# Evaluation of Electric Energy Losses in Kirkuk Distribution Electric System Area

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***Abstract*— Correct calculations of losses are important for several reasons. There are two basic methods that can be used to calculate technical energy losses, a method based on subtraction of metered energy purchased and metered energy sold to customers and a method based on modeling losses in individual components of the system.**
**For considering the technical loss in distribution system included: transmission line losses, power transformer losses, distribution line losses and low-voltage transformer losses.**
**This work presents an evaluation of the power losses in Kirkuk electric distribution system area and submit proposals and appropriate solutions and suggestions to reduce the losses .**
**A program under Visual Basic was designed to calculate and evaluate electrical energy losses in electrical power systems.**

**Key words : Electric Energy Losses, Electrical Distribution.**

## *1.Introduction*

The term “distribution line losses” refers to the difference between the amount of energy delivered to the distribution system and the amount of energy customers are billed. It is important to know the magnitude and causality factors for line losses because the cost of energy lost is recovered from customers.

Between 30 and 40 % of total investments in the electrical sector goes to distribution systems, but nevertheless, they have not received the technological impact in the same manner as the generation and transmission systems[1].

Calculations of losses in power systems have been attempted since long. Earlier efforts concentrated on energy loss estimation on a yearly basis and power loss estimations for maximum load situations. The estimated losses were important data when calculating the energy losses and planning grids[2]

There is no difference between a transmission line and a distribution line except for the voltage level and power handling capability. Transmission lines are usually capable of transmitting large quantities of electric energy over great distances. They operate at high voltages. Distribution lines carry limited quantities of power over shorter distances. Voltage drops in line are in relation to the resistance and reactance of line, length and the current drawn. For the same quantity of power handled, lower the voltage, higher the current drawn and higher the voltage drop. The current drawn is inversely proportional to the voltage level for the same quantity of power handled.

The power loss in line is proportional to resistance and square of current. (i.e. Ploss=I2R). Higher voltage transmission and distribution thus would help to minimize line voltage drop in the ratio of voltages, and the line power loss in the ratio of square of voltages. The primary function of transmission and distribution equipment is to transfer power economically and reliably from one location to another. Conductors in the form of wires and cables strung on towers and poles carry the high-voltage, AC electric current. A large number of copper or aluminum conductors are used to form the transmission path. The resistance of the long-distance transmission conductors is to be minimized. Energy loss in transmission lines is wasted in the form of I2R losses.

## *2. Location of Transformer*

Location of the transformer is very important as far as distribution loss is concerned.

Transformer receives HT voltage from the grid and steps it down to the required voltage. Transformers should be placed close to the load centre, considering other features like optimization needs for centralized control, operational flexibility etc. This will bring down the distribution loss in cables.

## *3. Transformer Losses and Efficiency*

The efficiency varies anywhere between 96 to 99 percent. The efficiency of the transformers not only depends on the design, but also, on the effective operating load.

Transformer losses consist of two parts: No-load loss and Load loss

1. No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core.

Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic field in the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core.

2. Load loss (also called copper loss) is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss varies with the square of the load current. (P = I2R). [3]

Losses in a distribution system can not be accurately determined on a system wide basis. In a distribution feeder, losses occur for the following reasons:

- line losses on phase conductors
- line losses on ground wire
- transformer core and leakage losses
- excess losses due to lack of coordination of var elements.
- excess loses due to load characteristics
- excess losses due to load imbalance on the phases.

The proper selection of the conductor size usually limits the line losses on phase conductors. The introduction of single-phase and two-phase systems causes additional losses on ground wires. Unbalanced load also adds line losses. The core losses of distribution transformer are sensitive to magnitude of system voltage. The quality of the transformer also effects the core loss. Since loads vary day to night and season to season the power factors along the feeder also vary. Without proper switchable var
elements additional line losses occurs due to the poor power factor throughout the systems. The load characteristics also play a role in a distribution system losses [4].

## *4. SYSTEM DISTRIBUTOIN LOSSES*

In an electrical system often the constant no load losses and the variable load losses are to be assessed alongside, over long reference duration, towards energy loss estimation. Identifying and calculating the sum of the individual contributing loss components is a challenging one, requiring extensive experience and knowledge of all the factors impacting the operating efficiencies of each of these components[3] .

## *5. CHRACHTERIZATION OF LOSSES*

To make it easier to investigate losses it is helpful to divide different types of losses into different categories. It is common to use two categories, technical losses and non-technical losses. Technical losses are losses that occur in electrical equipment, especially cables, overhead lines and power transformers. The other category, the non-technical losses, consists of losses not related to the physical power system but rather to loss sources like electricity thefts and errors in billing and meter reading. To find errors in networks and also to be able to reduce losses it is important for grid owners to know how much of the losses that are technical and how much that are non-technical.

### *5.1. TECHNICAL LOSSES*

There are different ways to classify technical losses. One possible classification is to use the categories load losses and no-load losses. This classification method is particularly useful when studying the dependence of losses on power flow. Current flowing through cables and other pieces of electrical equipment causes load losses.

### *5.2 NON- TECHNICAL LOSSES*

Non-technical losses, sometimes called "commercial losses", are very important because they often contribute to a large extent to the power that the utility is not paid for. Non-technical losses are often related to metering errors, inaccurate meters, improperly read meters and estimated consumption due to lack of meters. Unauthorized connections as well as administrative errors are other possible sources of non-technical losses. Most non-technical losses are associated with low voltage distribution networks. At medium voltage distribution level, non-technical losses are primarily caused by inaccurate meters and tampering with measurement transformers.
On transmission level, nontechnical losses are rare and can be neglected.

## *6. LOSS DETERMINATION METHODS*

Correct calculations of losses are important for several reasons. Trust between different operators; grid owners, energy suppliers, those responsible for energy balance, consumers and independent system operator, is essential. Everyone wants to get paid for the services they provide and no one wants to pay the bill for someone else. Accurate loss allotment maintains trust in the integrity of the grid owners.
Loss determination seems first quite simple; losses are the energy input to the grid minus the energy delivered to consumers. However, in practice it is not that easy. If high accuracy is wanted a lot of high quality data is necessary. Often sufficient data for a detailed analysis is not available. This problem can partly be overcome by the use of models and computer simulations. Sensitivity analysis can be used to study the influence of different parameters. [5], [6].

## *7. LOSS REDUCTION – TECHNICAL LOSSES*

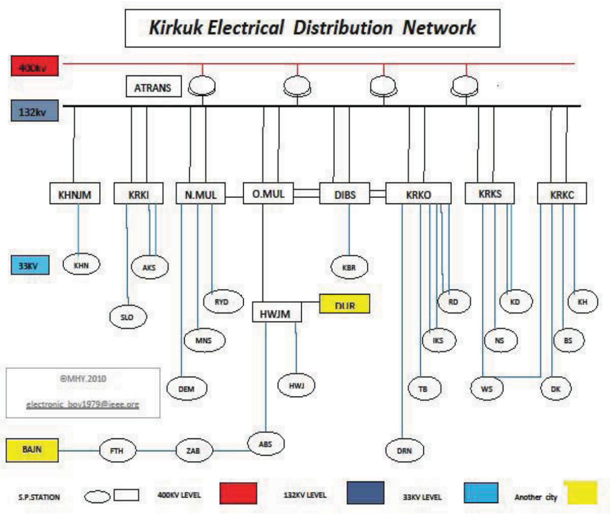
Additional energy needs to be produced and transferred to cover technical losses. During peak load non-renewable energy resources like gas and oil are often used and the energy prices at these occasions are high. Energy consumption increases continuously and if losses are successfully reduced, the length of life of the present networks are extended. By reducing losses, money can be saved and the impact on environment can be reduced.

The recently introduced trade with emission rights also makes it more economical to reduce losses during peak load. Reduction of losses in power systems reduces both the cost of energy production and energy transportation.
However it is often expensive and difficult to reduce technical losses. Replacement of old equipment is one way to reduce technical losses. Electrical power components are very expensive and built to last for a long time, often 30 years or more. They are too expensive to be replaced, if not necessary for other reasons e.g. damage. However when installing new transformers, cables and other pieces of equipment; losses should be taken into consideration.
The following measures may be taken to reduce technical losses:

- A flat voltage profile reduces the losses. If the network is not simply radial but more grid structured circulating currents will appear if the voltage profile is not kept at a common level throughout the network. The circulating currents cause losses. To avoid this, the voltage is allowed to vary only a few percent from nominal value.
- Reactive power compensation, i.e. keeping power factor close to 1, is a common way to minimize losses. By keeping the power factor close to unity, reactive power flow is reduced and thereby current flow and active power losses are reduced. At large inductive loads, for example large induction motors, capacitors are installed close to the load. In the case of long underground capacitive cables, shunt reactors can be needed to reduce the reactive power flow. By keeping the power factor close to one, not only currents through the lines are reduced but also the voltage drop over the line is reduced, resulting in a more flat voltage profile.
- Increasing the normal voltage level of the network reduces the losses; because at higher voltage a lower current is needed to transfer the same amount of power.
- Phase balancing is another way to reduce losses. Phase balancing means that all three phases carry the same amount of power. This is an issue especially for heavily loaded lines [7], [8], [9], [10].

## 8.KIRKUK DISTRIBUTION NETWORK

Kirkuk distribution network is shown in Figure( 1). Four 400/132KV Auto-Transformers feed 9* 132/33KV main stations by 16 lines of 132KV which feed 21* 33/11KV substations through 27 lines of 33KV. These substations feed Kirkuk distribution network by 161 feeders of 11KV.




*Figure(1): Kirkuk Distribution Network*

## 9. CALCULATION OF ENERGY LOSSES IN KIRKUK DISRIBUTION NETWORK

Lines losses calculations

$PL = 3 \text{ X } I^2 \text{ X } R \text{ X } L \text{ X } 10^{-3}$ [k Watt ] ..........................(1)

Where

PL : line losses in kilo watt

R : line resistance in ohms per kilometer

I : total current flow in amperes

L : line length in kilometers

33/11 KV transformer losses calculations

$$a = \frac{\sqrt{3} * VL * Itotal}{Stotal} \qquad \text{.........................(2)}$$

$$P_T = n\,[\,\alpha^2 X P_C) + P_i\,] \qquad \text{............(3)}$$

Where

PT : transformer losses in kilowatt

Pc : copper losses in kilowatt

Pi : iron losses in kilowatt

Pc and Pi values are as in Table( 1) for 33/11KV and Table (2) for 11/0.4KV transformer [11 ]

Total losses = 0.4, 11, 33KV line losses + 33/11, 11/0.4KV transformer losses

Table(1): 33/11KV transformers copper & iron losses

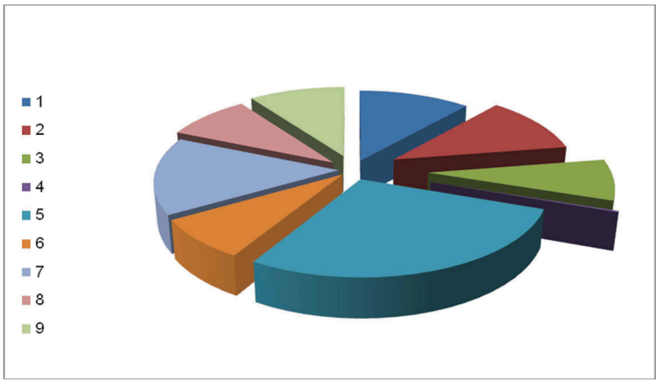
| Transformer Capacity MVA | Pi ( KW ) | PC ( KW) |
|---|---|---|
| 5 | 7.6 | 26 |
| 10 | 9.0 | 50 |
| 16 | 14.8 | 75.6 |
| 31.5 | 19 | 136 |

Table(2): 11/0.4KV transformers copper & iron losses

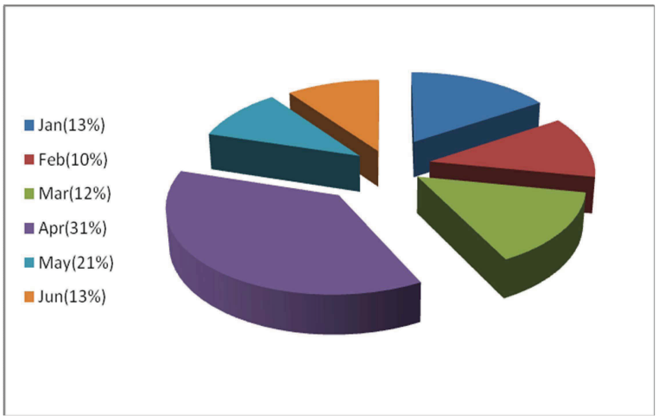
| Transformer Capacity KVA | Pi ( KW ) | PC ( KW) |
|---|---|---|
| 100 | 0.380 | 1.725 |
| 250 | 0.748 | 3.163 |
| 400 | 1.058 | 4.342 |
| 630 | 1.495 | 5.883 |
| 1000 | 2.128 | 9.430 |
| 1500 | 2.551 | 12.560 |

## 10. EVALUATION OF KIRKUK NETWORK ACCORDING TO ENERGY PURCHASED AND SOLD

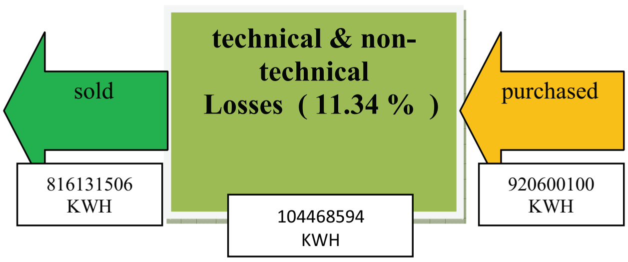
According to the data which was gathered from Directorate of Electricity Distribution of Kirkuk for six months as shown in Figures(2&3). The percentage of the difference between purchased and sold energy is equal to ( 11.34 %) as shown in Figure(4).



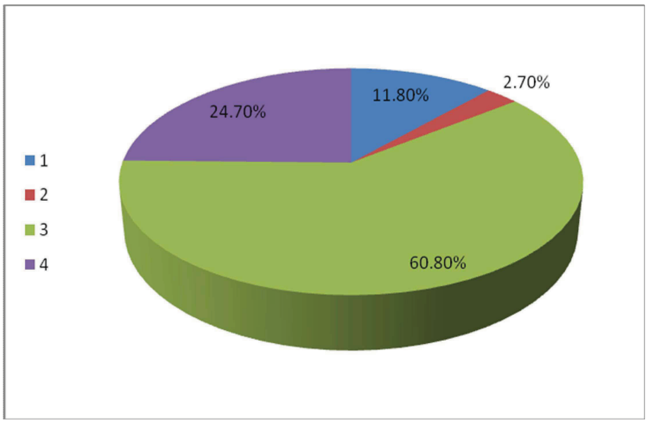

*Figure(2 )Metered energy purchased for Kirkuk area from 1/1/2010 to 1/7/2010*




*Figure(3 )Metered energy sold for Kirkuk area from 1/1/2010 to 1/7/2010*




*Figure(4 ):purchased and sold electrical energy in Kirkuk distribution system*



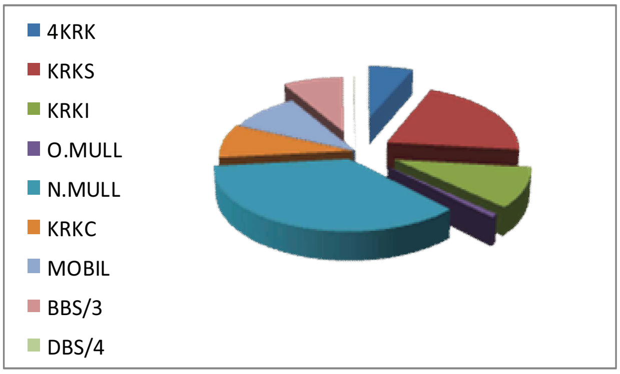

*Figure(5 ): Percentage losses for distribution system components*

**11. RESULTS AND CONCLUTION**

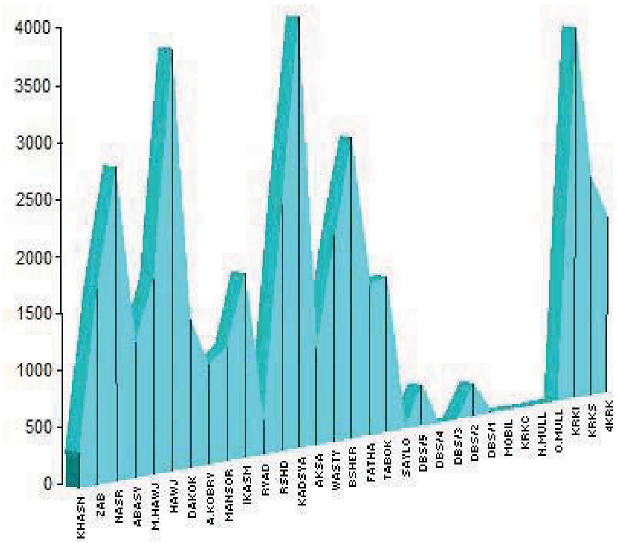
Losses calculation equations for each element in distribution system are displayed in the paragraph(9).
As shown in Figure5 losses percentage for each element calculated by the program was as follows:

| | | |
|---|---|---|
| 1 | lines Energy losses 33KV | 11.80% |
| 2 | 33/11KV transformers losses | 2.70% |
| 3 | 11KV lines Energy losses | 60.80% |
| 4 | 0.4KV lines Energy losses | 24.70% |

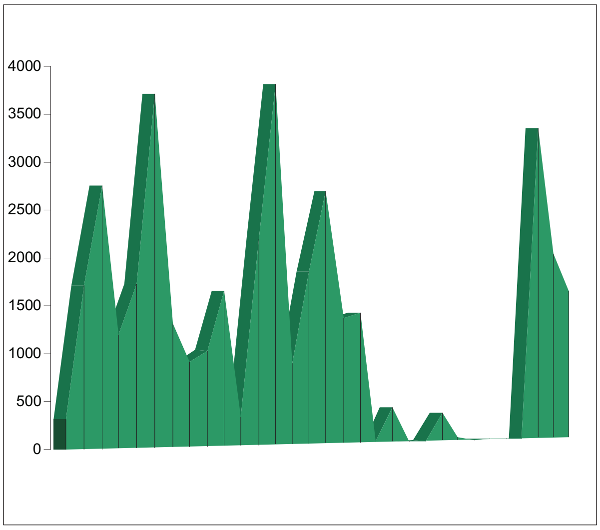
losses percentage for 33, 11, 0.4KV lines were shown in Figures 6,7 and 8 respectively.
We note that the highest percentage of losses were in 11 KV and 0.4 KV distribution lines. Therefore, proposals to address losses should focus on developing solutions to our large network in Kirkuk by addressing the bottleneck loads, low voltage load balancing network , increasing the number of distribution transformers and install them in load centers.




*Figure(6 ): Percentage losses for 33KV lines*



*Figure(7 ):Percentage losses for 11KV lines (sheet10)*



*Figure(8 ):Percentage losses for 0.4KV lines*

### *12. SUGGESTIONS AND RECOMMENDATION*

However it is often expensive and difficult to reduce technical losses, we suggest various methods for reducing technical losses on Kirkuk distribution network. These included*:*

- replacement of old equipment is one way to reduce technical losses. Electrical power components are very expensive and built to last for a long time, often 30 years or more.
- the installation of low-loss transformers
- operating transformers at efficiency-maximizing utilization rates.
- expanding the capacity of wires and cables on the network. This can be

  achieved by increasing the quantity or cross-sectional area of wires and cables. This may occur as the result of duplication carried out to improve system security of supply.
- network reconfiguration. This can take various forms, such as shortening the

  distances between entry and exit points, reducing the number of transformation levels and taking higher voltages nearer to end users.
- the improvement of power factors. The major part of the loss is taking place only in distribution sector which accounts for 80-90% of total T&D losses. Line losses in LT distribution lines may be considerably reduced by installing shunt capacitors of optimum rating at vantage points as decided during load stations. The optimum rating of capacitor banks for a distribution system is 2/3rd of the average KVAR requirement of that distribution system. The vantage point is at 2/3rd the length of the main distributor from the transformer.

  Capacitors are widely used in distribution system to achieve power loss reduction and to maintain the voltage profile with impermissible limits and to minimize the voltage flicker in power distribution networks. The extent of these benefits depends on the location, size, type and number of capacitors and the fast method of capacitor insertion.
- A flat voltage profile reduces the losses. If the network is not simply radial but more grid structured circulating currents will appear if the voltage profile is not kept at a common level throughout the network. The circulating currents cause losses. To avoid this, the voltage is allowed to vary only a few percent from nominal value.
- . Increasing the normal voltage level of the network reduces the losses; because at higher voltage a lower current is needed to transfer the same amount of power.

- Phase balancing is another way to reduce losses. Phase balancing means that all three phases carry the same amount of power. This is an issue especially for heavily loaded lines.

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