**IMPROVING INDIGENOUS DISTRIBUTION POWER SYSTEM EFFICIENCY USING POWER LOSS REDUCTION**

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**UNIVERSITY OF GUJRAT**

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**MUHAMMAD RAMIZ M.Sc Electrical Engineering 2016-18**

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**A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of Degree of**

**M.Sc**

**In**

**Electrical Engineering**

**BY**

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**(Muhammad Ramiz)**

**DEDICATION**

Dedicated to my parents (late) who always prayed and wished me the success in life. Their guidance and support will be missed in rest of my life.

**(Muhammad Ramiz)**

**DECLARATION**

I Muhammad Ramiz S/O Dildar Hussain, roll # 16064422-005, M.Sc Electrical Engineering scholar, Department of Electrical Engineering, Faculty of Engineering & Technology, University of Gujrat, Pakistan, hereby solemnly declare that this thesis titled “Improving indigenous distribution power system efficiency using power loss reduction” is based on genuine work, and has not yet been submitted or published elsewhere. I Furthermore, I shall not use this thesis for obtaining any other degree from this university or any other institution.

I also understand that if evidence of plagiarism is provided in my thesis at any stage, even after the award of the degree, the degree may be cancelled and revoked by the University authority.

**(Muhammad Ramiz)**

It is certified that Muhammad Ramiz S/O Dildar Hussain, roll # 16064422-005, M.Sc Electrical Engineering scholar, Department of Electrical Engineering, Faculty of Engineering & Technology, University of Gujrat, Pakistan, worked under my supervision and the above stated declaration is true to the best of my knowledge.

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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**THESIS** **COMPLETION CERTIFICATE**

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**ABSTRACT**

The current scenario of Pakistan power sector stipulates the financial and technical viability of the utility companies to meet the escalating demands of electricity. Financial resources are required for generation of electricity which Pakistan cannot afford in the present situation. Rather than generating more electric power, it is optimum to save the available electric power by upgrading the electric system. This research work focuses on the proposed strategies for Distribution Companies to upgrade the power distribution system by adopting the modern technologies.

# CHAPTER- 1

## INTRODUCTION

Improving the efficiency of the distribution system by technical analysis and loss reduction are the well known areas of every power system network and the major component of the power system that continuously contribute to the power losses is the transformer (Agüero & Member, 2012). The transformer is not the electricity generator but they are used in the electrical system to step-up or step-down the voltage so they are used as the voltage changers. The transformers are not 100 percent efficient because electrical losses are associated with the transformer. Inherently the efficiencies of the distribution transformers are elevated than those of other electrical systems. They are, however in the constant operation and comparatively have the long lifespan. As a consequence, a small rise in effectiveness can lead to handsome amount of energy savings over the transformer's lifespan (Najgebauer, Chwastek, & Szczyg owski, 2011).

The effect of transformer losses on system efficiency has been studied several times over the course of time. For example, study on the transformer losses was performed in 1977 by D.S Takach senior member of IEEE, Missouri observed that the yearly cost of the steel losses would be $1.23 billion if the consumed energy cost is about $0.03/KWh. Also evaluations in the utilities showed that the cost of NL losses can be in the range from $4000/KWh to $13500/KWh. Therefore, the evaluated cost of some transformers with NL loss will be high as compared to the initial cost of the transformer. The main subject of the transformer was NL losses but the factors that affect the activity of transformer and their measurement will become more important (Allen, 1984).

In the 1980s and 1990s, the efficiency of distribution transformer was improved due to the new and modern improved materials and manufacturing method but even then T&D losses were considered about 26.6% (Olivares et al., 2003). Improvement in the material core can reduce transformer losses extensively. Silicon steel lamination forms the transformer cores. These are also called electrical steel. Iron has ability to rapidly changing electrical field because it is a good conductor of electricity. The presence of varying magnetic fields produces very heavy and intense eddy currents. The electromagnetic shield can also reduce transformer losses because it prevents stray losses (Beaumont, 1988).

The fast transformation of molten metal alloy to solid metals was tried to increase solubility of solids into other forms of metals in the early 1950. At that time the “gun technique” was applied by P.Duwez for the formation of quick cooled metals but there was not any important progress occur until 1959. To eject the melted metal on the substrate of room temperature the shock wave technique was used and main purpose of this technique was to establish a stable amorphous metal alloy which required metal alloy to be cooled at very fast rate. There was another technique was formulated in which the liquid metal was ejected to spread out among the cold sides of an anvil and a piston is called “piston-anvil”. The modification of studies occur into silver-silicon, copper-germanium, copper-silicon, silver-germanium and gold-silicon alloys (Ng et al., 1991).

In the amorphous phase the quick solidification of the gold-silicon alloy was obtained under lowest melting point of the metal composition. The conversion of this amorphous alloy at a stable room temperature was led to palladium-silicon alloys. Tsuei and Duwez formulate successfully palladium-iron-silicon and palladium-cobalt-silicon showing “ferromagnetism” by transformation of palladium with cobalt, iron and other transition metals. The traditional metals with crystalline structures have similar interaction as in amorphous metals (Ng et al., 1991).

Duwez and Lin introduced amorphous metal with extra ordinary ferromagnetic properties successfully in 1966 that are based on iron-phosphorous-carbon. The extraordinary features of magnetism presented by the composition of iron, phosphorous, carbon. It is interesting to know that the amorphous iron-base alloy was obtained accidently when carbon crucible was used inadvertently with iron phosphorous, resulting in an amorphous iron-phosphorous-carbon alloy (Ng et al., 1991).

First iron base amorphous alloy was discovered with high rate of induction saturation that made it possible to use this metal in applications like transformer cores in around 1972. Chen and Polk discovered the iron-phosphorous-carbon alloys by using splat-cooling method. The formulation of amorphous ribbon is improved by the addition of elements like aluminum, silicon. It was recommended to formulate the crystalline structures of metals rather than amorphous because it was unexpectedly soluble in solid form of transition metals such as iron. This conclusion resulted in a milestone patent. In 1975 amorphous metals were produced by using casting techniques in the form of ribbon which were being used in the core of distribution transformers (Ng et al., 1991).

The property due to which amorphous core preferred on steel core is extreme low magnetizing losses for the transformers. As compared to conventional transformers the experimental transformers that are coated with amorphous metals having a 70% reduction in losses (Okonek, 1998). There is no crystallization of atoms occurs in amorphous metal alloys that differ it from the other metals. But these have a similar property like atoms are arranged in an instructed manner as in the gasses and other metals. Magnetization and demagnetization property are present in the amorphous metal alloys but No-load losses can be reduced from 60-70% in amorphous core transformers as compared to traditional transformer made up of silicon steel alloys. Because there are atoms do not contain crystallization that’s why amorphous metal alloys are differing from silicon steel metals. Random grain and magnetic domain structure are present that give high permeability as compared to conventional material resulting in a narrow area of hysteresis curve which reduces overall core losses (Soltanzadeh, Tavakoli, & Arbab, n.d.).

### 1.1: Problem Statement

Every electricity utility company has large number of distribution transformers which are used to distribute the electricity to the domestic and industrial consumers while the Installation and maintenance of distribution transformers are normally performed on daily basis. Whenever a distribution transformer is damaged or interrupted due to overloading or short circuits then a lot of electricity consumers are affected instantly without any prior notice. In such situation, the industrial consumers have to suffer adversely because interruption in the electric supply stops the production process and huge financial loss can happen to the owners of the industries. On the other hand domestic users also cannot afford the interruption in the electricity supply especially in the summer season when temperature is too high; hence reliability of the distribution transformer is mandatory for every electrical distribution system (Kogan, 1996). As the following research is based on efficiency of distribution system of the Gujranwala Electric Power Company (GEPCO) that has almost 65930 distribution transformers of different ratings that are installed according to the requirement of the load capacity. Recently there is extreme shortage of field workers in the GEPCO Company due to which process of clearing the fault on distribution transformer is very sluggish, especially when distribution transformer is interrupted at far end locations and only one are two persons are available on whole feeder to rectify the faults. Also the distribution transformers used in the GEPCO are of silicon steel core that emit green house gases and exhibits a handsome amount of NL and ON Load power losses (Inagaki, 2013.). ON load losses of the transformer are those which varies with the value of load connected but NL losses are fixed in range and present till the time the transformer is in ON position (Ramos & Chiachia, 2011). Due to the NL losses of the distribution transformers, GEPCO is bearing not only the huge economic loss but also the significant power of electric power is lost for no reason on daily basis. Therefore, for more efficient distribution system it required to upgrade the structure of distribution transformer in such a way that it would offer minimum power losses, high reliability, and be environment friendly having excellent performance on full load conditions.

### 1.2: Objectives and Scope of Study

To Main objective of the research are

* To analyze the indigenous and international power systems to find the major causes of power system losses
* To investigate the constraints of distribution system for power loss reduction
* To suggest new effective techniques to overcome power losses in the distribution network
* To elaborate the economic aspects of the proposed techniques of more efficient power distribution system

The research is aimed to study the indigenous power system of Pakistan for which GEPCO is selected as a role model and main focus is on improving the efficiency of the distribution system through latest power loss reduction techniques. After achievement of desired result the proposed model would be used by the Electrical distribution companies in the country to improve the efficiency of the power system by power loss reduction and to overcome the previous drawback due to which losses are being increased to maximum value.

For successful completion of research work it is required to have scheduled visits to power grid stations, testing labs and sub divisional offices of the GEPCO Company for collection of required data, collaboration with staff of planning department for software based evaluation, analyzing the performance of technical equipment with the standard figures to estimate the power loss factor and final comparison of outcome data with present data will provide the expected results.

# **CHAPTER– 2**

## **LITERATURE REVIEW**

**2.1: Power Sector Background of Pakistan**

In 1947, when Pakistan came into existence, its total population was 31.5 million and the total power production was only 60MW which means that every individual was able to consume only 4.5 units of electricity (Javaid, Hussain, Arshad, Arshad, & Idrees, 2011). Since 1913 Karachi Electric Supply Company (KESC) had been working as a private organization and was supplying the electricity to the Karachi and its nearby villages. After intendance of Pakistan in 1947, The Government of Pakistan took the charge of KESC in 1952 and handed over the responsibility of generation, T&D of electric power to the residential, commercial and industrial consumers of the country (Iqbal, Nawaz, & Anwar, 2013).

For the sake of development in the field of water and power sectors of the country, a semi-autonomous authority named as Water and Power Development Authority (WAPDA) was established in 1958 which was responsible of generating power through hydal and thermal generation projects (Javaid et al., 2011). In 1959 Pakistan entered in the zone of development by enhancing the power generation capacity to 165MW, and the efficient transmission network and distribution systems were established to overcome the swiftly increasing demand of energy. In 1965, the power generation capacity increased to 636 MW which was further raised to 1331MW in 1970 due to the addition of mangle dam in 1965 (Rauf, Wang, Yuan, & Tan, 2015).

Although Pakistan Atomic Energy Commission (PAEC) was established in 1956 but solemn efforts had been performed after 1960s, when Government of Pakistan had decided to work on nuclear projects and as a result Pakistan had started its first nuclear power reactor named as Karachi Nuclear Power Plant (KANUPP) in 1971 whose production was 137MW and it was really a striking effort towards the nuclear power generation (Khan & Ashraf, 2015). In 1976, the hydel generation capacity was lifted up with the construction of Terbella Dam and the total electricity generation was reached to 3000MW in 1980 (Iqbal et al., n.d.). After 1980 energy department struggled hard to increase the power production in accordance with the demands of residential, commercial, agriculture and industrial sectors but unfortunately the energy production growth lagged behind the energy demands. Also the growth in energy demand was around 4% annually till 1990s (Review, 2015).

In 1992 Govt. of Pakistan had planned to privatize the WAPDA and decided to acquire thermal generation from Independent Power Producers (IPPs) in 1993-1994. National electric regulatory authority (NEPRA) was came into existence in 1997 and its main responsibilities are to formulate policies, planning, implementation, operation and maintenance so as to provide reliable electricity facility to consumers (Kamran, 2018). In 2000s, the demand of electricity increased to 7% annually whereas in 2006-2007 the energy crises of Pakistan were at the worst level since the time of inception. Furthermore in May 2011 the energy shortfall crossed 7000MW which resulted in continuous load shedding of 8 to 10 hours in urban areas and 18 to 20 hours in rural areas of Pakistan (Rauf et al., 2015).

In 2014, the total installed capacity of power generation in the country was 22241MW which was further raised to 11.8% in 2015 and installed capacity was jumped to 24857MW. A comprehensive analysis on development of electric power for the year 1990 to 2015 in Pakistan performed by researchers of Blekinge Institute of Technology in 2015 and reveals results shown in figure-2.1 (Khan & Ashraf, 2015).

**Figure-2.1: Electric Power Development Since 1990s**

(Khan & Ashraf, 2015)

Figure 2.1 shows that there was maximum of 18.5% development achieved in the year 1994, while the minimum development in production of electricity was happened in the year 2012. In June 2015, the total shortfall of electricity was 5201MW which was supposed to be sustained till 2018 as projected by National Transmission and Dispatch Company (NTDC) because Pakistan in spite of having installed capacity of 24857 MW containing major share of 67.74% of thermal power plants, was hardly able to prevail over demand of 21701MW of electric power (Khan & Ashraf, 2015). According the quickly increasing demand of electricity, NTDC projected the electricity demand and supply for the year 2016-2020 which is shown in figure-2.2 (Kamran, 2018).

**Figure-2.2: Projected Power Demand and Supply for the Period 2016-2020**

(Kamran, 2018)

Figure 2.2 reveals that in 2016 the gap between electricity demand and supply was 4906 MW which was reduced to 3175MW in 2017, while in the year 2018 there was almost zero percent shortage of electricity was noticed in the country (Kamran, 2018). As the production capacity is increasing 7% while the demand is increasing 10 % annually and hence the power requirement in the country would be greater than 45000 MW till the year 2030 (Review, 2015).

2.2.5: Distribution Companies (DISCOs)

There are total 10 distribution companies (DISCOs) are functional for the sake of distributing the electric power throughout the country and recovering the bill payments from consumers. Names of DISOs and their electricity demand is presented in table-2.2 (ICCI, 2013) (“CPPA,” 2019.).

|  |  |  |
| --- | --- | --- |
| Table-2.2: Name of DISCOs and Electricity Demand | | |
| **S/No** | **Name of DISCO** | **Demand** |
| 01 | Lahore Electric Supply Company(LESCO) | 5270 MW |
| 02 | Faisalabad Electric Supply Company(FESCO) | 3082 MW |
| 03 | Gujranwala Electric Power Company(GEPCO) | 2276 MW |
| 04 | Multan Electric Power Company(MEPCO) | 3769 MW |
| 05 | Islamabad Electric Supply Company(IESCO) | 2565 MW |
| 06 | Hyderabad Electric Supply Company(HESCO) | 1290 MW |
| 07 | Peshawar Electric Power Company(PESCO) | 3170 MW |
| 08 | Quetta Electric Supply Company(QESCO) | 1715 MW |
| 09 | Sukkur Electric Power Company(SEPCO) | 1074 MW |
| 10 | Tribal area Electric Supply Company(TESCO) | 833 MW |
|  |  | (“CPPA,” 2019.) |

PAEC is

**

(Rengaraju & Pandian, 2014)

Figure-2.13 shows that Advanced Metering Infrastructure (AMI) was used along with home area network. Substations are using sensors for automation purpose. Video surveillance through Unmanned Arial vehicle (UAV) is being employed for remote monitoring. Among non-technical loss, electricity theft which is performed either by bypassing the energy meter or by manipulating the energy meters. Main unfair means of electricity theft are listed below (Rengaraju & Pandian, 2014)

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# CHAPTER- 3

## RESEARCH METHODOLOGY

3.1: Introduction to GEPCO

Gujranwala Electric Power Company (GEPCO) was established in 1977 as Area Electricity Board Gujranwala under the supervision of WAPDA. In 1998, GEPCO was declared as Distribution Company due to bifurcation of WAPDA and overall

# CHAPTER- 4

## RESULTS AND DISCUSSION

In this chapter two types of analysis have been performed. First one is the NL loss analysis in which NL losses of silicon core transformer and amorphous core transformer has been practically compared in the transformer testing lab. After performing NL analysis we shall be able to know the more efficient transformer between silicon core and amorphous core transformers. We are considering only NL loss analysis because we have only changed the core of the transformer and rest of parameter will remain the same therefore ON load losses are assumed to be same for both categories. The second analysis is the economic analysis which is a combination of initial cost of transformer and cost of NL losses of transformer. After performing economic analysis we shall be able to reveal the economic aspects of both types of transformers.

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# CHAPTER- 5

## CONCLUSIONS AND RECOMMENDATIONS

Currently the power sector of Pakistan is facing the major challenge of controlling line losses and electricity theft due to which load shedding is being applied on high loss feeders. On the other hand, overall losses in power distribution system are not only dropping the efficiency of the power system but also causing the massive economic loss for the power distribution companies. According to the literature review, power generation of Pakistan was 24828MW till 2018 in which 68% power is generating from the thermal resources. As the cost of thermal generation is very much high as compared to other type of generations therefore, for providing the electricity to the consumers at affordable rates Government of Pakistan has to bear the extra cost of thermal generation as compared to hydel generation. In such situation it is required to produce cheap electricity by installing new hydel projects, however due to present economic crisis in the country it is difficult to attain the financial resources. Hence the best strategy for optimization of power system is to save the available electric power except of generating more electricity.

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**APPENDIX-01**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Abbreviations Used in the Thesis** | | | | |
| **S #** | **Items** | | | **Abbreviations** |
| **1** | Transmission and Distribution | | | T&D |
| **2** | Gujranwala Electric Power Company | | | GEPCO |
| **3** | Karachi Electric Supply Company | | | KESC |
| **4** | Water and Power Development Authority | | | WAPDA |
| **5** | Pakistan Atomic Energy Commission | | | PAEC |
| **6** | Karachi Nuclear Power Plant | | | KANUPP |
| **7** | Independent Power Producers | | | IPPs |
| **8** | Captive Power Producers | | | CPPs |
| **9** | Small Power Producers | | | SPPs |
| **10** | Gross Domestic Product | | | GDP |
| **11** | National Transmission and Dispatch Company | | | NTDC |
| **12** | Alternative Energy Development Board | | | AEDB |
| **13** | Pakistan Electric Power Company | | | PEPCO |
| **14** | Private Power Infrastructure Board | | | PPIB |
| **15** | Generation Companies | | | GENCOs |
| **16** | Distribution Companies | | | DISCOs |
| **17** | National Electric Power regularity Authority | | | NEPRA |
| **18** | Chashma Nuclear Power Plant Unit | | | CHASNUPP |
| **19** | Government of Pakistan | | | GoP |
| **20** | Supervisory Control and Data Acquisition | | | SCADA |
| **21** | Non-Technical Losses | | | NTLs |
| **22** | No Load | | | NL |
| **23** | Advanced Metering Infrastructure | | | AMI |
| **24** | Distributed Generation | | | DG |
| **25** | Volt VAr Optimization | | | VVO |
| **26** | Electrical Transient Analyzer Program | | | ETAP |
| **27** | Mian Muhammad Panah | | | MMP |
| **28** | Small Industrial Estate | | | SIE |
|  | |  |  | |

**APPENDIX-02**

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| --- | --- | --- | --- | --- |
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