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Loss Reduction and Voltage Profile Enhancement of Electrical Distribution Network- A Review

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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

1. 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 instance, the Institute of Electrical and Electronics Engineers (IEEE) characterize DG as ―the age of power by offices that are adequately littler than focal producing plants in order to permit interconnection at about any point in a power framework. 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.

2. 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 Guass-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 registered framework Jacobian network utilizing chain rule. They have likewise proposed decoupled and quick decoupled circulation load stream calculations. 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.

3. 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.

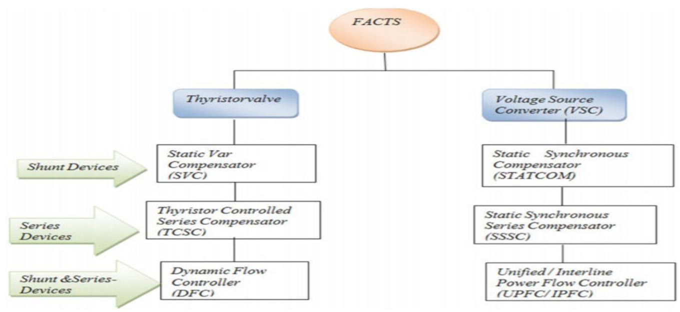

Figure 1: Overview Of major FACTS devices in terms of on power electronic devices

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)
  Compensator (TCSC) (arrangement associated)
- Thyristor Controlled Phase Shifting Transformer (TCPST) or Static PST (joined shunt and arrangement)
- The VSC based FACTS controllers include:
- Static Synchronous Compensator (STATCOM) (shunt associated)
- Static Synchronous Series Compensator (SSSC) (arrangement associated)
- Interline Power Flow Controller (IPFC) (joined arrangement)
- Unified Power Flow Controller (UPFC) (joined shunt-arrangement)

4. 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.

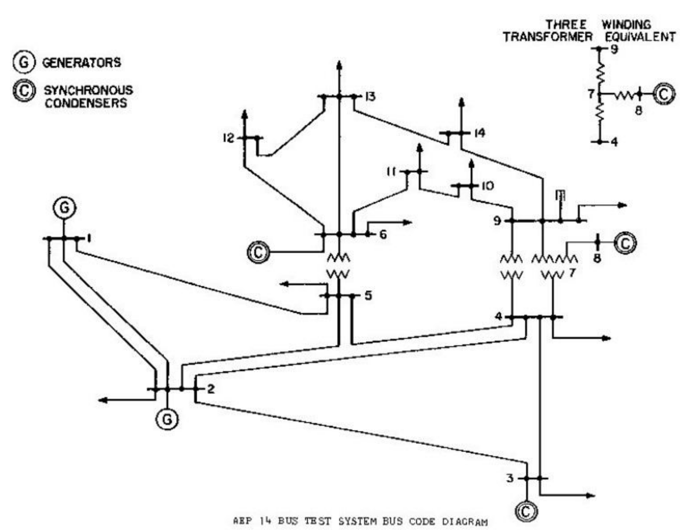

Figure 2: Flow Chart of IEEE 14 Bus Systems

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.

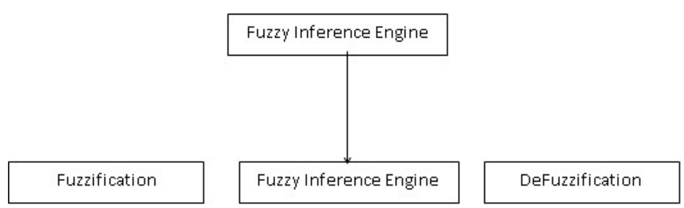

Figure 3: Fuzzy logic scheme

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.

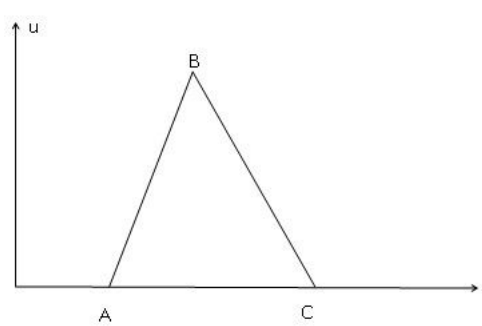

Figure 4: Triangular Fuzzy membership function

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).

5. 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.

REFERENCES

[1] Pranabesh Bala And Sovan Dalai, “Random Forest Based Fault Analysis Method In IEEE 14 Bus System”, 3rd International Conference On Condition Assessment Techniques In Electrical Systems (CATCON), IEEE 2017

[2] Mehmet Yesilbudak, Salih Ermis And Ramazan Bayindir, “Investigation Of The Effects Of FACTS Devices On The Voltage Stability Of Power Systems”, 6th International Conference On Renewable Energy Research And Applications (ICRERA), IEEE 2017.

[3] M. Venkateswara Reddy, Sishnu Prasad Muni And A. V. R. S. Sharma, “Enhancement Of Voltage Profile For IEEE 14 Bus System With Inter Line Power Flow Controller”, Biennial International Conference On Power And Energy Systems: Towards Sustainable Energy (PESTS E), IEEE 2016.

[4] A. Edrisian, A. Goudarzi, M. Ebadian Et Al., "Assessing The Effective Parameters On Operation Improvement Of SCIG Based Wind Farms Connected To Network", *International Journal Of Renewable Energy Research,* Vol. 6, No. 2, Pp. 585-592, May 2016.

[5] F. Selwa, L. Djamel, L. Imen, S. Hassiba, "Impact Of PSS And STATCOM On Transient Stability Of Multi-Machine Power System Connected To PV Generation*", 4th International Conference On Renewable Energy Research And Applications*, Pp. 1416-1421, 22-25 November 2015.

[6] B. Nikouei, N. M. L. Tan, S. F. Taghizadeh, M. A. A. Younis, "Design Of A 27-Level Cascaded Converter As FACTS Device For Voltage Sag Mitigation", *Australian Journal Of Electrical And Electronics Engineering*, Vol. 12, Pp. 232-241, November 2015.

[7] Y. Sugahara, T. Takeshita, "Suppression Control Of Module Capacitor Voltage Fluctuation For Cascade STATCOM", *3rd International Conference On Renewable Energy Research And Applications*, Pp. 722-727, 19-22 October 2014.

[8] S. Dalai, D. Dey, B. Chatterjee, S. Chakravorti, K. Bhattacharya, "Cross Hilbert-Huang Transform Based Feature Extraction Method For Multiple PQ Disturbance Classification", *1st International Conference On Condition Assessment Techniques In Electrical Systems (CATCON),* Pp. 314-317, IEEE 2013.

[9] D. Choudhary, "Enhancement Of Steady State Voltage Stability Using SVC And TCSC", *International Journal Of Scientific & Engineering Research,* Vol. 4, No. 1, January 2013.

[10] K. Kuthadi, N. Suresh, "Enhancement Of Voltage Stability Through Optimal Placement Of FACTS Controllers In Power Systems", *American Journal Of Sustainable Cities And Society*, Vol. 1, Pp. 36-44, July 2012.

[11] B. Singh, "Introduction To FACTS Controllers In Wind Power Farms: A Technological Review", *International Journal Of Renewable Energy Research*, Vol. 2, No. 2, Pp. 166-212, February 2012.

[12] K. E. Okedu, "Stability Enhancement Of DFIG-Based Variable Speed Wind Turbine With A Crowbar By FACTS Device As Per Grid Requirement", *International Journal Of Renewable Energy Research,* Vol. 2, No. 3, Pp. 431-439, June 2012.

[13] Luis Aromataris, Patricia Arnera, And Jean Riubrugent, “Improving Static Techniques For The Analysis Of Voltage Stability", Electric Power System Research, Vol. 33, No. 4, Pp. 901-908, May 2011

[14] S. Jiang, A.M. Gole, U.D. Annakkage, D. Jacobson, "Damping Performance Analysis Of IPFC And UPFC Controllers Using Validated Small-Signal Models", *IEEE Trans. Power Deliv.*, Vol. 26, Pp. 446-454, 2011.

[15] S. Musunuri, G. Dehnavi, "Comparison STATCOM SVC SSSC And TCSC Devices For Voltage Stability Improvement", *North American Power Symposium,* Pp. 1-7, 26-28 September 2010.

[16] R.L. Vasquez-Arnez, L.C. Zanetta, "A Novel Approach For Modeling The Steady-State VSC-Based Multiline FACTS Controllers And Their Operational Constraints", *IEEE Trans. Power Deliv.*, Vol. 23, Pp. 457-464, 2008

[17] A. Wiszniewski, "New Criteria Of Voltage Stability Margin For The Purpose Of Load Shedding", IEEE Transactions On Power Delivery, Vol. 22, No.3, , Pp. 1376-1370, IEEE 2007.

[18] M. Saravanan, S. M. R. Slochanal, P. Ventakash Et Al., "Application Of Particle Swarm Optimization Technique For Optimal Location Of FACTS Devices Considering Cost Of Installation And System Load Ability", *Electric Power Systems Research*, Vol. 77, Pp. 276-283, March 2007.

[19] L. A. Zarate, C. A. Castro, 1. L. Ramos, And E. R. Ramos, "Fast Computation Of Voltage Stability Security Margins Using Nonlinear Programming Techniques", IEEE Transactions On Power Systems, Vol. 21, No.1, Pp. 19-22, IEEE 2006.

[20] M. A. Abido, "Analysis And Assessment Of STATCOM-Based Damping Stabilizers For Power System Stability Enhancement", Electric Power Systems Research, 2005

[21] N. C. Sahoo, B. K. Panigrahi, P.K. Dash, And G. Panda, "Multivariable Nonlinear Control Of STATCOM For Synchronous Generator Stabilization", International Journal Of Electrical Power And Energy Systems, 2004

[22] K. A. Corzine, M. W. Wielebski, F. Z. Peng, And Wang, "Control Of Cascaded Multilevel Inverters," IEEE Trans. Power Electron, Vol. 19, No.3, Pp. 732-738, IEEE 2004.

[23] S. Gerbex, R. Cherkaoui, And A. Germond, "Optimal Location Of Facts Devices To Enhance Power System Security", IEEE Power Tech Conference, Bologna, Pp.L -7, IEEE 2003.

[24] L. Cong And Y. Wang, "Coordinated Control Of Generator Excitation And STATCOM For Rotor Angle Stability And Voltage Regulation Enhancement Of Power Systems", IEE Proc. Gener. Transm. Distrib., 2002.

[25] Hingorani, N.G., Gyugyi, "Understanding Facts Concepts And Technology Of Flexible Ac Transmission Systems", Institute Of Electrical And Electronic Engineers, New York, 2000.

[26] Fuerte-Esquivel, C. R., Acha, E., Tan, S.G., Rico, "Efficient Object Oriented Power System Software For The Analysis Of Large-Scale Networks Containing Facts Controlled Branches", IEEE Trans. Power System, Vol. 3, Issue 2, Pp- 464-472, IEEE 1998

[27] J. Zhang, 1. Y. Wen, S. Cheng, And Ma, "A Novel Svc Allocation Method For Power System Voltage Stability Enhancement By Normal Forms Of Diffeomorphism", IEEE Transactions On Power Systems, Vol. 22, No.4, Pp. 1819-1822, IEEE 1998.

[28] E. Uzunovic, A. Canizaresa, J. Reeve, "Fundamental Frequency Model Of Static Synchronous Compensator", *North American Power Symposium (NAPS)*, Pp. 49-54, October 1997.

[29] J. Brochu, F. Beauregard, J. Lemay, G. Morin, P. Pelletier, R.S. Thallam, "Application Of The Inter-Phase Power Controller Technology For Transmission Line Power Flow Control", *IEEE Trans. Power Del.,* Vol. 12, No. 2, Pp. 888-894, Apr. 1997.

[30] G. Sybille, Y. Haj-Maharsi, G. Morin, F. Beauregard, J. Brochu, J. Lemay, P. Pelletier, "Simulator Demonstration Of The Inter Phase Power Controller Technology", *IEEE Trans. Power Del.*, Vol. 11, No. 4, Pp. 1985-1972, Oct. 1996.