A Review on Distribution Network Reconfiguration

Pushpanjalee Konwar[1], Jesif Ahmed[2], Biswajit Sengupta[3], Mriganka Gogoi[4]

[1,2,,3,4]Assam Don Bosco University
Airport Road, Azara, Guwahati - 781017, Assam. INDIA.
[1]pushpanjalee.konwar@dbuniversity.ac.in
[2]jesif.ahmed@dbuniversity.ac.in
[3]biswajit.sengupta@dbuniversity.ac.in
[4]mriganka.gogoi@dbuniversity.ac.in

Abstract: ***In distribution systems, network reconfiguration is comprehended by changing the best possible status of placing the sectionalizing switches. It is generally performed for reducing the losses or for balancing the load in the system. Generally for the distribution systems, meshed networks are configured in a feeble manner with manifold supply points, but they are controlled with radial configurations by unbolting the redundant branches. The system should be recompensed, otherwise it creates disturbance which lead to variation in supply voltages. In this paper, a study related to network reconfiguration techniques is presented in order to avoid network congestion showing the importance of FACTS devices along with an overview of issues related to voltage collapses in distribution system.***

Keywords: Network Reconfiguration, FACTS devices, Voltage Stability.

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1. Introduction

Radial configuration is generally used for configuration of a distribution system. For improving the operating conditions of a system, the status sectionalising switches and tie switches is changed while transferring load from one feeder to the other. Rescheduling of distribution loads leads to improvement of voltage stability. The systems keep varying by becoming heavily loaded or lightly loaded at different times because the distribution systems is a amalgamation of manufacturing, mercantile, housing and lighting loads. Improvement of voltage profile in the feeders, smoothening out the peak demands and increasing the network reliability is also possible through reconfiguration.

Due to insufficient reserve of reactive power during heavy loading, voltage collapse occurrence is featured. Importance of voltage stability arises at this time in order to avoid pecuniary losses and entire system blackout .Additionally, a steady system put in to the reliability in system. The network reconfiguration has been performed by changing the operating condition of the switches in transmission lines connecting different buses. The idea looks particularly appealing since it allows transmission system operators to alleviate overloads by means of switching operations that may avoid costly generation or load restrictions.

Network reconfiguration of a power distribution system is an operation to alter the structure of distribution feeders by changing open-closed status of sectionalising and tie switches. By transferring loads from the heavily loaded feeders to the lightly loaded ones such that entire network becomes balanced one. Reconfiguration is a method to open few sectionalizing switches and closing few tie switches which has been dealt with an objective to reduce active and reactive power loss, to balance loads and to improve voltage profile.

The purpose to enhance system reliability is to allocate main feeder sectionalizing switches to minimize total costs for several considerations, e.g., load transfer and treatment approach of a failed distribution transformer. Networks are reconfigured to reduce real and reactive power loss and to relieve overload in the network for maintaining power loss minimization. One of the best methods for restoring a power system is recognition and access to the network reconfiguration. If the main skeleton-network is recognized appropriately, other parts of the network can be restored at the shortest possible time. Planning and design of power facilities is required with the main objective to ensure electricity supply of customers at minimum costs. When a permanent fault of the power network component occurs, power system reconfiguration can be performed for two reasons: One is the enabling the repairing and servicing of network or equipment that is inoperative and another is reducing the area and number of customers without electricity supply.

1.1 Objectives of network restructuring:

This review has the following distinct features:

- Firstly to dispatch problem, cost minimization and minimization of transaction deviations has been formulated with two different objective functions.
- Secondly to develop an Optimal power flow solution incorporating FACTS devices in a given market mode.

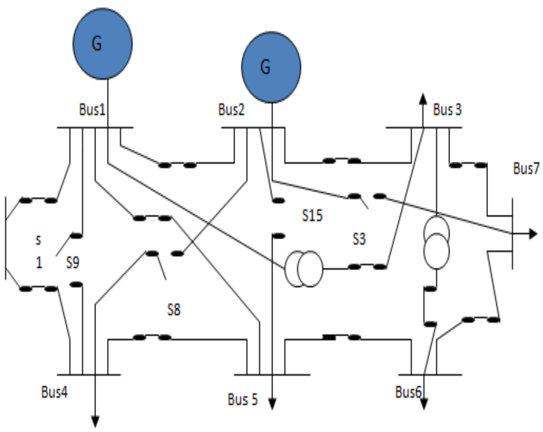

Figure 1: Eight bus system. [18]

In Fig.1, two generators are present wherein 8 buses are present. The generators are connected to the Bus 1 and Bus 2. Bus 3, 4, 5, 6 and 7 are considered as the load bus. If the total no of switches are considered as n, possible configurations are $2^{(n-1)}$ i.e we have 15 switches so the total no of configuration is $2^{(15-1)}$ or 2^{14}. Each set of switching configuration is for one configuration.

2. Literature review

Several researches have been conducted on network reconfiguration. Few of the literature survey that has been done are listed below:
Dommel and Tinney [2] presented a method called Penalty Function Optimization Approach for minimizing the fuel cost. Conventional and Intelligent tactics have been introduced in this paper for Optimum Power Flow.
Divi and Kesavan [3] applied Quasi-Newton Technique with an objective of application for shifted penalty function. Market operations and planning influences the ac Optimal Power Flow(ACOPF) in authentic world applications as a result techniques has to be developed and tested.

M.A. Kashem et al. [4] presented Automation of Distribution Networks with an objective of Voltage stability enhancement by network reconfiguration. This paper describes a solution method introducing a switching algorithm for network reconfiguration. Reconfiguration of distribution networks is possible by decreasing the combinational switching problems.

Chen et al. [5] presented Successive Linear Programming for minimizing the losses in ac-dc systems. A learning effect occurs when the decreases as cumulative production increases. Learning effects occur with the increase in cumulative production resulting to the decrease in amount of labor required per unit of production, This paper presents various solution methods for representing the learning effect.

Sterling and Irving [6] offered a idea on economic dispatch of active power with constraints relaxation using Linear Programming Approach. Satisfaction of various physical and operational constraints is obtained using security constrained dispatch in order to minimize operational cost of an electric power network. This paper highlights the factor that post-contingency corrective capability of the system is not taken into account as a result of which the solution obtained is cynical.

Megahead et al. [7] presented a detailed study on a Series of Constrained Linear Programming Problems for the treatment of the nonlinearly constrained dispatch problem. Due to susceptibility of power grids, unforeseen event analysis is significant for providing information about the susceptibility of power grids. Analysis of the contingency states is done by using topological structures. Selection of .the eventuality state is explained in this paper
Waight et al. [8] described the process for breaking the dispatch problem into one master problem and several smaller linear programming sub-problems applying the Combination of Linear Programming Methods with the Newton approach. Logarithmic barrier function plays a vital role in solving OPF leading to the usage of many interior-point methods . The three types of barrier method are described as primal, dual and primal-dual. These barrier methods may be used as different variants of the same system of nonlinear equations.

Burchett and Happ [9] explained the Augmented Lagrangian Type Objective Function for modifying the original problem to that of working out a series of linearly constrained sub-problems. The Lagrangian Relaxation technique in decree of Optimal Power Flow Problems is presented in this paper. Linear and nonlinear method implementations have attained a immense interest in applications to OPF. Usage of the Primal-Dual Interior Point Method leads to the solution of Optimal Power Flow considering various objective functions.

Nanda et al. [10] presented a OPF algorithm developed using the Fletcher's Quadratic Programming Method with an objective function of linearizing the constraints of a quadratic function. Optimal power-dispatch problems are resolved using Fletcher's Quadratic Programming methods. Distribution factors are used for solving various problems various problems are solved. Suggestions are being made for a new set of distribution factors.

Burchett et al. [11] presented the Successive Quadratic Programming Method for creating the exact analytical first and second derivatives of quadratic programs. Constraints in voltage stability is solved by applying multi-objective genetic algorithm It delineates the preventive control approach for voltage security enhancement and uses the Multi-objective genetic algorithm to solve this multi-optimization problem.

Vargas et al. [12] explained the Interior Point Method required for a security constrained dispatch problem. This paper presents a summary on very large scale integration circuit layout and economic dispatch in power system. Interior Point Method is exhibited over a MINOS simplex code. MINOS stands for Modular In-core Nonlinear Optimization System used for solving linear and nonlinear mathematical optimization problems. MINOS can be used for finding a possible point for a group of linear or nonlinear equalities and inequalities.

3. Background principle

3.1 Network congestion

In the distribution system, relative scarcity of resources and jagged distribution of network flow leads in network congestion. As a result, congestion control is necessary. When the producers and consumers of the electric energy aspire to produce and consume a power in total that would take the transmission system to operate at or beyond its transfer limit, the system is said to be congested. Congestion in electrical power industry is defined as the limitation of the transmission lines to reach their thermal limits or the load is unable to carry additional power.

The configuration shown in the Figure 2 is not a worldwide one. A system operator is selected for the entire system to make certain that the production and imports incessantly match the expenditure and exports. This system operator is identified as Independent System Operators (ISO). Customer does its changeover through a retailer directly with the generating company, depending on the type of a model. The retailer contacts the generating company and acquires the power from it. It then transfers using regulated T&D lines. The ISO is the one responsible for keeping track of different dealings taking place between various units.

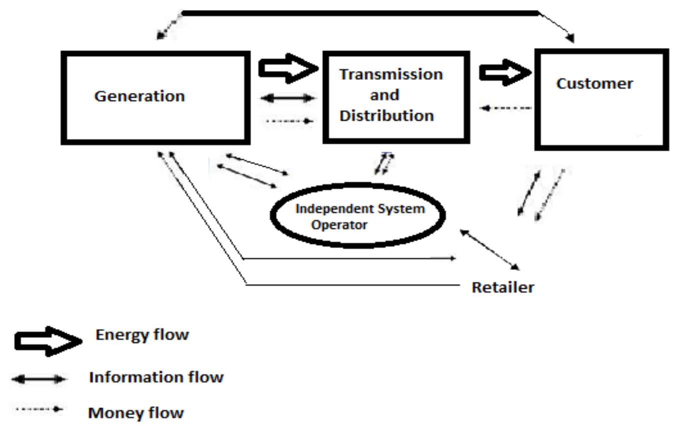

Figure 2: The typical structure of a deregulated electricity system [15]

Congestion management is an vital part of a properly planned electricity market, Due to congestion, electricity prices at various locations increases as well as power transmission losses plays an integral part to the varying prices. Transmission constraints in power networks should be taken care for a healthy electricity market.

3.1.1 Issues in network congestion

A transmission congestion charge is acquired when the system is inhibited by physical limits. To understand impact of congestion in networks, need to consider two interrelated issues.

1. Power transfer in a particular direction may impact line flows in large portion of system

2. This impact is commonly defined as the power transfer distribution factor (PTDF) once a line is congested, any new power transfers with a PTDF on the congested line above 5% cannot take place.

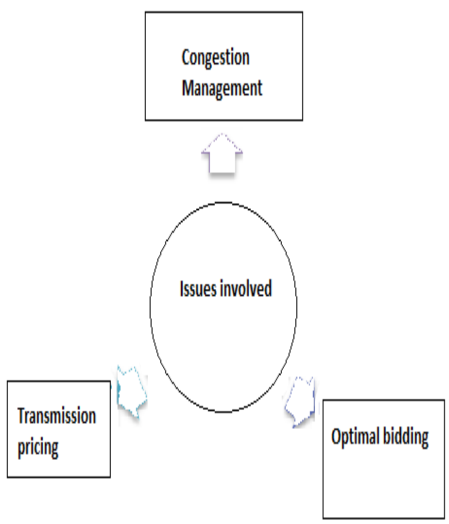

Figure 3: Network Congestion[15]

3.2 FACTS devices

FACTS (Flexible AC Transmission) devices have the capability to allow power systems to function in a more flexible, protected, and stylish way. In order to improve the performance of the system, FACTS devices are used for controlling the power flows in the grid. FACTS devices is used, even the operation of power system is complicated.

3.2.1 Importance of FACTS devices

FACTS devices are important for restructuring of a power system network since they can expand the usage potential of transmission systems by controlling power flows in the network. FACTS devices are operated so as to minimize line congestion. Effective FACTS based power flow control can be applied to relieve transmission congestion and improve the transfer capability of the network while voltage security and voltage stability constraint are satisfied and as a result transmission network can be effectively utilized.

3.2.1.1 Objective of congestion management

1. Minimized interference of the transmission network in the market for electric energy

2. Secure operation of the power system

3. Improvement of market efficiency

3.2.1.2 Types of facts devices

Shunt controller: Adjusting the system voltage by means of shunt reactive elements is known as shunt compensation. For eg. Static synchronous compensator (STATCOM), Thyristor-controlled reactor(TCR), Static VAR compensator (SVC).
Series Controller: Adjusting the system voltage by means of series reactive elements is known as shunt compensation. For eg. (Static synchronous series compensator) (SSSC), Thyristor-controlled series reactor(TCSC).

Combined shunt-series controller: It provides independent series reactive compensation for each line bus also transfer real power among the line d.c. power link. For eg. Unified power flow controller(UPFC)

3.3 Voltage stability

Voltage stability is concerned with maintaining acceptable voltage levels'(0.8 p.u) all system buses under normal conditions as well as when the system is being subjected to a disturbance. The voltage collapse phenomenon in power system is often attributed to lack of sufficient reactive power reserve when the power system experiences heavy loading.

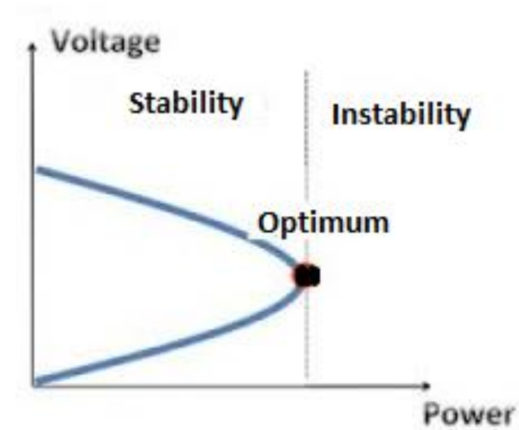

Figure 4: P-V characteristics for voltage stability[22]
Voltage stability is the capability to uphold load voltage magnitudes within particular operating limits under steady conditions. Voltage stability is concerned with maintaining 'acceptable voltage levels'(0.8 p.u) all system buses under normal conditions as well as when the system is being subjected to a disturbance. The voltage collapse phenomenon in power system is often attributed to lack of sufficient reactive power reserve when the power system experiences heavy loading

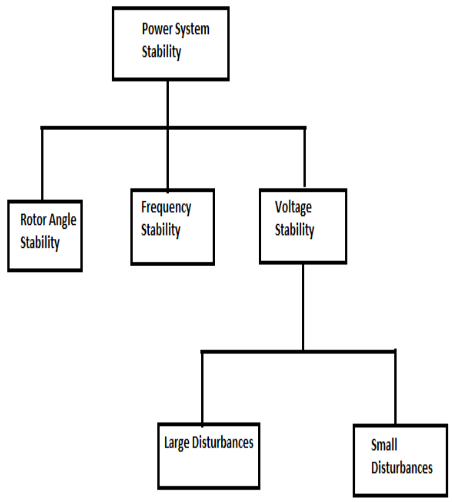

Figure 5: Power System Stability Network[21]

Large disturbance voltage stability:

It refers to the system's ability to maintain steady voltage following large disturbances such as, system faults, loss of generation or circuit contingencies

Small-disturbance voltage stability:

This stability is concerned with the ability of the system to maintain acceptable level of steady voltages, when subjected to small perturbations such as incremental changes in system load

3.3.1 Voltage constraints

Thermal Stability
The maximum amount of electrical energy that transmit on transmission line without overheating.

Voltage Limit
System voltage and change in voltage must be maintained with the range of acceptable deviation.
Stability Limit

Transmission system capable of surviving disturbances through the transient and dynamic period.

3.3.2 Issues of voltages collapses

Most of the incidents of voltage collapses are believed to be related to heavily stressed power systems where large amount of real and reactive power are transported over long extra high voltage (EHV) transmission lines while appropriate reactive power sources are not available to maintain normal voltage profiles at receiving end buses. The other principal causes of voltage instability are the excess load on the transmission lines, large distance of the generating sources and lack in local reactive compensation.

4. Summary

System reconfiguration results in a transmission system wherein the overloaded system is alleviated. The obtained system is a balanced one and the voltage profile of the system is improved. System reliability is one of the outcomes of system reconfiguration. Reconfiguration of power system network results in congestion management by usage of FACTS devices and also maintaining a steady voltage. FACTS devices can expand the capability of transmission systems with the help of reconfiguration of power system which results in controlling of power flows in the network. FACTS devices can be used in order to minimize line congestion. Commonly used FACTS devices are TCSC, STATCOM, UPFC etc. Managing load dispatch plays the vital role for controlling the activities in a power system. Voltage collapse happens due to large scale voltage instability. Reconfiguration reduces the infeasible load from the system to avoid voltage collapses.

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AUTHOR PROFILE

Mrs Pushpanjalee Konwar is an Assistant Professor in Electrical and Electronics Engineering in Assam Don Bosco University Guwahati. She received her M. Tech. degree from Assam Don Bosco University in 2014 and pursuing Ph.D. from NIT Nagaland. She has authored one book chapter published by IGI Global Journals and published 4 research papers in journals and conferences. Her area of research is biomedical instrumentation and power systems.

Mr. Jesif Ahmed, is working as an assistant professor in the Department of Electrical and Electronics Engineering, School Of Technology, Assam Don Bosco University, Guwahati, Assam, India. He is pursuing his Ph.D. from Gauhati University, Assam, India. His research interest includes study of electricity market, Power system optimization and transmission congestion management.

Biswajit Sengupta, is working as an Assistant professor in Electrical and Electronics department, School of Technology, Assam Don Bosco University, Assam. He did his M.Tech in Power Electronics and Power Systems and B.Tech in Electrical and Electronics Engineering from Assam Don Bosco University.

Mr. Mriganka Gogoi has received M.Tech degree from North East Regional Institute of Science and Technology (NERIST) in 2011. He worked as guest lecturer in NERIST for a period of six months. In 2012 he joined Assam Don Bosco University as Assistant professor in the department of Electronics and Communication Engineering. He has published 9 papers in national/international journal/conference. His research interest includes signal processing, watermarking and VLSI.