SAARC Study
Assessment of Energy Efficiency Potential through Energy Audit of Power Transmission and Distribution Grid Stations in Pakistan

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SAARC Energy Centre, Islamabad

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Foreword

SAARC Energy Centre (SEC) is mandated to initiate, coordinate and facilitate regional cooperation in energy sector in South Asia. It provides relevant information, updates on technology, and necessary expertise to the SAARC Member States to promote the integration of energy strategies within the region.

Import dependence for energy supplies in the Member States varies between 25% in case of Bhutan to 100% in case of Maldives [1]. With accelerated economic development, the energy consumption is increasing rapidly with resultant increase in further import dependence. Inefficient use of energy to support such economic growth further compounds the rate of growth in energy use with consequent environment degradation. Member States, therefore, need to prioritize energy efficiency to become competitive in the global market besides getting environmental dividends.

The draft SAARC Action Plan on Energy Conservation was accordingly prepared by SEC. The Plan also included the elements of SAARC Road Map on Energy Efficiency & Energy Conservation, recommendations of SAARC Working Group on Energy and various other valid suggestions made at several energy forms held in the region.

Keeping in view the above, SAARC Energy Center, Islamabad has been working towards achieving optimal energy efficiency. In this context, SEC launched a short term study for assessing energy efficiency potential through energy audit of Power Transmission and Distribution Grid Stations of Pakistan, which like other SAARC Member States is also an energy deficit country. For this purpose, services of Engr. Sohail Mumtaz Bajwa were engaged as a short term consultant. He was assigned a task to conduct energy audit of two grid stations, one from National Transmission and Dispatch Company (NTDC) and one from Lahore Electric Supply Company (LESCO).

The results of the study, which are highly important in view of real time data and situation in the power grid of Pakistan, shall be shared with the Member States in order to develop a future Road Map on Energy Efficiency & Energy Conservation as per recommendations of SAARC Working Group on Energy.

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Abbreviations and Acronyms

CPPA	Central Power Purchasing Agency
CSP	Concentrating Solar Power
CT	Current Transformer
DC	Direct Current
DISCO	Distribution Company
GENCO	Generation Company
GWh	Giga Watt-Hour
kVA	Kilo Volt-Ampere
kWh	Kilo Watt-Hour
LESCO	Lahore Electric Supply Company
Member States	South Asian countries including Afghanistan, Bangladesh, Bhutan, India, Nepal, Maldives, Pakistan and Sri Lanka
MWh	Mega Watt-Hour
MVAR	Mega VAR
N/A	Not Available/ Not Applicable
NEPRA	National Electric Power Regulatory Authority, Pakistan
NTDC	National Transmission and Dispatch Company, Pakistan
PT	Potential Transformer
PTW	Permit to Work
PV	Photovoltaics
T&D Loss	Transmission and Distribution Losses
T/F	Transformer
T/L	Transmission Line
SEC	SAARC Energy Centre, Islamabad
STE	Steam Turbine Engine
STG	Steam Turbine Generator
SVC	Static Var Compensator

Abstract

The objective of this research study is to conduct an energy audit of selected gird stations of power system of Pakistan in order to draw a picture of energy profile of the selected grid stations, which may ultimately help in achieving and maintaining optimum energy procurement and utilization by the utilities.

Pakistan is one of the developing countries facing acute shortage of power. Among others, the major reason for the sharp contrast between power supply and demand is T&D losses. As reported by Private Power and Infrastructure Board (PPIB), Ministry of Water and Power, the overall T&D losses were 20.13% in 2013[2]. Pakistan's T&D losses are well above the global average, even in comparison with developing countries. In Pakistan Power Sector, cost of energy and demand is rapidly increasing with respect to other countries. The two logical ways to bridge the gap between supply and demand are either increase the supply or curtail the demand through Energy Conservation/Energy Management. This report pertains to the later since it is the lowest hanging fruit.

The total energy loss measured at 220 kV Kot Lakhpat Grid Station of NTDC in terms of percentage of total energy import is 0.602 %. The breakup of these losses is as under:

220 kV Transformer Losses = 0.1249%

220 kV Switchyard Losses = 0.1489%

132 kV Switchyard Losses = 0.3335%

In the perspective of distribution sector, the total energy loss measured at 132 kV Qurtaba Grid Station of LESCO in terms of percentage of total energy import varies between 1.7% and 2.9%.

CHAPTER 1. Background

1.1 Power System

Electric power systems are real-time energy delivery systems i.e. power is generated, transported, and supplied the moment you turn on the light switch. Electric power systems are not storage systems like water systems and gas systems. Instead, generators produce the energy as the demand calls for it.

Generation, Transmission and Distribution are basic elements or sub-systems of a power system. Grid station or sub-station is the connection between these sub-systems. Figure 1.1 shows basic block diagram of a power system.

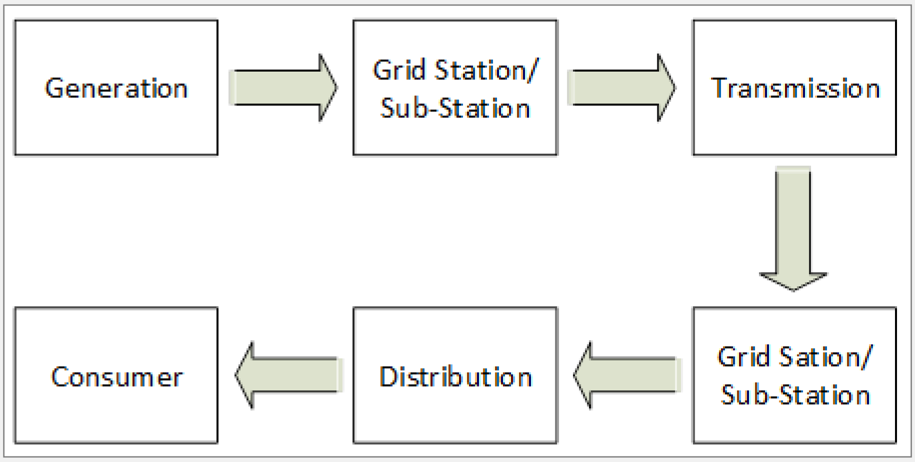

Figure 1.1: **Block Diagram of Power System**

1.2 Generation

Power generation plants produce the electrical energy that is ultimately delivered to consumers through transmission lines, substations, and distribution lines. Generation plants or power plants consist of three-phase generator(s), the prime mover, energy source, control room, and substation.

Generation of electricity is simply a conversion of energy of other form to electrical energy. Common types of energy resources used to generate electricity are:

- Fossils Fuels (coal, gas, oil)
- Nuclear
- Geothermal
- Hydro
- Solar

Typical generation voltages are 6.6, 11, 13.2 and 33 kV.

Fossil

For fossil fuel, steam turbines are used to generate electricity. Steam turbine power plants can use coal, oil, natural gas, or just about any material as the fuel resource.

High-pressure and high-temperature steam is created in a boiler, furnace, or heat exchanger and moved through a steam turbine generator (STG) that converts the steam's energy into rotational energy for turning the generator shaft. The overall steam generation plant efficiency varies from 20 to 35%.

Some of the drawbacks that could be encountered with coal fired steam generating power plants are:

- Environmental concerns from burning coal (i.e. acid rain)
- Transportation issues like rail systems for coal delivery
- Length of transmission lines to remote power plant locations

Nuclear

In nuclear power plants, a controlled nuclear reaction is used to make heat for producing steam needed to drive a steam turbine generator. Nuclear power plants don't require a lot of space, but they have to be built near a large water reservoir for cooling purposes. Disposal of nuclear waste is quite expensive; since it is radioactive, it has to be disposed of in such a way as it will not pollute the environment.

Geothermal

Geothermal power plants use hot water and/or steam located underground to produce the electrical energy. The hot water and/or steam are brought to the surface where heat exchangers are used to produce clean steam in a secondary system for use with turbines. Clean steam causes no sediment growth inside pipes and other equipment, thereby minimizing maintenance. The clean steam is converted into electrical energy much the same way as in typical fossil fueled steam plants.

Although geothermal energy is considered to be a good renewable source of reliable power, some are concerned that over the long term, the availability of this geothermal resource for power plants may be reduced over time.

Hydro

Hydroelectric power plants capture the energy of moving water, however, there are multiple ways for extracting the hydro energy. Falling water such as in a penstock, flume, or waterwheel can be used to drive a hydro turbine. Hydro energy can be extracted from water flowing at the lower section of dams, where the pressure forces water to flow. Hydroelectric power generation is efficient, cost-effective, and environmentally cooperative. Its production is considered to be a renewable energy source because the water cycle is continuous and constantly recharged.

Hydro units have a number of excellent advantages. The hydro unit can be started very quickly and brought up to full load in a matter of minutes. In most cases, little or no start-up power is required. A hydro plant is almost by definition a black start unit, A black start unit is the one which does not require electrical power to start. Hydro plants have a relatively long life; 50–60 year life spans are common. [3]

Solar

There are two primary technologies by which solar energy is commonly harnessed: photovoltaics (PV) and concentrating solar power (CSP). Solar energy can be more appropriately deployed through distributed generation, whereby the equipment is located on rooftops or ground-mounted arrays close to where energy is used.

The photovoltaic (sometimes called “voltaic” for short) type of solar power plant converts the sun’s energy directly into electrical energy. This type of production uses various types of films or special materials that convert sunlight into direct current (dc) electrical energy systems. Panels are then connected in series and parallel to obtain the desired output voltage and current ratings. Some systems use an energy storage device (i.e. battery) to provide electrical power during off sun-peak periods. This dc energy is converted to utility ac energy by means of a device called an inverter.

Concentrating solar power technologies use mirrors to concentrate (focus) the sunlight energy and convert it into heat for creating stream to drive a turbine that generates electrical power. CSP technology utilizes focused sunlight. CSP plants use mirrors to concentrate then sun’s energy and convert it to high-temperature heat. That heat is then channeled through a conventional generator. The plants consists of two parts: one that collects solar energy and converts it to heat, and another that converts the heat energy to electricity.[4]

1.3 Transmission

Electrical transmission systems carry large amount of power from power generation plants to electrical substations located near loads. Transmission systems can be sub-divided into two primary transmission and secondary transmission. Now-a-days transmission is almost exclusively three-phase.

The power generated at generating station is of low voltage level, however, this low voltage level power cannot be transmitted directly to consumer end since it does not involve an economical process. Electrical power is directly proportional to the product of electric current and voltage of system. So for transmitting certain electrical power from one place to another, if the voltage of power is increased then associated current of this power is reduced. Reduced current means less I^2R losses in system and less cross sectional area of conductor. Electrical power is thus transmitted at high voltage levels because of these reasons. The transmission voltage is, to a large extent, determined by economic considerations. High voltages require conductors of smaller cross-section which results in economy of copper and aluminum. But at the same time cost of insulating the line and other expenses are increased. Hence, the economical voltage of transmission line is one for which the saving in copper or aluminum is not compromised.

Typical transmission voltages are 500 kV, 220 kV, 132 kV, and 66 kV. Over-head transmission line and underground cable both are used for transmission purposes.

1.3.1 Over-head Transmission

Overhead transmission is cheap and there are no heating problems. In overhead lines, conductors are not covered by insulation instead air is used for insulation. Due to this reason, design of these lines requires a minimum clearance distance between them. But these lines suffer from adverse weather conditions, rain, wind and varying temperature.

1.3.2 Underground Transmission

Underground transmission is usually three to ten times costlier than the overhead transmission due to right of way requirements, obstacles, and material costs. It is normally used in urban areas or near unique infrastructure such as airports where overhead transmission is not an option. Cables are made of solid dielectric polyethylene materials and can have ratings on the order of 400 kV.

1.4 Distribution

Distribution system can also be divided into two subsystems- primary distribution and secondary distribution, similar to transmission systems. At the end of transmission line there is a sub-station/grid station, which preferably lies at the outskirts of a city because it is not safe to bring high voltage transmission lines into the city. Here voltage is stepped down to a safe level. Typical distribution voltages are in range of 3 kV to 33 kV.

For secondary distribution, power lines from sub-station (usually called feeders) are brought into the cities, where consumer connections are supplied from secondary of distribution transformers. These distribution transformers are located near loads and they can be either pole-mounted or else housed in kiosks at suitable points. The most common secondary distribution is 400/230 V, 3-Phase 4-wire system. Consumers are connected to distribution system through their service mains. The single-phase residential loads are supplied from any one line and the neutral whereas 3-phase, 400V is connected across 3-phase lines directly.

1.4.1 Configurations of Distribution

Distribution networks are divided into two types, radial or network, each explained below.

Radial Distribution

In this system, a number of independent feeders branch out radially from a common source supply i.e. sub-station. The distribution transformers are connected to taps along the lengths of feeders. A radial system is shown below in Figure 1.2.

One of the main disadvantages of this system is that the consumer has to depend on one feeder only so that if a fault or breakdown occurs in the corresponding feeder, his supply of power will completely cut off till the fault is repaired. Hence there is no absolute guarantee of continuous power supply.

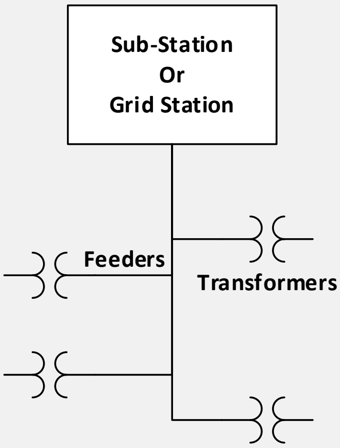

Figure 1.2: **Radial Distribution System**

Ring Distribution

For maintaining continuity of service, ring distribution system as shown in the Figure 1.3 is employed.

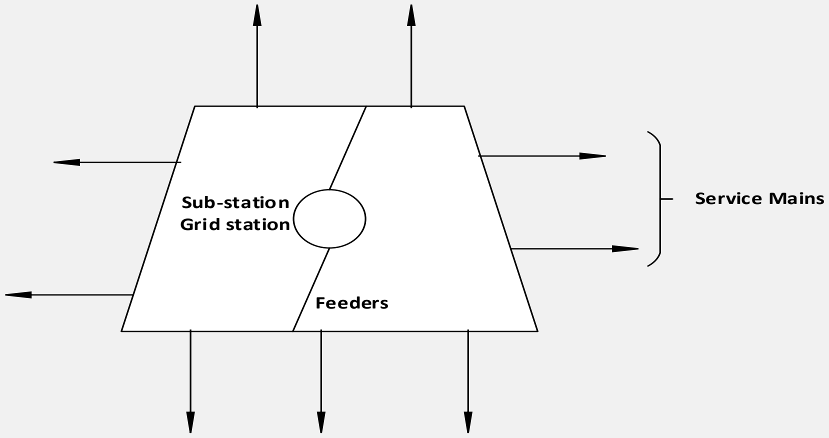

Figure 1.3: **Ring Distribution System**

Two feeders from sub-station provide power to the ring distributor. The ring distributor forms a complete loop and has isolating switches provided at the poles for isolating a particular section in case of faults. In this way, continuity of service can be maintained to other consumers on healthy section of ring distributor. The service mains are the connecting links between the consumer's terminals and the ring distributor. [5]

1.5 Sub-Station / Grid Station

As stated earlier, sub-station/grid station is a connection between generation, transmission and distribution. These sub-stations do not generate electricity; role of a substation is to regulate power supply in the network and to take care of the following functions:

- Transform voltage from high to low, or the reverse
- Helping manage voltage fluctuations
- Providing crucial network protection from electrical faults or equipment failure
- Allowing control of the network for maintenance and other work

According to contractual features, sub-stations are of the following four types:

1. Indoor
2. Outdoor
3. Underground
4. Pole-mounted

Sub-stations can also be characterized by the service requirements. But we are concerned only with the Transmission and Distribution sub-stations. Therefore, only brief detail about these two are provided.

1.5.1 Components of Sub-station

Sub-stations generally have switching, protection and control equipment, and transformers. Few of these components are discussed below.

Circuit Breaker

The purpose of a circuit breaker is to interrupt current flowing in the line, transformer, bus, or other equipment when a problem occurs and the power has to be turned off. Current interruption can be for normal load current, high-fault current (due to a short-circuit current or problem in the system) or simply tripped by protective relaying equipment in anticipation of an undesirable event or disturbance. A breaker accomplishes this by mechanically moving electrical contacts apart inside an interrupter, causing an arc to occur that is immediately suppressed by the high-dielectric medium inside the interrupter. Circuit breakers are triggered to open or close by the protective relaying equipment using the sub-station battery system.

The most common types of dielectric media used to extinguish the arc inside the breaker interrupter are listed below:

- Oil (clean mineral)
- Gas (SF6 or sulfur hexafluoride)
- Vacuum
- Air

Batteries

Batteries, located in substation control house, are used as a backup to power the control systems in case of a power blackout.

Current Transformers

Current transformers or CTs are used to scale down the high magnitude of current flowing in high-voltage conductors to a level much easier to work with safely. For example, it is much easier to work with 5 amperes of current in the CT's secondary circuit than it is to work with 1,000 amperes of current in the CT's primary circuit.

Lighting Arresters

Lightening arrestors are the instruments that are used in the incoming feeders to prevent the extremely high voltage entering the main station. This extremely high voltage is very dangerous to the instruments used in the substation. For preventing any damage to the costlier instruments, lightening arrestors are used.

The lightening arrestors do not let the lightening to fall on the station. If some lightening occurs, the arrestors pull the lightening and ground it to the earth. In any sub-station, protection is of major importance for which lightening arrestors are the first shield; the lightening arrestors are grounded to the earth so that it can pull the lightening to the ground. These are located at the entrance of the transmission line to the substation and as near as possible to the transformer terminals. Lightning arresters are installed on many different pieces of equipment such as power transformers, circuit breakers and bus bars.

Potential Transformers

Potential transformers (PTs) are used to scale down high voltages to levels that are safer to work with**.** PTs are also used for metering, protective relaying and system monitoring equipment. The instruments connected to the secondary side of the PT are programmed to account for the turns ratio scale factor**.**

Power Transformers

Transformers are essential components in electric power systems. They come in all shapes and sizes. Power transformers are used to convert high voltage power to low-voltage power and vice versa. Generation plants use large step-up transformers to raise the voltage of the generated power for efficient transport of power over long distances. Then step-down transformers convert the power to sub-transmission or distribution voltages, for further transport or consumption. Distribution transformers are used on distribution lines to further convert distribution voltages down to voltages suitable for residential, commercial, and industrial consumption.

Relays

A protective relay is a device that monitors system conditions (amps, volts, etc. using CTs and PTs) and reacts to the detection of abnormal conditions. The relay compares the real-time actual quantities against preset programmable threshold values and sends dc electrical control signals to trip circuit breakers or other opening devices in an effort to clear an abnormal condition on the equipment it is protecting. When system problems are detected and breakers are tripped, alarm indications are sent to system control and sometimes other protection operations are also initiated. As a result, equipment may be de-energized, taken off line, and consumers will be out of power with minimal equipment damage. The operation of protective relays is the stabilizing force against the unwanted destabilizing forces that occur in electric power systems when something happens, such as unanticipated power faults and lightning strikes.

Different types of relays are present in a sub-station including under/over voltage, over current and high/low frequency.

Disconnect Switches

There are many purposes for disconnect switches in sub-stations and power lines. They are used to isolate or de-energize equipment for maintenance purposes, transfer of load from one source to another under planned or emergency conditions, provide visual openings for maintenance personnel, and other reasons. Disconnect switches usually have low current interrupting ratings compared to circuit breakers. Normally, power lines are first de-energized by circuit breakers (due to their high current interrupting ratings), followed by the opening of the air disconnect switches for the isolation purpose.

Communication Equipment

Sub-stations commonly use microwave communication equipment for sustained communication with local and regional electric power system control centers. This system allows for rapid communication and signaling for controlling the routing of power.

A power line carrier is communication equipment that operates at radio-frequencies, generally below 600 kilohertz, to transmit information over electric power transmission lines. A high frequency signal is super-imposed on the normal voltage on a power circuit. The power line carrier is usually coupled to the power line by means of a coupling capacitor in conjunction with a line trap. [3]

1.6 Losses in Power Systems

Power generated in power stations pass through large and complex networks like transformers, overhead lines, cables and other equipments and reaches at the end users. However, electric energy generated by a power generation station does not match with the energy distributed to the consumers. A certain part of the energy is lost in the distribution network. This difference in the energy generated and distributed is known as Transmission and Distribution loss (T&D loss). Transmission and distribution losses correspond to the money not directly paid by the users. Due to higher losses, distribution sector is considered as the weakest link in the entire power sector.

Losses in power system are of two types:

1. Technical Losses
2. Non-technical Losses

We are discussing losses in whole power system first, after that losses in sub-station are defined also in details as main focus of this report is losses in the jurisdiction of sub-stations.

1.6.1 Technical Losses

The technical losses are due to energy dissipated in the conductors, equipment used for transmission line, transformer, sub-transmission line and distribution line, and magnetic losses in transformers.

The major amount of losses in a power system is in primary and secondary distribution lines. Therefore, the primary and secondary distribution systems must be properly planned to operate within limits. There are two types of technical losses.

Permanent / Fixed Technical Losses

Fixed losses do not change with the varying current i.e. these are constant. These losses transform into heat and noise, and occur as long as power system is energized.

Fixed losses on a network can be influenced by:

- Corona Losses
- Leakage Current Losses
- Dielectric Losses
- Open-circuit Losses
- Losses caused by continuous load of measuring elements
- Losses caused by continuous load of control elements

Variable Losses

Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, 1% increase in the current leads to an increase in losses of more than 1%. By increasing the cross section area of conductors for a given load, losses will fall, however, will incur further cost.

Variable losses in network are caused by:

- Impedance losses
- Heating due to current flow
- Losses caused by contact resistance

Reasons for Technical Losses

1. **Lengthy Distribution Lines:** Largely, kV and 415 Volts lines are extended over long distance to feed load in rural areas.
2. **Balancing 3-Phase Loads:** Balancing 3-phase loads throughout the system can reduce the losses significantly. It can be done relatively easily in case of overhead networks.

3. **Low Power Factor:** A low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn in high. And the losses proportional to square of the current will be higher. Thus, line losses owing to the poor power factor can be reduced by improving the power factor. This can be done by application of shunt capacitors.

1.6.2 Non-technical Losses

Non-technical losses are related to meter reading, defective meter and error in meter reading, billing of customer energy consumption, power theft and absence of energy audits for large industries, lack of periodic maintenance such as replacement of old conductors/cables, and estimating unmetered supply of energy.

Reasons for Non-technical Losses

1. **Metering Inaccuracies:** Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount registered by the meters. All energy meters have some level of error. Proper calibrated meters should be used to measure electrical energy. Defective energy meter should be replaced immediately.
2. **Billing Problems:** Faulty and untimely serving bill are dominating part of non-technical losses.
3. **Power Theft:** Theft of power is energy delivered to the customer that is not measured by the energy meter. Customer tempers the meter mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters, stopping the meters by remote control. [6], [7]

1.7 Losses in Sub-station / Grid Station

Grid station losses are considered as technical losses of power system. In grid station losses are due to:

1. Power Transformer
2. Losses caused by continuous load of measuring, control and protective elements
3. Losses in conductors i.e. bus bars.

In sub-station most of losses are because of transformers. Other losses are very small and negligible.

1.7.1 Transformer losses

Transformer losses fall into the following two categories:

1. No-load loss or Iron loss
2. Load loss or Copper loss

No-Load Loss or Iron loss

In an ideal transformer, the no-load current or magnetizing current will not cause any losses, although voltage is applied and a current flows. As already noted however, no power transformation is perfect. First, iron is an electrically conductive material, and current is not only generated in the loaded (or shorted) secondary coil but also in the core. This is true whether the output winding is loaded or not. For this reason, the core is not made from solid iron but rather of laminations of sheet iron. These are about 0.28 mm to 0.35 mm thick, equipped with an insulating oxide layer and with additives to reduce conductivity. This suppresses the so-called eddy currents in the core to a very low but not zero level. Secondly, some magnetism—known as hysteresis—remains within the core after the current has dropped to zero, and energy is needed twice per each full wave to remove this residual magnetism before re-magnetizing the iron with reverse polarity. The sum of these two effects is known as core loss. Core loss is present whenever the transformer is energized. Hysteresis losses rise linearly with the applied frequency and eddy-current losses rise by the square of the product of frequency by magnetization (flux density).

Load-Loss or Copper-Loss

The flow of a current in any electrical system also generates loss dependent upon the magnitude of that current. Transformer windings are no exception, and these give rise to the load loss of the transformer. Load loss is present only when the transformer is loaded, and its magnitude is proportional to the square of the load.

Load loss, or copper loss, tends to receive less attention than iron loss in the pursuit of energy efficient transformers. One reason is that the magnitude of the loss varies in accordance with the square of the load. Most transformers operate at less than half-rated load for much of the time, so the actual value of the load loss might be less than one quarter of the nominal value at full rated load. Only in the case of generator transformers, it is the usual practice to cost load losses at the same value as no-load losses, since normally it will be operating at or near full load. [8]

1.8 Energy Audit

Energy is very scarce commodity particularly in developing and underdeveloped countries. Cost of energy is spirally increasing day-by-day. Need for conservation of energy therefore cannot be over emphasized.

Energy Audit is considered to be an integral part of Energy Conservation / Energy Management as it facilitates the optimum use of available energy resources. The need to reduce energy costs is a crucial business practice for successful organizations, and energy audits have already begun to play a more significant role in managing energy expense and thus increasing profitability.

1.8.1 Definitions

1. Energy Audit is an inspection, survey and analysis of energy flows for Energy Conservation in a building, processor a system to reduce the amount of energy input into the system without negatively affecting the output(s). [9]
2. An energy audit is a preliminary activity towards instituting energy efficiency programs in an establishment. It consists of activities that seek to identify conservation opportunities preliminary to the development of an energy savings program. [10]
3. Energy audit is a technique used to establish pattern of energy use; identify how and where loses are occurring; and suggest appropriate economically viable engineering solutions to enhance energy efficiency in the system studied. [11]

1.8.2 Need for Energy Audit

In any power system, the three top operating expenses are often found to be energy (both electrical and thermal), manpower and material. With respect to manageability of the cost or potential cost savings in each of the three cost components, energy invariably emerges as atop ranker, and thus energy management function constitutes a strategic area in the perspective of cost reduction.

Energy Audit helps to understand more about the ways energy and fuel are used in power system, and helps in identifying the areas where losses can occur and more importantly where scope for improvement exists. The energy audit facilitates a positive orientation to the energy cost reduction, preventive maintenance and quality control programs which are vital for production and utility activities. Such an audit program helps to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, energy audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs.

1.8.3 The Benefits of an Energy Audit

There is a huge potential of energy savings from energy audits. Some benefits of energy audits are:

- Reduction in losses and energy savings thereof
- Quality improvements
- Reduction in required maintenance
- Better safety and protection

1.8.4 Audit Methodology

The general steps of energy audit are:

1. Facility Tour
2. Documents Review
3. Preliminary Data Analysis
4. Data Collection
5. Data Analysis
6. Report Submission, Discussion of Recommendation and Finalizing the Report with the Client

Facility Tour

A tour of the facility being audited is arranged to observe the various operations first hand. A meeting is scheduled between the auditor and all the key operating personnel to kick off the auditing project. The meeting agenda focuses on: Audit Objectives and Scope of Work, Facility Rules and Regulations, Roles and Responsibilities of the Project Team Members, and Description of Scheduled Project Activities.

Documents Review

During the initial visit and subsequent kick-off meeting, available facility documentation are reviewed with the facility representatives. This documentation should include all available architectural and engineering plans, facility operation, maintenance procedures and logs, and all equipment details.

Preliminary Data Analysis

Data and information is collected related to the past and present energy profile, the production and utilization of energy. The preliminary analysis of all the collected data should lead to identification of the annual trend and monthly fluctuation of total energy consumption.

Data Collection

At this stage, relevant data is collected with the help of facility staff. This data is usually in form of a charts and sheets having measuring readings. Data collection can be done on hourly, daily or monthly basis as required.

Data Analysis

After collecting data, calculations are performed to evaluate losses and efficiency.

Report Submission, Discussion of Recommendation with the Client and Finalizing the Report with the Client

The results of findings and recommendations are summarized in the final report. The report includes a description of the facilities and their operation, a discussion of all major losses, and possible solutions. The report incorporates a summary of all the activities and effort performed throughout the project with specific conclusions and recommendations.

CHAPTER 2. Rationale of the Study

The term "energy efficiency" is interpreted differently in national and international literature as well as in various scientific disciplines. The working definition, which will be presented here, reflects the very objective of this study. Energy efficiency is a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. Energy efficiency is one of the easiest and most cost effective way to combat climate change, clean air we breathe (less pollution), improve the competitiveness of our businesses and reduce costs for consumers thus considered as the lowest hanging fruit in terms of energy sustainability.

Grid stations receive the electricity from power plants through power transmission lines and transform it from high to lower voltage; are used to distribute electricity to consumers, supervise and protect the distribution network to keep it working safely and efficiently. Grid stations equipment include power transformers, switching devices such as circuit breakers and dis-connectors to cut power in case of a problem, and measurement, protection and control devices needed to ensure its safe and efficient operation.

The aim of this study is analyze performance of grid stations. For this purpose, an energy audit of two grid stations is undertaken, one from the transmission system and the other from the distribution system. Such an audit is performed to draw complete picture of energy profiles of grid stations being studied. While conducting energy audit of grid stations, energy imported, exported and losses are recorded. Losses in each section of grid station are evaluated like losses in transformers and losses in switchyards.

The outcome of this study is to identify areas in power system where most of the losses are occurring. So, that steps can be taken to minimize these losses. This will ultimately help in a lot of ways like:

- Reduction in quantum of power generation
- Energy and money savings
- Improvements in system quality

CHAPTER 3. Methodology

With the objective to achieve optimum energy efficiency at the grid station level, performance analysis was carried out on two grid stations using the methodology of energy audit.

The following steps were undertaken to conduct the research study;

a. Study of International practices
b. Selection of Grid Stations
c. Visit of selected grid stations and review of relevant documentation
d. Data Analysis
e. Drafting of Findings and Recommendations
f. Draft Report Writing
g. Submission of Draft Report to SEC
h. Incorporation of SEC comments and suggestions, and compilation of Final Report

3.1 Study of International Practices

In order to kick start the study, international interventions on energy audit were studied. In this context, different relevant studies already carried out in the past in different countries were studied. References to these studies have been used in this report.

3.2 Selection of Grid Stations

The power system of Pakistan comprises of three independent tiers i.e. Generation, Transmission and Distribution. As major contribution of T&D losses is on the account of Transmission and Distribution, therefore, a sample grid station from both the tiers was selected for application of energy audit techniques. Keeping in the study objectives, time constraint and available resources, it was decided to select the both grid stations located within the same geographical region. Therefore, following two, Air Insulated Switch Gear (AIS), grid stations were selected for the research / study purposes;

a. 220 kV New Kotlakhpat Grid Station (NTDC)
b. 132 KV Qurtaba Grid Station (LESCO)

3.2.1 National Transmission and Dispatch Company (NTDC)

National Transmission & Dispatch Company (NTDC) Limited was incorporated in 1998 and commenced commercial operation in the same year. It was organized to take over all the properties, rights and assets obligations and liabilities of 220 KV and 500KV Grid Stations and Transmission Lines/Network owned by Pakistan Water and Power Development Authority (WAPDA). Currently, NTDC operates and maintains twelve 500 KV and twenty nine 220 KV Grid Stations, 5,078 km of 500 KV transmission line and 7,947 km of 220 KV transmission line in Pakistan [12]. Existing NTDC transmission network is available as Figure 3.1.

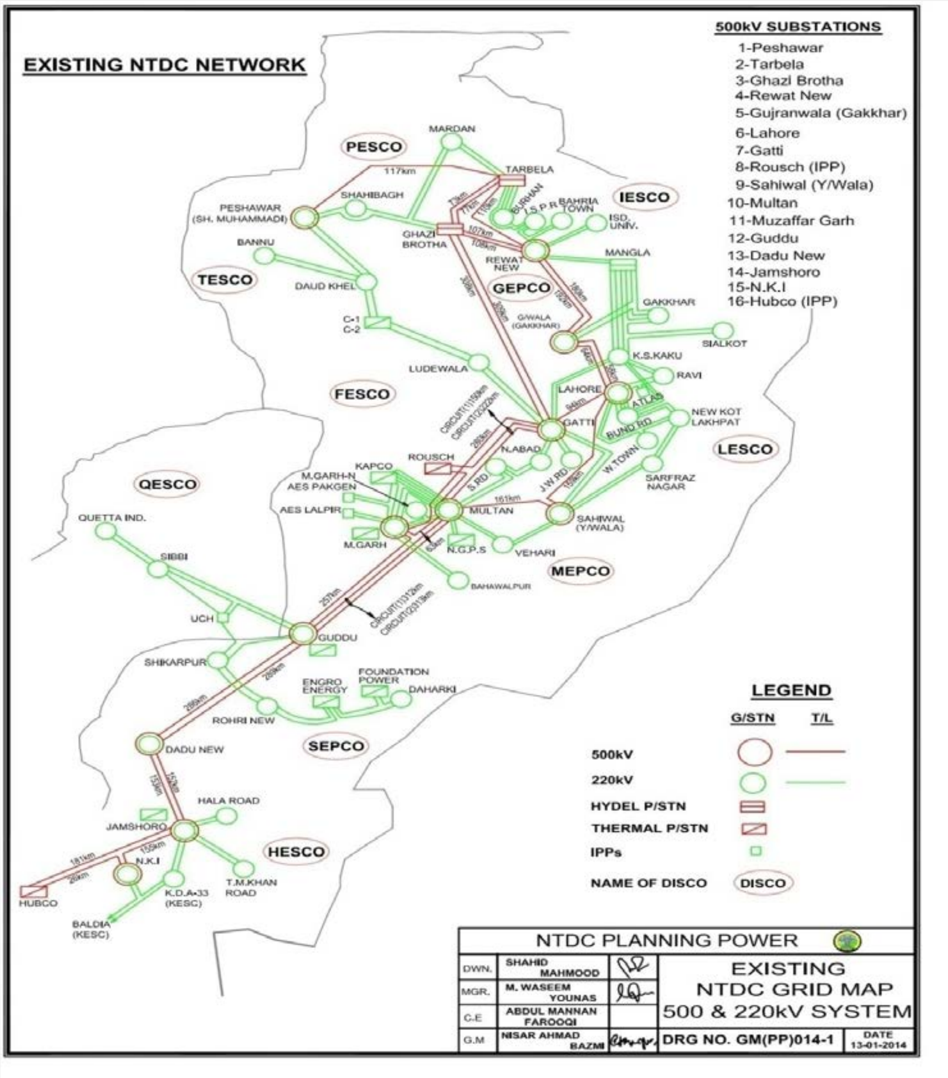

Figure 3.1: **NTDC Grid Map**

NTDC operates a longitudinal network i.e. it extends from North to South. Hydro generation is mainly in Northern part of the country, and major thermal generation in South and in lower middle part of network. Large load centers are remote from major generation sources. Contrasting seasonal variation exists in generation dispatch and in power flows. Bulk power flows from North to mid-country in summer season and from South to mid-country and North during the winter.

NTDC was granted Transmission License No. TL/01//2002 on 31st December 2002 by National Electric Power Regularity Authority (NEPRA) to engage in the exclusive transmission business for a term of thirty (30) years, pursuant to Section 17 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

Existing Transmission Network of NTDC

- 500/220 kV Grid Stations 12 Nos.
- 220/132 kV Grid Stations 29 Nos.
- 500 kV Lines 5,078 km
- 220 kV Lines 7,947 km

Functions:

Major functions of NTDC are;

a. **Central Power Purchasing Agency (CPPA)**

   Procurement of power from Generation Companies (GENCOs) and Independent Power Producers (IPPs) on behalf of Distribution Companies (DISCOs), for delivery through 500 kV and, 220 kV network.

b. **System Operator**

   Control and dispatch of generation facilities for secure, safe and reliable operation

c. **Transmission Network Operator**

   Operation and maintenance, planning, design and expansion of the 500 kV and 220 kV transmission network

d. **Contract Registrar and Power Exchange Administrator (CRPEA)**

   Recording, monitoring and novation of contracts relating to power purchase and bilateral trading system.

Table 3.1: **Abstract of NTDC's Prevailing Development Projects**

NTDC Future Projects			
Sr. No.	**Name of the Project**	**Scope of Work**	**Expected Completion**
1	Replacement of Depleted Material at the existing Grid Stations of NTDC Systems	220 kV sub-station with 2x250 MVA 220/132 kV T/Fs and allied equipment.	2014-15
2	220 kV Chakdara	220kV substation with 2x250MVA 220/132 kV T/Fs and allied equipment. In/Out of 220kV Shahi Bagh - Mardan S/C at Chakdara (85km)	2015-16
3	500 kV Faisalabad West	<u>Phase -I</u> 500kV D/C T/L for In/Out of 500 kV M. Garh – Gatti S/C at 500 kV Faisalabad West (2km) 220kV D/C T/L from 500 kV Faisalabad West to 220 kV T. T. Singh (45km) <u>Phase- II</u> 500kV D/C T/L for In/Out of 500 kV Multan-Gatti S/C at 500 kV Faisalabad West (30 km) 220kV D/C T/L from 500 kV Faisalabad West to 220 kV Lalian New (80km)	2016-17
4	Evacuation of Power from 1000 MW Quaid-e-Azam Solar Park at Lal-Suhanra	**Phase-I: Evacuation of 400 MW Solar (Proposed to be carried out by MEPCO)** • 132 kV D/C T/L for interconnection of 4x50 MW Solar Plants with proposed 132 kV Bahawalpur Cantt. – Lal-Suhanra S/C T/L (8km). • 132 kV D/C T/L for interconnection of 2x50 MW Solar Plants with proposed 132 kV Bahawalpur – Lal-Suhanra S/C at solar power plants (4km). • 132 kV D/C T/L from Bahawalpur New to Lodhran & looping In/Out of one circuit at 132 kV Baghdad-ul-Jaded Grid Station (40km)	2014-15

<table>
<tr><th colspan="4">NTDC Future Projects</th></tr>
<tr><th>Sr. No.</th><th>Name of the Project</th><th>Scope of Work</th><th>Expected Completion</th></tr>
<tr><td></td><td></td><td>Phase-II: Evacuation of 600 MW Solar (Proposed to be carried out by NTDC)
• 220 kV Grid Station at Lal-Suhanara with 3x250MVA, 220/132kV T/Fs along with allied equipment and accessories
• 220 kV D/C T/L from 220 kV Lal-Suhanra to 220kV Bahawalpur Grid Station (40km)
• Three 132 kV D/C transmission lines on Rail conductor from Solar projects sites to 220kV Grid Station at Lal-Suhanra having length of 8 km each (total-24 km)</td><td>2015-16</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Evacuation of Power from Wind Power Projects at Jhimpir & Gharo Wind Clusters</td><td>• 132 kV Jhimpir New Substation
• 132 kV Jhimpir New –TM Khan D/C T/L (82 km)
• 132 kV D/C T/L for interconnection of WPPs with 132 kV Jhimpir New (25 km)
• Upgradation of 132 kV Jhimpir substation to 220 kV substation with 3x250MVA, 220/132 kV T/Fs
• 220 kV Gas Insulated Substation (GIS) at Gharo with 2x250 MVA 220/132 kV T/Fs.</td><td rowspan="3">2016-17</td></tr>
<tr><td>• 220 kV double circuit transmission line from 220 kV Gharo to 220 kV Jhimpir sub-station
• 132 kV double circuit transmission lines for interconnection of WPPs to Gharo (20 km).
• 132 kV double circuit transmission lines for interconnection of WPPs to Jhimpir (65 km).
• Addition of 3rd 450 MVA, 500/220 kV transformer at 500 kV Jamshoro.</td></tr>
<tr><td>220 kV D/C T/L for in/out of Jamshoro –KDA S/C at 2x250 MW NBT Wind Power Plants (10 km)</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">Extension/ Augmentation of 500/220kV Rewat substation</td><td>Extension of 1x250 MVA 220/132 kV T/F</td><td rowspan="2">2014-15</td></tr>
<tr><td>Augmentation of 2x160 MVA 220/132kV T/Fs to 2x250MVA T/Fs</td></tr>
<tr><td rowspan="2">7</td><td rowspan="2">Addition/Re-enforcement of 220 kV Transmission</td><td>A new 220 kV D/C T/Line from Tarbela to Burhan (35.1km)</td><td rowspan="2">2015-16</td></tr>
<tr><td>Re-conductoring of 220 kV Tarbela-ISPR D/C T/Line (62.5 km)</td></tr>
</table>

NTDC Future Projects			
Sr. No.	**Name of the Project**	**Scope of Work**	**Expected Completion**
	Lines in Islamabad and Burhan area	In/Out of one circuit of 220kV Mansehra-ISPR D/C Transmission line at Islamabad University Substation (40 km)	
8	Power Dispersal from 1200 MW Thar Coal Based Power Plant	500 kV Thar – Matiari D/C T/L (250 km)	2015-16
		Two line bays with Shunt Reactors at 500 kV Matiari Switching Station	
9	220 D.I.Khan	220kV sub station with 220/132kV 2x250 MVA T/Fs along with allied equipment	2015-16
		220 kV D/C T/L for In/Out of 220 kV Chashma Nuclear-Ludewala S/C T/L at D.I Khan (100km)	
10	Extension/Augmentation of 500/220kV Rewat substation	Addition one 250 MVA 220/132 kV T/F	2015-16
		Augmentation of two 160 MVA 220/132kV T/Fs to 2x250MVA T/Fs	
11	Dispersal of Power From 147 MW Patrind Hydro Power Project	132 KV Patrind - Mansehra D/C T/L (45 km)	2015-16
		I/O of 132 kV Patrind - Mansehra S/C at Balakot (10 km)	
		I/O of 132 kV D/C Patrind - Mansehra G/S atMuzaffarabad-II (15 km)	
12	500 kV Faisalabad West (Phase-II)	500kV D/C T/L for In/Out of 500 kV Multan-Gatti S/C at 500 kV Faisalabad West (30 km)	2016-17
		220kV D/C T/L from 500 kV Faisalabad West to 220 kV Lalian New (80km)	
13	220 kV Mirpur Khas	220kV sub station with 2x250 MVA 220/132 kV T/Fs and allied equipment	2016-17
		I/O of 220kV Hala Road-T.M Khan Road D/C T/L at Mirpur Khas (70 km)	
14	220 kV Chakwal	220kV sub station with 2x250 MVA 220/132 kV T/Fs and allied equipment	2016-17
		In/out of 220 kV Mangla-Rewat S/C at Chakwal (60 km)	

NTDC Future Projects			
Sr. No.	Name of the Project	Scope of Work	Expected Completion
15	220 kV Mastung	220kV sub station with 2x250MVA 220/132 kV T/Fs and allied equipment.	2016-17
		220kV D/C T/L from Mastung to Sibbi (120 km)	
16	220kV GIS Shadman	220kV sub station with 2x250 MVA 220/132 kV T/Fs and allied equipment	2016-17
		2220 kV D/C cable from Shadman to Bund Road (30km)	
17	220 kV M-3 Industrial Estate Faisalabad	220kV sub station with 2x250 MVA 220/132 kV T/Fs and allied equipment	2017-18
		220 kV M3 Industrial Estate–Faisalabad New (70 km)	
		In/Out of 220 kV Faisalabad West-Lalian at 220 kV M3 Industrial (30 km)	
18	Dispersal of Power From 2x1100MW Nuclear Plants, 6x1200MW Imported Coal Based Plants at Gadani and 1200MW Thar Coal based Plants at Thar	Three 500kV D/C T/Ls from Power Plant to Gadani	2017-18
		±600kV HVDC T/Ls from Gadani to Lahore & Faisalabad	
		±600kV Converter Stations at Lahore, Faisalabad & Gadani	
		500kV Collector station at Gadani	
		500kV G/S at Lahore with 2x750 & 3x250MVA T/Fs.	
		500kV T/Ls for dispersal of power to Khuzdar, Quetta and N.K.I	
		±600kV HVDC T/L from Matiari to Lahore South	
		500kV D/C T/L from Thar to Matiari	
		Two 500kV D/C T/Ls from Nuclear Plants to Matiari.	
		± 600kV HVDC Converter station at Matiari	
19	500 kV system re-enforcement for evacuation of Power from 6600 MW Imported	Five 500 kV D/C T/Ls from Power Plants to Gadani collector station (20 km each)	2017-18
		500 kV HVAC T/L for In/Out of Lahore – Ghakhar at Lahore North (50 km)	
		500 kV Faislabad West - Ludewala – Peshawar D/C T/L (425 km)	

NTDC Future Projects			
Sr. No.	**Name of the Project**	**Scope of Work**	**Expected Completion**
	Coal Based Plants at Gadani (HVAC Component)	500 kV Gadani – NKI – Moro D/C T/L (330 km)	
		500 kV D/C T/L for I/O of Hub – Jamshoro at Gadani (6 km)	
		Two 500 kV D/C T/L for I/o of Sahiwal – Lahore south at Convertor station (25 km each)	
		500 kV Lahore North – Lahore South (70 km)	
		500 kV substation at Lahore North, 500 kV switching stations Ludewala and extensions at different grid stations.	
20	500 kV Islamabad West	In/Out of 500 kV Tarbela – Rewat S/C at Islamabad West (12 km)	2017-18
		In/Out of 500 kV G/Barotha–Rewat S/C at Islamabad West (15 km)	
		In/Out of 220 kV Tarbela–ISPR S/C at Islamabad West (15km)	
		In/Out of 220 kV Mansehra/Islamabad University–ISPR D/C at Islamabad West (15km)	
		500 kV sub-station with 2x750 MVA 500/220 kV and 3x250 MVA 220/132 kV T/Fs and allied equipment	
21	Dispersal of Power From Dasu Hydro Power Project	500 kV D/C T/L from Dasu to Palas (35 km)	2017-18
		500 kV D/C T/L from Palas to Mansehra (105 km)	
		500 kV D/C T/L from Mansehra to Islamabad West (100 km)	
		500 kV D/C T/L from Mansehra to Faisalabad West with 40% series compensation (375 km)	
		500 kV Switching Station at Mansehra	
		Extension at Islamabad and Faisalabad West	
22	Evacuation of Power from 1320 MW Bin Qasim Project	500 kV Double circuit T/Line from Bin Qasim PP to Matiari switching station(180 km)	2017-18
		Extension at 500 kV Matiari switching station (two line bays and shunt reactor)	
23	Evacuation of Power from	500 kV Double circuit T/L for In/Out of Sahiwal-Lahore Single circuit at Sahiwal PP (0.5 km)	2017-18

NTDC Future Projects			
Sr. No.	**Name of the Project**	**Scope of Work**	**Expected Completion**
	1320 MW Imported Coal based PP at Sahiwal	Addition of 1x600 MVA 500/220 kV transformer at 500 kV Sahiwal (Yousafwala)	
24	220 kV Jamrud	220 kV D/C T/L from Peshawar to Jamrud (10 km)	2017-18
25	500 kV Peshawar New	In/out of 500kV Tarbela – Peshawar at Peshawar New (2+2km) In/Out of 220kV Peshawar-Shahibagh S/C at Peshawar New (5km)	2018-19
26	220 kV Kohat	220 kV D/C T/L from Kohat to Peshawar New (50 km) 220 kV D/C T/L from Kohat to Bannu (150 km)	2018-19
27	500 kV Alliot Switching and Evacuation of associated HPPs	500 kV D/C T/L from Suki Kinari to Alliot (100 km) 500 kV D/C T/L from Alliot to Islamabad West (96 km) 500 kV Switching Station at Alliot	2019-20
28	Dispersal of Power From Diamer Bhasha Hydro Power Project	<u>500 kV D/C T/Ls</u> Basha I –Mardan new via Sawat Valley (337 km) Mardan New – Peshawar New (50 km) Basha I – Basha II (5 km) Basha II – Chillas (42 km) Chillas – Alliot (212 km) Alliot – Islamabad West (96 km) Alliot – Lahore (North) (330 km) Lahore North – Gujranwala (50 km) Lahore North – Lahore South (60 km) <u>500 kV Substations</u> 500 kV Substation Mardan 500 kV switching station Aliot 500 kV substation Lahore – North	2021-22

3.2.2 Lahore Electric Supply Company (LESCO)

The electricity supply service in Pakistan, initially, was undertaken by different agencies, both in public and private sectors, in different areas. In order to provide for the unified and coordinated development of the water and power resources, Water and Power Development Authority (WAPDA) was created in 1958 through WAPDA Act, 1958. The local areas electricity distribution service was being performed by various Regions of

WAPDA. Then the Area Electricity Board (AEB) Lahore, along with seven other AEBs in Pakistan, was established under the scheme of Area Electricity Boards in 1982, in order to provide more autonomy and representation to provincial government, elected representatives, industrialists, agriculturalists and other interest groups in functions of the AEBs.

The environment and structure of the power industry throughout the world are undergoing dramatic change. The power sector is moving from monopoly to competitive market and from integration to disintegration. To keep pace with this great change, the Government of Pakistan approved a Strategic Plan in 1994 as a consequence of which the power wing of WAPDA was unbundled into 12 Companies for generation, transmission and distribution of electricity.

Lahore Area Electricity Board was reorganized into one such corporatized entity under the name of Lahore Electric Supply Company (LESCO) with effect from March 1998, with the aim of commercialization and eventually privatization ultimately leading to competitive power market. [13]

Profile

LESCO has 3.58 million electricity consumers of different categories. Currently, there are eighty two 132 kV and eight 66 kV grid Stations operating in LESCO with total length of 2,600 km of 132 kV sub-transmission lines. There are 32 consumer grid stations of 132 kV.

Table 3.2: **LESCO Customers Distribution**

LESCO Customers Distribution			
No.	Customers	Customers (Millions)	Customers Mix %
1	Domestic	2.93	81.84
2	Commercials	0.51	14.25
3	Agriculture	0.056	1.65

Peak demand of LESCO in the year 2012-13 was 3069 MW, energy sale was 14285 GWh and energy purchased was 16457 GWh. The shares of domestic sector and industrial sector were 41.48% and 42.64% respectively with respect to total energy sale, which is not a healthy sign. In the year 2012-13 total sale of LESCO in terms of megawatts was

2663 MW, for the domestic sector it was 1512 MW, for medium & large industries it was 1151 MW and for small industries it was 117 MW.[14]

Area of Operation

LESCO is a wholly Government-owned power distribution utility with its headquarters located in the city of Lahore, the provincial capital of Punjab. LESCO is thus located in the northern part of Punjab. It has boundaries with the Gujranwala Electric Power Company Limited in the north, Faisalabad Electric Supply Company Limited in the east and Multan Electric Power Company Limited in the south.

LESCO's area of responsibility covers Civil Districts of Lahore, Kasur, Okara and Sheikhupura as illustrated in Figure 3.2.

Figure 3.2: **LESCO Operation Area**

Organizational Structure of LESCO

LESCO comprises of the following seven distribution Operation Circles, one Construction and one GSO Circle, as detailed below.

1.	North Lahore Circle	5 Divisions / 24 Sub Divisions
2.	Central Lahore Circle	5 Divisions / 26 Sub Divisions
3.	Eastern Lahore Circle	4 Divisions / 20 Sub Divisions
4.	Okara Circle	4 Divisions / 21 Sub Divisions
5.	South-Eastern LHR Circle	4 Divisions /21 Sub Divisions
6.	Sheikhupura Circle	5 Divisions / 29 Sub Divisions
7.	Kasur Circle	5 Divisions / 21 Sub Divisions

Future Expansion

LESCO is in process of huge upgradation in pursuance to the development of the National Power System Expansion Plan (NPSEP) 2015-20 through upgrading of its 66 kV and 11 kV system.

The specific tasks of the secondary transmission expansion plan were to:

- Expand the 132 kV and 66 kV systems
- Identify the 132/11 kV and 66/11 kV new substations as well as extensions an augmentations for the existing 132/11 kV and 66/11 kV transformers
- Verify that the 132 kV and 66 kV systems satisfy the planning criteria
- Verify that the short circuit levels at the 132 kV and 66 kV systems are within the permissible limits

Complete existing distribution lines along with proposed expansion structure of LESCO is shown in following in Figures 3.3 and 3.4.

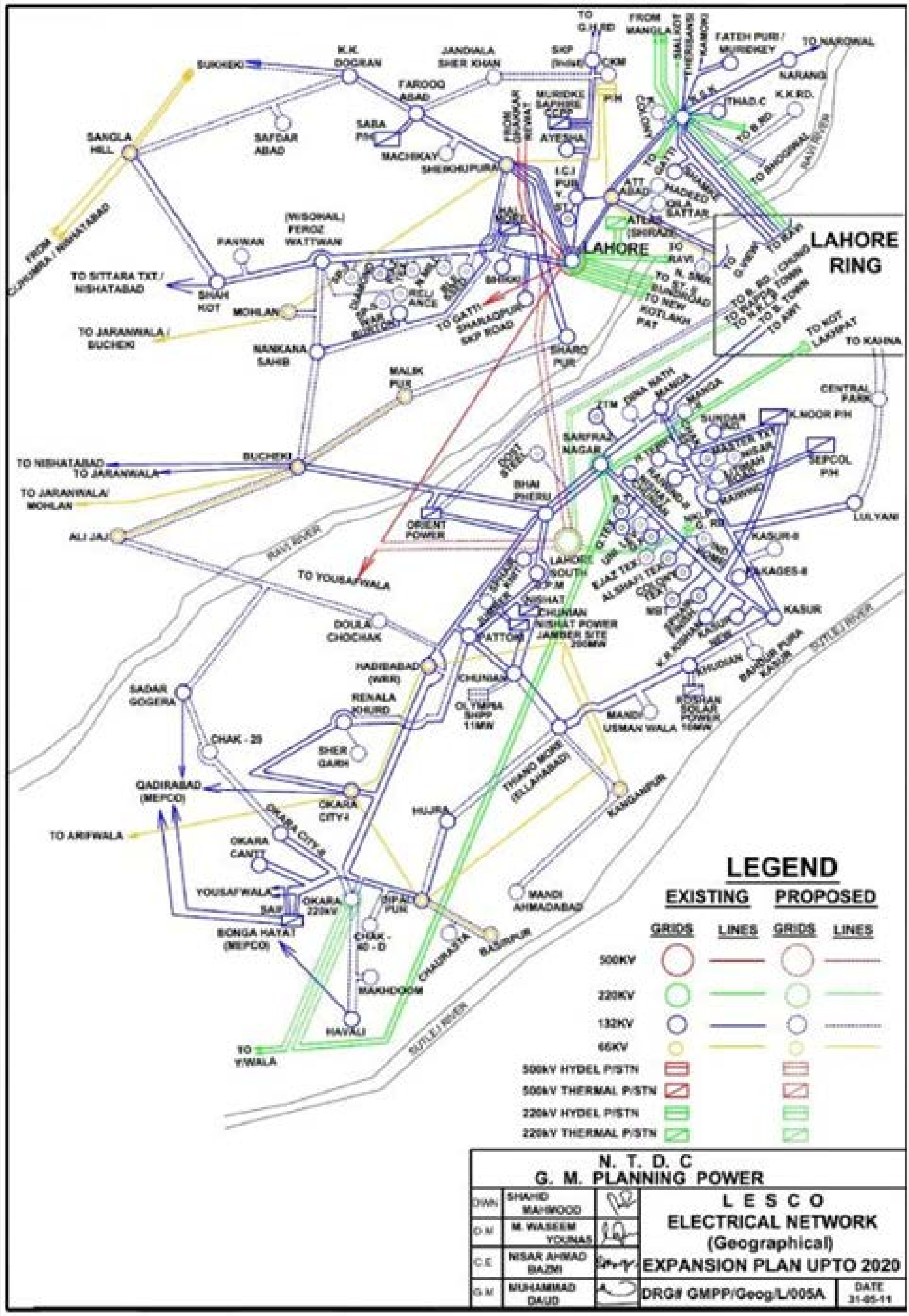

Figure 3.3: **LESCO Distribution Lines-I**

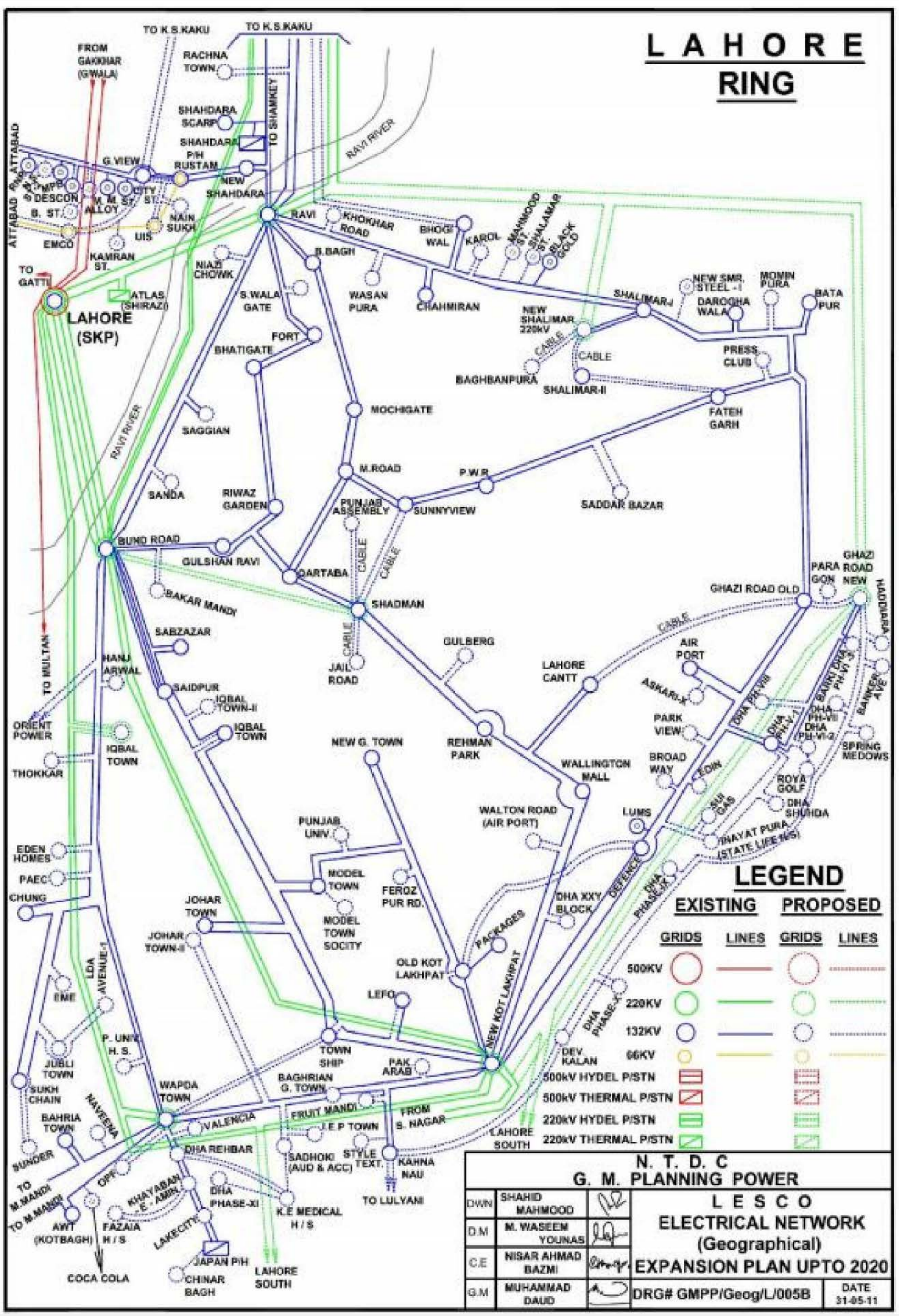

Figure 3.4: **LESCO Distribution Lines-II**

3.3 Visit of Selected Grid Stations and Documents Review

In order to pursue the main goal of this research study i.e. to calculate the total losses in a grid station, 220 kV Grid Station of NTDC at New Kot Lakhpat was visited. During initial visit, available substation documentation was reviewed. This documentation included single line diagram of the whole grid station, power plate ratings of transformers, metering points and accuracy classes of different meters and their C.Ts. The data obtained is as below in Table 3.3 (Switchyard Metering) and Table 3.4 (Transformer Metering).

Table 3.3: **Switch Yard Metering**

Kot Lakhpat Grid Station- Switch Yard Metering			
Name of Transmission Line	**Make and Type of Energy Meter**	**Accuracy Class**	**C.T. Accuracy**
220 kV NKLP-Wapda Town	AEM Eneriux-T	0.2s	0.5
220 kV NKLP-LHR-2 (SKP)	Elster A-1800	0.2s	0.5
220 kV NKLP-Sarfraz Nagar-I	Elster A-1800	0.2s	0.5
220 kV NKLP-Sarfraz Nagar-II	Elster A-1800	0.2s	0.5
220 kV NKLP-Bund Road-1	Elster A-1800	0.2s	0.5
220 kV NKLP-Bund Road-2	Elster A-1800	0.2s	0.5
132 kV NKLP-Johar Town-2	AEM Eneriux-T	0.2s	0.2
132 kV NKLP-Khana Nau	AEM Eneriux-T	0.2s	0.2
132 kV NKLP-Inayat Pura	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-Defence	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-Wallington Mall	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-Rehman Park	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-Town Ship	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-OKLP	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-Madina Town	AEM Eneriux-T	0.2s	0.5
132 kV NKLP-LEFO-Madina Town	AEM Eneriux-T	0.2s	0.5

Table 3.4: **Transformer Metering**

Kot Lakhpat Grid Station- Transformer Metering			
Transformer	**Make and Type of Energy Meter**	**Accuracy Class**	**C.T. Accuracy**
220/132 kV 250 MVA T-1	HV: Elster A-1800	0.2s	0.5
	LV: ISKARA	0.2s	0.2
220/132 kV 250 MVA T-2	HV: Elster A-1800	0.2s	0.5
	LV: ISKARA	0.2s	0.2
220/132 kV 250 MVA T-3	HV: AEM Eneriux-T	0.2s	0.5
	LV: ISKARA	0.2s	0.2
132/11.5 kV 20/26 MVA T-4	AEM Eneriux-T	0.2	0.5
132/11.5 kV 20/26 MVA T-4	ABB Ainrtal	1.0	0.5
132/11.5 kV 20/26 MVA T-4	ABB Ainrtal	1.0	0.5

It is evident from the data provided in the Tables 3.3 and 3.4 that the accuracy class of energy meters and their corresponding CTSs do not match. As informed by the grid station staff, it is due to extension of grid station in multiple phases. During these extensions, attention was not paid towards this aspect by the design engineers.

Selection of Cut off Points

During the study of grid station configuration, it was observed that both the grid stations, selected for the study, have electrical boundaries, which are beyond the limits of the objectives of the study. Therefore, following decision was taken:

1. In case of the NTDC New Kot Lakhpat grid station, the cut off point for the metering purpose shall be 132 kV bus bar as behind this point, the part of the grid station falls under the jurisdiction of LESCO.
2. For the LESCO Qurtaba grid station, the cut off point for the metering purpose shall be 11 kV bus bar as behind this point distribution network starts.

The single line diagrams for the study/metering purpose, of NTDC and LESCO grid stations are provide as Figure 3.5 and 3.6 respectively.

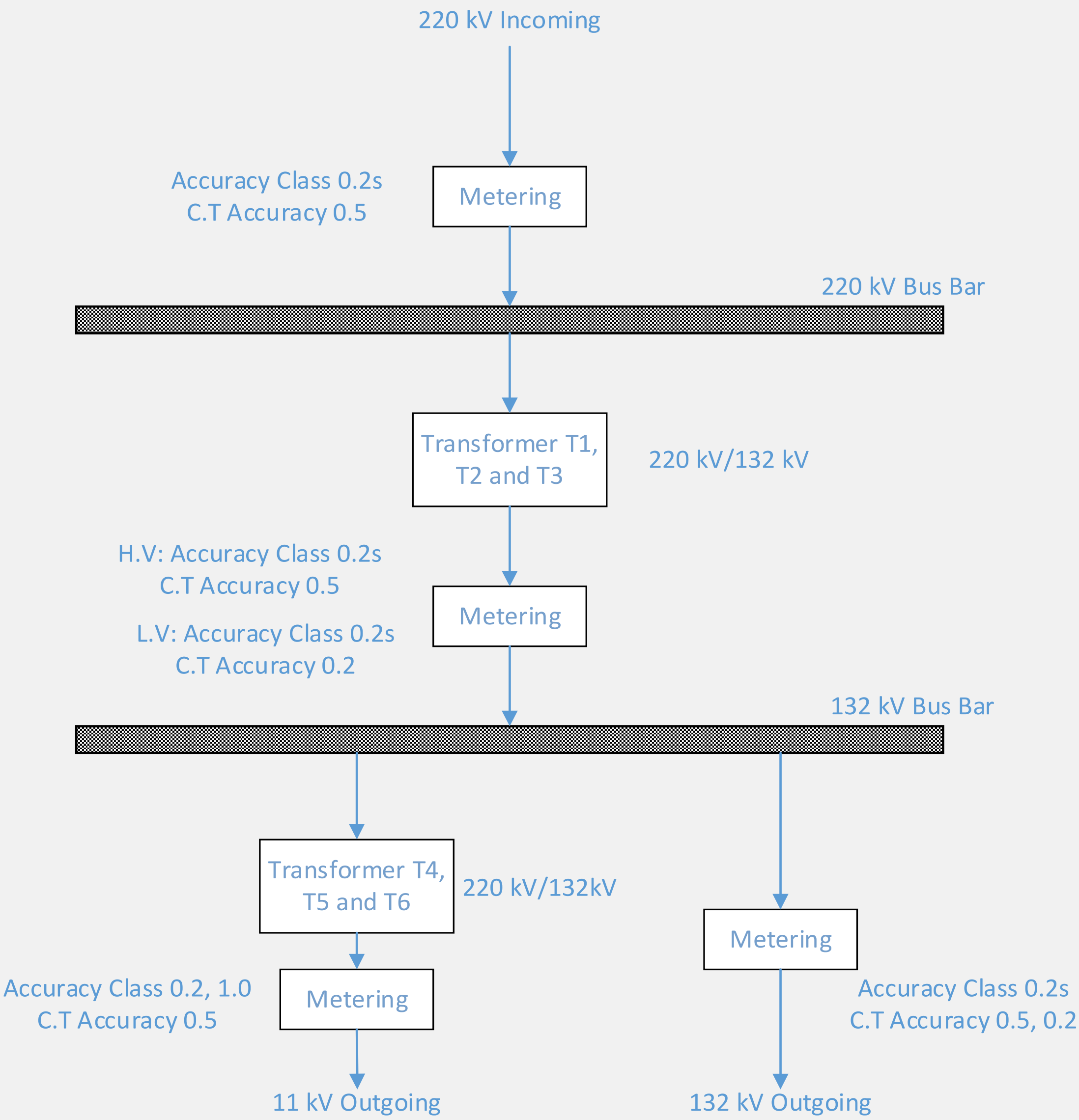

Figure 3.5: **Kot Lakhpat Grid Station Metering Points**

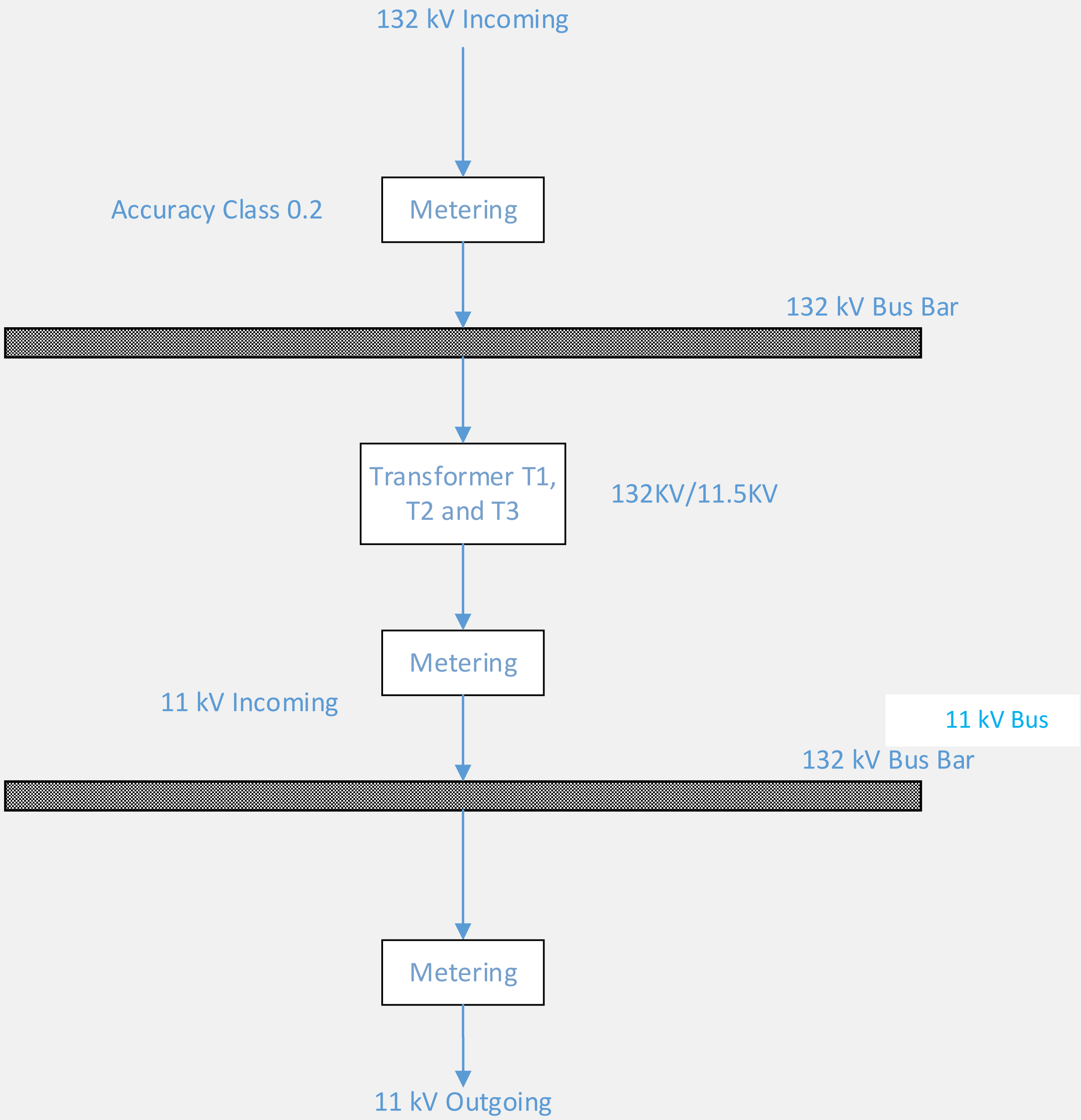

Figure 3.6: **132 kV Qurtaba Grid Station Metering Points**

Data Collection

After considering available metering points, readings of energy import and export were collected. Readings were noted after every eight (8) hours giving three (3) readings in a day at every point. For transformers, temperatures of high voltage (HV) side and low voltage (LV) side, and load current were also recorded.

Losses Calculation for 220 kV New Kot Lakhpat Grid Station

1. **Total Grid Station Losses**

   Difference between total energy import and export energy for one day gives total energy loss in the grid station.

$$Total\ Losses = Total\ Energy\ Import - Total\ Energy\ Export$$

$$Percentage\ Losses = \frac{Total\ Losses}{Total\ Energy\ Impot} \times 100\%$$

2. **Auto Transformer Losses (L1) 220/132/11 kV**

   Transformer losses were calculated as follows:

$$Losses = L1 = NL + Load \times \left(\frac{Load\ MVA}{Capacity\ (MVA\ Rating)}\right)^2 \times \left(\frac{235 + T_{wind}}{235 + 75}\right)$$

$$Energy\ Loss = Losses \times Time$$

Where:

NL is no-load losses and these are mentioned on transformer rating plate

$\left(\frac{235+T_{wind}}{235+75}\right)$ is temperature correction factor.

T_{wind} is winding temperature and it is calculated as:

$$T_{wind} = Ambient\ temperature + 55 \times \frac{Load\ MVA}{Capacity\ (MVA\ Rating)}$$

Load is average load on transformer:

$$Average\ Load = \frac{Total\ SMS\ Reading(MWh)}{24}\ MW$$

$$Load\ MVA = \frac{Average\ Load}{Power\ Factor}$$

Average power factor of transformers are shown in the Table 3.5.

Table 3.5: **Power Factor of Transformers**

Transformer Name	Power Factor
T-1	0.84
T-2	0.9
T-3	0.9

3. **220 kV Section Losses L2**

   Losses in 220 kV section were calculated as follows:

$$L2 = Energy\ Imported - Engery\ Exported - Total\ Energy\ Exported\ from\ Auto\ Transformer \times 0.9896 - L1$$

   Where:

   Both and $Energy\ Imported$ and $Engery\ Exported$ are of 220 kV lines.

   $L1$ is losses in auto transformers.

   0.9896 is correction factor due to difference in CT class at HV and LV side of transformer.

<u>Losses Calculation for 132 kV Qurtaba Grid Station</u>

1. **Total Grid Station Losses**

   Difference between total energy import and export for one day gives total energy loss in the grid station.

$$Total\ Losses = Total\ Energy\ Import - Total\ Energy\ Export$$

$$Percentage\ Losses = \frac{Total\ Losses}{Total\ Energy\ Impot} \times 100\%$$

2. **132 kV section Losses (L1)**

   Losses in 132 kV section were calculated as follows.

$$L1 = Energy\ Imported - Engery\ Exported$$

   Where:

   Both $Energy\ Imported$ and $Engery\ Exported$ are of 132 kV lines

3. **Transformer Losses (L2) 132/11 kV**

   Transformer losses were calculated as follows:

$$Losses = L1 = NL + Load \times \left(\frac{Load\ MVA}{Capacity\ (MVA\ Rating)}\right)^2 \times \left(\frac{235 + T_{wind}}{235 + 75}\right)$$

$$Energy\ Loss = Losses \times Time$$

   Where:

   NL is no-load losses and these are mentioned on transformer rating plate

   $\left(\frac{235+T_{wind}}{235+75}\right)$ is temperature correction factor.

   T_{wind} is winding temperature and it is calculated as:

$$T_{wind} = Ambient\ temperature + 55 \times \frac{Load\ MVA}{Capacity\ (MVA\ Rating)}$$

Load is average load on transformer:

$$Average\ Load = \frac{Total\ Reading(MWh)}{24}\ MW$$

$$Load\ MVA = \frac{Average\ Load}{Power\ Factor}$$

Average power factors of three transformers for given months are shown in Table 3.6.

Table 3.6: **Power Factors of Transformers**

Transformer Name	Power Factor
T-1	0.9
T-2	0.9
T-3	0.9

4. **11 kV section losses (L3)**
   Losses in 11 kV were calculated as

$$L3 = Incoming\ Energy - Outgoing\ Engery$$

3.4 Data Analysis

There were no electronic data loggers available on the both the grid stations. Therefore, it was decided that manual data collection shall be carried out. For this purpose, data collection forms were developed. The print out of these forms was given to the staff of the both grid station. The time schedule followed was as follows:

220 kV New Kot Lakhpat Grid Station

Start date	19th September 2014
End date	4th October 2014
Reading Interval	6 hours

132 kV Qurtaba Grid Station

Start date	20th September 2014
End date	5th October 2014
Reading Interval	6 hours

At the end of the above said periods, data analysis was carried out for both the grid stations. For the 220 kV Kot Lakhpat grid station, the energy data along with name plate data of the transformers was used to calculate the transformer losses. The energy data of this grid station showed logical behavior with a few exceptions.

However, during the analysis of 132 kV Qurtaba Grid Station, serious flaws were discovered in the data of 132 kV grid station. The total energy imported into this grid station was less than the total energy exported, which is logically not possible. After double checking the data and comparing with the log sheets of the grid station, it was concluded that this inaccuracy/mistake might has occurred due to human error. To overcome this aspect, a more simplified form was developed with an interval of 24 hours. Daily personal visits were made to the grid station and energy meter readings were recorded. The schedule followed was as given below:

Start date	11th October 2014
End date	18th October 2014
Reading Interval	24 hours

The data collected in the second attempt has been shown in the tables provided in the following section. The energy data collected from 12.11.2014 to 16.11.2014 and on 18.11.2014 again showed abnormal behavior i.e. energy export was more than the energy import.

The energy data collected from 12.11.2014 to 16.11.2014 and on 18.11.2014 again showed abnormal behavior i.e. energy export was more than energy import.

220kV New Kot Lakhpat Grid Station Energy Data

Table 3.7: **DATA RECORDED FOR ENERGY IMPORT & EXPORT (MWh) AT 220 kV LINES**

Date	Time	NKLP-BDR-II		NKLP-BDR-I		NKLP-SKP		NKLP-WTN		NKLP-SNR-I		NKLP-SNR-II	
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
19.09.2014	6:00	2602854	62706	1551573	5541	3737399	3581	525566	683191	2467580	144235	2494241	138655
	14:00	2603960	62706	1552705	5541	3738294	3581	525636	683224	2467672	144416	2494256	138660
	22:00	2605160	62706	1553939	5541	3739323	3581	525637	683396	2468156	144416	2494732	138660
20.09.2014	6:00	2605916	62706	1554722	5541	3740082	3581	525659	683547	2468639	144417	2495211	138661
	14:00	2606817	62706	1555646	5541	3740900	3581	525668	683635	2468829	144478	2495398	138721
	22:00	2607828	62706	1556682	5541	3741800	3581	525672	683822	2469204	144499	2495769	138742
21.09.2014	6:00	2608676	62706	1557558	5541	3742630	3581	525699	683995	2469554	144515	2496116	138758
	14:00	2609719	62706	1558630	5541	3743497	3581	525806	684017	2469626	144598	2496191	138840
	22:00	2610835	62706	1559775	5541	3744434	3581	525820	684083	2469915	144598	2496475	138840
22.09.2014	6:00	2611753	62706	1560717	5541	3745257	3581	525879	684167	2470253	144641	2496809	138883
	14:00	2612770	62706	1561767	5541	3746107	3581	525935	684202	2470332	144785	2496887	139025
	22:00	2613902	62706	1562933	5541	3747085	3581	525946	684354	2470754	144793	2497303	139033
23.09.2014	6:00	2614724	62706	1563775	5541	3747836	3581	525979	684429	2471145	144804	2497690	139044
	14:00	2615891	62706	1564980	5541	3748083	3581	526122	684435	2471247	144853	2497792	139092
	22:00	2616872	62706	1565988	5541	3748670	3581	526136	684545	2471690	144855	2498230	139094
24.09.2014	6:00	2617545	62706	1566682	5541	3749369	3581	526178	684648	2472086	144869	2498622	139108

Date	Time	NKLP-BDR-II		NKLP-BDR-I		NKLP-SKP		NKLP-WTN		NKLP-SNR-I		NKLP-SNR-II	
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
	14:00	2618294	62706	1567450	5541	3750172	3581	526228	684672	2472204	144923	2498740	139161
	22:00	2619107	62706	1568288	5541	3751074	3581	526229	684823	2472654	144930	2499185	139167
25.09.2014	6:00	2619758	62706	1568961	5541	3751779	3581	526239	685013	2473103	144933	2499627	139171
	14:00												
	22:00												
3.10.2014	6:00	2636446	62706	1586127	5541	3769984	3581	526886	688357	2480275	145677	2506471	139907
	14:00	2637323	62706	1587035	5541	3770752	3581	526888	688452	2480463	145732	2506658	139961
	22:00	2638319	62706	1588060	5541	3771675	3581	526888	688696	2480947	145732	2507137	139961
4.10.2014	6:00	2639053	62706	1588816	5541	3772387	3581	526900	688880	2481536	145732	2507511	139961
	14:00	2639955	62706	1589751	5541	3773196	3581	526902	689041	2481765	145787	2507739	140016
	22:00	2640914	62706	1590740	5541	3774102	3581	526902	689302	2482211	145787	2508182	140016

Table 3.8: **DATA RECORDED FOR ENERGY IMPORT & EXPORT (MWh) AT 132kV LINES**

Date	Time	NKLP-KNU		NKLP-J/Town-II		NKLP-Anaytpura		NKLP-DHS		NKLP-WML		NKLP-RMP		NKLP-TNS		NKLP-OKLP		NKLP-MDT		NKLP - LEFO - MDT	
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
19.09.2014	6:00	746357.3	29182.8	1817002.3	8092.4	27.6	2391240	26.7	3160088	1.8	1135266	24.4	843817.8	12.8	1162411	2.7	1469936	85.5	1422144	21.6	1442070
	14:00	746559.1	29185.1	1817447.1	8092.4	27.6	2392024	26.7	3160699	1.8	1135615	24.4	844026.5	12.8	1162774	2.7	1470240	85.5	1422601	21.6	1442434
	22:00	746868.7	29185.1	1818083.7	8092.4	27.6	2393028	26.7	3161623	1.8	1136089	24.4	844357.6	12.8	1163265	2.7	1470758	85.5	1423203	21.6	1442997
20.09.2014	6:00	747042	29185.1	1818489.9	8092.4	27.6	2393892	26.7	3162391	1.8	1136461	24.4	844523.3	12.9	1163265	2.7	1471129	85.5	1423624	21.6	1443362
	14:00	747217.7	29193.4	1818916.4	8092.4	27.6	2394642	26.7	3163050	1.8	1136829	24.4	844721.8	13	1163265	2.7	1471453	85.5	1424044	21.6	1443754
	22:00	747459.3	29193.4	1819459.6	8092.4	27.6	2395563	26.7	3163862	1.8	1137274	24.4	845000.6	13.1	1163265	2.7	1471926	85.5	1424562	21.6	1444256
21.09.2014	6:00	747614.3	29193.9	1819828.5	8092.4	27.6	2396350	26.7	3164660	1.8	1137665	24.4	845171.7	13.1	1163265	2.7	1472280	85.5	1424958	21.6	1444623
	14:00	747807.1	29193.9	1820055.3	8098.9	27.6	2397127	26.7	3165391	1.8	1138034	24.4	845336.7	13.1	1163570	2.7	1472655	85.5	1425432	21.6	1444698
	22:00	748038.2	29193.9	1820546.1	8098.9	27.6	2398030	26.7	3166243	1.8	1138469	24.4	845578.7	13.2	1163966	2.7	1473098	85.5	1425927	21.6	1445081
22.09.2014	6:00	748243.3	29193.9	1820970.6	8098.9	27.6	2398844	26.7	3167019	1.8	1138852	24.4	845735.4	13.2	1164224	2.7	1473462	85.5	1426331	21.6	1445460
	14:00	748411.5	29202	1821399.9	8098.9	27.6	2399573	26.7	3167613	1.8	1139190	24.4	845949.5	13.2	1164408	2.7	1473744	85.5	1426750	21.6	1445818
	22:00	748692.2	29202.2	1821980.7	8098.9	27.6	2400467	26.7	3168450	1.8	1139600	24.4	846249.7	13.2	1164897	2.7	1474228	85.5	1427336	21.6	1446248
23.09.2014	6:00	748880.2	29208.4	1822389.1	8098.9	27.6	2401366	26.7	3169180	1.8	1139847	24.4	846422.8	13.2	1165172	2.7	1474565	85.5	1427748	21.6	1446604
	14:00	749078.8	29215	1822833.9	8098.9	27.6	2402124	26.7	3169791	1.8	1140023	24.4	846602.9	13.2	1165541	2.7	1474880	85.5	1428171	21.6	1446982
	22:00	749278	29215	1823317.1	8098.9	27.6	2402972	26.7	3170679	1.8	1140333	24.4	846602.9	13.2	1165576	2.7	1475360	85.5	1428737	21.6	1447495
24.09.2014	6:00	749432.7	29215.4	1823682.5	8098.9	27.6	2403791	26.7	3171443	1.8	1140575	24.4	846602.9	13.2	1165576	2.7	1475717	85.5	1429144	21.6	1447873
	14:00	749588.2	29228.3	1824040.1	8098.9	27.6	2404549	26.7	3172051	1.8	1140788	24.4	846602.1	13.2	1165576	2.7	1476028	85.5	1429577	21.6	1448245
	22:00	749785.9	29228.3	1824512.9	8098.9	27.6	2405453	26.7	3172897	1.8	1141082	24.9	846602.9	13.2	1165576	2.7	1476491	85.5	1430130	21.6	1448748
	6:00	749897	29236.1	1824813.9	8098.9	27.6	2406253	26.7	3173600	1.8	1141316	25	846602.9	13.6	1165576	2.7	1476827	85.5	1430552	21.6	1449113

Date	Time	NKLP-KNU		NKLP-J/Town-II		NKLP-Anaytpura		NKLP-DHS		NKLP-WML		NKLP-RMP		NKLP-TNS		NKLP-OKLP		NKLP-MDT		NKLP - LEFO - MDT	
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
25.09.2014	14:00 [3]																				
	22:00																				
3.10.2014	6:00	753128	29557.1		8138.8	27.6	2422354	26.7	3188109	1.8	1146811	27.3	846603.1	15.7	1165852	2.7	1485730	85.5	1441392	21.6	1458609
	14:00	753337.2	29562.1	1833794.3	8138.8	27.6	2423084	26.7	3188731	1.8	1147123	27.3	846603.1	15.7	1166209	2.7	1486041	85.5	1441811	21.6	1458955
	22:00	753647.1	29562.1	1834448.5	8138.8	27.6	2424001	26.7	3189628	1.8	1147546	27.6	846603.1	15.7	1166685	2.7	1486511	85.5	1442372	21.6	1459444
4.10.2014	6:00	753826.9	29564.3	1834852.5	8138.8	27.6	2424816	26.7	3190361	1.8	1147928	27.6	846603.1	15.7	1166950	2.7	1486845	85.5	1442787	21.6	1459775
	14:00	753996.7	29567.5	1835292.9	8138.8	27.6	2425540	26.7	3191011	1.8	1148274	27.8	846603.1	15.7	1167300	2.7	1487157	85.5	1443185	21.6	1460134
	22:00	754242.7	29567.5	1835827.1	8138.8	27.6	2426424	26.7	3191869	1.8	1148702	27.9	846603.1	15.7	1167696	2.7	1487575	85.5	1443700	21.6	1460575

[3]Nil data corresponds to Permit to Work (PTW) i.e. line/ feeder was shut down for maintenance work.

Table 3.9: **DATA RECORDED FOR ENERGY EXPORT (MWh) AT 132kV SIDE OF AUTO-TRANSFORMERS (SECURED METERING SYSTEM) & 11kV OF POWER TRANSFORMERS**

Date	Time	TRamb (°C)	T1 (220/132/11kV)				T2 (220/132/11kV)				T3 (220/132/11kV)				T4 (132/11.5kV)			T5 (132/11.5kV)			T6 (132/11.5kV)		
			Export	Load(A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	Export	Load (A)	TRHV(°C) PP	Export	Load (A)	TRHV (°C) PP
19.09.14	6:00	29	1618570	380	42	44	1943245	630	50	46	1938680	630	50	57	205187	600	48	1200101	695	50	1151795	385	50
	14:00	36	1619341	700	50	50	1944488	1055	66	58	1939926	1055	66	82	205277.8	530	62	1200215	510	64	1151877	450	66
	22:00	32	1620480	885	52	54	1946015	910	70	64	1941448	910	70	84	205395.3	1000	58	1200324	950	58	1151980	830	58
20.09.14	6:00	29	1621309	530	42	46	1947150	575	48	45	1942580	575	48	54	205487.6	545	54	1200429	700	54	1152051	350	52
	14:00	36	1622174	580	50	56	1948194	710	60	53	1943621	710	58	70	205579.1	535	62	1200544	540	68	1152132	490	64
	22:00	28	1623227	780	53	55	1949410	875	60	54	1944834	875	60	69	205694.8	920	52	1200664	880	52	1152233	740	52
21.09.14	6:00	29	1624076	625	40	42	1950509	595	46	42	1945930	595	46	52	205786.7	425	46	1200768	620	44	1152302	270	42
	14:00	36	1624866	540	40	46	1951656	805	55	49	1947075	805	55	61	205786.7	425	46	1200768	620	44	1152302	270	42
	22:00	30	1625733	750	53	52	1953132	1050	63	60	1948545	1050	67	81	205977.8	920	54	1200924	750	56	1152440	590	56
22.09.14	6:00	29	1626511	575	42	44	1954341	660	54	50	1949751	660	54	62	206068.6	460	48	1201012	530	44	1152512	305	44
	14:00	38	1627287		50	53	1955397		60	58	1950802		60	74	206150.5	515	58	1201125	550	66	1152589	610	62
	22:00	32	1628345	890	50	53	1956846	1050	60	58	1952246	1050	60	74	206264.2	1020	58	1201253	960	60	1152694	830	56

Date	Time	TRamb (°C)	T1 (220/132/11kV)				T2 (220/132/11kV)				T3 (220/132/11kV)				T4 (132/11.5kV)			T5 (132/11.5kV)			T6 (132/11.5kV)		
			Export	Load(A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	Export	Load (A)	TRHV(°C) PP	Export	Load (A)	TRHV (°C) PP
23.09.14	6:00	29	1629105	480	40	42	1958038	535	52	48	1953434	535	48	62	206366.2	505	48	1201361	700	48	1152771	360	46
	14:00	37	1629888	535	50	52	1959153	690	58	58	1954544	690	56	62	206471.1	450	56	1201477	565	56	1152848	425	56
	22:00	31	1630845	800	48	49	1960311	870	51	51	1955700	870	57	63	206552.6	1050	50	1201609	950	48	1152955	810	48
24.09.14	6:00	28	1631554	605	42	44	1961337	720	50	44	1956721	720	48	54	206655.7	525	48	1201718	690	48	1153031	315	46
	14:00	36	1632260	540	50	50	1962264	620	52	48	1957646	620	50	56	206738.4	500	58	1201835	560	64	1153107	460	62
	22:00	29	1633200	755	48	50	1963392	925	60	55	1958770	925	60	72	206872.9	920	52	1201916	89	54	1153224	760	50
25.09.14	6:00	28	1633999	485	40	42	1964389	480	44	40	1959767	480	42	48	206948.7	490	48	1202066	665	46	1153281	310	44
	14:00																						
	22:00																						
3.10.14	6:00	26	1653155	620	42	43	1986001	495	45	42	1981310	495	46	51	209264.6	490	48	1204622	660	46	1155555	310	48
	14:00	37	1654039	620	52	54	1987016	825	58	51	1982322	825	56	66	209354.7	690	62	1204735	530	58	1155645	590	56
	22:00	30	1655205	620	52	54	1988266	965	59	53	1983568	965	52	58	209467.7	480	58	1204853	845	54	1155770	890	58
	6:00	26	1656043	470	42	43	1989343	530	46	42	1984641	530	46	53	209563.1	440	42	1204953	790	44	1155855	710	42

Date	Time	TRamb (°C)	T1 (220/132/11kV)				T2 (220/132/11kV)				T3 (220/132/11kV)				T4 (132/11.5kV)			T5 (132/11.5kV)			T6 (132/11.5kV)		
			Export	Load(A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	TRLV (°C) PP	Export	Load (A)	TRHV (°C) PP	Export	Load (A)	TRHV(°C) PP	Export	Load (A)	TRHV (°C) PP
4.10.14	14:00		1656932	470			1990302	500			1985597	500			209563.1	440	42	1204953	790	44	1155855	710	42
	22:00	31	1658045	890	52	52	1991412	930	52	52	1986792	930	52	54	209755.9	650	54	1205151	690	56	1156048	820	52

Table 3.10: **CALCULATION OF ENERGY IMPORTED AND EXPORTED (MWh) AT 220 KV LINES**

Interval		NKLP-BDR-II		NKLP-BDR-I		NKLP-SKP		NKLP-WTN		NKLP-SNR-I		NKLP-SNR-II		Total Energy Imported	Total Energy Exported	Net Energy Imported
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export			
1(19.09.2014-20.09.2014)	1day	3062	0	3149	0	2683	0	93	356	1059	182	970	6	11016	544	10472
2(20.09.2014-21.09.2014)	1day	2760	0	2836	0	2548	0	40	448	915	98	905	97	10004	643	9361
3(21.09.2014-22.09.2014)	1day	3077	0	3159	0	2627	0	180	172	699	126	693	125	10435	423	10012
4(22.09.2014-23.09.2014)	1day	2971	0	3058	0	2579	0	100	262	892	163	881	161	10481	586	9895
5(23.09.2014-24.09.2014)	1day	2821	0	2907	0	1533	0	199	219	941	65	932	64	9333	348	8985
6(24.09.2014-25.09.2014)	1day	2213	0	2279	0	2410	0	61	365	1017	64	1005	63	8985	492	8493
7(25.09.2014-03.10.2014)	7days	16688	0	17166	0	18205	0	647	3344	7172	744	6844	736	66722	4824	61898
8(03.10.2014-04.10.2014)	1day	2607	0	2689	0	2403	0	14	523	1261	55	1040	54	10014	632	9382

Table 3.11: **CALCULATION OF ENERGY IMPORTED AND EXPORTED (MWh) AT 132 KV LINES**

Interval	NKLP -KNU		NKLP-J/Town-II		NKLP-Anayt pura		NKLP-DHS		NKLP-WML		NKLP-RMP										Total Energy Imported	Total Energy Exported
	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp		
1	684.7	2.3	1487.6	0	0	2652	0	2303.2	0	1194.7	0	705.5	0.1	853.7	0	1193.5	0	1479.9	0	1291.8	2172.4	11676.6
2	572.3	8.8	1338.6	0	0	2457.7	0	2269	0	1204.2	0	648.4	0.2	0	0	1151.3	0	1333.4	0	1261.1	1911.1	10333.9
3	629	0	1142.1	6.5	0	2493.7	0	2358.3	0	1186.9	0	563.7	0.1	959.4	0	1182.1	0	1373.3	0	837.7	1771.2	10961.6
4	636.9	14.5	1418.5	0	0	2522.1	0	2161.6	0	995	0	687.4	0	947.1	0	1102.3	0	1417.2	0	1143.3	2055.4	10990.5
5	552.5	7	1293.4	0	0	2424.8	0	2263	0	727.8	0	180.1	0	404.2	0	1152.3	0	1395.6	0	1269.5	1845.9	9824.3
6	464.3	20.7	1131.4	0	0	2462.2	0	2156.5	0	740.8	0.6	0	0.4	0.1	0	1110.2	0	1408.5	0	1240	1596.7	9139
7	3231	321	8513.5	39.9	0	16101.2	0	14509.7	0	5495	2.3	0.2	2.1	276.1	0	8902.4	0	10839.4	0	9495.5	11748.9	65980.4
8	698.9	7.2	1525.1	0	0	2462	0	2251.3	0	1116.9	0.3	0	0	1098.2	0	1115.1	0	1395.6	0	1166	2224.3	10612.3

Table 3.12: **CALCULATION OF ENERGY IMPORTED AND EXPORTED (MWh) AT TRANSFORMERS**

Interval	Secured Metering System				11kV Side of Power Transformers			
	T1	T2	T3	Total Energy Exported	T4	T5	T6	Total Energy Exported
1	2739	3905	3900	10544	300.6	328	256	884.6
2	2767	3359	3350	9476	299.1	339	251	889.1
3	2435	3832	3821	10088	281.9	244	210	735.9
4	2594	3697	3683	9974	297.6	349	259	905.6
5	2449	3299	3287	9035	289.5	357	260	906.5
6	2445	3052	3046	8543	293	348	250	891
7	19156	21612	21543	62311	2315.9	2556	2274	7145.9
8	2888	3342	3331	9561	298.5	331	300	929.5

Table 3.13: **CALCULATION OF ENERGY LOSS WITHIN THE SUBSTATION (MWh)**

Interval	220kV		132kV		11kV[4]	Total			
	Imported	Exported	Imported	Exported	Exported	Imported	Exported	Losses	%age
1	**2**	**3**	**4**	**5**	**6**	**7 =2+4**	**8=3+5+6**	**9=7-8**	**10=9/7x100**
1	11016	544	2172.4	11676.6	887.2	13188.4	13107.83	80.57	0.61%
2	10004	643	1911.1	10333.9	891.8	11915.1	11868.65	46.45	0.39%
3	10435	423	1771.2	10961.6	738.1	12206.2	12122.74	83.46	0.68%
4	10481	586	2055.4	10990.5	908.3	12536.4	12484.80	51.6	0.41%
5	9333	348	1845.9	9824.3	909.2	11178.9	11081.51	97.39	0.87%
6	8985	492	1596.7	9139	893.7	10581.7	10524.66	57.04	0.54%
7	66722	4824	11748.9	65980.4	7167.3	78470.9	77971.69	499.20	0.64%
8	10014	632	2224.3	10612.3	932.3	12238.3	12176.56	61.74	0.50%
Total (1~8)	**136992**	**8495**	**25329.9**	**139523.6**	**13333.9**	**162315.9**	**161338.44**	**977.45**	**0.602%**

[4]This column contains the energy exported on 11kV side plus the transformation losses of 3No.PowerTransformer, as our scope is to calculate the losses of within 220kV and 132kV yard. Please refer to the metering diagram for details

Table 3.14: **BREAK UP OF LOSSES**

Interval	Average Loading of Transformer (MVA)						Average Winding temperature (°C)						Energy Losses in Transformers (MWh)						Total Losses (MWh)	
	Auto-Transformer			Power Transformers			Auto-Transformer			Power Transformers			Auto-Transformer			Power Transformers			Auto-Transformer	Power Transformer
	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6		
1	135.86	180.79	180.56	13.92	15.19	11.85	59.89	69.77	69.72	59.44	62.12	55.07	4.29	6.88	6.87	0.89	0.98	0.77	18.04	2.63
2	137.25	155.51	155.09	13.85	15.69	11.62	60.20	64.21	64.12	59.29	63.20	54.58	4.35	5.32	5.29	0.89	1.01	0.76	14.97	2.65
3	120.78	177.41	176.90	13.05	11.30	9.72	56.57	69.03	68.92	57.61	53.90	50.57	3.60	6.66	6.62	0.84	0.74	0.67	16.89	2.24
4	128.67	171.16	170.51	13.78	16.16	11.99	58.31	67.65	67.51	59.15	64.18	55.37	3.95	6.25	6.21	0.88	1.05	0.78	16.42	2.70
5	121.48	152.73	152.18	13.40	16.53	12.04	56.73	63.60	63.48	58.35	64.96	55.46	3.63	5.16	5.13	0.86	1.08	0.78	13.93	2.71
6	121.28	141.30	141.02	13.56	16.11	11.57	56.68	61.09	61.02	58.69	64.08	54.48	3.62	4.56	4.54	0.87	1.04	0.75	12.72	2.66
7	135.74	142.94	142.48	15.32	16.90	15.04	59.86	61.45	61.35	62.40	65.76	61.81	29.97	32.48	32.31	6.89	7.74	6.76	94.76	21.39
8	143.25	154.72	154.21	13.82	15.32	13.89	61.52	64.04	63.93	59.23	62.42	59.38	4.66	5.27	5.24	0.88	0.99	0.89	15.17	2.76

132 kV Qurtaba Grid Station Energy Data

Table 3.15: DATA RECORDED FOR ENERGY IMPORT & EXPORT (MWh) AT 132 kV LINES AND ENERGY EXPORT (kWh) AT 11kV SIDE OF POWER TRANSFORMERS

Date	Time	SDM-3 Shadman		SDM-4 Shadman		E5Q1 Bund Road		RWG-4 Rewaz Garden		T1 (132/11.5 kV)			T2 (132/11.5 kV)			T3 (132/11.5 kV)			T_{amb} (°C)
		Import	Export	Import	Export	Import	Export	Import	Export	Export	Load (A)	T_{HV} (°C)	Export	Load (A)	T_{HV} (°C)	Export	Load (A)	T_{HV} (°C)	
10.11.2014	14:00	17609.6	571554.5	16446.2	581575.6	950557.9	30.6	35690.5	53021.5	82932252	340	40	32693187	370	40	167176	320	42	25
11.11.2014	14:00	17878.2	571554.5	16446.2	581575.6	950557.9	30.6	35690.5	53021.5	83009052	220	40	32739989	250	40	167224	200	40	25
12.11.2014	14:00	18167.2	571554.5	16446.2	581575.6	950557.9	30.6	35690.5	53021.5	83085930	170	32	32787269	250	32	167279	340	32	25
13.11.2014	14:00	18375.9	571554.5	16446.2	581575.6	950587.1	30.6	35690.5	53021.5	83170221	310	34	32834532	310	35	167323	190	34	24
14.11.2014	14:00	18375.9	571554.5	16446.2	581575.6	950737.7	30.6	35690.5	53021.5	83255869	380	32	32883490	370	34	167381	280	34	25
15.11.2014	14:00	18461.4	571554.5	16446.2	581575.6	950829.3	30.6	35690.5	53021.5	83328706	360	34	32928940	340	32	167431	280	30	25
16.11.2014	14:00	18716.4	571554.5	16446.2	581575.6	950829.3	30.6	35690.5	53021.5	83400272	260	38	32972895	250	38	167479	260	40	24
17.11.2014	14:00	18974.5	571554.5	16446.2	581575.6	950829.3	30.6	35690.5	53021.5	83475153	320	38	33015476	380	38	167526	230	38	24
18.11.2014	14:00	19220.4	571554.5	16446.2	581575.6	950829.3	30.6	35690.5	53021.5	83543268	240	38	33058490	200	38	167572	140	38	24

Table 3.16: **DATA RECORDED FOR ENERGY EXPORT (kWh) AT 11 kV FEEDERS OF T1**

Date	Time	LHQ		Raj Ghar		AlFalah		State Bank		Rahat Park		CTO	
		Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)
10.11.2014	14:00	938580	10	10323090	70	4077811	50	11087396	100	13706741	90	1775529	20
11.11.2014	14:00	939757	10	10332948	70	4082926	40	11099149	100	13716737		1776604	20
12.11.2014	14:00	940980	20	10340663	150	4088572	50	11111099	100	13727903	50	1777699	20
13.11.2014	14:00	942269	20	10352330	150	4093443	40	11123538	100	13739552	60	1778583	20
14.11.2014	14:00	943465	20	10362353	140	4098499	40	11135414	100	13753806	80	1779765	20
15.11.2014	14:00	944184	10	10371926	130	4102822	40	11145503	80	13765557	100	1780390	20
16.11.2014	14:00	944448		10381728	70	4105939		11155139	90	13777962	100	1780914	20
17.11.2014	14:00	945248	10	10391245	70	4109829	50	11165930	100	13789853	90	1782006	20
18.11.2014	14:00	946441	10	10400720	70	4114783	50	11174613	110	13799147		1783220	20

Table 3.17: **DATA RECORDED FOR ENERGY EXPORT (kWh) AT 11 kV FEEDERS OF T2**

Date	Time	LOS		B.Pur House		Mozang Adda		Punch Road		Temple Road	
		Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)
10.11.2014	14:00	17816934	70	36476707	90	38129372	110	22280971	50	16674999	50
11.11.2014	14:00	17824427	50	36486154		38143851	100	22288523	50	16682454	50
12.11.2014	14:00	17830177	50	36499261	90	38157723	100	22296305	60	16688502	40
13.11.2014	14:00	17838484	90	36508780	60	38171750	100	22303773	60	16696462	60
14.11.2014	14:00	17846065	80	36521862	100	38185274	100	22310988	40	16703683	50
15.11.2014	14:00	17853632	80	36533721	100	38197741	90	22318006	40	16710463	30
16.11.2014	14:00	17858923		36545664	110	38210540	80	22325350	60	16716125	
17.11.2014	14:00	17864335	100	36556960	90	38222518	90	22332354	50	16722649	50
18.11.2014	14:00	17872941	60	36565758		38235202	90	22338009		16729581	50

Table 3.18: **DATA RECORDED FOR ENERGY EXPORT (kWh) AT 11 kV FEEDERS OF T3**

Date	Time	Mall Road		Queens Road		Mozang Adda		Punch Road		Temple Road	
		Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)	Export	Load (A)
10.11.2014	14:00	7405269	80	7882645	100	69151975	100	53029167	40	3001.14	100
11.11.2014	14:00	7414921	60	7893859	100	69174958	PTW	53049895	40	3003.56	PTW
12.11.2014	14:00	7424848	50	7905771	100	69205050	100	53070593	40	3006.92	50
13.11.2014	14:00	7432751	60	7917326	100	69222953	100	53090670	30	3009.34	50
14.11.2014	14:00	7443801	50	7928657	100	69256672	100	53109466	30	3012.65	50
15.11.2014	14:00	7453350	50	7940031	100	69283303	80	53127828	40	3015.68	60
16.11.2014	14:00	7460678	PTW	7950058	70	69311640	100	53145121	20	3018.65	70
17.11.2014	14:00	7470499	PTW	7959211	100	69339184	100	53163294	30	3020.9	PTW
18.11.2014	14:00	7479800	PTW	7970790	120	69360549	PTW	53181987	20	3023.43	PTW

Table 3.19: **CALCULATION OF ENERGY IMPORTED AND EXPORTED (MWh) AT LINES AND TRANSFORMERS**

Interval	132kV Lines											11kV Incoming Panels			
	SDM-3 Shadman		SDM-4 Shadman		E5Q1 Bund Road		RWG-4 Rewaz Garden		Total Energy Imported	Total Energy Exported	Net Energy Imported	T1	T2[5] (M.F=2)	T3[1] (M.F=2000)	Total Energy Exported to 11kV System
	Import	Export	Import	Export	Import	Export	Import	Export							
1(10.11.2014-11.11.2014)	268.6	0	0	0	0	0	0	0	268.6	0	268.6	76.8	94.56	96	266.404
2(11.11.2014-12.11.2014)	289	0	0	0	0	0	0	0	289	0	289	76.878	94.526	110	281.438
3(12.11.2014-13.11.2014)	208.7	0	0	0	29.2	0	0	0	237.9	0	237.9	84.291	97.916	88	266.817
4(13.11.2014-14.11.2014)	0	0	0	0	150.6	0	0	0	150.6	0	150.6	85.648	90.9	116	299.564
5(14.11.2014-15.11.2014)	85.5	0	0	0	91.6	0	0	0	177.1	0	177.1	72.837	87.91	100	263.737
6(15.11.2014-16.11.2014)	255	0	0	0	0	0	0	0	255	0	255	71.566	85.162	96	255.476
7(16.11.2014-17.11.2014)	258.1	0	0	0	0	0	0	0	258.1	0	258.1	74.881	86.028	92	246.143
8(17.11.2014-18.11.2014)	245.9	0	0	0	0	0	0	0	245.9	0	245.9	68.115	94.56	96	266.404

Table 3.20: **CALCULATION OF ENERGY EXPORTED (MWh) AT 11 kV LINES**

Interval	T1 (Outgoing Feeders)						T2 (Outgoing Feeders) (OutgoingFeeders)					T3 (Outgoing Feeders)					Total Energy Exported
	LHQ M.F=1	Raj Ghar M.F=2	Alflah M.F=2	State Bank M.F=2	Rahat Park M.F=2	CTO M.F=2	LOS M.F=2	B.Pur House M.F=2	Mozang Adda M.F=2	Punch Road M.F=2	Temple Road M.F=2	Mall Road M.F=2	Queens Road M.F=2	F.Sher Road M.F=1	Ganga Ram M.F=0.5	Samnabad M.F=8000	
1	1.177	19.716	10.230	23.506	19.992	2.150	14.986	18.894	28.958	15.104	14.91	19.304	22.428	22.983	10.364	19.36	87.312
2	1.223	15.430	11.292	23.900	22.332	2.190	11.5	26.214	27.744	15.564	12.096	19.854	23.824	30.092	10.349	26.88	86.910
3	1.289	23.334	9.742	24.878	23.298	1.768	16.614	19.038	28.054	14.936	15.92	15.806	23.11	17.903	10.0385	19.36	94.518
4	1.196	20.046	10.112	23.752	28.508	2.364	15.162	26.164	27.048	14.43	14.442	22.1	22.662	33.719	9.398	26.48	95.578
5	0.719	19.146	8.646	20.178	23.502	1.250	15.134	23.718	24.934	14.036	13.56	19.098	22.748	26.631	9.181	24.24	82.806
6	0.264	19.604	6.234	19.272	24.810	1.048	10.582	23.886	25.598	14.688	11.324	14.656	20.054	28.337	8.6465	23.76	80.051
7	0.800	19.034	7.780	21.582	23.782	2.184	10.824	22.592	23.956	14.008	13.048	19.642	18.306	27.544	9.0865	18	84.416
8	1.193	18.950	9.908	17.366	18.588	2.428	17.212	17.596	25.368	11.31	13.864	18.602	23.158	21.365	9.3465	20.24	77.948

[5]Multiplying factor for Energy Meter, wherever the MF has been mentioned in the column heading, the reading of energy meter has been multiplied by MF to obtain the actual energy

Table 3.21: **CALCULATION OF ENERGY LOSS WITHIN THE SUBSTATION (MWh)**

Interval	132kV		11kV Incoming	11kV Outgoing	Total Loss in Substation	
	Imported	Exported	Exported	Exported	Losses	%age
1	**2**	**3**	**4**	**5**	**6=5-2**	**10=6/2x100**
1	268.6	0	266.404	264.062	4.538	1.7%
2	289	0	281.438	280.484	8.516	2.9%
3	237.9	0	266.817	265.089	-27.1885	-11.4%
4	150.6	0	299.564	297.583	-146.983	-97.6%
5	177.1	0	263.737	266.721	-89.621	-50.6%
6	255	0	255.476	252.764	2.2365	0.9%
7	258.1	0	254.043	252.169	5.9315	2.3%
8	245.9	0	246.143	246.494	-0.5945	-0.2%
Total (1~8)	**1882.2**	**0**	**2133.622**	**2125.366**	**-243.165**	**-12.9%**

Table 3.22: **BREAKUP OF LOSSES (Transformers)**

Interval	Average Loading of Transformer(MVA)			Average Winding temperature(°C)			Energy Losses in Transformers(MWh)			Total Losses(MWh)
	Power Transformers			Power Transformers			Power Transformers			Power Transformer
	T1	T3	T3	T1	T3	T3	T1	T3	T3	
1	3.56	4.33	4.44	21.91	26.57	26.76	0.526	0.528	0.557	1.611
2	3.56	4.38	5.09	21.91	26.64	27.89	0.526	0.529	0.569	1.623
3	3.90	4.38	4.07	21.91	26.14	25.61	0.526	0.528	0.551	1.606
4	3.97	4.53	5.37	21.91	25.42	26.88	0.526	0.531	0.574	1.631
5	3.37	4.21	4.63	21.91	24.85	25.58	0.526	0.526	0.560	1.611
6	3.31	4.07	4.44	21.90	24.11	24.76	0.526	0.523	0.557	1.606
7	3.47	3.94	4.35	21.91	23.88	24.60	0.526	0.522	0.555	1.603
8	3.15	3.98	4.26	21.90	23.45	23.94	0.526	0.522	0.554	1.602

Table 3.23: **BREAKUP OF LOSSES**

Interval	Total Losses in Grid Station (MWh)	Break Up of Losses in different Segments of Substation (MWh)					
		Power Transformer	%age	132 kV Yard	%age	11 kV Panels	%age
1	4.538	1.611	35.5	0.585	12.9	2.342	51.6
2	8.516	1.623	19.1	5.939	69.7	0.954	11.2
3	-27.1885	1.606		-28.917		1.7285	
4	-146.983	1.631		-148.964		1.981	
5	-89.621	1.611		-86.637		-2.984	
6	2.2365	1.606		-0.476		2.7125	
7	5.9315	1.603		4.057		1.8745	
8	-0.5945	1.602		-0.243		-0.3515	
Total (1-8)	**-243.165**	**12.893**		**-251.422**		**8.257**	

CHAPTER 4. Conclusion

4.1 Conclusion

Basic Elements of Conclusion

- The study was based on as per actual values of energy recorded at the selected grid stations.
- The energy loss has been expressed as percentage of energy input of the grid stations.
- The energy loss measured at NTDC grid station was much less than that at LESCO grid station, which has logical justification.
- The average system loss of the NTDC network is 3.25 % as ref [15]. The major portion of this loss is transmission loss comprising of I^2R and Corona loss.
- The monthly losses calculated by the grid station staff of NTDC for complete one year was obtained. The losses, through this study, derived for the months of October and November of the year 2014 were compared with the losses evaluated by the relevant grid station. According to the grid loss data, the losses during the month of October and November 2014 were calculated as 0.45% and 0.11 % respectively. Whereas the losses calculated as per this study report were 0.6%. On average, the grid station or transformation loss calculated by the grid staff of NTDC for New Kot LakhPat varies between 0.11 and 2.59, which seems to be on the higher side when compared with a recent independent study [15]. Hence the authenticity of the grid station loss data needs to be further verified.
- There are more than one thousand grid stations of 132 kV in Pakistan. Similarly there are thirty two number of 220 kV grid stations in NTDC network. For such a large population of grid stations, the sample size of one grid station from NTDC and one grid station from DISCO is very small. Therefore, no generalized statement or conclusion can be drawn from the results of this study.
- Due to time constraint the duration of study was not large enough to record the impact of variation in load due to seasonal changes.

Statistics

Keeping in view the cut off points of grid stations as mentioned above, the total energy loss measured at 220 kV Kot Lakhpat Grid Station of NTDC in terms of percentage of total energy import is 0.602 %. The breakup of these losses is as under:

- 220 kV Transformer Losses = 20.75%

- 220 kV Switchyard Losses = 24.75%
- 132 kV Switchyard Losses = 55.40%

Whereas the total energy loss measured at 132 kV Qurtaba Grid Station of LESCO in terms of percentage of total energy import varies between 1.7% and 2.9%. It may be noted that this loss calculation is based on readings /data collection of 10th November 2014 to 12th November 2014. The data for the remaining days was not used for the study purpose due to serious flaws in it.

It may also be noted that as per recent study [13] conducted by NTDC through M/s Power Planner International the energy loss as percentage of energy import in 2012 – 2013 was 3.25%.

Possible Reasons for Flawed Data of 132 kV grid Station

The apparent possible reasons behind the flawed data could be following;

1. Human Error
2. Malfunctioning of metering equipment
3. Mis-match of metering equipment due difference on accuracy class of different equipment
4. Deteriorated metering equipment
5. Maintenance issues of measuring equipment
6. Negligence of utility towards losses in the system
7. Time lag between the two readings i.e. incoming and outgoing. Ideally the import and export readings should be taken at the same point of time. However, due to manual readings, this was not possible. However, any abnormal delay in this context can cause serious error in interpretation of readings.

4.2 Recommendation and the Way Forward

1. Efforts should be made to overcome the above highlighted shortcoming/errors.
2. Utilities should take the issue of transformation/grid station losses seriously. Best efforts should be made by the management, in this context.
3. Data loggers should be installed in grid stations to have clear picture of the losses.
4. The installation of switched shunt capacitor banks at 11 kV and 132 kV levels to bring the power factor of distribution network as high as possible is very important since during peak conditions the reactive demand of the Distribution

Companies has to be met by transporting reactive power via the NTDC Network causing heavier flow on the 500 kV and 220 kV lines. This also causes the 500 kV and 220 kV line to be operated at higher voltage level to provide the necessary voltage gradient for flow of reactive power towards the distribution network. The voltage profile of the Distribution network can be improved with the following arrangements:

i. Installation of capacitor banks at 132 kV and 11 kV and bus bars of substations which will allow reactive demand to be met locally and reduce the reactive power flowing through transmission lines and 500/220 kV and 220/132 kV transformers. It may not be out of place to mention here that NTDC has already taken a positive step in this direction. In the said context, NTDC has decided to install 450 MVAR Static VAR Compensator (SVC) at 220 kV Kot Lakhpat grid station. The project is under construction phase. It has been awarded to M/s ABB (Sweden). The cost of the project is 23 Million US$. It is expected to be completed by the year 2016. After the completion of the project the issue of Var compensation in this part of the NTDC network shall be solved to quite an extent. Especially during the peak summer season when the major share is of Inductive load (air-conditioners), the problem of system stability shall be solved fairly to a large extent. In the recent past, major blackout has occurred due to this reason.

ii. Installation of capacitor banks at 11 kV feeders and LT feeders

iii. NEPRA should play a proactive role in terms of improvement of power factor. The Utilities responsible for lower power factor need to be penalized.

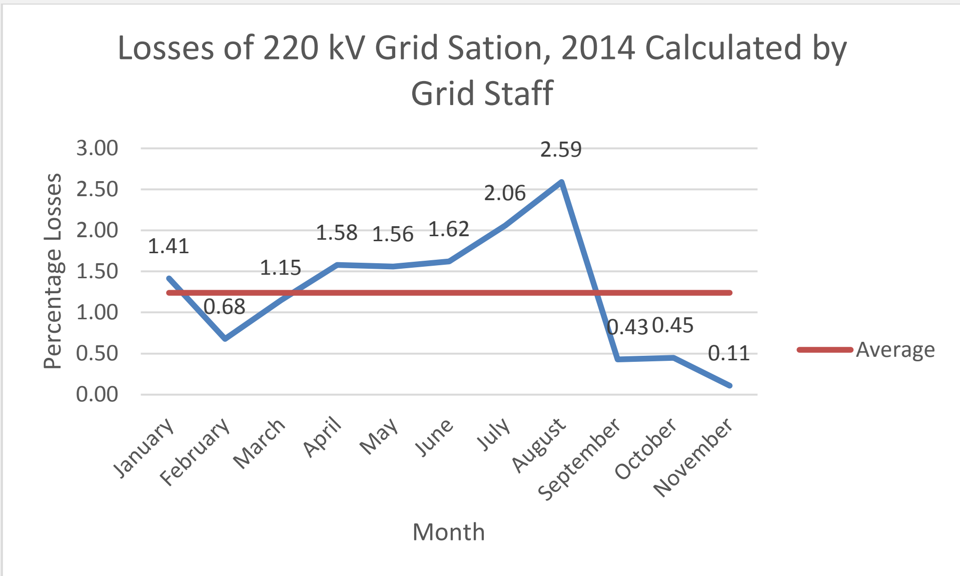

Figure 4.1: **Grid Station Losses Calculated by Grid Staff**

Table 4.1: **Losses of 220 kV New Kot Lakhpat Grid Station Calculated by Grid Staff**

Month	Energy Imported	Energy Exported	Auxiliary	Losses
	kWh	kWh	kWh	%age
January	251,518,900	247,939,159	24,856	1.41
February	233,193,300	231,584,716	18,316	0.68
March	248,800,700	245,932,551	16,562	1.15
April	293,912,400	289,247,095	19,090	1.58
May	403,911,400	397,568,093	32,579	1.56
June	461,361,300	453,837,244	38,612	1.62
July	452,467,000	443,123,068	39,183	2.06
August	434,147,900	422,847,608	38,558	2.59
September	360,975,500	359,400,418	34,202	0.43
October	311,928,000	310,500,168	26,896	0.45
November	260,880,200	260,576,585	21,464	0.11
			Average Losses	**1.24%**

ANNEXURES

Annexure I. Technical Data of 220 kV New Kot Lakhpat Grid Station, Lahore

Table A.1: **220 kV Transmission Lines**

NAME OF TRANSMISSION LINE	220 KV BDR-NKLP CCT I&II	220 KV NKLP-SNR CCT I&II	220 KV Y/WALA-SNR CCT I&II
NO. OF LOCATIONS	BDR-NKLP-1-52	NKLP-SNR 1-131	Y/WALA-SNR 1-294
TYPE OF TOWER	EG,EA, TA,H, LA,M	JKD, EA,EG	JKD, EA,EG
NAME OF CONDUCTOR	RAIL	RAIL	RAIL
CAPACITY OF CONDUCTOR (AMP)	868 AMP.	1250 AMP.	1250 AMP.
TYPE OF TRANSMISSION LINE	SINGLE	TWIN	TWIN
LINE LENGTH (KM)	17	48	108
CCT WISE LENGTH (KM)	34	96	216
TOTAL NO. OF TOWERS	52	131	294
TOTAL NO. OF DEAD TOWERS	9	18	31
DATE OF ENERGIZATION	24.06.1988	04.04.1995	03.04.1996
NAME OF GRID STATION	NKLP LAHORE	NKLP LAHORE	YOUSAF WALA

Table A.2: **220 kV Circuit Breakers**

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
1	D3Q1	NMG	ITLEY	245 MHME IP	155185			1996	15/12/2003
2	D4Q1	Reva Alsthom	FRANCE	GL 314	1110590010 12049814 Rep 06/3	1110590010 12049812 Rep 06/2	1110590010 10049412 Rep 06/1	2004	23/2/2011
3	D5Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	1992/2136578-6C			1989	23/03/1995
4	D6Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	2131316-6			1989	15/10/1994
5	D7Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	2131316-2			1989	24/09/1993
6	D8Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	2131316-8			1989	24/09/1993
7	D9Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	2131316-18			1989	04/04/1995
8	D10Q1	SPREACHAR ENERGIE	SWITZERLAND	HGFI 14-1A	2136578-6			1989	19/03/2003
9	D11Q1	SPREACHAR ENERGIE	SWITZERLAND	SB6M245	40006506			2006	24/5/2009

Table A.3: **132 kV Circuit Breakers**

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
1	E1Q1	GEC ALSTHOM	SWITZERLAND	GL 212	16793-0010-4			1998	14/01/2005
2	E2Q1	ABB	SWEDEN	HPL145-25 A1	11670			1991	28/11/2002
3	E3Q1	GEC ALSTHOM	SWITZERLAND	GL212	16793-0010-2			1998	26/3/2005
4	E4Q1	AEG	GERMANY	S1-145F14031SR	94-9885.44-01			1994	27/04/2004
5	E5Q1	GEC	SWITZERLAND	Gl-212	16793-0010-9			1998	10/08/1968
6	E6Q1	GEC ALSTHOM	SWITZERLAND	GL212	16793-0010-8			1998	18/10/2005
7	E7Q1	GEC ALSTHOM	SWITZERLAND	GL212	16793-0010-3			1998	29/04/2005
8	E8Q1	GEC ALSTHOM	SWITZERLAND	GL212	16793-0020-10			1997	29/10/2002
9	E9Q1	Sieyuen	CHINA	LW36-145/W/T4000-4C) DH 120086	7812637			2012	06/11/2014
10	E10Q1	GEC	SWITZERLAND	FKF1-2	14580-0040-09			1998	18/01/2008
11	E11Q1	ABB	SWEDEN	HPL145-25 A1	7812733			1991	20/08/1995
12	E12Q1	ABB	SWEDEN	HPL145-25 A1	7812743			1991	20/08/1995

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
13	E13Q1	ABB	SWEDEN	HPL145-25 A1	8028168			1991	10/06/1995
14	E14Q1	ABB	SWEDEN	DO	7812741			1991	10/06/1995
15	E15Q1	GEC ALSTHOM	SWITZERLAND	GL212	16793-0010-7			1998	29/10/2002
16	E16Q1	ABB	SWEDEN	HPL145-25 A1	7812725			1991	25/10/1996
17	E17Q1	ABB	SWEDEN	HPL145-25 A1	78687			1991	25/10/1996

Table A.4: **220 kV BUS ISOLATORS**

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
1	D2Q11	GALLILO	ITLEY	S2X245	113879			1974	14/04/1979
2	D2Q12	GALLILO	ITLEY	S2X245	113874			1974	14/04/1979
3	D3Q10	GALLILO	ITLEY	S2 X245	113873			1974	14/04/1979
4	D3Q11	GALLILO	ITLEY	S2 X245	113875			1974	14/04/1979
5	D3Q12	GALLILO	ITLEY	S2 X245	113876			1974	14/04/1979
6	D4Q11	GALLILO	ITLEY	S2 X245	113877			1974	07/01/1979
7	D4Q12	GALLILO	ITLEY	S2 X245	113878			1974	07/01/1979
8	D5Q10	GALLILO	ITLEY	S2 X245	113872			1974	07/01/1979
9	D5Q11	GALLILO	ITLEY	S2 X245	113881			1974	07/01/1979
10	D5Q12	GALLILO	ITLEY	S2 X245	113880			1974	07/01/1979
11	D6Q11	ENERGOINVEST	YOGOSLAVIA	VRV214	60048			1974	15/10/1994
12	D6Q12	ENERGOINVEST	YOGOSLAVIA	VRV214	60051			1988	15/10/1994
13	D7Q10	ENERGOINVEST	YOGOSLAVIA	VRV214	60006			1988	24/09/1993

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
14	D7Q11	ENERGOINVEST	YOGOSLAVIA	VRV214	60025			1988	24/09/1993
15	D7Q12	ENERGOINVEST	YOGOSLAVIA	VRV214	60035			1988	24/09/1993
16	D8Q10	ENERGOINVEST	YOGOSLAVIA	VRV214	60004			1988	24/09/1993
17	D8Q11	ENERGOINVEST	YOGOSLAVIA	VRV214	60013			1988	24/09/1993
18	D8Q12	ENERGOINVEST	YOGOSLAVIA	VRV214	60023			1988	24/09/1993
19	D9Q10	ENERGOINVEST	YOGOSLAVIA	VRV214	60009			1988	04/04/1995
20	D9Q11	ENERGOINVEST	YOGOSLAVIA	VRV214	60022			1988	04/04/1995
21	D9Q12	ENERGOINVEST	YOGOSLAVIA	VRV214	60047			1988	04/04/1995
22	D10Q10	ENERGOINVEST	YOGOSLAVIA	VRV214	60003			1988	19/03/2003
23	D10Q11	ENERGOINVEST	YOGOSLAVIA	VRV214	60058			1988	19/03/2003
24	D10Q12	ENERGOINVEST	YOGOSLAVIA	VRV214	60015			1988	19/03/2003
25	D11Q11	CHINA	CHINA	245KV2-5OM	6.26			2006	24/5/2009
26	D11Q12	CHINA	CHINA	245KV2-5OM	6.2			2006	24/5/2009

Table A.5: **132 kV BUS ISOLATORS**

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
1	E1Q11	CHINA	CHINA	145KV2.5CM/KV	6.163			2006	23/2/2011
2	E1Q12	CHINA	CHINA	145KV2.5CM/KV	6.167			2006	23/2/2011
3	E2Q11	CHINA	CHINA	145KV3.1CM/KV	6.196			2006	25/9/2011
4	E2Q12	CHINA	CHINA	145KV3.1CM/KV	6.161			2006	25/9/2011
5	E3Q11	CHINA	CHINA	145KV2.5CM/KV	6.198			2006	12/5/2011
6	E3Q12	CHINA	CHINA	145KV2.5CM/KV	6.164			2006	12/5/2011
7	E4Q11	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
8	E4Q12	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
9	E5Q11	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	01/08/1963
10	E5Q12	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	01/08/1963
11	E6Q10	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
12	E6Q11	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
13	E6Q12	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
14	E7Q10	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
15	E7Q11	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
16	E7Q12	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
17	E8Q10	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	19/10/1963
18	E8Q11	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	28/08/1972
19	E8Q12	SIEMENS	GERMANY	H260ED130T111EC11-8000T	30369900			1963	28/08/1972
20	109	CHINA	CHINA	N/a	N/a			2012	06/11/2014
21	E9Q11	CHINA	CHINA	H260ED130TEC11-8000T	30369900			2006	27/03/2012
22	E9Q12	CHINA	CHINA	H260ED130TEC11-8000T	30369900			2006	27/03/2012
23	E10Q11	L.K.NESS	FRANCE	SBB 60-600A	6476			1978	24/04/1980
24	E10Q12	L.K.NESS	FRANCE	SBB 60-600A	6400			1978	24/04/1980
25	E11Q10	CHINA	CHINA	GW4145 D	262			1991	20/08/1995

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
26	E11Q11	CHINA	CHINA	GW4145 D	263			1991	20/08/1995
27	E11Q12	CHINA	CHINA	GW4145 D	253			1991	20/08/1995
28	E12Q10	CHINA	CHINA	GW4145 D	214			1991	20/08/1995
29	E12Q11	CHINA	CHINA	GW4145 D	212			1991	20/08/1995
30	E12Q12	CHINA	CHINA	GW4145 D	251			1991	20/08/1995
31	E13Q10	CHINA	CHINA	GW4145 D	236			1991	10/06/1995
32	E13Q11	CHINA	CHINA	GW4145 D	237			1991	10/06/1995
33	E13Q12	CHINA	CHINA	GW4145 D	244			1991	10/06/1995
34	E14Q10	CHINA	CHINA	GW4145 D	256			1991	10/06/1995
35	E14Q11	CHINA	CHINA	GW4145 D	247			1991	10/06/1995
36	E14Q12	CHINA	CHINA	GW4145 D	241			1991	10/06/1995
37	E15Q11	SIEMENS	GERMANY	H260ED130TEC11-8000T	30369900			1963	01/02/1968
38	E15Q12	SIEMENS	GERMANY	H260ED130TEC118000T	30369900			1963	01/02/1968
39	E16Q10	CHINA	CHINA	GW4145 D	240			1991	25/10/1996

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
40	E16Q11	CHINA	CHINA	GW4145 D	250			1991	25/10/1996
41	E16Q12	CHINA	CHINA	GW4145 D	242			1991	25/10/1996
42	E17Q10	CHINA	CHINA	GW4145 D	238			1991	25/10/1996
43	E17Q11	CHINA	CHINA	GW4145 D	41			1991	25/10/1996
44	E17Q12	CHINA	CHINA	GW4145 D	234			1991	25/10/1996
45	PT-3	CHINA	CHINA	145KV2.5CM/KV	6.158			2006	31/7/2011
46	PT-4	CHINA	CHINA	145KV2.5CM/KV	Not Available			2006	31/7/2011

Table A.6: **220 kV OVER HEAD BUSBAR**

Sr. No.	Code	Make	Country	Type	Serial Number	Year of Manufacture	Date of Commission
1	220 KV BUS BAR NO.1- 2	600MM SINGLE CONDUCTOR OLD YARD	PAKISTAN	FLEXI ABLE TWIN CONDUCTOR	BUS BAR NO.1- 2	1974	1974
2	132 KV BUS BAR NO.1 -2	HOTHORN DUBLE CONDUCTOR OLD YARD	PAKISTAN	FLEXIABLE	BUS BAR NO.1- 2	2011	2011(double conductor)
3	132 KV BUS BAR NO.1 -2	ALUMINIUM PIPE	PAKISTAN	REGID	BUS BAR NO.1- 2	1995	1995

Table A.7: **11 kV SWITCH GEAR**

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
1	I-C T-4	SIEMENS	PAKISTAN	8BD4 – WAPDA VERSIO	Not Available			1996	06/07/1999
2	I-CT5	PEL- HUNDIE	PAK KORIA	WPV-25-1	3561-9			2003	07/03/2004
3	I-C T6	PEL- HUNDIE	PAK KORIA	WPV-25-1	3561-8			2003	14/03/2004
4	BUS COUPLER	PEL- HUNDIE	PAK KORIA	WPV-25-C	3564			2003	14/03/2004
5	BANK CAP: T4	PEL- HITACHI	PAK JAPAN	V15-F-31	Not Available			2003	06/12/2005
6	BANKCAP: T5	MEIDEN	JAPAN	VFT-12	ML3151-8			1983	15/09/1983
7	BANK CAP: T6	MEDIEN	JAPAN	VFT-12	ML3638-7			1983	15/09/1983
8	NISHTER	PEL- HITACHI	PAK JAPAN	WPV-25-0	299816			1994	30/04/2006
9	NISHTER	PEL- HITACHI	PAK JAPAN	WPV-25-0	299819			1994	30/04/2006
10	NFP RD:	PEL- HITACHI	PAK JAPAN	WPV-25-0	299812			1994	06/07/1999
11	SPARE	PEL- HITACHI	PAK JAPAN	WPV-25-0	3128123			1996	08/06/2000
12	DHALOK	PEL- HITACHI	PAK JAPAN	WPV-25-0	3128124			1996	08/06/2000
13	AUX	PEL- HUNDIE	PAK KORIA	WPV-25-0	356311			2003	07/03/2004
14	PUNJAB SOCIETY	PEL- HUNDIE	PAK KORIA	WPV-25-0	356312			2003	19/12/2005

Sr. No.	Code	Make	Country	Type	Serial Number			Year of Manufacture	Date of Commission
					R	Y	B		
15	KHANA-I	PEL- HUNDIE	PAK KORIA	WPV-25-0	356319			2003	07/03/2004
16	INDS-2	PEL- HUNDIE	PAK KORIA	WPV-25-0	3562180			2003	07/03/2004
17	GENHOSPITAL	PEL- HUNDIE	PAK KORIA	WPV-25-0	3562172			2003	DO
18	GLAXO	PEL- HUNDIE	PAK KORIA	WPV-25-0	356314			2003	DO
19	SPARE	PEL- HUNDIE	PAK KORIA	WPV-25-0	356318			2003	DO
20	HALOKI	PEL- HUNDIE	PAK KORIA	WPV-25-0	3562175			2003	23/07/2005
21	M S COMFRT	ALSTOM	PAKISTAN	CONSUMER	-			2003	20/02/2002
22	STEEL MELT	PEL-HUNDIE	PAK KORIA	WPV-25-0	356317			2003	14/03/2004
23	SUFI ABAD	PEL-HUNDIE	PAK KORIA	WPV-25-0	356316			2003	DO
24	SPARE	PEL-HUNDIE	PAK KORIA	WPV-25-0	3562179			2003	DO
25	SM FACTORY	PEL-HUNDIE	PAK KORIA	WPV-25-0	356315			2003	17/12/2005
26	SAROBA	PEL-HUNDIE	PAK KORIA	WPV-25-0	3562176			2003	14/03/2004
27	KHANA-2	PEL-HUNDIE	PAK KORIA	WPV-25-0	3562177			2003	DO
28	INDS-1	PEL-HUNDIE	PAK KORIA	WPV-25-0	3562174			2003	DO

Annexure II. Technical Data of Transformers

220 kV GRID STATION NTDC NEW KOT LAKHPAT

Table A.8: **220 kV AUTO TRANSFORMER**

Description	T-1	T-2	T-3
Manufacturer	TBEA Shenyang	TBEA Shenyang	TBEA Shenyang
Capacity (ONAN/ONAF1/ONAF2)	160/200/250 MVA	160/200/250 MVA	160/200/250 MVA
Voltage Transformation Ratio HV/LV/Tertiary	(220±13×0.77%)/132/11 kV	(220±13×0.77%)/132/11 kV	(220±13×0.77%)/132/11 kV
Vector Group	YNa0d1	YNa0d1	YNa0d1
Temperature Rise Oil / Winding	50°C/55°C	50°C/55°C	50°C/55°C
No Load Losses (100% Voltage)	48.32 kW	53.00 kW	54.40
Load Losses (at ONAF2 and principal tap)	463.84	478.95	478.94
% Z between HV-LV at ONAN base:			
i) %Z at principal	15.52%	15.10%	15.18%
ii) %Z at extreme plus	15.97%	21.15%	21.56%
iii) %Z at extreme minus	15.82	11.05%	11.05%
OLTC make	MR-Germany	MR-Germany	MR-Germany
No. of Taps	27	27	27
Date of Commission	23/2/2011	13/7/2009	24/5/2009

Table A.9: **132 kV POWER TRANSFORMER**

Description	T-4	T-5	T-6
Manufacturer	ANSALDO	Elta	HEC HATTAR
Capacity (ONAN/ONAF)	20/26 MVA	20/26 MVA	20/26 MVA
Voltage Transformation Ratio HV/LV	132/11.5 kV	132/11.5 kV	(132 ± 13×0.77%)/11 kV
Vector Group	Dyn11	DY11	DYn11
Temperature Rise Oil / Winding	50°C/55°C	45°C/50°C	50°C/55°C
No Load Losses (100% Voltage)	N/A	N/A	19.305 kW
Load Losses (at ONAF and principal tap)	N/A	N/A	65.27 kW
%Z between HV-LV at ONAN base:			
i) %Z at principal	9.64%	10.76%	9.875%
ii) %Z at extreme plus	N/a	10.92%	10.54%
iii) %Z at extreme minus	N/a	10.84%	9.518%
OLTC make	MR-Germany	MR-Germany	MR-Germany
No. of Taps	27	27	27
Date of Commission	N/a	28/08/1972	07/08/2005

Table A.10: **220 kV CURRENT TRANSFORMER**

Sr. No.	Code	Make	Country	Type	Date of Commission
1	D2Q1	China	China	LB7 245W2	29/07/2007
2	D3Q1	China	China	LB7 245W2	10/06/2007
3	D4Q1	MAGRINI	ITLEY	ATG245L-C3	07/01/1979
4	D5Q1	China	China	LB7 245W2	22/06/2007
5	D6Q1	EMEK	TURKY	ATA245-600-2400	15/10/1994
		HAFELY	FRANCE	IOSK245	2003
6	D7Q1	EMEK	TURKY	AT4245-600-2400	24/09/1993
7	D9Q1	EMEK	TURKY	AT4245-600-2400	24/09/1993
8	D10Q1	EMEK	TURKY	AT4245-600-2400	04/04/1995
9	D10Q1	EMEK	TURKY	AT4245-600-2400	25/06/1995
		HAFELY	FRANCE	IOSK245	2003
10	D11Q1	HAFELY	FRANCE	IOSK245	24/5/2009

Table A.11: **132 kV AUTO TRANSFORMER**

Sr. No.	Code	Make	Country	Type	Date of Commission
1	E1Q1	CHINA	CHINA	f	27/4/2011
2	E2Q1	CHINA	CHINA	LB6-145W2	13/7/2009
3	E3Q1	CHINA	CHINA	LB6-145W2	24/5/2009
4	E4Q1	SIEMENS	GERMANY	ASOF 150	24/4/2003
5	E5Q1	BBC SWITZERLAND	SWITZERLAND	AOK145HC	03/01/2011
6	E6Q1	SIEMENS	GERMANY	ASOF 150	19/10/1963
7	E7Q1	SIEMENS	GERMANY	ASOF 150	19/10/1963
		ASEA	SWEDEN		
8	E8Q1	HAFELY	FRANCE	IOSK 145A	29/10/2002
9	E9Q1	EMEK	TURKY	AT4-145-300-1200	09/09/2001
10	E11Q1	EMEK	TURKY	AT4-145-300-1200	20/08/1995
11	E12Q1	EMEK	TURKY	AT4-145-300-1200	20/08/1995
12	E13Q1	EMEK	TURKY	AT4-145-300-1200	10/06/1995
13	E14Q1	EMEK	TURKY	AT4-145-300-1200	10/06/1995
14	E15Q1	BBC	SWITZERLAND	AOK145HC	03/01/2011
15	E16Q1	EMEK	TURKY	AT4-145-300-1200	25/10/1996
16	E17Q1	EMEK	TURKY	AT4-145-300-1200	25/10/1996

Table A.12: **220 kV POTENTIAL TRANSFORMER**

Sr. No.	Code	Make	Country	Type	Date of Commission
1	D3Q1	GALLIO (1)	ITELY	TCS	14/04/1979
		HAFELY(2)	FRANCE	245E	
2	D5Q1	HAFELY	FRANCE	CVE 245	07/01/1979
3	D7Q1	HAFELY	FRANCE	CVE 245	24/09/1993
4	D8Q1	HAFELY	FRANCE	CVE 245	24/09/1993
5	D9Q1	HAFELY	FRANCE	CVE 245	04/04/1995
6	D10Q1	HAFELY	FRANCE	CVE 245	19/03/2003
7	PT BUS BAR-1	GALALLIO	ITELY	TC245E	1974
8	D4Q1	HAFELY	FRANCE	CVE 245	23/2/2011
9	D6Q1	HAFELY	FRANCE	CVE 245	13/7/2009
10	D11Q1	HAFELY	FRANCE	CVE 245	24/5/2009

132 kV GRID STATION QURTABA CITY, LAHORE

Table A.13: **132 kV POWER TRANSFORMER**

Description	T-1	T-2	T-3
Manufacturer	Siemens	Siemens	Siemens
Capacity (ONAN/ONAF)	31.5/40 MVA	31.5/40 MVA	31.5/40 MVA
Voltage Transformation Ratio HV/LV	132/11.5 kV	132/11.5 kV	132/11.5 kV
Vector Group	DYn11	DYn11	DYn11
Temperature Rise Oil / Winding	50℃/55℃	50℃/55℃	50℃/55℃
No Load Losses (100% Voltage)	20.56 kW	21.70 kW	21.07 kW
Load Losses (at ONAF and principal tap)	89.62 kW	89.94 kW	88.49 kW
Aux Losses (ONAF)			
% Z between HV-LV at ONAN base:			
i) %Z at principal	10.30%	10.37%	10.23
ii) %Z at extreme plus	10.82%	10.83%	10.62 %
iii) %Z at extreme minus	9.96%	9.96%	10.04%
No. of Taps	23	23	23

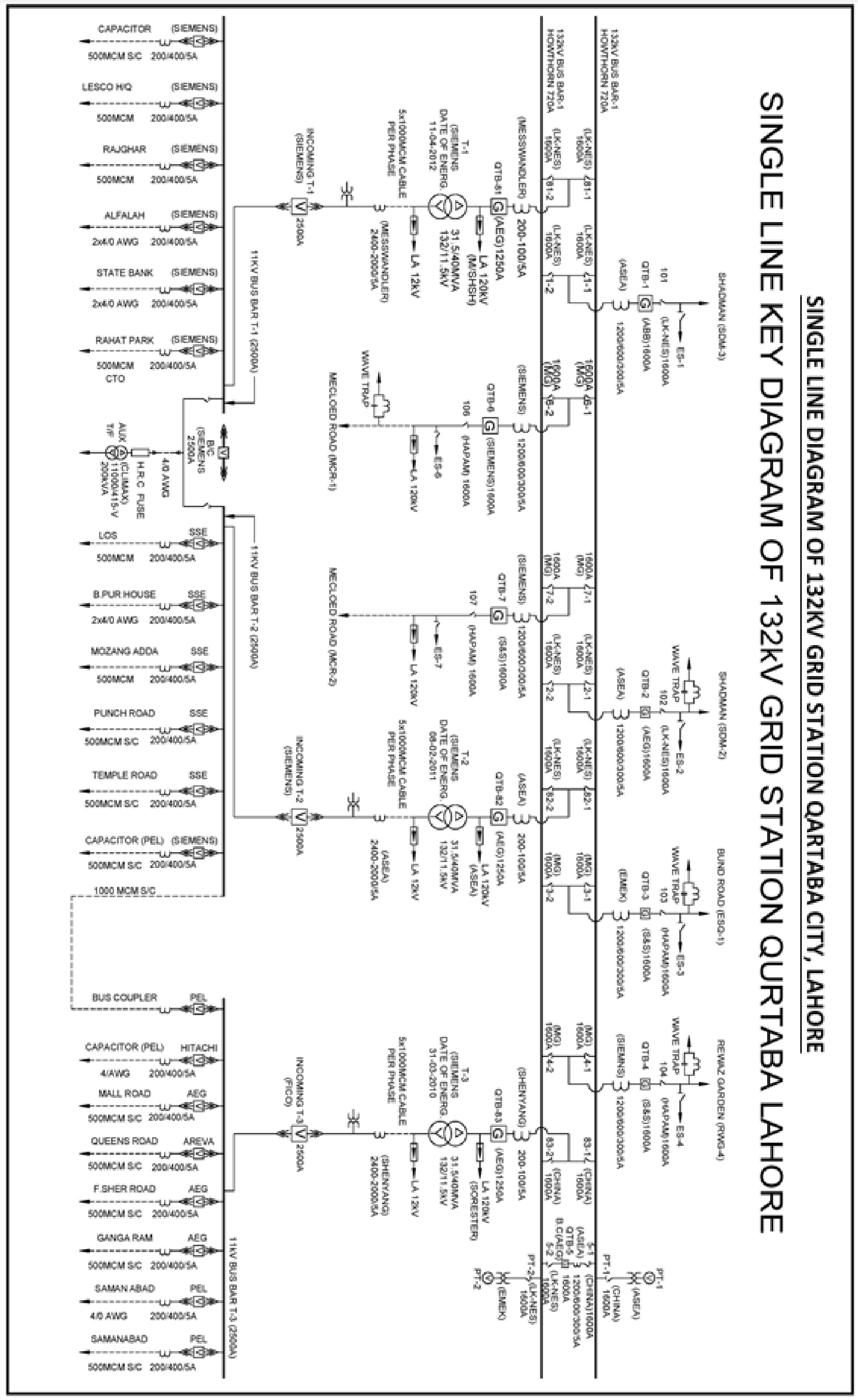

Figure A1: Single Line Diagram of 132 kV Grid Station Qartaba,

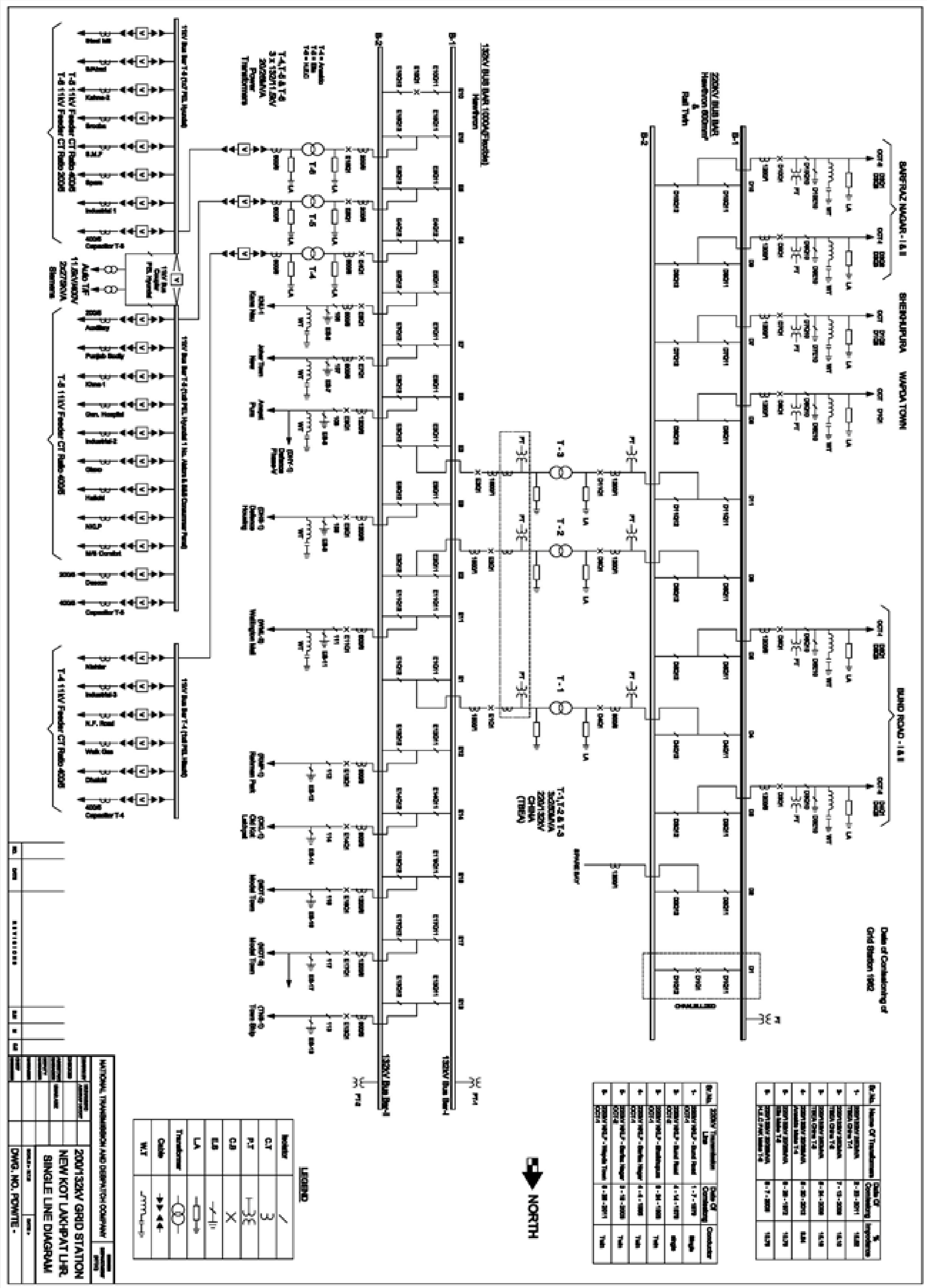

Figure A2: Single Line Diagram of 220 kV Grid Station NKLP,

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