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SVC and DSTATCOM Comparison for Voltage Improvement in RDS Using ANFIS

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Abstract**—**This paper investigates the performance comparison of SVC (Static VAR Compensator) and DSTATCOM (Distribution Static Synchronous Compensator) to improve voltage stability in Radial Distribution System (RDS) which are efficient FACTS (Flexible AC Transmission System) devices that are capable of controlling the active and reactive power flows in a power system line by appropriately controlling parameters using ANFIS. Simulations are carried out in MATLAB/Simulink environment for the IEEE-4 bus system to test the ability of increasing load. It is found that these controllers significantly increase the margin of load in the power systems.

Keywords**—**SVC, DSTATCOM, voltage improvement, ANFIS.

I. Introduction

On low voltage, different types of load respond differently to voltage variation. For every one percent drop in voltage, approximate wattage reduction will be 1.6% in filament lamps and 2% in resistance loads. Induction motors draws more current, resulting in overheating and reduction in the life of the motors. Insulation of motor winding may be weakened due to overheating, which may cause short circuit and burning of motors in due course. The line losses will be high due to increase in current. This will further increase the voltage drop in the line [1]-[4]

In industrial areas, it has been observed that under certain critical loading conditions, the distribution system experiences voltage collapse. Due to this phenomenon, system voltage collapses periodically and need to supply an urgent reactive compensation to avoid repeated voltage collapse [5]-[7]. FACTS Controllers help in increasing the operational efficiency of power systems without affecting the reliability of supply [8]-[11]. The application of reactive power compensators in Power System was commenced in the late seventies. SVC-FCTCR has negligible inertia compared to synchronous condensers and can have a super fast response (2-3 cycles) that enables the control of reactive power in the limit range [12]. DSTATCOM can enhance the power distribution capability and thus extends the steady state stability limit [13].

In recent years, new artificial intelligence-based approaches have been proposed to design a FACTS-based supplementary damping controller. These approaches include particle swarm optimization [14], [15], genetic algorithm [16], and differential evolution [17]. Since 1989, artificial neural networks (ANN) methodology has captured the interest in a large number of applications in electrical power engineering

An Adaptive Neuro-Fuzzy Inference System (ANFIS) combines the fuzzy qualitative approach with the adaptive capabilities of neural networks to achieve improved performance [18], [19]. Compared to a standard fuzzy logic controller, a control system based on this concept can be trained without significant expert knowledge.

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II. System Model

A. The Fixed Capacitor Thyristor Controlled Reactor

The TCR provides continuously controllable reactive power only in the lagging power-factor range. To extend the dynamic controllable range to the leading power-factor domain, a fixed-capacitor bank is connected in shunt with the TCR. The TCR MVA is rated larger than the fixed capacitor to compensate (cancel) the capacitive MVA and provide net inductive-reactive power should a lagging power-factor operation be desired. The fixed-capacitor banks, usually connected in a star configuration, are split into more than one 3-phase group. Each capacitor contains a small tuning inductor that is connected in series and tunes the branch to act as a filter for a specific harmonic order. For instance, one capacitor group is tuned to the 5th harmonic and another to the 7th, whereas yet another is designed to act as a high-pass filter. At fundamental frequency, the tuning reactors slightly reduce the net MVA rating of the fixed capacitors. An FC–TCR compensator is shown in Fig. 1.

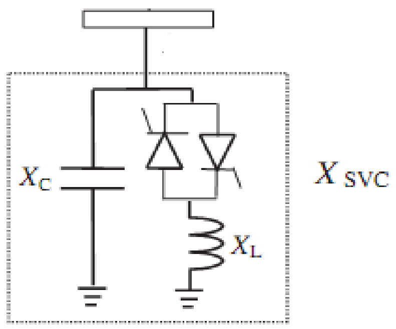

Fig. 1 Static VAR compensator

B. Distribution Static Synchronous Compensator

A DSTATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). A single-line DSTATCOM power circuit is shown in Fig. 2 where a VSC is connected to a utility bus through magnetic coupling. D-STATCOM is seen as an adjustable voltage source behind a reactance—meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a DSTATCOM a compact design, or small footprint, as well as low noise and low magnetic impact. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage [20].

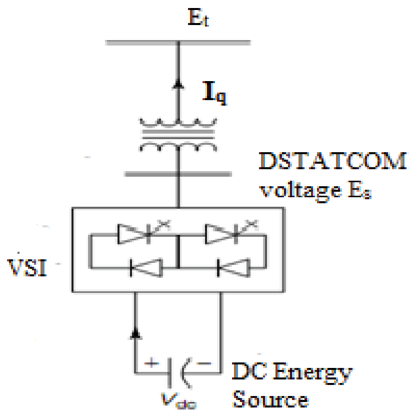

Fig. 2 Single line diagram of DSTATCOM

III. NEURO FUZZY CONTROLLER

Controller employs a Phase-Locked Loop (PLL) to synchronize the three phase voltages at the converter output with the zero crossings of the fundamental component of the phase-A terminal voltage. Therefore, the PLL provides the angle ϕ to the abc-to-dq0 (and dq0-to-abc) transformation. The AC Voltage regulator is responsible for controlling the terminal voltage through the reactive power exchange with the ac network. In this PI, regulator provides the reactive current reference I_q Ref, which is limited between +1pu capacitive and -1pu inductive is shown in Fig. 3

Responsibility of ANFIS controller in DC voltage regulator is to maintain the dc voltage constant through a small active power exchange with the ac network, compensating the active power losses in the transformer and inverter. In this ANFIS regulates the reactive current reference Id_Ref, which is limited between + 1 pu capacitive and -1pu inductive. As shown in Fig 4, this regulator has one droop characteristic, usually +/-5% tolerance allows to voltage limit.

The network has been trained using 5000 sample training data, which are generated under the consideration of the different operating conditions and dynamic behavior of the power system

In DSTATCOM, two inputs error and change of error and one output current have been used for the training of ANFIS. Each input variable has 7 membership functions output has 49 functions Fig. 5 shows ANFIS input output plot.

In SVC, Complex power is taken from power measuring block, in which power factor angle is taken as input of fuzzy controller. According to power factor angle, control output (firing angle) is provided by ANFIS controller. Input (the Power factor angle) has 3 membership functions and the Output (the firing angle) has 3 functions. Fig. 6 shows ANFIS input output plot for SVC.

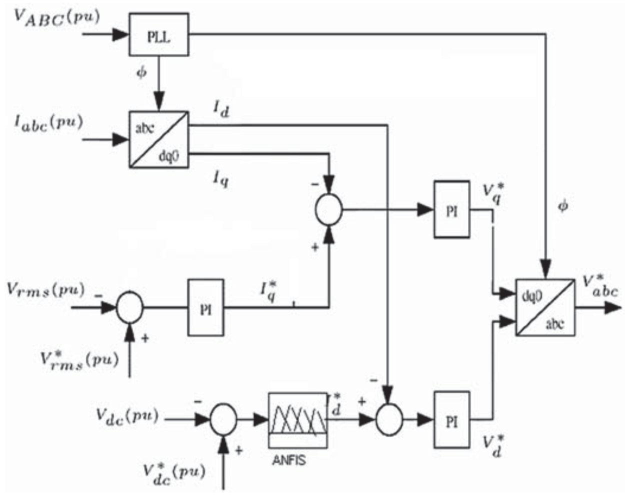

Fig. 3 DSTATCOM control circuit

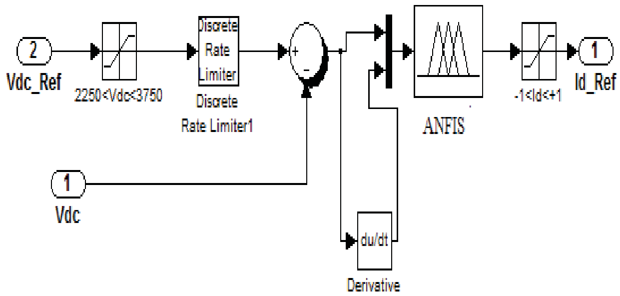

Fig. 4 Neuro Fuzzy Controller in DC Voltage regulator

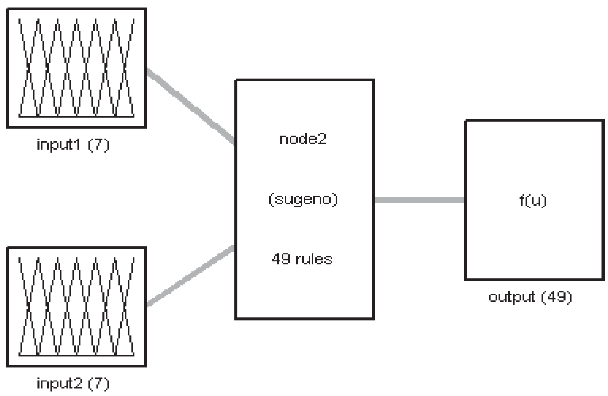

Fig. 5 DSTATCOM-ANFIS input output diagram

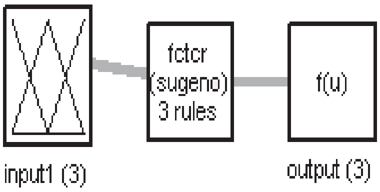

Fig. 6 SVC-ANFIS input output diagram

IV. Test System

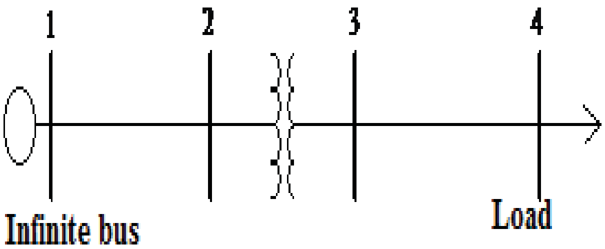

Fig. 7 Single line diagram of IEEE 4 bus RDS

A DSTATCOM and SVCs are used to regulate voltage on 24.9 KV distribution network. Two feeders 2000ft and 2500ft transmit power to loads as shown in Fig. 7 [21]. DSTATCOM and SVC are separately tested for voltage stability and loading capacity with ANFIS. The comparisons of load voltage, current, THD, and load power for different controllers are shown in Figs. 8-10 and Table I. SVC-ANFIS simulation results are shown in Figs. 11-13, DSTATCOM–PI simulated results are shown in Figs. 14-16 and DSTATCOM-ANFIS results are shown in Figs. 17-19

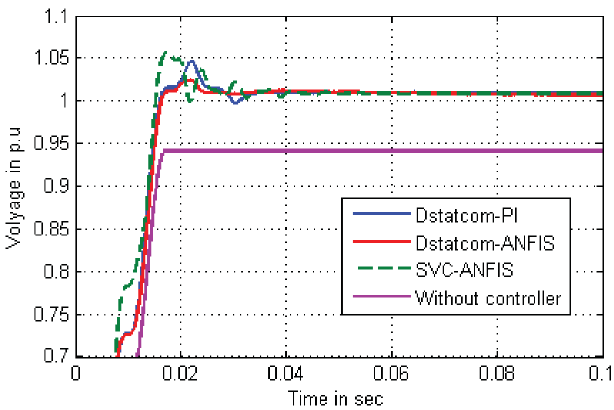

Fig. 8 Per Unit voltages at bus 4

TABLE I
Active and Reactive Power of SVC and DSTATCOM

	1	2	3	4
P	1.593E+06	1.83E+06	1.843E+06	1.845E+06
Q	7.717E+05	8.865E+05	8.645E+05	8.526E+05

1= No controller; 2= SVC-ANFIS; 3=DSTATCOM-PI; 4= DSTATCOM-ANFIS

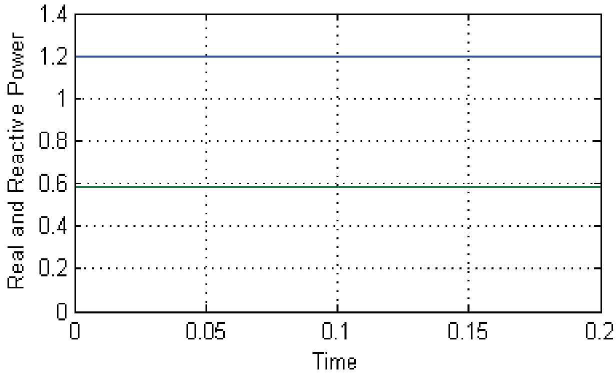

Fig. 9 Real and Reactive Power without controller

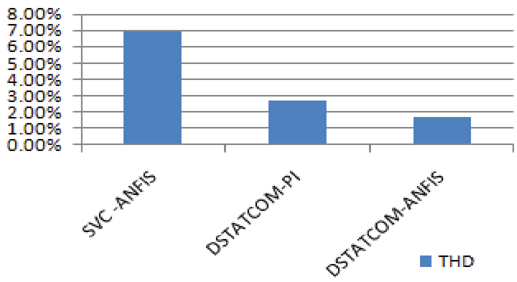

Fig. 10 Total Harmonic Distortion (THD)

A. SVC

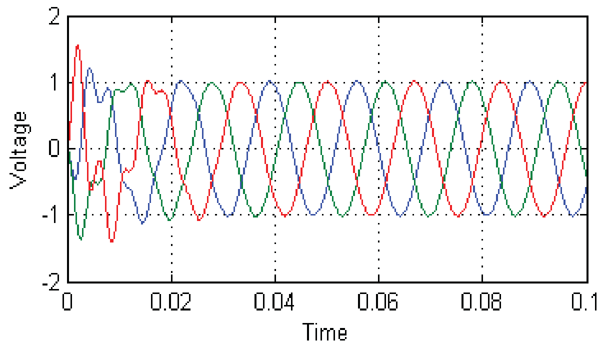

Fig. 11 Load voltage SVC-ANFIS

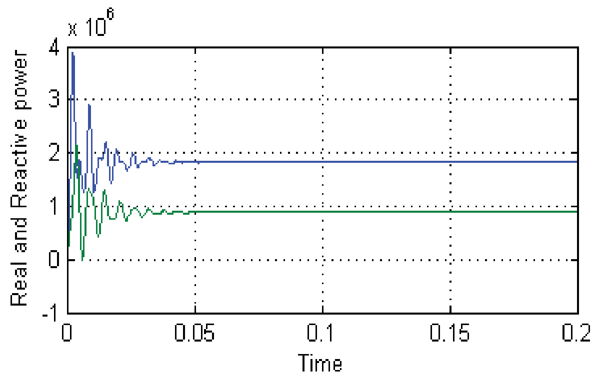

Fig. 12 Real and reactive Powers

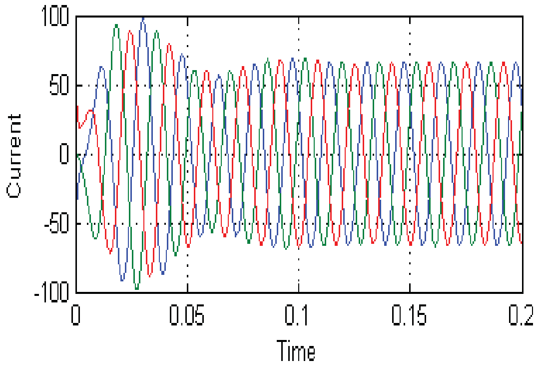

Fig. 13 Load current

B. DSTATCOM PI

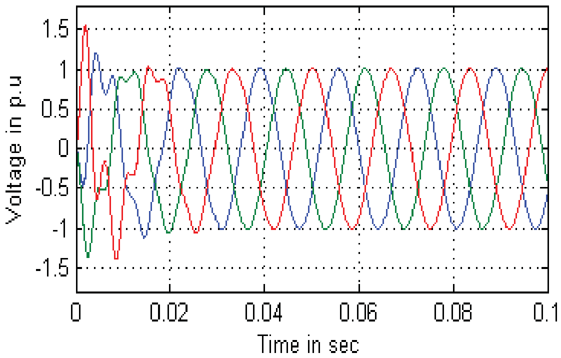

Fig. 14 Load voltage

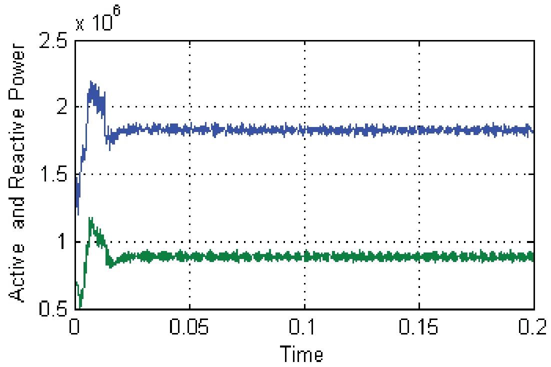

Fig. 15 Real and Reactive Powers

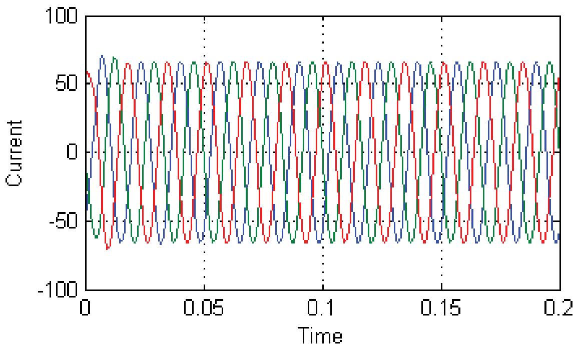

Fig. 16 Load current

C. DSTATCOM –ANFIS

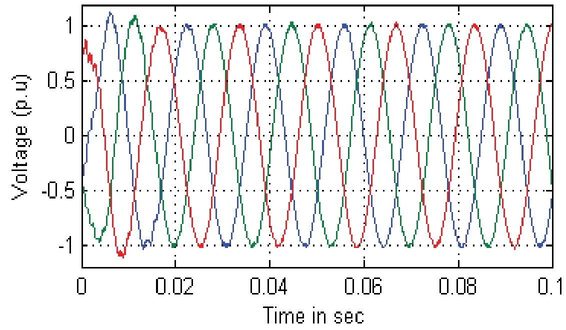

Fig. 17 Load voltage DSTATCOM-ANFIS

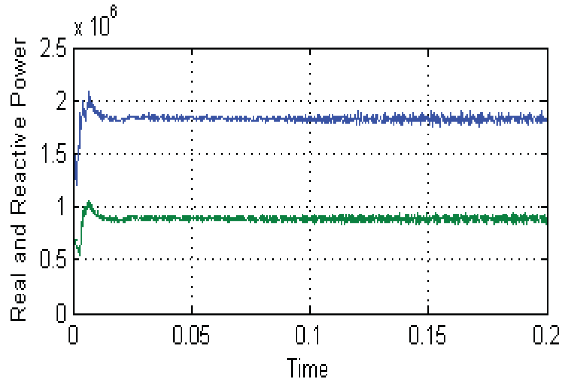

Fig. 18 Real and Reactive Powers

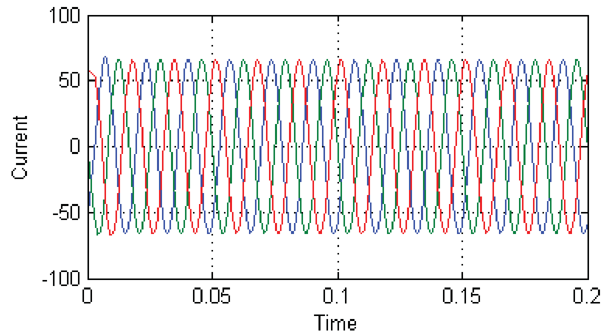

Fig. 19 Load current

V. Conclusion

The simulation result shows that the voltage sags can be mitigated by inserting DSTATCOM and SVC in the 4 bus distribution system. Also, it is found that these controllers significantly increase the margin of load in the power systems from 1.593MW to 1.845MW. Thus, it can be concluded that by adding DSTATCOM with ANFIS has a superior capability in power quality improvement when compared to DSTATCOM- PI and SVC -ANFIS controllers.

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