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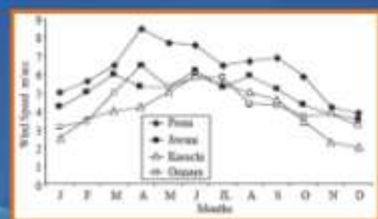
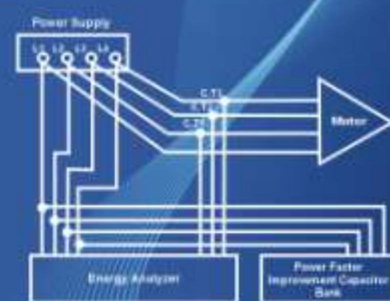
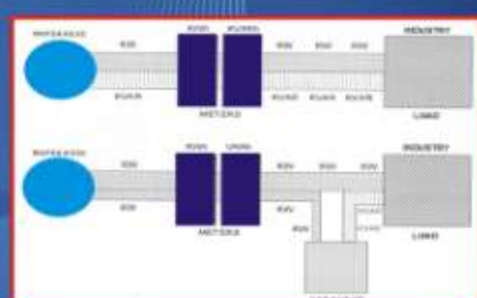


General Layout of PV Station (System Configuration)





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Journal of The Institution of Electrical and Electronics Engineers Pakistan

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Disseminate Technical Knowledge

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Editorial

This volume of the New Horizons is a very special issue. Besides the normal research articles, this volume contains the National Power Policy of 2013 with short comments of the President and an old research paper authored by Engr.Syed Tanzeen Hussain Naqvi. He had authored this paper in 2005 and this fact remains its beauty, because the contents and also the conclusion of this paper is even true today. In fact, it is prophetic in nature. We are thankful to the President who has commented on this research paper, which is duly printed as part of this paper.

In addition to the above, Engr. Riaz Ahsan Baig has contributed two important papers under the heading of Solar Energy- Today and Tomorrow and Solution to the Energy Crisis. Both these papers are based on original research and over 40 years of hands down experience as a practicing engineer. As usual, our President Engr. Tahir Basharat Cheema has contributed two very important papers related to power sector under the heading of, "The Political Economy of Power Sector'' and under the title, "Failing Writ and the Power Sector''. Both these papers have opened up new vistas for discussion amongst the engineering profession in general and for the power sector professionals in particular. Actually, both papers are amazing and clearly leading us to the conclusion that Engr. Cheema is indeed the foremost specialist in the sector.

The other papers carried by New Horizons pertain to the vast field of power factor improvement. The three separate research papers under the general heading of power factor improvement relate to induction motors, energy conservation and lastly is the paper on evaluation of benefits of PF improvement. All of these papers are spear headed by our HSG, Prof. Dr. Suhail Aftab Qureshi.

It is also pertinent to state that applied research is extremely important and consequently needs to be taken-up on a sustained basis. Unfortunately, the situation in the country is not that conducive and which speaks volumes about the Country's future. We at the IEEEP are mind-full of these crises and are striving hard to overcome this serious drought. However, we would take the opportunity of requesting our members to help and contribute in this regard.

We wish our members a very happy EID!

The Editor

Comments on the
National Power Policy 2013

By

Engr. Tahir Basharat Cheema, President, IEEEP

The very fact that the present government has crafted a national power policy after it assumed charge of the country, speaks well about its intentions. Moreover, even if the detractors of the policy poke holes in the document, still the issuance of the policy is welcome.

A study of the document reveals that much is there, but much needs to be included in the same. As very well paraphrased recently by the Supreme Court of Pakistan, the policy is indeed deficient as regards the treatment of current receivables of the system and nor does it tackle or talk about the imperative pillars of a sustainable policy viz. captive power, micro grids, concepts of feed-in and net-off tariffs, legislation to take care of such innovations, the re-crafting of budgetary mechanism and the finance bill to incorporate innovations and to provide for the availability of finance for these solutions, which all are of a great importance for any sustainable power system.

Unfortunately, the policy needs to include more on regulatory and corporate affairs too-specially when a hefty 50 % of Pakistan's generation capacity is that of the IPPs, which had been installed in the late 1990's and early 2000's. The policy should have contained information about the existing efficiencies of both the GENCOs and the IPPs viz a viz the current ones, what retrofit and re-powering could do and how in the span of next five years, the existing efficiencies could be brought-up to the current international standards. These facets are simply missing. Up-grading of the existing technologies, thus, should be the name of the game and surely a corner-stone of any viable and sustainable policy. In other words, the concepts of conservation and energy efficiency are to be appropriately treated in the policy with a detailed road map and distinct milestones to be achieved by the country and that too in a time bound manner.

Another serious omission is that the goals of the policy are not clear; simply stating that the present shortages would be mitigated by the end of the coming five years will never do. Actually, the policy should integrate itself into the greater national policy, if any, that has been or will be crafted which would be needed to pull Pakistan out of its present stalled state to that of a developed nation. There is requirement to mention the goals vividly and in shape of per capita use of electricity, availability of power for both industrial and agriculture use etc. This should be while also quoting the exact level of generation in MWs that is needed to mitigate the present shortages, the growth rate evident each year, the proposed growth rate to be achieved on the basis of industrialization and growth in agriculture and so on. And lastly whether some indigenization was possible or not. As roughly 20,000 MW of additional generating capacity is to be added to the system (and about 30,000 MW if the NTDC planners are to be believed) in the next five years, there is a requirement to tap all resources for it-including the manufacturing and production facilities in Pakistan and so on. On the other hand, it would be extremely sad to see all the generating equipment being simply imported, while in-country contribution remains restricted to bricks and mortar only. Besides, the local industry and business should also benefit from the activity and this all has to be built in a viable policy. Energy autarchy is another issue that merits consideration.

In view of the above, I would ask all members to read through the power policy and then offer comments, which could thereafter be formulated into concrete proposals and recommendations to be sent to the government.

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National Power Policy 2013

1. INTRODUCTION

The Ministry of Water and Power of the Government of Pakistan has developed an ambitious power policy to support the current and future energy needs of the country. This bold strategy will set Pakistan on a trajectory of rapid economic growth and social development. Simultaneously, it will address the key challenges of the power sector in order to provide much needed relief to the citizens of Pakistan.

This document will frame the broad contours of the energy policy articulating the vision for the power sector, highlighting its key challenges, setting major goals, summarizing policy principles, and highlighting the strategy devised to achieve Pakistan's aspirations. This document does not elaborate on issues surrounding operational strategy, nor does it lay out detailed implementation plans.

The major sections of the report follow:

2. VISION

"Pakistan will develop the most efficient and consumer centric power generation, transmission, and distribution systems that meets the needs of its population and boosts its economy in a sustainable and affordable manner."

3. CHALLENGES

Pakistan's power sector is currently afflicted by a number of challenges that have led to a crisis:

1. A yawning supply-demand gap where the demand for electricity far outstrips the current generation capacity leading to gaps of up to 4,500-5,500 MW. The supply-demand gap has continuously grown

over the past 5 years until reaching the existing levels. Such an enormous gap has led to load-shedding of 12-16 hours across the country.

2. Highly expensive generation of electricity (~ Rs. 12/unit) due to an increased dependence on expensive thermal fuel sources (44% of total generation). RFO, HSD, and Mixed are the biggest sources of thermal electricity generation in Pakistan and range in price from ~ Rs. 12/unit for mixes, to ~ Rs. 17/unit for RFO, and a tremendously expensive ~ Rs. 23/unit for HSD. Dependence on such expensive fuel sources has forced Pakistan to create electricity at rates that are not affordable to the nation and its populace.

3. A terribly inefficient power transmission and distribution system that currently records losses of 23-25% due to poor infrastructure, mismanagement, and theft of electricity. The cost of delivering a unit of electricity to the end consumer has been estimated at Rs. 14.70 by the NEPRA. This means that the inefficiencies are costing the tax payers additional 2.70 rupees per unit over and above the cost of generation (~Rs. 12). The Ministry of Water and Power has estimated the true cost of delivering a unit of electricity to the end consumer at greater than Rs. 15.60 after taking into account the collection losses and the real losses to the distribution companies. If the system assumes the NEPRA suggested transmission and distribution loss of 16%, the theft alone is estimated to be costing the national exchequer over Rs. 140 billion annually.

4. The aforementioned inefficiencies, theft, and high cost of generation are resulting in debilitating levels of subsidies and circular debt. Reducing these losses would lead to significant improvement in the bankability and profitability of the sector, and could be used to improve the efficiency of the power system/network as a whole.

5. The limited and crumbling transmission system of Pakistan has created serious issues of access to electricity, particularly in Balochistan and other far flung areas of the country.

4. GOALS

To achieve the long-term vision of power sector and overcome its challenges, the Government of Pakistan has set the following nine goals:

i. Build a power generation capacity that can meet Pakistan's energy needs in a sustainable manner.

ii. Create a culture of energy conservation and responsibility.

iii. Ensure the generation of inexpensive and affordable electricity for domestic, commercial, and industrial use by using indigenous resources such as coal (Thar coal) and hydel.

iv. Minimize pilferage and adulteration in fuel supply.

v. Promote world class efficiency in power generation.

vi. Create a cutting edge transmission network.

vii. Minimize inefficiencies in the distribution system.

viii. Minimize financial losses across the system.

ix. Align the ministries involved in the energy sector and improve the governance of all federal and provincial departments as well as regulators.

A clear strategy has to be articulated for each of the aforementioned goals in order to actualize the power sector's aspirations.

5. TARGETS

Pakistan has set key targets in terms of the demand-supply gap, affordability, efficiency, financial viability and governance of the system. The extent to which the policy can meet these targets will measure the success of the policy and the nation's ability to overcome the key problems afflicting the power sector.

Supply Demand Gap: Goals i and ii pertain to this target

- Target: Decrease supply demand gap from 4500-5000 MW today to 0 by 2017.

Affordability: Goal iii pertains to this target

- Target: Decrease cost of generation from 12c/ unit today to ~10c/ unit by 2017.

Efficiency: Goals iv to vii pertains to this target

- Target: Decrease transmission and distribution losses from ~23-25% to ~16% by 2017.

Financial Viability and Collections: Goal viii pertains to this target

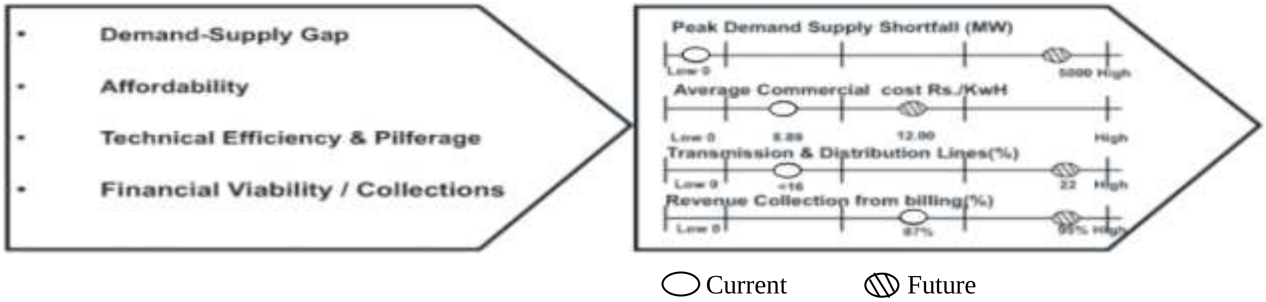
- Target: Increase collection from ~85% to 95% by 2017.

Governance: Goal ix pertains to this target

- Target: Decrease decision making processing time at the Ministry, related departments and regulators from long to short durations.

  The exact processing times are not currently available; will be established shortly.

Challenge Area	Target Aspiration



6. POLICY PRINCIPLES

The process of policy and strategy formulation is informed by the following organizing principles:

(i) efficiency, (ii) competition, and (iii) sustainability.

6.1 EFFICIENCY

Efficiency is the cornerstone of developing competitiveness. The principle of efficiency will be predicated on three pillars: merit order, transparency / automation, and accountability.

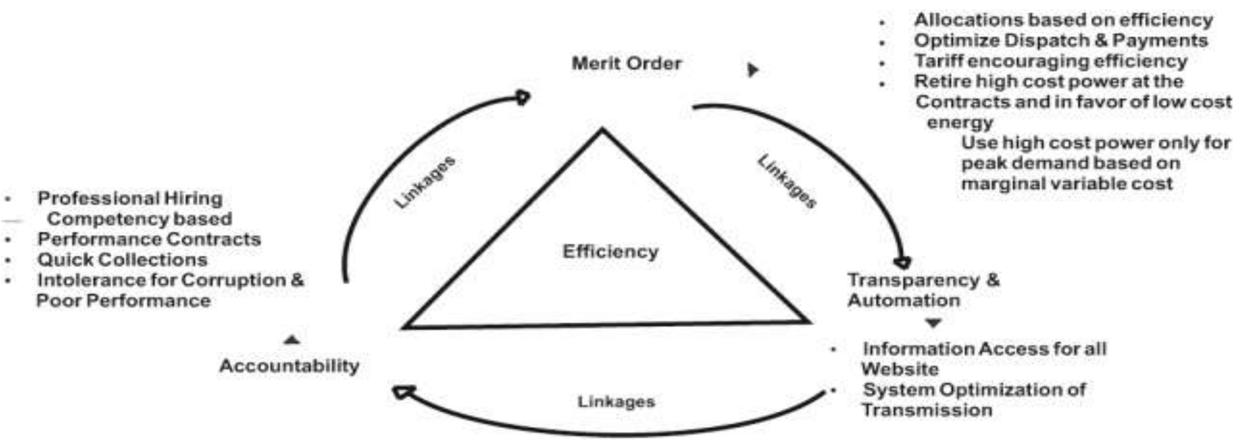
Merit order will be observed all across the system-fuel allocation, dispatch, payments, and power mix. Merit order allocations will obviously come into play once the supply and demand gaps have been minimized.

Transparency will be achieved by providing seamless access to information through a public website.

Accountability will be ensured by hiring professionals solely on the basis of competency, signing performance contracts, and exercising zero tolerance towards corruption and poor performance.

The above is illustrated in the following image:

Policy for Efficiency



6.2 COMPETITION

Competition creates the edge essential for developing a robust energy cluster. The principle of competition will be built on three pillars: infrastructure development, up front tariff and competitive bidding, and key client management.

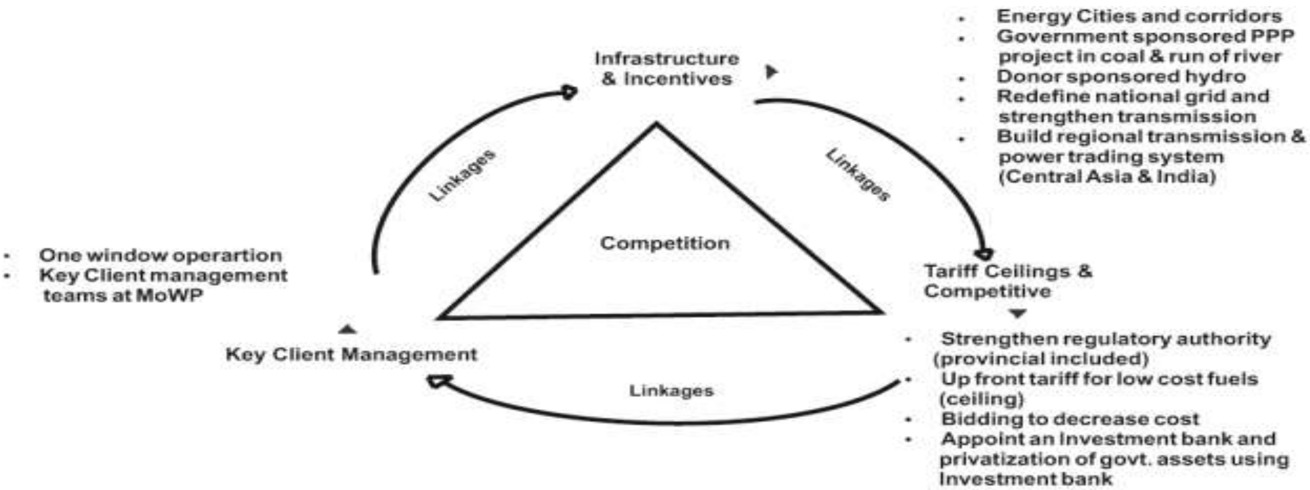
Infrastructure will be developed and incentives provided to attract greater private sector investments. Government would like to limit its role to policy making, and unless necessary, service delivery will be promoted through a fiercely competitive and transparent private sector.

In this light, NEPRA will be strengthened to create a world class regulatory authority with sophisticated and efficient capacity to establish tariffs and set the foundation for a competitive bidding process.

The government will assign “key client managers or relationship managers” at the MoWP who will act as a ‘one window operation’ for investors in the power sector and ensure the timely completion of investments and projects.

The above is illustrated in the following image.

Policy for Competition



6.3 SUSTAINABILITY

Sustainability is the underpinning of long term transformation. The principle of sustainability will be grounded on three pillars: low cost energy, fair and level playing field, and demand management.

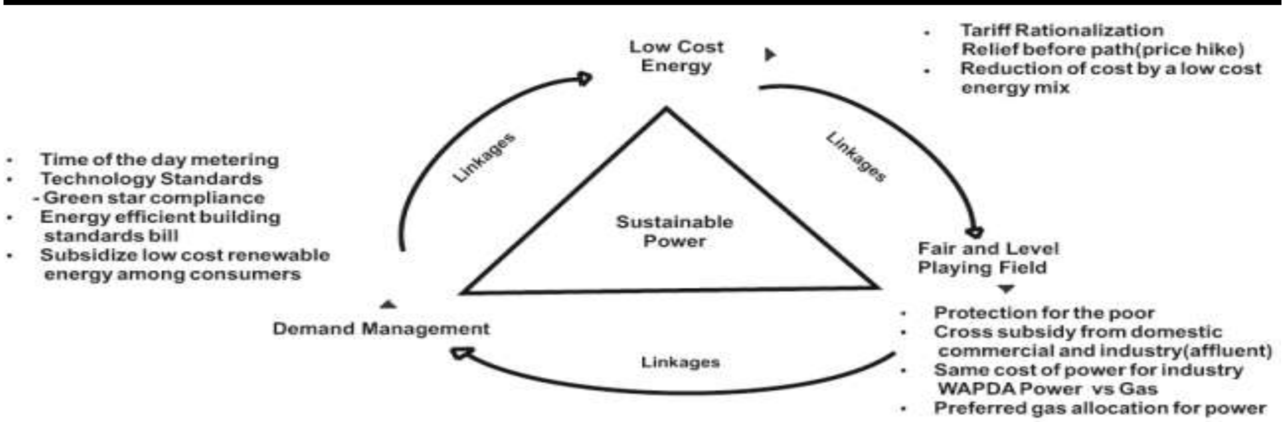
Altering the fuel mix towards less expensive fuels will lead to low cost energy. Investments required for the low cost fuel mix will necessitate rationalization of the electricity tariff.

Fairness will be ensured by protecting the poor and cross-subsidizing their consumption from the affluent. A level playing field will be created by providing power at comparable prices to all industrial users.

Demand management will be introduced through novel policy, pricing and regulatory instruments.

The above is illustrated in the following image:

Policy for Sustainability



7. STRATEGY

Within the framework of the above policy principles, the GoP has designed strategies for each of the goals listed in section 4 to actualize its vision and overcome the power crisis.

7.1 SUPPLY STRATEGY

The supply strategy will meet Goal (i):

Build a power generation capacity that can meet Pakistan's energy needs in a sustainable manner.

The broad contours of the supply strategy are illustrated in the following figure:

Overall, the strategy to achieve the above goal is focused on attracting and directing local and foreign investments towards rapidly expanding the power generation capacity. Investments can only be encouraged if the sector is made attractive and bankable by eliminating all subsidies, except for those that target the abject poor, to prevent build-up of circular debt. The poor (consumers using up to 200 units) will be protected from any price escalation. To the extent

Supply Capacity Strategy	
Goal: Build a power generation capacity that can meet Pakistan's energy needs in the long-term	
Strategy	
Incent Investment through New Econ Model	• Target power and gas subsidy directly only at the abject poor. • Provide more expensive but dedicated electricity to users utilizing captive power and generators. • Phase out subsidy over period of three years.
Bring Existing Capacity Online	• Retire circular debt immediately and clear GST refunds. • Set maximum delay limit for payables (RPO 45-60 days/Gas 30-45 days. • Provide financing to plans that lie dormant due to lack of funds or disputes.
Complete Pipeline Projects	• Bring pipeline projects online on war footing. • Prioritize projects can be brought online in two to three years, particular coal, run-of-the-river and bio-mass projects. • Assign key project manager from Ministry of Water and Power to each pipeline project with the sole responsibility of ensuring project comes online.

Possible tariff rationalization will minimize or eliminate subsidy within the industrial, commercial and bulk consumers.

In developing new power generation projects, a preference shall be afforded to up-front or feed-in tariff which shall set the upper ceiling. In addition, competitive bidding may be used to minimize the cost of generation. Previous policy frameworks (such as 2002 power policy) may also continue to be operational. However, the 2013 power policy shall override any other policy in relation to energy issues to the extent of inconsistencies.

In the short run, the government has already brought the existing capacity online by retiring the circular debt. This action has provided financing to plants that were previously dormant due to a lack of feedstock and / or disputes. The retirement of debt has resulted in an additional supply of over 1700 MW. In tandem, an aggressive rehabilitation and expansion program for the GENCOs is underway which would add 1,447 MW within a year rehabilitation projects at Guddu, Jamshoro, and Muzzafargarh will yield 700 MW while the expansion of Guddu will add 747 MW.

The maximum delay limits for payables set for RFO and gas (listed in the diagram above) should also apply to hydel IPPs and Wapda in order to ascertain that national power generation capacity does not sit idle in the future.

In the medium term, the MoWP will attract new investments and expedite the pipeline projects on a war footing. A number of projects have reached or will reach financial closure within 2013 – these include 50 MW FFC Energy Limited, 56MW Zorlu Jhimpir project, 50 MW Foundation Wind Energy 1.50 MW China Three Gorges, and 50 MW Foundation Wind Energy II. Thus 256MW have already reached financial closure this year , and an additional 100 MW (Sapphire and Metro) will reach financial closure by the end of 2013. The Uch-II power project (404 MW) has reached financial closure already and is expected to come online by December 2013. Grange Power Holding is also scheduled to reach financial closure shortly and should be online by October 2014.

In addition to the above listed projects that have reached financial closure, LOS have been issued for 450 MW worth of wind energy projects and an additional 2,276 MW of wind projects are currently in the feasibility assessment process. This cumulative 2,276MW of wind electricity (if deemed feasible) could come online in 2016. At the same time, 341MW of solar energy projects are currently in the feasibility assessment process and could come online by 2015 if deemed feasible. There is also a push towards Begasse which could yield 83 additional megawatts of electricity by 2016.

A significant push will also be made towards building medium and long-term hydel capacity in the country. Six projects totaling 388 MW of hydel power are expected to be completed by February 2015. The smaller Patrind and Gulpur hydropower projects are expected to be completed by December 2017 and will add 247 MW to the grid. An additional 969MW is anticipated from the Neelum-Jhelum HPP project by November 2016. A number of hydel projects are expected to come online in 2017 including the fourth Tarbela expansions which have the potential to add 1,910MW (1,410MW in fourth expansion 500M in fifth expansion).

The government is also poised to announce a coal corridor with capacity to generate 6000 – 7000 MW in the near future.

In the long run, large infrastructure programs including the Indus Basin Cascade will be aggressively developed. Dasu has a potential of generating 2,160 MW, Patan 2,800 MW and Thakot 2,800 MW. The detailed engineering design of these projects is being carried out and will optimally be constructed using BOT PPP method.

Other longer-term projects are also under consideration, such as Bunji (7,100 MW Potential) and Diamer-Bhasha (4,500MW potential) whose completion by 2020 could ensure the energy independence and security of Pakistan.

To achieve the medium and long terms goals, the government will develop infrastructure and provide incentives to attract private power investments. The government will set the foundations of energy cities and corridors, and sponsor public private partnership (PPP) for coal and run of river projects. The government will assign "key client managers or relationship managers" at the MoWP who will act as a 'one window operation' for investors in the power sector and ensure the timely completion of investments and projects.

The government is actively considering innovative business models including various wholesale business models supported by wheeling charges. These innovative business models once concluded may allow the generation companies to sell electricity to NTDC, DISCOs and private sector alike. Successful implementation of these models will encourage rapid investments in power generation, bring power generation closer to the load centres and result in a reduction in electricity prices.

Encouraging the private sector to participate in the utility marke; necessitates a world class regulatory function. NEPRA will be strengthened in this regard, and a word-class regulatory will control the Tariff and competitive Bidding process. Up-front tariffs will be set for low cost fuels and competitive bidding will be used to push the costs further downwards.

7.2 DEMAND STRATEGY

The demand management strategy will meet Goal (ii).

Create a culture of conservation and responsibility.

The brand contours of the demand management strategy are illustrated in the following figure.

Demand Management Strategy	
Goal: create a culture of energy conservation and responsibility	
Strategy	
Improve Technology Standards	• Strategy conservation and product labeling standards • Ban imports of non efficient consumer electronics in Pakistan. • Provide Pakistani manufacturers three year time limit to bring products up to par with efficiency
Time of Use Tariffs	• Impose specific timings and restrictions for : • Shopping and other recreation activities, billboard lighting , street lighting, commercial lighting, noon lighting , air conditioning. • Introduce 'Time of Use' meters that charges different rates for peak and off-peak electricity usage.
Pricing Single	• Provide more expensive but dedicated electricity to heavy users utilizing captive power plants and generators (commercial and residential) • Phase out subsidy over period of three years • Phase true economic cost of electricity generation to consumer over time • Maintain Subsidy for abject poor.

The GoP will pass energy conservation legislation aimed at three key areas: a) technology / product labeling standards, b) power time of use, and c) improving the energy efficiency of the existing and new infrastructure.

The strategy will set energy conservation and product labeling standards which would ban the import of inefficient electronics into the country. The local industry will be granted a three-year exemption period to bring its product production to the required levels of power efficiency. Green energy building codes will be established and introduced across the County.

Energy services companies may also be encouraged in the private sector to audit and improve the energy efficiency of the existing industrial, commercial and residential footprint and create a culture of conservation and productivity.

The strategy may also impose timing restrictions for evening commercial activities and introduce 'time of use' metering to discourage utilization during the peak hours by charging different rates for on-and off-peak timings. Solar and alternative power solutions will be encouraged for end users. Street lighting , electronic billboards, neon lighting, shop front signage, etc. in addition, the price signal articulated through reducing and targeting subsidy (mentioned in the above section) will naturally optimize demand and utilization.

A conservation program base upon energy save lighting in already underway with a potential of saving 1000MW all 50 million consumers were to be converted to florescent bulbs.

In addition, technology solutions such conical bafflers of water heaters will be introduced.

7.3 AFFORDABLE POWER STRATEGY

The affordable power strategy will meet Goal (iii):

Ensure the generation of inexpensive and affordable electricity for domestic commercial & industrial use.

The broad contours of the affordable power strategy are illustrated in the following figure.

Affordable Power Strategy	
Goal: Ensure the generation of inexpensive and affordable electricity for domestic, commercial and industrial use.	
Strategy	
Move Towards Cheaper Fuels	• Identify expensive RFO and HSD plants and convert them to gas of coal. • Shift tariff incentives towards low cost energy sources (hydel, run of the river, gas, coal, nuclear, biomass etc.) • Proliferate mining across the country and expedite coal projects at Thar blocks.
Gas Conservation For Power	• Increase price of gas consumption for all users except for poor residential users. • Reduce utilization of gas in CNG and UFG in particular. • 10% gas diversion can generate 2,000 MW • Divert gas to the power sector and ensure firm supply to the power plants.

The strategy focuses on shifting on shifting Pakistan's energy mix toward low cost sources such as hydel, gas, coal, nuclear and biomass. Local and foreign investments will be aggressively sought for small and medium size run of river hydel projects. Selected hydel projects under development will be positioned for privatization. Multilateral agencies will be invited to partner in large infrastructural hydel projects. LNG terminals will be developed on war footing to rapidly increase the gas supply for the power and industrial sectors. In addition, gas will be preferentially directed to the power sector by eliminating UFG. Nuclear power will be developed in close collaboration with friendly countries such as China. Development of coastal energy corridors based upon imported coal (mixed later with local coal), rapid proliferation of coal mining all across the country-especially at Thar, and conversion of expensive RFO based plants to coal are the central tenets of coal policy. The proposed strategy will change the energy mix of Pakistan in favour of low cost sources and significantly reduce the burden of energy to the end consumer.

Generation Strategy	
Goal: Promote world class efficiency in power generation.	
Strategy	
Provide Fuel to Efficient Plants	• Establish plant efficiency through heat rate testing. • Prioritize and allocate fuel based upon the efficiency levels. • Make allocations and efficiency levels transparent online. • Monitor the efficiency of these plants on a continuous basis.
Privatize GENCOs	• Either privatize; or lease GENCOs to private sector on the basis of O&M contracts. • Pilot two GENCOs immediately. • Prepare the remaining GENCOs for subsequent privatization through corporatization.

7.4 SUPPLY-CHAIN STRATEGY

The supply-chain strategy will meet Goal (iv):

Minimize pilferage and adulteration in fuel supply.

Once the relief from load shedding is forthcoming because of a decreased supply and demand gap, this strategy will focus on redirecting the supply of fuel from inefficient GENCOs to the most efficient IPPs. This reallocation alone has the potential of saving Rs. 3 billion per month and generation an additional 500 MW of electricity. At the same time, the MoWP will sign performance contracts with GENCOs, PSO, and fuel transporters and hold them accountable for the quality and theft of oil. Fuel procurement contracts may be made open sourced to eliminate the power of a single supplier. Leakage will be plugged by building fuel pipelines where possible and open decanting. More specifically a 22KM pipeline will be constructed to plug the supply chain leakage in Muzzafargarh. In the event that fuel is found to be missing or adulterated, the full economic value of the fuel will be appropriated to the end receiver.

Supply Chain Strategy	
Goal: Minimize pilferage and adulteration in the fuel supply to improve productivity.	
Strategy	
Redirect Supply to IPP's	• Reduce allocation to GENCOs until they are at higher efficiency levels. • Move fuel allocation from GENCOs to IPPs. • Moving 4000 mtoe from GENCOs to IPPs will save Rs. 75 billion / year. Rs. 13 billion / month spent on GENCOs produces 650 MW. 10 billion / month at IPPs produces 1,150 MW.
Accountability Liberalization and Quality Assurance	• Sign performance contracts with GENCOs, PSO, and fuel transporters. • Open fuel procurement contracts through tendering to eliminate role of single supplier. • Eliminate trucking and open decanting by building pipelines (for Muzaffargarh TPS). • Measure the quantity and quality of fuel moving from the port of GENCO. • Appropriate full economic, value added cost of quality or quantity loss to the end receiver.

The broad contours of the supply chain strategy are illustrated below:

7.5 GENERATION STRATEGY

The generation strategy will meet Goal (v)

Promote world class efficiency in power generation.

The broad contours of the strategy are illustrated below:

The strategy focuses on establishing plant efficiency through external heat rate testing, building a merit order accordingly, and allocating fuel to the more meritorious plants. Merit order will privilege fuel allocation on the basis of efficiency and optimize dispatch and payments. Transparency will be achieved by providing greater and easier access to information through a public website. Allocations will be made public online to increase the transparency. The strategy calls for the privatization or O&M based leasing of GENCOs.

7.6 TRANSMISSION STRATEGY

The transmission strategy will meet Goal (vi)

Create a cutting-edge transmission network.

The broad contours of the strategy are illustrated below:

Transmission Strategy	
Goal: create a world class transmission and distribution network.	
Strategy	
Optimize Transmission	• Sign performance contracts with NTDC. -2.5% are NEPRA allowed losses; 3.6% are the current existing losses. • Dispatch based upon economic order. • Install transmission effectiveness analysis software and hardware to optimize transmission. Software already exists but has not been utilized due to lack of technical expertise.
Redefine and Redesign National Grid	• Build future medium/small sized power plants closer to load centers to minimize line losses. • Expand high voltage transmission lines further North beyond Ravat. • Impose specific timings and restrictions for : Majority of new hydel projects will be situated beyond Ravat. High voltage lines minimize losses. • Strengthen 220KV rings around large cities to minimize losses. • Redesign merit order to also take into consideration transmission losses of plants.
Incent Private Sector Investments	• Creates a new business model based upon wholesales transactions, exchanges and wheeling charges • Incentivize the private sector to make investments in transmission, especially for the new generation plants placed off gird or in areas where the grid is weak.

The strategy is based on installation of upgraded SCADA software to optimize transmission and monitor its losses. Dispatch will be based on economic order and internal/audit controls will be established on dispatch and payment.

The transmission strategy requires the redesigning of the national grid in a manner that minimize line losses. Plants will be built to load centres. High voltage transmission lines will be expanded and the 220kv rings around cities will be strengthened.

Private sectors will be provided incentives to build and strengthen the transmission infrastructure. Innovative business and regulatory models will be deployed to weaken the monopolies, increase efficiencies, and decrease costs through competition. Wheeling charges and whole sale markets may be introduce multiple buyers and sellers in the market place.

Regional transmission networks may also be encouraged to promote power trade and optimize deficits and surpluses.

7.7 DISTRIBUTION STRATEGY

The distribution strategy will meet Goal (vii)

Minimize inefficiencies in the distribution system.

The broad contours of the strategy are illustrated below:

In the short-term, performance contracts will be signed with the heads of DISCOs (distribution companies) and their respective boards focused on reducing distribution losses due to technical reasons, theft, and lack of recovery / collections. Board independence and appointment of competent board members is the corner stone of improving the performance of DISCOs.

Distribution Strategy	
Goal: Minimize operational and financial inefficiencies in the distribution system	
Strategy	
Performance Contracts (Short Term)	• Sign Performance contracts with the key stakeholders / heads of the distribution companies (DISCOs) to ensure their accountability with respects to effective distribution • Ensure that performance contracts cover Reduction in distribution losses (technical losses as well as theft related losses) Full collections of distribution companies recoverable from consumers using ATC index
Smart Metering and Feeder level accounting (Short Term)	• USAID has funded smart Meters at all feeders in Pakistan. Project is 65% complete and will finish in 60 days. • Use Smart Meters to Develop and online system of monitoring electricity distribution from CDPs, feeders, transformers and consumer end meters. • Manage profit and loss accounts at the federal level • Hold XEN accountable for P&L and reward of remove
Privatization of DISCOs	• Privatize a limited number of DISCOs as pilot and document key learnings • Devolve the P&L of the remaining DISCOs to the feeder level and hold XEN accountable to improve performance • Privatize all DISCOs over a period of time

Smart meters will be installed at the feeder and CDP level, profit and loss accounts will to be managed at the feeder level. And the accountability will be appropriated to the Executive engineers. A regime of reward and punishment will be used to improve efficiency and decrease theft. A theft Act will be passed that would harshly punish defaulters and other electricity thieves to eliminate theft at the consumer level.

In the medium term, the efficiency will be improved by privatizing a selected number of DISCOs. The remaining DISCOs will be privatized over a period of time.

7.8 FINANCIAL EFFICIENCY STRATEGY

The financial efficiency strategy will meet Goal (viii):
Minimize financial losses across the system
The broad contours of the strategy are illustrated below.

Financial Efficiency Strategy	
Goal: Minimize financial losses across the system	
Strategy	
Collect Receivable	• Automatically adjust already agreed upon amounts by provinces and government debt to power sector form the NFC Award and department budgets • Appoint independent reliable Adjuster to settle payment disputes with provinces and govt. depts. Within a period of three to six months • Agree upon transparent procedures for future billing and collections. • \collect GST refunds form FBR and devise a mechanism to avoid future build-ups
Punish Defaulters and eliminate theft	• Eliminate transmission and distribution theft • Focus load-shedding in areas where collections are low • Pass legislation that allows for defaulters and connections to be severed - Defaulters connections are severed after 50 days of nonpayment. - Defaulters will only be reconnected with prepaid based meters

GST refunds will be collected from the FBR and a mechanism will be built to avoid future build-ups.

The financial efficiency strategy is geared towards punishing private defaulters and proposes severing the electric connections of defaulters after 60 days of non-payment and only reconnecting them to the grid with pre-paid meters. External connection agencies may also be sourced to improve cash flows. At the same time, load shedding may be focused on areas of high theft and low collections as opposed to the current structure of indiscriminate load-shedding.

The strategy also covers the independent audit of all financial transactions within power sector. An independent firm will be used to audit these transactions and ensure the greatest degree of financial propriety within power sector.

7.9 GOVERNANCE STRATEGY

The governance strategy will meet Goal (ix)

Align ministries involved in the energy sector and improve governance

The governance strategy calls for the notification of an official coordination committee comprising the Ministry of Water & Power, the Ministry of Petroleum, the Ministry of Finance, the Ministry of Planning and Development a member from each province, and a representative from AJK and GB each This council will ensure information integration between all these ministries and will assist in policy formulation and decision making related to energy. The CCI will provide monitoring and oversight to the implementation of the National Power Policy.

The strategy requires the reformation of structural and regulatory aspects of NEPRA and OGRA to improve efficiencies. New business models including power exchanges and wheeling charges will be explored. NEPRA's reform will include a change in the establishment period for the base tariff form 8-10 months to 90 days, the aim of this reform will be to minimize to potential for circular debt accumulation.

Finally, the Ministry of Water and Power will be restructured to strengthen its functional expertise. Directorates will be created for key functions (i.e. generation, transmission and distribution) key organizations such as CPPA, PPIB, AEDB, and NTDC will be reformed.

The board contours of the strategy are illustrated below.

Governance Strategy	
Goal: Align the ministries involved in the energy sector and improve governance	
Strategy	
Reform and coordinate Planning	• Notify official Coordination Council between Ministry of Water & Power. Ministry of Petroleum, Ministry of Finance and Planning Commission. Ensure information integration between all ministries. • Reform the structural and regulatory aspects of NEPRA and OGRA • Restructure Ministry of Water and Power to strengthen functional expertise Create directorates for each function (Generation, Transmission, Distribution) Ensure power sector reform (PEPCO, CPPA, NTDC)

The strategy requires the reformation of structural and regulatory aspects of NEPRA and OGRA to improve efficiencies. New business models including power exchanges and wheeling charges will be explored. NEPRA's reform will include a change in the establishment period for the base tariff form 8-10 months to 90 days, the aim of this reform will be to minimize to potential for circular debt accumulation.

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The board contours of the strategy are illustrated below.

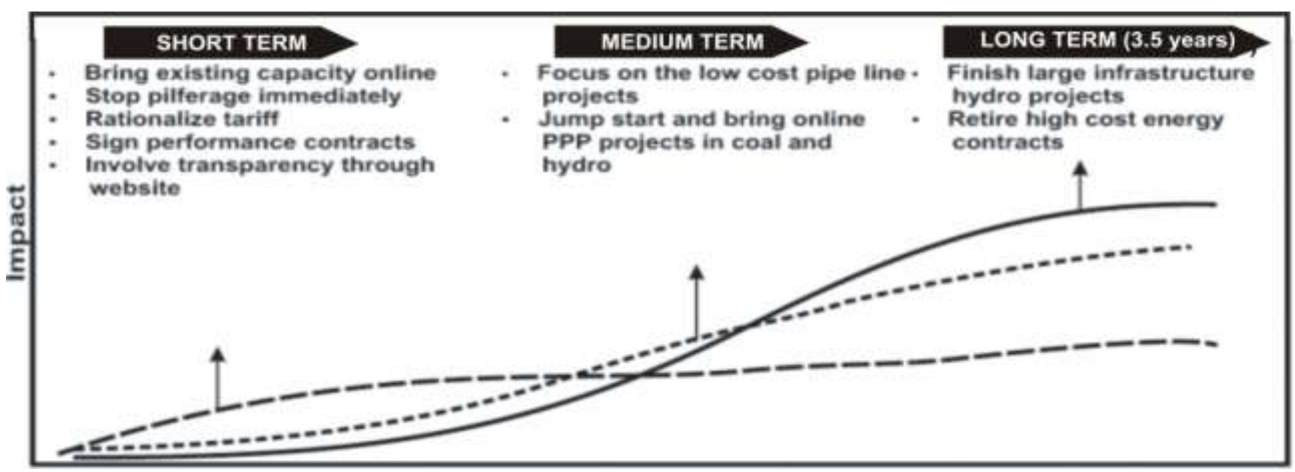
8. PRIORITIZATION

The strategy has been prioritized to maximize the impact of the various strategic initiatives. In the short term we will bring existing capacity online, stop thefts of all form, rationalize the tariff, sign performance contracts, and ensure transparency. In the medium term we will bring low-cost pipeline projects online, and jump start coal and hydro PPP projects. Finally, in the long term we will finish large infrastructure hydel projects and retire high cost energy contracts to ensure that Pakistan moves towards cheap electricity generation.

9. IMPACT

The successful implementation of this policy will lead to enormous improvement within the power sector. By 2017, the supply-demand gap could be eradicated completely; and by the end of the five-year term of the current government the country will have a power surplus which can then be regionally traded. In essence, by the end of the decade Pakistan could be transformed from energy strapped, importer of power to a regional exporter of power. The Cost of power

generation will be reduced to an affordable amount and the efficiency improvements in transmission and distribution will decrease the burden of power to the end consumer. In summary, prosperity and social development will become a reality in a Roshan Pakistan.



Comments on the Article

By

Engr. Tahir Basharat Cheema, President, IEEEP

Engr. Naqvi authored this article in 2005, when it was published in the media with great aplomb. Because the article is basically original research of the highest order, hence IEEEP's board of publication's decision to carry this article as research in the New Horizons makes great sense. The best point about this article is that it is prophetic in nature and stands true even now, although it was originally crafted almost 7-8 years ago.

The paper's truthfulness can lead to another conclusion viz. that the managers of the power sector have in-fact not been able to deliver in the past decade or so. Here, the professional may castigate the generalist and the political bosses for the loss, while these gentlemen may hold the professional for the rot. A discerning eye, on the other hand, would hold both the sides responsible for the present morass. That the situation carries on as usual in something that needs focus and thought.

There is thus a need to look deep into the issues and ensure that the downhill slide stops or at least slows down before stopping altogether. This wish of ours will, however, need to be considered by taking the present political scenario in mind. We have a government that wishes to deliver, a private sector including the civil society which seems to have had enough, multinational developmental agencies (IMF, WB, ADB, etc.) which support induction of private sector into the works and lastly the poor and disadvantage of Pakistan, who are crying for the government to discharge its social obligations by providing services at a low cost and without any profit-taking or rent-seeking. All in all, it is a very serious issue needing deep insight and hard work, before any solution emerges on the horizon. Another facet that needs consideration is the fact that a small, but influential, group still believes that WAPDA's consolidation into an integrity utility once again can contain the rot and also serve the people appropriately.

In view of the above, while congratulating Engr. S.T.H. Naqvi for his insight into the power sector, I take this opportunity to invite the readers of the instant article to ponder as to how we would be able to come out of the presently ongoing crises and can the reforms (to some beneficial and to some the reason for the current bleak situation) be turned back.

Quotation

Man is at the bottom an animal, midway a citizen and at the top divine. But the climate of this world is such that few ripen at the top.

Henry Ward Beecher

Words = 1980

Drag of WAPDA's Breakup!

By

Engr. S.Tanzeem Hussain Naqvi
Ex-Chairman KESC
Ex Member (Power) WAPDA
Former Chief Executive (PEPCO)
Immediate Past President IEEEP

It is a foregone conclusion that WAPDA's Power Wing would be broken up in the coming January. It is foregone because prepositions once set in motion- at least in Pakistan, are never re-thought and nor ever corrected. With this breakup would shift the control of operations to the implementation team under the Federal Ministry of Water and Power. But for more chances of intervention at the lowest of the level, every one, including the federal ministry of water and power, would be a loser. And as a classic replay of things, electricity operations in Pakistan would once again start anew- circa 1950s. As to when would these be re-integrated once again is another story. This can be as near as a couple of years or a decade away. Additionally, but in a purely sociological manner, the Country would be poorer by another national entity viz. WAPDA's unified Power Wing with forces of regionalism becoming more stronger. In case the GoP is unable to arrange for a unified electricity tariff for the whole country through injection of billions of subsidy- some say up to Rs 120 billion an year, then the rift is bound to become more evident. All this is going to happen because Pakistan wishes to qualify for a USD 750 million loan ostensibly being sought to reform and re-structure the existing Power Sector. As to what was actually needed to be done has been amply listed in my earlier article published last week under the title "Unbundling WAPDA's Power Wing: bane or a boon". However, the loss likely to occur in shape of wastage of imperative technical resource is scary enough for me to make an effort to explain the gravity of the situation herein under.

Whenever an entity reaches a level of maturity, it probably is the time when setups like central and unified planning, a composite design department, a standards giving body, training institutions and legal aid or law wings are considered a must. Similar was the case with WAPDA's Power Wing- incidentally an entity that employed some 1, 25,000 persons on its rolls out of the 1, 48,000 or so for the whole WAPDA. So much was the seriousness of purpose that the central planning department had it's own sources and tools for gathering true and correct data. It was then able to forecast and plan for as much as twenty five years in advance. Most of the advancement taking place in the Country was based on this work. Besides the above, a very strong commercial procedures and tariff formulating department too was setup. However, the later part of this was not able to deliver much because of the fact that tariff was being formulated/ fixed by the GoP alone till as late as

2002, where-after, NEPRA has started flexing it's muscles a little. This fact, however, cannot belittle the hard earned experience and expertise of this resource and nor stop people bemoaning it's loss.

Similarly has been WAPDA's composite power wing design department- which was able to take care of all such needs of the Country. This composite entity encompassed a standards giving setup, issuances of which have been followed both all over Pakistan and in the Middle-East and Africa. The standards and specifications issued by this department are of such a mark that these are the envy of the world. It would also be not out of place to state that these standards set by WAPDA's Power Wing have no match what so ever in neighboring countries like India, Sri Lanka or Bangladesh. I have personal knowledge that Chinese standards are quite lax in comparison to WAPDA's compatible edicts specially in the fields of electrical products like meters, line hardware and transformation equipment.

Like all big time employers, WAPDA too setup HRM and HRD setups. These though remaining much under assail from the non-professional management- specially during the period 1993-1997 and 1998-2003 can still be beefed up to handle the most complex of the requirements and breakup thereof, very much eminent due to unbundling in the offing, can be most disconcerting. The allied training edifices built up during the last forty years are also in a quandary and would surely face the axe- specially when the unbundled corporatized components of WAPDA's Power Wing are free to go anywhere to train their employees; which

again would be difficult as these would not be able to spare staff for training in compassion to such nominations from the unified Utility. Additionally, these companies would also not be able to recruit training reserves. And the training would now depend upon the resolve of a company's CEO- which would further depend upon the finances available with it. With only three of the DISCOs making worthwhile profits, prospects of regular training would surely be a distant dream. All this would thus result in more poorer service for the customers of loss making unbundled companies and even more losses because of lesser level of technical resource at their disposal. It indeed is a dismal picture. Similarly, breakup of the unified and integrated power wing would result in dismantling of the existing legal expertise and thus the unbundled entities would have mediocre legal help at their disposal.

All the above translates into the fact that unbundling is indeed a retrograde step and would besides leading to great losses in service, technology and a uniform tariff for the country, would also result in an unprecedented depletion of technical resource and expertise.

On the other hand, solely for the sake of argument let us discuss the possibility ever of creation of all the above at the level of the newly (fully) corporatized entities. This discussion would also take into consideration the various edicts of NEPRA- the regulator in this case. We would also discuss the powers of the regulator and it's will to enforce its writ. This all would be done in light of the present imbroglio, wherein NEPRA stands pitted against the Ministry of Water and Power, with the Finance Ministry watching as a bystander. The PM's statement that NEPRA should keep on independently adjudicating and determining the various tariffs and allied issues without pressure from any quarters also needs to be discussed in conjunction with the actual happenings of the times.

Coming to the first of the issues viz, creation of similar auxiliary and ancillary setups by each of the unbundled companies, we can conclude that this may not be possible because of the cost involved and due to the fact that a true setup may be more than what one company may need or be able to sustain. As such both cost and an extra piece of establishment would ensure that nothing of the sort would happen and at the most a truncated or a very small setup may be allowed to be retained. Specifically talking about the work of central planning, we see that NEPRA requires the National Transmission and Dispatch Company (NTDC) to do it, with each of the nine DISCOs and the three GENCOs pitching regularly with the required information and inputs. This all envisages that thirteen totally independent companies- with their own problems to cope with (specially the issue of economics and saving on expenditure etc.) to cooperate and provide for the central planning. As this would be for the whole country, which includes KESC, one can imagine the problems and the level of planning which NTDC would be left to conduct.

What would happen to the design and standards giving setups. These too are going to face similar problems because NEPRA Act does not cater for it. All the companies would know have their own standards- a step backwards. All this would not have been difficult in case the debunddling *was* taking place in the USA, where state commissions and various other standards giving setups would have taken care of the issue. In Pakistan the PS&QCA- Pakistan Standard & quality Control Authority (ex Pakistan Standards Institute) has left the power sector to WAPDA alone and would not be able to do anything for this sector ever- at least in the near future. As a further proof, we can look into the working of the some independent DISCOs specially under the Army control of 1998-2003, when the brigadier CEOs made their own standards and in the process procured assorted equipment. I would not consider this as a corrupt practices, but would liken it to something normal being undertaken by an individual on an invention trip, which is the case when existing standards are either unknown or the person stands bereft of a specific issue's evolution process. Such a kind of thinking is normal for non- professionals and probably why such an individual should never be handed over a technical undertaking to run.

Similar would be the fate of other specialized entities like legal aid and the legal departments and even the estates and services setups All in all, WAPDA's off-springs (wrested out through sheer force) would be poorer images of the progenitor and that too of circa early 1970s. Another loss would be the specialized technical creations like the RTL (Research and Test Lab) and the GTWS (Gas Turbine Workshop), both at Faislabad and the EHV (Extra High Voltage) laboratory at Rewat. Once available for all of WAPDA's Power Wing, these would now onwards be left to cater specifically for their owners alone. This would, unfortunately, not alone be a loss in the availability of services but primarily a loss in expertise leading to a stunted level of technical resource for the country. WAPDA's state of art composite inventory control system would also feel the axe- indeed an excellent efforts to go waste. This system had been devised in the late 80s and is more than compatible with the presently much advertised and sought after manufacturing resource planning or the MRPII system. The axing of this system would lead to duplication for all the so-called corporatized entities. Furthermore, it all would also be strange in the backdrop of NRL's (National Refinery Limited) proposed sale and the battle of giants to acquire it. It seems that both PSO and the Attock Group (another giant on the shopping spree) are making no secret of their enormous interest in acquisition of NRL's strategic equity so as to achieve a vertical integration of operations — a most for any operator worth it's salt. It also is needed to save companies like PSO and the Pakistan Oil field (a Attock Group flagship holding) from the dreaded uncertainty on the supply side. Thus while others even in the private sector are going for integration (specially on the vertical side), WAPDA has been rent asunder in a bid to reform the Power Sector as a whole.

Privatization, on the other hand, is a subsequent issue but needing immediate attention as immensely profitable units/ pieces of the Power Sector are being readied for sale and that too when the hopeful are planning purchase on the basis of the value of real estate alone. Reportedly, a party interested in the purchase of FESCO has just based it's offer on the expected sale proceeds of this particular DISCOs extremely expensive real estate holdings. PESCO, another name on PC's sale list is reported to be kept there just to hoodwink the public as this toss making company cannot possibly be sold in an atmosphere where only the best are doled out with the GoP left to ward-off for the continuous losses. Prime examples would be Javedan Cement, Morafco (oil and ghee), Karachi Machine Tool. Pak-Iran Textiles, Harnai Woolen Mills and such like loss making units, while the family silver in long gone and safety ensconced in the private coffers of the select few. So much for private entrepreneurship and the basic reason for privatization.

Quotation

- In the first place God made idiots, This was for practice. Then he made school boards.

Mark Twain

- A good teacher, like a good entertainer first must hold his audience;s attentiohn. Then he can teach his lesson.

John Hendrik Clarke

- The gift of teaching is a peculiar talent, and implies a need and a craving in the teacher himself.

John Jay Champan

- A poor surgeon hurts one person at a time. A poor teacher hurts [a whole classroom].

Ernest Bayer

- A university should be a palce of light, of liberty and of learning.

Benjamin Disraeli

- Advice is seldom welcome; and those who want it the most always like it the least.

Lord Chesterfield

- The more virtuous any man is, the les easily does he suspect others to be vicious.

Cicero

- Good manners are the art of making those people easy with whom we converse. Whoever makes the fewest persons uneasy is the best bred in the company.

Janathan Swift

Impact of Power Factor Improvement Program on Motors in U.E.T Distribution System.

Prof. Dr. Suhail A . Qureshi[1], Engr. Abdul Sattar Malik[2], Zahir J. Pracha[3]

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Abstract

University of Engineers & Technology (UET) is one of the renowned institution is Pakistan, consisting of widely spreaded Transmissions and distribution system. Large number of transformers of different ratings (25,50,100,200 and 400 KVA) are installed at different location is the power system. Power is fed from WAPDA (Water and Power system Development Authority) at one point. The power system of U.E.T is connected mostly with inductive loads, such as tube lights, fans and large motor for pumping drink water and for disposal stations. Power factor improvement technique is one of the methods for conservation of Energy. Electric motors installed at different location are selected to implement power factor improvement program by installation of capacitors. This paper includes the Energy conservation evaluation after power factor improvement.

1.0 Introduction

The development of technology will take considerable time as it has many basic problems, technical as well as economical. Thus immediate solution lies in the conservation of energy. Investments made towards the conservation of energy not only lead to saving to the end user, but also helpful in reducing the burden of additional generation requirements. Conversation of energy has become the hot topic due to recent development in past few decades. It has now been established fact that investments made in the field of energy conversation yield in net overall saving along with other benefits. Industry being the largest consumers, has become the first and foremost target for the energy conversation program. We as a nation come to face with the reality of times and have to allocate the highest priority to energy conversation. Electrical energy is most convenient form of energy as it can be transmitted, distributed and utilized over a very large area. The major consumption of electricity by the industrial sector, the high cost of electricity, and the costly effects of load shedding altogether provide strong basis for reducing the electricity consumption.

From the above discussion it can be concluded that by adopting energy conservation techniques lot of energy saving can be done thus saving lot of money. As per WAPDA statistics cost of complete installation / generation of a powerhouse generating one KW of energy is approximately comes out to be US$ 450 / KW. So total cost of installation for 1 MW of a powerhouse becomes US $ 4,50,000 and in terms of Pak. Rupees it is Rs. 270,00,000(where 1 US $ = @ Rs. 60) [1,2].

Electric motors are large contributor to poor power factors because motors generally operate under light loads. Low power factors do not necessarily increase peak KVA demand because of the reduction in load. For example, the power factor of an electric motor is lowest when the motor is lightly loaded. This occurs when both its power draw and contribution to the electrical peak demand is the least. Energy can be conserved by reducing $I^2.R$ losses by increasing the copper conductor used in the stator winding. Iron losses can be reduced by using better grade of alloy for laminations, and by increasing the length of the core.

Friction and windage losses can be reduced by proper lubrication of the pulley and assembly more over correct size of motor be selected as per load requirement.

This paper Particular deals with evaluation of Energy conserved by power factor improvement of individual motor installed in U.E.T distribution system.

These motors are of different rating varying from 10HP to 80HP, used for Pumping drinking water and other installed at the disposal of dirty water.

Before installing the capacitor at each motor, Energy analysis were performed using a very sophisticated equipment, called Energy/harmonic Analyzer. Using Energy Analyzer exact rating in KVAR of the capacitors were determined. All the parameter such as current (I), Voltage (V), Kilowatts (KW), Kilo Volt Ampere Reactive (KVAR) and etc, are observed before and after the installation of capacitors.

2.0 Methods of Power Factor Correction

Following are the different methods of power factor correction that can be implemented according to the type of the load, such as constant, variable, domestic, industrial or commercial [4,5].

- Individual Power Factor Correction.
- Group Power Factor Correction.
- Central Power Factor Correction.
- Fixed Power Factor Correction.
- Automatic Power Factor Correction.
- Mixed Power Factor Correction.

2.1 Individual Power Factor Correction

This is the easiest way to improve the power factor. Capacitors are installed to he individual loads in parallel. No additional switches or protection devices are required for the capacitors.

2.2 Group Power Factor Correction

When the loads is immense then dividing the whole load into smaller groups results in the power factor correction.

This type of correction is called group power factor correction.

2.3 Central Power Factor Correction

The capacitors are connected directly to the main switchboard or in the sub-station. It is further subdivided into.

2.4 Fixed Power Factor Correction

The capacitors are permanently connected to the line and they have to be remained switched ON or switched manually.

2.5 Automatic Power Factor Correction

This is the most rational solution of power factor improvement of highly variable loads. It is based on a capacitor bank divided into many groups or units and controlled by automatic electronic equipment.

2.6 Mixed Power Factor Correction

This method allows power factor regulation when values are close to unity. In this system units are split into different areas and very small central power correction is required.

When we are talking about the power factor improvement of the distribution system of power supplying authorities (e .g. WAPDA). The best solution is to connect capacitor with each and every inductive load, whether it is industrial or commercial (e.g. fan, washing machine, water pumps etc.) But the solution is not feasible as it involves a lot of effort and lot of money to fulfill the requirement.

2.7 Location of Capacitors

Several factors must be considered before deciding where to install the capacitor. Variation in loads, load factor, load distribution, circuit layout, length of circuit, voltage condition, - all effects the capacitor location. Capacitor can be located to act as group correction or as a localized correction.

A group correction can be made at the primary or secondary side of the transformer or in the plant e.g. at a main switchgear or motor control center bus. Group correction is necessary where load shift radically between feeders and where motor voltage are low such as 230V.

In some cases the power from the main distribution center to various plant location and to individual loads shifts frequently between feeders. In these cases it is necessary to make a correction in one part of the plant first and then in the other part later.

It is more advantageous, however to use a group capacitor located approximately the same distance from the loads at all times. This enables the operator to switch off the portions of the centrally located capacitors to meet specific varying load condition.

If capacitors were connected at the individual motors, then lot of capacitors would be needed, resulting in increase cost. An exception arises where there are long feeders and where the gain from individual load application pays for the higher cost of the capacitors. Where motors circuits are running at 230V at which the cost of the capacitor is twice that of higher voltage units, it is more economical to use group installation.

2.8 Localized Corrections

Placing the capacitor directly on motors and switched with the motors can make localized power factor correction. To obtain the maximum benefits should be connected as near as possible to the load or near the end of feeders. When specifying equipment to improve power factor, the engineer should take into account that improvement should take place only from the point of application toward the source of power and not in the opposite direction.

By placing a capacitor at the load reduces the losses in the circuit between load and the metering point. The reduced losses can be determined by investigating the length of the circuits and transformations, the net grains in the form of released transformer capacity and loss reduction in transformers and circuits.

Another advantage of placing capacitors near loads is a voltage increase. This results in better performance of motor. The voltage increase, when compared to normal voltage, is practically constant from no load to full load of the feeder.

3.0 Capacitors installation on Motors

Capacitors are normally installed near induction motors terminals and switched as a unit with the motor. When connected in this manner, the amount of KVAR should be limited to values that do not cause voltage rise at the motor due to self-excitation [7,10].

When capacitors switched as a unit with the motors are located on the motor side of the overload relay, the line current actuating the relay will be lower in value than the motor current at all loads. When connecting capacitor in this manner, it is recommended that size of he overload relay be based on the decreased value of line current. Hence, a smaller relay will be necessary.

When capacitors are divided into a number of banks and located on the feeders close to the motor, the voltage increase under no load conditions will be smaller than if the capacitors would be located at one point on the main feeder. It means that it is not necessary to switch to switch the capacitors with the motor to avoid Over voltage at light load. In this case it is advisable to distribute the capacitors on the smaller feeders branching out from the main source and keep them continuously connected.

3.1 Economic Considerations

As for as the economic consideration is concerned it is observed that maximum benefits can be obtained by installing the capacitors directly at the loads. In some applications, it is economical to take advantage of load diversity and then to locate the capacitors further cack on the system to obtain return on capacitor investment.

Industrial plants usually have number of small loads. Since the capacitors are manufactured in standard sizes, it is impractical to use the correct size capacitor at each load.

Also, all these small loads are not on all the time. Because of this diversity it is advantageous to install a single capacitor at a central location, which may be the main bus of a switchgear or motor control motor.

In most plants only 60% of the loa connected are operating at the same time –40% is standby. This means a capacitor located at the main bus would have to be only 60% of the KVAR necessary for capacitors located at individual loads.

The system operating voltage also has an influence on the economics of capacitor location. This is because 230V capacitors are twice as much costlier than 415V capacitors. An economic comparison should also include the capacitor's switching device. For 2.4 kV or 11KV capacitors are most economical, the proper switching device costs more than 415V switching devices.

A careful analysis of all technical and economical aspects including load utility-rate schedules, released KVA, reduced losses, voltage improvement, prices of power factor correction devices based on previous consideration will decide the best selection and location of power factor improvement methods.

4.0 Energy Analysis of U.E.T Motors

There are various aspects, which are to be taken into the consideration while Performing energy analysis of the distribution system of U.E.T. Some of which are as under;

1. Analysis of various motors installed at the pumping stations.
2. Analysis of the motors before and after Capacitor installation.

4.1 Analysis of the motor

For the comprehensive and complete analysis of motors installed at the pumping stations of the UET, energy analyzer equipment was used. In the analysis procedure, energy analyzer was attached with the motor installed while keeping the load on the motor ON and complete set of data was obtained showing the frequency, current in each phase, line current, line voltage, power factor, active power, apparent power, reactive power, distortion factor, KWH, KVARH etc.

This analysis was performed to calculate what ratings of capacitors are required for the power factor improvement in addition to other outputs. The complete set of analysis, which was done with the energy analyzer of all the motors installed in the pumping station, has been attached in the annexure. Final analysis after the installation of the required capacitors done again to check the power factor. It was observed that power factor of the motors has been increased remarkably moreover other factor like voltage increase, current drawn decreases, decrease of KVA rating etc. Fig:1 Shows the set-up of Energy Analysis Performed on the motor, the same setup is used on each motor. Results of he analysis before and after the installation of capacitors have been shown in the Annexure.[1]

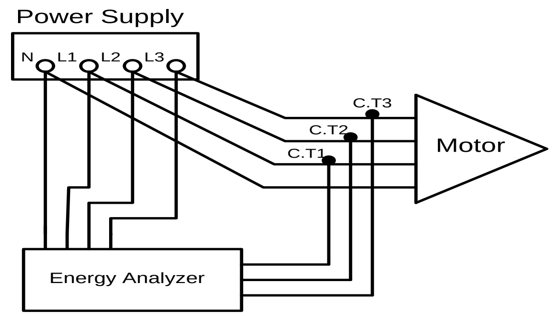

Fig 2 Energy Analysis arrangement.

5.0 Comparison of Motor Parameters before and After Installation of Capacitors

Energy Analyzer is Elcontrol Brand,(VIP model, made in Italy) is being used to perform the analysis of motors. The analysis of Five motors installed at different locations in U.E.T is Presented below.

5.1 Annexi Block Motor Analysis

Rating of the motor are as follows;

P = 50HP, V = 415 Vols, I = 67 Amps.

Following are different Parameter before and after installation of 20KVAR, P.F.I Capacitor bank on the motor installed at Annexi Blolck Pumping station.

20-KVAR Capacitor rating was Suggested by Energy Analyzer.

Fig 2 Shows the arrangement of power Factor Improvement Program.

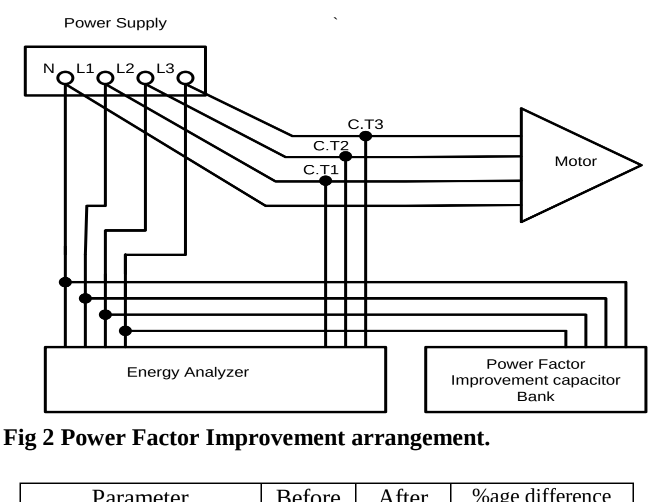

Fig 2 Power Factor Improvement arrangement.

Parameter	Before	After	%age difference
P.F	0.876	0.988	+12.78%
I (Amp)	80.199	70.76	-13.34%
V	388.3	393.58	+1.36%
KVA	45.26	39.81	-12.04%

The variation in voltage, Current, Power factor, KVA KW and KVAR for each Phase of the motor are show in Table-1 in Annexture (I).

Note: **-**ive sign shows reduction in the Parameter and +ive sign shows increase in the Parameter Values.

5.2 RT (Resident Tutor) House Motor

Rating of the motor are as follows;

P = 40HP, V = 400, I = 45Amps.

Following are different Parameters before and after installation of 20KVAR, P.F.I Capacitor bank on the motor installed at R.T House Pumping station.

20-KVAR Capacitor rating was Suggested by Energy Analyzer.

Parameter	Before	After	%age difference
P.F	0.760	0.989	+30.13%
I (Amp)	47.91	36.60	-23.61%
V	387.9	389.6	+0.43%
KVA	32.19	24.70	-23.27%

The variation in voltage, Current , Power factor, KVA, KW and KVAR for each Phase of the motor are shown in Table-2 in Annexture (I).

Note:- ive sign shows reduction in the Parameter and +ive sign shows increase in the Parameter Values.

5.3 Colony Pumping Station Motor

Rating of the motor are as follows;

P = 80HP, V = 380, I = 112Amps.

Following are different Parameter before and after installation of 25KVAR, P.F.I Capacitor bank on the motor.

25 KVAR Capacitor rating was Suggested by Energy Analyzer.

Parameter	Before	After	%age difference
P.F	0.868	0.992	+14.28%
I (Amp)	86.05	73.29	-14.82%
V	383.1	388.3	+1.35%
KVA	57.10	49.29	-13.68%

The variation in voltage, Current, Power factor, KVA, KW and KVAR for each Phase of the motor are shown in Table-3 in Annexture (I).

Note:- ive sign shows reduction in the Parameter and +ive sign shows increase in the Parameter Values.

5.4 Main Block Motor

Rating of the motor are as follows;

P = 40HP, V = 380Volts, I = 58 Amps.

Following are different Parameters before and after installation of 25 KVAR, P.F.I Capacitor bank on the motor.

25KVAR Capacitor rating was Suggested by Energy Analyzer.

Parameter	Before	After	%age difference
P.F	0.865	0.980	+13.29%
I (Amp)	56.74	49.72	-12.37%
V	377.2	379.0	+0.47%
KVA	37.07	32.64	-11.95%

The variation in voltage, current, Power factor, KVA, KW and KVAR for each Phase of the motor are shown in Table-4 in Annexture (I).

Note: **-**ive sign shows reduction in the Parameter and +ive sign shows increase in the Parameter values.

5.5 Disposal Plant Motor

Rating of the motor are as follows;

P = 10 HP, V = 380 Volts, I = 15 Amps.

Following are different Parameter before and after installation of 5KVAR, P.F.I Capacitor bank on the motor. 5-KVAR Capacitor was Suggested, by Energy Analyzer.

Parameter	Before	After	%age difference
P.F	0.590	0.976	+65.42%
I (Amp)	8.938	5.223	-41.56%
V	372.9	375.5	+0.70%
KVA	5.773	3.397	-41.16%

The variation in voltage, current , Power factor, KVA, KW and KVAR for each Phase of the motor are shown in Table-5 in Annexture (III)

Note: **-**ive sign shows reduction in the Parameter and +ive sign shows increase in the Parameter.

6.0 Conclusions

In this research work, the main emphasis is placed in evaluation of Energy savings by Power Factor Improvement, of motors installed in the Distribution System of University of Engineering & Technology (U.E.T) Lahore, Pakistan.

This Power factor improvement was achieved by installing Capacitor on the motor installed at different locations in U.E.T.

Initially, each of the motor was connected with Energy Analyzer and different Parameter were measured, such as Current, Voltage, Power (KW, KVA, KVAR) and power factor. From this energy Analyzer the rating of the Capacitor required to improve the Power factor from existing value to a value more than 0.90, is determined.

After installing the Capacitor across the motor, all Parameter, e.g., Current, voltage, Power, (KW, KVA, KVAR) are once again measured. It has been observed that by installing capacitors across the motors, the following parameters were found reduced;

- Current (A)
- Power (KW, KVA)

The following parameter were found increased by improving power factors;

- Power Factor (Cosϕ)
- Voltage (V)

It has been observed that the energy conserved by power factor improvement entirety depends on the existing power factor of the motor and quality of the material used in manufacturing of the motor.

The maximum saving in current as results from different motor is 41.56 %. This result is obtained from Disposal plant motor, where the power factor was improved from a value of 0.59 to 0.976.

7.0 References

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Annexture - (I)

Phase	**Current (Amps)**		**Voltage (Volts)**		**P.F (CosΦ)**		**Apparent power (KVA)**		**Active Power (KW)**		**Reactive Power (KVAR)**	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	68.7	59.4	367.1	373.0	0.881	0.991	14.53	12.76	13.35	12.64	6.88	1.75
1.2	72.6	62.8	376.7	376.2	0.886	0.983	15.42	13.35	13.83	13.33	7.72	2.49
1.3	71.0	61.8	375.3	375.3	0.880	0.989	15.31	13.50	12.80	13.35	7.26	2.01
Mean	70.76	61.32	368.3	374.8	0.876	0.988						
Total							45.26	39.81	39.63	39.32	21.86	6.25

Table 1. Showing Computerized energy Analysis of Annexi Block Motor

Phase	**Current (Amps)**		**Voltage (Volts)**		**P.F (CosΦ)**		**Apparent power (KVA)**		**Active power (KW)**		**Reactive Power (KVAR)**	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	47.3	35.11	387.4	389.2	0.725	0.981	10.64	7.93	7.71	7.78	7.73	1.54
1.2	49.9	36.52	387.0	388.8	0.778	0.995	10.43	8.16	8.11	8.12	6.56	0.81
1.3	47.91	38.29	389.4	390.0	0.776	0.990	11.14	8.610	8.64	8.54	7.03	1.24
Mean	47.91	36.60	387.9	389.6	0.760	0.989						
Total							32.19	24.70	24.46	24.44	20.92	3.59

Table 2. Showing Computerized Energy Analysis of RT House Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Befor	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	84.1	70.5	382.5	387.9	0.848	0.998	18.65	15.83	15.81	15.64	9.89	2.45
1.2	81.5	70.5	382.5	387.9	0.884	0.996	17.92	15.74	15.84	15.68	8.38	1.37
1.3	92.7	79.0	384.2	390.0	0.873	0.992	20.56	17.74	17.94	17.60	10.04	2.22
Mean	86.05	73.29	383.1	388.3	0.868	0.989						
Total							57.10	49.29	49.59	48.92	28.31	6.04

Table 3. Showing Computerized Energy Analysis of Colony Motor

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	53.4	47.0	378.0	379.5	0.867	0.981	11.62	10.28	10.07	10.08	5.80	2.02
1.2	59.9	52.0	377.4	379.1	0.856	0.973	13.11	11.41	11.22	11.10	6.78	2.64
1.3	6.9	50.2	376.3	378.5	0.872	0.985	12.34	10.80	10.76	10.80	6.04	1.87
Mean	59.74	49.72	377.2	379.0	0.865	0.980						
Total							37.07	32.64	32.05	31.98	18.62	6.53

Table 4. Showing Computerized Energy Analysis of Main Block Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	8.52	4.96	373.4	375.7	0.616	0.987	1.831	1.073	1.127	1.059	1.443	0.173
1.2	9.47	5.73	373.3	375.9	0.589	0.973	2.041	1.246	1.206	1.212	1.655	0.289
1.3	8.83	4.99	372.0	374.9	0.566	0.968	1.896	1.081	1.073	1.046	1.563	0.273
Mean	8.938	5.223	372.9	375.5	0.590	0.976						
Total							5.773	3.397	3.406	3.317	4.661	0.735

Table 5. Showing Computerized Energy Analysis of Disposal Plant Motor.

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N.E.C. (U.S.A.) and Ground Fault Circuit Interrupter (GFCI)

By

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1.0 ABSTRACT

NEC (USA) is being used in the U.S.A. for well over hundred years. It pertains to issues related with distribution of electrical power in Domestic, Industrial and Commercial areas.

"Ground Fault Circuit Interrupter" abbreviated as GFCI is a device which will immediately trip a feeding single phase circuit when its leakage current is 30 milliampere or more and in this way it will protect the life of a person who happens to touch a live conductor.

In this paper it is explained as to what is GFCI and how it functions. Further the various clauses of NEC, which dictate that in certain places GFCI must be used, are discussed in detail. In the end, its use in Pakistan is strongly recommended.

2.0 INTRODUCTION

It is admitted on all hands that "Electricity" has played an unparalleled role and brought in enormous benefits to mankind. However, due to defective wiring and defective leaky electrical machinery, some times it has caused electrocutions. It is roughly estimated that every year more than one hundred persons get electrocuted in Pakistan in their houses and work places.

As soon as a person touches a live conductor, current starts flowing from the conductor to the ground through the body of the person. Since the resistance of the body of an adult person is considered as 1000 ohms, so the voltage of the conductor as well as the time in seconds are the two factors which will determine whether the person who has touched the live conductor will survive the shock or not. Suppose the voltage of the conductor is 230 volts, then the current flowing through the body to the ground will be 230/1000 = 230 milli-amperes. However, if the voltage of the conductor is 120 volts (in U.S.A. and Saudi Arabia, usually 120 V is the rated voltage in houses and commercial places) then the current flowing through the body of the person will be 110/1000 = 110 milli-amperes. A perusal of Figure – 1 will show that for a 230 V circuit, within 40 milli seconds the circuit, which is feeding the above said conductor must trip open to protect the above mentioned person from possible electrocution. In fact GFCI is a device which will trip the defective circuit within 30 milliseconds and so it protects the lives of persons who happen to accidently touch the live conductor. Some versions of GFCI are available which have even 15 milli second trip time.

3.0 SOME BACKGROUND OF NATIONAL ELECTRICAL CODE (U.S.A.)

The National Electrical Code (abbreviated as NEC) is one of many codes and standards that are published by the National Fire Protection Association (NFPA), a not-for-profit corporation. The First Edition was issued during the year 1896. The code is revised every three years in order to keep up with new materials, tools, and methods that are constantly being developed. This work is performed by 21 separate committees, each consisting of approximately 10 to 15 persons, the majority of them engineers. Members of each committee meet several times, discuss all proposed changes, accepting some and rejecting others, and rewrite (as required) the sections of the Code that were assigned to their committee. Then, they circulate the changes among the various committees, coordinate the changes, and rewrite again. So, obviously, the updating of the NEC is a tedious task. But the real difficulty is that it must remain applicable to all types of electrical installations, leaving no "gaps". Because of this, it becomes rather difficult to interpret in some instances. For this reason, Handbooks are also available which are written by prominent and experienced persons and these Handbooks are very useful as hundreds of photographs and sketches are included therein. Reference (1) is a Handbook which is also published by NFPA (U.S.A.).

NEC is being used not only in U.S.A. but also in some other countries such as Saudi Arabia and Kuwait etc.

In Saudi Arabia historically the Eastern Region has more American influence due to the presence of ARAMCO which has been carrying out the trade of crude oil for the past 80 years. The author happened to see some contracts regarding Thermal Power Plants which were awarded by SCECO East (now it is called S.E.C.) and which contained reference of above said NEC. In Dammam area, GFCI as well as sockets, switches and wiring devices are generally in accordance with N.E.C. (U.S.A.).

4.0 WORKING PRINCIPLE OF A GFCI

The schematic of GFCI is as shown in Figure 3.

As shown in Figure 3 GFCI consists of a small current transformer surrounding live and neutral wire. The secondary winding of current transformer is connected to relay circuit which can trip the circuit breaker which is connected in the circuit.

Under normal conditions, the current in line and neutral conductor is same so the net current (I_L - I_N) flowing through the core is zero. Eventually there will not be any production of flux in the core and no induced e.m.f. So the breaker does not trip.

If there is a fault due to leakage from live wire to earth or a person by mistake happen to touch the live terminal then the net current through the core will no longer remain as zero but equal to IL - IN which will set up flux and emf in C.T. As per the preset value, the unbalance in current is detected by C.T. and relay coil is energized which will give tripping signal for the circuit breaker. As C.T. operates with low value of current, the core must be very permeable at low flux densities.

The GFCI provides protection against electric shock when a person comes in contact with live parts, resulting in flow of current from body to earth. A properly connected GFCI detects such small currents in milli-amperes flowing to earth through human body or earth wire and breaks the circuit to reduce the risk of electrocution to humans.

In the absence of GFCI and with a continuous flow of small fault or leakage current to earth undetected for a considerable period may create hot spots which may result into fire.

If the fault current passes to the ground through the body of a person, who had touched the live conductor accidently, then GFCI will trip in less than 30 milliseconds and thus will protect the person from possible electrocution.

The function of "Test Push Button" is that while carrying out commissioning tests after installations, it is to be confirmed whether GFCI will trip or not when called upon to do so. Further, after regular intervals of time (say after a lapse of one month) the Test Push Button is pressed to confirm whether or not the device (i.e. GFCI) is performing its job properly.

5.0 SOME ASPECTS REGARDING GFCI

GFCI is available in the market in the form of a socket (refer to Figure 2) or in the form of a GFCI fitted circuit breaker. In the case of a circuit breaker, it is installed in the Distribution Panel (D.P.) and then it will protect all the sockets which are fitted to that circuit which is protected by GFCI fitted Circuit Breaker.

Plug-in type sockets are also available in the market which can be easily fitted in an ordinary socket which is usually available in a house or commercial installation or a factory.

In U.K (IEE Wiring Regulation), GFCI is termed as RCD i.e. Residual Current Device. Some times, a term "ELCB" is used in the Technical Literature/books which stands for Earth Leakage circuit Breaker. This is the same thing as GFCI.

6.0 N.E.C. (U.S.A.) clauses which are related to GFCI

In the following paragraphs, those clauses are indicated which are given in N.E.C. Some explanation is also provided.

(Important Note: In the U.S.A., utilization voltage in domestic and commercial places is usually 120 volts. This is the voltage between a phase wire and a ground wire. However, in U.K and Pakistan, this phase to ground voltage is 230 volts. So, in Pakistan all the following clauses can be employed but the only difference will be that 230 volts GFCI should be used).

Clause No. 210.8: Ground-Fault Protection for Personnel.

6.1 Dwelling Units

Ground-Fault circuit protection may be used in any location, circuits, or occupancies and will provide additional protection from line-to-ground shock hazards.

(1) For personnel protection, ground-fault circuit-interrupter protection is a requirement for all 125 volt, single-phase 15 and 20 ampere receptacle outlets installed in bath-rooms.

(2) Ground-fault circuit interrupter (GFCI) protection for personnel is required on all 125 volt, single-phase, 15 or 20 ampere receptacles installed in garages. Garages usually have concrete or dirt floors, which are always considered at ground potential.

If a receptacle is not readily accessible, a GFCI is not required. Exceptions to NEC Section 210.8(A)(5) are not to be considered as meeting the requirement of Section 210.52(G). In a garage where you have the receptacles without GFCI protection for specific purposes, electric drills or other tools could be easily plugged into one of the receptacles. Since the floors of garages are usually concrete or dirt and the walls are made from brick, these locations could be hazardous when one is using a defective hand drill unless a GFCI is installed in those outlets.

(3) The Code requires that all 125 volt, single-phase, 15 and 20 ampere receptacles that are installed outdoors have GFCI protection.

In outdoor locations, any socket which is accessible to a person (i.e. where he may plug-in a portable drilling machine or other portable tool) must be GFCI fitted.

(4) All 125-volt, single-phase receptacles installed in basements or crawl spaces are required to be GFCI receptacles, except if they serve only laundry circuits, sump-pump circuits, or specific-use circuits (such as to a freezer). See NEC for two exceptions.

(5) Any kitchen receptacle-serving countertop areas shall have a GFCI for protection of the people. In kitchen, there is usually a sink. Any receptacle which is within 6 feet from the sink then the same must be a GFCI fitted receptacle. However, if the distance between the receptacle and the sink is more than 6 feet, then GFCI is not required and an ordinary socket can be employed.

Note:

Receptacles for refrigerators and freezers are exempt from GFCI protection for people. However, if these are within the 6-feet limit from the sink, a shock hazard might still be present. In that case a GFCI is a must.

(6) All 125-vol, single-phase, 15 or 20 ampere countertop receptacles within 6 feet (1.83 m) of a sink must have GFCI protection.

(7) All 125-volt, single-phase, 15 or 20 ampere countertop receptacles within 6 feet (1.83 m) of a sink in or on a boathouse, dock, or seawall must have GFCI protection.

6.2 Other Than Dwelling Units

(1) In nondwelling occupancies, such as industrial or commercial placesof business, all 125 volts, 15 or 20 amp receptacles that are installed in bathrooms must have GFCI protection. This includes such receptacles installed in hotel rooms and similar locations.

Bathroom – A bathroom is an area including a basin and at least one of the following: a tub, a toilet, or a shower.

It would appear to the reader that a ground-fault circuit interrupter would be the least expensive and the most positive protection for the overall pictures.

(2) All 125-volt, 15- or 20-amp receptacles installed on roofs of a building must have ground-fault protection for personnel. Note that this does apply to receptacles installed on the roofs of dwelling units and that the NEC does make an exception for dedicated receptacles serving snow-melting equipment. For more detail, refer to N.E.C.

7.0 SOME SIGNIFICANT BENEFITS OF GFCI

Reference (2), which was published in the year 1955 and prior to the invention of GFCI, has indicated data of some fatal accidents which were caused while operating faulty portable tools e.g. drilling machines etc. According to the above said book, in the year 1952, more than 40 persons got electrocuted and more than 869 got badly injured. This is inspite of the fact that rated voltage in U.S.A is about 120 volts. So, in Pakistan, where the rated voltage is 230 volts (phase to ground) it is easy to guess as to how many similar accidents would have taken place. According to a rough estimate at least 100 persons every year would have suffered fatal accidents by accidently touching live conductor or defective drilling machines.

In view of the above discussion, WAPDA and PEPCO are urged to take some concrete action and get introduced GFCI in domestic, commercial and industrial places in the light of NEC (U.S.A.). In this regard, Government is also urged to get prepared some “Wiring Regulations” and in this regard help from NEC (USA) can be taken. This step will go a long way and save the lives of hundreds of workers from possible electrocutions who happen to accidently touch a live conductor or a defective portable tool. This step will also protect children who insert their finger in some socket.

8.0 CONCLUSION AND RECOMMENDATIONS

NEC (USA) is an extremely useful document and a Design Guide which is being used in USA and in Saudi Arabia as well as in some other Countries. It includes many important topics including GFCI.

As indicated in Reference (2), prior to the invention of GFCI, more than 40 persons had been electrocuted in USA in one year alone and the cause of their deaths was that the portable tools (for example, a drilling machine) which they were using were defective and they suffered electric shocks and got electrocuted, though the voltage was merely 120 volts. Later on, NEC compelled users to use GFCI fitted receptacle for operating such drills and it brought in good results.

As per NEC, at the following places GFCI must be used.

a. In bathroom, any socket must be GFCI fitted

b. In basements, all sockets must be GFCI fitted. (There are a few exceptions for washing machines. Refer to NEC).

c. In kitchen, sockets which are within 6 feet from sink, must be GFCI fitted.

d. In outdoor area (of a house etc.), every accessible socket must be GFCI fitted.

In Pakistan, GFCI is rarely used. Here, it is roughly estimated that more than 100 persons are electrocuted every year due to the electric shocks which workers receive. Such precious lives can be easily saved by the use of GFCI.

WAPDA and PEPCO as well as Government’s Electrical Inspectors are strongly urged to follow the relevant clauses given in NEC and include these in their documentation regarding “Application for New Connections”. Further, there is a need to introduce “Wiring Regulations” and it must be prepared in the light of N.E.C. (U.S.A.) to ensure the safety of workers in work places and children in homes who may happen to touch accidently a live conductor.

9.0 REFERENCES

- National Electrical Code Handbook, published in year 2011, published by NFPA, U.S.A.
- Industrial Power Systems Handbook by Donald Beeman, Publisher: MCGRAW – Hill Boll Co. U.S.A.

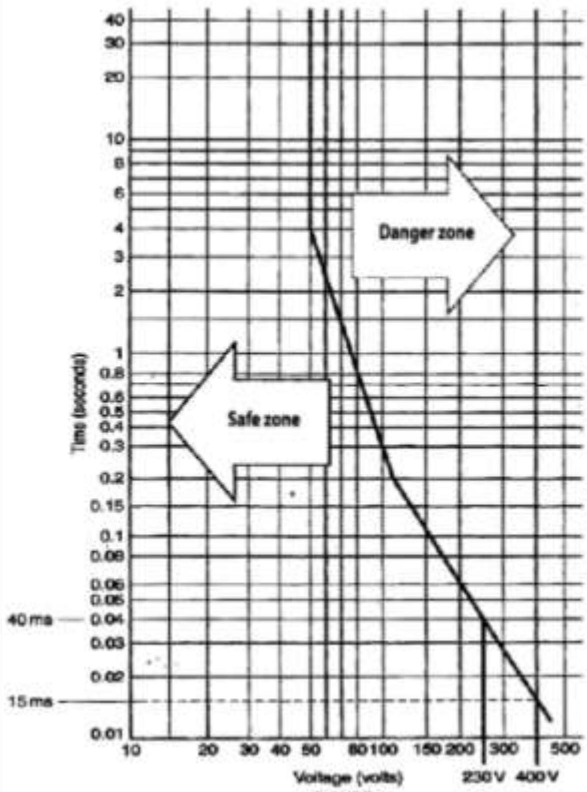

FIGURE 1
CURVE SHOWING TRIPPING TIME OF A CIRCUIT FOR PROTECTION AGAINST ELECTROCUTION

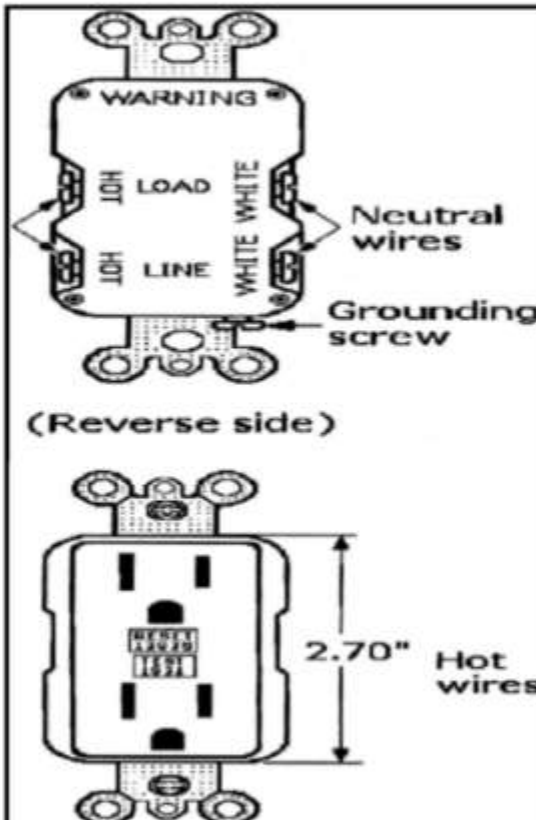

FIGURE 2
SOME VIEWS OF GFCI

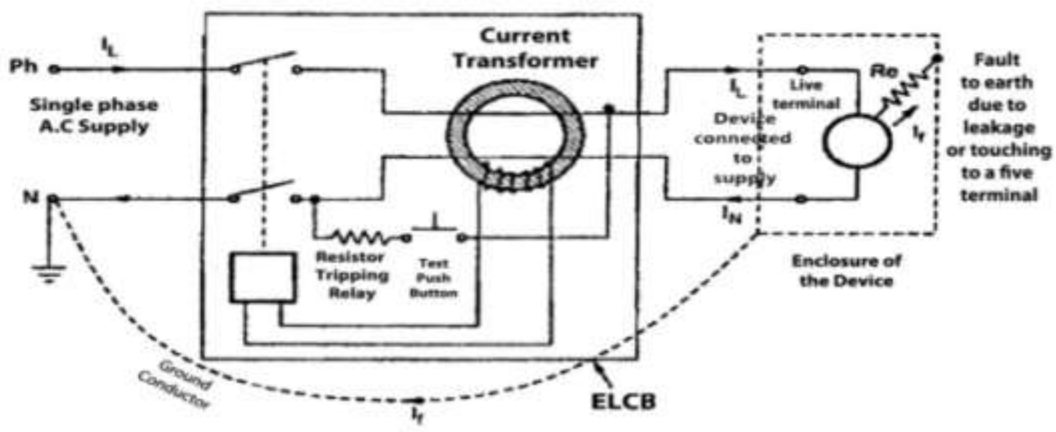

FIGURE 3
DIAGRAM FOR GFCI SCHEMATIC

Words: 1232

The Political Economy of the Power Sector!

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The media is replete with pundits opining on the Power Sector. Most of the gentlemen have, unfortunately, fallen short of coming-up with viable solutions that could possibly mitigate the ongoing hydra-headed crisis. Additionally, no one has discussed the political economy and the effect of illegal reaping of the same. Nor have the exact details of the political economy of the Pakistani Power Sector ever been listed.

Insight into the issue reveals that the political economy of the Pakistan Power Sector is command based and where a central political agent commands its operations. As is wont of a command based economy, the Pakistan Power Sector is facing shortages with no mechanism to improve the system's natural supply and demand dynamics. It is further seen that the level of shortages are directly proportional to the competence of the political command. Furthermore, the political economy encompasses first of all, the filling-up of as many as twenty to thirty high level management positions by any incumbent government. This has emerged after debundling of WAPDA's Power Wing into four generations companies (GENCOs), one transmission and dispatch company (NTDC) and ten distributions companies (DISCOs). Under the new reform regime, NEPRA as the regulator has also been set-up providing five more management slots to be filled-in in shape of the Authority's Chairman and the four Provincial members. Additionally, there is the National Power Construction Company (NPCC), the Alternate Energy Development Board (AEDB), the Private Power & Infrastructure Board (PPIB), the National Energy Conservation Centre (ENERCON), Engineering Development Board (EDB), the office of the Engineering Advisor to the Ministry of Water & Power, the Water & Power Development Authority (WAPDA) itself with the position of its Chairman and the three Members and some other smaller organizations including the National Engineering Services of Pakistan (NESPAK) to contend with. All in all, it is very interesting for any government to be able to dole out the positions to its protégées and other camp followers.

Besides, the ability of fill-up these positions, the political economy of the power sector allows for the government to intervene in its day to day operations and to also arrange for further posting and transfer of mid-level and even junior functionaries at will. Mostly, it is seen that the top level of the government would concentrate on having the higher management of its own, while the constituency level politics dictates that SDOs, line superintendents and even meter readers are of choice for the MNAs and MPAs. It has become a dictum in DISCOs that if you want to highlight electricity thieves, the right way would be to transfer the area meter reader and then list-out the various VIPs and their henchmen who would come to the transferred official's rescue.

Another facet of the political economy of the power sector is government's pressure on it to take-up what is erroneously billed as village electrification. Incidentally, during the last ten to fifteen years, this activity has converted into dera-electrification and nothing else. Individual farm houses, poultry farms, tube wells, fish farms and even plain fields have been provided power under the above misnomer. That, this activity with an outlay of over Rs.100 billion during the last decade has resulted in extra losses for the DISCOs, has never been considered as anything of consequence or wrong. Further, that dera-electrification cannot be justified under any condition too has not been considered. That these electrifications are cost-prohibitive, having negative cost-benefit ratios and then result in blatant abstraction of energy is also forgotten. Actually, this bogus and spurious electrification is considered as a great vote catcher, with pundits claiming that such an activity cannot be stopped and would remain an important pillar of the political economy of the power sector in the future too.

Thereafter, comes the relegation of central planning as used to be in WAPDA times. Consequently, new sub-transmission lines, grid stations, 11KV distribution feeders, distribution transformers and even LT lines are mostly being laid down under outside orders and tutelage. Such arbitrary planning has led to increase in line losses and lopsided operations. The DISCOs, thus, do not have control over much of their operations.

Then comes the much touted energy loss reduction (ELR) programme and the actual benefits it has since accrued for the DISCOs. Looking back in history, we see that WAPDA took-up the ELR programme in early 1980s through US Aid funding, which was then bolstered by help from other MLDAs (multi-lateral developmental agencies) like World Bank and the ADB. Because of pressure from without – primarily political, huge expenditures are being used to add junk to junk instead of any improvement for the system. During the last ten years, these funds were nearly being used to open-up new areas for electrification. In other words, each rupee being spent on the program was in fact adding on the original loss figure.

The energy crisis and the current shortages have further added to the political economy and now the relevant pressure group can somewhat order around the DISCOs as to where the supplies have to go and for which duration. Actually, without laying down the broader principles for spreading the shortages, each luminary would vie for the maximum chunk of the pie and this saw prime ministerial and even ministerial towns receiving more than the normal share – surely to the detriment of others.

Procurement and contracting is another area where poaching by exterior forces is rampant. There is great pressure on the managements to accommodate favorites. Actually, no one believes that the cadre can be honest and would decide these issues on merit. This has resulted in below par procurement and contracts that do not fulfill any test of time.

Then comes access to recruitments in the power sector. And, this has been misused to the hilt. Merit was relegated to the back burner and slowly the power sector has become poorer in content. This resulted in reduced ability of the sector to deliver. In addition to the above facets of intervention, there are a few other smaller areas which too are the subject of illegal poaching. However, firewalling of major areas can save the smaller areas from intervention etc.

From the above, it is seen that the political economy of the power sector is highly lucrative and can be a happy hunting ground for those in power. Additionally, we see that outside meddling increased from 2006 onwards and then reached a crescendo last year. It is further concluded that it all has been detrimental to the operations and has lead to the near permanent down grading of the sector. It can also be said that the present crisis may have its roots in illegal reaping of the economy and that correction can only take place if the political economy of the power sector is not allowed to be controlled from outside and that merit is made the hall mark. The political government may thus lay down the broader contours of the policies and then follow-on the performance of those it has selected (on merit) to manage the sector.

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Solar Energy – Today and Tomorrow

By

Engr. Riaz Ahsan Baig

1. GENERAL

Today no one can deny that our country is suffering from shortage of power, so badly needed for economic growth of the country, halting agriculture and industrial development.

To meet the shortage of power demand, we need to utilize all the available indigenous resources in Pakistan particularly Wind Mills, Hydle Potential, Thar Coal and Solar Energy, which has a great potential to meet our power demand and is emerging as a most potent source of renewal energy. Solar energy if sincerely exploited can bring a revolution in World in the very near future, and GOP must give due priority for its development in Pakistan to meet shortage of power.

2. SOLAR POWER

2.1 Potential

Solar energy is one sector which can be developed fast to resolve the energy shortage. God has gifted Pakistan with plenty of solar energy. We receive high level of radiation about 1kW per sq. meter all through the year which if converted to electricity can produce 4.9 to 7.0 $kWh/m^2/day$. Total potential of energy available in Pakistan amounts to 2.9 million MW. We see bright future for Pakistan as non depleting solar energy resource is available.

2.2 Major Types

Solar Power is the conversion of sunlight electricity, either directly using photovoltaic (PV) or indirectly using concentrated solar power (CSP), so there are two major sources of solar power which will be discussed with respect to type of technology, application, economy, cost, their present and the future status.

i. Photovoltaic Cell (PV)

ii. Solar Thermal Power (CSP)

3. PHOTOVOLTAIC CELL

Broadly speaking photovoltaic cell technology can be classified into

- Traditional crystalline silicon technology (SC)
- Thin Film solar Cells (TFSC) technology

There are currently three different generations of solar cell. The first Generation (those in the market today) are made with crystalline semi conductor wafers, typically silicon. These are the SC's everybody think of when they hear "Solar Cell".

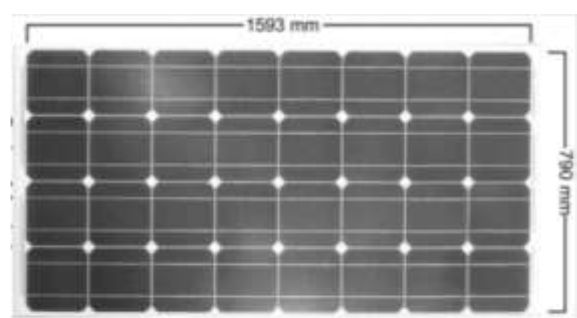
Second Generation Solar Cell are based on thin film technology. These Solar Cell focus on lowering the amount of material used as well increasing the efficiency.

The goal of third generation solar cells is to increase the efficiency using second generation solar cells (thin film) and using materials that are found abundantly on earth. This has also been a goal of the thin film solar cells. With the use of common and safe materials, third generation solar cells should be able to be manufactured in mass quantities further reducing the costs. The initial costs would be high in order to produce the manufacturing processes, but after that they should be cheap.

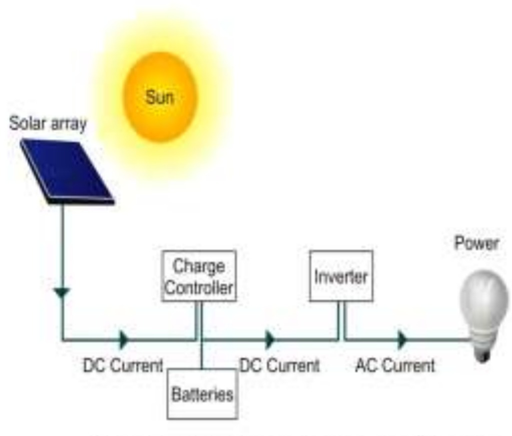
3.1 Silicon Technology

Traditional crystalline silicon technology uses photovoltaic modules using silicon. Nitride Mono or Multi Crystalline Silicon cells. Most of the today's manufacturers of photovoltaic models uses this technology and have made investment worth of billion of dollars for establishment of factories and R&D. In this technology a relatively thick layer is deposited on substrate. The maximum efficiency achieve by use of this technology ranges between 8-15%. Data of one of the renowned Chinese manufacturer is enclosed for photovoltaic modules.

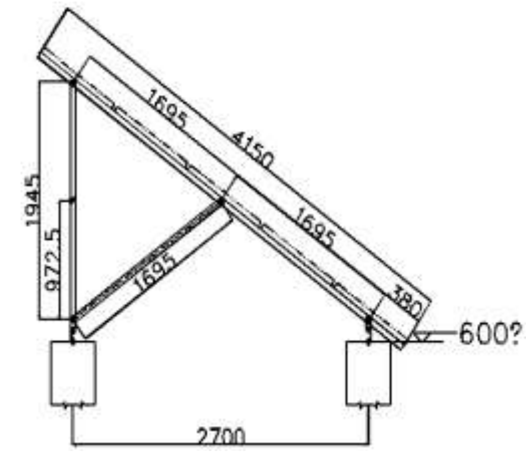
Solar Panels



Solar Model
Consisting of 32 pcs



General Layout of PV Station (System Configuration)



Mounting Arrangement of Typical Solar Panel

TYPICAL SOLAR PANELS (BRANDED)

3kW, 5kW AND 10kW SYSTEM CONFIGURATION AND ESTIMATED COST OF HIGH QUALITY PROJECT WITH 25 YEARS OF WARRANTY FOR SOLAR PANEL

Name of Equipments	Specification			Quantities/Cost U.S$		
	3kW	5kW	10kW	3kW	5kW	10kW
Solar panel	135W	160Wp	170W	24pcs/3000$	32pcs/5000$	63pcs/10,000$
Solar Array Support	3240/135-24			1set/500$	1set/800$	1set/800$
Charging Controller	60A/48V	5KW	15KW	1set/200$	1set/300$	1set/500$
Inverter	3000KVA	5KW	15KW	1set/300$	1set/500$	1set/1000$
Maintenance Free Deep Cycle Batteries (Average Life 10 Years)	1500AH	2500AH	5000AH	2,000$	3,300$	6,600$
Distribution Box/Anti-thunder Protector	Indoors			1set/200$	1set/300$	1set/500$
Installation Charges				300$	400$	500$
TOTAL COST				**6500$**	**10800$**	**19,900$**

PER WATT COST COMPARISON & SPACE REQUIREMENT

Description	Quality	3kW	5kW	10kW
Cost/Watt for 6 Hours Backup	High Quality Branded Products	2.2$	2.1$	2.0$
Cost/Watt for 12 Hours Backup	High Quality Branded Products	2.8$	2.7$	2.5$
Cost/Watt Without Batteries	High Quality Branded Products	1.5$	1.4$	1.35$
Cost/Watt for 6 hours backup	Commercial Grade	2.0$	1.9$	1.8$

ESTIMATED SPACE REQUIREMENT

Open Space Required for Panels		30m^2	40m^2	60m^2
Indoor Room Space for Batteries, Inverter etc.		6m^2	8m^2	10m^2

3.2 Thin Film Soloar Cells (TFSC)

A thin-film solar cell (TFSC), also called a thin-film photovoltaic cell (TFPV), is a solar cell that is made by depositing one or more thin layers (thin film) of photovoltaic material on a substrate. The thickness range of such a layer is wide and varies from a few nanometers to tens of micrometers.

Many different photovoltaic materials are deposited with various deposition methods on a variety of substrates. Thin-film solar cells are usually categorized according to the photovoltaic material used:

- Amorphous silicon (a-Si) and other thin-film silicon (TF-Si)
- Cadmium Telluride (CdTe)
- Copper indium gallium selenide (CIS or CIGS)
- Dye-sensitized solar cell (DSC)
- Plasmonic Solar Cell (PSC)

The silicon is deposited on glass, plastic or metal which has been coated with a layer of transparent conducting oxide (TCO).

Since the invention of the first modern silicon solar cell in 1954, incremental improvements have resulted in modules capable of converting 12 to 18 percent of solar radiation into electricity. The performance and potential of thin-film materials are high, reaching cell efficiencies of 12–20%;

Most popular Thin Film technologies are Plasmonic Solar Cells (PSC) and Dye-Sanitized Solar Cells (DSC). Dye-sensitized Solar Cells which is likely to reduce cost and space requirements and is under development will be discussed here:

3.2.1 Dye-Sensitized Solar Cell

A dye-sensitized solar cell (DSSC, DSC or DYSC) is a low-cost solar cell belonging to the group of thin film solar cells. It is based on a semi conductor formed between a photo-sensitized anode and an electrolyte,

Because it could potentially be made of low-cost materials, and does not require elaborate apparatus to manufacture, this cell is technically attractive. Likewise, manufacture can be significantly less expensive than older solid-state cell designs. It can also be engineered into flexible sheets and is mechanically robust, requiring no protection from minor events like hail or tree strikes. Although its conversion efficiency is less than the best thin-film cells, in theory its price/performance ratio should be high enough to allow them to compete with fossil fuel electrical generation by achieving grid parity.

Advantages

DSSCs are currently the most efficient third-generation solar technology available. Other thin-film technologies are typically between 5% and 13%, and traditional low-cost commercial silicon panels operate between 12% and 15%. This makes DSSCs attractive as a replacement for existing technologies in "low density" applications like rooftop solar collectors, where the mechanical robustness and light weight of the glass-less collector is a major advantage. They may not be as attractive for large-scale deployments where higher-cost higher-efficiency cells are more viable, but even small increases in the DSSC conversion efficiency might make them suitable for some of these roles as well.

Disadvantages

The major disadvantage to the DSSC design is the use of the liquid electrolyte, which has temperature stability problems. At low temperatures the electrolyte can freeze, ending power production and potentially leading to physical damage. Higher temperatures cause the liquid to expand, making sealing the panels a serious problem.

Replacing the liquid electrolyte with a solid has been a major ongoing field of research.

Latest Developments

A group of researchers at Georgia Tech made dye-sensitized solar cells with a higher effective surface area by wrapping the cells around aquartz optical fiber and claimed that a sun-tracking system would not be necessary for such cells, and would work on cloudy days when light is diffuse.

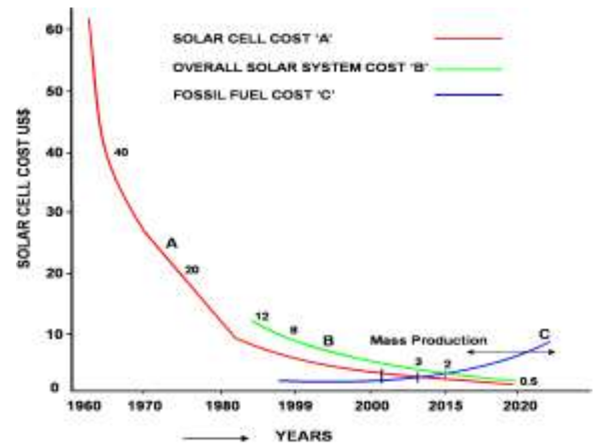
Dyesol and Tata Steel Europe announced in June 2011 the development of the world´s largest dye sensitized photovoltaic module, printed onto steel in a continuous line and targeted development of Grid Parity Competitive BIPV solar steel that does not require government subsidized feed in tariffs.

4. PRODUCTION AND COST OF SOLAR CELLS

Thin-film producers still enjoy in 2009 price advantage as its production cost is 20% less than that of silicon modules. It is expected that the production cost of thin-film will continue dropping (40% less than silicon), as Chinese producers are now putting more resources into R&D and partnering with manufacturing equipment suppliers. Out of several photovoltaic materials used, Dye-Sensitized Solar Cell is likely to be commercialized in the near future being light weight and cheaper in cost.

In recent years, the manufacturers of thin-film solar modules are bringing costs down and gaining in competitive strength through advanced thin film technology. However, the traditional crystalline silicon technologies will not give up their market positions for a few years because they still hold considerable development potential in terms of the cost.

The need for cheaper and more efficient solar cells is huge. In order for solar cells to be considered cost effective, they need to provide energy for a smaller price than that of traditional power sources such as coal and gasoline. The movement toward a more green world has helped to spark research in the area of plasmonic solar cells. Currently, solar cells cannot exceed efficiencies of about 30% (First Generation). With new technologies (Third Generation), efficiencies of up to 40-50% can be expected. With a reduction of materials through the use of thin film technology (Second Generation), prices can be driven lower. Solar manufacturing equipment suppliers intend to score cost of below US$1/W. The below graph shows how the cost of solar cell has reduced over the last four decades. It is expected with the present trend of research and development, solar energy is likely to be the cheapest source of energy by the year 2015, when mass production will start, beating all other power sources. It is estimated that solar panel cost which is about US$1.5/Watt today will come down to US$0.5/Watt by the year 2020.



5. APPLICATIONS

5.1 In Global Scenario

i. Solar cells have a great potential to help rural electrification. An estimated two million villages near the equator have limited access to electricity and fossil fuels and that approximately 80% of people in the world do not have access to electricity. When the cost of extending power grids, running rural electricity and using diesel generators is compared with the cost of solar cells, many times the solar cells win. If the efficiency and cost of the current solar cell technology is decreased even further, then many rural communities and villages around the world could obtain electricity when current methods are out of the question. Specific applications for rural communities would be water pumping systems, residential electric supply and street lights.

ii. Low cost solar panels and batteries will be provided to poor communities in 14 countries in Africa and Asia in the next four years under U.N Development Programme. A total of 33 million people in 14 countries will be able to make use of Solar Energy for commercial, business and economic development. This will save 520 million dollars annually spend on purchase of Kerosene or biomass fuel in low income villages. Similarly in Bangladesh, millions of houses have been electrified by solar panels.

5.2 Applications in Pakistan

i. We should make maximum use of solar panels without batteries, as batteries are the weakest link in the solar power system. Maintenance of batteries is not only difficult but also cost expensive. Here under some situations are given where no back up is required or utility supply can be used as stand by power.

ii. Thousand of tubewells in Sind and Punjab Provinces are not functioning due to non availability of power supply thus badly effecting production of agriculture. In Sind Province thousands of additional tubewells are also needed to lower the underground water level which will also boost crop production and will have great socio-economic impact on life of people. In these areas solar powered tubewells can be installed without provision of batteries, which will substantially reduce the cost of solar power supply system and will also make the system maintenance free. In case of backup of supply from a utility is available, excess power generated can be fed back into the utility power supply system, thus substantially compensating the cost of Solar System.

iii. Solar power can be installed for running small industries, factories, in commercial areas and even to meet domestic loads particularly air conditioning loads during the day time in summer season with backup power supply, from Distribution Companies

iv. Power Supply with backup to Remote Areas In addition Distribution Companies instead of expending their power supply network to far flung areas, should install solar power to supply electricity to individuals or communities. It will be more economical to install solar power in these areas as it will hardly cost US$2.0/Watt against fuel based power supply cost of US$2-3/Watt in addition to meeting 24% - 30% line losses and expensive fuel supply cost of Rs.10-15/Unit. Hydle power which is the cheapest source of power supply cost US$1.2 – 1.5/Watt. Adding transmission & distribution cost of network line losses and maintenance cost of network, the overall cost works out to US$2.0 to 2.5/Watt, which is quite compatible to solar photovoltaic cost of today. It is estimated that a solar P.V station will recover its cost within 8-10 years at the average generation cost of today in Pakistan.

v. Where standalone Solar System is used, elimination of Inverter and batteries can be considered which will result in reduced cost and maintenance free system, provided supply of D.C appliances for the proposed system is ensured. One such application is D.C submersible water pumps the detail of which is discussed hereunder:

The D.C submersible pumps, run by solar system consists of following parts:

i. Solar Panel

ii. Control Panel for Controlling and Protection

iii. Brush less DC Motor drive

iv. Submersible pump

The D.C submersible water pump along with solar power supply are available from 2HP to 30HP, with 2” to 6” dia pipe for 45 to 300 feet deep water level. To give the reader an idea about cost, information has been collected from a well known Cerman Manufacturer including cost of installation and fitting which ranges from Rs. 0.5 to 3 million depending on requirements of water output and depth, the detail of which are as under:.

The cost of submersible tubewells can be further reduced by 30% if manufactured/assembled locally.

Installation of solar D.C tubewells are highly economical, highly reliable and cost of maintenance is low. The cost is compatible with conventional tubewells taking into account free power supply from the solar panels.

Dia	Solar Panel Capacity	Water Level	Output Liter/Day	Cost in Rs. Million
2.5”	2280 Watt (3HP)	50’	125000	0.52
4”	4800 Watt (6.5 HP)	50’	235000	1.1
6”	16000 Watt (21.5 HP)	50’	856000	2.9
2.5”	4560 Watt (6.1 HP)	100’	141000	1.1
4”	10200 Watt (13.7 HP)	100’	276000	2.1
5”	16000 Watt (21.5 HP)	100’	498000	2.9

5.3 Large Plant Applications

There are also large plant based on solar cell technology in the World. Since 1997, PV development has accelerate due to high increase in prices of oil & gas, global warning concerns. Photovoltaic production growth has average of 40% per year since 2000 and installed capacity reached to 39.8GW at end of 2010. Following is the list of largest photovoltaic power plants under construction & commissioned in the World

List of Large Under Construction Projects

Sr #	Project	Country	DC Power (MW)	Status
1.	Desert Sunlight Project	California USA	550	Under Construction
2.	Topaz Solar Farm	California USA	550	Under Construction
3.	Blythe Solar Power Project	California USA	550	Under Construction
4	California Valley Solar Ranch	California USA	250	Under Construction
5.	Antelope Valley Solar Ranch	Antelope Valley USA	230	Under Construction
6.	Gujrat Solar Park	Patan District, India	210	April, 2012

List of Large Completed Projects

Sr#	Project	Country	DC Power (MW)	Completion Date
1.	Golmud Solar Park	China	200	2011
2.	Sarnia Photovoltaic Power Plant	Canada	97	2009–2010
3.	Montalto di Castro Photovoltaic Power Station	Italy	84.2	2009–2010
4.	Finsterwalde Solar Park	Germany	80.7	2009-2010
5.	Okhotnykovo Solar Park	Ukraine	80	2011
6.	Solarpark Senftenberg	Germany	78	2011
7.	Lieberose Photovoltaic Park	Germany	71.8	October 2009
8.	Rovigo Photovoltaic Power Plant	Italy	70	November 2010
9.	Olmedilla Photovoltaic Park	Spain	60	September 2008
10.	Strasskirchen Solar Park	Germany	54	December 2009
11.	Puertollano Photovoltaic Park	Spain	50	2008

6 SOLAR THERMAL ENERGY

i. Solar thermal energy (STE) is a technology for harnessing solar energy for thermal energy(heat). Solar thermal collectors are classified by the United States Energy Information Administration as low-, medium-, or high-temperature collectors. Low-temperature collectors are flat plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat plates but are used for heating water or air for residential and commercial use. High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production.

ii. Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant. A wide range of concentrating technologies exists; the most developed are the parabolic trough, the solar power tower. Various techniques are used to track the Sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage.

iii. Where temperatures below about 95 °C are sufficient, as for space heating, flat-plate collectors of the nonconcentrating type are generally used. Because of the relatively high heat losses through the glazing, flat plate collectors will not reach temperatures much above 200 °C even when the heat transfer fluid is stagnant. Such temperatures are too low for efficient conversion to electricity.

iv. The efficiency of heat engines increases with the temperature of the heat source. To achieve this in solar thermal energy plants, solar radiation is concentrated by mirrors or lenses to obtain higher temperatures – a technique called Concentrated Solar Power (CSP). The practical effect of high efficiencies is to reduce the plant's collector size and total land use per unit power generated, reducing the environmental impacts of a power plant as well as its expense. Up to 600 °C, steam turbines, standard technology, have an efficiency up to 41%. Above 600 °C, gas turbines can be more efficient.

The most popular Solar Thermal Plant are parabolic through Solar System and Tower Solar Plants commonly known as “heliostat”

6.1 Parabolic Trough Designs

Parabolic trough power plants use a curved, mirrored trough which reflects the direct solar radiation onto a glass tube containing a fluid (also called a receiver, absorber or collector) running the length of the trough, positioned at the focal point of the reflectors. The trough is parabolic along one axis and linear in the orthogonal axis. For change of the daily position of the sun perpendicular to the receiver, the trough tilts east to west so that the direct radiation remains focused on the receiver.

Full-scale parabolic trough systems consist of many such troughs laid out in parallel over a large area of land. Since 1985 a solar thermal system using this principle has been in full operation in California in the United States. It is called the SEGS system. Other CSP designs lack this kind of long experience and therefore it can currently be said that the parabolic trough design is the most thoroughly proven CSP technology.

6.2 Power Tower Designs

Power towers (also known as 'central tower' power plants or 'heliostat' power plants) capture and focus the sun's thermal energy with thousands of tracking mirrors (called heliostats) in roughly a two square mile field. A tower resides in the center of the heliostat field. The heliostats focus concentrated sunlight on a receiver which sits on top of the tower. Within the receiver the concentrated sunlight heats molten salt to over 1,000 °F (538 °C). The heated molten salt then flows into a thermal storage tank where it is stored, maintaining 98% thermal efficiency, and eventually pumped to a steam generator. The steam drives a standard turbine to generate electricity. This process, also known as the "Rankine cycle" is similar to a standard coal-fired power plant, except it is fueled by clean and free solar energy.

The advantage of this design above the parabolic trough design is the higher temperature. Thermal energy at higher temperatures can be converted to electricity more efficiently and can be more cheaply stored for later use. Furthermore, there is less need to flatten the ground area. In principle a power tower can be built on a hillside. Mirrors can be flat and plumbing is concentrated in the tower.

6.3 Storage of Energy

Solar energy is not available at night, making energy storage an important issue in order to provide the continuous availability of energy. Research is going on to develop new techniques to store energy.

6.3.1 Molten Salt Storage

A variety of fluids have been tested to transport the sun's heat, including water, air, oil, and sodium, but molten salt was selected as best. Molten salt is used in solar power tower systems because it is liquid at atmosphere pressure, it provides an efficient, low-cost medium in which to store thermal energy, its operating temperatures are compatible with today's high-pressure and high-temperature steam turbines, and it is non-flammable and nontoxic.

The uniqueness of this solar system is in de-coupling the collection of solar energy from producing power, electricity can be generated in periods of inclement weather or even at night using the stored thermal energy in the hot salt tank. Normally tanks are well insulated and can store thermal energy for up to a week. As an example of their size, tanks that provide enough thermal storage to power a 100-megawatt turbine for four hours would be about 9 m (30 ft) tall and 24 m (80 ft) in diameter.

The Andasol power plant of 150MW in Spain is the first commercial solar thermal power plant to utilize molten salt for heat storage and nighttime generation. It came online March 2009.

Heat Transfer

Molten salt coolants are used to transfer heat from the reflectors to heat storage vaults. The heat from the salts are transferred to a secondary heat transfer fluid via a heat exchanger and then to the storage media, or alternatively, the salts can be used to directly heat graphite. The graphite is located on top of the tower. Heat from the heliostats goes directly to the storage. Heat for energy production is drawn from the graphite. This simplifies the design. Graphite is used as it has relatively low costs and compatibility with liquid fluoride salts. The high mass and volumetric heat capacity of graphite provide an efficient storage medium

Cost

A cost/performance comparison between power tower and parabolic trough concentrators is estimated that electricity could be produced from power towers for 5.47 ₡/kWh and for 6.21 ₡/kWh from parabolic troughs. The capacity factor for power towers was estimated to be 72.9% and 56.2% for parabolic troughs. There is some hope that the development of cheap, durable, mass producible heliostat power plant components could bring this cost down.

6.3.2 *Requirement of Water*

A design which requires water for condensation or cooling may conflict with location of solar thermal plants in desert areas with good solar radiation but limited water resources. A good suitable location for CSP Plants is where sufficient heat radiation and plenty of good quality water is available.

6.4 Application in the World

Commercial concentrating solar thermal power (CSP) plants were first developed in the 1980s. The 354 MW SEGS CSP installation is the largest solar power plant in the world, located in the Mojave Desert of California. Other large CSP plants include the Solnova Solar Power Station (150 MW), the Andasol solar power station (150 MW), and Extresol Solar Power Station (100 MW), all in Spain. The 370 MW Ivanpah Solar Power Facility, located in California's Mojave Desert, is the world’s largest solar thermal power plant project currently under construction. 553MW new capacity is proposed in Solar Park, California.

Morocco is building five solar thermal power plants. The sites will produce about 2000 MW by 2012. Over ten thousand hectors of land will be needed to sustain all of the sites.

In July 2011, Iran inaugurated Iran's biggest solar power plant in Mashhad which produces 72,000 kilowatt-hour electricity per year. Following are the few CSP plants installed:

Capacity (MW)	Name	Country	Location	Notes
354	Solar Energy Generating Systems	USA	Mojave Desert California	Collection of 9 units
150	Solnova Solar Power Station	Spain	Seville	Completed 2010
150	Andasol solar power station	Spain	Granada	Completed 2011, with 7.5h thermal energy storage
100	Extresol Solar Power Station	Spain	Torre de Miguel Sesmero (Badajoz)	Completed December 2010
75	Martin Next Generation Solar Energy Center	USA	Florida	steam input into a combined cycle
64	Nevada Solar One	USA	Boulder City, Nevada	

7. RECOMMENDATIONS

Government of Pakistan should channelize its policies to boost Solar Energy and to attract entrepreneur for investment in Pakistan by adopting following measures:

i. One widow facility in real terms be provided to investors where all matters relating to inviting of tenders till award of contract and settlement of tariff etc. for supply of power to DISCO’s be entrusted to AEDB only. To achieve the objective, broad line guidelines and set parameters be laid down to work within the required work frame. In case AEDB is not fully equipped with the required infrastructure and manpower, some experts from WAPDA / NTDC be transferred to AEDB on deputation to expedite project processing.

ii. Government of Pakistan should legislate to make solar power plants a mandatory requirement for all housing schemes as a major source of power supply.

iii. There should be no additional burden on entrepreneurs bringing foreign investment in Pakistan in form of Deposit Fees or Guarantees.

iv. Government of Pakistan should arrange funds from Donar Agencies for solar electrification of Villages / Abbadies and Tubewells located in for flung areas where extension of Utility Network is an expensive proposition.

v. Banks should be instructed to facilitate loans for solar electrification projects to individuals or companies as is being done in case of car financing.

vi. Import of all components used in Solar Power Plants / Panels should be duty free.

vii. Solar Power Plants of 500 MW capacity be installed as IPP in Punjab & Sind where water and sun is available in abundance.

viii. A practical system should be evolved to encourage formers to adopt solar tubewell system as discussed under Clause 5.2(v) which is a highly economical and a viable solution to save conventional energy instead of getting power supply from the National Grid. GOP should also take in-hand similar projects for installation of D.C submersible pumps run by solar under partnership with formers, to lower level of underground water and reduce salinity which will help to boost crop production and to maintain solar tubewells in good running conditions in their own interest

Annex-A

DATA OF TYPICAL SILICON NITRIDE MONOCRYSTALLINE SILICON PANELS

These Panels are normally manufacture in the range of 75Watt to 250Watt but herein performance characteristics of three model are given

Performance			
Rated Power (P_{max})	135W	160W	170W
Power Tolerance	±3%	±3%	±3%
Nominal Voltage	12V	24V	24V
Warranty	25 Years	25 Years	25 Years
Qualification Test parameters			
Temperature Cycling Range	-40^0C to $+80^0$C		
Damp Heat Test	85^0C, 85% relative humidity		
Front and Rear Static Load Test (eg: Wind)	2,400 Pa (50psf)		
Front Laod Test (eg: Snow)	5,400 Pa (113psf)		
Hailstone Impact Test	25mm Æ (1 inch) at 23m/s (52mph)		
Typical Electrical Characteristics			
Rated Power (P_{max})	135W	160W	170W
Voltage at P_{max} (V_{mp})	17.4V	35.1V	35.6W
Currentat P_{max} (I_{mp})	7.8A	4.6A	4.8A
Open Circuit Voltage (V_{DC})	22.1V	44.2V	44.3V
Mechanical Characteristics			
Dimensions (L x W x D) mm	1510x674x50	1593x790x50	1593x790x50
Weight	12 kg	15 kg	15 kg
Cells	36	72	72

Words 2,396

Failing Writ and the Power Sector !

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It is a foregone conclusion that the Pakistani Power Sector has not been able to deliver. Consequently, the public is facing power cuts from anything between 12 to 20 hours – depending upon whether they reside in the urban areas or the rural sprawl. Commerce and industry is facing an extreme crunch with loss of production and livelihood – not a threat only; but in actuality a bane for the Country. According to experts, the national economy has taken a hit of more than 2 % of the GDP. On the other hand and which most of the people do not take as the truth, the GoP during the calendar years 2008 till 2012 has provided for a power subsidy equaling Rs. 1.2 trillion. Imagine, what would have happened if the need to provide subsidies had somehow not been there. What could this colossal amount have done for the people of Pakistan? In order to explain the value of Rs. 1.2 trillion, we see that the total expected cost of the 4500 MW Diamer Bhasha colossus, spread over 8-10 years, in today's conversion rate is less than the amount expended through subsidies during the last five years.

In view of the above facts, it becomes imperative to understand the issue in it's entirety and to also pinpoint the main malady. The explanations that are rife in the market to the effect that the issue is because of inaptitude and incompetence of the professionals working in the sector coupled with nepotism by politicians may have some truth, but fact of the matter remains that the actual issue is totally different and the above line of thought may be a direct or a tangential result of the actual or the main malady.

What exactly are the problems? Why is it so that presently there remains a huge gap between the revenues collected by DISCOs and the expenditures for generation, transmission of power and lastly distribution of electricity up-till the customer mains. More so, when we see that 3000 MW generation capacity on the average remains idle, while the Country faces a 5500 MW shortfall these days. Similarly, why it is so that the sector owes nearly Rs. 435 billion to the OMCs (oil marketing companies), the two gas utilities (SNGPL and the SSGCL) and other gas prospecting companies, IPPs, WAPDA for its extremely cheap hydro generation and for other such like liabilities. It is also a question that harks for an answer as to how the present sectoral receivables have reached the astronomical figure of Rs. 425 billion.

A little insight into the works reveals that even the Federal Government is not up to mark with its payment of electricity bills and presently owes Rs. 7 billion to the Sector. Detailed scrutiny leads us to a free for all situation, where strangely the federal departments seem not to have even anticipated the correct level of expenditures these would have had to incur for electricity purchases and nor have they correctly budgeted the same. Consequently, it becomes nigh impossible for them to make the payment on time. Even the defense installations fall in to this category. However, besides the constant float of nearly Rs.5-7 billion, the Federal Government / Line Departments do eventually clear their bills, by leaving the new ones un-paid and so on. It is not comprehended by any one that the electricity utilities do not operate like normal commercial entities and that the margins built-in by the regulator viz NEPRA do not cater for continued non-payments and facility for bridge financing till such time the customers clear their outstanding bills.

Under this heading, the instant study would include the long outstanding issue of continued non-payment by the AJK Government, which receives around 300 MW from PESCO, IESCO & GEPCO. The present default has reached the figure of Rs.23 billion. The AJK Government pleads that the GoP had promised to peg the electricity tariff to a lowly figure of Rs.3.29 per unit, while the rest (whatever it was and to whichever height it would reach in the future) of the tariff would be the GoP's liability. According to information, this issue is pending resolution since the last five years, while the sector is forced to reduce its generation accordingly. This shows breach of rules, with AJK just receiving its slice of power and not clearing the bills which are beyond the figure of Rs.3.29 per units. Both, the MoW&P and MoF, have unfortunately not been able to do anything to clear the issue.

Then comes the issue of provinces, which acting like rogue entities have to pay Rs.90 billion of un-paid bills. Even the Province of Punjab, which was very regular in making payments till 2009 is a defaulter to the tune of Rs.9 billion, while the Government of Sindh carries the victory cup with payables of over Rs.50 billion. The standard reply to any query is that the utility bills are incorrect. Since the last three years, the provinces have also started questioning the veracity of billing system and would rather negotiate the payments instead of accepting calculations based on technical parameters. It is also forgotten that the covenants signed between the provinces (the actual offices / line departments) and the electricity utilities at the time of being connected to the electricity mains, duly stipulate that complaints against billing have to be made within a set number of days of receipt of the offending bills. And it would be illegal, if the bills are simply deferred and converted into huge disputes afterwards. In case of the provinces too, the utility expenditures are not correctly budgeted and nor is there any check on misuse in the field. As a check against non-payment by the Provinces, the office of Federal Adjustor was created and housed in the Ministry of Finance, with powers to make at-source deductions from the federal outlays for provinces in 1980s. Subsequently, this became dormant and remained so till 2009, when it was revived. However, rejuvenation of this office could not make any difference, as GoS simply moved the Sindh High Court and succeeded in baring any at-source deductions. As far is known, the status quo continues. The again shows the haughtiness of provincial authorities and a disregards for the law.

Thereafter drops in the long festering issue of unchecked supply to the Karachi Electric Supply Company (KESC) and the over Rs.50 billion payables on its account. Without going in to the details of a power purchase agreement (PPA) which is mostly considered suspect, we see that the KESC does not make any monthly payment at all to the NTDC, while the later only receives the subsidy amounts due to KESC from the GoP, which at the most makes up about 35% of the total monthly bill. This is regular practice under the pretext that because the GoP is late in making payments for the KESC supply to the federal government offices in the latter's jurisdiction, GoS is not making regular payments and that the Karachi Local Government also delays payments with Karachi Sewerage and Water Board further raising the ante by not making payments in time, hence KESC can stop payment to the NTDC – specially, when it too is government owned. That all of these entities have distinct formations without any link with each other and that KESC receives the supply from NTDC on the basis of a PPA that does not allow for the recipient to act in the manner which the KESC does, is not able to deter the privatized utility to change its tactics. On the other hand, one thing is very very clear that the sector has been deprived of its legitimate revenue to the tune of Rs.50 billion or US $ 500 million on account of which it is forced to reduce its generation for the rest of the country, without any constriction for the defaulter's receipt. As KESC is a private entity, one can imagine the clout it enjoys, its temerity and the ability to flout rules to hold legitimate payments at will.

Thereafter, comes the issue of purely private customers who presently owe nearly Rs.250 billion to the Sector. It is nearly impossible for the utilities to disconnect most of these premises and nor does anyone feel awkward about being a defaulter. Additionally, we see that each month, theft and stealing of energy adds-up another Rs.5 billion to the losses and the utilities cannot do much about it. This constant hemorrhage is responsible for further decline in the generation capability and thus directly contributes to the level of load shedding around us.

Not to be left behind and considering the Power Sector as easy pickings, the Federal Board of Revenue (FBR) has stopped GST refunds to DISCOs and the NTDC with a volume of more than Rs.100 billion by creating counter claims. Presently, the DISCOs are in litigation, with winners being the lawyers and to some extent the FBR management, which could claim higher revenues to its credit. Imagine the withdrawal of Rs.100 billion from the already loss making sector and the domino effect on generation. It must also be remember that governmental owned entities are not that proficient in legal issues and thus the rest of the government has to support their operations and not feed on them.

On the other hand, it is important to delve into another issue that prevails in our times. The politicos are posting CEOs of various power sector entities at will and in some cases even for a consideration – thus negating the principle of merit and leading to wrong persons for these important jobs. These so-called leaders of the sector are thus busy in feeding their benefactors instead of serving the people. The mere fact that the politicos are able to get away with such shenanigans speaks of most weak State of Pakistan and its ensuing writ. And, while all of the above is happening, we see that the monthly fuel price adjustments (MFPA), taking care of the rise of fuel prices over and above the oil price built in the calculations laying out the consumer end tariff and amounting to a whopping Rs.80 billion or so, are stayed by the courts. Similarly, bills not to the liking of the customers are also stayed in negation to the basic spirit of section 54-c of the Electricity Act – all acting as an impetus to the law breakers. As the law requires deposit of the total offending bill with Courts or 50% deposit in case the issue is brought before the Electric Inspectors, shelving of the same is greatly detrimental to the utilities and thus directly leads to reduction in the generation level. Another issue that needs attention is the NEPRA operations mired in delays, that cannot be condoned. Imagine, tariff petitions submitted in June, 2012 being only decided in April, 2013 with no one to cater for the uncovered expenditure for the last ten months or so, which equals a stupendous Rs.100 billion or so.

Another issue that merits attention is the public outcry and opposition to conservation measures. That it indeed is a low hanging fruit and able to yield nearly 1000 MW in reduced demand in simply side stepped. The half a century old Shops and Commercial Establishments Ordinance (accepted, adopted and renewed by all the provinces) which require shops etc to close at 8.00 p.m. every day is simply not accepted for implementation. The provinces have been showing their inability to implement this law. So such for the governmental writ.

From the above, it is seen that the Power Sector is in a free fall with no one helping it to sustain the operations. The people are not paying their bills and are also indulging in theft and stealing of energy, the federal government is not paying on time, AJK continues to default and provincial governments just receive power and then promptly forget to pay the bills, FBR considers the sector as easy picking and the politicos thrive on making undue postings. The readers can post all of the above negatives to the accounts of sectoral professionals. In other words, they would specifically hold the DISCOs responsible for not properly billing the customers and thence for the lowly recoveries. However, it must be remembered that the utilities are not policing authorities and nor do they posses magisterial powers. It is the general writ of the state that allows utilities worldwide to function appropriately.

A deep insight into the above leads us to the conclusion that actually the state is missing from the scene and all of the issues directly emanate out of this sterility and nothing else. Actually, it is this weakness that allows all the above junkets. Conversely, if the state was strong then governmental customers would pay-up like other consumers, the provincial governments could never have even thought to stop payments; FBR, NEPRA and even the Courts would have fully adhered to the law; AJK would not just subject its people to normal Pakistan tariff and insist on a low tariff, KESC would make timely payments to the NTDC and the public at large would ensure full payments and adherence to the agreements in place. Conservation would also find its place in our lives.

The recipe thus for resuscitation of the Power Sector remains primarily in enforcing the writ of the State across the board. Everything else would fall into its own place. The federal government entities would behave like normal customers with the provincial governments doing likewise and so on. Specifically, all of these entities would support the electricity operations and not act as inhibiting factors. Rogue entities would not be able to break the law etc. The other issues concerning the requirement to somehow fastly reduce the cost of service through positive change in the energy mix, fuel mix and even the customer mix and other such issues will follow automatically. Capacity additions would take place and slowly with the right persons for the sector; it would start delivering to the benefit of the public.

****

Quotation

- Before I got married I had six theories about bringing up children; now I have six children and no theories.

  John Wilmot

- The hand that rocks the cradle may not rule the world, but it certainly makes it a better place.

  Margery Hurst

- A bachelor nevr quite gets over the idea that he is a thing of beauty and a bioy forever,

  Helen Rowland

Pakistan Today

Energy Conservation by Power Factor Improvement

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1. Introduction

This Paper is Particularly written on all important parameters of Power Factor and method of its improvement. After going through all important topics relating to Power factor and its improvement techniques, suggestions will be discussed for implementation of a Program on (University of Engineers & Technology) U.E.T for the Purposes of Energy Conservation. Our modern civilization often called the machine age is more truly the energy age. Through the ages man has successfully devised more and more complex machines to make things and perform services. Man could succeed with this program only as he discovered the sources of energy to power his machines.

There are basically two sources of energy.

1) Renewable sources
2) Non - Renewable sources

The renewable sources are wind sun, waves and energy from water. These sources are continuously replaced by nature and therefore they are inexhaustible.

The renewable sources of energy are also called conventional sources of energy and these are fossil fuels such as coal, gas, oil and nuclear fuels. These sources are limited in nature and would exhaust one day. As the conventional sources are likely to be exhausted one day, the generation of electrical energy from non-conventional sources assumes a greater significance.

Energy conversation is equivalent to energy generation. As power generation is becoming expansive day by day, therefore conversation of energy has started playing the pivotal role toward the nation's economy. As population grows at an alarming rate resulting in also increase of economic growth, electrical is in short supply. Improving energy efficiency in an electrical system has become the major issue.

There are major area i.e., Low Power Factor, Less Efficient motors and lighting sources causes increased current, increased power losses and ultimately reduced voltage. Load scheduling by using most efficient energy consuming devices can converse energy to great extent.

Energy conversation by power factor improvement is the burning issue of today. The main objective of this research is to develop methodology and guideline for an Electrical Engineer to implement the technique for Power factor Improvement. Including analysis of Electrical network.

This paper considers all possible means to conserve energy. However special attention be given on Energy conservation by power factor Improvement by installing Capacitors on power system component, such as tube lights, motors and transformers. This paper include all possible information regarding Energy Conservation by Power factor Improvement.

2. Power Factor

The concept of power factor is essential in order to become familiar with the term of conservation of electricity especially for those who are not electrical engineers. The following discussion is an attempt to explain power factor in a simple way, avoiding theoretical detail of inductance and capacitance. It also explain causes of low power factor, affects of low power factor and its measurement with the help of certain examples thereby further the ideas.

2.1 Basic Concepts

Most loads on an electrical distribution system can be placed in one of three categories:

- Resistive
- Inductive
- Capacitive

In an AC supply system both voltage and current alternate their values sinusoidal w.r.t time. That is why in case of purely load the voltage and current waveforms are in phase as shown below in the figure 1.

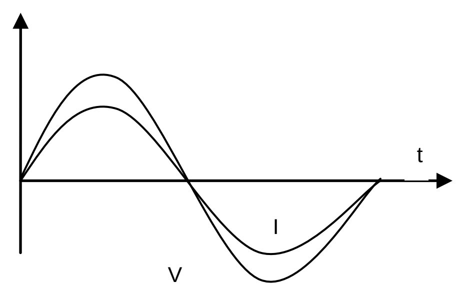


Figure:1 Voltage and current waveform in Pure resistive Load. Power = P = V x I.

in this case the useful power available from the circuit is maximized, Since peaks of voltage and current occur simultaneously. When an electric circuit contains inductive devices then the current tends to lag behind the voltage. This has been illustrated below in figure 2. [1].

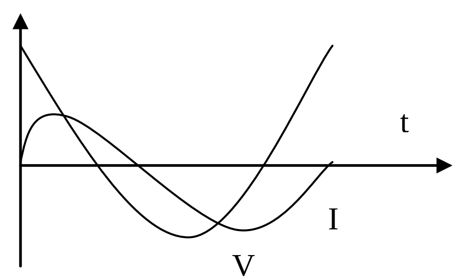


Figure: 2 Current lagging voltage by angle ϕ
Power (P) = V x I Cosϕ.

Similarly for capacitive loads the current leads the voltage as shown below in figure 3. [1].

Error!

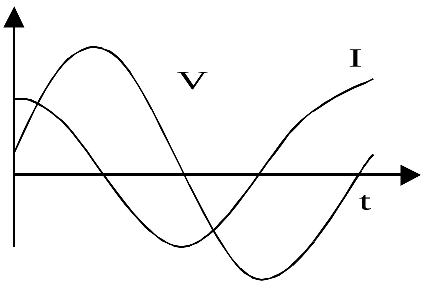


Figure:3 Current leading voltage by angle ϕ

Power (P) = V x I Cosϕ.

The most common of these on modern system is the load. Typical examples include transformers, fluorescent lighting and AC induction motors.

Inductive loads require two kinds of power to function properly.

- Active power (KW)- actually performs the works.
- Reactive power (KVAR)- sustains the electromagnetic field.

A common example of reactive power can be seen in an unloaded AC motor. When all the load is removed from the motor, it might be expected that the no-load current would drop to zero. In actual fact the no-load current will generally show a value between 25% and 30% of full load current. This is due to the fact of the continuous demand for magnetizing current by any induction load [2].

Active power is the total power that would be read on a wattmeter. Apparent power is the combination of reactive and active power.

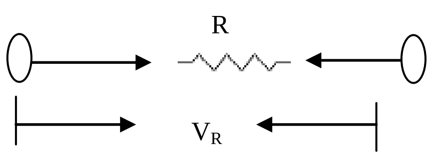
2.2 Types of Load

$\phi = 0$

Cos. $\phi = 1.0$

P = VI COS ϕ = VI (Single – Phase.)

P= √3 VICOSϕ=√3 VI, (Three – Phase.)

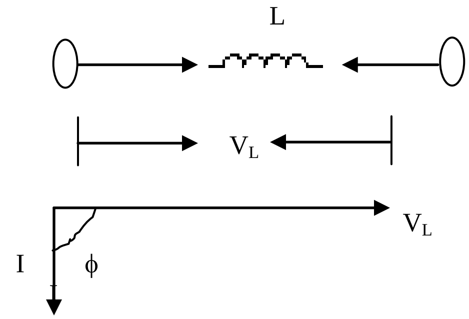


2.2.1 Pure Inductive Load

$\phi = -90^0$

COS $\phi = 0$

P = 0, (either single – Phase or three Phase.)

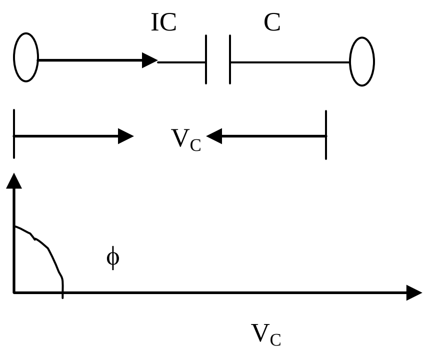


2.2.2 Pure Capacitive Load

$\phi = 90^0$

COS $\phi = 0$

P = 0, (either single Phase or three Phase.)



2.2.3 Inductive Load

$\phi = 0 - 90^0$

Lagging Power Factor

COSϕ = I – 0

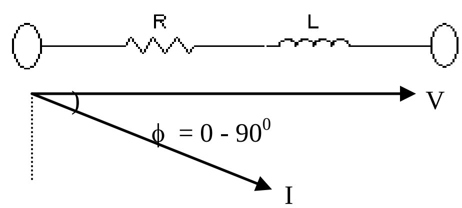
P = VI COSϕ, (Single Phase.)

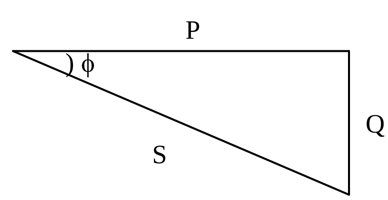
P = √3 VI COS ϕ (Three phase.)

P = KWATTS

Q = KVAR

S = KVA





2.2.4 Capacitive Load

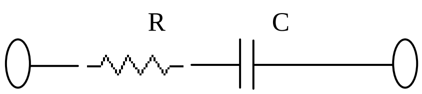
$\phi = 0 - 90^0$ Leading Power factor

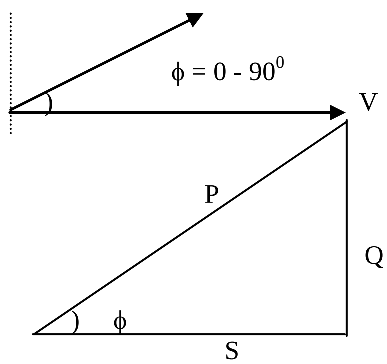
COS $\phi = 1 - 0$

P = KW

Q = KVAR

S = KVA





3. What is Power Factor?

This is the relationship between working (active) power and total power consumed (apparent power). Essentially, power factor is a measurement of how effectively electrical power is being used and vice versa. It can be expressed as

$$\text{Power Factor} = \frac{\text{Active Power}}{\text{Total Power}} = \frac{P}{S}$$

Where

S = Total power of the generator (or used)

P = Power consumed in the load (active power)

Q = Reactive power stored in magnetic field or wasted power.

$$\text{Power Factor} = \frac{P}{S} = 1, \text{ unity power factor.}$$

Which means total power is consumed in the load. This is only possible under the following conditions.

1. Load is Purely resistive (≤ 5% loads only).
2. KVARS are being supplied by some other source.

3.1 Power and power factor

Three types of powers are associated with generators supplying electrical energy energy to the power system.

Total power = S = VI = (units = KVA)

Active power = P = VI Cosϕ = (units KW)

Reactive power = Q = VI Sinϕ = (units KVAR)

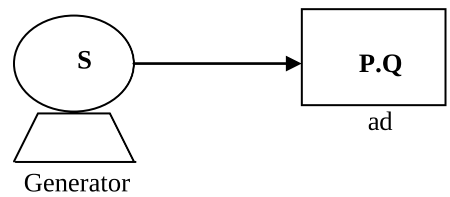
V = voltage: Volts

I = Current: Ampere

ϕ = Physical displacement of V & I.

Mathematical relationship of these powers.

S = P + jQ



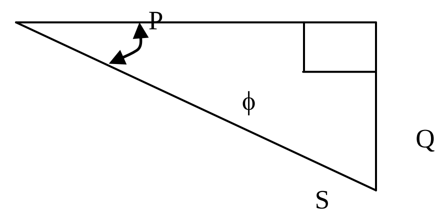


Figure: 4 Vectorial representation of Generator and Load.

A distribution system's operating power is composed of two parts. Active (working) power and reactive (non-working) magnetizing power. The active power performs the useful worked the reactive power does not as its only function is to develop is to magnetic fields required by inductive devices.

Power factor of a motor decreases as the load on the motor increases. Therefore, when more inductive reactive power is required, more apparent power is also required. This geometric relationship of apparent power to active power is traditionally expressed by the right-angled triangle relationship of [3, 4];

Cos ϕ = p.f = KW/KVA

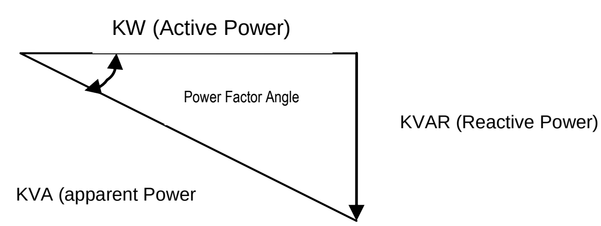


Figure: 5 Vector Relationships [1].

3.2 Leading and Lagging Power Factor

Power factor is said to be lagging when current lags the voltage and similarly when the current leads the voltage power facto is said to be leading power factor or more precisely, a load is said to have leading power factor if the direction of flow of KVAR is away from the load, and lagging power if the direction of flow of KVAR is toward the load. Inductive loads require KVAR flow towards the load for magnetization, thereby yielding lagging power factor. Generally in industrial plants factor is always because of the inductive load.

In case of leading power factor load were generating KVAR. An over excited synchronous motor or when system is over compensated with capacitors, thus causing net flow of KVAR. A leading power factor is termed as "Capacitive" [5,6].

3.3 What is Low Power Factor?

If the ratio of active power (P) to total power (S) is less than one (unity) then the power factor is low, which means total power is not being consumed.

$$P.F = \frac{P}{S}$$

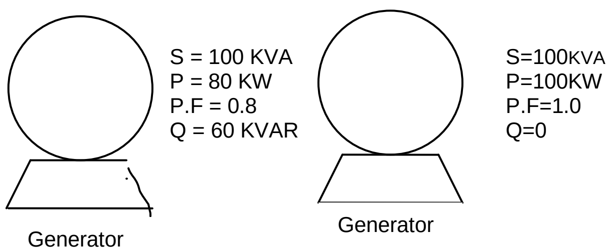


Figure: 6 Two Generator at different Power factor

Following are the main type of the equipment having poor power factor.

(a) Induction motors of all types.

(b) Mercury vapour lamps and lamps operated with chokes.

(c) Power and distribution transformers. An unloaded transformer is purely an inductive load.

(d) Synchronous motors (under motors have low power factor) [7].

- (i) Welding plants.
- (ii) Reactors
- (iii) Induction furnaces.
- (iv) Neon signs and fluorescent lights.
- (v) Arc lamps.
- (vi) Arc and resistance furnaces.

3.4 Power factor of Various Loads

Nature of Load	Power Factor
➢ Radio	0.9
➢ Vacuum Cleaner	0.6 to 0.7
➢ Tube Light	0.5 to 0.9
➢ Electronic Equipment	0.4 to 0.95
➢ Mercury Vapor Lamp	0.4 to 0.6
➢ Cold Storage	0.76 to 0.80
➢ Heavy Engineering and Molding	0.48 to 0.75
➢ Rubber Extrusion and Molding	0.48
➢ Window Type Air Conditioner	0.62 to 0.85
Industrial Induction Motor	
➢ No Load	0.18
➢ 25% Full Load	0.56
➢ 75% Full Load	0.81
➢ 100% Full Load	0.85
➢ 125% Full Load	0.86
➢ Washing Machine	0.6 to 0.7

3.5 Effects of Low Power Factor

Low power factor has various negative impacts, which on turn reduces the overall efficiency and cost effectiveness of a plant and the equipment. Following are the effects of low power factor [8];

- Power Factor Penalty.
- System Capacity.
- System Overloading.
- System Losses.
- Voltage Instability.
- Increase in Capital Cost.

4. System Capacity

Low power factor results in lowering the capacity of the system must carry the total current, but only active current provides the useful power. For example as the power factor drops from 1.0 to 0.9 as shown below from the graph, Power is used less effectively. Therefore,10% more current is required than when the power factor was 1.0 to handle the same load. A power factor of 0.7 requires approximately 100% (twice as much) as required when the power factor was 1.0 to handle the same load and similarly if a transformer bank rated at 500KVA can only provide 400KW of power if the power factor is 0.8. If the power factor were improved to 0.9, 450 KW of power can be provided. In this case by improving the power factor from 0.8 to 0.9 an additional 50KW of capacity were released. On the other hand, if the power hand, if the power factor were to drop 0.7, only 350KW of useful power could be provided [6].

4.1 System Overloading

Lower power factor means increased demand for reactive current by the load, which means more apparent current and hence more apparent KVA us required by the load. This increased power has to be supplied by a generator or a transformer and is to be transmitted over conductors and all of this equipment have a fixed rated KVA capacity. The extra demand of these equipment or an extra cost in increasing the rated KVA capacity to meet the increased reactive power demand. The current thus increased in return causes increase in copper losses ($P = I^2R$) and decrease in the efficiency of both apparatus and the supply system, which results in overloading and hence burning of the associated equipment [9].

4.2 System Losses

Lower power factor also causes an increase in distribution losses. Since copper losses in the circuit are proportional to the square of he current in the circuit. Hence, the increase in current means increase in the system losses. Due to increase in the system losses, the efficiency of the system suffers. It also raises the temperature of the conductors, transformer, switchgear, generators and allied equipment which ultimately decreases the life of insulators.

4.3 Voltage Instability

Another drawback to low power factor operation is the instability cause caused to the system voltage. Voltage fluctuations are more common at low power factor conditions and voltage regulation also becomes poor. It is not economical to improve the power factor in plants for voltage improvement alone, better voltage stability is usually an additional benefit of the power factor correction.

4.4 Increase in Capital Cost

At Low power factor system capacity decreases therefore large size of conductors, transformers, switchgears, etc, are needed to meet the requirement result in the increased cost.

4.5 Advantages of power Factor Improvement

When should you look at power factor correction? Below mentioned points outline the benefits that power factor correction could bring you. Reduced energy costs by reducing your peak energy demand. Eliminate the cost of upgrading your power distribution system by making better use of your power. Reduce power fluctuations caused by switching on heavy loads within your installation. Power factor improvement provides economic as well as system advantages. Detail of some of them in mentioned below.

4.6 Cost Saving

Most of the power supplies authorities like Water and Power Development Authority (WAPDA) & Karachi Electirc Supply Company (KESC) divide their tariff structure into fixed and variable charges. The fixed charges are indicated in the maximum demand indicator and the variable charge are including the KWH energy unit charges. The factor penalty charges are based on the deviation of power factor from the power factor required by the supply authorities e.g. if required power factor is 0.90 and if the equipment p.f is 0.7 then the difference 0.20 is multiplied by the fixed charges to get the p.f penalty charges. The saving in the penalty charges is one the main advantages of high power factor factor and investment in the field of power factor improvement.

4.7 Reduction in System Losses

Transmission losses are proportional to the square of the current (copper losses I^2R). Since capacitor decreases the supply current so line losses are decreased for the same value of KVA improved power factor means less wattles current, which means less copper losses thereby increasing their efficiency and life span [1, 2,3].

4.8 Improvement in System Voltage

Since the power factor improvement reduces the reactive current in the network voltage drops in the network due to reactance is reduced resulting in some raising of the voltage level in the network. This can be well explained by the following formula.

$$V = RI \cos\Phi + XI \sin\Phi$$

Indicating that the voltage are sum of the voltage drops voltage drops through resistive and reactive loads. If KVAR current reduces due to power factor improvement then the second part of the formula is reduced. The logic behind the p.f improvement is effective in reducing voltage drops in that manner that in an industrial plant the reactance play an important role and by reducing reactive current the voltage drops are automatically reduced [8].

5. Measurement of Power Factor

Power factor can be measured by the following methods:

- Direct measurement of Power Factor.
- Voltmeter, ammeter, wattmeter method.
- Two single phase energy meters method.

5.1 Direct measurement of Power Factor

The power factor of a circuit or installation can be measured directly from a power factor meter where power factor meter meter is not available then uses other methods.

5.2 Voltmeter, ammeter, wattmeter method

Power factor of an installation can be calculated by reading of these meters. Power factor can be calculated by the following relationship.

Power = V x I x p.f(For single phase circuit)

Power = 3 x V x I x p.f (For three phase circuit)

5.3 By Two single phase Energy Meters

The power factor of a three phase balanced load can be calculated by comparing the disc speed of two single phase watt-hour meters connected to measure the total power consumption for a short period of time. “a” is the ratio of the slow meter speed to the fast meter speed. It is used to calculate the power factor.

Power factor $= (a + 1) / (2a^2 - a + 1)$

If one of the meters is running backward, the ratio “a” is negative indicating less than 0.5 power factor.

The above test can also be performed with help of two wattcmeters in the same manner [5,6].

6. Power Factor Improvement Techniques

Power factor improvement is one of the techniques, which contribute towards the conservation of electrical power along with a number of other benefits. A number of different techniques can be applied to improve the power factor. The technique adopted in this regard is claimed to be most efficient as the power factor capacitor banks are designed after computerized energy analysis on each load center.

6.1 How to Improve the Power factor

The power factor can be improved by supply KVAR to the loads (inductive type.) "Capacitor is a source of KVARS"

therefore the power factor of a connected load can be improved by installing power factor improvement capacitors/capacitor banks.

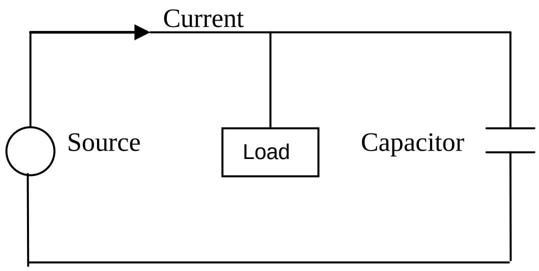


Figure: 7 Showing Source, Load and Capacitor in parallel [1].

6.2 Role of KVARS

As inductive loads are primarily responsible for the poor factor because it requires reactive power to setup necessary for its operations whereas the capacitive load requires negative KVAR. So capacitive load can be considered as KVAR generator.

Theoretically an adjustable capacitor installed in parallel with an inductive load can be adjusted in such a way that the leading current to the capacitor is exactly equal in magnitude to the component of the current in the inductive load which in fact is lagging the voltage by 90^0. Thus the resultant current is in phase with the voltage. The inductive circuit still requires positive reactive power but the net reactive power is zero. For reason it is more convenient to use capacitor to supply this reactive power to the inductive load. For finding the capacitor KVAR required to improve the power factor to particular value can be explained with the help of the example.

Consider a load of p (KW) being supplied by a generator and having power factor as Cos Φ2 capacitor is added in parallel to the load. We can find the KVAR rating of the capacitor.

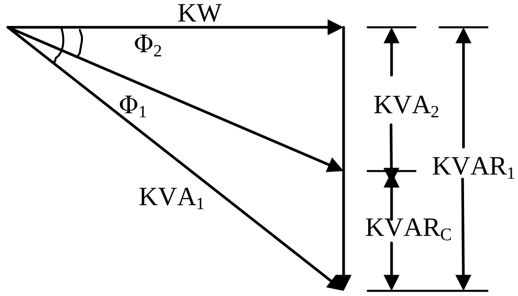


Figure: 8 Improvement of power factor due to capacitor [2].

$\text{Tan } \Phi_1 = KVAR_1/ KW \Rightarrow KVAR_1 \text{ Tan } \Phi_1$ (Before improvement)

$\text{Tan } \Phi_2 = KVAR_2/ KW \Rightarrow KVAR_2 \text{ Tan}\Phi_1$ (After improvement)

Hence capacitor rating required for improving p.f from $\text{Cos}\Phi_1$ to $\text{Cos } \Phi_2$ is

$KARC = KVAR1 - KVAR2 = KW \text{ Tan } \Phi_1 - KW \text{ Tan } \Phi_2$

$= KW (\text{Tan } \Phi_1 - \text{Tan } \Phi_2)$

$KVARC = KW \, \Delta \, \text{Tan}\Phi$

Where Δ TanΦ is called KW multiplier.

6.3 Sources of KVARS

There are two types of equipment by which KVAR can be drawn from the supply.

6.3.1 Rotary

The rotary equipment consists of

- Synchronous condenser
- Phase advancer.

6.3.2 Static

The static equipment consists of

- Static capacitor.

6.3.3 Synchronous condenser

When synchronous motor is used not for driving the load but for power factor improvement only then synchronous motors and synchronous motors and synchronous condensers may act as kilovar generators. Their ability to generate kilovar is a function of excitation and in the case of synchronous motors it act as function of load. When under excited they do not generate sufficient kilovar to supply their own needs and consequently must tame additional kilovars from the system. When overexcited (normal operation) they can supply their own kilovar requirements and in addtion supply kilovars to the system. Thus they can be called as kilovar requirements and in addition supply kilovars to the system. Thus they can be called as kilovars generators. Synchronous motors supplying capability can be termed as function of excitation and load. Synchronous condenser is rarely used in the industry because of high initial cost, low efficiency and rotating losses [9].

6.3.3.1 Advantages

(i) It can be varied over wide range.

(ii) Inrush current is smooth.

(iii) Load as well as p.f can be drawn from such condenser.

6.3.3.2 Disadvantages

(i) Synchronous condenser needs more maintenance.

(ii) Components of the synchronous condenser are more costly.

(iii) Low efficiency due to rotating losses.

(iv) Whole of the system is disturbed due to the failure of one unit.

From the above discussion it can be concluded that synchronous condenser are not economical for the power factor improvement.

6.3.4 Phase Advancer

For large induction motors having poor power factor phase advancing is a method of manipulating phase angle in order to improve the power factor. The phase advancer are just like an AC exciter which is mounted on the shaft, the AC exciter being connected in such a way so as to inject current in the induction motor rotor circuit at slip frequency. By providing magnetizing ampere-turns in the rotor instead of getting magnetizing ampere-turns, it neutralizes the lagging component of the stator current thereby raising the power factor.

6.3.5 Static Capacitor

Capacitor is an energy- conserving. Capacitor acts as kilovar generator because it provides the magnetizing requirements (KVAR) of he induction devices. This can be further explained as. When capacitor and induction devices are installed in the same circuit there will be exchange of magnetizing current between them or more simply one can say that the leading current taken by the induction devices. Because the capacitor or relieves the supply line of supplying magnetizing current to the induction device. The capacitor may be regarded as kolivar generator, since it actually supplies the magnetizing requirements of the induction device.

6.3.6 Capacitor Banks

The individual capacitor container is called a unit. The available ratings of these units are 5, 10, 20, 25 and 50 KVARS.

A number of such units are installed in series, parallel-series arrangement to achieve the desired voltage and current ratings. Such assemblies are called capacitor banks. Three phase capacitor banks can be connected in star grounded or grounded or in delta arrangement.

6.3.6.1 Advantages

1. Capacitor bank is a dry types dielectric so there is no chance of any leakage.
2. Maintenance of capacitor bank is very easy.
3. They are lightweight, easy to install, and reliable.
4. All capacitor are surrounded by vermiculite, which is an inorganic inert, fire-proof and non-toxic material. In case of failure the vermiculite absorbs safely the energy produced within the capacitor box and extinguishes any possible of fire.

6.3.6.2 Disadvantages

1. The capacitor banks are of fixed rating and can't be changed.
2. In rush, current is not smooth.
3. Load can't be drawn from the capacitor bank.

6.4 Comparison of KVAR Sources

The following factors ate to be considered in the installation for power improvement equipment.

1) Capital cost
2) Running cost
3) Maintenance cost
4) Life of the equipment installed
5) Reliability of the equipment
6) Space required

Generally it is observed that for normal industrial installations the capital cost of the rotating machinery, both synchronous and phase advancing makes its use uneconomical and in addition the wear and tear inherent in all rotary machines involves additional expenses for upkeep and maintenance.

The synchronous motors are more efficient than the induction motors, but when exciter losses are included with synchronous motor losses, the total losses compare almost equally with induction motor losses. However the cost of the synchronous motor in standard ranges does not compare favorably with the induction motor losses. However the cost of the synchronous motor in standard ranges does not compare favorably with the induction motors. It is generally found that speed below 500 r.p.m and ratings above 50 HP or at medium speeds 500 to 900 r.p.m and rating above 500 HP of synchronous motors compare favorably with the induction motors. Sometimes unloaded synchronous machines are installed in power systems solely for power factor correction. Such machines are synchronous condensers and may be more economical than static capacitors in larger sizes. Synchronous motors have the advantage that they are capable of supplying smoothly varying values of the KVARS and adjusting the motor field rheostat can changes the number [7, 8].

The cost of the static capacitor is quite low as compared with the other equipment used and they can be used with high efficiency on all types of installations. They are compact, reliable, highly efficient, easy to install. From the above one can safely conclude that power factor correction by means of capacitor is economical and hence it is universally used.

7. Methods of Power Correction

Following are the different methods of power factor correction that can be implemented according to the type of the load, such as constant, variable, domestic, industrial or commercial [18].

- Individual Power Factor Correction
- Group Power Factor Correction
- Central Power Factor Correction
- Fixed Power Factor Correction
- Automatic Power Factor Correction
- Mixed Power Factor Correction

7.1 Individual Power Factor Correction

This is the easiest way to improve the power factor. Capacitors are installed to he individual loads in parallel. No additional switches or protection devices are required for the capacitors.

7.2 Group Power Factor Correction

When the loads is immense then dividing the whole load into smaller groups results in the power factor correction. This type of correction is called group power factor correction.

7.3 Central Power Factor Correction

The capacitors are connected directly to the main switchboard or in the sub-station. It is further subdivided into.

7.4 Fixed Power Factor Correction

The capacitors are permanently connected to the line and they have to be remained switched ON or switched manually.

7.5 Automatic Power Factor Correction

This is the most rational solution of power factor improvement of highly variable loads. It is based on a capacitor bank divided into many groups or units and controlled by automatic electronic equipment.

7.6 Mixed Power Factor Correction

This method allows power factor regulation when values are close to unity. In this system units are split into different areas and very small central power correction is required.

When we are talking about the power factor improvement of the distribution system of power supplying authorities (e .g. WAPDA). The best solution is to connect capacitor with each and every inductive load, whether it is industrial or commercial (e.g. fan, washing machine, water pumps etc.) But the solution is not feasible as it involves a lot of effort and lot of money to fulfill the requirement.

The only possible solution is to improve the power factor by automatic power factor regulation/correction. In large power system setup it is quite economical to install automatic power factor correcting capacitor banks on each and every main supply point [7].

Hence the next possible location of power factor connection is on the low-tension side of the transformer. Automatic power factor regulation is the suitable solution for the power factor correction of highly variable loads. It is based on the capacitor bank divided on many groups or units and is controlled by electronic equipment known as power factor improvement regulator or relay.

The power factor relay continuously monitors the load variation and switches the capacitor units in order to keep the power factor at the desired level. The number of groups, which are called steps, is to be chosen according to the type of load and variation. With an accurate choice in the value of reactive power for each step, a precise CosΦ can be achieved. In order to design an accurate steps or banks of capacitors, regular monitoring of the load variation on each transformer of the power system is required. This variation can be observed from the stored from the stored data after regular interval with the help of computerized energy analyzer.

This energy analyzer is capable of storing data as phase, line currents, phase and line loads, KVAR required and KVAR supplied to maintain certain value of power factor etc. The connections of the analyzer on the transformer are show in the figure below.

The energy analyzer should be connected to each transformer for at least 24 hours, 2 days in summer and 2 days in winter (one working day and one holiday).

Although it is very laborious and time consuming job, however results obtained by this method are helpful in designing power factor improvement capacitor banks.

In order to save the time, transformer having similar type of load can be grouped and results obtained from one or two transformers are adequate for capacitor bank.

The circuit diagram showing connection of the energy analyzer & PFI capacitor banks with the transformer is shown below.

Shunt capacitors are economical when used with the individual equipment. They are particularly useful in high voltage system where it is not possible to use synchronous phase modifiers without transformers.

7.7 Shunt Capacitor

A shunt capacitor is a capacitive reactance in parallel with load. The shunt capacitor is used as a single unit or in-group of units to supply lagging KVAR to the system. It supplies the current to counter the out of phase component of current required by an inductive load.

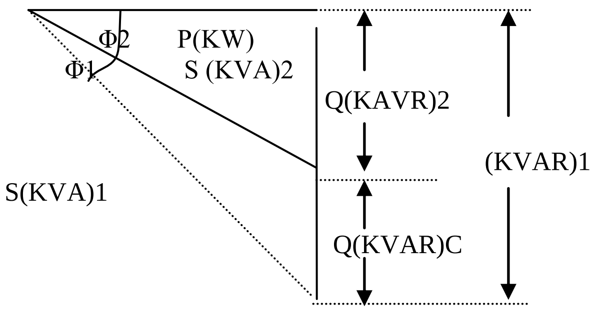
A serious disadvantages with the shunt capacitor is that at no load or light load voltage at the receiving end exceeds the sending end voltage. To overcome this difficulty the capacitor bank is provided with fixed or variable element so that with the rise or fall of the voltage the variable element may be removed or added to the bank to decrease or increase the capacitance [6,7].

7.8 Capacitor Ratings / Standards

Power factor correction capacitors are rated in electrical units called " vars ". One var. is equivalent to one volt-ampere of reactive power. Vars, then units of measurement for indicating just how much reactive power the capacitor will supply.

As reactive power is measured in the thousands of var's the letter " K " (abbreviation for " kilo " meaning thousands) recedes the var, creating the more familiar " KVAR " term.

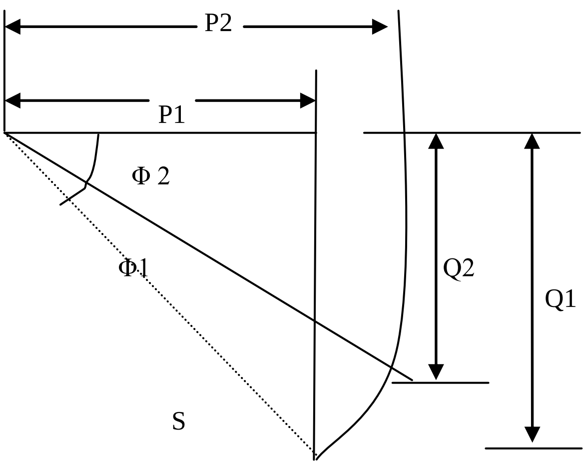
The capacitor KVAR rating then shows how much reactive power the capacitor KVAR rating then shows how much reactive power the capacitor will supply. Each unit of the capacitor's KVAR will decrease the inductive reactive power demand (magnetized demand) by the same amount.



Cos Φ = 0.9

KVA (Saving) = S (KVA)1 – S (KVA)2

Figure: 9 Vectorial representation of p.f. improvement [2].



Cos Φ = 0.9 KW (Saving) = P1 – P2

Figure:10 Power factor improvement of an electric load [2].

See illustration below, a low voltage network requires 410 KW of reactive power at full load, and power factor is measured to be 0. 70. Therefore the system full load consumption of apparent power is 579.5 KVAR of capacitive reactive power is installed the power factor will rise to 0.96 and the KVA demand will be reduced from 579.5 to 424.3 KVA.

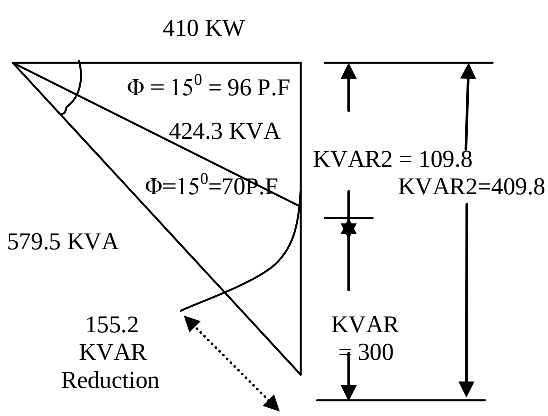


Figure:11 power factor Improvement By Capacitor Bank [7].

8. Power factor correction calculation

The data required for the calculation of power factor correction is as under. Active power and CosΦ, or active power, active energy and reactive energy. This data can be obtained from the following methods:

8.1 From the Energy meters

The data can be collected by using energy meter at regulate intervals for number if days of days for fixed interval 'n'. The formula used for this purpose is

KW = (KWH - KWHo) / n

KVAR = (KVARH1 - KVARHo) / n

Where KWHo and KVARHo are the reading at the start of the interval.

From this method accurate calculations for power factor correction can be made. The results can be more accurate if the interval 'n' is short.

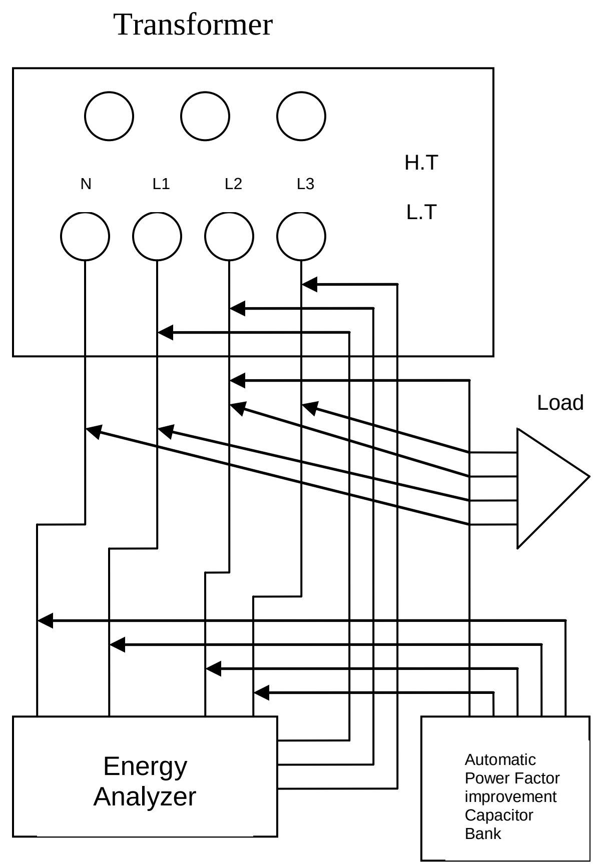


Figure: 12 Connection of PFI capacitor bank energy analyzer on the L.T of the T/F [1].

8.2 By power line analyzer

By using power line analyzer one can find more complete and comprehensive ser of data. These analyzers also provide the harmonic analysis of the power line. Due to presence of the harmonics capacitor banks starts drawing over current then it is compulsory to use the filters.

8.3 Using Table

By finding different parameters and with the help of the table one can calculate the capacitive reactive power to keep the power factor in limits. Following method be adopted to calculate the power from the table.

8.4 Finding KW and CosΦ

Consider the power triangle of the figure.

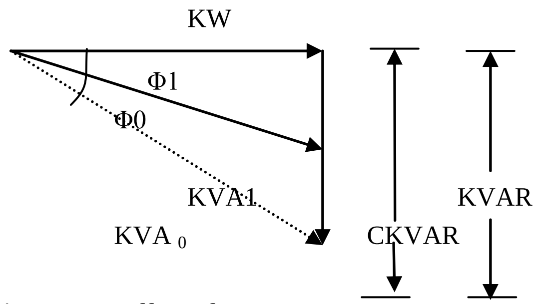


Figure: 13 Effect of Power Factor Improvement.

KVAR at actual p.f. = KW x Tan – Φ_0
KVAT at Improved p.f. = KW x Tan – Φ_1
CKVAR = KW (Tan Φ_0 Tan Φ_1)
= KW x k

where k = (Tan Φ_1 - Tan Φ_2)

Find the value of Cos Φ nearest to the one of the load. On this line move to the right till reaching the desired column of Cos Φ. At this value of factor 'k' is found. The necessary reactive power is then

KVAR = k x KW

Finding 'KW' and 'KVAR'

We can also find

Tan Φ = KVAR / KW

By using the table first column, a value as close to one is selected. Move on the same line of this value till the column of the wanted Cos Φ is found. At this point the value of 'k' factor is obtained.

The capacitive reactance is than calculated with the following formula.

KVAR = k x KW

From the energy bill

By finding the working hours during the billing period. Average active power can be calculated.

KW = KWH / n

Where n = working hours

This method is useful in case of very uniform loads and for variable loads it is not advisable.

9. Power Factor Improvement

In order to introduce awareness among people to keep their power factor high, it is necessary that tariff rates for AC power is such that the overall net charges per KWH of the energy utilized depend on power factor of the consumers. Some of them are described below:

i) The total electricity bill is adjusted against KVARH instead of KWH.

ii) The total bill is adjusted in such a way that it depend upon the deviation of load p.f. from the standard value say 0.90. The bill is increased by a constant percentage for each unit p.f. deviation from 0.90 say for each decrease of 0.01 from 0.90. Similarly it would be bonus for each increase of unit p.f. value.

iii) The most commonly used tariff is two part tariff i.e. The fixed charges instead being based upon KW maximum demand are based on KVA maximum demand so that they become inversely proportional to the power factor.

(iv) If load p.f were 0.9 then 450 KW maximum demand represent 450 / 0.9 = 500 KVA maximum demand.

(v) If load power factor was 0.7 then 450 KW maximum demand is equal 450 / 0.7 = 643 KVA maximum demand.

Cost on KWH consumed for both power factors will be same, it is only the maximum demand charge which will vary with the power factor.

10. Conclusion

After going through all important Parameter of Power factor improvement, it is suggested that energy can be conserved by implementing Power factor improvement Program. It is Suggested after going through the Study of the electrical installation of U.E.T that Capacitors can be installed on the inductive loads, such as,

(i) Tube lights
(ii) Pumping motors
(iii) Transformers.

After installation of Capacitor of appropriate rating for the above loads, evaluation of energy conserved can be made.

The evaluation of energy conservation by installing Power factor improvement Capacitor is Left for another research work.

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Quotation

- Man is at the bottom an animal, midway a citizen, and at the top divine. But the climate of this world is such that few ripen at the top.

Henry Ward Beecher

- I don’t think you have to teach people how to be human. I think you have to teach them how to stop being inhumane.

Eldridge Cleaver

Evaluation of Benefits by Power Factor Improvement on L.T. Side of Transformers in Distribution System

(Case Study)

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1.0 Introduction

Energy conservation is equivalent to energy generation. As power generation is becoming expensive day by day, therefore conservation of energy has started playing a pivotal role toward the nation's economy. As population grows at an alarming rate resulting in also an increase in economic growth, electrical is in short supply. Improving energy efficiency in an electrical system has become a major issue.

There are major areas i.e., Low Power Factor, Less Efficient motors and lighting sources which causes increased current, increased power losses and ultimately reduced voltage. Load scheduling by using most efficient energy consuming devices can conserve energy to great extent.

This paper particularly deals with the evaluation of the impact of the Power Factor Improvement on the transformer installed at different locations in the distribution System. In this paper the Distribution System of University of Engineering & Technology (U.E.T), Lahore Pakistan, has been taken as a test case.

Impact of Power Factor improvement by installing power capacitor on each transformer, saving in transmission and distribution lines, are also evaluated from L.T side of transformer up to the metering panel of WAPDA installed at one Point in H.T. (11KV). It is to noted that U.E.T is fed at one Point and is on Bulk Power Supply Tariff of WAPDA. Therefore all reduction in losses adds to reduced Unit Charges by WAPDA hence overall reduction in the Electricity Bill is evaluated.

2.0 Methods of Power Factor Correction

Following are the different methods of power factor correction that can be implemented according to the type of the load, such as constant, variable, domestic, industrial or commercial [1].

- **Individual Power Factor Correction**
- **Group Power Factor Correction**
- **Central Power Factor Correction**
- **Fixed Power Factor Correction**
- **Automatic Power Factor Correction**
- **Mixed Power Factor Correction**

3.0 Analysis of Transformers

The calculation were performed by improving the power factor of each transformer installed in the U.E.T network from 0.7 to 0.95 at full load as well as on 60% load.

Results were observed in the shape of %age saving both in terms of KVA and KW. Total KVAR required to achieve this power factor were calculated at the end.

Transformers Installed in the U.E.T Network are as under:-

1. 50 KVA = 05 Nos.
2. 100KVA = 12 Nos.
3. 200 KVA = 11 Nos.

3.1 Saving of Transformer at Full Load (50 KVA)

3.1.1 KVA Saving Calculation (50 KVA Transformer)

Improving Power Factor from 0.7 to 0.9

$KVA_1 = 50$

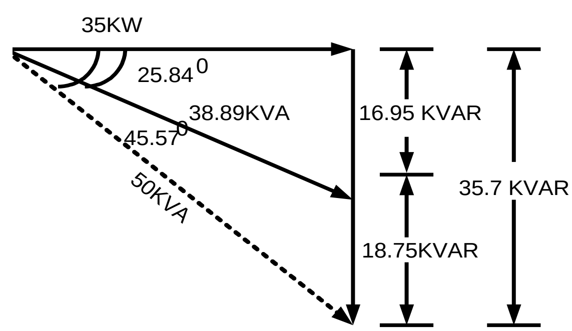
$Cos ø_1$ 0.7

$P = 50 \times 0.7 = 35KW$

$KVAR_1 = Sin (Cos^{-1} 0.7) \times 50$

$KVAR_1 = Sin (45.57) \times 50$

$KVAR_1 = 35.7KVAR$



$KVA_2 = KW / Cos \phi$

$KVA_2 = 35 / 0.9 = 38.89$

$KVAR_2 = Sin (Cos^{-1} 0.9) \times 38.89$

$KVAR_2 = 16.95$ KVAR

$$\% \text{ Age saving in KVA} = \frac{KV_1 - KVA_2}{KVA_1} \times 100$$

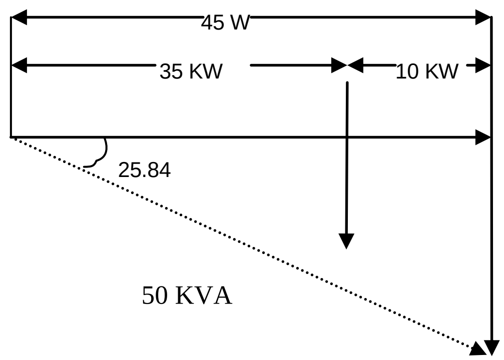
$$= \frac{(50 - 38.89)}{50} \times 100$$

$= 22.2$ %

3.1.2 Active power (KW) Calculations (50 KVA Transformer)

KW = KVA Cosϕ

P_1 = 50 x Cos ϕ =50 x 0.9



P_1 = 45 KW
Saving in KW = 45 – 35
= 10 KW

P_1 = 45 KW
Saving in KW = 45 – 35
= 10 KW

% Age saving = $\frac{(45 - 35)}{35}$ x 100
= 28.57%

Total KVAR required = 18.75

At present there are 05 Nos of 50 KVA transformers in the UET network. So for five 50 KVA transformers in UET distribution system KVARS required are as under.

Total KVARS for five nos. 50 KVA transformers = 5 x 18.75 = 93.75- KVAR

3.2 Saving of Transformer at Full Load (100 KVA)

3.2.1 KVAR Saving Calculation (100 KVA Transformer)

Improving power Factor from 0.7 to 0.9

KVA_1 = 100

KVAR = $KVAR_1 - KVAR_2$

KVAR = 35.7 – 16.95 = 18.75

$Cos\phi_1$ = 0.7

P = 100 x 0.7 = 70KW

$KVAR_1$ = Sin (Cos^{-1} 0.7) x 100
= Sin (45.57) x 100
= 71.39 KVAR

$Cos\phi_2$ = 0.9

KVA_2 = KW / Cosϕ

KVA_2 = 70 / 0.9 = 77.78

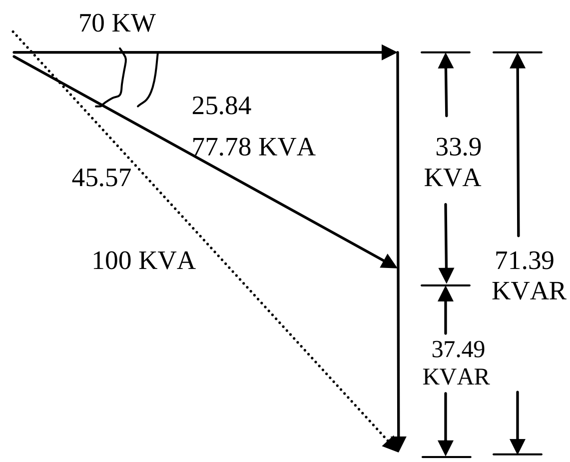
$KVAR_2$ = Sin (Cos^{-1} 0.9) x 77.78
= 33.90 KVAR

KVA required = ($KVAR_1$ - $KVAR_2$) / KVA_1
= 71.41 – 33.90 = 37.50

%Age saving in KVA= $\frac{KVA_1 - KVA_2}{KVA1}$ X 100

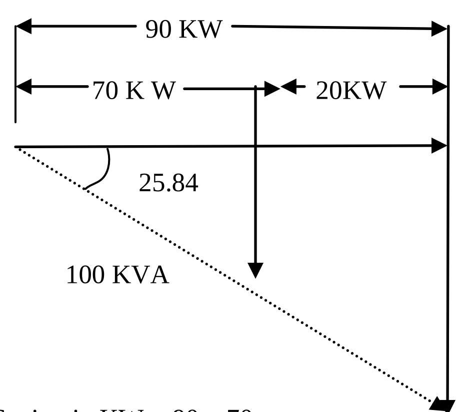
= $\frac{(100 - 77.78)}{100}$ X 100

= 22.2 %



3.2.2 KW Saving calculations (100 KVA Transformer)

Kw = KVA Cosϕ
P_1 = 100 X $Cos\phi_2$
P_1 = 100 X 0.9
P_1 = 90 KW



Saving in KW = 90 – 70
= 20 KW

%Age saving = $\frac{(90 - 70)}{90}$ x 100
= 22.22%

3.2.3 Total KVAR Required

Total KVAR required = 37.49

At present there are 12 Nos of 100 KVA transformers in the UET network. So for twelve 100 KVA transformers in UET distribution system KVAR required are as under.

Total KVARS for twelve 100KVA transformers = 12 x 37.49 = 450 KVAR

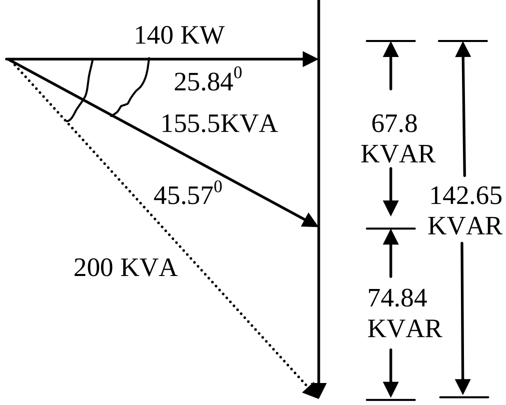
3.3 Transformer at Full Load (200 KVA)

Improving Power Factor From 0.7 to 0.9

3.3.1 KVA Saving Calculation (200 KVA Transformer)

KVA_1 = 200
$Cos\phi_1$ = 0.7

P = 200 x 0.7 = 140 KW
$KVAR_1$ = $Sin(Cos^{-1} 0.7) \times 200$
= Sin (45.57) x 200
= 142.65 KVAR



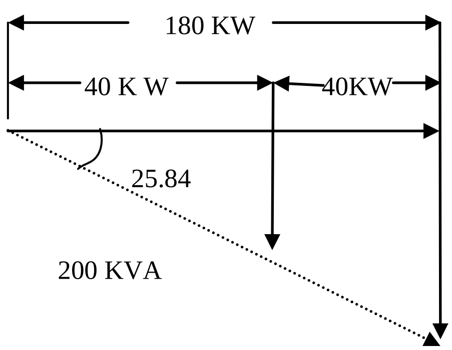
$Cos\phi_2$ = 0.9
KVA = KW / $Cos\phi$
KVA_2 = 140/ 0.9 = 155.5
$KVAR_2$ = $Sin(Cos^{-1} 0.9) \times 155.5$
= 67.80 KVAR

$$\text{Saving in KVA} = \frac{KVA_1 - KVA_2}{KVA1} \times 100$$

$$= \frac{(200 - 155.5)}{200} \times 100$$

$$= 22.2\%$$

3.3.2 KW Saving Calculation (200 KVA Transformer)



For Active Power (KW)

KW = KVA $Cos\phi$
P_I = 200 x $Cos\phi_2$
= 200 x $Cos\phi_2$
= 200 x 0.9
= 180 KW
Saving in KW = 180 – 140
= 40KW

$$\text{\%Age saving} = \frac{180 - 140}{140} \times 100$$

= 28.57%

3.3.3 Total KVAR required

KVAR required = 74.84

Total KVAR required

For 11 NOS Transformer = 74.84 x 11 = 824 KVAR

At present there are 11 Nos of 200 KVA transformers in the

UET network. So for eleven 200 KVA transformers in UET distribution system KVARS required are.824

4.0 Low Power Factor Penalty Charges

Low power factor results in the form of penalty by the WAPDA. Investment in the power factor improvement are made to avoid the low factor penalty charges. However, in WAPDA and KESCO where the electric utilities have a penalty based rate structure, power factor correction capacitor and systems can generate a one-year or less payback.

4.1 Analysis of U.E.T. Power System

Due to the power factor UET pays huge amount as penalty charges to WAPDA. By proper adopting a technique for power factor improvement, penalty charges can be avoided. WAPDA has fixed 0.90 power factor for the consumers and any consumer having power factor less than the prescribed value has to pay the penalty and WAPDA is planning to increase its power factor to 0.95. As per WAPDA tariff structure is concerned, UET electricity load falls in the C2 (A) type, (Tariff 28) category whose formula for finding the low power factor LPF is as under.

Penalty = Energy Charges * (0.9 - Power Factor)
Energy Charges = KWh Units * Unit Rate
(Rs. 0.69 From Tariff Table)

Hence the penalty along with the cost of capacitors to avoid penalty charges is calculated. Then the tentative recovery payback period is also calculated. For energy analysis of U.E.T. distribution system detail drawing showing all electrical equipment like transformers, motors etc with ratings along with their respective distances from the source were drawn that will facilitate in the calculation work. Results like current drawn, KVAR required to achieve this power factor and saving in KVA and saving in terms of cost due to power factor penalty will be calculated at the end.

4.2 Analysis of U.E.T. Electricity Bills

For calculating the reduction / saving in the bills of UET, complete system was essential and for this purpose electricity bills of UET for the whole year- 1997 were analyzed. The detail is as under:

Month/Year	KW	KWH	KVARH	$P.F_1$
01 / 97	1200	565000	280000	0.9
02 / 97	1200	479600	280000	0.86
03 / 97	700	227408	180000	0.78
04 / 97	500	193300	130000	0.83
05 / 97	500	249200	228000	0.74
06 / 97	940	463600	321500	0.82
07 / 97	1000	509000	332700	0.84
08 / 97	1100	489300	315700	0.84
09 / 97	1050	608900	376400	0.85
10 / 97	1200	611100	275000	0.91
11 / 97	700	408700	255000	0.85
12 / 97	1200	437100	328500	0.80

Table showing various Units Consumed / Month (YEAR – 97)

1. Data Available (From Electricity Bill) of Jan, 1997.

Year / Month = 1 / 97
KW = 1200
KWH = 565000
KVARH = 280000

Load factor = KWH / (730 x KW)
= 565000 / (730 x 1200)
= 0.644

$P.F_1$ = Cos (Tan^{-1} (KVARH/KWH)
= Cos (Tan^{-1} (280000 / 565000)
= 0.897 ≈ 0.9

KVA Load = KW / $P.F_1$
= 1200 / 0.9
= 1333.3

PF_2 = 0.95

$KVAR_1$ = KW (Tan (Cos^{-1} 0.9))
= 1200 (Tan (Cos^{-1} 0.9))
= 581.18

$KVAR_2$ = KW (Tan (Cos^{-1} 0.95))
= 1200 (Tan (Cos^{-1} 0.95))
= 394.42

KVAR required = $KVAR_1$ - $KVAR_2$
= 581.18 - 394.42
= 186.75

KVA Saving = KW (1 / $P.F_1$ - 1 / $P.F_2$)
= 1200 (1 / 0.9 - 1 / 0.95)
= 70.17

WAPDA imposes penalty on the consumer having power factor less than 0.9 and for that WAPDA has divided its tariff as per load type and UET tariff type C2 (A) 28 of which unit rate penalty is 0.69.

Penalty Charges = Total Energy charges x Power factor

Whereas
Total Energy charges = KWH units * Unit rate
(Rs. 0.69 from tariff table)

Penalty Charges = KWH Units x 0.69 x (0.9 - P.F)
= NIL because P.F is 0.9

2 Data Available (From Electricity Bill) of Feb, 1997.

Year / Month = 2 / 97
KW = 1200
KWH = 479600
KVARH = 280000

Load factor = KWH / (730 x KW)
= 479600 / (730 x 1200)
= 0.547

$P.F_1$ = Cos (Tan^{-1} (KVARH / KWH)
= Cos (Tan^{-1} (280000 / 479600)
= 0.86

KVA Load = KW / P.F1
= 1200 / 0.86
= 1395.34

PF_2 = 0.95

$KVAR_1$ = KW (Tan (Cos^{-1} 0.86))
= 1200 (Tan (Cos^{-1} 0.86))
= 712.03

$KVAR_2$ = KW (Tan (Cos^{-1} 0.95))
= 1200 (Tan (Cos^{-1} 0.95))
= 394.42

KVAR required = $KVAR_1$ - $KVAR_2$
= 712.03 - 394.42
= 317.60

KVA Saving = KW (1 / $P.F_1$ - 1 / $P.F_2$)
= 1200 (1 / 0.86 - 1 / 0.95)
= 132.19

WAPDA imposes penalty on the consumer having power factor less than 0.9 and for that WAPDA has divided its tariff as per load type and UET tariff type C2 (A) 28 of which unit rate penalty is 0.69.

Penalty Charges = Total Energy charges x Power factor

Whereas
Total Energy charges = KWH units * Unit rate
(Rs. 0.69 from tariff table)

Penalty Charges = KWH Units x0.69x(0.9 - P.F)
= 479600 x 0.69 x (0.9 - 0.86)
= Rs. 13236.96

Similarly all the Calculation are made for different monthly data obtained from Bill.

WAPDA imposes penalty on the consumer having power factor less than 0.9 and for that WAPDA has divided its tariff as per load type and UET tariff type C2 (A) 28 of which unit rate penalty is 0.69.

Penalty Charges = Total Energy charges x Power factor

Whereas
Total Energy charges = KWH units * Unit rate
(Rs. 0.69 from tariff table)

Penalty Charges = KWH Unitsx0.69 x (0.9 - P.F)
= 463600 x 0.69 x (0.9 - 0.82)
= Rs. 25590.72

5.0 Power Distribution System Losses of U.E.T.

For calculating HT line losses in the distribution system of U.E.T., exact length of the HT line from the source to the transformer is measured from the electrical design map of the U.E.T. Presently in the U.E.T. network total number of transformers are as under.

1. 50 KVA = 5 Nos.
2. 100 KVA = 12 Nos.
3. 200 KVA = 11 Nos.

5.1 Overall Reductions in HT Line Losses connected to 50 KVA Transformers

Total number of transformers = 5 Nos.

KVA = 50
P.F1 = 0.7
P.F2 = 0.95
KW = KVA Cosϕ
Power = 50 X 0.7
= 35 KW

Line Voltage = 11000V

$$l_1 \text{ (current at P.F}_1\text{)} = \frac{P}{\sqrt{3} \times V \times \cos\phi} = \frac{35 \times 1000}{\sqrt{3} \times 11 \times 10^3 \times 0.7} = 2.624 \text{ Amps.}$$

$$l_2 \text{ (current at P.F}_2\text{)} = \frac{P}{\sqrt{3} \times V \times \cos\phi} = \frac{35 \times 1000}{\sqrt{3} \times 11 \times 10^3 \times 0.95} = 1.934 \text{ Amps.}$$

Resistance of dog conductor=0.0002733 Ω / meter
Length of HT cable from the source

TF1 = 873m, TF2 = 1040m, TF3 = 1068m,
TF4 = 2400m, TF5 = 2561m

5.1.1 Reduction in HT line losses Connected to TF1 (50KVA)

Power losses at P.F$_1$ (0.7) = $(I_1)^2$ R x Length
= $(2.624)^2$ x 0.0002733 x 873
= 1.643 Watts

Power losses at P.F$_2$ (0.95) = $(I_2)^2$ R x Length
= $(1.934)^2$ x 0.0002733 x 873
= 0.892 Watts

Reduction in HT line losses = 1.643 - 0.892
= 0.751 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(1.643 - 0.892) \times 100}{1.643} = 45.69\%$$

5.1.2. Reduction in HT line losses Connected to TF2 (50KVA)

Power losses at P.F$_1$ (0.7) = $(I_1)^2$ R x Length
= $(2.624)^2$ x 0.0002733 x 1040
= 1.957 Watts

Power losses at P.F$_2$ (0.95) = $(I_2)^2$ R x Length
= $(1.934)^2$ x 0.0002733 x 1040
= 1.063 Watts

Reduction in HT line losses = 1.957 - 1.063
= 0.894 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(1.957 - 1.063) \times 100}{1.957} = 45.69\%$$

5.1.3. Reduction in connecter to HT line losses Connected to TF3 (50KVA)

Power losses at P.F$_1$ (0.7) = $(I_1)^2$ R x Length
= $(2.624)^2$ x 0.0002733 x1068
= 2.009 Watts

Power losses at P.F$_2$ (0.95) = $(I_2)^2$ R x Length
= $(1.934)^2$ x 0.0002733 x 1068
= 1.091 Watts

Reduction in HT line losses = 2.009 - 1.091
= 0.918 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(2.009 - 1.091) \times 100}{2.009} = 45.69\%$$

5.1.4. Reduction in connecter to HT line losses Connected to TF4 (50KVA)

Power losses at P.F$_1$ (0.7) = $(I_1)^2$ R x Length
= $(2.624)^2$ x 0.0002733 x 2400
= 4.517 Watts

Power losses at P.F$_2$ (0.95) = $(I_2)^2$ R x Length
= $(1.934)^2$ x 0.0002733 x 2400
= 2.453 Watts

Reduction in HT line losses = 4.517 - 2.453
= 2.064 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(4.517 - 2.453) \times 100}{4.517} = 45.69\%$$

5.1.5. Reduction in connecter to HT line losses Connected to TF5 (50KVA)

Power losses at P.F$_1$ (0.7) = $(I_1)^2$ R x Length
= $(2.624)^2$ x 0.0002733 x 2561
= 4.819 Watts

Power losses at P.F$_2$ (0.95) = $(I_2)^2$ R x Length
= $(1.934)^2$ x 0.0002733 x 2561
= 2.617 Watts

Reduction in HT line losses = 4.819 - 2.617
= 2.202 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(4.819 - 2.617) \times 100}{4.819} = 45.69\%$$

Total HT line losses of 5 x 50 KVA transformers at 0.7 PF_1
= 14.945 Watts

Total HT line losses of 5 x 50 KVA transformers at 0.95 PF_2
= 8.116 Watts

Reduction in line losses = 14.945 - 80116
= 6.829 Watts

$$\% \text{ Age Reduction in HT losses} = \frac{(14.945 - 8.116) \times 100}{14.945}$$
= 45.69 %

5.2 Overall HT Line Losses Calculation Connected to of 100 KVA Transformers

Total number of transformers = 12 Nos.
KVA = 100
PF_1 = 0.7
PF_2 = 0.95

KW = KVA Cosϕ

Power = 100 x 0.7
= 70 KW
Line Voltage = 11KV

$$l_1 \text{ (current at P.F}_1\text{)} = \frac{P}{\sqrt{3} \times V \times \cos\phi}$$
$$= \frac{70 \times 1000}{\sqrt{3} \times 11 \times 10^3 \times 0.7}$$
= 5.248 Amps.

$$l_2 \text{ (current at P.F}_2\text{)} = \frac{P}{\sqrt{3} \times V \times \cos\phi}$$
$$= \frac{70 \times 1000}{\sqrt{3} \times 11 \times 10^3 \times 0.95}$$
= 3.867 Amps.

Resistance of dog conductor = 0.0002733 Ω / meter
Length of HT cable from the source

TF1 = 833m, TF2 = 894m, TF3 = 1071m,
TF4 = 1156m, TF5 = 1159m, TF6 = 1214m,
TF7 = 1313m, TF8 = 1451m, TF9 = 1512m,
TF10 = 1591m, TF11 = 1676m, TF12 = 2036m,

5.2.1 Reduction in HT line losses connecter to TF1 (100KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(5.248)^2$ x 0.0002733 x 833
= 6.270 Watts
Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(3.867)^2$ x 0.0002733 x 833
= 3.405 Watts

Reduction in HT line losses = 6.270 - 3.405
= 2.865 Watts

$$\% \text{ Age reduction in HT line losses} = \frac{(6.270 - 3.405) \times 100}{6.270}$$
= 45.69%

5.2.2. Reduction in HT line losses Connected toTF2 (100KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(5.248)^2$ x 0.0002733 x 894
= 6.729 Watts
Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(3.867)^2$ x 0.0002733 x 894
= 3.654 Watts

Reduction in HT line losses = 6.729 - 3.654
= 3.075 Watts

$$\% \text{ Age reduction in HT line losses} = \frac{(6.729 - 3.654) \times 100}{6.729}$$
= 45.69%

5.2.3. Reduction in HT line losses Connected to TF3 (100KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(5.248)^2$ x 0.0002733 x1017
= 7.655 Watts
Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(3.867)^2$ x 0.0002733 x 1017
= 4.157 Watts

Reduction in HT line losses = 7.655 - 4.157
= 3.498 Watts

$$\% \text{ Age reduction in HT line losses} = \frac{(7.655 - 4.157) \times 100}{7.655}$$
= 45.69%

Similarly losses are Calculated for each 100-KVA Transformer

5.3 Overall Reduction H.T Line losses Connected to 200 KVA Transformers

Length of HT Cable from the source

TF1 = 58 m, TF2 = 180 m, TF3 = 220 m,
TF4 = 373 m, TF5 = 587m, TF6 = 700 m,
TF7 = 1056 m, TF8 = 1343 m, TF9 = 1343 m,
TF10 = 14301m, TF11 = 1451m

5.3.1. Reduction in HT line losses Connected toTF1 (200 KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(10.497)^2$ x 0.0002733 x 58
= 1.746 Watts
Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(7.735)^2$ x 0.0002733 x 58
= 0.949 Watts
Reduction in HT line losses = 1.746 - 0.949
= 0.797 Watts

$$\% \text{ Age reduction in HT line losses} = \frac{(.746 - 0.946) \times 100}{1.746}$$
= 45.69%

5.3.2. Reduction in HT line losses Connected toTF2 (200 KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(10.497)^2$ x 0.0002733 x 180
= 5.420 Watts
Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(7.735)^2$ x 0.0002733 x180
= 2.944 Watts

Reduction in HT line losses = 5.420 - 2.944
= 2.476 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(5.420 - 2.944) \times 100}{5.420}$$

= 45.69%

5.3.3. Reduction in HT line losses Connected toTF3 (200 KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(10.497)^2$ x 0.0002733 x 220
= 6.625 Watts

Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(7.735)^2$ x 0.0002733 x 220
= 3.598 Watts

Reduction in HT line losses = 6.625 - 3.598
= 3.027 Watts

$$\text{\% Age reduction in HT line losses} = \frac{6.625 - 3.598 \times 100}{6.625}$$

= 45.69%

5.3.4. Reduction in HT line losses Connected toTF4 (200 KVA)

Power losses at $P.F_1$ (0.7) = $(I_1)^2$ R x Length
= $(10.497)^2$ x 0.0002733 x 373
= 11.232 Watts

Power losses at $P.F_2$ (0.95) = $(I_2)^2$ R x Length
= $(7.735)^2$ x 0.0002733 x 373
= 6.10 Watts

Reduction in HT line losses = 11.232 - 6.10
= 5.132 Watts

$$\text{\% Age reduction in HT line losses} = \frac{(11.232 - 6.10) \times 100}{11.232}$$

= 45.69%

Similarly Calculation were done for all 200KVA Transformer

6.0 Transformer Copper Losses

Distribution transformers generally have two types of losses
1 Copper losses (I^2.R Losses)
2 Iron losses (Fixed losses)

Copper losses are proportional to the square of the load currents. Standard Distribution Transformer losses at different loading are given in the table below.

Transformer Capacity	Maximum Current	%Age Load vs. Losses in Watts					
		25 %	50 %	75%	100 %	125 %	150 %
50 KVA	72 Amps	248	468	833	1345	2003	2807
100 KVA	144Amps	436	815	1346	2330	3466	4855
200 KVA	288Amps	708	1320	2413	3905	5823	8167

6.1 Reduction in Copper losses of 50 KVA Transformer

KVA before P.F improvement at 0.7 = 50 KVA
KVA after P.F improvement at 0.95 = 36.84 KVA

$$\text{Reduction in KVA after improvement} = \frac{(50 - 36.84)}{50} \times 100$$

= 26.3 %

Standard losses at 100% load = 1345 Watts
(From above table)
Standard losses at 75% load = 833 Watts
(From above table)
Reduction in copper losses = 1345 – 833 = 512Watts

$$\text{\%Age reduction} = \frac{(1345 - 833)}{1345} \times 100$$

= 38%

Total reduction for 5 x 50 KVA transformers = 5 x 512 = 2560Watts.

6.2 Reduction in Copper losses of 100 KVA Transformer

KVA before P.F improvement at 0.7 = 100 KVA
KVA after P.F improvement at 0.95 = 73.68 KVA

$$\text{Reduction in KVA after improvement} = \frac{(100 - 73.68)}{100} \times 100$$

= 26.3 %

Standard losses at 100% load = 2330Watts
(From table)
Standard losses at 75% load = 1346 Watts
(From table)

From table)
Reduction in copper losses = (2330 – 1346)= 984Watts

$$\text{\%Age reduction} = \frac{2330 - 1346)}{2330} \times 100$$

= 42.23%

Total reduction for 12 x 100 KVA transformers =12x 984 = 11808Watts.

6.3 Reduction in Copper losses of 200 KVA Transformer

KVA before P.F improvement at 0.7 = 200 KVA
KVA after P.F improvement at 0.95 = 147.37 KVA

$$\text{Reduction in KVA after improvement} = \frac{(200 - 147.37)}{200} \times 100$$

= 26.3 %

Standard losses at 100% load = 3905 Watts
(From table)
Standard losses at 75% load = 2413Watts
(From table)
Reduction in copper losses = (3905 – 2413)
= 1492Watts

$$\text{\%Age reduction} = \frac{(3905 - 2413)}{3905} \times 100$$

= 38.2%

Total reduction for 11 x 200 KVA transformers = 11 x 1492 = 16412Watts.

6.4 Overall Reduction in Copper losses

(i) Total reduction of Copper Losses for 5 x 50 KVA transformer
= 5 x 512 = 2560Watts.

(ii) Total reduction of Copper Losses for 12 x 100 KVA transformer = 12 x 984 = 11808Watts.

(iii) Total reduction of Copper Losses for 11 x 200 KVA transformer = 11 x 1492 = 16412Watts.

Total saving in Copper losses of all transformers = 2560 + 11808 + 16412 = 30780Watts = 30.780KW

Units saving per day = (30.78 x 24) = 738.72 KWH
Units saving per month = (30.78 x 24 x 30) = 22161.60KWH
Units saving per year = 269632.80 KWH

7.0 Total saving Analysis of Transformers

Following are the overall results of the above mentioned calculations.

1. Total Nos. of 50 KVA transformers = 5 Nos
2. Total Nos. of 100 KVA transformers = 12 Nos
3. Total Nos. of 200 KVA transformers = 11 Nos

Table below Showing Variation in with Change in Power P.F.I.

KVA		Power (KW)		Power Factor (Cosϕ)	
Before	After	Before	After	Before	After
50	36.84	35	47.50	0.7	0.95
100	73.68	70	95	0.7	0.95
200	147.36	140	190	0.7	0.95

Total KW before power factor improvement (0.7 P.F) = 2555

Total KW After power factor improvement (0.95 P.F) =3455

Total savings = (3455 – 2555) = 900 KW

$$\text{Total Saving in KW (\%age)} = \frac{(3455 - 2555)}{2555} = 35.7\%$$

Total cost of installation /generation of power house = US Dollars 450/KW

So Total cost for generation of 900KW of energy = 900 x 450 = US $ 405,000 = Rs. 60 x 405,000

Total saving in terms of Pak Rupees = Rs.24300000

Total KVA before power factor improvement (0.7 P.F) = 3650

Total KVA after power factor improvement

(0.95 P.F) = 2689.32

$$\text{Total Saving in KVA} = \frac{(3650 - 2689.32) \times 100}{3650} = 26.3\%$$

Total HT line losses of (5 x 50KVA, 12 x 200 KVA) all transformers at 0.7 P.FI = 397.473 Watts.

Total HT line losses of (5 x 50KVA, 12 x100KVA, 11 x 200KVA) all transformers at 0.95 PF_2 = 215.84 Watts.

Reduction in HT line losses = 397.473 – 215.841 = 181.632Watts.

$$\text{\%Age reduction in HT line losses} = \frac{(397.473 - 215.841) \times 100}{397.473} = 45.69\%$$

8.0 Overall saving Analysis by Power Factor improvement on L.T Side of Transformers

Case I: (As Per General Analysis)

(i) Units saving/year due to transmission line losses = 1591.035 KWH

(ii) Units saving year due to transformers copper losses = 269632.80KWH

Total saving year in units due to power factor improvement = 1591.035 + 269632.80 = 271233.84KWH.

Whereas rate/unit = Rs.6/-

Total saving year = 271233.84 x 6 = Rs. 16, 27,403

Case II(As per Actual Consumption During Year 1997)

Total penalty charges due to low power factor for the whole year 1997 = Rs. 20, 11,101.00

9.0 Conclusion

Hence from the analysis it is concluded that power factor improvement on L.T. Side of all transformers can yield following advantages

(i) Reduction in KVA demand (26.3%)

(ii) Reduction in energy losses of transmission lines (45.69%)

(iii) Total saving in KW (35.7%)

(iv) Saving is terms of Units (KWH) is 2, 71,233 KWH

It has been Concluded that by improving Power Factor on the low Tension (L.T) side of the transformer, a huge amount of Energy can be saved, not only by reduction in Copper losses of transformer itself but also by reduction in copper losses of transmission lines of the Distribution System. This reduction in losses is in turn reduces the KWH (Unit). There-fore it help in reduction in the Electricity Bills of the Organization and institutions.

This reduction in a losses also increases the overall life of the whole Electrical Component of the Distribution System.

10.0 References

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Quotation

- Self-reflection is the school of wisdom.

Baltasar Gracian

- Wisdom is great tghan knowledge, for wisdom includes knowledge and the due use of it.

Joseph Burritt Sevelli Capponi

- The unexamined life is not worth living.

Plato

- Life is either a daring adventure of nothing.

Helen Keller

Solution to Energy Crises
Part-I: Bridging Gap between Demand and Power Supply

By
Engr. Riaz Ahsan Baig

1. GENERAL

Government of PML (N) is in waiting to take over shortly the responsibility of the Government of Pakistan but at present is in a fix to tackle the energy crises.

Previous Governments have failed to meet the country's power requirements, so badly needed for economic growth of the country, without which there can be no industrial development and agriculture production, which forms backbone of country's economic growth (GDP).

Listed below are some major reasons for failure of previous Governments to meet the Power System demand which is outcome of mismanagement, bad governance and corrupt practices:

i.) Delayed implementation of projects

ii.) Higher cost of generation which is beyond the consumer capacity to pay

iii.) Higher system losses, technical and administrative (theft of energy)

iv.) Non recovery of arrears from consumers, Federal and Provincial departments, KESC and AJK

v.) Higher cost of administrative charges and inefficiency

vi.) Negligence of operation and maintenance of power system

vii.) Corrupt practices

The approach to tackle the problem of energy crises is based on ground realities and facts, and a practical approach has been adopted to resolve the issues in the shortest possible time. Solution to Energy Crises has a very wide scope and will be covered under the following three topics separately as under:

Part-I: Bridging the Gap between Demand and Supply

Part-II: Institutional Reforms

Part-III: System Losses & Recovery of Arrears

2. BRIDGING THE GAP BETWEEN POWER DEMAND AND SUPPLY

Since energy permeates economy higher GDP growth cannot be achieved without sustainable growth in energy sector GOP has to give top priority to power generation to boost economy.

Today the peak demand of electricity is about 17300 MW while the generation is about 12000 MW thus resulting in short fall of about 5000 MW to 6000 MW. Additional power demand is proportional to increase in GDP growth. If the GoP intends to raise GDP and economic condition, a proportional increase in power demand is ought to occur, which must be taken into account while planning load growth for the future.

As a rough estimate load growth of 2000 MW to 3000 MW p.a is expected during the next five years.

All the planned projects in Pipeline for addition of power in the system have been listed, to judge if the addition of power is sufficient to cater for the load demand for the next five years.

To work out "Solution to the Energy Crises", the proposed measures for addition of power in the system have been divided in two phases:

Phase-I is spread over from July 2013 to June 2015.

Phase-II will cover the period from July 2015 to 2018.

3. PHASE-I: PROJECTS IN PIPELINE

To meet with the power shortage, status of the existing power stations and power generators in pipeline has been studied. All such available sources are listed here under which can be expedited if persuaded at Ministry level.

3.1 Hydropower Projects

i. Large Hydropower Projects

Out of 59000 MW indentified projects, we have tapped only 6500 MW over the past 65 years, and 1422 MW projects are in pipeline likely to be completed by June 2015. Here under is the list of some of the hydropower projects which are in pipeline and can be completed within next two years.

Table-I
Summary of Planned Hydle Addition Under Phase-I

Sr. No.	Name of Project	Capacity (MW)	Progress
1.	Jinnah Hydropower Project Mianwali	96	Ready for Commissioning
2.	Rehabilitation of Jabban Hydropower Malakand KPK	22	80%
3.	Golan Gol Chitral KPK	106	Feb, 2015
4.	Keyal Khawar Kohistan	122	10%
Total		**346**	

ii. Small Hydropower Projects

In addition to above there are about 250 MW of small hydropower projects of 9 MW and above capacity in Punjab, the list of which is enclosed at **Annexure-A**. Letter of Invitation (LOI) for these. projects were issued as early as the year 2007 bu t could not be commenced due to hindrances created by the concerned departments and are held up at various stages due to burocratic attitude of the concerned departments. If properly followed, and co-ordinated by Government of Punjab these projects can be completed in the next two years adding 250 MW of power in the system.

3.2 **Thermal and Wind Power Plants**

About 2550 MW of Thermal and Wind Power Plants are at various stages of implementation and can be completed within the next two years if supported and pushed by GoP removing bottle necks hindering their completion, and are listed hereunder:

Table-II

Summary of Planned Thermal/Wind Addition Under Phase-I

Sr. No.	Name of Project	Agency	Fuel	Capacity (MW)	Commissioning Date
Fiscal Year: 2013-14					
1	**Nandipur Power Project**	**GENCO**	Oil/Gas	425	Oct. 2013
2	**Guddu New CC**	**GENCO**	Gas	747	Dec. 2013
3	**Rehabilitation of GENCOS**	**GENCO**	Gas	245	Dec. 2013
4	**UCH-II**	**PPIB**	Gas	404	Dec. 2013
5	**Pakistan Wind Energy**	**AEDB**	Wind	5	Apr. 2014
6	**Hydropower Dawood**	**AEDB**	Wind	50	May. 2014
7	**Master Wind Enginer**	**AEDB**	Wind	50	Jun. 2014
8	**Chichoki Malian**	**GENCO**	RFO/Gas	525	Jun. 2015
10	**Yunus Energy**	**AEDB**	Wind	50	Jul. 2014
11	**Tenaga Generasi**	**AEDB**	Wind	50	Jul. 2014
Total				**2551 MW**	

4. PHASE-II: PROJECTS IN PIPELINE (YEAR 2015 TO 2018)

Under Phase-II, commencing from July 2015 and ending June 2018 about 10300 MW of power generation is planned to be added in the systems, the details of these projects are given in **Annexure-B**, the summary is as under:

Table-III

Sr. No.	Name of Project	Agency	Capacity (MW)
1	**Hydropower Projects**	**WAPDA**	3994
2	**Hydropower Projects**	**SHYDO**	510
3	**Hydropower Projects**	**PPIB**	247
4	**Hydropower Projects**	**IPP**	1490
Sub-Total (MW)			**6241**
4	**Wind Power Projects**	**AEDB**	2222
5	**Thermal Power**	**PPIB**	297
6	**Imported Coal**	**GENCO**	1200
7	**CHASHNUPP -IV**	**PAEC**	340
Sub-Total (MW)			**4059**
Total Phase-II (MW)			**10300**

Table-IV

Total Planned Generation Addition Under Phase-I & Phase-II

1.	Total Phase-I (MW)	2897
2.	Total Phase-II (MW)	10300
Total MW (Phase-I + Phase-II)		**13,197**

5. PRESENT STATUS OF POWER GENERATION AND DEMAND

The present status of installed and derated power in the WAPDA system is as under:

Table-V

Existing Installed Capacity and Derated Capacity

Sr. No.	Type of Power	Installed Capacity	Capability to Deliver	
			Summer	**Winter**
1	Major Hydro Units	6427	6714	3756
2	Small Hydro Units	89	56	41
3	GENCO-I	1024	840	840
4	GENCO-II	1690	1180	1180
5	GENCO-III	1921	1550	1550
6	GENCO-IV	150	30	30
7	IPPs + Nuclear	9142	8299	8299
Total (MW)		**20,443**	**18,669**	**15,696**

Our capability of power system to deliver from October to May is only 15696 MW while the system maximum demand is 17300 MW. Apparently there is 1604 MW of power shortage during peak load hours subject to availability of full generation.

Our present demand although suppressed, is 15000 MW while generation is 9500 MW, thus resulting in shortfall of 5500 MW. It varies on day to day basis depending on environmental, weather conditions and availability of water in dams for power generation.

Having a firm generation of 15696 MW, for all the times, the load shedding to the tune of 5500 MW is because of mismanagement ultimately resulting in non-payment to PSO & IPPs. **If GoP manages to make outstanding payments to PSO & IPPs load shedding will be reduced to half of its present value. It is assessed from data that if all IPPs, GENCO's, hydle generation and thermal generation are brought on the bus, load shedding in the forth coming months of summer will be nominal**.

6. ESTIMATING CAPACITY REQUIREMENT AND SHORT FALL

6.1 To estimate installed generation capacity requirement, we have to take into account derated value of thermal generation, spinning reserve, unit's outages, for maintenance and reduced generation due to low water level in winter season. To evaluate all these factors is a complex proposition, however based on our experience a figure of 20% if added to the power demand to workout installed capacity will be fairly reasonable for continuous power supply.

Similarly we have to add a load growth factor on the load demand which is estimated to be 8% per annum of the demand at present. By adding derating factor and a factor for load growth estimated requirement of installed capacity is worked out for the next five years as given in the table below:

6.2 According to above estimates WAPDA System will be needing 14300 MW of additional power over the next five years, which will result in proportionate change in GDP per Capita and will alter structure of the economy for fast industrial growth. Over the past five years, industrial and agriculture growth were all suppressed due to non availability of power in the country.

Over this period, according to data collected 13197 MW of power is planned to be added, which according to above estimates is short by about 1000 MW during the first two years.

7. RESERVATIONS AGAINST SMALL HYDROPOWER PROJECTS AND WIND MILLS

7.1 There are dozens of small hydropower projects and wind mills which are planned for commissioning to fulfill the power requirements from the year 2012 to 2017. As the formalities to be fulfilled of small projects are similar to that of a large project, therefore efforts put in for completion of small projects are almost equivalent.

Commissioning of these projects according to schedule even if hectically followed by the Govt. with Provinces, AJK, AEDB, NEPRA, PPIB, WAPDA, DISCO's, and SHYDO will remain doubtful and will not be manageable by the Federal Government. It is estimated that 50% of these projects may either be delayed or deferred during course of fulfilling formalities. It's a catch where new Govt. may be trapped and fail to fulfill the required generation gap between demand and supply even after lapse of their tenure.

Table-VI
Load Forecast From Year 2013-2018

Year	Power Demand at Beginning of year (MW)	Factor for load Growth @ 8% of Demand (MW)	Total Demand at end of the year (MW)	Derating Factor @ 20% of 2 (MW)	Total Demand (MW)	Available installed Capacity (MW)	Capacity to be Added (MW)	Planned capacity to be Added (MW)
1	**2**	**3**	**4 = 2+3**	**5**	**6 = 4+5**	**7**	**8 = 6-7**	**9**
2013-14	17300	1384	18684	3460	22144	20443	1701	1000
2014-15	18684	1495	20179	3737	23916	21120	2796	1500
2015-16	20179	1614	21793	4036	25829	22809	3020	2500
2016-17	21793	1743	23536	4359	27895	24634	3261	3300
2017-18	23536	1883	25419	4707	30126	26605	3521	3500
						Total	**14,299 (MW)**	**11,800 (MW)**

7.2 The induction of IPP's according to 1994 policy supported by the World Bank at a much higher generation cost compared to similar projects in other countries at that time will continue to hurt Pakistan economy for decades to come. The cost of generation of IPP's and GENCO's has jumped from Rs.6.00 per unit in 2009 to Rs.16.00 per unit in the year 2012 due to increase in Furnace Oil prices from Rs. 26,500 per metric ton to Rs. 74,000 per metric ton over the same period. So thermal generation on Furnace Oil be avoided in future. We intend to make the same strategic blunder by inducting 2500 MW of wind mills at the higher cost of 13 to 14 cents /unit while cost in other countries is almost the half. The higher cost of wind mills will give a blow to the dwindling economy of Pakistan by creating additional debt services as Government is facing today. We have to be wise enough now to select such resources of energy which are affordable, to keep the wheel of industry running and to support agriculture growth.

7.3 The question arises who is responsible for such a erratic planning by not taking into account the time factor and economic conditions. The answer is "Corruption", since there is no writ of the Government for over decades. Transparency international says "The continuing higher levels of corruption and poverty plaguing many of the under developed World's societies amount to an ongoing humanitarian disaster and slaughter of poor human beings and this calls for more focused and co-ordinated approach to strengthen the institutions for governance".

At top levels, corruption has given birth to foreign influence and relations with foreign agencies which has completely destroyed discipline, governance resulting in economic failure and needs to be controlled with iron hands to save the country.

8. SOLUTION TO THE PROBLEM

8.1 General

Everyone knows that there is no dearth of energy resources in Pakistan but still we are suffering from power shortage due to lack of our strategic planning, bad governance, and Will to do in national interest compounded with corrupt practices.

In my humble opinion, we can still overcome these problems if we divert our forces sincerely and dedicatingly in the right direction. Our objective is to produce energy at **affordable** prices within the time schedule to fill the energy gap.

Keeping in view the reservations shown in Para-7 (Page-7) following measures are suggested to improve the situation as promised by the incoming Government to the nation for which GoP has to take some daring and bold steps as Mr. Shahbaz Sharif did the miracle of completing Metro Bus Project in Lahore within one year against normal period of 3 years which will be remembered in history of Lahore for all times to come and if GoP did the work with the same spirit, goal will be achieved (InshaAllah).

8.2 Short Term Measures Under Phase-I

The total generation which is likely to be added in the system during Phase-I if completed as scheduled, amounts to 2550 MW against the requirement of 4500 MW. To meet with this shortage following steps are suggested:

8.2.1 Projects in Pipeline

a. Projects listed in Table-I & Table-II of this paper must be supported by GoP and pushed forward for early completion.

b. Nandipur and Chichoki Malian having capacity 925 MW are gas / oil based power stations. These power stations should be completed as per schedule and GoP must ensure supply of gas for these power stations.

c. Some of the small hydropower projects with capacity of about 50 MW or above scheduled for completion under Phase-II, already in pipeline may be pushed forward for early completion.

d. Feasibility study of six number thermal power plants of 50 MW each, based on indigenous coal are ready for implementation with PPIB. These power plants can be commissioned within next two years.

e. Handling of small projects is gigantic job but still success is expected and GoP may be in position to add at least 3000 MW of power on small hydle and gas within next 2 years.

8.2.2 Other Options

a. Highest priority shall be given to optimal use of gas, CNG for private vehicles other than public transport may be banned, and the gas so saved may be diverted for power generation.

b. Another option of affordable energy available is to import power from neighboring countries but it is a time consuming process, and chances of success to complete these projects in shorter period are very little.

8.3 Medium Term Measures Under Phase-II

8.3.1 Hydle power generation from "Run of River" is easy to construct with little environmental and resettlement problems compared to big reservoir dams but unfortunately GoP has kept "Run of River" big hydle generation at low priority. Based on "RoR hydle projects" a substantial power generation capacity of 25,000 MW is available in northern areas as per details enclosed at **Annexure-C**, which must be tapped on top priority and completed within next 3-4 years on war footing and BOOT basis. These projects may be assigned to investors with the condition of time frame. Following projects which are nearer to load centres and are relatively easier to construct are listed below:

Sr. No.	Project	Capacity (MW)	Remarks
1	DASU	4320	These projects are in process of detailed design. All activities at whatever stage they are, may be stopped and negotiated at GoP level on BOOT basis, otherwise these projects may take more than a decade for their completion due to non-availability of financing.
2	PATTAN	2800	
3	THAHKOT	2800	
Total		**9920**	

8.3.2 Tarbela Extension Project with a capacity of 1410 MW, for which financing has already been arranged from the World Bank and contract awarded should be given special attention and got completed on war footing basis by offering special incentives to the contractor for early completion.

8.3.3 Neelum-Jhelum hydropower project having generation capacity of 925 MW should also be paid special attention for completion within next three years otherwise, at present pace of progress it may take another half a decade for its completion. The problem of its interconnection also needs to be resolved on priority.

8.3.4 About 2000 MW of generation is also expected from small hydropower projects as listed at Annex-A under Phase-II, which may be expedited by pressurizing respective agencies / provinces.

8.3.5 Priority should be given to install power houses on indigenous coal.

8.3.6 Institutional reforms and reduction in system losses will also have great financial impact by virtue of savings and will be discussed separately under Part-II and Part-III of the paper.

8.3.7 **Other Resources**

i. Ther Coal has reserves of over 186 billion tons worth of 25 trillion dollars, which has the capacity to generate 60,000 MW of power for 100 years or more. At least two power houses of 600 MW each be initiated on BOOT basis.

ii. Due to limited gas resources in Pakistan, gas pipe line from Iran is inevitable, which is required for power generation and industry. GoP is requested to go ahead with this project, irrespective of U.S.A resistance.

iii. Wind energy is also a most potent source of energy. At least 15000 MW of proven energy is available but unfortunately AEDB has issued LOI / LOS to prospective investors at exorbitantly high rate of 15₵ to 16₵ per unit which is not affordable, and needs to investigated to bring the price down to 6-8₵ per unit as prevailing in the neighboring countries by facilitating the investors. The reasons for high prices in Pakistan are elaborated in my paper **"Solar Energy – Today and Tomorrow"**, which may help GoP in resolving this issue. It is suggested that all LOI / LOS issued may be renegotiated, and bids invited on ICB basis, which may reduce the cost to a reasonable level. This may also require change in Power Policy for Alternate Energy Sources, closing doors of negotiation.

8.4 **Measures for Immediate Relief**

Following steps are suggested for immediate relief:

8.4.1 **Utilization of IPP's to their Full Capacity**

Not to utilize the existing power generation based on furnace oil to its full capacity because of high cost is damaging to national economy. If industry is deprived of one unit of electricity it results in production loss of Rs.100/- in addition to unemployment of labour. Agriculture output is also badly affected if power supply to tube wells is curtailed at time of its need.

AEDB has fixed tariff of wind energy at US Cents 14-17 /unit while solar energy may cost between 18 cents – 23 cents /unit.

So there is no feasible and viable alternate readily available to fill the energy at affordable prices except to utilize the existing potential of IPP's to their full capacity as an immediate measure. The loss so incurred may be adjusted through tariff.

8.4.2 **Revenue Loss Adjustment through Tariff**

Tariff may be rationalized except for life line single phase consumers, to bridge the financing gap between cost of production and sale price. Only single phase domestic consumers should fall under the life line category and subsidy given for consumption upto 150 units only. Rest of units be charged at flat rate as may be decided by NEPRA eliminating different slabs of tariff. In addition following measures be taken which will substantially increase the revenue. All three phase consumers will pay all units consumed at the rationalized tariff rate without any subsidy.

i. A minimum charge of Rs. 350/- per month be levied on all single phase meter consumers if the consumption is less than Rs. 350/- per month.

ii. A minimum charge of Rs. 1500/- per month be levied to all three phase consumers if consumption is less than Rs. 1500/- per month.

iii. Tariff may be rationalized and a flat tariff introduced as may be decided by NEPRA eliminating all different slabs of tariff.

iv. Additional levy of 25% over the flat tariff may be imposed for domestic consumers using more than 2000 units.

By taking above steps revenue will substantially increase and will reduce financing gap and accumulation of circular debt without burdening the life line consumers.

8.4.3 **Solar Energy**

GoP should encourage and support installation of PV solar system (without batteries) in all private, semi Govt. and Government offices, business centres, shopping plazas, shops and housing societies etc. replacing diesel/petrol generators and UPS, which is a burden on Govt. economy, to make use of solar energy as a main source of power during day time and utility supply as a standby. This will reduce demand of power during sun hours, saving utility energy for peak load hours or when there is no sunshine.

In addition solar power tubewells run on submersible D.C motor is a viable and economical substitute for saving conventional energy. For more details please refer to my paper on **"Solar Energy – Today and Tomorrow"**.

GoP should support formers for installation of solar tubewells to boost crop production.

8.4.4 **Theft of Energy**

To control theft of energy special incentives be given to meter readers, meter inspectors as a percentage share to energy saved. I am of firm opinions that human nature can be changed with good environment and the employees involved in theft will switch over to honourable living when substantial amount is paid to them as honoraria every month. More details will be covered in Part-III of this paper **"System Losses and Recovery".**

8.4.5 **Restructuring**

Prior to disintegration of WAPDA there was only one post of grade 20 of Chairman in each Area Electricity Board, which has been replaced by about 12 posts of Grade 20 or 21 in each DISCO, resulting in heavy overhead expenditures. Cutting down by 50% to 70% of these Grade 20 or Grade 21 positions will not only result in substantial savings in Admin and non-development expenditure but also improve efficiency to great extent. More details in this context will be covered in Part-III of this paper **"Institutional Reforms"**.

8.4.6 **Conservation of Energy**

Conservation of energy is another option. Conventional Relief Measures are being listed hereunder, which may be implemented in true spirit:

a. Closing of Commercial and Shopping Centers during Peak Hours

All commercial and shopping centers except essential services such as restaurants, hotels, bakers etc. are to be closed before peak load hours. In lieu thereof they may be allowed to work on Sundays from 12 hours to 23 hours for convenience of customers. This step is expected to save energy of 300 MW.

b. Staggering of Holidays for Industry

Industries should stagger their holiday from

Monday to Saturday except Sunday on which day total industry should work.

Industry shares a load of 28% of total load demand. Staggering of industrial load over 6 days of the week will have a great impact in equalizing the load demand during the day time, in addition to chopping the peak load to some extent.

c. Adjustment of working shifts for Industry and Power Supply to Tubewells

In case of dedicated feeders supplying power to industry running on double shifts, are to be shutdown during peak load hours from 19 hours to 22 hours. Industry running on double shifts may adjust their timing accordingly. Similarly power supply to Tubewell through dedicated feeders is to be shutdown during peak load hours. This step is estimated to save 100 MW power without effecting industrial and agriculture output. However small industry must be supplied power from 9 AM to 5 PM without interruption.

d. Use of Energy Savers to replace incandescent Lamps

There are 12 million domestic consumers in WAPDA system, out of which 90% are poor and cannot afford to purchase Energy Savers to replace incandescent lamps, which needs to be promoted. GoP should consider to reduce price of Energy savers by withdrawing sales tax and import duties. Consideration may also be given to subsedise this item, as this step will result in huge saving of 1000 MW of power during peak load hours.

e. Functional Activities & Street Lights

All functional activities in Hotels and Restaurants must stop by 10 PM. Alternate street lights should be switched on during whole night.

f. Communication Through Media

Media be extensively used to educate people by emphasizing economical use of air conditioners, switching off unnecessary lights, use of Energy Savers etc. Domestic appliance such as irons, water pumps etc. should not be used during peak load hours.

g. Load Shedding Timings for Comfort

i. There should be no load shedding on 11 PM 5 AM at night for domestic consumers for their comfort to have a sleep without disturbance.

ii. There should be no load shedding for all industrial consumers from 9 AM to 5 PM for industrial growth and for employment of labour.

Annexure-C

List of Run of River, Hydle Project

S.No	Project	Capacity (MW)
1	Bunji - Astore	7100
2	Dasu - Kohistan	4320
3	Thakot - Battagram	2800
4	Patan - Kohistan	$ 2,800.00
5	Yulbo - Skardu	2800
6	Tungas - Skardu	2100
7	Dudhnial HPP - Neelum	960
8	Lower Palas Valley - Kohistan	665
9	Middle Spat Gah - Kohistan	501
10	Lower Spat Gah - Kohistan	496
11	Middle Palas Valley - Kohistan	398
12	Upper Spat Gah - Kohistan	277
13	Upper Palas Valley - Kohistan	157
14	Keyal Khwar - Khoistan	122
15	Phandar - Ghizar	80
16	Basho - Skardu	40
17	Harpo - Skardu	34.5
18	Trappi - Mansehra	30
Total		**25680.5**

Quotation

- Freedom is absolutely necessary for progress in science and the liberal arts.

Benedict Spinoza

- The tree of liberty grows only when watered by the blood of tyrants.

Bertrand de Barerer de Vieuzac

- Liberty without obedience is confusion, and obedience without liberty is slavery.

William Penn

- Justice is truth in action.

Benjamin Disraeli

- Delay in justice is injustice.

Walter Savage Landor

- What a cage is to the wild beast, law is to the selfish man.

Herbert Spencer

- A good and faithful judge prefers what is right to what is expedient.

Horace

- The real danger is not that computers will begin to think like men, but that men will begin to think like computers.

Sydney J. Harris

- A woman is as old as she looks before breakfast.

Edgar Waston Howe

- The four stages of man are infancy, childhood, adolescennce and obsolescence.

Al Linkletter

Analysis of Future Demand & Energy Sustainability for Pakistan

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Abstract

Pakistan is the 6th largest country in the world but as a whole it is an energy deficit country. Per capita energy generation is very low at a level of 581 KWh as against the world average per capita is 2,657 KWh. Growth of electricity demand has been uneven and demand of electricity in Financial Year (FY) 2010 remained more than 11% [1]. Pakistan is facing swear power shortfall. To match these requirements, country needs more energy. Keeping these requirements in mind, we find some solutions easy to implement in short term, lower in cast, sustainable and most importantly environment friendly. Our focus is on Renewable Energy Technologies (RETs) because these resources do not deplete with the passage of time and are not a serious burden on country's economy. To harness energy through RETs we discussed on geothermal, wind, waste, biomass, solar and hydropower.

1. Introduction

Lower-middle income developing countries like Pakistan are facing severe energy crisis. Economy of Pakistan is increasing at an average rate of 7 %(2004-2008). Due to this, energy demand has been increased drastically at the rate of 8.4 % per year. Power supply shortfall was reached up to 5,000 MW during peak summer season of 2009 **[1]**. Electric energy is being supplied through different resources including natural gas (47.5%), oil (30.5 %), hydropower (10.9 %), coal (9.2 %), LPG (0.7 %), and nuclear (1.2 %) **[1]**. Total capacity of electrical power generation of Pakistan is 19681 MW but actual available energy is far less than the nominated capacity because of poor maintenance and high line losses (30%). Private sector is providing 40% (7941 MW) of total energy requirement to cope with public sector in bridging the demand and supply gap. The backbone of country's economy is industry and agriculture, so more electric power is required to maintain the economy. In addition, if Pakistan's GDP remains as low as 3% then in 2020, it will require 37300 MW of electric power **[2]**. To meat this huge electric power requirement in future, country will have to produce electricity by all available resources.

Moreover, Pakistan is a net importer of energy and every year a heavy amount of its total budget is consumed in importing crude oil. In 2008, 12 billion dollar were spent on importing crude oil and this amount will exceed 27 billion dollar in 2018 **[1]**. Keeping the geographical location of Pakistan in mind, there are number of sources through which country can produce electricity; hydroelectric, natural gas, fuel oil, coal, biomass, geothermal, solar power, tidal waves, wind, nuclear and peat are most viable means of electric power production and most of them are environment friendly. Moreover some of these sources can provide power supply to the distant off-grid areas of the country. To harness all these renewable energy resources, Government of Pakistan has prepared Renewable Energy Policy to invite investors for Independent Power Projects (IPPs) and to build long-term projects **[3]**. Motivated by all these facts and objectives, we tried to find some solutions keeping the reliability, cost, and environmental effects in mind.

2. Geothermal Energy

The energy that is extracted form the core of the earth is known as geothermal energy. Geothermal energy is a renewable, sustainable, cost effective and environment friendly energy source. Major advantage of geothermal energy over other Renewable Energy Technologies (RETs) is that it can provide power to the grid throughout the year, independent of weather. About 24 different countries are using this energy to support the online grid stations. Typically this energy is only limited to the areas near to the edges of the tectonic plates. A global geotectonic plate (Indian plate) passes through Pakistan as shown in the map.

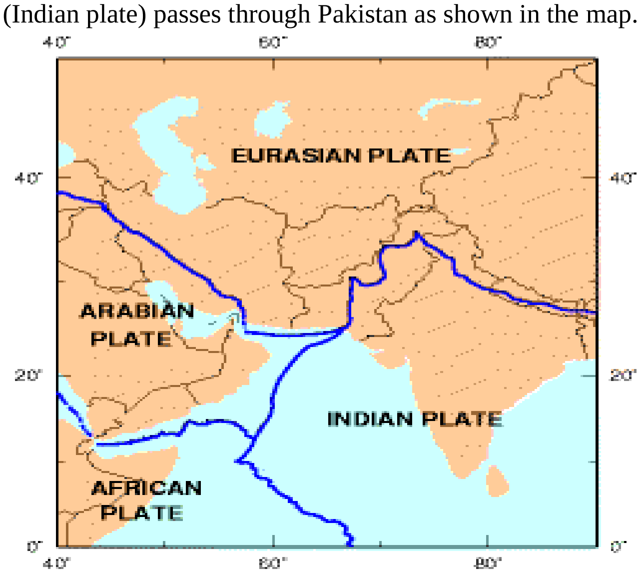

Figure 1: Edge of Indian plate [4]

Capital cost for this type of Renewable Energy Technology (RET) depends on the depth of the well, as depth of well increases cost of project increases exponentially **[5]**. For a typical 50 MW plant the total cost is $60 Million where drilling cost accounts for $50 Million of the total amount. Moreover, in a binary geothermal system emission of CO_2 is almost equal to 0% as compared to thermal energy **[6]**. Following nine phases are required to explore any location for development of geothermal field.

1. Identification of geothermal phenomena
2. Classification of geothermal fields with respect to production
3. To Locate the productive zones
4. To ascertain the useful geothermal location
5. To estimate the size of the source
6. To determine the heat content that a geothermal well will discharge
7. To compile the data for future monitoring
8. To assess the values of environmentally sensitive perimeters
9. To determine the characteristics that may cause problems during the development of field

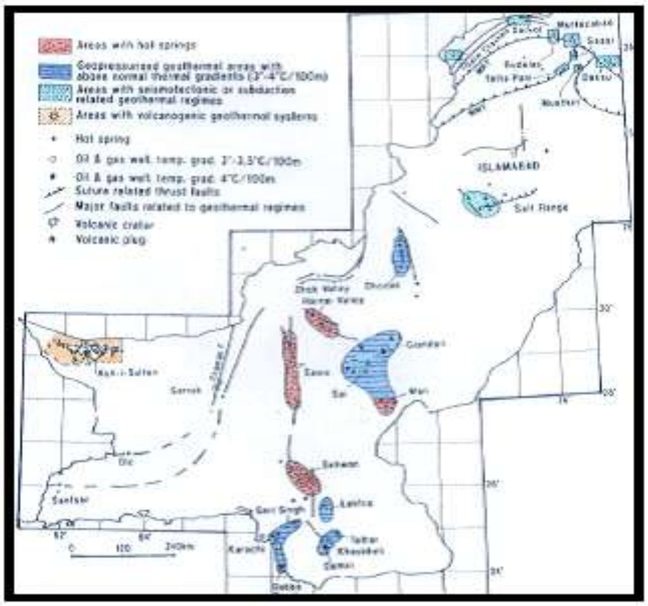

Figure 2: Geothermal Sources in Pakistan [5]

In Pakistan, first three steps have been undertaken on a limited scale and locations for extraction of geothermal energy have been identified as shown in the map but it requires more practical work for the development of a productive field **[5].**

3. Wind Energy

Mountains and coastal areas with high average and recurrent wind potential are the best option for the development of a wind farm. Length of coast in Pakistan is about 1,120 kilometer and population living in these areas is about 10 million **[7]**. According to the demand and production of electricity, Water and Power Development Authority (WAPDA) does not have capacity to supply electric energy to these areas. Moreover, cost to provide electricity to these areas is very high as compared to demand. In this situation, the only way to provide energy in the most of these areas is through wind generators. According to Pakistan Meteorological Department, average annual wind speed is above 3.5 m/sec in Karachi, Ormara, Jivani and Pasni**[7]**.

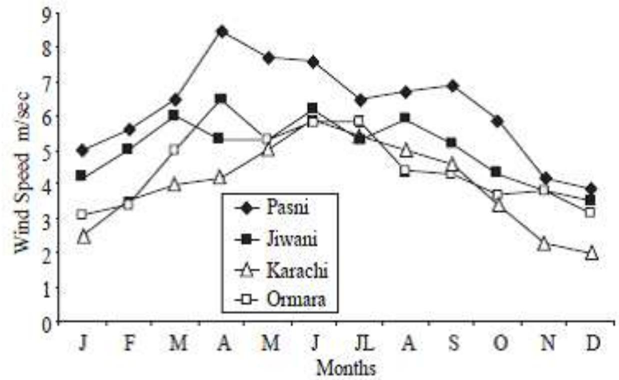

Figure 3:Monthly wind speed of four coastal Cities

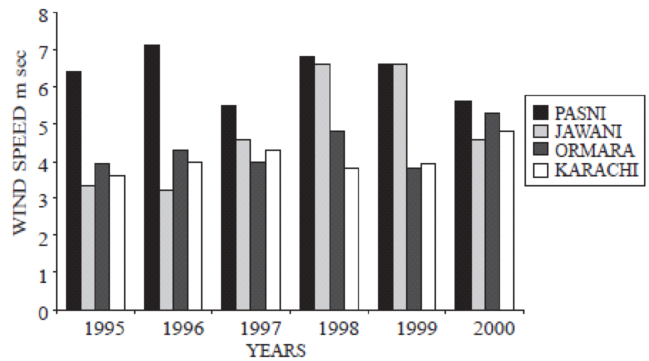

Figure 4:Yearly Wind speed of four coastal locations

Location	Maximum	Minimum	Annual Average
Karachi	5.9	2.0	3.5
Ormara	5.8	3.1	3.6
Jivani	6.2	3.5	5.0
Pasni	8.5	3.9	6.3

Table 1: Wind speed of four coastal locations in m/sec

Depending on the size of rotor, a wind turbine requires mutual separation of about 300 to 500 meters **[8]**. Therefore, a larger site is required for the development of a wind farm. Luckily, larger sites are available in Ormara, Jivani and Pasni. In this situation 4 KW generators can b used in all four locations but a 20 KW generator can only b used in Pasni and Jivani. There are numerous other places to develop wind farm but only in Jhampir (Southern Sindh), ZorluEnerji Pakistan Ltd. has developed first wind farm, which will be capable of 50 MW but only 6MWs are being produced in its first phase. Government and private land is available on a large scale and most of the land is barren. Access through sea and land is very easy, which is a key factor in the transportation of wind turbine generators and other mechanical equipment.

4. Energy from waste

4.1 Waste in Pakistan

In recent decade, waste-to-energy technologies have been developed to produce clean energy through the combustion of municipal solid waste in specially designed power plants equipped with the most modern pollution control equipment to clean emissions. Biomass and waste to energy plants are used not only to generate sufficient power but also used to cleanup the environment as well by conserving non-renewable fossil fuel resources and reducing the environmental impacts of trash disposal.

We produce different type of waste in our homes, offices, factories, farms and hospital etc. we want to reduce its amount and want to recycle to re-use that wasted material to avoid the pollution in environment.

Pakistan is a developing country and produces too much waste material, which gives birth to serious environmental problems. As the population increases, solid waste materials also increase. Pakistan has been producing 20,034,120 ton\year (urban areas are producing 9,409,700 ton\year and rural areas are producing 10,624,420 ton\year, add 3% for hazardous waste) solid waste on the basis of population 2004 [9]. Above calculationsshow that at present, solid waste generation in Pakistan is 54,888 tons\day and it can be estimated that solid waste in 2014 will be 71,018 tons per day [9].Most of the waste material is used in sanitary land filling, compositing and incineration in Pakistan. Crude open dumping is most popular method all over the Pakistan but this is adding to air pollution caused by the uncover damped waste itself. Waste material has been recycled to re-use this material.

4.2 Energy produced in different countries by waste

United Kingdom produced 28 million tones of solid waste material everyday which produced 1700 MW of energy. This is enough for 2.7 million of households and 11% of total energy needs of UK [10].

United state of America is producing 2500 MW of energy from the solid state of waste.

4.3 Energy produced by different material

* Material	**BTU per pound
Plastics	11,000 – 20,000
Rubber	10,900
Newspaper	8,000
Corrugated Boxes (paper)	7,000
Yard Wastes	3,000
Food Wastes	2,600
Average for MSW	4,500 – 4,800

Table 2: Energy produced from different materials

*Source: Council on Plastics and Packaging in the Environment **BTU stands for British Thermal Unit and is defined as the amount of heat required to raise the temperature of one pound of water one degree (Fahrenheit)

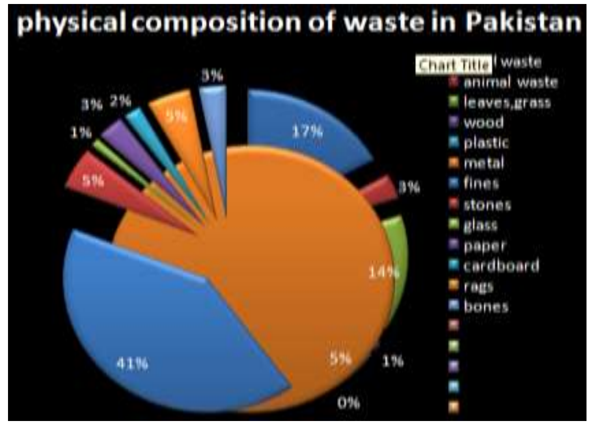

Figure 5: physical composition of solid waste in Pakistan [6]

Material	FSD	KRI	PWR	QTA
Plastic & rubber	4.80	6.40	3.10	8.20
Metals	0.20	0.75	0.30	6.20
Paper	2.10	4.10	2.10	2.20
Cardboard	1.60	2.40	1.90	1.30
Rags	5.20	8.40	4.30	5.10
Glass	1.30	1.50	1.50	1.50
Bones	2.96	3.60	1.70	2.60
Food waste	17.20	21.50	13.80	14.40
Animal waste	6.80	3.00	7.50	1.70
Leaves, grass etc	15.60	14.00	13.60	10.25
Wood	0.70	2.25	0.66	1.50
Fines	43.00	29.76	42.00	44.00
stones	4.60	3.50	7.30	7.80

Table 3: Physical waste composition of waste (% weight) in different cities [10]

4.4.Procedure of energy produced by waste material

1. Trucks dump trash ready for burning.
2. Crane lifts waste from pit up into furnace.
3. Trash is burned at high temperatures.
4. Heavy ash is collected and removed for disposal.
5. Heat from furnace makes steam in boiler.
6. Steam drives turbines and makes electricity.
7. Smoke and gases pass through scrubber to remove dangerous chemicals.
8. Fabric filter removes any leftover tiny ash particles.

9. Light ash is collected after scrubbing and filtering.

10. Remaining gases escape up smokestack.

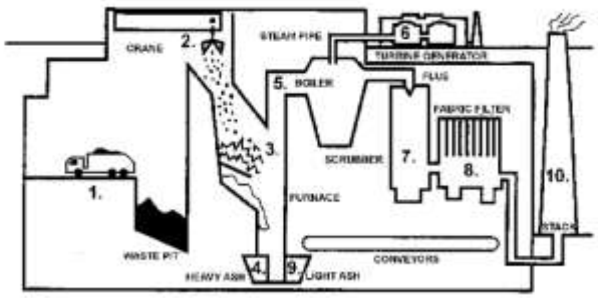

Figure 6:Process of producing waste energy

5. Biomass

There is large amount of crop residue produced by Pakistan every year. Pakistan is producing millions of tons of biomassannually the form of crops residue, rice husk, and wood mills waste, cotton processing waste and corn pith, which can be easily used in the production of gas. And ultimately this gas can be used to generate electricity.

5.1 Biomass Energy produced by different counties

Biomass energy technology has been used in different countries .biomass based technology cogeneration technology is well established in the pulp and paper industry, plywood industry as well as a number of agro-industries.For example, sugar mills and palm oil mills. India is the one of the largest developer of sugar mill based energy. There are 358MW has installed and 389MW is under installation. [11]

Brazil **is** the largest sugarcane producer in world. In Brazil there is full potential of condensing extracting steam turbine based cogeneration is estimated to be about 9000 MW (Walter, 2002); however, the industry appears to ready for investments in modern cogeneration. [11]

- **Types of biomass energy**

5.2.1.Bio fuels

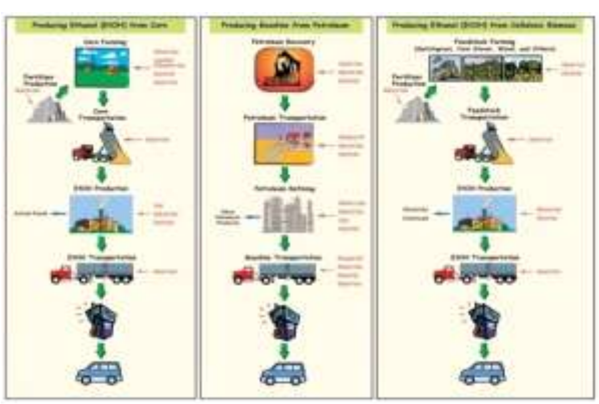

Figure 7: extracting of bio fuels

Crops are used in the production of fuels, which can be used for different purposes. This fuel can be used in the production of electricity which is effective and costless for the production of energy.

Country	fuel wood	Agri-residues	Animal dung	charcoal
China	**51.6**	**77.2**	**2.9**	**-**
India	**69.5**	**20.8**	**33.2**	**0.5**
Nepal	**3.1**	**1.2**	**0.8**	**-**
Pakistan	**17.5**	**7.3**	**8.5**	**-**
Philippines	**7.6**	**2.3**	**-**	**0.3**
Sri Lanka	**2.6**	**0.5**	**-**	**-**
Vietnam	**15.8**	**3.9**	**-**	**0.1**
total	**167.7**	**113.2**	**44.0**	**0.9**

Table 4: Estimated biomass saving potential (Million tones year-1) through efficiency improvements in theselected countries (Bhattacharya et al., 1999)

5.2.2. Crop's residue

Crop residue, rice husk, and wood mills waste, cotton processing waste and corn pith are used for the production of energy .we can burn the Crop's residue, rice husk, and wood mills waste, cotton processing waste and corn pith which is cost effective source of heat.From this heat we produced steam from water which rotates the turbine and electricity is produced. China is capable of 3,500 to 4,100 MW of biomass based capacity and India is capable of 1,400 to 1,700 MW [11].

The major crops and waste utilized in the Compendium's technology entries are as follows:

5.2.3.Types of Crop Waste

- **Coconut -** Fronds, husk, shell
- **Coffee -** Hull, husk, ground
- **Corn -** Cob, Stover, stalks, leaves
- **Cotton -** stalks
- **Nuts -** Hulls
- **Peanuts -** Shells
- **Rice -** Hull/husk, straw, stalks
- **Sugarcane -** Biogases
- **Agricultural Crops -** Mixed crops
- **Mixed type -** Agricultural crops and waste including non-organic wastes

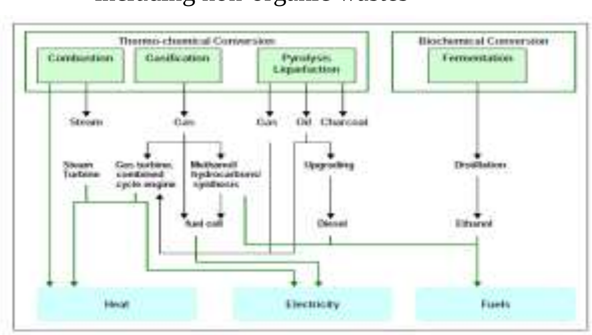

Figure 8:process of produce energy

6. Solar energy

Solar energy is the radiant light and heat from the sun. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties· **[12]**.In every second, sun produces 400×10^{24} watt energy. The earth receives 174 peta watts energy from solar radiation and 30% reflected back· **[13]** "Solar water splitting for hydrogen production with monolithic reactors". Solar Energy has been used in Pakistan for different application including stand alone rural telephone exchanges, repeater stations, highway emergency telephones, cathodic Protection, refrigeration for vaccine and medicines in the hospitals etc. The Public Health Department has installed many solar water pumps for drinking purposes in different parts of the country. Both Government and private sector are taking interest in the Popularization and up gradation of photovoltaic activities in the country. Solar energy helps to maintain green friendly environment.

In Pakistan average availability of sun is about 16 hours in a day. And 10 hours are required to produce enough energy from the sun for the normal use of a house. In Pakistan intensity of solar energy from sun is 1900-2200 kWh per square meter, which is enough to produce about 100,000 MWs of electricity [14].

Cost of the equipment for production of the solar energy in different amount,5 kW, 6kW cost show in the table.

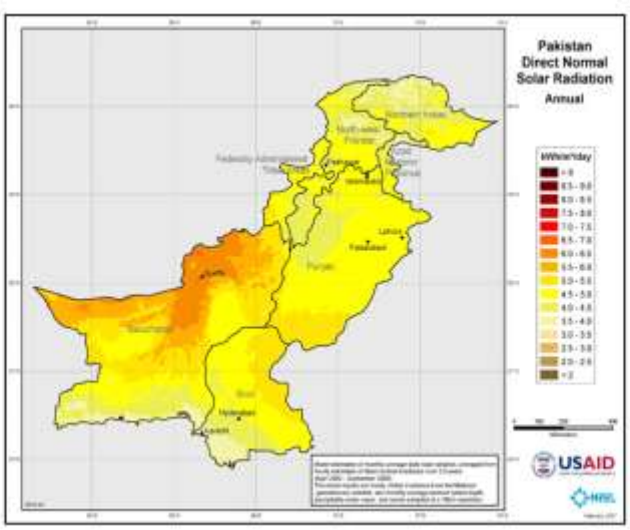

Figure 9: Solar energy map of Pakistan

Equipment	Price with 25 years warranty for solar panel	Price with 10 years warranty fpr solar panel
Total system cost	$28000	$14550
Tax/Duty/Shipping/Customs clearance fee	$1550	$1550
Installation	$750	$750
Total	$23100 + GST	$16850 + GST

Table 5: Solar Plans for 5.0 Kilo Watts

6.0 Kilo Watts Solar Plan		
Equipment	Price with 25 years warranty for solar panel	Price with 10 years warranty for solar panel
Total system cost	$25000	$17500
Tax/Duty/Shipping /Customs clearance fee	$1650	$1650
Installation	$850	$850
Total	$27500 + GST	$20,000 + GST

Table 6: Solar Plans for 6.0 Kilo Watts

6.1. Solar Thermal vs. Photovoltaic

Solar thermal technology is not same as the solar panel and photovoltaic energy. Solar thermal process concentrates on energy generation. The light from sun produces heat to run the heat engine that produces the electricity. Other photovoltaic directly produce the electricity from heat. The solar panel is used in daylight to produce the energy. In daylight storing electricity is not sufficient process compare with the heat storing process in day store heat and in night convert into electricity. Solar thermal more use to produce the energy in large scale. Australia and spain more energy produce from the solar thermal.Southern California Edison to use solar thermal technology to generate 245 MW of power.

7. Hydropower

Water is a prime mover for economy of any country because energy generated through water is cheaper than any other resource of energy production. Pakistan has high potential to generate energy through hydropower. For the selection of dam site, geographical location has paramount importance and it is time taking and money conserving process. In Pakistan different sites has been identified for the generation of electricity; up to 55,000 MW. Further more, this capacity can be increased up to 100,000 MW [15]. But installed capacity is 6443.56 ~ 6444 MW [16]. Main source of water is moon soon rains and melted glaciers in summer season. To make use of this water through out the year, Pakistan has to build large reservoirs .But currently Pakistan can store only 13% of annual flow of rivers [15].

According to hydrological survey in northern areas of Pakistan, there are considerable small streams and waterfalls having violent and strong flow for power production through micro-hydroelectric power plants (MHP). By using MHP plants up to 100 KW. It is estimated that 300 MW can be generated through perennial waterfalls [17]. From the irrigation canal, hydropower can be generated in the range of 1MW to 10MW. Especially in the province Punjab have network of irrigation canal at many places where low head and high discharge can produce to get maximum efficiency [17].

Channel Name	Discharge in feet power cube/seconds	Fall height	Power (MW)
Baloki-Sulamanki Link-1	12500	10.64	10.00
Baloki-Sulamanki Link-2	9000	17.86	10.72
Chenab-Jhelum	13527	41.70	40.00
Upper Chenab	16500	8.83	9.70
TP link Canal	12000	3.00	12.28

Table 7: Various channel locations, discharge, fall height, Power [19]

Pakistan have huge potential of water from tidal waves due to gravitational pull by moon. Indus delta extraction ispresent around 170 Km with creek system. In these creeks, water flow with very high velocity. By making the barrages on creeks we can produce electric power up to 1100KW [18] .

Conclusion

The existing scenario of renewable energy in Pakistan is presented in the paper with the help of available data and illustrations. It is clear from the information provided that except hydro power, contribution of other six renewable energy sectors is still to be harnessed in a proper way on national level to get something productive. Country has a large potential to produce electricity from wind and solar energy to provide electricity to distant areas with are far from the national grid system, where the structural development cost is too much as compared to the energy demand. However, more organized studies are required to asses the potential of the RETs in the country.

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Role of masses to Conserve Energy by Power Factor Improvement program and Formation of Govt- Policy

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Abstract

Who does not know that Power factor Improvement is one of the technique which helps in conservation of electrical energy alongwith number of other benefits. A number of different techniques can be used to improve the power factor. The main objective of this paper is to recommend the Govt official to declare a policy, after going through proper channel, at national level so that the benefits achieved by an engineering approach, such as power factor improvement, could be fruitful in reducing the burden on power system and hence reducing the severity of energy crisis in our country Pakistan.

This paper first of all present different studies performed by different organizations to authenticate the achievements in terms of energy conservation by power factor improvement. These results presented are result of practical study performed by WAPDA, ENERCON, Khawaja Electronics Pvt. Ltd. and the author himself in UET.

At the end recommendations will be presented to give a guide line to Govt. authorities to formulate a policy for industry to achive the benefits of quality improvement of products.

1. Introduction

The development of technology will take considerable time as it has many basic problems, technical as well as economical. Thus immediate solution lies in the conservation of energy. Investments made towards the conservation of energy not only lead to saving to the end user, but also helpful in reducing the burden of additional generation requirements. Conversation of energy has become the hot topic due to recent development in past few decades. [1]

It has now been established fact that investments made in the field of energy conversation yield in net overall saving alongwith other benefits. Residential clients being the largest consumers, has become the first and foremost target for the energy conversation program. We as a nation come to face with the reality of times and have to allocate the highest priority to energy conversation. Electrical energy is most convenient form of energy as it can be transmitted, distributed and utilized over a very large area. The one of the major consumption of electricity by the industrial sector, the high cost of electricity, and the costly effects of load shedding altogether provide strong basis for reducing the electricity consumption.

More than 40% of the electric load is domestic which uses a lot of low quality loads, with low power factor, such as tube lights, fans, motors etc.

Electric motors are large contributor to poor power factors because motors generally operate under light loads. Low power factors do not necessarily increase peak KVA demand because of the reduction in load. For example, the power factor of an electric motor is lowest when the motor is lightly loaded. This occurs when both its power draw and contribution to the electrical peak demand is the least. Energy can be conserved by reducing I^2R. [2]

This paper also deals with evaluation of energy conserved by power factor improvement of individual motor installed in U.E.T distribution system.

These motors are of different rating varying from 10HP to 80HP, used for Pumping drinking water and other installed at the disposal of dirty water.

Before installing the capacitor at each motor, Energy analysis was performed using a very sophisticated equipment, called Energy/harmonic Analyzer. Using Energy Analyzer exact rating in KVAR of the capacitors were determined. All the parameter such as current (I), Voltage (V), Kilowatts (KW), Kilo-Volt- Ampere Reactive (KVAR) and etc, are observed before and after the installation of capacitors. [2]

A similar study is also presented which was performed on WAPDA system, by Khawaja Electronic pvt. Ltd. Similarly ENERCON and WAPDA performed a study which has also been the part of this paper.

2. What is Power Factor?

Power Factor is the ratio of active power to the total power (apparent power).

$$Power\ Factor = \frac{Active\ Power}{Total\ Power} = \frac{P}{S}$$

S = Total Power of Generator (or used)
P = Power Consumed in the load (active power)
Q = Reactive power Stored in magnetic field.

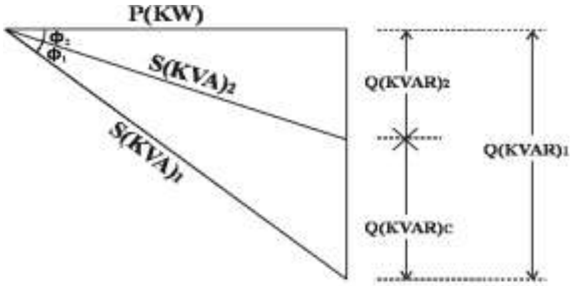
3. How to Improve the Power Factor?

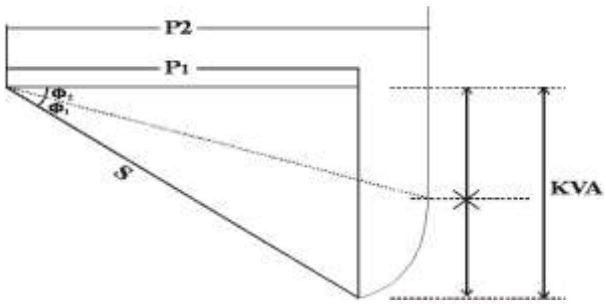
The power factor (P.F) can be improved by supplying KVAR to the loads (inductive type) and “Capacitor is source of KVARs”.

Therefore the power factor of connected load can be improved by installing power factor improvement capacitors/capacitor banks.[5]

3.1 KVA and KW Saving

Vectorial representation of P.F Improvement. 1&2 refer to before and after improvement of P.F. [5]





COSΦ2 = 0.9

KW (Saving) = P1 – P2

4. Different Methods of Power Factor Improvement.

Following are different methods of power factor improvement which can be implemented according to the type of load, such as constant variable, domestics, industrial and commercial.

a. Individual Power factor correction

b. Group Power factor correction

c. Central Power factor correction

C_1: Fixed Power Factor regulation.

C_2: Automatic Power Factor regulation.

C_3: Mixed Power Factor regulation.

When we are talking about the power factor improvement of distribution system of power supplying company (e.g WAPDA) the best solution is to connect capacitor with each and every inductive load, whether it is domestic, industrial or commercial (e.g. Fan. Washing machines, water pumps, motors tube wells and etc). But this solution is not feasible as it require lot of effort and lot of funds, to be implemented.

The only possible solution is to improve power factor by the C2 method, i.e. Automatic Power Factor correction/regulation. In the power system such as WAPDA it is quite uneconomical to install automatic power factor correction capacitor banks on each and every client's mains supply point.

Hence the next possible location of the power factor correction is the secondary side (L.T. Side) of the transformer. Automatic power factor regulation is the most suitable solution of power factor correction of highly variable loads (such as WAPDA'S consumer). It is based on capacitor bank divided in many group or units and controlled by electronic equipment, known as PFI regulator or relay.

The PFI relay continuously monitors the load variation and switches capacitor units on or off in order to keep the Power Factor at the desired level. The number of groups, which are called steps is to be chosen according to the type of load and its variation. With an accurate choice in the value of the reactive power for each step, a precise cosØ can be achieved. In order to design accurate steps or banks of capacitors regular monitoring of the load variation on each transformer of the power system is required. This variation can be observed from the stored data after regular intervals, with the help of computerized Energy Analyzer.[1]

This Energy Analyzer is capable of storing data such as, phase & line current, phase and line voltage, phase and line loads, KVAR supply and required to maintain certain fixed value of Power Factor etc.

The connections of the Analyzer on the transformer are shown in fig:1.

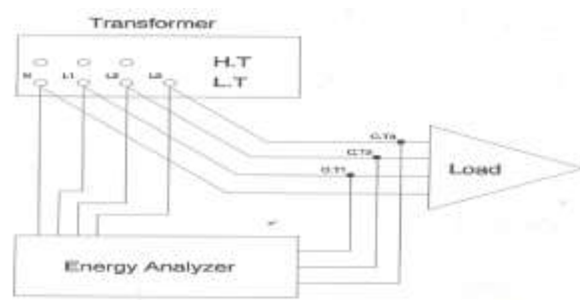


Figure:1 One line diagram of transformer and Energy Analyzer Connections.

The energy analyzer should be connected to each transformer for at least 24 hours, 2-days in summer and 2-days in winter (One working day and one holiday).

Although it is very much laborious and time consuming practice, however the results obtained are helpful in designing precise automatic Power Factor Improvement capacitor plant.

In order to save time and labour the transformer rating with similar type of load can be grouped and results obtained from one or two of such transformer (with same rating in KVA) in the power system. Hence different transformers will have different size of PFI plants.

The circuit diagrams, showing connections of the Energy Analyzer & PFI capacitor banks with the transformer, is shown in fig:2

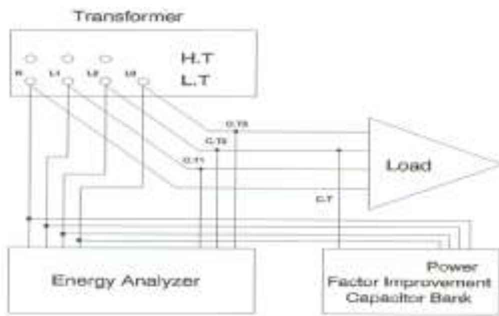


Figure:2 One line diagram showing connections for energy analyzer and PFI Capacitor Bank with the transformer.

5. ENERCON Project Report

In one of the paper, published in "The Electrical Engineering" Journal, "Power Factor improvement in industry" a project launched by ENERCON is described in detail. According to the paper motioned above, ENERCON (National Energy Conservation Centre) piloted the idea of energy conservation and system capacity release through power factor improvement of industry in Pakistan. [4]

The estimate made by the ENERCON projected the power factor improvement at 2,400 industrial units had the potential of relieving around 76MW of system capacity. [4]

The idea being highly novel and given the fact that the average pay back period of the amount invested is equipment and installation was of the order of few months.

6. WAPDA'S Study on PFI Program

According to WAPDA'S study on the Lahore region, regarding the improvement of Power factor to 0.95, following are the findings.[1]

Tariff	KVA Saving	KVAR Req.	Investment	Penalty Charged	Payable Period (month)
B-2	98918	139737	41921100	5448951	8
B-3	44865	79731	23919300	2156255	11
B-4	1708	4168	1250400	9432	133
C-1(a)	3	6	1800	44	41
C-1(b)	3660	4711	1413300	72631	19
C-2(a)	2206	4508	1352400	223912	6
C-2(b)	13083	20570	6171000	1404734	4
Total	164443	253431	76029300	9315959	8

A similar tariff wise abstract for power factor 0.95, for the region of Multan is as follow.[3]

Tariff	KVA Saving	KVAR Req.	Investment	Penalty Charged	Payable Period (month)
B-2	161527	211752	63527100	8962835	7
B-3	45365	60779	18233700	1632199	11
B-4	-	-	-	-	-
C-1(a)	-	-	-	-	-
C-1(b)	6358	7629	2288700	138128	17
C-2(a)	-	-	-	-	-
C-2(c)	2073	4224	1267200	208163	6
Total	215323	284384	85316700	10941325	8

Another study of tariff wise abstract for p.f. 0.95, for the region of Faisalabad is as follow.

Tariff	KVA Saving	KVAR Reqd.	Invest.	Penalty Charged	Payable Period (month)
B-2	80718	99929	29978700	6995970	4
B-3	25869	30812	9243600	766316	12
B-4	1796	4116	1234800	4704	263
C-1(a)	-	-	-	-	-
C-1(b)	915	1591	47730	85152	6
C-2(a)	09	139	41700	13283	3
C-2(c)	4983	8014	2404200	056043	4
Total	114350	144601	43380300	8521468	5

From these studies it is observed that a large amount of KVA saving can be obtained by improvement of power factor by installing capacitor in the power system. It is also observe that payback period, by installing PFI (Power Factor Improvement) plants.

7. Salient Features of the Power Factor Improvement Capacitor Banks

- PFI Capacitor bank should be designed at least after 24-hours computerized energy analysis on each location of installation.
- The automatic Power Factor improvement capacitor bank should be capable of controlling the requirement of KVARs to achieve Power Factor as close as unity.
- It should be compact and efficient.
- It should be protected against, over voltage, over-current over-temperature, switching surges and harmonics.
- It should be protection according to IEC standard IP55. i.e. for outdoor applications

8. Practical Demonstration Showing the Benefits of Power Factor Improvement

Fig:3 is demonstrating the benefits of power factors improvement before and after installation of PFI capacitor bank on the L.T. side of transformed. Energy Analysis with the help of Energy Analyzer are performed at three different location in WAPDA power system. Then from the result/data obtained, an accurate power factor Improvement Capacitor Banks were designed for these three locations. [1]

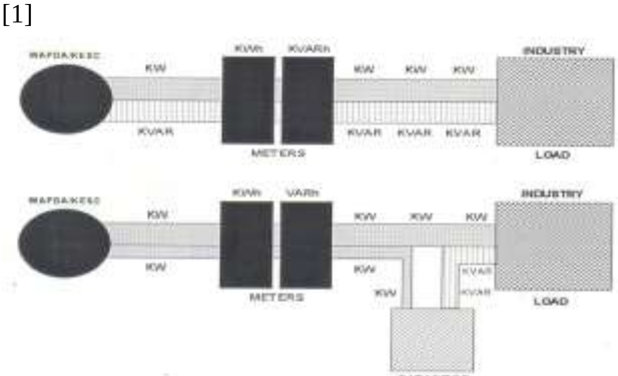


Figure:3 Benefits of Power Factor improvement before and after the installation of capacitor.

Fig:4, is showing the result of the practical demonstration of KEL (Khawaja Electrocnic Pvt. Ltd.) performed at one of the three different locations in the WAPDA power system, in the Shalimar Grid Station area.

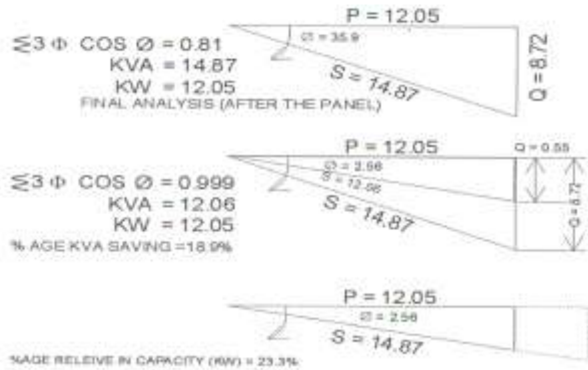


Figure:4 Power triangles for location No-1 (Shalimar Sub-Division Naseer Abad) on Transformer of 100KVA, before and after the power factor improvement.

9. Capacitors installation on Motors in UET

University of Engineeries & Technology (UET) is one of the renowned institution is Pakistan, consisting of widely spreaded Transmission and distribution system. Large number of transformer of different rating (25,50,100,200 and 400 KVA) are installed at different location is the power system. Power is fed from WAPDA (Water and Power system Development Authority) at one point. The power system of U.E.T is connected mostly with inductive loads, such as tube lights, fans and large motor for pumping drink water and for disposal stations. Power factor improvement technique is one of the methods for conservation of Energy. Electric motors installed at different location are selected to implement power factor improvement program by installation of capacitors. This paper includes the Energy conservation evaluation after power factor improvement.

Capacitors are normally installed near induction motors terminals and switched as a unit with the motor. When connected in this manner, the amount of KVAR should be limited to values that do not cause voltage rise at the motor due to self-excitation

When capacitors switched as a unit with the motors are located on the motor side of the overload relay, the line current actuating the relay will be lower in value than the motor current at all loads. When connecting capacitor in this manner, it is recommended that size of he overload relay be based on the decreased value of line current. Hence, a smaller relay will be necessary.

When capacitors are divided into a number of banks and located on the feeders close to the motor, the voltage increase under no load conditions will be smaller than if the capacitors would be located at one point on the main feeder. It means that it is not necessary to switch the capacitors with the motor to avoid over voltage at light load. In this case it is advisable to distribute the capacitors on the smaller feeders branching out from the main source and keep them continuously connected.[2]

As far as the economic consideration is concerned it is observed that maximum benefits can be obtained by installing the capacitors directly at the loads.

A careful analysis of all technical and economical aspects including load utility-rate schedules, released KVA, reduced losses, voltage improvement, prices of power factor correction devices based on previous consideration will decide the best selection and location of power factor improvement methods.

10. Energy Analysis of UET Motors

There are various aspects, which are to be taken into the consideration while Performing energy analysis of the distribution system of U.E.T. Some of which are as under;

1. Analysis of various motors installed at the pumping stations.
2. Analysis of the motors before and after Capacitor installation.

10.1 Analysis of the motor

For the comprehensive and complete analysis of motors installed at the pumping stations of the UET, energy analyzer equipment was used. In the analysis procedure, energy analyzer was attached with the motor installed while keeping the load on the motor ON and complete set of data was obtained showing the frequency, current in each phase, line current, line voltage, power factor, active power, apparent power, reactive power, distortion factor, KWH, KVARH etc.[2]

This analysis was performed to calculate what ratings of capacitors are required for the power factor improvement in addition to other outputs. The complete set of analysis, which was done with the energy analyzer of all the motors installed in the pumping station, has been attached in the annexure. Final analysis after the installation of the required capacitors done again to check the power factor. It was observed that power factor of the motors has been increased remarkably moreover other factor like voltage increase, current drawn decreases, decrease of KVA rating etc. Fig:1,2 Shows the set-up of Energy Analysis Performed on the motor, the same setup is used on each motor. Results of he analysis before and after the installation of capacitors have been shown in the table 1,2,3,4 and 5at the end.

11. Comparison of Motor Parameters before and After Installation of Capacitors

Energy Analyzer is Elcontrol Brand, (VIP model, made in Italy) is being used to perform the analysis of motors. The analysis of Five motors installed at different locations in UET is Presented in table 1,2,3,4 and 5.

12. Evaluation Showing Effect of Improvement in Power Factor To Reduce Per Unit Cost

The Fig:5 shows the connection of tube light under steady state condition alongwith the installation of capacitor to improve the power factor.

Table 6 and Table 7 show the benefits of power factor improvement with installation of capacitor across chokes of different brands available, SCHWABE and HELVAR, respectively.

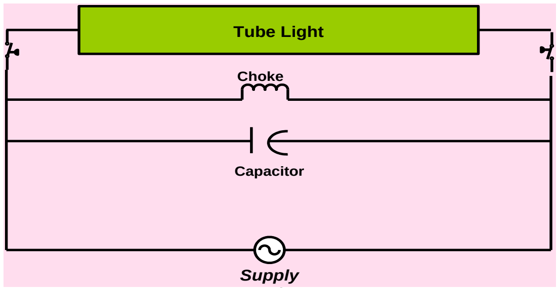


Figure:5 Installataion of capacitor on tube lights.

Table: 6 Schwabe choke parameters

SCHWABE	
Inductance: 0.756H	
Without Capacitor	**With Capacitor 3.5µF+-5%**
Voltage: 225 VAC	Voltage: 225 VAC
Ampere: 465 mA	Ampere: 217 mA
Wattage:46 W	Wattage: 46W
Power Factor: 0.57	Power Factor: 0.95

Table: 7 Helvar Choke parameter

HELVAR	
Inductance: 0.0.91H	
Without Capacitor	**With Capacitor 3.5µF+-5%**
Voltage: 225 VAC	Voltage: 225 VAC
Ampere: 352 mA	Ampere: 208 mA
Wattage:44 W	Wattage: 44W
Power Factor: 0.56	Power Factor: 0.95

It is recommeded that all clients using Tube-light must install capacitor with it to achieve the benefits of power factor Improvement.

13. Government Policy for Electric Equipment Manufacturing Industry

We have a large number of industrial units in Pakistan. Few of the large and renowned manufacture, of motors, refrigerator, Air condition, washing machines and many other household produce equipment with good quality.

When we say quality means equipment with acceptable Power Factor, i.e. 0.9 and minimum acceptable harmonic contents i.e. THD less than 10%. But we have large number of cottage industry manufacturing low quality household equipment such as choke of lights, small motor, washing machine etc., etc.

Now-a-day Power Quality is one of the major issue of the world. The quality issue are too many but we have two mains issues to be addressed at the moment;

1- Power Factor
2- Harmonics

Our Govt. Should take steps towards formation of policy at the national level for all manufacturing units in Pakistan to meet the minimum Power Quality standards, i.e Power factor not less than 0.9 and harmonic contents in voltage and current (THD) less than 10%.

Any manufacturing unit found manufacturing their equipment beyond the acceptable limits should be penalized and should be charge for this act of creating problem in the power system. Although the cost of the equipment will be little more but the benefits are too high.

14. Overall Results of Practical Studies

In this research work, the main emphasis is placed in evaluation of Energy savings by Power Factor Improvement.

This Power factor improvement was achieved by installing Capacitor on the motor installed at different locations in UET and P.F.I plants at different locations in WAPDA Power System.

Initially, each of the motor was connected with Energy Analyzer and different Parameter were measured, such as Current, Voltage, Power (KW, KVA, KVAR) and power factor. From this energy Analyzer the rating of the Capacitor required to improve the Power factor from existing value to a value more than 0.90, is determined.

After installing the Capacitor across the motor, all Parameter, e.g., current, voltage, Power, (KW, KVA, KVAR) are once again measured. It has been observed that by installing capacitors across the motors, the following parameters were found reduced;

- Current (A)
- Power (KW, KVA)

The following parameter were found increased by improving power factors;

- Power Factor (Cosϕ)
- Voltage (V)

It has been observed that the energy conserved by power factor improvement entirety depends on the existing power factor of the motor and quality of the material used in manufacturing of the motor.

The maximum saving in current as results from different motor is 41.56 %. This result is obtained from Disposal plant motor, where the power factor was improved from a value of 0.59 to 0.976.

Power Factor improvement program can only be efficient if the power factor improvement capacity banks are designed accurately and located at an appropriate location.

The Power Factor improvement of a Power system from a power factor of 0.8 to 0.99 relieved the capacity as much as 23.3% (in KW) AND 18.9% (In KVA) based on study performed on WAPDA system. Power Factor improvement hence results in the following benefits.

1- Capacity Relieve.

2- Reduction in Energy losses of transformer.

3- Reduction in Energy loss of transmission line.

4- More efficient utilization of power system generators, cables, lines and other switch gear.

Broadly speaking there are two main portions of the loads in any power system which consume power, one is industrial sector and other is residential sector.

Industry is imposed low Power factor penalty by supply authority, therefore most of the clients are bound to improve their Power Factor by installation of Capacitor. But no body bother about power factor improvement of equipment installed at our residences as no penalty is imposed on residential Tariff of WAPDA.

It is not possible to impose low power factor penalty on residential clients.

It is therefore recommended that the Govt. of Pakistan must process a policy through proper channel to formulate a policy to be enforced on the manufactures of house hold gerdgets, such as fans, pumps, small motors, chokes energy sarvers, etc. etc. This policy will force the manufactures to produce the products with improved quality (i.e power factor more than 0.9 and THD less than 10%).

It is also recommended that all the Energy saver available in the market should be checked for their power factor and harmonic contents before installation. The one with power factor close to 0.9 and THD less than 10% must b e preferred.

15. Overall Conclusions

It is not possible to impose low power factor penalty to residential clients and they are more than 40% of the overall consumption of power in any power system. It is therefore concluded that all the equipment installed at the residential clients premises should be fitted with capacitor as per requirement depending on their rating.

It is also concluded that Government should declare a policy for the electrical equipment manufacturing industry to produce quality products with power factor not less than 0.9 and Harmonic contents, THD not more than 10%. Any manufacturer violating this low should be penalized.

By implementation of the above recommendation a large amount of Energy will be conserved and we will come to great extent, out of the Energy crisis in future.

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Note: It is to inform that the above paper has also been Published.

Prof. Dr. Suhail A. Qureshi, Farhan Mahmood, **"Role of masses of Conserve Energy by Power Factor Improvement program and Formation of Govt-Policy",** Presented in UCP IEEEP Multi Topic Conference, May-27, 2009. Lahore. Pakistan.

Table 1. Showing Computerized energy Analysis of Annexi Block Motor

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active Power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	68.7	59.4	367.1	373.0	0.881	0.991	14.53	12.76	13.35	12.64	6.88	1.75
1.2	72.6	62.8	376.7	376.2	0.886	0.983	15.42	13.35	13.83	13.33	7.72	2.49
1.3	71.0	61.8	375.3	375.3	0.880	0.989	15.31	13.50	12.80	13.35	7.26	2.01
Mean	70.76	61.32	368.3	374.8	0.876	0.988						
Total							45.26	39.81	39.63	39.32	21.86	6.25

Table 2. Showing Computerized Energy Analysis of RT House Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	47.3	35.11	387.4	389.2	0.725	0.981	10.64	7.93	7.71	7.78	7.73	1.54
1.2	49.9	36.52	387.0	388.8	0.778	0.995	10.43	8.16	8.11	8.12	6.56	0.81
1.3	47.91	38.29	389.4	390.0	0.776	0.990	11.14	8.610	8.64	8.54	7.03	1.24
Mean	47.91	36.60	387.9	389.6	0.760	0.989						
Total							32.19	24.70	24.46	24.44	20.92	3.59

Table 3. Showing Computerized Energy Analysis of Colony Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Befor	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	84.1	70.5	382.5	387.9	0.848	0.998	18.65	15.83	15.81	15.64	9.89	2.45
1.2	81.5	70.5	382.5	387.9	0.884	0.996	17.92	15.74	15.84	15.68	8.38	1.37
1.3	92.7	79.0	384.2	390.0	0.873	0.992	20.56	17.74	17.94	17.60	10.04	2.22
Mean	86.05	73.29	383.1	388.3	0.868	0.989						
Total							57.10	49.29	49.59	48.92	28.31	6.04

Table 4. Showing Computerized Energy Analysis of Main Block Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power(KVA)		Active power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	53.4	47.0	378.0	379.5	0.867	0.981	11.62	10.28	10.07	10.08	5.80	2.02
1.2	59.9	52.0	377.4	379.1	0.856	0.973	13.11	11.41	11.22	11.10	6.78	2.64
1.3	6.9	50.2	376.3	378.5	0.872	0.985	12.34	10.80	10.76	10.80	6.04	1.87
Mean	59.74	49.72	377.2	379.0	0.865	0.980						
Total							37.07	32.64	32.05	31.98	18.62	6.53

Table:5 Showing Computerized Energy Analysis of Disposal Plant Motor.

Phase	Current (Amps)		Voltage (Volts)		P.F (CosΦ)		Apparent power (KVA)		Active power (KW)		Reactive Power (KVAR)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1.1	8.52	4.96	373.4	375.7	0.616	0.987	1.831	1.073	1.127	1.059	1.443	0.173
1.2	9.47	5.73	373.3	375.9	0.589	0.973	2.041	1.246	1.206	1.212	1.655	0.289
1.3	8.83	4.99	372.0	374.9	0.566	0.968	1.896	1.081	1.073	1.046	1.563	0.273
Mean	8.938	5.223	372.9	375.5	0.590	0.976						
Total							5.773	3.397	3.406	3.317	4.661	0.735

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