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VOLTAGE PROFILE ENHANCEMENT OF ELECTRICAL DISTRIBUTION NETWORK USING FUZZY LOGIC CONTROLLER

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Abstract— Flexible AC Transmission Systems (FACTS) Controllers are used to increase transmission capacity by damping the power system oscillations and regulating the bus voltage at which the Static Compensator is connected. The focus in this paper is to describe the use of Fuzzy Logic Controller with STATCOM Controllers and compare them in static voltage stability improvements for the damping of the IEEE 14 Bus power system oscillations. A Single line diagram of the IEEE 14 Bus standard system is used in this paper with load assumed to be represented by constant impedance. The size and installation location for load margin improvement and price discussions are addressed. The IEEE 14 Bus is modeled using the elements of Simulink. The effectiveness of the proposed controllers, the improvements in power quality and in voltage profile is demonstrated. In the simulation, the results of the proposed model for the Fuzzy Logic Controller based STATCOM are determined.

Keywords: - IEEE 14 bus System, Fuzzy Logic Controller, STATCOM Technology, MATLAB Simulink

I. INTRODUCTION

Power flow solution is the basic requirement for analysis and optimization of any power system. The steady state operating condition of a system can be obtained from the power flow solution. The operation and planning studies of a distribution system require a steady state condition of the system for various load demands. At the operating stage, the power flow is used to ensure that voltages and currents are within the predefined ranges for expected loads. In confronting to distribution system, because of radial structure and high resistance to reactance ratios, distribution systems are ill-conditioned and traditional methods such as Newton Raphson and fast decoupled power flow are inefficient at solving such systems [1]. Modifications of the conventional algorithms to incorporate the high resistance to reactance ratios have been suggested by many researchers. To meet the constantly increasing load demand, penetration of distributed generation in distribution systems is also increasing. These increasing connections of distributed generations have made distribution system more complex from topological and operational point of view. So the need for a robust, efficient and fast power flow solution technique has been identified [2].

Recent development of power electronics introduces the use of FACTS devices in power systems. FACTS devices are capable of controlling the network condition in a very fast manner and this unique feature of FACTS devices can be exploited to improve the transient stability of a system. Reactive power compensation is an important issue in electrical power systems and shunt FACTS devices play an important role in controlling the reactive power flow to the power network and hence the system voltage fluctuations and transient stability. The flexible AC transmission system (FACTS) are now recognized as a viable solution for controlling transmission voltage, power flow, dynamic response ,etc. and represent a new era for transmission systems. It uses high-current power electronic devices to control the voltage, power flow, etc. of a transmission system [3].

FACTS devices are very effective and capable of increasing the power transfer capability of a line, if the thermal limit permits, while maintaining the same degree of stability. SVC and STATCOM are members of FACTS family that are connected in shunt with the system. Even though the primary purpose of shunt FACTS devices is to support bus voltage by injecting (or absorbing) reactive power, they are also capable of improving the transient stability by increasing (decreasing) the power transfer capability when the machine angle increases (decreases), which is achieved by operating the shunt FACTS devices in capacitive (inductive) mode. Previous works on the topic prove that shunt FACTS devices give maximum benefit from their stabilized voltage support when sited at the mid-point of the transmission line [4]. The proof of maximum increase in power transfer capability is based on the simplified model of the line neglecting line resistance and capacitance. However, for long transmission lines, when the actual model of the line is considered, the results may deviate significantly from those found for the simplified model.

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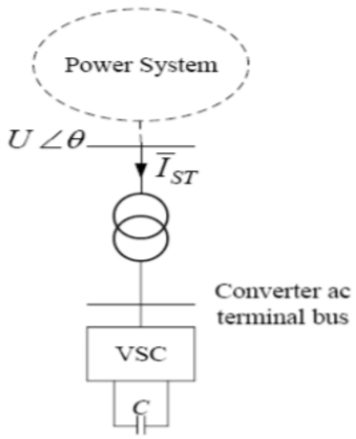

Figure 1: Line diagram of STATCOM

II. VOLTAGE STABILITY AND ITS CLASSIFICATION

Voltage stability refers to the ability of the power system to maintain steady voltages at all the buses in the system after being subjected to a disturbance from a given initial operating point. It depends on the ability of the power system to maintain/restore equilibrium between the load demand and supply. Instability appears in the form of a progressive fall or rise of voltage of some buses. A possible consequence of voltage instability is the loss of load in a particular area, tripping of lines and/or other elements by their protections, leading to cascading outages. This could give way to loss of synchronism of some generators [5]. Voltage collapse is the process wherein, a sequence of events accompanying voltage instability lead to a black-out or abnormally low voltages in major parts of the power system. At low voltages, the stable operation may continue after the transformer tap changers reach their boost limits with intentional and /or unintentional tripping of some loads. The remaining load is voltage sensitive and it so happens that the connected demand at normal voltage is not met [6]. So, if the post disturbance equilibrium voltages are below acceptable limits, a voltage collapse, partial or total blackout is bound to occur.

The time scale for the course of events that develop into a collapse varies from few seconds to several tens of minutes. Accordingly, voltage stability is classified into four categories [7].

Large disturbance voltage stability: It refers to the ability of the system to maintain steady voltages following occurrence of large disturbances like system faults, loss of generation or circuit contingencies. This ability is determined by the system load characteristics and interaction of both continuous and discrete controls and protections. To analyze the large disturbance voltage stability, the system dynamics for the entire time frame of disturbance need to be captured. A suitable model of the system needs to be framed and a compressive analysis needs to be carried out so as to get a lucid picture of stability. The period of study may be from a few seconds to tens of minutes [8].

Small disturbance voltage stability: This type of stability concerns the ability of the system to maintain steady acceptable voltages, when subjected to small disturbances such as gradual changes in the system load. It is called the small disturbance or steady state voltage stability. Such small disturbances on the system can be analyzed by linearizing around the pre-disturbance operating point. Steady state voltage stability analysis aids in getting a qualitative picture of the system; i.e. how much stressed the system is, or how close the system is to the point of instability. This form of stability is influenced by the system load characteristics, continuous and discrete controls at a given instant of time. The basic methods that contribute to the small disturbance stability are essentially of steady state nature. So, the static voltage stability analysis is effectively used to estimate the stability margins. The time span of disturbance in a power system, that may cause a potential voltage instability problem, can be classified as short-term and long-term. Short term Voltage Stability- Automatic voltage regulators, excitation systems, turbine and governor dynamics fall in this short-term time scale, which is typically of the order of a few seconds. Induction motors, electronically operated loads and HVDC interconnections also fall in this category. The analysis requires solution of appropriate system differential equations. If the system is stable, the short-term disturbance dies out and the system enters into slow long-term dynamics [9].

Long term Voltage Stability- The long term time frame is of the order of a few minutes to tens of minutes. Components operating in this time frame are transformer tap changers, thermostatically controlled loads and generator current limiters. The analysis requires long term dynamics system simulation [10].

III. PROPOSED METHODOLOGY

A 100-Mvar STATCOM regulates voltage on a three-bus 500-kV system. The 48-pulse STATCOM uses a Voltage-Sourced Converter (VSC) built of four 12-pulse three-level GTO inverters. Look inside the STATCOM block to see how the VSC inverter is built. The four sets of three-phase voltages obtained at the output of the four three-level inverters are applied to the secondary windings of four phase-shifting transformers (-15 deg., -7.5 deg., 7.5 deg., +7.5 deg. phase shifts). The fundamental components of voltages obtained on the 500 kV sides of the transformers are added in phase by the serial connection of primary windings. Please refer to the "power_48pulsegtoconverter" example to get details on the operation of the VSC.

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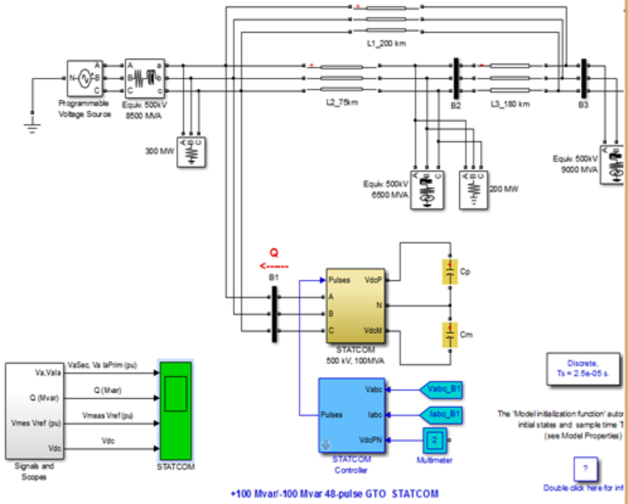

Figure 3: Simulink Model of STATCOM

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.

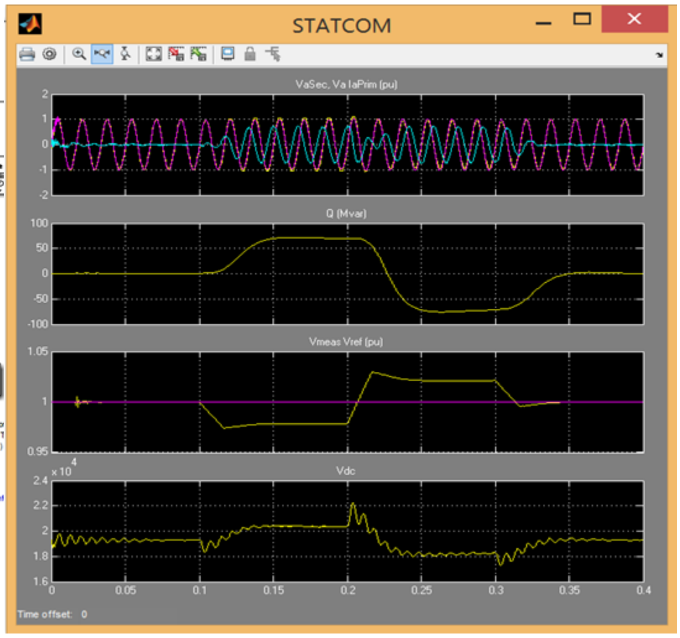

Figure 4: Output Waveform of the STATCOM

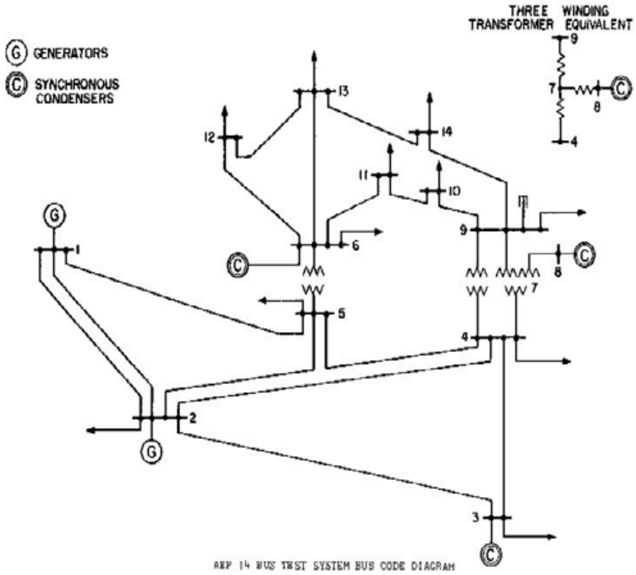

Figure 5: Flow Chart of IEEE 14 Bus Systems

S. No.	Bus No.	Voltage	Voltage Angle	Current	Current Angle
1.	1	0.78 V	-6.38	0.41 A	-23.80
2.	2	0.78 V	-6.39	0.22 A	-7.47
3.	3	0.76 V	-8.39	0.27 A	146.60
4.	4	0.77 V	-8.12	0.37 A	176.54
5.	5	0.77 V	-7.68	0.06 A	160.44
6.	6	0.77 V	-6.97	0.37 A	-24.42
7.	7	0.77 V	-7.31	0.28 A	137.23
8.	8	0.80 V	-3.76	0.33 A	140.73
9.	9	0.75 V	-9.23	0.25 A	-38.59
10.	10	0.75 V	-9.13	0.08 A	-41.93
11.	11	0.76 V	-8.19	0.03 A	-35.41
12.	12	0.76 V	-8.01	0.05 A	-22.71
13.	13	0.76 V	-8.19	0.11 A	-31.44
14.	14	0.74 V	-9.84	0.12 A	-28.39

S. No.	Bus No.	RMS Voltage	RMS Current
1.	1	0.56 V	0.29 A
2.	2	0.55 V	0.15 A
3.	3	0.54 V	0.19 A
4.	4	0.54 V	0.26 A
5.	5	0.55 V	0.04 A
6.	6	0.55 V	0.26 A
7.	7	0.55 V	0.20 A
8.	8	0.57 V	0.23 A
9.	9	0.53 V	0.18 A
10.	10	0.53 V	0.06 A
11.	11	0.54 V	0.02 A
12.	12	0.54 V	0.03 A
13.	13	0.54 V	0.08 A
14.	14	0.52 V	0.08 A

Table I: 14 Bus Systems with Voltage and Current

TABLE II: 14 Bus Systems with RMS Voltage and Current

IV. Simulation Result

To get the better result as compared to PI controller based STATCOM we use Fuzzy Logic Controller STATCOM. In the study we see that FLC based STATCOM provides better result as well it is more reliable in uncertain cases like varying loads and fault conditions. We'll discuss these cases later on.

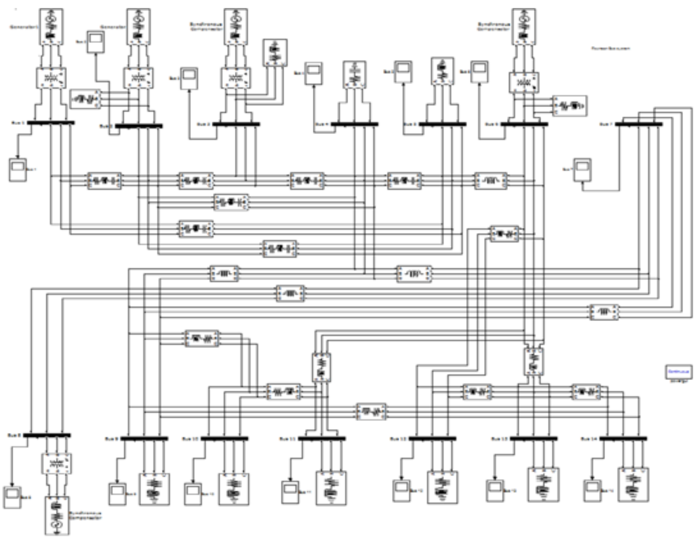

Figure 6: Simulink Model of IEEE 14 Bus Systems

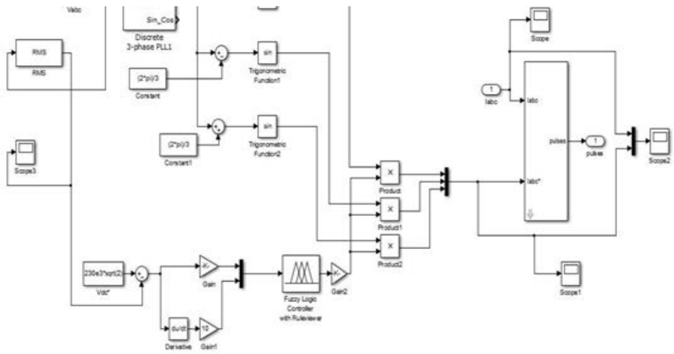

Figure 7: Control scheme of FLC based STATCOM

In the above fig we have used a fuzzy logic controller instead of conventional PI controller. There are two inputs of FLC and one output. This output is tuned by changing the gain and other parameters. The parameters are changed in such a way so that error signal is minimized. To get the desired result we must apply a rule base a system. Fig given below shows the rule base for FLC. Rule base is changed by hit and trial method to achieve the desired result.

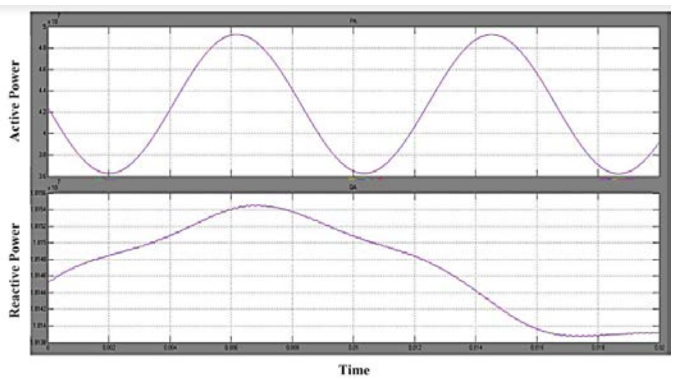

Figure 7: Simulink result of active and reactive power in of IEEE 14-bus system with FLC based STATCOM

The diagram shows the active and reactive power waveform of phase A. Active power waveform is a pure sinusoidal which was distorted in case of PI controller. Thus active power waveform has been clearly improved after applying FLC in STATCOM for control purpose. Reactive power is also slightly increased in this case.

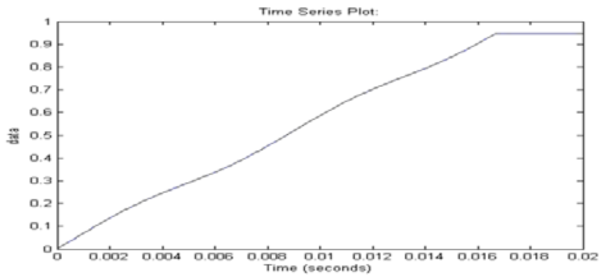

Figure 8: Voltage v/s time plot of bus-1 of IEEE 14-bus system with FLC based STATCOM

Table III: Comparison Result

S. No.	Parameters	Previous Work	Present Work	Improvement
1.	Algorithm Used	Design IEEE 14 Bus System based on Inter line Power Flow Controller	Design IEEE 14 Bus System based on Fuzzy Logic Controller	-
2.	Highest Voltage	0.78	0.96	18.75%
3.	Active Power	3.5028× 10^7 W	4.9× 10^7 W	28.51%
4.	Reactive Power	1.5014× 10^7 W	1.8155× 10^7 W	17.30%

V. Conclusion

Now-a-days electric power systems all over the world are undergoing a phase of increased size and complexity due to rising load demand and expansion. This situation leads to the excessive burden on the power distribution systems posing many challenges before the distribution system utilities. Minimization of real power loss and maintaining voltage profile are the major requirements for a distribution system apart from cost reduction. Distributed generation is a small scale generation, connected to distribution system generating power from renewable or non-renewable energy sources using both modern and conventional technologies. Recently, use of distributed generation is being encouraged because of its numerous benefits such as reduced system loss, voltage profile improvement, enhanced system reliability, relieved transmission and distribution congestion etc.

REFERENCES

[1] M. Venkateswara Reddy, Sishnu Prasad Muni and A. V. R. S. Sarma, “Enhancement of Voltage Profile for IEEE 14 Bus System with Inter line Power Flow Controller”, 2016 Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTS E).

[2] A. Wiszniewski, "New criteria of voltage stability margin for the purpose of load shedding", IEEE Transactions on Power Delivery, Vol. 22, No.3, ,July 2007 pp. 1376-1370.

[3] Gyugyi, L, Fuerte-Esquivel, C. R., Acha, E., Tan, S.G., Rico, 1.1., 'Efficient object oriented power system software for the analysis of large-scale networks containing facts controlled branches', IEEE Trans. Power System 3(2) 1998, pp- 464-472.

[4] Hingorani, N.G., Gyugyi, “Understanding facts concepts and technology of flexible ac transmission systems”, Institute of Electrical and Electronic Engineers, New York, 2000.

[5] K. A. Corzine, M. W. Wielebski, F. Z. Peng, and 1. Wang, "Control of cascaded multilevel inverters," IEEE Trans. power electron, vol. 19, no.3, May 2004,pp. 732-738.

[6] L. A. Zarate, C. A. Castro, 1. L. Ramos, and E. R. Ramos, "Fast computation of voltage stability security margins using nonlinear 158 programming techniques", IEEE Transactions on Power Systems, Vol. 21, No.1" February 2006,pp. 19-22.

[7] J. Zhang, 1. Y. Wen, S. 1. Cheng, and 1. 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,

[8] S. Gerbex, R. Cherkaoui, and A. 1. Germond, "Optimal location of facts devices to enhance power system security", IEEE Power Tech Conference, Bologna, June 2003, pp.l -7.

[9] A. E. Hammad, “Analysis of Power System Stability Enhancement by Static VAR Compensators”, IEEE Trans. PWRS, 1986.

[10] K. R. Padiyar and R. K. Varma, “Damping Torque Analysis of Static VAR System Oscillations”, IEEE Tran. PWRS, 1991.

[11] A. R. Messina, O. Begovich, and M. Nayebzadeh, “Analytical Investigation of the Use of Static VAR Compensators to Aid Damping of Interarea Oscillations”, Electric Power Systems Research, 1999.

[12] M. Parniani and M. R. Iravani, “Optimal Robust Control Design of Static VAR Compensators”, IEE Proc. Genet. Transm. Distrib., 1998.

[13] M. A. Abido, “Analysis and Assessment of STATCOM-Based Damping Stabilizers for Power System Stability Enhancement”, Electric Power Systems Research, 2005.

[14] N. C. Sahoo, B. K. Panigrahi, P.K. Dash, and G. Panda, “Multivariable Nonlinear Control of STATCOM for Synchronous Generator Stabilization”, Int. J. of Electrical Power and Energy Systems. 2004.

[15] 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.