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Editorial

Dear members,

Assalam-mo-Alycum,

Here is another volume of our research journal. It is comprising of number of papers and reports on variety of issues. One of the paper is from Australia and rest of the papers and reports are from our authors from Pakistan.

Of course there is delay in publication of this particular issue because of a number of multiple reasons. One of the major reasons for delay is because of the delay in receiving papers from our authors and their referees. The other reason is perhaps our journal is not on the approved list of HEC. We are trying to get the approval of our journal from HEC after getting the ISBN number from France.

We will try our best to publish the next volume of our journal in time, Inshaa-Allah.

We request all our members to sent us research publications at their earliest.

Thanking you.

The Editor

Design of Underground Fire Detection System

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Abstract-

Fire has long been a concern for underground mine workers. A mine fire can occur at any time and may result in a partial or total evacuation of all mining personnel and the loss of lives. Since fire can grow rapidly, time is the critical element. Prompt detection, timely and accurate warnings to those potentially affected, and a proficient response by underground miners can have a tremendous impact on the social and economic consequences on an underground fire.

The objective of this paper is to design an underground fire detection system that can provide an underground sub-station or electrical network with a very early fire detection system ensuring a high level of protection against all types of fires. The implementation of this product integrates several technologies to enhance its operation as a fire detection network and offers users convenience driven functions. The design incorporates IR and RF communications, to effectively network the detection system and allows remote control over the device. It also incorporates a main converted DC supply, together with operational capabilities from existing fire detection methodologies.

The Underground Fire Detection System (UFDS) offers an alternative. The UFDS utilizes both a smoke detector and a temperature sensor. When the user is preparing to perform an activity that could potentially result in a false alarm they can use their chosen infra-red device to turn off the smoke detector. While the smoke detector is inactive the temperature sensor remains active. This system will also address an alarm system that will be relatively low cost, fast, reliable, and will ultimately help save lives. It is intended to aid the safety measures already in place and to ensure the underground miners are working in an environment that is safe.

I Introduction

There has been significant progress over the years in reducing the number of lives lost due to mine fires. Today, there is a better scientific understanding of fire risk within the mining community and ways to minimize risk when a fire does occur. This is mostly attributed to improved fire resistant materials, better detection systems, fire suppression systems, and a more skilled workforce. Research conduced over a long period has led to a dramatic increase in performance especially within the detection of a fire. At the same time, due to nature and characteristics of mining, fire is an unpredictable certainty.

Small fires will always occur in underground mines, however, it is the fires that transpire close to transformers, substations and switch-gear that are of more importance. Fire detection technology tends not to be as effective as underground personnel for detecting fires, although the fraction of fires discovered by monitors has increased over the years. Moreover, personnel are mobile and can survey a larger area than fixed detectors, and possess a sensitive detector the nose. However, as mines become more automated there are fewer personnel working underground than in previous years.

Electricity is one of the important causes of fires in the mining industry. It may originate from short circuiting, overheating of machines, electrical bulbs, cable bursting and such other causes. It is therefore essential to have a system that will detect any disturbance in an electrical area.

To understand the gravity of this issue, Fig. 1 demonstrates the seriousness of underground incidents and the percentage at which these incidents occur. It illustrates the fact that underground fires again play a significant role in major incidents, being at 15% of total incidents in a year. This places an emphasis on the absolute importance to install fire detection systems in underground substations in order to reduce the severity of these statistics and also safeguard underground miners. As indicated on the pie graph, 30 % of all incidents include geo technical hazards including rock-falls and other falling objects. Explosions and fires have a respective 20% and 15% chance of occurrence in a given year period. These figures are sufficiently indicative of the need to improve current safety measures with regards to fire safety in a mine [1].

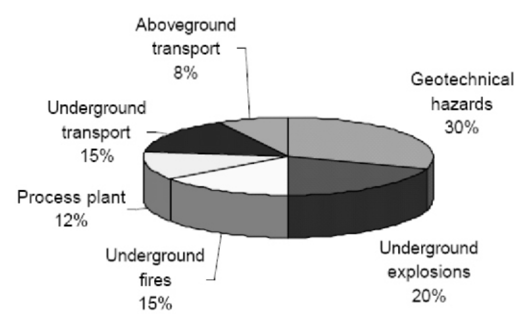

Figure 1: Percentage of Accidents that Occur in a Mine.

Such limitations on current designs include the incapacity of the power supply to provide continuous and un-interrupted long term supply, the incapacity of the alarm warning system to successfully notify an individual of a fire's presence, to incorporate a sensor that will be able to distinguish between the harsh and dusty mine dust, passing vehicle diesel fumes and determine the level of carbon monoxide, and the production of spurious alarms. These limitations introduce the human element to the equation.

Many fire detection devices are powered by a DC source such as a standard alkaline battery. At some stage the batteries supply shall diminish. If there is no on-board warning device or designated individuals to inspect these devices and to maintain a regular maintenance check of these detectors then the devices are in a state of in-operation and, misleadingly, shall not activate an alarm when a fire is actually present. Other situations may arise when an alarm has activated and an individual removes the battery to silence the alarm; or when the underground power system has tripped, mining personnel may forget to reset the system. These factors are crucial and must not be taken lightly.

Another life threatening situation may occur where the mining personnel may be working next to a switch-room or transformer and are using machinery that generates a loud audible noise. What if a fire was to break out or if one of the high voltage cables were to start smouldering? The alarm system may operate but depending on the situation of the fire detection module relative to the working party, he/she may not become aware of the fires presence. Although not commonplace, the scenarios outlined above do occur and any such fire detection systems that can guard against such disasters correctly could be labelled a global fire detection system.

The Underground Fire Detection System (UFDS) must improve on current fire detection technology. It must be able to detect fires with accuracy and repeatability. It can improve upon current fire detection technology by detecting a fire in its early stages and disregarding false alarms. The sensors have to perform to the level outlined by Mine Standards Australian [2]. The UFDS will address each of the scenarios discussed above by incorporating several design technologies and user-friendly functions to achieve operational longevity and accuracy.

The UFDS integrates two wireless communication systems to effectively network each individual unit and access functions such as shutdown mode and an Auxiliary / Emergency lighting system. Three stages of incipient smoke (alert, action, and fire) will be indicated on the dedicated PC console. Once a warning has been activated the fire alarm program will be able to indicate the percentage of smoke being detected and the origin of the smoke within the mine.

A controller unit is required that can interpret infra-red (IR) signals and, if required, disable the smoke detector for a specific period of time. This may be required when underground explosions occur and high levels of dust and ammonia are flushed throughout the mines main drives. Disabling of the smoke detector during this time allows the smoke particles to disperse and thus prevent unnecessary fire preventative steps in the advent of false alarm. If more time is required the IR device can be used to start the disable time period again.

The product will run of mains power but requires a reliable and effective backup power supply to accommodate power failures. The system also utilizes the detection qualities of two different fire detection sensors. This allows for the UFDS to be installed in areas of the dwelling that produce harmless smoke without initiating false alarms. The system also allows the operator to act appropriately and direct mining personnel to check out the status of the location.

This paper gives an overview on the particular system that will be used to combat an underground fire. The fire alarm system design will be constructed to comply with the mines safety standards and the mines individual communication and electrical layout. The main purpose of this paper is to design a fire detection system that will detect an underground mine fire at the earliest possible stage and notify personnel on the surface of the mine instantaneously.

It is hoped that further detailed studies and possible implementation of this design be incorporated in fire detection systems to further enhance the safety measures already in place in underground electrical networks. All the external factors are combined that arise in the mines ore body and on an everyday work shift. Using this data, a sensor can be calibrated to overcome all these potential problems. A complete design of the fire detection system will be devised including the telecommunications that will allow the overall system to be continual monitored by an operator on the surface of the mine. Overall, this paper hopes to increase the safety standards of the mining industry through improved understanding of mine fires and utilizing the very latest in fire detection technology.

II GENERAL SPECIFICATIONS

It is important that the product is durable. Australian Standards specify that in the case of an audible alarm design, the sound exhibited must be louder than 75dBA [3]. The construction of the detector must ensure that it is impossible to remove a detachable heat-sensitive element from an installed device without generating an alarm signal. Normal handling during installation and servicing must not affect the products performance.

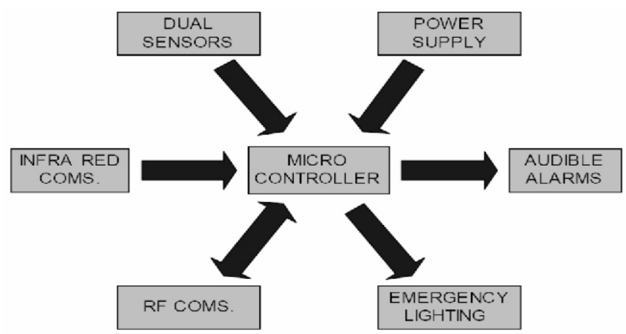

Figure 2: Hardware Block Diagram Layout

III Technical Specifications

For the Underground fire detection system to provide means of protection against the situations described in the introduction it is first necessary to define a set of operational specifications that the design must adhere to. These operational specifications provide a systematic solution to the problems of inconsistent and substandard fire detection.

A. Operational Specifications

The UFDS shall operate to the following operational specifications:

* It is required to perform to the same level of accuracy that current automated fire detection and alarm systems are capable of, with some improvements upon these technologies [3].
* It should incorporate the ability to operate in environments were other alarms are removed from because of their vulnerability to false alarms. This will protect previously vulnerable areas within the underground electrical network. Thus it requires the ability to achieve improved levels of discretion regarding genuine fire threats and false alarms.
* Offer a high degree of detection ability in the presence of both smoldering and high heat.
* In a state where the fire detection module is not in the presence of a fire the system shall provide a means of controlling a system of Auxiliary Lighting.
* The system shall provide a method of detection that allows it to be installed in situations where 'innocent smoke' is produced (passing vehicles thus producing low levels of carbon monoxide must be included in the pre-set threshold of the detecting system) without activating false alarms. The system shall also provide a high degree of protection from fires whilst operating in these areas.
* In the presence of a detected fire the UFDS shall provide a means of activating all the fire detection modules installed in the mines lease. Conversely, whilst operating in standby mode the UFDS alarm mechanisms must be able to be triggered by external means.
* When installed the UFDS must be powered by such a means that shall provide a continuous supply without large and un-identifiable down times.
* The UFDS shall provide a means of disabling the onboard warning mechanisms for a set period of time.

A failsafe measure, such that the danger environment is not left unguarded at any time, is required. There is a potential risk that an individual will disable the smoke detector and then leave the area unattended. For example, if an individual is working in the switch-room and using a power tool that will ultimately generate a percentage of carbon monoxide that will subsequently trigger the alarm. Therefore the UFDS should be disabled to prevent a false alarm. However, if they are then distracted by an unforeseen circumstance the alarm will remain offline and thus increase the chance of a fire near a sub-station being undetected. The failsafe measure must also be impervious to false alarms, otherwise the product becomes redundant

B. Minimum Cost

The possibility of this design being a marketable product, it is in the designers/manufacturers best interest to produce a design that will operate to specifications whilst keeping the cost of manufacture to a minimum. The design shall be a tradeoff between operating efficiency and cost.

C. Stability and Reliability

The UFDS is designed to be capable of functioning within a number of environments. As a result there is no way to determine at what time or what exact circumstances a fire is likely to occur. The UFDS must be vigilant without exception from the time it is installed until that section of the mine is not being used anymore or decommissioned. An unreliable fire safety device could result in terrible consequences for the miners and serious legal ramifications for the producers. The UFDS must possess flawless accuracy and repeatability.

D. Hardware

It is imperative that the UFDS have a reliable power source. As a result the UFDS requires transformer circuitry to convert 240V AC mains power to DC power that is at a level that can be used to power certain circuitry effectively. It is also important that the transformer does not produce unacceptable amounts of heat. This would adversely affect the accuracy of the heat sensor and potentially create more false alarms than the design saves.

Obviously, the UFDS must be powered at all times and cannot afford to be disabled by a power outage. Therefore the power supply chosen must be able to provide a continuous supply to the fire detection module. It must be able to convert the incoming 240V AC active to neutral supply down to a highly efficient regulated 5V DC output to supply all low voltage circuitry.

E. Output Voltage Tolerance

Since the power supply is needed to supply a relatively low voltage DC output to voltage sensitive equipment the output tolerance or ripple must be kept to a minimum. In researching the possible alternatives a number of alternatives became apparent. The possible alternatives were globally broken down into two groups.

Rectified mains, converted down to a relative DC level, or

Rectify the incoming mains; implement a Switched Mode Power Supply (SMPS) integrated circuit.

F. Infrared Module

The infrared module supplies two functions for the operational specifications. The infrared network allows the system to control the operation of the auxiliary lighting system and also provide the necessary timed shutdown function. This system shall be able to decode the relevant encoded binary signals up to a transmission distance of 10 meters [4].

G. Radio Frequency Network

The radio frequency (RF) module provides the wireless network functions for the product. Wireless media will be implemented as it alleviates the need for a hardwired network thus reducing the cost of installation. The RF network must be able to encode and decode relevant RF signals and must be able to transmit signals within a 15m omni-direction diameter [5].

H. Controller Specifications

The controller will have to have a clock rate that is higher than the minimum sampling rate. The minimum sapling rate is determined by the Nyquist Theorem [6]. The sampling rate will be in the range of kilohertz while micro controllers work in the megahertz range. This means that there will be ample processing power.

I. Ionization Sensor

The ionization sensor consists of an Ionization Chamber and associated integrated circuitry. The ionization sensor must adhere to the detection accuracy that is set out by the mining company. The respective personnel on a mine may collect data so that the sensor can be adjusted to sense a particular threshold of carbon monoxide and alert authorities accordingly. This will generate greater accuracy of the UFDS and indicate at what percentage the sensor is detection the carbon monoxide.

J. Temperature Sensor

The temperature sensor is a reusable 'Fixed Level Temperature Sensor'. It shall operate at within the necessary temperature range and within a certain level of accuracy stipulated by the Australian Standards [3].

Based on underground research, it was decided to use a Negative Thermal Coefficient (NTC) thermistor as the sensor in the heat sensor circuit. The NTC operates within the temperature range required for effective fire sensing within a mine. The NTC also has only ±1 °C of error. This is within the error specifications allowed by Australian Standards [3, 7].

Characteristically the resistive value of the NTC thermistor decreases as the ambient temperature increases. Alternatively, it may be said that as temperature decreases the resistance of the NTC thermistor increases.

The Steinhart-Hart equation (1) can be used to calculate the resistance value of the NTC thermistor at any given temperature.

$$1/T_{Kelvin} = A + B(\ln R) + C(\ln R)^3 \qquad (1)$$

where:

T is the temperature (in Kelvin)

R is the resistance at T (in Ohms)

A, B, and C are the Steinhart-Hart coefficients which vary depending on the type and model of thermistors and the temperature range of interest [7].

This equation is used to derive a precise temperature of a thermistor since it provides a closer approximation to actual temperature. Fig.3 displays the characteristic resistance curve as a function of temperature. It illustrates three curves with varying values for B.

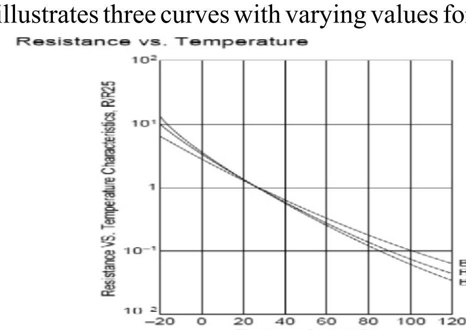

Figure 3: Resistance Temperature Characteristics [7]

IV. Software Specifications

The hardware design relies on a reliable and effective software design. The software is required to interpret the input data from the sensors and buttons and output the correct data to the alarm and the Light Emitting Devices (LEDs).

The program can be considered as three code modules. The main module will contain a loop that continuously checks for signals from the heat and smoke detectors. The following module will also be required to accurately measure the time that the smoke detector is disabled for. The last module is required to interpret the information regarding the disable function and determine that the user wants the detection system disabled.

V. Micro controller

The use of a microprocessor will reduce the complexity and quantity of the circuitry in the system. The processor can control the timing and sequence of events. Each subsection is linked together through the processor and consequently control of the system is made easier. For example, the communication system can be implemented with error detection, and inputs and outputs can be activated or deactivated with desired. There are several factors that need to be considered when choosing a microprocessor. In this case, operating speed are most important factors than size and cost. Ideally, the fire alarm when triggered will send a signal simultaneously to the surfaces monitoring system and alert the operator of smoke detection in one of the under grounds substations.

The input signal from an infrared remote can be dealt with in a number of ways. An analogue to digital converter would simply convert the embedded code but is not absolutely necessary. External interrupts are desired so that a signal from the senor is easily detected and dealt with. There are also options for the interface between the processor and the communications to the surface. These include a standard I/O or a UART port. In this system a UART port is an ideal solution as data can be transmitted and received serially at a high baud rate with few difficulties with timing issues [8].

The two most sensible languages to program microcontrollers with are C and assembly languages. Programming in C results in a less optimized code. The software for the UFDS is a small piece of code. The onboard chip within the microcontroller contains sufficient onboard memory to allow the luxury of developing this software with C instead of assembler. The embedded software will have interrupt capabilities that are required for the IR sensors.

For the sampling to be accurate the sampling of every IR signal must be exactly at the start of the signal. An interrupt allows the sampling to be highly accurate. The other inputs do not require accuracy in the same range as the IR sampling. These inputs can therefore be interpreted with poling techniques. Once the issues associated with converting the data to a form that the microprocessor can interpret and read are dealt with the rest of the software is basic coding practices [8]. Fig. 4 illustrates three major modules of code that are required for the UDFS.

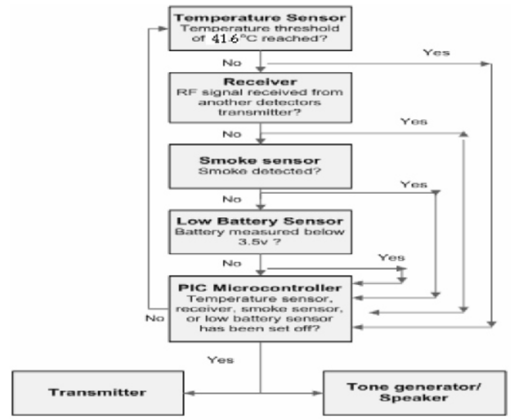

Figure 4: Microcontroller Flow Diagram

The main module of the UFDS is an infinite loop. The task of testing for the presence of smoke or heat is performed every time the loop in enacted. Prior to testing for the presence of smoke the code checks to see if the smoke sensors has been disabled. If this is the case the code returns to detecting heat or carbon monoxide. When either the heat or smoke sensors sense carbon monoxide or a pre-described threshold of heat, the alarm will activate by sounding an alarm and activating an alert on the dedicated PC terminal on the surface of the mine, where the user will be able to act accordingly. The alarm modules will continue until the user resets the system and an all clear code has been initialized.

The infrared interrupts is the most complicated piece of code that will be implemented on the UFDS. The UFDS has to learn one IR signal and then compare any incoming signals with this learnt signal. The infrared interrupts checks if the signal is to be learnt or compared, this determines if the signal needs to be saved, it then performs the sampling operation. Although this method works it would be more memory efficient to sample the signal and check if it is the incoming signal or the programming signal just before it is saved. Memory conservation is not critical to the success of the UFDS and as a result the more efficient code was not at the time incorporated. When the UFDS is in the program mode and has learnt the signal it returns to the main module. If the UFDS is not in program mode before it returns to the main module it has to check to see if incoming signal and programmed signal match. If the programmed signal and the incoming signal are a match it disables the smoke detector. If they do not match the data relating to the incoming signal is discarded.

VI. Conclusion

Due to the special working environment and complex geological conditions, the mining industry has a high rate of accidents. With the restraints underground, current safety monitoring systems are not sufficient. The introduction of the UFDS technology makes it possible to estimate the condition of mine both quantitatively and qualitatively. The objective of this paper was to design an underground fire alarm network that could provide the mining industry with a fire detection system that could ensure a high level of protection against smoldering smoke or large flames that are near high risk areas such as an underground sub-station.

This underground fire detection system has been designed to specifications produced by the mining environment. Sensors and RF communications will play a big part in the designing process within this investigation. Designing an accurate code that can be implemented in the PIC microprocessor will ofcourse be devised and solving the potential problems stipulated in this paper will be one of the major focuses during further investigations.

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AMI Initiatives for Improvement in the Power Sector

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1. What is Advanced Metering Infrastructure (AMI)

AMI, in its essence, serves to move data and control signals between a consumer's energy consumption and the distribution company (such as LESCO or KESC) that provides the electricity. AMI utilizes "Smart Meters" which are able to record household, commercial or industrial energy consumption throughout the day at fixed intervals (for example, every half hour). This data (known as "interval data") is stored in the meter and can then be transmitted to the distribution company via some communication medium (for example GPRS over mobile phone networks) or physically read by connecting a handheld unit to the Smart Meter. In both cases, the interval data is then centrally collected at the distribution company. This most basic level of AMI is called Automated Meter Reading (AMR). More sophisticated use of AMI requires two-way communication between the distribution company and the Smart Meter so data can be transmitted in real time to the distribution company and tariffs and other control signals can be sent to the meter. Thus AMI is the foundation for a two way connected electrical distribution network, what is sometimes called an "Electri Net".

Throughout the world, distribution companies have started deployments of AMI. For example, as of 2008, 5%of all meters in the US were Smart Meters. Some countries such as Italy have implemented 100% Smart Meters for all types of customers.

2. Why is AMI relevant in Pakistan?

In general, distribution companies around the world see three key types of benefits from AMI.

The first set of benefits is around better customer service through AMI. This includes:

* More accurate and prompt billing: Since Smart Meters are generally tamper proof and their reading can be automatically correlated with data from check meters, AMI ensures that customers are not assessed greater usage than their actual consumption.
* Faster resolution of disputed bills; Since detailed electrical consumption data is available through AMI, any dispute resolution is made much easier than the current monthly unit reading process.
* Better outage management due to faster detection: Smart Meters can send out alert signals in the event of an outage to help the distribution company pinpoint the outage location.
* More rate options and bill savings opportunities for customers because AMI enables dynamic pricing.

The second group of benefits from AMI is improvements in the core operations of the distribution company (DISCO). The most significant benefit of AMI in Pakistan would be the reduction in distribution losses.

High distribution losses in Pakistan are well known and documented. The combined Technical and Commercial loss as reported by the distribution companies to NEPRA in 2008 ranges from 11.5% to 35%. Most of these losses occur in the 11kv and below distribution system. The commercial loss or power theft component of this total distribution loss is assumed to range anywhere from 5% to 20% in the various DISCOs. To put this in perspective, a1% distribution loss approximately Rs. 850 million for LESCO. Thus, a 5% commercial loss would represents approximately Rs 4.3 Billion or $ 50 Million revenue loss every year.

What can AMI do to address this issue? Firstly, implementing accurate, tamper-resistant smart meters that can automatically report interval meter data to a centralized system can help act as a check on the discretionary powers in meter reading currently enjoyed by line staff. Secondly, by installing auto-reporting check meters on the distribution transformers as well as feeders, coorelations can be made between energy supplied and energy consumption reported from th installed meters to detect any unmetered connections.

The transition to AMI in meter reading can be understood as a move from manual, analong reading to digital, automated reading. For example, in the 1980s telephone bills from Pakistan Telecom (PTCL) were subject to error and frau. Mechanical readings in the exchanges meant that line staff had considerable leeway in assigning calls the volume of calls from one subscriber to another. In the early 90s, as PTCL moved to digital exchanges and detailed itemized billing, the possibility of fraudulent billing was essentially eliminated. This resulted in a huge increase in customer satisfaction, at least with respect to billing. The same revolution will be achieved as we migrate from analong to digital meter reading in electricity distribution with the same increase in customer satisfaction.

The third group of AMI benefits is demand management. There are two main approaches proposed for this:

a) Dynamic Pricing: This model relies on some variant of Time of Use pricing with significantly higher tariffs during peak hours. There are many models of dynamic pricing ranging from fully real-time prices for bulk customers, to various types of Critical Peak Pricing (CPP) including standard Time of Use tariffs in which the tariff for defined peak periods is higher to more sophisticated tariff models such as Peak Time Rebates which are incentive schemes which reduce your bill if consumption is decreased below a baseline. Dynamic Pricing is well understood and has been demonstrated in pilot rollouts internationally to reduce peak usage from 10% to 25% if effectively designed and implemented. To implement dynamic pricing, Smart Meters are needed in order to calculate the tariff on a time of use basis accurately.

b) Direct Load Control: This model allows for the energy flow to be set at a peak threshold on a per meter basis at specific times during the day. This allows the distribution company to do load shedding without having to completely switch off entire feeders as is currently the case. For example, assume a DISCO needs to shed 50 MW between 6pm and 7pm on a given day. The current method of achieving this is by turning off approximately 15 feeders entirely (each feeder providing about 3 MW of power). With Direct Load Control, Smart Meters could be centrally controlled to allow no more than say 1.5 KW to each customer. Approximately 15,000 high load residential customers could be peak curtailed in this manner to shed approximately 50 MW.

To understand this better, we need to examine the actual usage profile extracted from billing data in our distribution companies.

A typical distribution company like LESCO has about 150 subdivisions. We define high load subdivisions as those that consume more than 100 million units per annum. There are approximately 35 such subdivisions in LESCO. Of these subdivisions, lets take a closer look at 6 subdivisions that should have high residential loads as well. We select subdivisions in Gulberg and DHA in Lahore.

Firstly, we remove the industrial load from the data. (This is typically 35% - 50% of the total load in these subdivisions). We then look at the data for two classes of customers: the top 500 non-industrial consumers and High Load consumers defined as those consuming more than 1,000 units during July. The following table shows both the consumption of units and the customer count for these six subdivisions.

	Residential and Commercial Customers Only				
	Units Consumed in July 2008			**R&C Customer Count**	
Subdivision	Top 500 Customers	High Load Customer	Subdivision Total	High Load Customer	All Customer
1511	1648467	4474218	945133	2574	19480
1513	1739634	4762851	9447128	2610	19202
1515	2055704	5590578	11016179	2817	25061
1516	2123378	5156128	10771142	2477	24718
1523	1771710	7446213	12995377	4333	21197
1524	1892411	7710938	13431604	4277	23090

From the data above, 19100 high load, non-industrial, customers out of a total of 132748 customers consumed 35 million units out of a total of 67 million units in July 2008. In other words, 14% of the non-industrial customers consumed 52% of the load. Secondly, using a standard load profile, the peak consumption of these 19100 customers can be estimated to be approximately 70 MW. Note that this is the data from only six subdivisions out of 150 in LESCO.

If we assume that there are a total of 100000 such high load customers in the entire DISCO that would correspond to a peak load (of these customers) of approximately 350 MW. By implementing Direct Load Control on only one third of these customers at a time, we should be easily able to shed 100 MW of peak load. We note that during this type of load shedding, the lights will still be on, the fans will work and probably the television and refrigerator also. The main thing that customers will not be able to use is the air conditioner.

Compared to the current situation, where during load shedding, the customer gets no power at all, this would be a highly attractive option.

3. What do we need to implement AMI? Smart Meters and Meter Data Management

To implement AMI, DISCOs need to invest in two main components: Smart Meters and Meter Data Management (MDM) systems. We have already discussed Smart Meters in some detail. What is MDM?

Before we describe MDM, we need to understand a key operational change that happens when you shift to Smart Meters. The volume of meter data during this shift to AMI increases by a factor of 100 to 1000. For example, lets assume you implement 10000 smart meters in a DISCO. Currently, the electronic meters from these connections generate one meter reading per month for a total of 10000 readings. With AMI, even hourly meter readings will generate approximately 7.5 Million reading per month. Clearly this volume of data cannot be manually managed or controlled.

Managing this interval data is what MDM does. MDM is a solution for managing, analyzing and publishing interval meter data. Some of its key functions include:

* Meter Date Collection: Interfacing with head end systems provided by Smart Meter vendors so that interval data can be imported into the MDM system as well as sending out control and tariff commands to meters.
* Validation, Estimation and Editing: this provides a framework for validating meter data as it comes in from AMI and manual meter reading.
* Exception Management: Smart meters are able to

generate various events and alarms (for example, a Tamper Alert, a Power Outage alert). MDM allows these events to be consolidated and then specific business actions can be triggered to respond to the events.

* Interface to Billing: A key role of the MDM system to aggregate interval data from AMI and other meters and pass it on to the billing system which is typically not able to directly utilize interval data.

* Revenue Protection: By aggregating and correlating meter data, MDM can be used for revenue protection. For example, by correlating the data from a distribution transformer and the four loads connected to it, MDM can highlight energy differences and help detect unauthorized, unmetered connections. Secondly, by establishing standard load profiles for various classes of residential, commercial and industrial loads, MDM can validate the meter data and highlight differences between expected and measured loads. This feature can be used to also check standard electronic meter connections since profiles can be established even for meters with monthly, manual meter readings. By performing these checks automatically and across every single meter read, every month, MDM can help significantly reduce the volume of commercial loss in a DISCO.

4. Why have we not implemented AMI?

In this section we address some of the standard concerns raised regarding AMI implementation in Pakistan.

Its too expensive: This is the most common objection against AMI.To answer this question, lets first examine where, and in what scale, would we implement AMI. If we examine LESCO data, there are approximately 8500 significant load industrial connections in LESCO out of a total of 2.8 Million customers. The 8500 customers represent approximately 44% of the energy consumption and 47% of the billing in LESCO. So these 8500 customers generate approximately Rs 40 Billion in revenue. Installing heavy-duty AMI meters that cost Rs 40000 per meter at these customers would cost a total of Rs 34 Million. This represents the billing generated in less than half a day by these customer! Clearly, implementing tamper proof, high accuracy and high reliability Smart Meters at the industrial loads makes complete business sense. The second place where we might implement AMI is at the transformer level. LESCO has a total of approximately 20000 100KVA and 200KVA transformers. Installing Smart Meters at the transformer level would cost approximately Rs. 400 Million. But doing so would allow the DISCO to accurately assess commercial losses to within one single transformer in a given feeder. This would allow the DISCO to move aggressively against the areas where significant commercial loss is occurring something that cost LESCO probably Rs 4 Billion per year.

Finally, installing Smart Meters with Direct Load Control on 100000 high load residential and commercial connections would cost approximately Rs 2 billion. However. This would generate the ability to shet 100 MW of peak load without turning off the electricity entirely to the customer. This would both significantly increase customer satisfaction and reduce the cost of purchasing expensive peak time electricity

There are no standards for Smart Meters: While this was true a few years ago, today the IEC has published extensive standards to ensure that Smart meters can be procured which are standards compliant.

We will have vendor lock-in with Smart Meters: Another concern typically raised regarding the use of Smart Meters is that the DISCO will have suffer from vendor lock in and will be forced to utilize meters from only one vendor. This concern is misplaced, with the use of a Meter Data Management (MDM) system the DSICO is able to use a system which is multi-vendor compliant and able to be integrated with any type of Smart Meter.

We cannot establish two way communication with Smart Meters: With the wide spread availability of GPRS technology (at least in major urban centers) and support of GPRS from most smart meter vendors, the question of communication technology has now been effectively answered. The great advantage of GPRS is that the infrastructure for this mode of communication has already been established by the mobile phone companies and hence there is no need for a DISCO to incur the capital expense of establishing a communication network.

Conclusion

We have sought to establish in this paper the benefits of AMI technology for DISCOs in Pakistan. The key question for AMI in Pakistan is not why but when.

Sustainable Energy Development & Linking Renewable Energy Resources

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Abstract

In this paper, efforts have been made to utilize the available information regarding energy consumption, generation and demand from various sources for analysis of our present system to sustain future energy growth. Renewable resources must be linked with the existing power generation to meet with future challenges. This paper focuses on the energy crisis, oil shortages and renewable potentials in a global perspective and then some recommendations have been made for sustainable energy development.

Index Terms -- Sustainable Energy, Energy Resources, Energy Crisis, Renewable Resources

I. Introduction

Mankind has constantly pursued economical and plentiful energy resources. For centuries the main energy source was firewood, while for over the last 100 years most of the energy has appeared in the shape of fossil fuels. For example, the US presently gets more than 75% of its energy from fossil fuels. But these fuels have finite reserves. The extent of the reserves, and when they will vanish has been discussed for a long time. No one is sure when day will come, or what sort of price instability and geopolitical turbulence could come with global fossil fuel shortages. For a few fossil fuels, such as coal, reserves are enough for many years at current rates. But for others time is becoming short, with most experts forecasting worldwide oil production to peak in the next ten years [1].

Economic development and rising standards of living have led to a remarkable increase in electricity demand in the past decades. As a consequence, strategy planners are now facing the challenge of meeting future electricity demand growth in a way which is both sustainable and clean.

Currently, 85% of all power generation is non-renewable, causing several worlds' most injurious ecological ills -- greenhouse gases, acidic rain, and poisonous wastes. Yet, huge potential for wind, tidal, hydro, solar and geothermal sites exist throughout the world. Most of these renewable resources are in remote locations. With HVAC and HVDC, these potentials are now within reasonable transmission distance. These renewables are significant given the predictions of World Energy Council of a doubling of primary energy demand within next twenty five years as developing countries rise economically and in population [2].

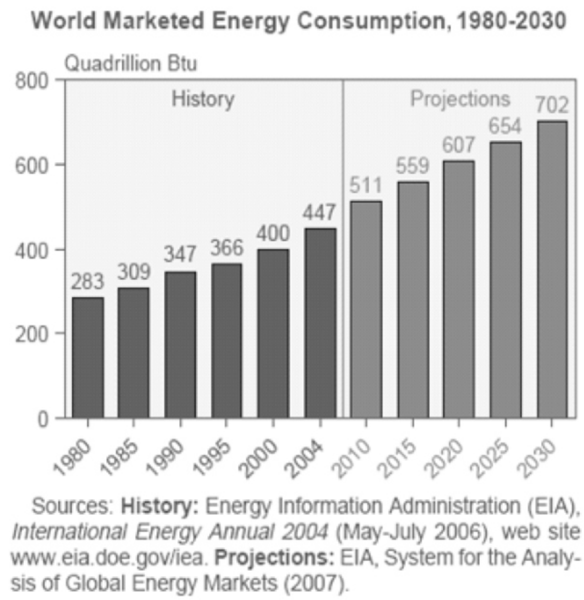

Fig. 1 - *World Marketed Energy Consumption, 1980-2030*

As in the previous numerous years, the crushing majority of power expansion is from fossil fuels and nuclear sources. The main obvious existing model is China. Addition of huge thermal station each month is predicted over the next twenty years. Although initial consumption per capita was very low, this energy growth rate is predictable to make China world's major consumer in the coming decade [3].

II. Global Perspective

In 2008, total worldwide energy consumption was 474 exajoules with more than 82% derived from fossil fuels. This is equivalent to an average power utilization rate of 15 TW. Industrial users consume about 37% of the total 15 TW. Personal and commercial transportation consumes 20%; residential heating, lighting, and appliances use 11%; and commercial uses (lighting, heating and cooling of commercial buildings, and provision of water and sewer services) amount to 5% of the total. About 27% of the world's energy is lost in energy transmission and generation. Fuels mostly comprises of Oil, Gas and Coal [15].

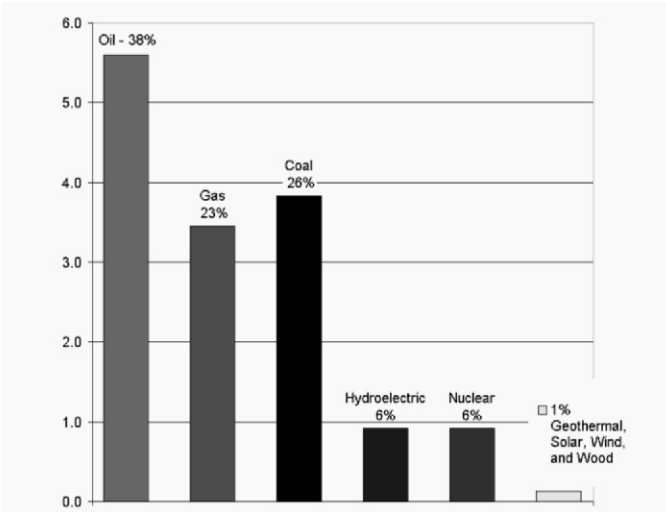

Fig. 2 - *Worldwide energy sources (TW)*

The development of HVAC and DC interconnected systems keep on to grow around the world. North America is a proven energy infrastructure -- providing huge cost savings in power business, emergency backup and reduced capacity requirements. Economic development in Latin America, China, India, and Southeast region of Asia is putting the requirement for additional capacity and transmission networks to deliver this power. Developing nations will now need to leave their old development formulas and transitions for sustainable prosperity. The most challenging for this world is now to choose the suitable energy path for China, India and Southeast Asia. More than half of world's population lives in this region, and connection between renewable resources is very necessary if we need sustainable power and clean environment.

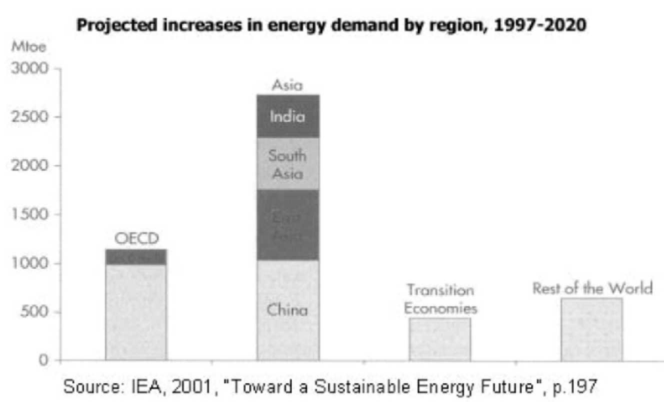

Fig. 3 - *Projected increase in demand by region, 1997-2020*

A system planner Michael Hesse Wolfe summarized Mid-East solar potential by saying, "There is enough for all. One statistic is enough. On the Arabian peninsula there is enough solar energy every year which is equivalent to their entire petroleum reserve that ever was. Every year. . . We have an abundance of renewable energy resources on hand. It is up to us as we near the turn of the century to think seriously about developing these resources for the benefit of humanity and the planet" [6]. Effort is being made to make solar PV cost effective by Sanyo Electric. Sanyo plans to install large solar arrays in deserts. Their studies show that installation of solar PV on just 4% of world's deserts would be sufficient to meet entire energy needs of the world. [14].

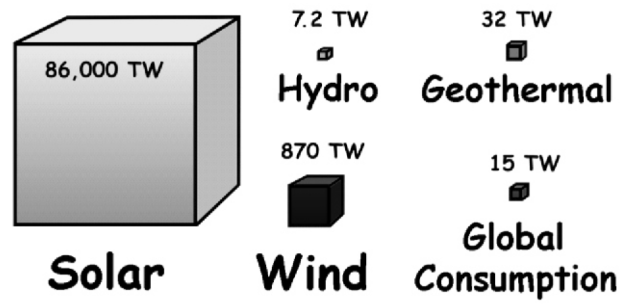

Fig. 4 - ***Available renewable energy.***

In many African countries such as Cameroon, Nigeria and Democratic Republic of Congo rolling blackouts has become a routine of daily life resulting from the shortage of electric supply and ever expanding demand with a combination of aging electricity supply infrastructures, non-diversification of energy sources, overloading of electricity mains [4, 5].

Other developing countries, particularly Asian countries like India and Pakistan have daily outages of up to 8 hours in even the capital and major cities. Villages are affected a lot more than this. Main reasons for these can be classified to old equipment, fuel shortage, and a high occurrence of power theft [7].

System losses in most of countries are very high when compared with the international target of less than 10%. In Ghana, system losses are below 5% and this resulted from the creation of the energy commission (EC) and energy foundation (EF) which defined a new power structure allowing private sector investment in power generation and creating an open access transmission systems to provide non-discriminatory transmission services and to enhance competition as well as to promote sustainable development and efficient consumption of energy.

A long-term strategic plan must be in view to meet with upcoming energy demand and sustainable electric supply, using renewable resources, because fossil fuels are running short. From the most resources, which are available now or in future, wind is currently considered in Europe to grasp the attention and contributing in the next few decades a significant fraction of electrical energy. Power generation from wind is believed to cause no problems and is a state of the art technology [8].

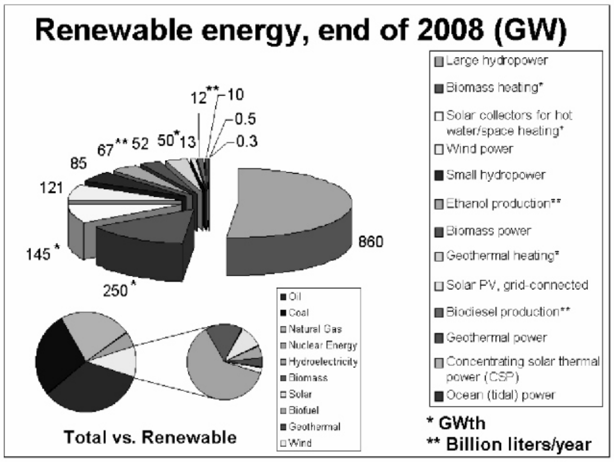

Fig. 5 - *Renewable energy sources worldwide at end of 2008*

III. Recommendations

A move away from using electricity in devices that solely produces heat. Electric cookers, kettles, hot water and space heaters convert electrical energy into heat energy. Due to the considerable conversion inefficiencies inherent in generating electricity, a unit of electrical energy contains only about 40% of the heat energy that was used to make it. Accordingly, to get the same heat from burning a litre of gas at the point of use, two and a half time as much fuel would be required in a power station. *Infrastructures* that would be needed to support this recommendation would include shifts from electric to gas cookers, from immersion heaters to gas/biomass boilers and even from electric kettles to gas-fired modes of boiling water. This may require the expansion of the gas network infrastructure. Energy efficient appliances must be used to get more output power for the same sort of equipment. While these changes could be phased in over a number of years it is vital for the government to make the public aware of the choices that are available to them and the importance of electricity conservation [9, 11].

Investment in renewable generation. Pakistan has a wind generation potential of 0.346 million MW, 2.9 million MW of solar generation potential and more than 1,00,000 MW can be generated from coal for the next 300 years. In order to achieve these levels of renewable energy penetration certain *infrastructural* changes will be required. A more flexible generation plant mix will be required which could include increased interconnection and demand side management. If government gives a chance to investors for unleashing such a huge power potential, we will certainly not only sustain our energy needs, but also can export this energy for future economic growth [10, 12].

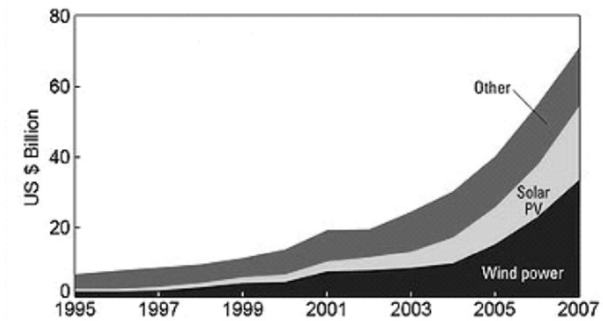

Fig. 6 - *Global renewable energy investment*

Demand side smart metering. Smart metering can offer a lot more than just time specific tariffs and savings on meter-readings. Sophisticated smart meters can operate as integrated building management systems, constantly communicating with the grid and with all devices within the premises. Smart meters can allow many revolutionary changes in how a power system deals with demand. For example, demand shedding can prioritized and domestic tariffs can be adjusted depending on the required level of reliability, loads can be scheduled, and tariffs could be revolutionized with sophisticated time and location specific pricing. The potentials are endless. While smart metering can be implemented immediately there are a number of *infrastructural* issues which must be addressed to maximize the potential of any such scheme. Flexibility is imperative and should be incorporated from the start, proprietary standards and protocols should be avoided. Given that smart meters, once installed in homes and businesses, may remain operational for well over twenty years it would be short sighted to lock into an inflexible, supplier specific solution. The IT infrastructure supporting smart meters should be open and flexible and allow for upgrading to more sophisticated meters in the future.

Increased interconnection. Increased interconnection is an *infrastructural* recommendation which would have significant benefits. Increased interconnection would significantly improve security of supply. In addition, an increase in interconnection would significantly increase the flexibility of the electricity system.

Distributed Generation (DG): Network operators in order to fasten electricity generation should make use of distributed generation equipment (fuel cells, wind, photovoltaic cells...) which if connected to the distribution grids will give raise to the following merits:

- Allowing customers to continuously generate their own electricity with or without grid backup.

- Improving customer power quality and reliability
- Meeting continuous power supply, premium power or cogeneration needs of the residential markets
- Generating a portion of electricity onsite to reduce the amount of electricity purchased during peak price periods
- Being used as standby or emergency power to backup network based power
- Licensing customers to sell excess generation back on to the grid when their own demand is low, mostly during peak pricing periods.

Despite the numerous merits of DG, this most however be connected taking into consideration quality of supply, network reliability and safety for DG is capable of back feeding into the transmission and distribution system during a power outage [13].

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Lifetime & Energy Consumption Analysis for Cluster-based Wireless Sensor Networks with Topology Constraints

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Abstract

Due to the wide diversity of deployment options of sensor nodes in wireless senor networks, the topologies so formed can have a wide range of distribution and density characteristics. Clustering is one of the most popular approaches used in wireless sensor networks to conserve energy and increase node as well as network lifetime and LEACH is among the most popular clustering protocols proposed for wireless sensor networks. In this paper we have carried out network lifetime and energy consumption analysis for clustered wireless sensor networks based upon LEACH protocol for periodic monitoring applications with topology constraints. Simulation results based upon this protocol identify some important factors that induce unbalanced energy consumption among sensor nodes and hence affect the network lifetime due to the topology constraints for wireless sensor networks. This highlights the need for an adaptive clustering protocol that can increase the network lifetime by further balancing the energy consumption among sensor nodes.

Index Terms--*Wireless Sensor Networks, Deployment, Network Lifetime, Clustering Protocols, Topology Constraints*

I. Introduction

Advancements in wireless communication technology, availability of lightweight, compact and portable computing devices along with integrated and miniaturized sensors have made distributed sensing and computing possible and practical. A wireless sensor node is a battery-operated device, capable of sensing physical quantities, data storage, limited amount of computational and signal processing capability and wireless communication. A Wireless Sensor Network (WSN) consists of a large number of wireless sensor nodes working collaboratively to achieve some common objective. WSN can have one or more sinks or base stations which collect data from sensor nodes. These sinks act as an interface through which the WSN interacts with the outside world. Major advantages of WSNs over the conventional networks deployed for the same purpose are greater coverage, accuracy, reliability and all of the above at a possibly lower cost. Some of the early works on WSNs [1], [2], [3] have discussed these benefits in detail.

Networking hundreds or even thousands of unattended sensor nodes is receiving a lot of interest in the research community. These networks form a new class of ad-hoc networks having their specific characteristics and challenges. Random distribution and high density implies that periodic battery replacement will be tremendously inconvenient or more likely impossible and small size of these nodes implies limited physical space for batteries. Therefore sensor nodes operate as long as their batteries are not depleted. This employs that performance metrics of these networks are different from those of conventional networks, emphasizing on low power consumption and low cost rather than data throughput or channel efficiency. Several applications have been envisioned for WSNs in the field of environment, disaster relief, facility management, preventive maintenance, precision agriculture, medicine and health [4], [5], [6]. Broader range of applications for WSNs has led to the development of many protocols where energy efficiency has been taken as an essential consideration.

In a WSN, the number of nodes per unit area the (density of the network) can vary considerably. Different applications will have very different node densities. Even within a given application, density can vary over time and space because nodes fail or move, the density also does not have to homogeneous in the entire network (because of the imperfect deployment, for example) and the network should adapt to such variations. Due to the wide diversity of deployment options of sensor nodes in wireless senor networks, the topologies so formed can have a wide range of distribution and density characteristics. They range from well planned, fixed deployment of sensor nodes (e.g. in machinery maintenance applications) to random deployment by dropping a large number of nodes from an aircraft over a forest fire. In addition, sensor nodes can be mobile themselves and compensate for shortcomings in the deployment process by moving, in a post deployment phase, to positions such that their sensing tasks can be better fulfilled. They could also be mobile because they are attached to other objects (in the logistics applications, for example) and the network has to adapt itself to the location of nodes.

Clustering is one of the most popular approaches used to achieve the specific performance requirements of these types of networks. Although formation and maintenance of clusters introduces additional cost due to the control messages required for the purpose, still cluster-based WSNs have taken much attention of the researchers due to their better performance. LEACH (Low-Energy Adaptive Clustering Hierarchy) [7], [8] is among the most popular clustering protocols proposed for WSNs. Simulation results presented in [8] do indicate better performance of the LEACH protocol over static clustering and MTE (Minimum Transmission Energy) protocol [8], [9]. In order to further optimize the performance of the LEACH protocol, their remains a need to identify the factors that affect the network lifetime by inducing unbalanced energy consumption among sensor nodes in cluster-based WSNs due to topology constraints. In this paper we have tried to analyze factors that affect the network lifetime by inducing unbalanced energy consumption among sensor nodes in cluster-based WSNs based upon LEACH protocol for periodic monitoring applications with topology constraints. The remainder of the paper is arranged as follows. Section-II provides the background about cluster-based WSNs based upon LEACH protocol. Section- III provides the brief description about the proposed scenario. Development of the simulation environment using OPNET to identify the factors inducing unbalanced energy consumption among sensor nodes and thus affecting the network performance due to topology constraints has been discussed in section-IV. Based upon the simulation results, conclusions have been drawn and some recommendations for future work have been proposed in section-V.

II. Background

Low-Energy Adaptive Clustering Hierarchy (LEACH) [7], [8] is a distributed clustering protocol that utilizes randomized rotation of local CHs to evenly distribute energy consumption among sensor nodes in the network. LEACH targets the situations in which dense network of nodes are reporting to a central sink with each node can also reach the sink directly. The basic idea is that nodes elect themselves as CHs according to some probability in such a way that the expected number of CH should be constant in each round. Nodes that are not elected as CHs join one of the elected CHs based upon cluster joining algorithm. In LEACH, ordinary nodes join the nearest elected CH as their CH for the incoming round.

In LEACH, the whole operation is divided into many rounds. Each round includes a set-up phase and a steady-state phase. The steady state phase is divided into many frames. Number of frames in the steady state phase can be varied as per requirements. During the set-up phase all nodes are organized into clusters with each cluster having its own CH through short messages communications. During this phase, all nodes broadcast short messages using Carrier Sense Multiple Access (CSMA) MAC protocol [10]. All the other nodes of a cluster are known as member nodes. For all of its member nodes, every CH sets up TDMA schedules, which are later used to exchange data between the member nodes and the CH. With the exception of their time slots, the member nodes can spend their time in sleep state to conserve energy. Following the set-up phase, the data are transferred from member nodes to CHs according to the TDMA schedule during each frame, aggregated to reduce redundant data and then passed on to the base station (BS) at the end of the frame.

To reduce inter-cluster interference, members of each cluster in LEACH communicate using direct-sequence spread spectrum (DSSS). Each CH while broadcasting the TDMA schedule also broadcasts the spreading code that is later used by its member nodes. All the nodes in the cluster transmit their data to the CH using this spreading code and the CH filters all received energy using this spreading code. LEACH protocol forms clusters in a distributed manner, where nodes make autonomous decisions without any centralized control. Each sensor elects itself to be a CH at the beginning of round r with probability Pi(t) such that the expected number of CH nodes for that round is k. Thus, if there are N nodes in the network

$$E[\#CH] = \sum_{i=1}^{N} P_i(t) * 1 = k \qquad (1)$$

To ensure that all nodes are CHs the same number of time, LEACH protocol requires each node to be a CH once in *N/k* rounds on average. If $C_i(t)$ is the indicator function determining whether or not node has been a CH in the most recent (r mod N/k) rounds (i.e. $C_i(t)$=0 if node has been a CH and one otherwise), then each node should choose to become a CH at round r with probability

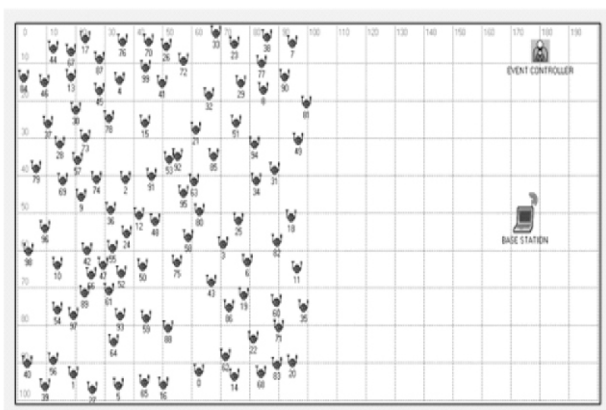
$$P_i(t) = \begin{cases} \dfrac{k}{N - k * (r \bmod N/k)} & : \quad C_i(t) = 1 \\ 0 & : \quad C_i(t) = 0 \end{cases} \qquad (2)$$

III. Brief Description Of The Proposed Scenario

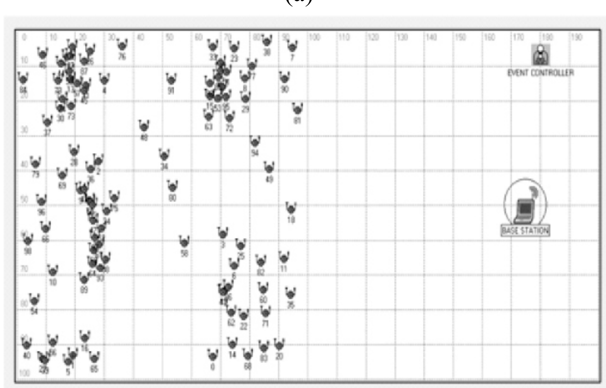
Due to the wide diversity of deployment options of sensor nodes in wireless senor networks, the topologies so formed can have a wide range of distribution and density characteristics. They range from well planned, fixed deployment of sensor nodes (e.g. in machinery maintenance applications) to random deployment by dropping a large number of nodes from an aircraft over a forest fire. Different applications will have very different node densities and even within a given application, node density can vary over time and space because of nodes failure and movement.

As already mentioned, in this paper we have tried to analyze factors that affect the network performance by inducing unbalanced energy consumption among sensor nodes in cluster-based WSNs based upon LEACH protocol due to topology constraints. Four different scenarios of the simulation environment comprised of 100 and 400 nodes with uniform and non-uniform distribution in a sensing field as per network specifications used in [7], [8]. A snapshot of these scenarios for 100 uniformly & non-uniformly deployed nodes using OPNET-based simulation environment is shown in Fig. 1(a) & (b) respectively. Similarly 1(c) & (d) show the snapshot for the scenarios of 400 uniformly & non-uniformly deployed nodes.

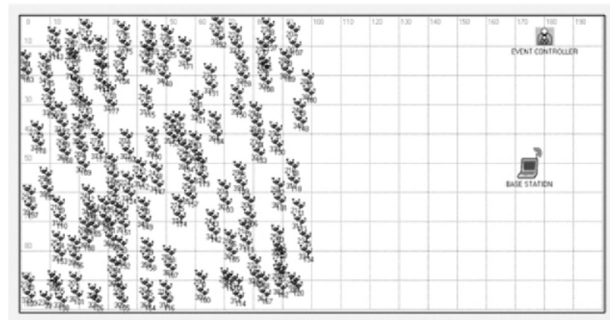
For simplicity authors of the LEACH protocol propose a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Fig. 2. For the theoretical and simulation work described in this paper, both the free space (d^2 power loss) and the multi-path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and receiver [11]. Power control can be used to invert this loss by appropriately setting the power amplifier. If the distance between the communicating nodes is less than a threshold, the free space (*fs*) model is used; otherwise the multipath (*mp*) model is used. Thus, to transmit an *l*-bit message over a distance *d*, the radio expends



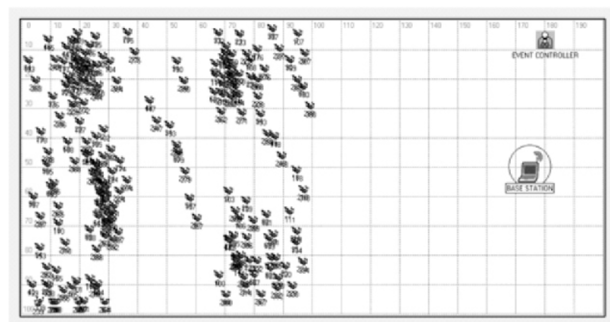
(a)



(b)



(c)



(d)

Fig. 1: Network topology snapshots for OPNET-based simulation environment for topology constraints (a) partially uniform topology of 100 nodes, (b) non uniform topology of 100 nodes, (c) partially uniform topology of 400 nodes, (d) non uniform topology of 400 nodes

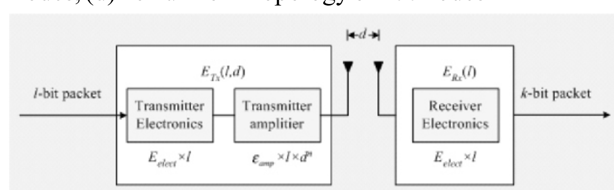


Figure 2. Radio energy dissipation model

$$E_{Tx}(l,d) = E_{Tx\text{-}elect}(l) + E_{Tx\text{-}amp}(l,d)$$
$$= \begin{cases} lE_{elect} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elect} + l\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \qquad (3)$$

where E_{elec} is the RF radio circuitry energy, ε_{fs} is the amplification energy required to overcome the free space loss, and ε_{mp} is the amplification energy required to overcome multi-path loss. To receive the same message, the radio expends

$$E_{Rx}(l) = E_{Rx\ elect}(l) = lE_{elec} \quad (4)$$

Table I summarizes different communication energy parameters as proposed in [7], [8].

Table 1Radio Model Communication Paranaters

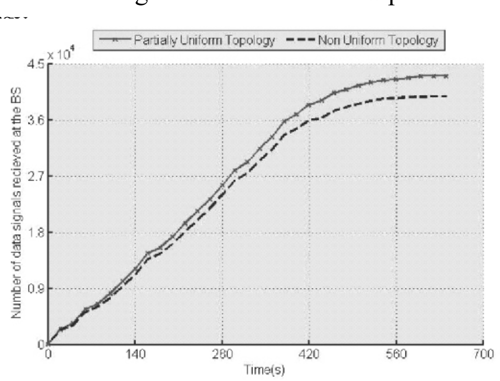
Parameter name	Notation	Value
RF radio circuitry energy	E_{elect}	50 nJ/bit
Amplifier energy for free space loss	$_{fs}$	10 pJ/bit/m^2
Amplifier energy for multi-path loss	$_{mp}$	0.0013pJ/bit/m^4
Threshold distance	d_0	87m
Data aggregation energy	E_{DA}	5nJ/bit/signal

IV. Simulation Work

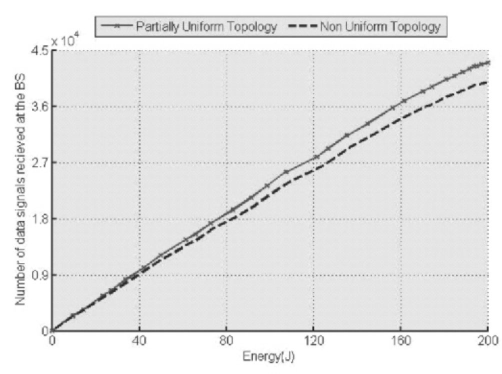
Fig. 3(a) shows the number of data signals arrived at the BS over time for uniform and non-uniform topology of 100 nodes. We can see from these results that for the case when sensor nodes are uniformly distributed in the sensor field, more data signals are received at the BS. Fig. 3(b) shows the number of data signals received at the BS per unit amount of energy. Again we can see that for the case when sensor nodes are distributed more uniformly in the sensor field, more data signals are received at the BS per unit amount of energy indicating uniform and efficient energy utilization.

Fig. 3(c) shows the number of nodes alive over time. Fig. 3(d) shows the number of nodes alive over number of data signals arrived at the BS. For the case when nodes are distributed more uniformly in the sensor field, the trend lines follow the sharp edge effect more than the case when the nodes are non-uniformly distributed in the sensor field.

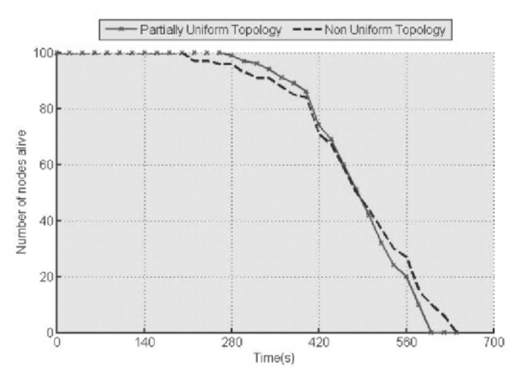
Fig. 4(a) shows the number of data signals arrived at the BS over time for uniform and non-uniform topology of 400 nodes. We can see from these results the case when sensor nodes are uniformly distributed in the sensor field, more data signals are received at the BS. Fig. 4(b) shows the number of data signals received at the BS per unit amount of ene



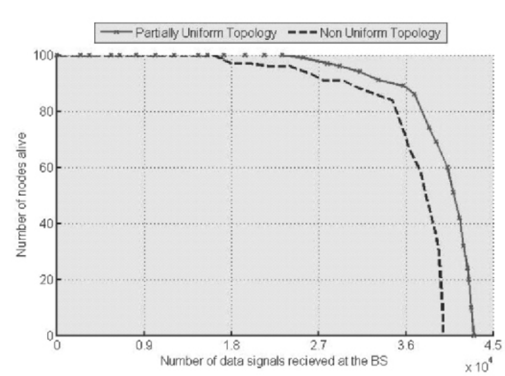
(A)



(b)



(c)



(d)

Fig. 3: Simulation results for 100 node network with topology constraints (a) Number of data signals received at the BS over time, (b)Number of data signals received at the BS per given amount of energy, (c) Number of nodes alive over time, (d) Number of nodes alive per amount of data sent to the BS

Again we can see that for the case when sensor nodes are distributed more are received at the BS per unit amount of energy indicating uniform and efficient energy utilization. Fig. 4(c) shows the number of nodes alive over time. Fig. 4(d) shows the number of nodes alive over number of data signals arrived at the BS. For the case when nodes are distributed more uniformly in the sensor field, the trend lines follow the sharp edge effect more than the case when the nodes are non-uniformly distributed in the sensor field.

V. Conclusion & Recommendations

In this paper we have carried out network lifetime and energy consumption analysis for cluster-based WSNs based upon LEACH protocol with topology constraints. OPNET based simulation environment for the LEACH protocol was developed and experiments were carried out for four different topologies having different density and distribution characteristics. Simulation results indicate that partially uniform topologies provide more balanced energy consumption among sensor nodes when compared with the non-uniform topologies. It was also observed that the partially uniform topologies with less density provide better sharp edge effect when compared with non-uniform topologies of dense network. All these observations indicate the need for a more generalized standardized & adaptive clustering technique that can increase the network lifetime by further balancing the energy consumption among sensor nodes while taking the topology constraints into consideration.

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Introducing Single-Phase Distribution System

By
RIAZ AHSAN BAIG

ABSTRACT

The author conducted a study to analyze the causes of interruption in the WAPDA Distribution System and tried to find out least cost solution to the problem. According to the analysis 70% of the interruption are visible faults due to poor maintenance and workmanship which mostly constitute loose jumpers and connections, improper conductors clearances, loose binding of conductor to insulator, improper line sag and imbalance load on the transformers etc. In the opinion of the author WAPDA has unnecessarily extended three-phase system to all the domestic consumers which in his opinion should be changed to single-phase system. Single-phase system is not only 30% to 40% cheaper but will also improve power supply by reducing interruptions drastically. The author has strongly advocated his view point supported by calculations and reasons.

1. Basic Concept

An electric power system can be defined to consist of a generation, a transmission and a distribution system. The distribution system called primary and secondary system is spread throughout the entire load area serving each individual consumer load. The primary and secondary system can be of overhead or underground construction. Throughout residential, rural, commercial and industrial areas, three-phase overhead system predominates. In developed countries underground system is used to feed downtown areas and heavy commercial loads which is quite expensive. Due to its high cost WAPDA has not adopted underground system although it is more reliable than overhead system.

2. Wapda Distribution System

2.1 In developed countries distribution system, on national average, is roughly equal in capital investment to generation facilities and constitute 40% to 50% of total investment in power system. Thus distribution system rates high in economic investment that makes careful engineering, planning, design, construction and operation. In WAPDA, Distribution System has the lowest priority, while more importance is given to higher voltages. The distribution cost in WAPDA is about 10% of total investment.

2.2 99% of WAPDA Distribution System is three-phase overhead and radial. The overhead radial system cannot be free from outages, caused by lightning, hanging tree limbs, wire, strings, kites, winds and dust storms, vehicle accidents, pollution etc, but WAPDA has worsen the situation due to poor workmanship, lack of maintenance and non compliance to their own standards. The system is being expanded without taking into account loading and voltage drop, in addition to poor standard of construction resulting in damage to equipment, high level losses and poor standard of supply delivered to the customers. A lot of work has been done under Energy Loss Reduction (ELR) programmes over the past years. It has not achieved the desired results due to lack of proper planning..

2.3 The interruptions on WAPDA distribution system are numerous. The power supply system is far from satisfactory and cannot be compared with any national or international standard. We as a nation have accepted this enormity as a norm. Although sudden failure of power supply in sultry and sizzling weather puts every one to inconvenience, but the public restricts themselves to cursing WAPDA, while in developed countries suits are filed even if there is an interruption of power supply for a few minutes. Thanks to our accepting people, who believe that disruption of power supply is a matter of routine, and part of their living. The question arises why WAPDA has failed to achieve the required performance standards? We have to analyze and find a solution to improve the existing system within our available resources.

3. Fault Analysis

3.1 In view of limited financial resources available it is imperative to analyze the causes of interruption in the system and fix priorities. The least cost solutions with maximum impact on improvement in system efficiency should be handled first. For this purpose I carried out analysis of distribution system by collecting data of interruptions from few sub-divisions in Lahore some years back, the results of which are given hereunder. It may be noted that 70% of the system interruptions lie under the category of “Low Tech Faults' and mostly constitute visible faults on line VIZ loose jumpers/connectors, improper conductor clearances, excessive sage due to large spans, which can be resolved within available financial resources.

High and Medium tech faults constitute 20% of the total and are difficult and expensive to work with. These faults should be dealt later, once the low tech faults have been fully attended.

Fault Analysis

c	Causes	Percentage
HI TECH Faults (Difficult to Identify)	1) Switching Surges 2) Lightning discharge 3) Power frequency synchronisation problems 4) Harmonics 5) Corona 6) Capacitances & inductance of Transmission Line 7) Air pollution	5%
Medium TECH (Simpler to identify)	1) Equipment failures/malopration 2) Relay malfunctions 3) Indiscriminate trappings 4) Lack of proper protection 5) Insulation Co-ordination	15%
Low Tech Faults (Common Fault, Most of them Apparent & Visible)	1) Non compliance to standards a) Construction b) Materials - Loose Jumpers & Connections - Improper conductor clearances - Loose binding of conductor with insulators - No or Poor earthing - Improper line sag - Unequal or excessive tension on conductors (poles out of alignment) - Broken or cracked insulators - Improper protection to equipment - Imbalance of three phase loads	70%
Low TECH Faults (Beyond Control)	1) External interferences 2) Lightening, Wind storm, Kites, Traffic Accidents Bridge	10%

4. Options For Improvement:

4.1 It may be noticed from the fault analysis that majority of faults mostly constitute loose jumper connections, improper clearances, excessive sag, overhanging branches of trees and nuisance of kite strings. All these problems can be resolved with proper operation and maintenance of the distribution system which WAPDA has failed to achieve over the past four decades. There could be several options to improve the Power Supply System. One of the most economical approach to resolve this issue is to change the existing three phase system to single phase system which is being widely used and practiced in U.S.A. and will be discussed at length here under.

4.2 Single Phase System

4.2.1 The simplest Form of single-phase system is the supply to consumers through radial feeders which depending upon geographical position of the load center with respect to the location of the grid station. Here are few examples to illustrate single-phase distribution system.

a) When load center is located within the grid station, each individual phase goes directly to its area right from the sub-station and each phase feeds a defined area as shown in Fig 1. Such system is not very popular as future expansions of the system could create a problem of load balance.

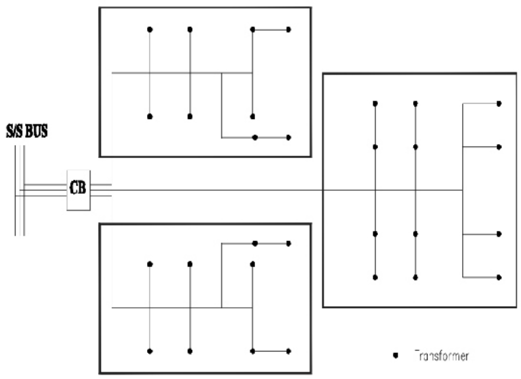

Fig-1: Phase area feeder system

B) When load centers are located at a distance from the sub-station 11 kV, 3 phase express feeder is laid to the load centers and no load is distributes over this portion. The typical example of this is the villages located in small clusters over the area. The express feeder is so designed that it passes close to the load centers. Single phase feeders are taken out near the load centers from the three phase express feeders and then bifurcated into single phase feeder in three different directions which feeds the consumers as shown in Fig 2.

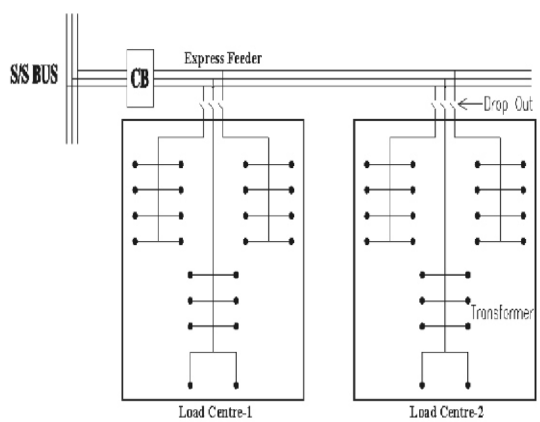

Fig-2: Express feeder distribution system

C) A more extensive radial 11 kV circuit is shown in Fig 3. Three phases 11 kV circuit passes through the load center where it can feed three phase supplies to commercial and industrial areas. Single-phase feeders are taken from three-phase main line to feed residential areas. Such a radial feeder is more commonly used in low-density urban areas.

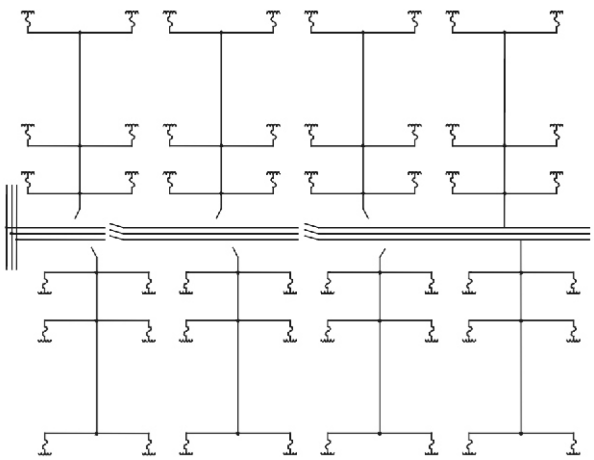

Fig-3:

d) A more reliable and commonly used system for domestic areas is loop system. The loop feeder start from a sub-station and returns to the sub-station. Single-phase lateral feeders are tapped off the main to obtain the load area coverage as shown in Fig. 4.

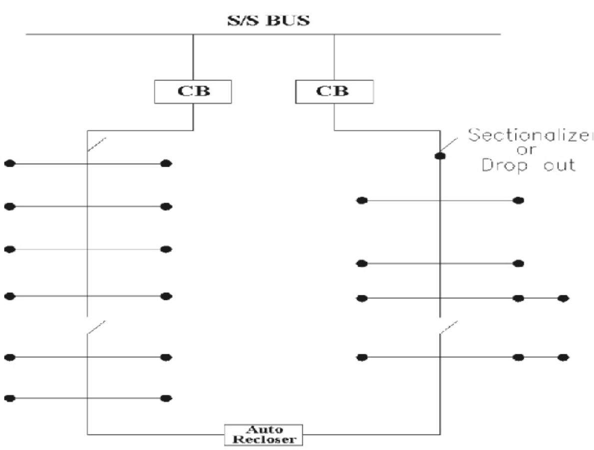

Fig -4: Loop Circuit Arrangement

e) A most reliable single and three phase system used in high density urban areas is the inter connected Network mesh System of distribution feeders which are served by several distribution sub-stations or network units located through out the area.

f) It is very advantageous to use auto reclosers and line sectionlizers as shown in Fig 5. A fuse may be used as line sectionalizer. On long feeders to minimize fuse blowing due to temporary faults, a line recloser must be added along the feeder. It opens instantaneously for a fault and then recloses. On each subsequent tripping, if fault persists, tripping will take place with some specified time delay until temporary fault is cleared. If fault on a section is permanent it will be cleared by blowing of the fuse. In cases where it is difficult to co-ordinate the fuse blowing with re-closer operation autoline sectionalizers can be used instead of fuses. Positive co-ordination between circuit breakers, recloser and fuses or sectionalizers is essential to eliminate faulty sections or clear temporary faults.

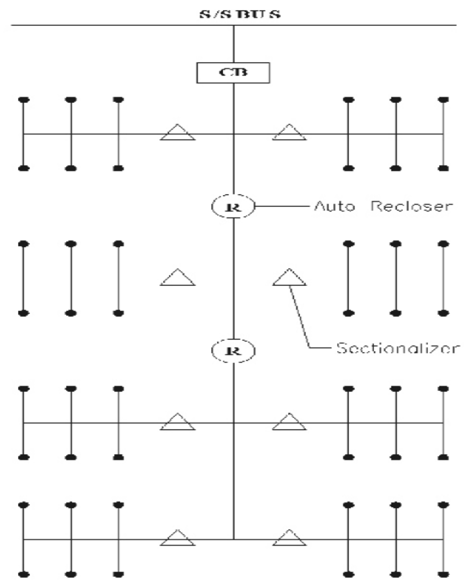

Fig-5

4.2.2 Following is a typical example of WAPDA 11 kV three-phase radial feeder, feeding to domestic consumers. In this system almost all the domestic consumers are fed through three-phase supply.

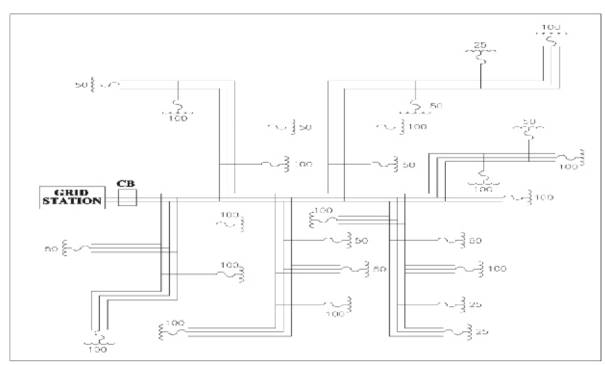

Fig-6: Typical WAPDA 11 kV 3-phase radial feeder

The above three-phase feeder when represented on a single-phase system would be as under:

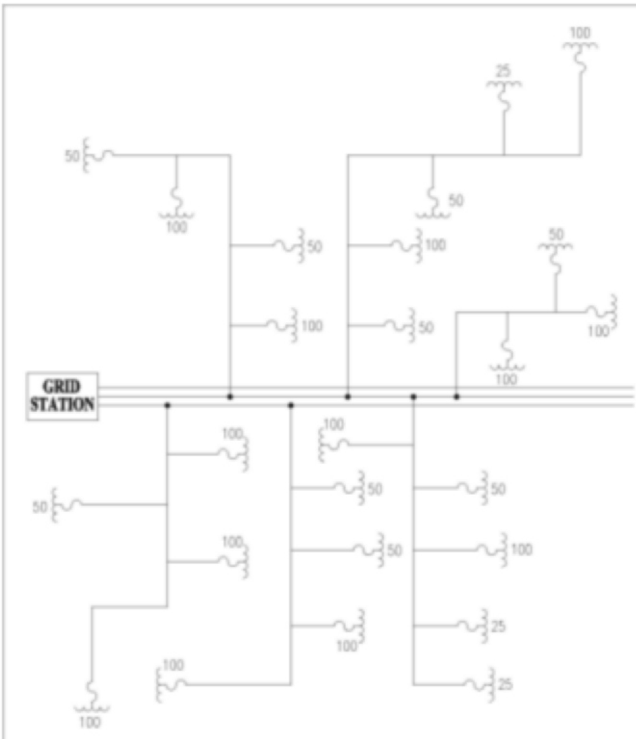

Fig-7: 3-phase feeder shown in Fig-6 converted to Single-phase System

Comparing the two system one can imagine the savings in terms of cost and reliability of service which will be discussed next.

4.2.3 Cost Comparison of Three Phase and Single Phase System

The cost comparison of single and three phase system assuming I KM length of HV feeder with 2 Nos. transformer of 100 KVA each and 1 KM length of LT feeder is as under:

a. Cost of 3 phase system

	Qty	Unit rate	Cost
- 3 phase 11 kV line with P.C poles & Dog Conductor	1 KM	408,000	408,000
- 100 KVA (11/0.4 KV) complete S/S	2 Nos.	175,000	350,000
- 3 Phase Service connection with 7/0.36, 4 core cable	30 Nos.	9400	282,000
- LT line with rabbit conductor	1 KM	225,000	225,000
Total Cost			**1,265,000**

b. Cost of single phase system

- Single phase 6.3 KV Line with P.C. poles & dog conductor (No cross arms, No supports only one conductor)	1 Km	272,000	272,000
Single phase 100 KVA transformer (6.3/0.24 KV) transformer s/s complete	2 Nos.	140,000	280,000
LT line with two wasp conductors	1 KM	120,000	120,000
- Services 3 phase with 7/064 conductors	30 Nos.	4500	135,000
Total Cost			**807,000**

Cost of single phase system is at least 30% cheaper compared with three single phase system. We can have still more savings up to 40% of total cost by designing lighter poles for single conductor. In addition single phase system will drastically reduce cost of maintenance and improve power supply.

4.3 Advantage of Single-Phase System over Three-Phase System

The advantages of single-phase system over three-phase system are elaborated below:

i. Single-phase system is 30% to 40% cheaper compared to three-phase system.

ii. Single Phase Transformer have less losses compared to 3-phase system which makes the system more efficient.

iii. It is simpler and easier to maintain Single-phase.

iv. 11 kV single-phase system can be laid down in narrow streets as cross-arms are eliminated.

v. 30% larger span can be used with the same height of structures.

vi. There will be no phase to phase short circuits due to improper sags, unequal or loose tension on conductor, broken or tilted cross-arms.

vii. Over hanging branches of trees will not cause any short circuit as in case of three-phase system.

viii. There will be no short circuits on 11 kV feeders due to kite strings.

ix. There will be no problem due to imbalance of loads on single-phase transformers as in case of three-phase system.

x. Three-phase transformers are more vulnerable to short circuits compared to single-phase transformer.

xi. Damage to grid station equipment will be reduced proportionate to reduction in faults on 11 kV system.

xii. Balancing of load on 11 kV feeders will be easy.

4.4 How to change existing Three-Phase System to Single-Phase System

There may be some apprehensions that how the existing three-phase system can be used with the single-phase system. Following are suggestions to implement this change in a systematic manner and in phases:

i. Three-phase transformers when burnt should be replaced with single-phase transformer of the same rating upto 100kVA transformer.

ii. All the three-phase conductors on L.T. feeder should be short circuited by fixing a conductor across the three-phases to change it to a single-phase supply.

iii. Three-phase meters need not to be replaced and will continue to record energy on three conductor single-phase supply without any effect on its performance.

iv. Each DISCO will prepare a programme for conversion of three-phase systems to single-phase system, feeder-wise and in phases as under:

- Programme should be carried out feeder-wise.
- Under this programme all the existing three-phase transformers on a 11 kV feeder should be replaced with single-phase transformers.
- Central conductor on the cross should be shifted first and fixed to the pin insulator installed on top of the structure.
- All cross-arms, spare insulators and pins along with two conductors per phase of 11 kV feeder should be removed. Similarly all the excess conductors and insulators of L.T. lines should be removed thus creating an inventory of billions of rupees which can be used for the future system expansion.
- Spared three-phase transformers should be used for replacement of burnt transformer instead of procuring new ones.

4.5 Design of Single Phase Transformers

An article on Single Phase Transformers was published in IEEEP Newsletter in October 2009 from Karachi Local Centre advocating its advantages over three phase transformers. In single phase transformers two primary voltages can be used i.e. 11kV between two phases or 6.35kv between phase and the neutral. In this article 11kV line to line voltage with two 11kV bushings on the transformer is preferred over the 6.35kV feeding to the transformer for advantages given below; although in USA mostly single conductor primary voltage is used.

1. These transformers are designed for line to line connection & can also be connected to get three phase supply i.e Dyn II. Whereas 3 ph transformers of line to ground design can only be connected to form YNyno & require separate neutral earthing terminal for HV & LV windings.

2. If these transformers are designed for phase to neutral connection then if by default neutral is disconnected in that case voltage on L.T terminals can be raised upto abnormally high value.

3. To avoid electric coupling of the HV & LV windings as a protection against Fault.

In my opinion single phase 11/0.24kV transformer may be preferred to substitute the existing three phase transformer in the already electrified area. For new areas single phase 6.35/0.24kV may be more economical.

5. Recommendations

i) DISCO's MUST consider to introduce single phase distribution system for supply to domestic and small commercial consumers in all rural and urban areas. It will not only reduce 20% to 30% of investment and maintenance costs but will also drastically reduce interruptions, prolonging life of distribution transformers and equipment installed at grid stations.

ii) All 3 phase small transformers on damage may be replaced with single-phase units thus substituting three-phase with single-phase system, where applicable. We can replace the existing three-phase system to single phase in stages. It may added that existing three-phase LT distribution network can be very effectively used on single-phase system without any change.

Quality Improvement In Power Distribution Companies

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Service system improvement story GEPCO has developed as company in 1999 by distributing the WAPDA into DISCOs (Distribution Supply Company), the system such as LESCO, GEPCO, IESCO and etc. Only Discus the detail of GEPCO with all effects. The system of WAPDA totally clasps. Which attributes its domestic turnaround to its massive system improvement (SI)? The employee's are 12523 which are not trained, so large numbers of employees have gone training programs/skill development after training programs. They extensively use a process called competitive bench marking because bench marking is a formal process of measuring the quality of their products. It means that all the employee's are well trained from excellent Academy/Institute's which plays the vital role for the system improvement.[1]

Last four years ago, like may other DISCOs means utility companies was in a state of near-crisis by the shortage of oil, water and other resources which was not managed properly, by these effects. The energy prices were sky rocketing. So that customer had dissatisfaction with WAPDA (PEPCO). Every DISCOs was rising even faster than energy prices with additional surcharges such as N.J Surcharge. In such circumstance GEPCO return on investment for improving the Distribution system. The GEPCO upgraded the Grid system by adding the power transformers and new grid station. There are 51 grid stations which are under load. As well as changes the L.T line, remove the damage Poles/structures and added no. of Distribution of T/F to serve the better service to their customers. In short the GEPCO provide better services to the customers than others.

Having committed to several significant capital expenditure, the company would be forced to ask the employee's for yet rate increase the working efficiency to relief the customers. If GEPCO long term survival might well depend on making even heavier expenditure to reduce the company dependence on oil planning for the future but simply in coping with its current problems. For firstly in PEPCO especially GEPCO executives realized how bureaucratic style, but only act as professionals inflexible their company had become during good time.[1][4]

1.1 Operational Behavior of GEPCO

GEPCO founded in 1999 and based in Gujranwala was Gujranwala largest utility company. GEPCO consists of six districts with four circles one P.D one M&T and on GSO and etc. GEPCO supply the electricity to 221212 customers. GEPCO newly acquired companies in technical services financial services and revenues collected for Govt as well as GEPCO itself profitable company, if GEPCO conducting extensive research on the concept of system improvement and quality control (SIAQC). The team consists of six members, the team observed a management presentation with university professors/ company head by improving the story of SIAQC. The format adapted from the board and company managers presented their story with logical flow of data, displayed through basic statically control techniques with the help of customers or question air data from public.[2][6]

1.2 SIAQC Format

This Structure which allows a team to display its work at different location for awareness to the customers in a standardized the standard instruction.

1) Reason for improvement
2) Current situation
3) Analysis
4) Education and awareness
5) Countermeasures
6) Results
7) Standardization
8) Future plans
9) Co-Ordination
10) Training as per work
11) Seminars for awareness

It provides both the team and CEO special team with clear picture of the logical process used for improvement.

Quality improvement program (QIP) which is a central part of any company process called policy deployment, that task is managed by management task team.[3][4][6]

1.3 Network Data Collection

In Distribution network, the basic data contained with all aspects in one page called service interruption in system (SIS). Every interruption occurs in the system may be reported as a data base and compare with the previous one. The period was measured as the system was reliable or not.

The SIS report contains the data

1) Time of electric supply off/ restored.

2) No of consumer effect/area

3) Cause of Supply failure with detail list

4) Response time for restoration

5) Struggle for restoration with facilities

The data base is serious problem for the improvement of the system. Actual effects are not steam lined / delivered one member of the team is so expert that purify the reporting data and discuss with the C.E.O after analyze that effect and effects of the employees with detail base on that lines.

a) Reporting is correct/incorrect

b) Filled Time is correct/incorrect as per actual duration

c) Data is computerized for comparisons.

d) Data of lost of energy as per effect area.

The team finds out the procedure to resolve the matters to reduce interruption and control that type of mishaps.[3][5][8]

1.2.1 Current Situation

The object of the current situation of the (SIAQC) is to select a specific problem and set a target to set right that problem and set a target to set right that problem improvement of system as number of problems that is only the wastage of time which single one is not completed. After selection of target than facilitated the workers how to be done in the first step. If the team achieve the goal than I Think as field worker the frequency of interruption per customer be reduces as approximate 20%.

So the team collects the data to help it focus analysis. That team only reaches new ideas for the improvement of the system not engaged for other purposes. At those types of large companies, Vehicles are effected number of customers by no availably, based on the percentage impact vehicles had on customer interruptions. The team set a target improvement of goal calling reduction of service unavailability due to vehicles.[6]

1.2.2 Analysis

It identify and verify the root causes of the problem / failure which was selected for analysis

1) Correct / exact data with all standard specification

2) Problems of system

3) What are the root cause

4) Verify the root cause and data

5) Correct Distance for approach at fault location.

The matter was investigate / examined with all source of customer interruption vehicles plays a vital role on customer interruption.

Developing the cause effect with the scope of error to be analyzed. Most of the effect reveal the problems be selected for analysis. All the causes are listed. The members of team study the roots of power line and position of poles that are installed on a curve and had been hit several times by vehicles. The all looked up and all immediately realized and set right that pole which on in curve on the road than interruption may be reduces and customers are not affected by this act.

This analysis once again revealed that through poles close the road was number one is term of number of occurrences “poles on the outside of curve” was number one is terms of number of customers affected. Therefore “Pole on the outside of curve” was the root cause, that team chose to work on it with close observation through question air by the customers.[2][3][4]

1.2.3 Countermeasures

The system improvement (SI) to plan the objects and then implemented in the correct direction to solve the problem.

The team activates the employee's to develop and evaluate the basic root cause. The team find out the list of countermeasures that would be neutralize the root cause. In that root causes, the problems can be solved, therefore problems will always remains but reduce.[8]

The techniques are identifying by implemented countermeasures.

1) Educated the employee's

2) Mind set as per problem / network.

3) Cost benefit analysis

4) Act Plan.

<u>SIAQC by Cause</u>

Causes	NO of Occurrences
Lighting	10
Unknown	15
Wind	12
Vehicles	04
Trees	18
Bird / Animal	02
Accidents	01

Some canines are ignorable. The objects is to confirm the effect of problems and root causes be decreased by meet with the targets by achieve the object then following activities are confirmed properly.

1. Compare the problems before and after the remedial measures.

2. Confirm the effect of the countermeasures.

3. Compare the results obtained with the targets.

4. Compare the efficiency of the employees.

Therefore special assignments are given to special group of expertise after inestigation the final version presented to the authority in formal and informal meetings by implementation of countermeasures. The authority has nominated an officer to inform the big / important consumer after the remedial measures confidence of consumer built up on the service men and betterment of good repute of the authority.[1][4][7]

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WAPDA's Annual Loss of Rs. 130 Billion Reasons And Remedies:

Syed Tanzim Hussain Naqvi
Ex-Member Power WAPDA and Chairman KESC

Government of Pakistan and General Public thinks that Wapda's annual loss of Rs. 130 billion is due to its inefficiency and incompetence and negligence in controlling theft of power is "Not Correct".

The actual reason is the increase in annual expenditure along with high payments to IPP (Independent Power Producers), which cannot be attributed as Wapda's own fault. As a matter of fact, WAPDA is now forced to buy bulk of power from IPP which are supplying power to WAPDA at the rate of approximately Rs. 8 to Rs. 10 power unit, as against its own thermal power plants cost of Rs. 3 to Rs. 4. In past, until year 2003, the power sharing was follows:

*	Wapda's hydro power station	40%
*	Wapda's own thermal power stations	40%
*	Independent Power Producers	20%

But after year 2003, WAPDA's own thermal plants started de-rating its capacity and WAPDA was not allowed by previous government of Pakistan to add new power stations and also not allowed to upgrade the old generating station resulting in Wapda's own generating capacity de-rated from 6000 MW to 2500 MW. The current estimated position of Wapda's dependable capacity is as follows:

*	Wapda's hydro power station	30%
*	Wapda's own thermal power stations	15%
*	Independent Power Producers	55%

If we evaluate the Generation Capacity with Tariff Revenue Cost Earning, the results are alarming:

1. Wapda's generation cost is in the range of Rs. 8.25/unit
2. Wapda's Revenue Earing Cost in the range of Rs. 5.75/unit
3. Hence Wapda's loss/unit is Rs. 2.50/unit

If this loss per unit is multiplied with the total units sold in a year, it comes out to be an alarming high figure of Rs. 130 billion loss per annum. (52 billion units x Rs. 2.50 = Rs. 130 billion)

Had Wapda been allowed to upgrade their own old power stations or be allowed to add new generating plants against their old units at various places like Shahdara, Faisalabad, Multan, Guddu and Jamshoro then Wapda's own thermal generation would have increased from 15% to at least 40%. Which clearly means reduction in WAPDA's generation cost/unitfrom Rs. 8.25 to Rs. 5/6 per unit, making Wapda a profitable organisation even with current tariff structure.

Not to allow Wapda to add its won power station by previous government has not only subjected Wapda to a huge loss of billions of rupees but has also gifted painful load-shedding of R2500 to 40000 MW last season. Apart from this turmoil present government is bringing Rental Power Projects which are going to cost tariff rate of USD 0.15 to 0.16 (i.e. Rs. 12.5 to 13.5/unit) paying way for another mega crisis. It is expected this rental power project plan would incur a total loss of Rs. 20 billion alongwith more expenditure in terms of import of extra furnace oil. Government of Pakistan should have allowed Wapda to add new power station on "War-footing" basis, to not only stop load-shedding but also making Wapda a profitable organization.

Another aspect worth consideration is the NEPRA and government of Pakistan has approved Tariff Increase to the range of 24$ by June 2010. The detail are:

* Tariff increase in May 2009 was (+) 31%
* Tariff increase by June 2010 would be (+) 24%

If we convert such tariff increases into unit costs, it would given the following figures:

* average selling cost of WAPDA in May 2009 was Rs. 7.50/unit (increase of 31%)
* Average selling cost of Wapda in June 2010 would be Rs. 9.33/unit (increase of 24%)

In other words tariff increase would be (+) 64%. It is true that WAPDA's annual loss of Rs. 130 billion can be controlled by increasing the tariff based on the fact that the new generating cost of Rs. 9.40/unit against selling rate of Rs. 9.33/unit. But NEPRA and Government of Pakistan has forgotten that tariff increase up to Rs. 9.33/unit would not only "Increase the theft of power", but would also create public outcry and furthermore problems for industrial and Commercial consumers.

Remedies:

1. Government of Pakistan must allow Wapda to add its new power plants on war-footing, not only to reduce the cost of generation but also to decrease dependence of power supply from IPPs and decrease the import of furnace oil.
2. Coal base power plants must be installed on urgent basis by awarding contracts to two to three parties on technical competency basis.
3. Kalabagh dam must be started, it has been stopped just on consensus grounds which has nothing to do with technically and financially feasible project. No other country needs such consensus on these kind of projects. India has constructed 28 dams out which 2-3 are on our river water.
4. Wapda must be allowed to operated independently on its own administrative and technical merit.

Concept Building Through Block Diagram Using Matlab/simulink

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Abstract

In this paper, basic concepts of block diagrams have been discussed. Block diagrams have their own significance in every discipline of engineering. A block diagram is reduced to its canonical from using block diagram algebra. We simulated the same problem in MATLAB and SIMULINK. We applied the step input and observed the behavior of the system.

Index Terms - Transfer function, block diagram.

I. Introduction

In different disciplines of engineering as Electrical, Chemical and Mechanical engineering, there are several ways to represent a system or a process like block diagram, signal-flow graph (SFG), schematic diagram and layout diagram.

Block diagrams are used to represent a system or process using blocks. Whereas schematic diagrams are simplified representation of an electrical circuit. They represent the elements of a system using graphic symbols rather than realistic pictures [1-3].

A signal-flow graph is a special type of block diagram that shows the relations among the variables of a set with the help of nodes and arroes. Schematic diagram and layout diagram are used extensively in electrical engineering. Layout diagram shows the width of each wire on the printed circuit board (PCB) [1-4]

Initially key parameters of any physical system are defined for doing mathematical modeling. Then differential equations governing the system are developed. Then a transfer function for the whole system is determined and a block diagram is constructed [1].

II. Basics Of Block Diagram

A block diagram is a shorthand pictorial representation of the cause and effect relationship between the input and output of a physical system. Block diagrams are equally useful in management sciences, criminal justice and economics for the modeling and analysis of the system [1-4].

We can represent any complicated system and its characteristics in a simple block diagram for our convenience, or we can represent a complete process by using block diagram representation.

Canonical form of a diagram contains only one block with single input and single output as shown in fig 1.

Fig. 1 Basic Block Diagram

Block diagram of a linear time-invariant (LTI) system consists of four elements as shown in fig 2 [1]:

1. Signals
2. Systems
3. Summing Junctions
4. Pick off points

The three fundamental configurations in which blocks can be connected are [1-3]:

1. Series form
2. Parallel form
3. Feedback from

Any finite number of blocks in series may be algebraically combined by multiplication of transfer functions [1-3] as shown in fig 3(a).

Any finite number of blocks in parallel may be algebraically combined by either addition or subtraction according to the condition as shown in fig 3(b). Fig 3(c) shows feedback topology, which forms the basis of control systems engineering [1].

Block diagrams can also be simplified using the rules of block diagram algebra. Summing/pickoff point(s) can be easily relocated for the purpose of simplification by simply following the shifting rules [1-3] as shown in fig 4.

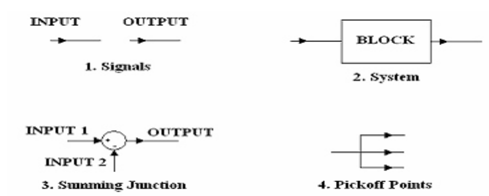
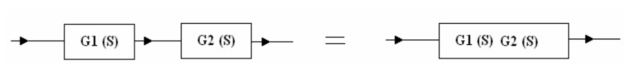
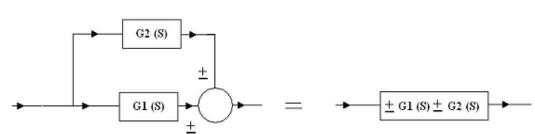


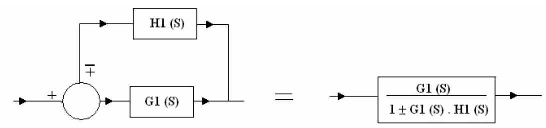
Fig. 2 Elements of Block Diagram



(a) Series Configuration



(b) Series Configuration



(C). Feedback Configuration

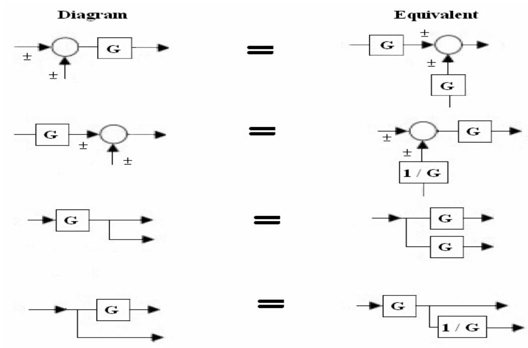


Fig. 4 Basic Block Diagram Transformations

III. Advantages and Disadvantages Of Block Diagrams

Block diagram representation of any system offers the following educational advantages [5-7]:

1. A block diagram is a direct, graphical illustration of a set of coupled, linear differential equations.
2. Each block describes a specific process within the system in terms of a transfer function. Dimensionally, transfer functions can be ratios of interdisciplinary quantities.
3. The interactive coupling among all processes in the system is clearly shown and provided by the block interconnections.
4. Any input/output relationship is determined from a straight forward rearrangement of the block diagram. These simple graphical manipulations may provide additional insight into the behavior of the system. Thus it effectively portrays the interrelationship of distinct parts of the system.
5. Generally the number of operations required to carry out a complete block diagrams reduction are fewer and more direct than would be necessary to eliminate variables in the original equations. Also, the reduction process gives graphical significance to algebraic operations and is less susceptible to error.
6. The block diagram representation readily lends itself to the study of specific problems involving synthesis and system optimization.

The disadvantages of block diagrams are as follows [5-7]:

1. The differential equations that describe the system must be known.
2. The method is essentially a frequency-domain technique.
3. Block diagrams rely heavily upon the concepts of linear system theory (e.g., Transfer functions, feedback.
4. Since a block diagram involves high-level view of the system, it does not offer the details information required for comprehensive planning and analysis.

IV. Manual Solution

We will solve an example of block diagram to find its canonical form. The step by step solution is given below in fig

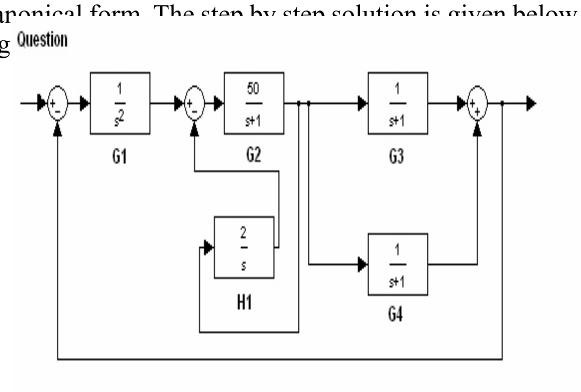


Figure 5(a)

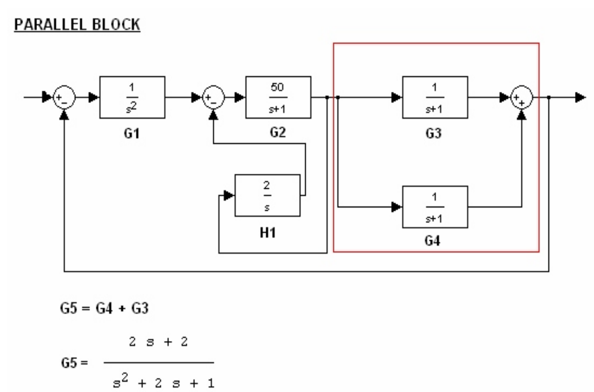


Figure 5(b)

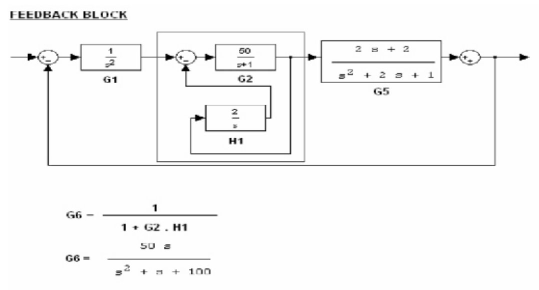


Figure 5(c)

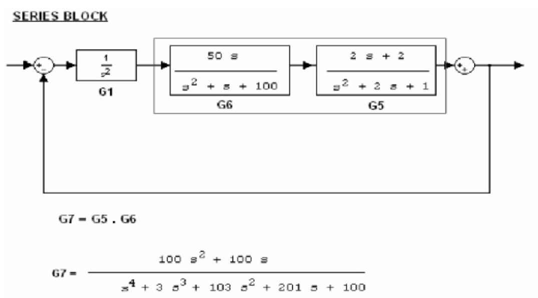


Figure 5(d)

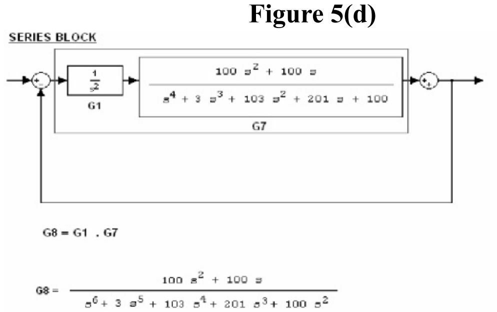


Figure 5(e)

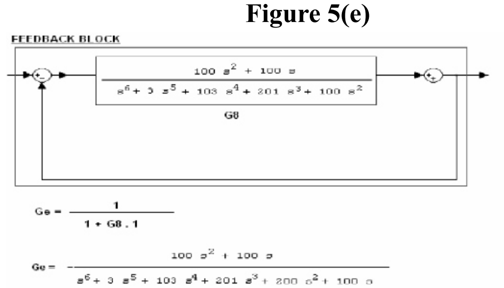


Figure 5(f)

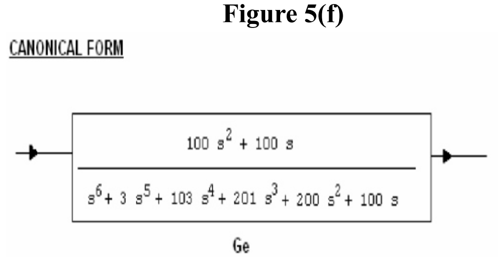


Figure 5(g)

V. System Simulation With the help of Matlab and Simulink

Now for analyzing the behavior of the system shown in fig. 6, we used MATLAB and SIMULINK.

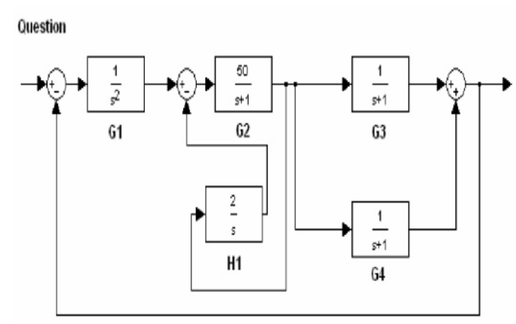
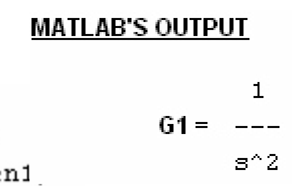


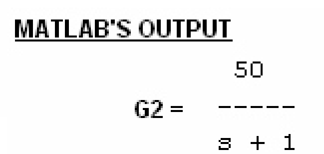
Fig 6

A. MATLAB Simulation

We defined the transfer function by using MATLAB's command "tf (num, den)" where num and den are user defined variables. Then, we used different commands to solve series, parallel and feedback configurations.

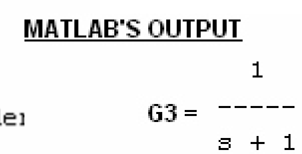
```
num1=1;
den1=[1 0 0];
G1=tf(num1,den1
```



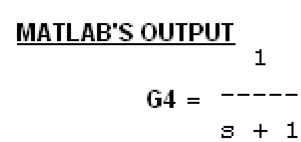



```
num2=50;
den2=[1 1];
G2=tf(num2,den2)
```

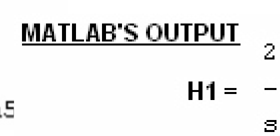
```
num3=[1];
den3=[1 1];
G3=tf(num3,de
```




```
num4=[1];
den4=[1 1];
G4=tf(num4,den4)
```




```
num5=2;
den5=[1 0];
H1=tf(num5,den5
```



```
G5=parallel(G3,G4)
```

MATLAB'S OUTPUT

PARALLEL

```
          2 s + 2
G5 =  -------------
      s^2 + 2 s + 1
```

```
G6=feedback(G2,H1)
```

FEEDBACK **MATLAB'S OUTPUT**

```
           50 s
G6 =  -------------
      s^2 + s + 100
```

```
G7=series(G5,G6)
```

SERIES **MATLAB'S OUTPUT**

```
                 100 s^2 + 100 s
G8 =  -----------------------------------------
      s^6 + 3 s^5 + 103 s^4 + 201 s^3 + 100 s^2
```

```
G8=series(G1,G7)
```

SERIES **MATLAB'S OUTPUT**

```
                 100 s^2 + 100 s
G7 =  -----------------------------------
      s^4 + 3 s^3 + 103 s^2 + 201 s + 100
```

```
Ge=feedback(G8,1)
```

FEEDBACK **MATLAB'S OUTPUT**

```
                     100 s^2 + 100 s
Ge =  -----------------------------------------------
      s^6 + 3 s^5 + 103 s^4 + 201 s^3 + 200 s^2 + 100 s
```

Fig 7 MATLAB Commands & Their Outputs

Fig. 7 shows all the MATLAB commands. After reducing the block diagram using block diagram algebra to its canonical form, we applied the step input to observe the behavior of the given system as shown in fig 8.

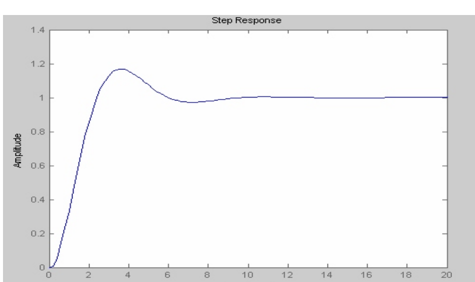


Fig 8 MATLAB output

B. SIMULINK

Now we implement the same block diagram in SIMULINK and applied step input as shown in fig. 9, and observed its output as shown in fig 10.

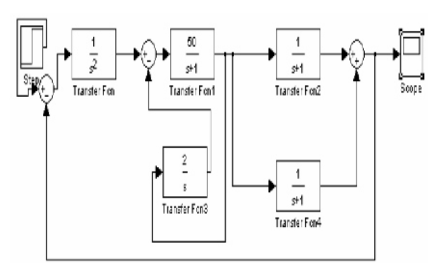


Fig 9. SIMULINK Implementation

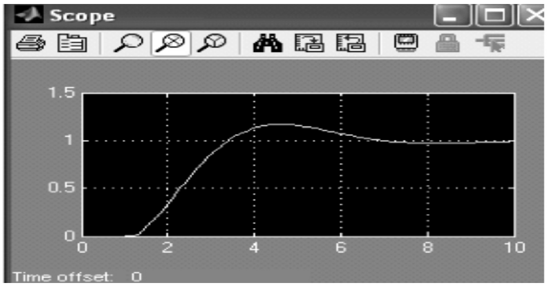


Fig. 10 SIMULINK Output

VI. Conclusion

We have revisited the basic concepts of block diagram as these are being employed for designing new systems or processes and improving present ones. Firstly, we solved a block diagram manually. Secondly, we simulated the same system in MATLAB and SIMULINK. The output waveforms showed similar results. This approach makes teaching of block diagrams a much easier task. It is concluded that block diagrams are a valuable source of concept building, and are educationally beneficial in various engineering and non-engineering disciplines.

Acknowledgment

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Quotation

*. Courage is grace under pressure
-- Ernest Hemingway

* A timid person is frightened before a danger, a coward during the time and a courageous person afterwards.
-- Jean Paul Friendrich

* Fear always springs from ignorance.
-- Ralph Waldo Emerson

* The thing a woman will consent to discover in a man whom she loves, or on whom she simply depends, is want of courage.
-- Joseph Conrad

* The man who knows when not to act is wise. To my mind, bravery is forethought.
-- Euripides

* Our greatest glory is not in ever falling but in rising every time we fall.
-- Confucius

* To generalize is to be an idiot.
-- William Blake

* The human heart refuses to believe in a universe without a purpose.
-- Immanuel Kant

* Great works are performed not by strength but by Preserverance.
-- Samuel Johnson

* There is nothing like dream to create the future.
-- Victor Hugo

* I am an idealist. I don’t know where I am going but I’m on my way.
-- Carl Sandburg

* It is very bad thing to become accustomed to good luck.
-- Publilius Syrus

* Fame is proof that the people are gullible.
-- Ralph Waldo Emerson

NOTES

NOTES

Quotation

*. The harder you work, the luckier you get.
-- Gray Player

* Never look down to test the ground before taking your next step; only he who keeps his eye fixed on the far horizon will find the right road.
-- Dag Hammarskjold

* Not failure, but low aim, is crime.
-- James Russell Lowell

* The tragedy of life doesn't lie in not reaching your goal. The tragedy lies in having no goal to reach.
-- Benjamin E. Mays

* Men of genius do not excel in any profession because they labor in it, but they labor in it because they excel.
-- William Hazlitt

* Nothing great will ever be achieved without great men, and men are great only if they are determined to be so.
-- Charles de Gaulle

* To escape criticism -- do nothing, say nothing, be nothing.
-- Elbert Hubbard

* A horse never runs so fast as when he has other horses to catch up and outpace.
-- Ovid

* The beginning is the most important part of the work.
-- Plato

* Ask, and it shall be given you; seek, and ye shall find; knock, and it shall be opened unto you.
-- Matthew

* When you soar like and eagle, you attract the hunters.
-- Milton s. Gould

* A problem is a chance for you to do your best.
--Duke Ellington