

Review Paper on Electrical Distribution Network for Loss Reduction and Voltage Enhancement

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Abstract— *Now-a-days the Flexible AC Transmission Systems (FACTS) is very popular and essential device in power systems. After introducing the FACTS technology, power flow along the transmission lines becomes more flexible and controllable. Several FACTS-devices have been introduced for various applications in power system. Before incorporating DG unit in the distribution system, it has to be ensured that the size and the location are critically decided. This underlines the importance of optimal DG allocation and sizing. This can be achieved by solving an optimization problem. In this work, a multi-objective optimization problem is formulated which aims at minimization of real power loss, improvement of voltage profile, enhancement of stability etc. subject to the operating constraints.*

Keywords: - IEEE 14 bus System, UPFC, FACTS Technology, MATLAB/Simulink.

I. INTRODUCTION

The electrical energy sector is facing substantial changes worldwide. This phase is characterized by a dramatically increase in the electrical energy consumption especially in developing countries. The major challenge for power system engineers is to meet the ever increasing load demand with available generating capacities. One of the best solutions to meet the increasing demand is integration of renewable energy sources at distribution level. The distribution system is an important part that provides final and vital link between the utility and consumers. It is the most visible part of the supply chain [1]. Though about 30% to 40% of total investment in the electrical sector is utilized in the distribution system, they have not fully received the technological impact as the generation and transmission systems. The distribution system is classified into primary distribution network and secondary distribution network. A primary distribution network delivers power at higher than utilization voltage from the substation to the point where the voltages are further stepped down to the value at which the energy is utilized by the consumers. The secondary distribution network supplies power to the consumer premises at levels of utilization voltages [2]. Based on the scheme of connections, the primary distribution system may be a Radial Distribution System (RDS) or a Mesh system. Most of the primary distribution systems are designed as radial distribution systems having exclusively one path between consumers and substation. The main advantages of RDS

are simplicity of analysis, simpler protection schemes, lower cost and easy predictability of performance. Primary feeder voltage of 11kV and 33kV are very common. The secondary voltage at the consumers is 415/230 V [3].

In regards to the rating of the distributed generation, different definitions are in use. For example, the Institute of Electrical and Electronics Engineers (IEEE) define DG as —the generation of electricity by facilities that are sufficiently smaller than central generating plants so as to allow interconnection at nearly any point in a power system. The electric power research institute (EPRI) defines distributed generation as generation from _a few kilowatts up to 50MW [4].

Due to large variations in the definitions used in the literature, many different issues like purpose, location, technology, environmental impact and mode of operation are considered to define distributed generation more precisely. In the interest of broad application, the definition of DG adapted in this work is _any type of generation that is connected to a distribution power system which does not exceed 50MW of peak power production capabilities.

II. LITERATURE REVIEW

Optimal planning and operation of a power system requires steady state power flow analysis. Power flow analysis determines the steady state voltage at each bus of the system and also real and reactive power flowing in each of the lines. Power flow solution forms the basis of all optimization problems. The distribution network is radial in nature having high R/X ratio whereas the transmission system is loop in nature having low R/X ratio. The distribution systems are known as ill conditioned power systems. The conventional Newton-Raphson [5] and Gauss-Seidel methods, used for transmission system analysis may provide inaccurate results and pose converge problems for the distribution networks.

Many methods of power flow solution for radial distribution systems have been reported in the literature. Kersting [6] has developed a load flow method for solving radial distribution networks by converting distribution networks based on ladder network theory into a working algorithm. In this method, updates in currents and voltages during the forward sweep and backward sweep give

directly voltage correction. Baran and Wu [7] have proposed a method based on iterative solution of three fundamental equations representing voltage, real and reactive power. They have computed system Jacobian matrix using chain rule. They have also proposed decoupled and fast decoupled distribution load flow algorithms. Chiang [8] has presented decoupled load flow method for distribution networks and also proposed the effect of convergence criteria for the solution of distribution systems. In fact, the decoupled and fast decoupled methods proposed by Chiang are similar to that of Baran and Wu.

Das et al. [8] have proposed load flow technique for solving radial distribution networks, in which they have put forward a unique bus, branch and lateral numbering scheme which help to evaluate exact real and reactive power loads fed through any bus and to obtain bus voltages. These methods involve only the evaluation of simple algebraic expression of receiving end voltage which does not involve any trigonometric terms, as in the case of conventional load flow method. Zhang and Cheng have proposed a modified Newton method for radial distribution systems which is capable of achieving robust convergence and high efficiency.

In, Venkatesh et al. presented an accurate voltage solution method which formulates a set of equations to describe RDS. This set of equations comprises $3(N-1)$ second order equations and an equal number of variables for an N bus system. These equations are solved using first order Newton Raphson technique. This set of equations model accounts for elements such as transformers, transmission lines, shunt capacitors, constant PQ loads and constant impedance loads. Arvinhababu et al. in have been presented a robust decoupled power flow technique based on line current flows in rectangular coordinates for radial distribution systems. In this method power flow equations are developed in terms of line currents instead of bus powers and transformed by a constant matrix for perfectly zeroing the off-diagonal blocks of the Jacobian matrix in order to decouple the problem into two sub-problems without making any assumptions on voltage magnitudes, angles and the R/X ratios.

III. FACTS CONTROLLER

Flexible AC Transmission System (FACTS): Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability. The various basic applications of FACTS-devices are:

- Power flow control
- Increase of transmission capability
- Voltage control

- Reactive power compensation, stability improvement
- Power quality improvement
- Power conditioning.

The fig 1.1 is for classification of FACTS Controllers Based on power electronic devices. In this fig, left hand side column of FACTS-devices employs the use of thyristor valves or converters. This valves or converters are well known since several years. They have low switching frequency and low losses. The devices of the right hand side column of the fig has more advanced technology of voltage source converters based mainly on Insulated Gate Bipolar Transistors (IGBT) or Insulated Gate Commutated Thyristors (IGCT). Pulse width modulation technique is used to control the magnitude and phase of the voltage.

By the means of flexible and rapid control over the AC transmission parameters and network topology, FACTS technology can facilitate the power control, enhance the power transfer capacity, decrease the line losses and generation costs, and improve the stability and security of the power system. FACTS technology opens up new opportunities for controlling and enhancing the useable capacity of present, as well as new upgraded lines. FACTS are an evolving technology and can boost power transfer capability by 20–30% by increasing the flexibility of the systems. By providing added flexibility, FACTS device offers continuous control of power flow or voltage, against daily load changes or change in network topologies.

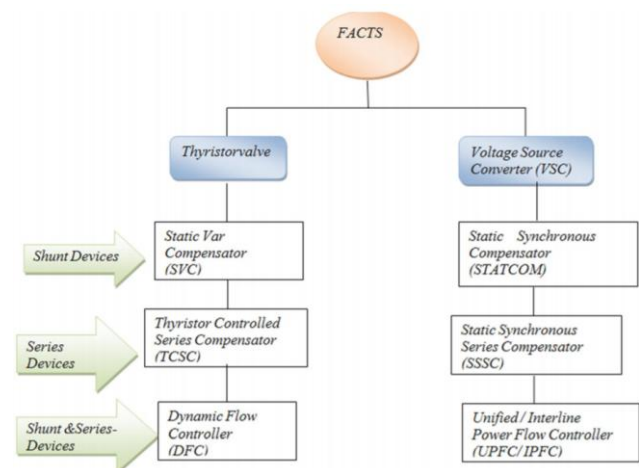


Figure 1: Overview Of major FACTS devices in terms of on power electronic devices

Classification of FACTS Controllers

In general, FACTS controllers can be divided into four categories [1-4]:

- Series Controllers
- Shunt Controllers
- Combined series-series Controllers

- Combined series-shunt Controllers

Depending on the power electronic devices used in the control, the FACTS controllers can be classified as [1, 3]:

- Variable impedance type
- Voltage Source Converter (VSC) type

The variable impedance type controllers include:

- Static VAR Compensator (SVC), (shunt connected)
- Thyristor Controlled Series Capacitor or Compensator (TCSC) (series connected)
- Thyristor Controlled Phase Shifting Transformer (TCPST) or Static PST (combined shunt and series)

The VSC based FACTS controllers include:

- Static Synchronous Compensator (STATCOM) (shunt connected)
- Static Synchronous Series Compensator (SSSC) (series connected)
- Interline Power Flow Controller (IPFC) (combined series-series)
- Unified Power Flow Controller (UPFC) (combined shunt-series)

IV. PROPOSED METHODOLOGY

The UPFC is the most powerful and versatile FACTS-equipment used to control the power flow and stability of the power system. UPFC can be act static as well as dynamic condition also. Static is an analysis at the steady state condition and dynamic is an analysis at the transient condition such as faults occurs in transmission system. This chapter described about basic principle of UPFC and load flow analysis.

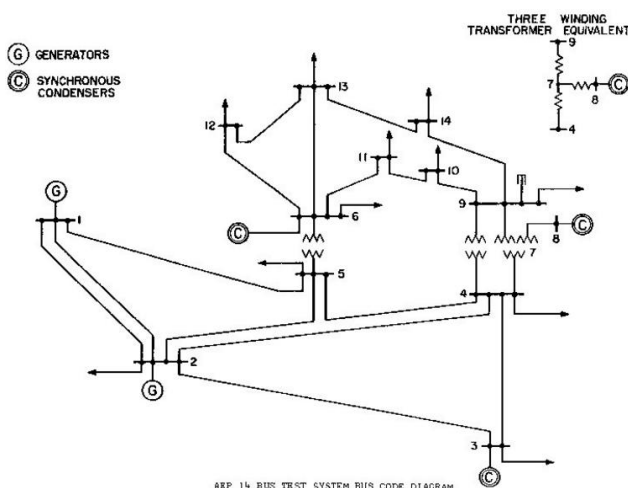


Figure 2: Flow Chart of IEEE 14 Bus Systems

Distributed Generation

In order to meet the ever increasing demand in the deregulated and restructured power system, with the constraints on new generation plants and transmission lines, distributed generation (DG) has emerged as an efficient alternative. Changed government policies and increased availability of small capacity generation technologies are supporting the increased development and deployment of distributed generation. Environmental concerns have motivated the use of renewable distributed generation. Integration of DG in distribution system provides significant benefits to the system such as voltage support, loss reduction, transmission and distribution capacity release and improved system reliability etc. Traditional distribution systems are designed to operate with unidirectional power flow i.e. from source to load. Integration of DG in distribution system alters the power flow and imposes a different set of operating conditions on the network. This may lead to problems such as reverse power flow, voltage rise, increased fault levels and instability [30]. Before placement of DG, it has to be ensured that the size and the location have to be proper. It has been observed that the installation of DGs of improper size at non optimal places may result in increased system losses and overall cost thereby nullifying the very purpose of connecting it to the system. This underlines the importance of optimal DG allocation.

Fuzzy Set Approach

Fuzzy logic is an extension of Boolean logic designed to work with imprecise or vague data. Where classical requires yes and no values, fuzzy logic can handle concepts such as “may be”, “nearly and “very”. In fuzzy systems, values are indicated by a number (called a truth value) in the range of 0 to 1, where 0 represents absolute falseness and 1 represent absolute truth. While this range evokes the idea of probability, fuzzy logic and fuzzy sets operate quite differently from probability. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth.

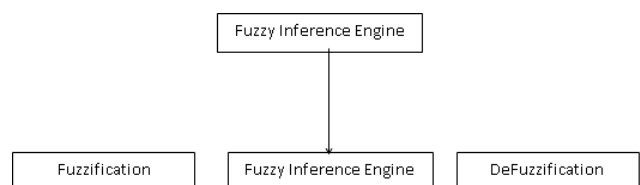


Figure 3: Fuzzy logic scheme

Taking the advantage of handling uncertain and vague data, fuzzy logic can be implemented in the proposed work. In the proposed scheme we use the architecture of fuzzy controller to develop a fuzzy logic. Fuzzy controller is inflected in three basic elements: fuzzification, fuzzy inference and defuzzification. In a fuzzy system, these

parameters are found in the fuzzification and defuzzification routines. Calculated degrees of membership in the fuzzifier are calculated according to fuzzification, inference and defuzzification. IF-THEN rules are constructed according to our scheme. In the work, the computation of the IF part uses minimum operator AND aggregation. The defuzzified output is in the range 0 – 1.0 shows no membership and 1 shows full membership. For each membership function linguistic variables are defined. The membership function taken is triangular. The function can be completely defined with reference to the points A, B, and C is shown in figure 4.

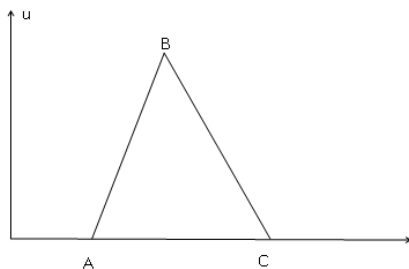


Figure 4: Triangular Fuzzy membership function

The membership value of points A and C have a membership value of 0 whereas the point B has a membership value of 1.0. For further reference, these three points would henceforth be represented as the triplet (A, B, C). Hence, any fuzzy variable can be easily defined and represented by this triplet (A, B, C).

V. SIMULATION RESULT

One of the three voltage sources used in the 500 kV system equivalents can be varied in order to observe the STATCOM dynamic response to changes in system voltage. Open the "Programmable Voltage Source" menu and look at the sequence of voltage steps which are programmed.

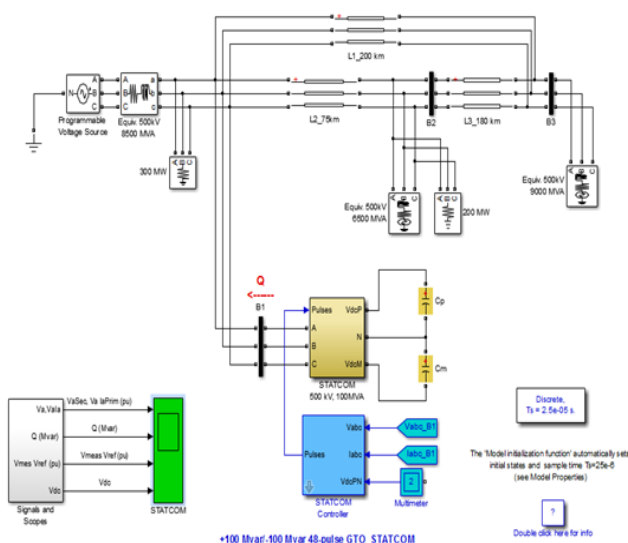


Figure 3: Simulink Model of STATCOM

During steady-state operation the STATCOM control system keeps the fundamental component of the VSC voltage in phase with the system voltage. If the voltage generated by the VSC is higher (or lower) than the system voltage, the STATCOM generates (or absorbs) reactive power. The amount of reactive power depends on the VSC voltage magnitude and on the transformer leakage reactance. The fundamental component of VSC voltage is controlled by varying the DC bus voltage.

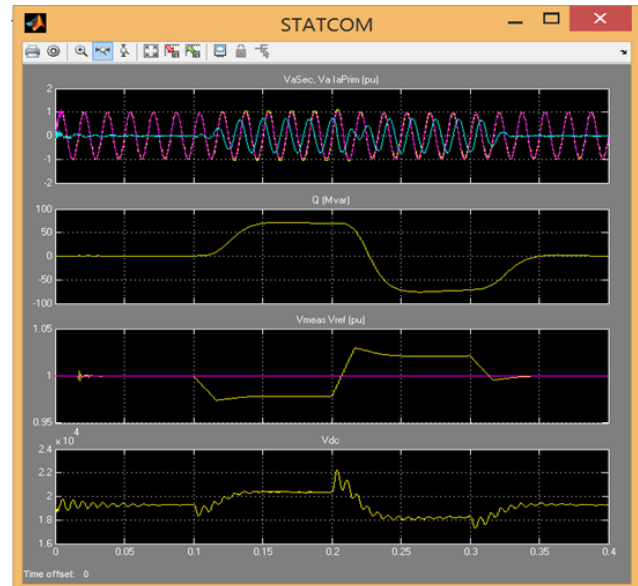


Figure 4: Output Waveform of the STATCOM

VI. CONCLUSION

As most of the primary distribution systems are designed as radial in nature, the studies performed in this research work are on radial distribution system and are assumed to be balanced for ease of simplicity in computations. Distribution systems are normally equipped with capacitors, voltage regulators, tap changing transformers etc. for better operation and control. To optimize these resources along with the incorporation of DG is a difficult task. Many researchers have developed different methods to obtain the solution of this problem. Growing number of publications indicate at its potential. Keeping this in view, an attempt is made in this work to present novel approaches for analysis and optimization in radial distribution system with incorporation of DG.

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