Maximization of Revenue Generation by Analysis of Losses in Distribution System Using Matlab Simulation

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Abstract: Today's challenge in electricity consumption in India is on how to use electricity wisely. In recent year, electric power demand has increased drastically due to superiority of electric energy to all other forms of energy and the expansion of power generation and transmission has been severely limited sequel to limited resources, environmental restrictions and lack of privatization as can be found in the developing countries of the world like Nigeria, Togo, India, etc. India currently suffers from a major shortage of electricity generation capacity, even though it is the world's fourth largest energy consumer after United States, China and Russia. All energy supplied to a distribution utility does not reach to the end consumer. A substantial amount of energy is lost in the transmission and distribution system by way of technical and non technical losses. The distribution system accounts for highest technical and non technical losses in the power system. The transmission and distribution losses in our country, which were around 15% up to 1966-67, increased gradually to 30% by 2012-13. The purpose of this paper is to analyze both Technical and Non Technical Losses in power sector with the help of a case study and MATLAB Simulation in power systems.

Keywords: Technical Losses, Non Technical Losses, Electricity Act-2003, Load flow solution

1. Introduction

Electricity is central to achieving economic, social and environmental objectives of sustainable human development. In the present digital age electricity has emerged as the most crucial and critical input for sustaining the process of economic as well as social development [1]. But it quickly became an essential part of daily life, something now taken for granted by almost everyone in the industrialized world. At its most fundamental level, what it does is give us light and heat when it is dark and cold. That is, electricity liberates humanity from the constraints of nature and contravenes the ordering of day and night.

The power that travels through poles and wires is an invisible yet vital force that connect us each to the other. Power is about the way in which electricity is generated and distributed. The way decisions about the generation and distribution of electricity are made affects us all. There are certain losses which affect the economy of the power system. In India the percentage of transmission and distribution losses has been quite high [5]. Growth of different sectors of economy is not possible without matching development of the electricity sector. In fact it has become essential ingredient for improving the quality of life and its absence is usually associated with poverty and poor quality of life [2]. Sub-transmission and distribution systems constitute the link between electricity utilities and consumers, their revenue realization segment. For consumers, it represents the face of the utility. Efficient functioning of this segment of the utility is essential to sustain the growth of power sector and the economy.

2. Technical losses in power systems

Technical losses in power systems are naturally occurring losses, which are caused by actions internal to the power system and consist mainly of power dissipation in electrical system components such as transmission lines, power transformers and measurement systems. Technical losses can involve degrees of turbine efficiency in generation, together with substation, transformer, and line related losses. The most common examples of technical losses include the power dissipated in transmission lines and transformers due to their internal electrical resistance [3]. Technical losses are possible to compute and control, provided the power system in question consists of known quantities of loads. Computation tools for calculating power flow, losses, and equipment status in power systems have been developed for some time. Improvements in information technology and data acquisition have also made the calculation and verification of technical losses easier [4]. These losses are calculated based on the natural properties of components in the power system, which include resistance, reactance, capacitance, voltage, and current.

3. Non Technical losses in power systems

Non-technical Losses (NTLs) refer to losses that occur independently of technical losses in power systems. NTLs are caused by actions external to the power system and also by the loads and conditions that technical losses computations fail to take into account. NTLs relate to the customer management process and can include a number of means of consciously defrauding the utility concerned [9,10]. More specifically, NTLs mainly relate to power theft in one form or another and can also be viewed as undetected loads; customers' that the utilities don't know exist. NTLs are more difficult to measure because they are often unaccounted by the system operators and thus have no recorded information. Two major sources which contribute to NTLs are: (i) component breakdowns and (ii) electricity theft.

4. Electricity Act-2003

Recognizing the need for the Reform process covering the entire facets of the electricity sector comprising generation, transmission and distribution to the consumers, a comprehensive Electricity Bill was drafted in 2000 following a wide consultative process. After a number of amendments, the bill finally sailed through the legislative process and was enacted on 10 June, 2003. It replaces the three existing legislations governing the power sector, namely Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998. The Electricity Act, 2003 mandates that Regulatory Commissions shall regulate tariff and issue of licenses and that State Electricity Boards (SEBs) will no longer exist in the existing form and will be restructured into separate generation, transmission and distribution entities. Regulatory function has been taken away from the purview of the government. The

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Electricity Act, 2003 mandates licensee-free thermal generation, non-discriminatory open access of the transmission system and gradual implementation of open access in the distribution system which will pave way for creation of power market in India.

5. Load Flow Solution

The solution to the power flow problem begins with identifying the known and unknown variables in the system. The known and unknown variables are dependent on the type of bus. A bus without any generators connected to it is called a Load Bus. With one exception, a bus with at least one generator connected to it is called a Generator Bus. This bus is referred to as the Slack Bus. In the power flow problem, it is assumed that the real power and reactive power at each Load bus are known. For this reason, Load Buses are also known as PQ Buses. For Generator Buses, it is assumed that the real power generated and the voltage magnitude |V| is known. For the Slack Bus, it is assumed that the voltage magnitude |V| and voltage phase θ are known [6,7]. Therefore, for each Load Bus, the voltage magnitude and angle are unknown and must be solved for; for each Generator Bus, the voltage angle must be solved for; there are no variables that must be solved for the Slack Bus. In a system with N buses and R generators, there are then 2(N − 1) − (R − 1) unknowns. In order to solve for the 2(N − 1) − (R − 1) unknowns, there must be 2(N − 1) − (R − 1) equations that do not introduce any new unknown variables. The possible equations to use are power balance equations, which can be written for real and reactive power for each bus [8]. In the program, the resistance and reactance values are taken from 11 kV data sheet. A line conductor of 120 mm^2 has been chosen & the line length has assumed to be 3 km. Then Z bus is formed and hence Y bus can be calculated using following relation:

Ybus = 1/ZBus. A load profile of 24 hours has been shown for simplicity and the further calculations have been done with the help of Newton-Raphson method. Fig 1.1 shows the variation of the loads during 24 hours.

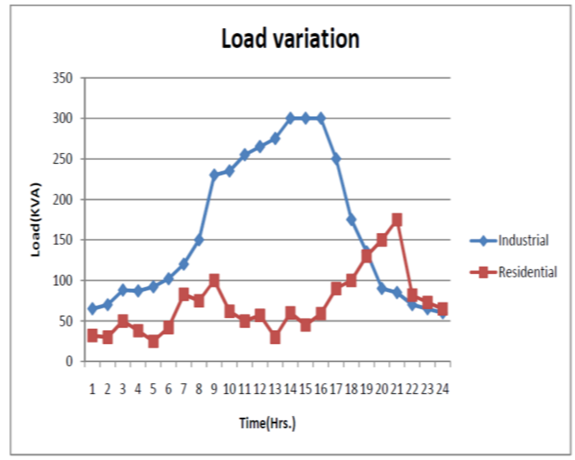

Fig 1.1 Load variations over 24 hour

Fig 1.1 shows the industrial load has its peak demand during day times and the residential load demand is more during morning and evening hours. The load peaks are at 300 kVA for load1 and 175 kVA for load 2. The average load demands (sum of peak values / no. of hours in a day) are 161 kVA and 70.95 kVA for load 1 and load 2, respectively (Load 1= Industrial, Load 2= Residential). Variation in power factors are shown in Fig 1.2 below over 24 hours.

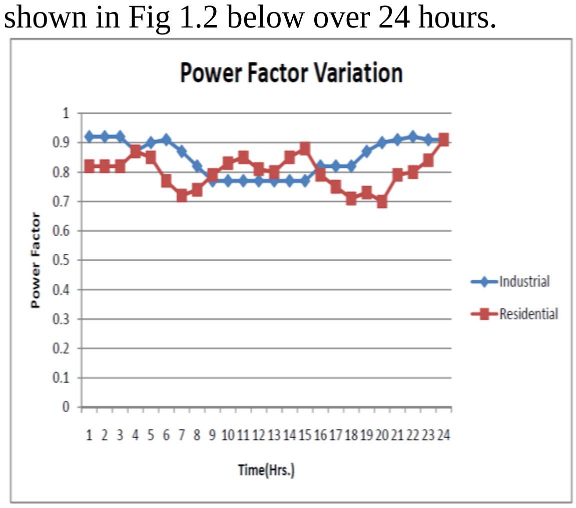

Fig 1.2 Variation of power factor over 24 hours

Algorithm used in Program

1. The impedance value of the transmission line has been taken from 11 kV datasheet. A conductor diameter of 120 mm^2 has been taken.

2. Loads for Two Bus System: A two bus system is considered and each bus is assumed to be taken as load bus. At bus1 industrial load is taken and at bus 2 residential load is assumed. Data for kVA demand and power factor for 24 hours is taken for both loads to calculate hourly losses. Average of load demand for both loads is taken to calculate average losses.

3. Calculation of Active and Reactive Power: Active and reactive power demand at both buses is calculated using the given data. Also the power angle is calculated in both degree and radian value.
P = kVA demand × power factor
Q = kVA × sin ($\cos^{-1}$(pf))

4. Load Flow Studies: load flow studies using Newton-Raphson method has done to calculate the final value of voltage at both buses so as to calculate the losses. The following steps are done for load flow studies.

5. Formation of Y_{bus} matrix: Y_{bus} is formed using the given data for the impedance of both loads and the transmission line connecting the loads. Y_{bus} is assembled using equation
$Y_{bus} = A^T YA$.

6. Initial Values for voltage and load angle at each bus: initial values are assumed at each bus of the system. Initial voltage is taken as 1 p.u. and load angle is taken as 0. Bus 1 is assumed to be slack bus and bus 2 is taken as load bus.

7. Calculation of Total Power at load bus: The initial values of voltages and loads are used to calculate P2 and Q2 at load bus 2 as bus 1 is assumed as slack bus.
P2 = $\sum_{j=1}^{n} Vi\,Vj \cos(\delta i - \delta j - \gamma ij)$ + load Power of bus 2
Q2 = $\sum_{j=1}^{n} Vi\,Vj \cos(\delta i - \delta j - \gamma ij)$
where n is number of buses and i =2.

8. Formation of Jacobian Matrix: Jacobian matrix is formed using P2 and Q2 using the following relations.

$$[J] = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix}$$

Where

a) $\frac{\partial P}{\partial \delta}$ is an n×n matrix where the elements are calculated as follows:
$\frac{\partial Pi}{\partial \delta i} = \sum_{j=1}^{n} Vi\,VjYij \sin(\delta i - \delta j - \gamma ij)$
for diagonal elements, and
$\frac{\partial Pi}{\partial \delta k}$=|Vi||Vk||Yik|sin(δi–δk–γik)
for i ≠ k

b) $\frac{\partial P}{\partial V}$ is an n×n matrix where the elements are calculated as follows:
$\frac{\partial Pi}{\partial Vi}$=|Vi||Yij|cosγij+$\sum_{j=1}^{n} Vi\,Yij \cos(\delta i - \delta j - \gamma ij)$
for diagonal elements, and

$\frac{\partial Pi}{\partial Vk}$=|Vi||Yik|Cos(δi–δk–γik)
for i ≠ k

c) $\partial Q/\partial \delta$ is an n×n matrix where the elements are calculated as follows:

$\frac{\partial Qi}{\partial \delta i} = \sum_{j=1}^{n} Vi\,VjYij \cos(\delta i - \delta j - \gamma ij)$
for diagonal elements, and

$\frac{\partial Qi}{\partial \delta k}$=|Vi| |Vk| |Yik|Cos(δi–δk–γik)
for i ≠ k

$d)\ \partial Q/\partial V$ is an n×n matrix where the elements are calculated as follows:

$\frac{\partial Qi}{\partial Vi}$ = -Vi Yij sin γij + $\sum_{j=1}^{n} Vi\, Yij \sin(\delta i - \delta j - \gamma ij)$ for diagonal elements, and

$\frac{\partial Qi}{\partial Vk}$=|Vi||Yik|sin(δi–δk–γik)
for i ≠ k

9. Calculation of change in voltage n load angle due to change in load: The variations vectors ΔV and Δ δ are computed by using the following equation:

$$\begin{bmatrix}\Delta V\\ \Delta\delta\end{bmatrix} = [J]^{-1}\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}$$

This change in voltage and load angle at bus 2 is added to initial values and new value of voltage n load angle is calculated at bus 2.

$V_2^1 = V_2^0 + \Delta V$

and

$\delta_2^1 = \delta_2^0 + \Delta\delta$

Similarly iterations are done and the value of voltage and load angle is updated ateach step until ΔQ < tolerance.

10. Calculation of losses: After iterations final value of voltage and load angle is used to calculate active and reactive power losses.

11. Losses are calculated both in Watts and Per Unit (p.u.) system. Equation yields the sum of average power losses throughout the power system. Even the losses are calculated from the average value of data.

12. Data for Non Technical Losses: An inductive load is taken as NTL load and its Additional VA demand is added to load 2. The power factor is also added to bus 2.

13. Repeat Steps No. 3 to 11 with added demand.

14. Calculation of increase in losses and load demand due to NTL: The increase in losses due to NTL is calculated both in p.u. and Watts. The increase in losses is calculated taking the difference between the losses without NTL and with NTL. Also the increase in load demand is calculated in p.u. and Watts. All calculations are done both for average data of loads and hourly data for both loads. These values are used to make bar graphs.

Conclusion

The total system losses are composed of technical & non technical losses. Technical losses are due to physical aspect and Non-technical losses due to unauthorized line tapping or meter by passing. Non technical losses are difficult to measure because of the presence of T & D losses in it and also it is not possible to segregate NTL from them. In this paper , I have taken a two bus system with one bus as slack bus and load is on another bus. The load profiles of simple industrial area and residential area has been taken. Then a small percentage of NTL has been added to one of the load and the increased load and losses have been shown with the help of Newton-Raphson load flow method and MATLAB. The power factor contributions chosen here are negative because the NTL load is assumed to be inductive. The readings of one full day have been taken. Non-technical losses (NTL) in all forms are very real and significant problems for utilities companies.

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