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Investigations on Voltage Stability Improvement using STATCOM in Multi Area System

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ABSTRACT: This work deals with modeling and simulation of four area system with and without fault. This work also deals with improvement in voltage stability during heavy load condition by adding STATCOM. The main contribution of their paper are (i) use of STATCOM and battery energy storage to enhance transient stability and produce better voltage regulation with PMSG.(ii) analyzing the application of nonlinear control theory for stabilizing controller in closed loop. The results of closed loop simulation with PI and fuzzy controller are presented. The results indicate that there is improvement in the response of the closed loop system by using fuzzy logic controllers.

KEYWORDS: Fuzzy Logic Controller (FLC), Permanent Magnet Synchronous Generator (PMSG).

I.INTRODUCTION

Power system stabilizer is a term in which AC power system denotes a condition of remaining synchronism. Small disturbance occurs due to system loading and switching operations. Large disturbances are due to faults, loss of generation, losses of load. Problem of analyzing large disturbances called as transient stability [1].Voltage stability problems are occurred due to change in voltage level caused by transients. The variation in the voltage at the grid side leads to rotor angle deviation which causes stability problems. The voltage and angle are allowed to vary for certain limits only. Beyond this limit the system becomes unstable [2].Facts devices are developed for power system is performance and for dynamic control. STATCOM one of the facts devices is used and fuzzy logic controller is implemented for switching operation of STATCOM [3].Reactive power compensation is one of the major power system problems and the facts device STATCOM plays one of the vital role in controlling the reactive power flow to the network, stability angle and the fluctuation in voltages [4]. The active and reactive components of STATCOM current are controlled normally by using PI controller. Whenever voltage collapse at the buses the STATCOM supplies almost constant reactive power without disturbing by the voltage across it [4],[5]. Nowadays the fuzzy logic controller has most advantages. It is a nonlinear controller therefore it is not sensitive to topology of system, operation condition changes and parameters. This feature is specialty to the power system [4]. In this paper, STATCOM is designed along with the fuzzy logic controller to improve the transient stability of AC power system[6]. Performance of PI and fuzzy logic controller are analyzed and the simulations results show that there is improvement in voltage and maintain stability of the system. Simulation works are done using MATLAB/SIMULINK software.

II.SYSTEM MODEL AND ASSUMPTIONS

The modeling STATCOM is demonstrated in [7]. Figure.1 shows the Basic structure and Figure.2 shows the typical steady state V–I characteristic of STATCOM. STATCOM is a shunt-connected device, which controls the voltage at the connected base to the reference value by adjusting voltage and angle of internal voltage source. STATCOM exhibits constant current characteristics when the voltage is low/high under/over the limit. This allows STATCOM to deliver constant reactive power to the system. Reactive power absorbed or supplied by STATCOM is automatically adjusted so as to maintain voltages of the buses to which they are connected. The advantages of STATCOM are small size, lower costs and flexible regulation from capacitive range to inductive range. The STATCOM can be operated over its full output current range even at very low voltage. The maximum capacitive or inductive output current of the STATCOM can be maintained independently of the AC system voltage.

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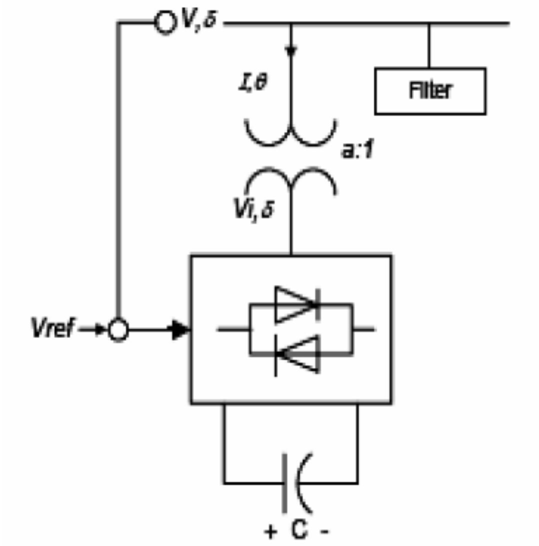

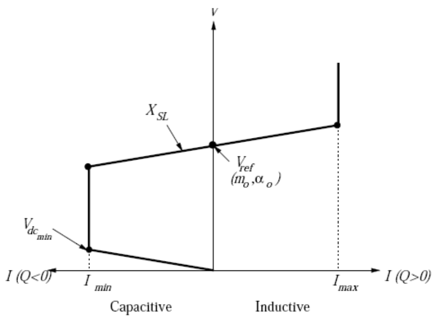

STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system. In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances. From the dc.side capacitor, a three phase voltage is generated by the inverter. This is synchronized with the a.c supply. The link inductor links this voltage to the ac supply.

III.EFFICIENT COMMUNICATION

Fuzzy logic controller, approaching the human reasoning that makes use of the tolerance, uncertainty, imprecision and fuzziness in the decision-making process, manages to offer a very satisfactory performance, without the need of a detailed mathematical model of the system, just by incorporating the expert‘s knowledge into fuzzy rules. In addition, it has inherent abilities to deal with imprecise or noisy data; thus, it is able to extend its control capability even to those operating conditions where linear control techniques fail (i.e., large parameter variations). FLC voltage regulator is fed by one input that is voltage error (Ve).
The rules for the proposed FLC voltage controller are:
i) If Ve‘ is ENVVH‘ Then I‘ is INVVH‘
ii) If Ve‘ is ENVH‘ Then I‘ is INVH‘
iii) If Ve‘ is ENH‘ Then I‘ is INH‘
iv) If Ve‘ is ENM‘ Then I‘ is INM‘

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v) If Ve‘ is ENL‘ Then I‘ is INL‘
vi) If Ve‘ is EZ‘ Then I‘ is IZ‘
vii) If Ve‘ is EPL‘ Then I‘ is IPL‘
viii) If Ve‘ is EPM‘ Then I‘ is IPM‘
ix) If Ve‘ is EPH‘ Then I‘ is IPH‘
x) If Ve‘ is EPVH‘ Then I‘ is IPVH‘
xi) If Ve‘ is EPVVH‘
Then I‘ is IPVVH‘

This paper focuses on fuzzy logic control based on mamdani's system. This system has four main parts. First, using input membership functions, inputs are fuzzified, then based on rule bases and inference system, outputs are produced and finally the fuzzy outputs are defuzzified and applied to the main control system. Error of inputs from is chosen as input. Fig. 6 shows input and output membership functions. To avoid miscalculations due to fluctuations in wind speed and the effects of noise on data, triangular membership functions are chosen to have smooth and constant region in the main points.

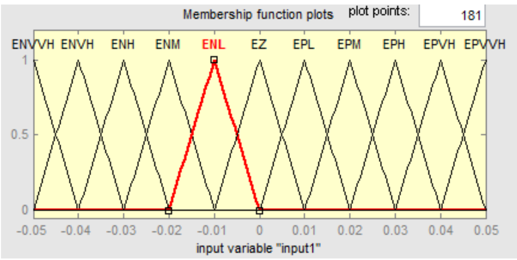

Fig 3 Input membership function

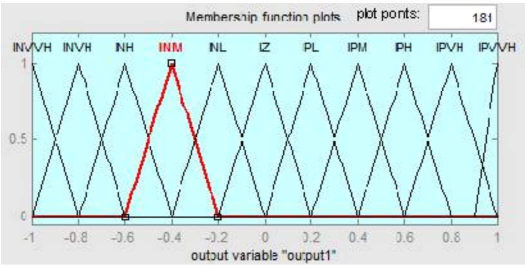

Fig 4 Output membership function

TABLE 1: Rules of fuzzy logic controller.

ε /Δ	NB	NM	NS	Z	PM	PB
NB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	Z	NS
NS	PM	PM	PM	PS	NS	NM
Z	PM	PS	PS	Z	NM	NM
PS	PS	PS	Z	NS	NM	NM
PM	PS	Z	NS	NM	NM	NB
PM	Z	NS	NS	NM	NB	NB

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IV. SIMULATION RESULTS

In the thirty bus system, nine buses are generator buses and 21 buses are load buses. Reactive power at bus 4,reactive power at bus 17, are shown in figures 6,7and 8 respectively. There is no improvement in the voltage of load buses since there is no voltage compensation device connected to them.

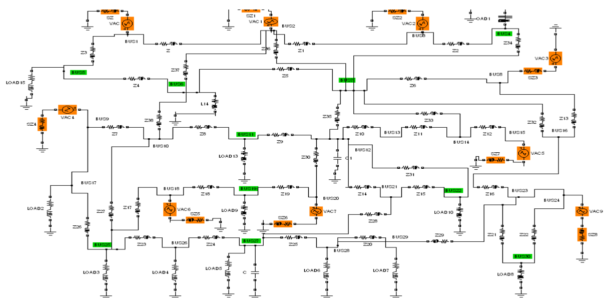

Fig 6 30 Bus system without STATCOM

The reactive power variation at bus 4 is shown in this graph without connecting the device the reactive power is $1.21*10^5$ it is improved to $1.22*10^5$ with the connection of STATCOM.

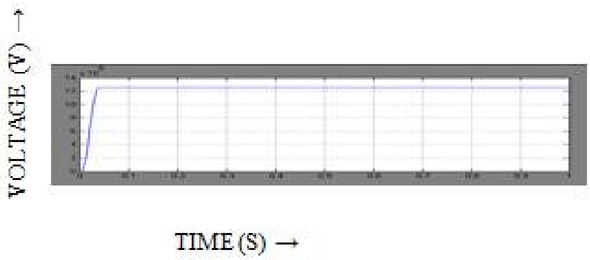

Fig 7 Reactive power at bus 4

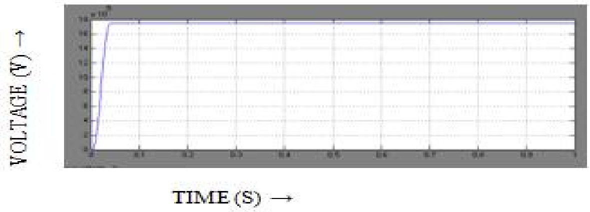

Fig 8 Reactive power at bus 17

Thirty bus system with STATCOM is shown in Fig 9.The real and reactive power at bus 17 and bus 25 are shown in Figs 10&11 respectively. The voltage drop occurs due to the load 2.It is compensated by injecting the voltage in the system.

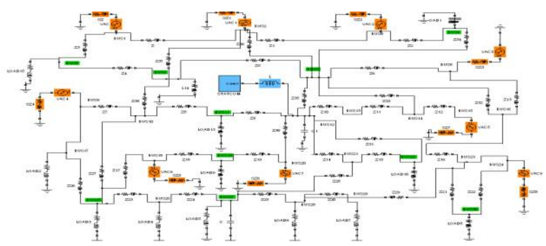

Fig 9 Thirty Bus system with STATCOM

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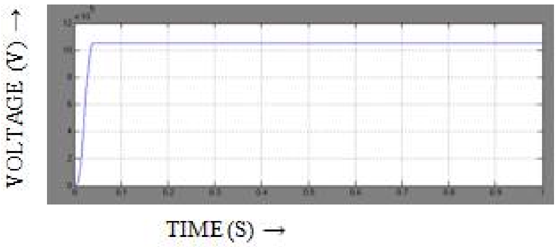

Fig 10 Reactive power at Bus 17

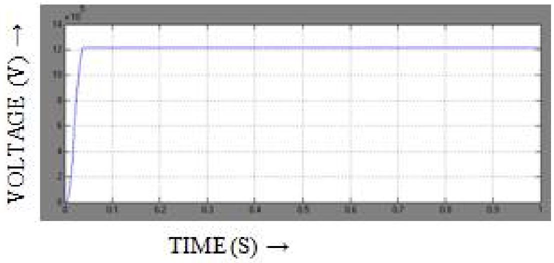

Fig 11 Reactive power at Bus 2

TABLE 2

Summary of real and reactive powers

	Reactive power without STATCOM MVAR	Reactive power with STATCOM MVAR
Bus-4	1.21	1.22
Bus-5	1.09	1.12
Bus-11	1.00	1.06
Bus-17	1.57	1.573
Bus-19	1.27	1.28
Bus-22	0.97	0.977
Bus-25	1.12	1.27
Bus-27	1.025	1.03
Bus-30	0.89	0.893

The closed loop system with PI controller is shown in Fig 12.The output voltages of statcom,load1&load2,are shown in Fig 13.The real and reactive powers are shown in Figs 14&15 respectively.

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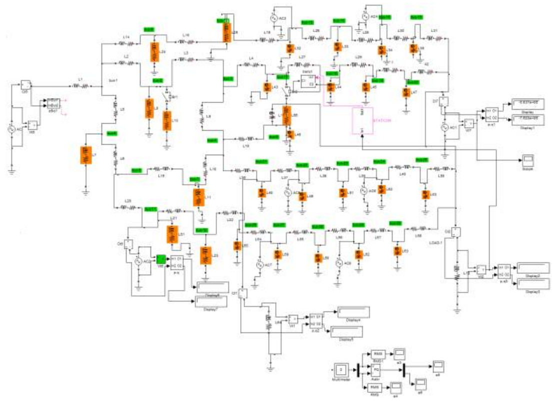

Fig 12closed loop controlled thirty bus system with PI controller.

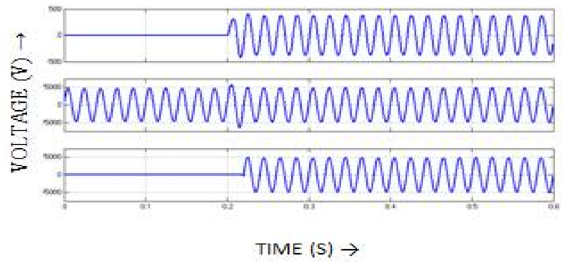

Fig 13 Output voltage of statcom, load 1&load 2

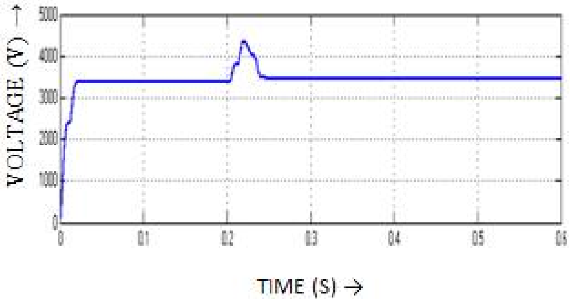

Fig 14 Real power.

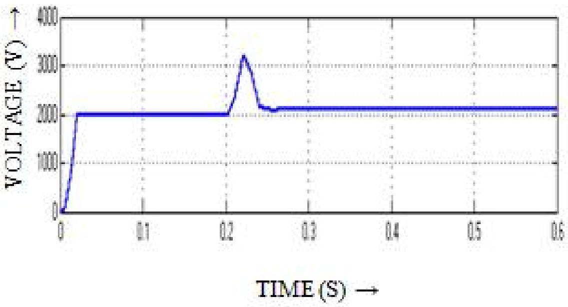

Fig 15 Reactive power.

The closed loop system with fuzzy controller is shown in Fig 16. The main disadvantage of conventional PI controller is inability to react toabrupt changes in the error signal, because it is inefficient during nonlinear variation. Fuzzy logic controller is much efficient in dealing with nonlinear ties. The determination of output control signal is done in an inference engine with a rule base having if-then rules. With the rule base, the value of the output is according to the value of the error signal and the rate of error.

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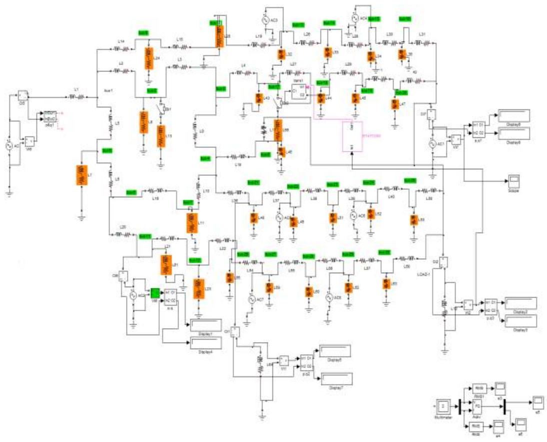

Fig 16 closed loop controlled thirty bus system with fuzzy controller.

The closed loop system with fuzzy logic controller is shown in Fig 16.The output voltages of statcom, load1&load2 are shown in Fig 17. The real and reactive powers are shown in Figs 18&19 respectively.

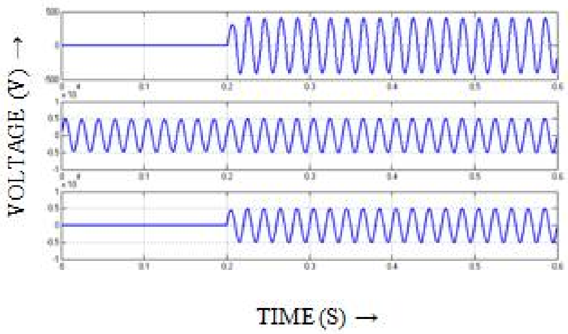

Fig 17 Output voltage of statcom, load 1&load 2

TABLE 3:

Comparison of responses in thirty bus systems

Controller	ts	tr	Ess
PI controller	0.25	0.23	1.8
FLC	0.21	0	0.06

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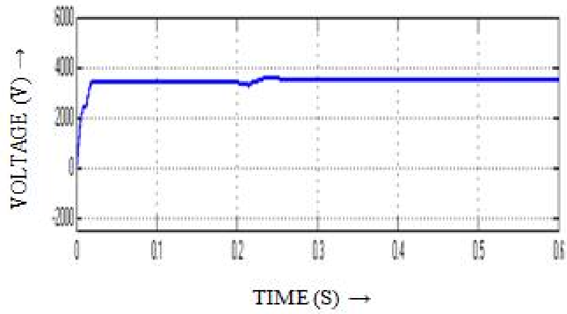

Fig 18 Real power

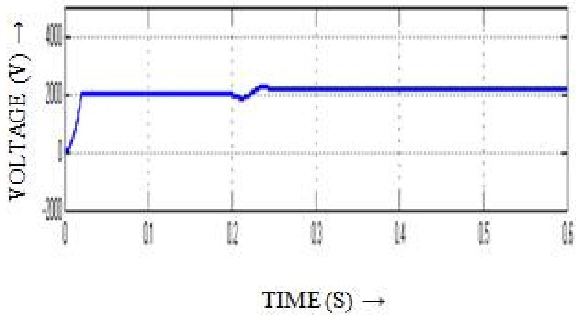

Fig 19 Reactive power

V. CONCLUSION

Thirty bus systems with and without STATCOM and thirty bus with PI and fuzzy logic controller systems are modeled and simulated successfully. The results indicate that STATCOM can improve the voltage stability and duration of sag is reduced due to the injection of reactive power. The stability of the system is maintained with uninterrupted flow of power to the load. The setteling time and steady state error are reduced using FLC. Power quality improvement in thirty bus system is done in the present work. Power quality improvement in fifty bus system will be done in future.

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