Power Loss Minimization Using Network Reconfiguration

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Abstract— The 11th India's Economic Development Plan(2007-2012) proposes a very important goal of "Power for all": supply electricity to all Indian households without interruption y the end of the plan in 2012. Currently the potential demand for electricity in India exceeds by about 15% ,resulting in regular power cuts households, business and industries.
Power loss in distribution system occurs due to resistance of transmission line. This resistance of line included from generating station to load i.e. resistance of distribution and transmission line. Resistance of distribution system is large compare to transmission system. Therefore, 80% losses occur in the distribution system. Ideally, losses in a power system should be around 3 to 6%. In developed countries it is not more than 10%. However, in developing countries like India, the percentage of active losses is around 20%. Therefore, It should be minimized to meet excess demand of 15%.

Keywords— Distribution System; Network Reconfiguration; Loss Minimization; Radiality; Tie Switches; Sectionalize Switches.

I. INTRODUCTION

India is the fifth largest producer and consumer of electricity in the world. However 24X7 power supply still remains a dream. World Resource Institute estimates electricity transmission and distribution losses in India is to be 27%.

Due to uncertainty of system loads on different feeders, which vary from time to time, the operation and control of distribution systems is more complex particularly in the areas where density of load is high. Power loss will not be minimum for a fixed network configuration for all cases of varying loads. This thing can be understand by maximum power transfer theorem.

Hence, there is a need of reconfiguration of network from time to time. Network reconfiguration is the process of altering the topological structure of feeder by changing the status of sectionalizing and tie switches. In general, networks are re-configured to reduce real power loss and to relieve overload in the network. Distribution system network contains sectionalizing switches and tie switches. Sectionalizing switches are normally closed but tie switches are normally open. These switches are shown in the diagram 1.0. Network reconfiguration is changing network topology by using sectionalizing switches and tie switches.

Power loss in distribution system occurs basically due to resistance of transmission line. Therefore, 80% losses occur in the distribution system. Distribution system have low voltage level than transmission system. Due to which power loss is more in distribution system than transmission system. Basically, losses in a power system exceeded from 3% to 7% due to high resistance of distribution system. In developed countries, this loss is not more than 10%.

Distribution system network contains sectionalizing switches and tie switches. Sectionalizing switches are normally closed but tie switches are normally open. For better coordination of protective relay and circuit breaker radial nature of network is maintained. But today DG's are present in the distribution to supply to distribution system which breaks the radial nature of the power network. In this paper without DG's, network is being reconfigured. To manage a loss reduction program in a transmission and distribution system, it is necessary to use efficient and effective computational tools like MATLAB that allow quantifying the loss in each different network element to determine minimum loss configuration.

The complexity of the problem arises from the fact that distribution network topology has to be radial and power flow constraints are nonlinear in nature. The loss minimum or load balancing reconfiguration problem for the open loop radial distribution system is formulated as a combinational optimization problem and hard to solve.

Throughout history, mankind has faced optimization problems and made great efforts to solve them. Optimization is the process of finding the best way to use available resources, while at the same time not violating any of the constraints that are imposed. In other words, we may say that we wish to define a system mathematically, identify its variables and the conditions they must satisfy, define properties of the system, and then seek the state of the system (values of the variables) that gives the most desirable (largest or smallest) properties. This general process is referred to as optimization.

One important area in which distribution automation is being applied is the area of network reconfiguration. Network reconfiguration refers to the closing and opening of switches in a power distribution system in order to alter the network topology, and thus the flow of power from the substation to the customers. There are two primary reasons to re-configure a distribution network during normal operation. Depending on the current loading conditions or fault condition, reconfiguration may become necessary in order to eliminate overloads on specific system components such as transformers or line sections. In this case it is known as load balancing.

More than 30 years ago, the French engineers A. Merlin and H. Back perceived an opportunity to reduce technical losses by exploring a change in the status of normally closed and normally open switches [Merlin, 1984]. They proposed the 'network reconfiguration problem', for which the solution should provide the best status for all the switches in a primary distribution network, best in the sense that they provide a radial configuration supplying all loads with the minimum of power loss. However, because the number of possible solutions for the network reconfiguration problem grows exponentially with the number of switches, it is difficult to find an optimal solution when the size of network increases [Dolatdar, 2009].

In the past decade or so, with the advances in communication and data processing technology, electric utility companies have interested in distribution automation. It is apparent that with the increasing complexity of power distribution systems, it is becoming essential to automate some tasks that have always been done manually. Automation in distribution system can reduce human error and risk of life. It has also been estimated that utilities could save as much as 10% of their annual maintenance and operating expenses by taking advantage of this technology. [Kendrew, 1989]

II. OBJECTIVE

Objective of this research paper is to discuss the reconfiguration of 33-bus distribution system and calculating corresponding loss. Loss of different configurations is determine by multiplying the square of current with resistance. In terms of loss, voltage limit, current limit and radiality problem can be specify as following-

Minimize $f = I^2 r$; Where r is resistance of transmission line.

$$\det (A) = 1 \text{ or } -1 \text{ (radial system)}$$

$\det (A) = 0$ (not radial); Where A is bus incidence matrix of given system.

III. TYPICAL POWER NETWORK

An understanding of basic design principles is essential in the operation of electric power systems. This section briefly describes and defines electric power generation, transmission, and distribution systems (primary and secondary). Figure 1.1 shows a one-line diagram of a typical electrical power generation, transmission, and distribution system.

The transmission systems are basically a bulk power transfer links between the power generating stations and the distribution sub-stations from which the power is carried to customer delivery points. The transmission system includes step-up and step-down transformers at the generating and distribution stations, respectively. The transmission system is usually part of the electric utility's network. Power transmission systems may include sub transmission stages to supply intermediate voltage levels. Sub-transmission stages are used to enable a more practical or economical transition between transmission and distribution systems. It operates at the highest voltage levels (typically, 230 kV and above). There are also a few transmission networks operating in the extremely high voltage class (345 kV to 765 kV).
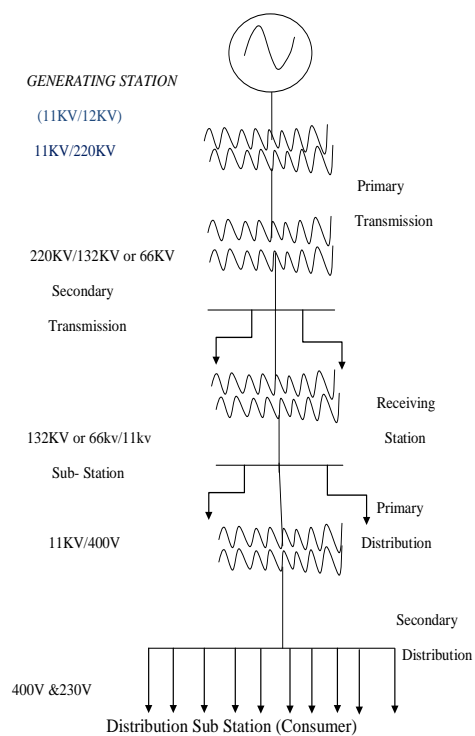

Figure1.1 :Typical AC Transmission and Distribution System(single-line diagram)

As compared to transmission system sub-transmission system transmits energy at a lower voltage level to the distribution substations. Generally, sub-transmission

systems supply power directly to the industrial customers. The supply voltages are usually in the range of 11 kV to 35 kV. The distribution system is the final link in the transfer of electrical energy to the individual customers. Between 30 to 40% of total investment in the electrical sector goes to distribution systems, but nevertheless, they haven't received the technological improvement in the same manner as the generation and transmission systems. The distribution network differs from its two of siblings in topological structure as well as its associated voltage levels. The distribution networks are generally of radial or tree structure and hence referred as Radial Distribution Networks (RDNs). Its primary voltage level is typically between 400V to 35 kV, while the secondary distribution feeders supply residential and commercial customers at 120/240/440 volts. In general, the distribution system is the electrical system between the substation and the consumers' premises fed by the transmission system. It generally consists of feeders, laterals (circuit-breakers) and the service mains.

IV. TYPES OF SWITCH IN DISTRIBUTION SYSTEM

There are two most important switches sectionalize switch and tie switch. Reconfigurations of the network are performing using these two switches. It's described in detail below:

A. Sectionalize Switch

Sectionalize switches are that switches which connect section lies between two consecutive buses. It connects the load section. The resistance and reactance of these sections are minimum in comparison to tie line. Sectionalize switches are normally closed. By opening of sectionalize switches distribution system radiality maintain. The main purpose of sectionalize switches is the isolation or restoration of the loads during a fault or a maintenance.

For example, when a fault occurs on sections of the feeder, all the load sections which are surrounded by the cut (tie) switches, including fault point, are isolated from the system by the following procedure.

- A protective relay detects the faults and "trips" the circuit breaker

- A fault section is detected by reclosing circuit breaker and sectionalize switches one by one(when fault section is energized, protective relay detects the fault again)

- The load sections between the bus and fault section are energize again.

B. Tie Switch

Tie switches are the switches which connects two non-consecutive buses. It connects one feeder to another feeder. The resistance and reactance of these sections are generally high compare to sections. Tie switches are normally open. It is closed during reconfiguration to change topology of network.

In proposed research 33-bus system is taken as test system. All tie switches and sectionalize switches discussed above are shown below. Power from transmission system receives by substation and this power distributed to different load through lines keeping voltage and frequency constant at different buses. Line number 33,34,35,36 and 37 are called as tie switch because it connects two non consecutive buses. Line number 1 to 32 is sectionalizing switches because these connect two consecutive buses. It is clear from diagram shown below in figure 3.2.
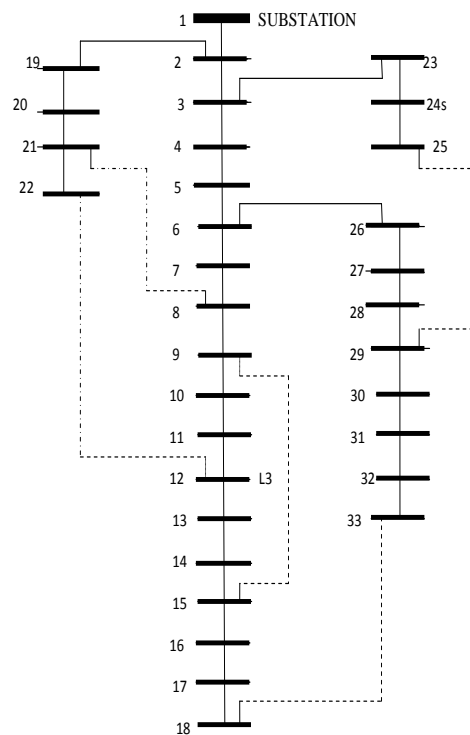

Fig.6.1   33-bus radial distribution system Single-Line Diagram(With Tie Switches)

V. MATHEMATICAL MODELING

Power flows in a distribution system are computed by the following set of simplified recursive equations derived from single-line diagram given below –

In this diagram   is sending end voltage and   voltage at Kth bus.   And Q_k are active and reactive power flow from bus k to bus k+1. Y_{k1} and Y_{k2} are admittance between line and ground.

Source: [Rao2013]

From above single-line diagram power equation can be given as-

The power loss in the line section connecting buses k and k+1 may be computed as

$$P_{loss}(k, k+1) = R_k \frac{P_k^2 + Q_k'^2}{|v_k|^2} \dots \dots \dots \dots \dots \dots (6)$$

The objective function of the problem is formulated to maximize the power loss reduction in distributed system, which is given by-
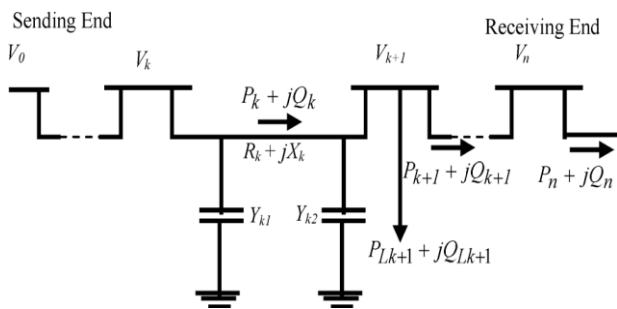

Figure 5.1 Single line diagram of main feeder.

f = min. (P_{Loss})

Where   and   are voltage and current at Kth bus.

det(A) = 1 or -1 (radial system)

det(A) = 0 (not radial),

Where A is incidence matrix.

VI. CONFIURATIONS ANALYSIS

In case1 min loss configuration obtained by closing the tie switch2. Magnitude of real power loss is 5.9041 KW for minimum loss configuration and magnitude of total real power loss for maximum loss configuration is 6.3410 KW. Therefore percentage saving of power is 6.8%.

In case2 minimum loss configuration obtained by closing the tie switch 1and 3 simultaneously. Magnitude of total real power loss is 12.287 KW for minimum power loss configuration and real power loss for maximum loss configuration is 12.603 KW. Therefore percentage saving of power is 2.5%.

Although predefined sectionalize switches are opened to remove loop in the distribution system. While it may be different sectionalize switches on the basis of removal of fault section for service restoration.

VII. CONCLUSION

In India, exceeded demand can be fulfil by reducing transmission and distribution losses. There is a great demand of reduction of power loss in distribution system because it is very high about 23% of total power generation. If we reduce the loss in distribution one side then another side we save environment from pollution.

VIII. BENEFITS OF THE RESEARCH

The research proved the following the benefits:

- Active power can saved maximum up to 6.8%.Saved energy will reduce energy shortage and peak shortage by 6.8%.
- Saving of 6.8% energy will further reduce additional burning of coal consequently pollution will reduce. Ultimately environment will save.

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