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Electrical Distribution Network for Loss Reduction and Voltage Enhancement

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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

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].

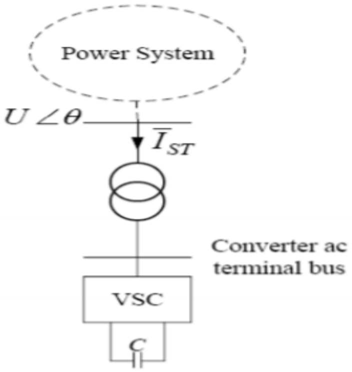


Figure 1: Line diagram of STATCOM

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. 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.

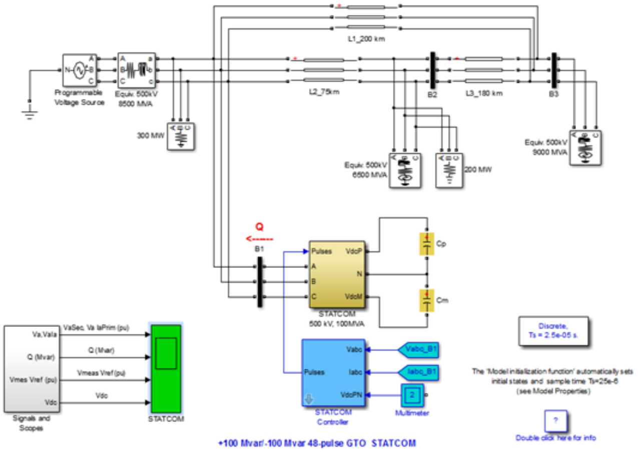


Figure 2: Simulink Model of STATCOM

Please refer to the "power_48 pulse gtoconverter" example to get details on the operation of the VSC. 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.

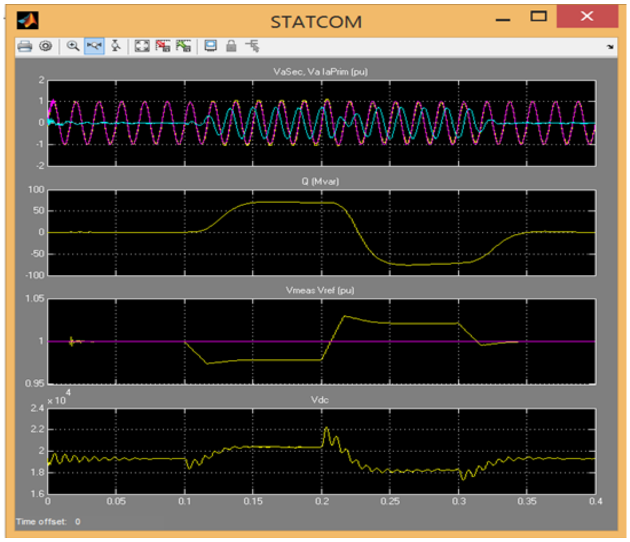


Figure 3: Output Waveform of the STATCOM

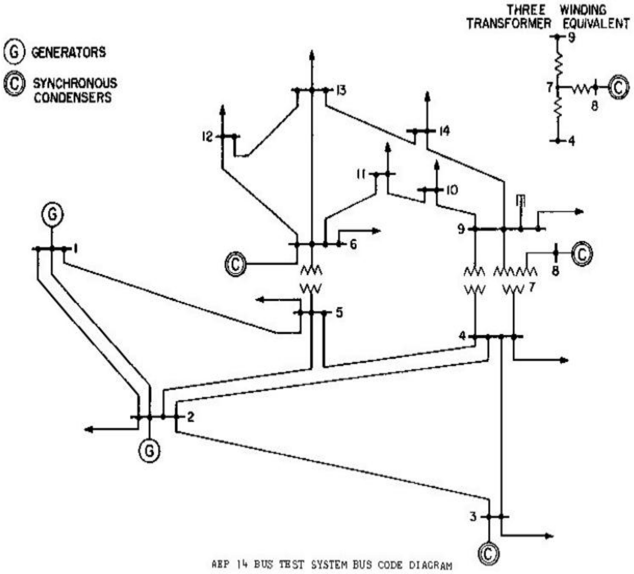


Figure 4: Flow Chart of IEEE 14 Bus Systems

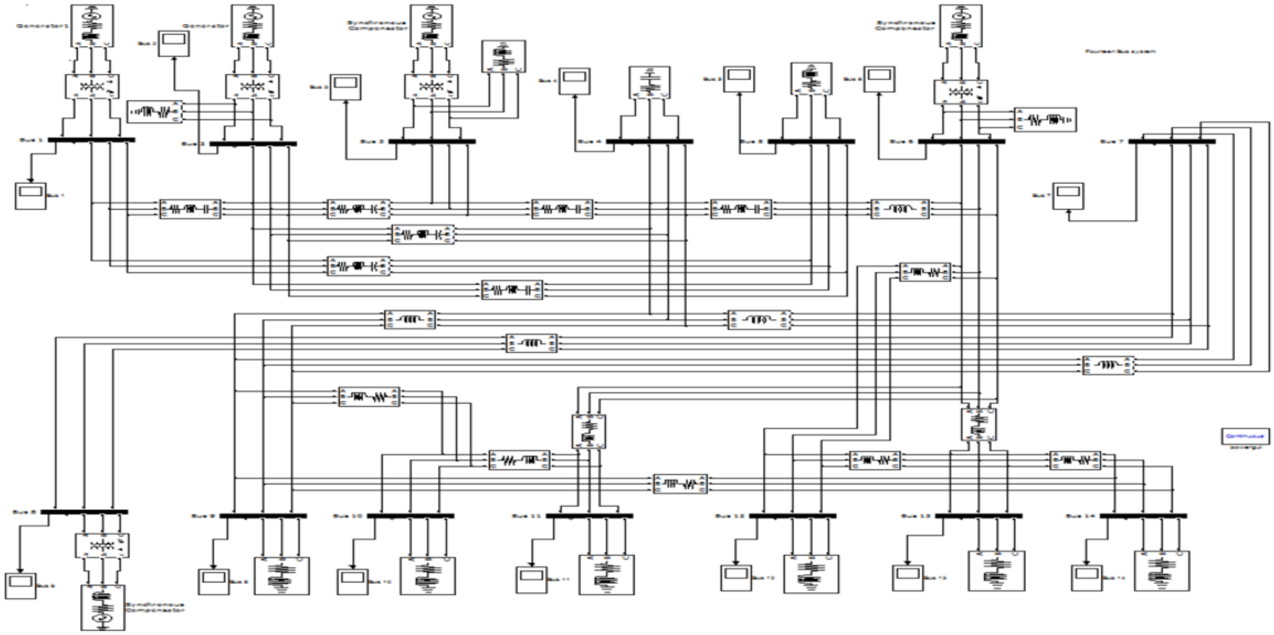


Figure 5: Simulink Model of IEEE 14 Bus Systems

Table I: 14 Bus Systems with Voltage and Current

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

Table II: 14 Bus Systems with RMS Voltage And Current

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

IV. SIMULATION RESULT

To get the better result as compared to PI controller based STATCOM we use Fuzzy Logic Controller STATCOM.

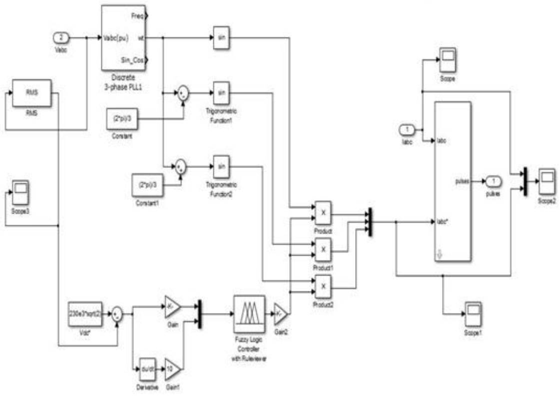


Figure 6: Control scheme of FLC based STATCOM

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.

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.

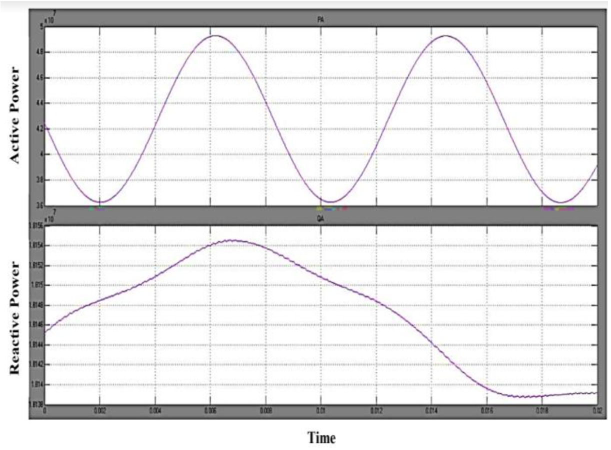


Figure 7: Simulink result of active and reactive power in of IEEE 14-bus system with FLC based STATCOM

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.

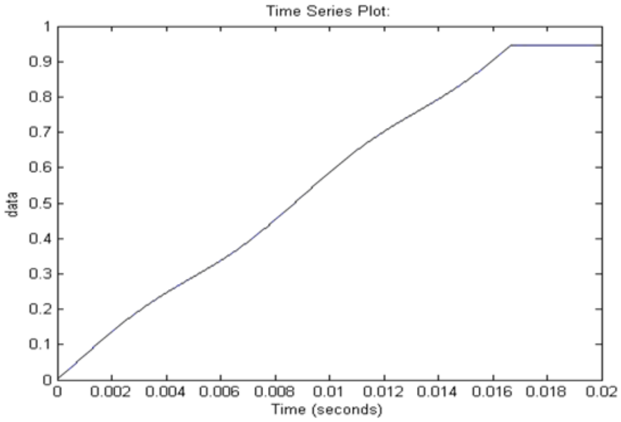
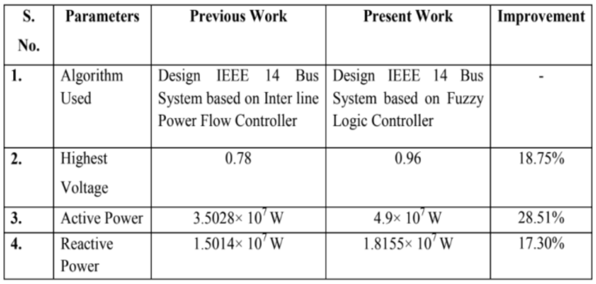


Figure 8: Voltage v/s time plot of bus-1 of IEEE 14-bus system with FLC based STATCOM

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

This paper proposes the three multilevel topologies and they cover different needs for different type of applications. The multi carrier PWM modulation control techniques are introduced in these topologies to get reduced harmonics at the output voltage THD and to improve the efficiency of the inverter. Thus the proposed inverter topologies with the proposed modulation method control techniques are validated through the detailed simulation analysis along with the conventional two level voltage source inverter, and it was shown that the output voltage levels are increased in the multi-level inverters to approach near sine wave and to get the higher voltage and reduced Total Harmonic Distortion.

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