Electrical Energy Regulation and Load Management for addressing Power Crisis in Pakistan

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***Abstract*— In Pakistan the electrical power is generated mainly by using non-renewable sources of energy, such as fossil fuels (Furnace oil, Natural gas, Coal) nuclear and renewable sources like hydel, solar, wind power. The country is facing severe short fall in the energy sector since last two decades. This shortfall is affecting the industrial development as well as economic growth. The governments have been planning various strategies and these are being implemented, in order to resolve the issue of power crises. A cost effective method applied, to conserve the electrical energy and narrow down the gap between demand and supply, is the use of Automatic Meter Reading (AMR) and the Load Data Improvement Program (LDIP). Composite Efficiency Index (CEI) is presented in this research using two variable factors i.e. line losses of 11KV feeder and its revenue recovery of energy bill amount. The CEI is being used as key instrument in preparing schedule for rational and indiscriminate load management plan. It is also helpful to meet the shortfall between power supply and demand which ultimately results into energy conservation**

***Keywords*—LDIP, Energy Conservation, AMR, Line Losses, CEI**

I. INTRODUCTION

Pakistan is facing severe power crises. The role of electrical power is an essential part to attribute toward the enhanced industrial growth and raise the living standard of general public. Energy play key role in the lives of human being, in its development and reshaping. Figure 1 depictive share of oil is 29%; gas contributes for 50%, while the rest of 21% shared between hydel, liquefied petroleum gas, nuclear, and coal energy. The primary source of energy supplies as indicated in Figure 1 is insufficient to meet even the present energy need of Pakistan. Pakistan facing energy crises, has spend about billions of US dollars per year to import oil to meet its requirement, with annual growth rate of almost 1% the electrical energy is generated by two means in Pakistan i.e. renewable and non-renewable resources [data taken by WAPDA]

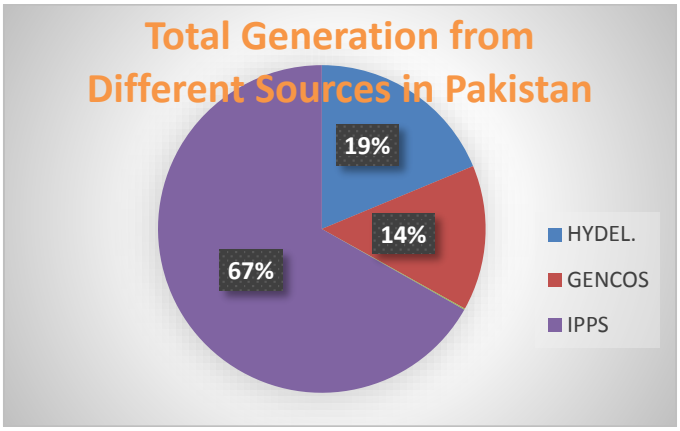

Figure 1: Total Generation from Different Resources in Pakistan

In order to cope with this crucial situation the government, ultimately made a plan and formulated the energy power policy focusing mainly on the development of thermal power sector to meet the energy demand on midterm basis. In this context in 1994 the government inked an agreement with the independent power producers (IPP's) to construct thermal power plants so that to get narrow the gap between the demand and supply.

In Pakistan the electrical power is generated mainly by using mostly non renewable sources of energy, such as fossil fuels (Furnace oil, Natural gas, Coal) nuclear and renewable sources like hydel, solar, wind power. The government shall needs to focus on it to exploit the potential of other renewable prospective energy sources, such as biogas, geothermal, tidal wave energy, so that to produce the clean electrical energy, which is being more environment friendly.

In this regard the government has planned and various strategies being implemented, in order to resolve the issue of power crises. One of the immediate and most cost effective way adopted on short term basis was to conserve the electrical energy by educating, motivating the people by bringing change in their behavior of energy consumption, by giving incentives, like two part tariff, subsidized the duties on efficient energy gadgets to industrial, commercial and

domestic consumers, enabling them to replace the inefficient energy consumption gadgets with the energy star and efficient one. It is pertinent to note that the energy conservation achieved in this way will required no need of heavy capital investment and long period of time.

Renewable Energy: In Pakistan the electrical energy produced using major conventional sources of fuel such as Fossil Fuels (Furnace Oil, HSD, and Natural Gas), Hydle and small part of nuclear. The other important clean and environment friendly electrical source of energy is renewable one. These sources of electrical energy are solar, wind, geothermal, biomass, hydle and tidal. In this very essential field to make benefit of the natural resources Pakistan is lacking. Now the government of Pakistan is vigorously pursuing to make use of this opportunity [1].

Figure2: Renewable Energy Sources

Non-Renewable Energy: It is the conventional source of energy which is being use at greater rate and depleting fast. The major sources of fossil fuels comprising, Furnace oil, LNG, Natural gas, HSD, Coal and Nuclear as shown in figure. Worldwide energy requirement is being met with mostly through use of the fossil fuels. On the other hand the massive use of fossil fuels by the highly industrialized as well as under developed world, poses critically environmental threat to the earth planet in the shape of emission of green house gases (GHG) and other health hazardous gases. The future prospect of non renewable energy share would still be at high level to meet the demand of electrical energy [2].

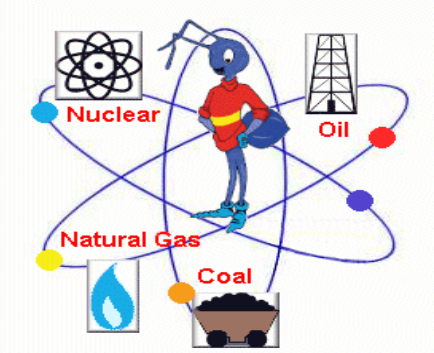

Figure 3: Non-Renewable Energy Sources

In Pakistan mainly the electrical energy is generated by using mostly non renewable sources of energy, fossil fuels (Furnace oil, Natural gas, Coal) nuclear and renewable sources such as hydel, solar, wind power. The other renewable prospective sources, biogas, geothermal, tidal wave energy which needs the focus of the government to exploit its potential to produce clean electrical energy, being more environments friendly.

The country faces severe short fall in electrical power since last two decades and still continue, which affect severely the development and economic growth as well as adds woes and miseries to the lives of people. After 1980 no major development have been done in the field of hydro electric power sector and ultimately the government made a plan and formulated energy power policy focusing mainly on the development of thermal power sector. In 1994 the government inked an agreement with the independent power producers to construct thermal power plants to narrow the gap between the demand and supply. The government vigorously peruses the policy of energy conservation, because there is tremendous potential to conserve the energy without being investing huge capital for the installation of power plants, by just adopting the energy conservation measures and replacement of inefficient electrical gadgets with the energy star and efficient one. In this regard to bring about the change in consumers behavior by educating them regarding the importance and necessity of the saving the electrical energy which help both, in the shape of reduction in the demand, and their cost of energy bill amount as well as saving in the national exchequer.

In the electrical transmission and distribution the technical Losses are occurs inevitably because of the characteristic property of the conductive material. Hence we have to try to keep it at minimum level. To keep it at minimum possible level it is necessary to find out the causes of losses in system and its remedial measures.

There are two types of technical losses i.e. fixed losses and variable losses as shown in figure. Fixed losses do not change as per change in current. These losses appear in the form of heat and noise. When the transformer is given supply these losses starts to occur. These losses are around 25% to 30% of total technical losses [2].

In the high voltage level transmission system corona losses occurs of which impact must be considered. Variable technical losses in system are mainly due to current opposition by resistivity of conductor and winding material of transformers. Variable losses differ with the amount of current. These losses are directly proportional to square of the current. The percentage of these losses turn around 75 to 80 that of total technical losses. We can reduce these losses by increasing the cross sectional area of lines and cables for a given load. These losses are analyzed through Computer Aided Simulations of Distribution Network. Accuracy depends on network operating parameters i.e. Load, Load Factor, System Configuration, Conductor Size, Diversity Factor, Voltage, Frequency, and Length of Line, Transformers and Load Density. At high voltage level the transmission losses are at the lower level comparatively, high quality of

power supply with no voltage drop, less burn out of motor. Extension of primary distribution line i.e. 11.5KV near to the premises of the consumer and Installation of low capacity single phase distribution transformers according to the load demand of consumer's instead of large capacity transformer feeding numerous consumers, will help in reduce the losses [7].

II. Litrature Review

The electricity is an essential commodity in the development and growth of the economy of the country. Electricity considered as a most important factor in production and consumption in the economy around the globe, (IEA, 2005). Demand for electricity is more than the supply of electricity generated in Pakistan. The total power generation capacity of Pakistan in 1947 was 60 Mega Watt (MW) and demand was almost the same. The installed capacity of electrical energy increased with the course of time i.e. in 1970 636 MW, in 1975 1331 MW, in 1980's 3000 MW and in 1990-91 8000 MW. As the population grew up the demand for consumption of electrical energy also increased in all sectors accordingly. During the period of 1960-1980 the main focus of the policy makers was on Hydel electricity generation projects but missing the idea of developing the power generation houses using alternatives sources of fuels in order to increase the generation and meet the demand of electricity. Resultantly there was gap between demand and supply occurs and the country start facing severe electric power shortages and outages, which has been affecting the lives of people in all sectors as well as slowed down the economic growth of the country [8].

In recent years main focus was made on the construction of thermal power plants with the main source of fossil fuel disturbing greatly the price of electricity in the country because the other alternative generation resources of electricity like hydel and renewable ones ignored miserably. This worst situation in shortfall of electricity and incapacitated power generation system unable to meet the total demand of the country raised because of the sheer lake of vision, commitment and political instability.

The major electrical power producers in the country are Water and Power Development Authority (WAPDA), Karachi Electric (K.E), Independent Power Producers (IPPs), Pakistan Atomic Energy Commission (PAEC). The total installed capacity of power in Pakistan is 22,797 MW in 2016 and with the passage of time the power houses become old and its efficiency, is dropped to almost 17000 MW. During the hot summer season the country faces a shortfall of around 4000MW to 5000MW.

From the day of independence till 1990's the country was self sufficient to meet its electrical energy demand, but no major power projects were established after 1980's and the demand was tremendously increased due to the load growth rate in the industrial, commercial and domestic sector, which signals the severe power crises to come in the near future. Many factors were contributing in the power crises of the country, such as the failure to construct timely the power houses, the incapacitated and old transmission and distribution system to cater the increase demand, result into system constraints, and poor administrative control (theft of electricity) and management on the distribution side. The PESCO (Peshawar Electric Supply Company) was facing such power crises in more crucial way because of the shortfall and its power system constraints.

The consumers lack the knowledge about the incentives to use and effectively applied the demand response program. There is another effective tool to response automatically to the incentives is the Home Energy Management (HEM) system. The main feature of HEM program is to minimize consumer bill amount that will contribute in making the consumer will take part actively in the demand response program to make it fruitful [3].

The sustainable socio-economic development mainly relies on a workable future power grid to gain this goal. A properly functioning future power grid will be able to contribute to (i) environmental friendly de-carbonization of energy sources, (ii) improvement in efficiency to process conversion and end user (iii) clean transportation [4].

Many consumers are investors who would have little interest in the electrical energy conservation due to the factors such as ignorance, lack of knowledge about the technical skill of modern technology and its financial impact. The financing issue is another factor which hinders the potential benefit to be achieved in this regard [5].

The Power Distribution Companies (DISCO's) and NPCC/RCC has planned to utilize the existing infrastructure in an efficient and cost effective way by reducing and shifting peak load demand during peak hours by installing Load Data Improvement Program (LDIP) and adopting two part tariff policy for the consumers which resultantly benefit the consumers by conserving electrical energy and saving the cost of bill amount [6].

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III. Motivation

Due to the prevailing power crises, since long therefore, the country in general and PESCO in particular, is being facing, huge scheduled and un-scheduled (due to system constraint), power outages (load shedding) for long hours, which has to be carried out to meet the gap between power supply and demand so that to ensure power network system stability, reliability and avoid total blackout and breakdown.

In order to mitigate the severity of the shortfall in electrical energy and to minimize the gap between demand and supply, the government should have planned and framed policies to provide and ensure all the available resources to execute these plans. For this purpose to achieve the goal, there are several plans which are to be considered and implemented on top priority basis i.e.

1- Immediate plan
2- Short term plan
3- Medium term plan
4- Long term plan

The problem of power crises needs to be resolved as earliest as possible to bringing relief and prosperity in the lives of public and meet the power demand of industry, cost effectively. There are several plans and strategies being considered and under implementation phase, the smart grid approach is one of the best prospective solutions to the problem. The smart grid apply the modern technology to involve and interact the general consumers with the power utilities smartly by diverting the huge energy consumption gadgets during peak demand hours to off peak low tariff zone.

IV. Automatic Meter Reading

Conventional meter reading data collected by human is not an efficient way to meet the continuously increasing demand of domestic sector. The automatic meter reading (AMR) system is the solution to this issue which functions in automated mode to record the readings and transmit to the remote control center automatically of all type of consumers such as industrial, commercial and domestic one.

The AMR meters use the communication module which enables it to receive and send the electrical data and other relevant information over the telecommunication network to central system. The AMR meters use one-way communication.

The conventional system had been in use since years needed to be replaced by modern system using the advance technology so that to redress the issues related with the conventional meter reading system. The extensive potential benefit and facility of this modern system, cannot be denied either by the utility or the consumers.

V. Load Data Improvement Program

Load Data Improvement program was installed in the Peshawar Electric Supply Company (PESCO) by using the modern technology of Automatic Meter Reading. Its main purpose is to monitor, supervise and control effectively the load management program with interaction of grid substation staff using this technology, in order to minimize un-scheduled load shedding and give relief to the general public and other consumers such as commercial and industrial ones. With the application of this program overloading of power and distribution network system during peak hours is made manageable, ensure stable power flow by avoiding unwanted breakdown, also make ensuring electrical energy conservation and reduced cost of consumer bill amount while carrying out load shedding implementation on the basis of composite efficiency index (CEI).

Advantages of Load Data Improvement Program:

- Minimizing the Technical Losses & Improves the system reliability
- Help Improves the System voltage
- Improves the power factor which results in demand reduction resulting electrical energy conservation.
- Helpful in Preventive Maintenance
- Help to avoid overloading of power transformer and extend its life.
- Reduces billing errors
- Maximize the service confidence.
- Maximize the information about power usage to conserve electrical energy and save money.

The Data received from the AMR meters installed at the 11KV incoming and outgoing feeders as shown in figure 4.

- AMR meters are installed at the Grid station 11KV outgoing panels, commercial and industrial consumers.
- From the grid station the meter sends the recorded data over the GPRS, GSM, 3G or 4G LTE, on the availability of each of them, and utilizes the media.
- The data is then transmitted to the Central Data repository Center at Lahore; the telecom center's installed MSC (Mobile Switching Centers) at the centre, enable to receive and consolidated the data near to real time for monitoring, control, supervision and analysis.
- At the Central Data Center 4 servers National Operation Center (NOCs) are installed which performs the functions.
    - One Receives the data from the meters installed at the incoming and outgoing feeders.
    - Second server performs the compilation process.
    - Third server maintains the database.
    - Fourth server supplies the data to the different end users i.e. NPCC/RCC, Ministry of Water and Power and Power Distribution Centers at company head quarter level.
- Web based application is used to access the server and retrieve the data from the Central Data repository Center and is accessed over a static IP internet connection.

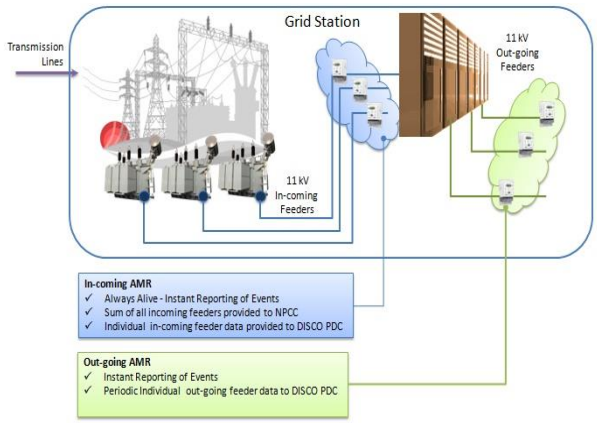

Figure 4: LDIP Architecture

VI. Proposed Methodology

By adopting this modern technology, enables the power distribution company (Discos) to apply CEI (Composite Efficiency Index) based load management plan, on all 11KV feeders for different periods of hours. Feeders having lowest figures of CEI are worst ones in terms of high losses and poor recovery of revenue, facing long duration of load shedding thus enabling to avoid overloading, breakdowns any damage to precious power equipments, ensuring smooth and stable load curve during the peak demand hours ,which results in to reduce the technical/administrative loss in power and distribution network system and ultimately conserves the energy and save the cost of bill amount of consumers and also the national exchequer in million of rupees

$$CEI = \frac{(100 - \%age\ Line\ Losses) * \%age\ Private\ Recovery}{100}$$

For example
Name of Grid Substation: 132 KV Sakhi Chashma
Name of 11KV Feeder: Chaghar Matti
%age Line Losses (Progressive July – June 2016)= 77.4
%age Private Revenue Recovery = 7.3

$$CEI = \frac{(100 - 77.4) * 7.3}{100}$$

CEI = 1.65 %age

The feeder lies in the category of 0 – 10 % range of CEI as shown in table 1, which reveals the worst condition in line losses and revenue and therefore the highest number of interruptions of power supply is carried out on this as well as on all such feeders accordingly in order to get narrow the gap between power supply and demand, avoid overloading, breakdown of power network system also result in electricity energy conservation and saving in the bill amount of consumer and the national exchequer during peak hours particularly. The percentage loss, recovery and CEI are depicted in figure 5 for 11KV feeders. Interventions are also presented in 1 hour interval in each case.

S.No	CEI Category	No of Interruptions Feeders (01-Hour Each)	No of 11KV Feeders
1	0 – 10 %	20	61
2	10.1 – 20 %	20	71
3	20.1 – 30%	16	76
4	30.1 – 40 %	14	61
5	40.1 – 50 %	12	63
6	50.1 – 60 %	6	104
7	60.1 – 70 %	4	104
8	70.1 – 80 %	4	88
9	80.1 – 90 %	4	35
10	90.1 % and Above	0	49
11	Industrial + other Feeders	0	200

Table 1: CEI categories for 11KV feeders

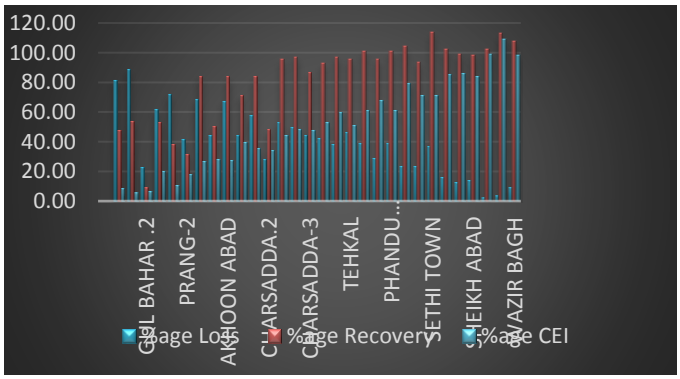

Figure 5: %age Loss, Recovery & CEI

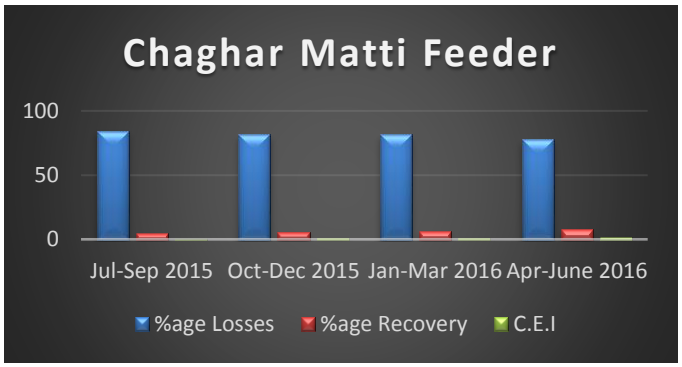

Figure 6: Chaghar Matti Feeder

Figures 6, 7 and 8 represent the same percentage data of selected feeders of Chaghar Matti, Lala and Mall road respectively. The data analysis is being presented for 1 year.

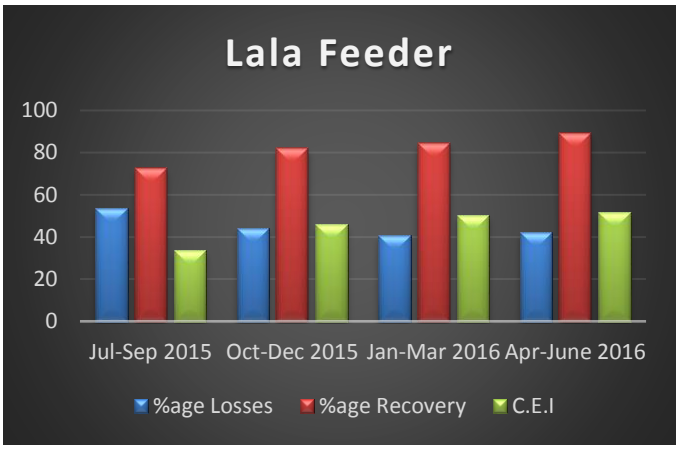

Figure 7: Lala Feeder

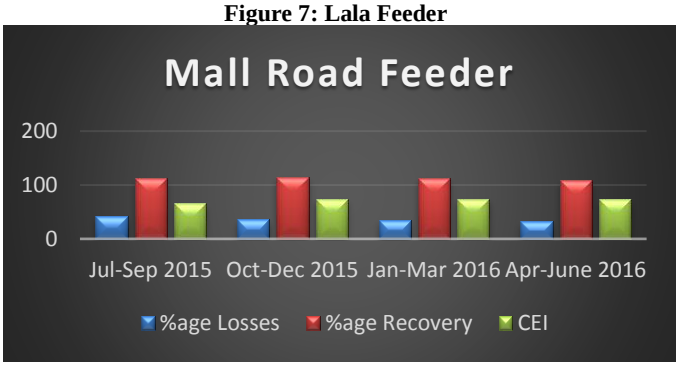

Figure 8: Mall Road Feeder

Month	Quota Allowed (MW)	Power Utilized (MW)	Saving (MW)	Load Shedding (MW)	Computed Demand (MW)
Jul-15	1543	1342	201	837	2179
Aug-15	1728	1453	274	807	2261
Sep-15	1690	1358	332	820	2179
Oct-15	1592	1324	268	673	1997
Nov-15	1328	1110	217	613	1723
Dec-15	1316	988	328	717	1705
Jan-16	1438	1017	421	901	1918
Feb-16	1492	986	506	1055	2041
Mar-16	1454	984	470	913	1897
Apr-16	1347	925	422	838	1763
May-16	1312	978	334	899	1877
Jun-16	1564	1278	287	927	2205
Average	1484	1145	338	833	1979

Table 3: PESCO power flow data for 1 year

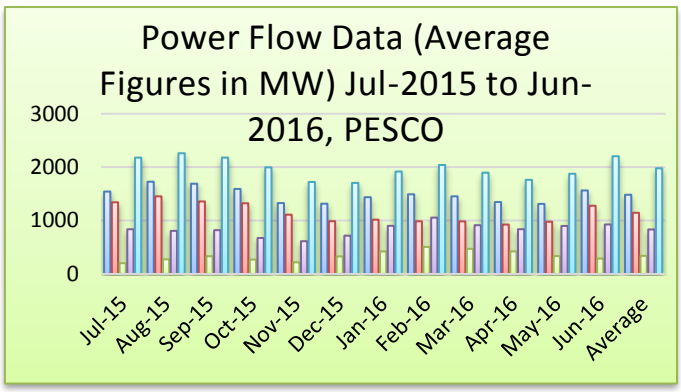

Figure 9: Showing PESCO Power Flow

The figure 9 illustrates the one year July 2015 to June 2016 the quota allocated, power utilized, saving, load shedding and computed demand of the PESCO. The saving in power is made possible due to the CEI based load shedding being carried out indiscriminately on the 11.5 KV distribution feeders, represented by the green vertical lines.

VII. Conclusion

This system provides almost near to real time information regarding power flow in the network system and enabling the operator sitting in the control room to monitor, control and analyze it so that to avoid unscheduled load shedding, overloading, brownout and save power network system from the blackout and conserve energy.

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