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VOLTAGE SAG IMPROVEMENT BY PARTICLE SWARM OPTIMIZATION OF FUZZY LOGIC RULE BASE

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ABSTRACT

In this paper improvement in voltage sag by using PSO optimized fuzzy controller is described. Dstatcom is the FACTS device used in voltage sag improvement. Particle swarm optimization (PSO) is used to optimize the if then rules of the fuzzy controller. In this system a Dstatcom is placed in a three phase system to control the voltage sag. A fuzzy controller is designed to control the output of Dstatcom. The whole system is simulated using MATLAB Simulink. The fuzzy controlled Dstatcom output is compared with a PI controlled Dstatcom output. The system without Dstatcom is also simulated using MATLAB Simulink. The fuzzy controller rules are optimized using particle swarm optimization and the results are also compared with other systems.

Keywords: voltage sag, dstatcom, fuzzy logic, optimization, fuzzy logic controller, particle warm optimization.

1. INTRODUCTION

Power quality is a set of electrical boundaries that allows an equipment to perform in its specified manner. Voltage sag and voltage swell are the common power quality issues. Voltage sag is defined as a decrease in voltage to between 0.1 and 0.9 pu in rms voltage for a duration of 0.5 cycle to 1 minute [2]. Voltage sag occurs mainly due to faults and the short circuit current results in decrease of voltage [6]. Graphical representation of voltage sag is shown in Figure-1. In this paper we consider voltage sag due to three types of faults namely single line to ground fault (SLG), double line to ground fault (DLG), and three phase fault.

As the demand of electric power is increasing day by day, the transmission networks are found to be very weak so that they cannot supply unreliable supply with good quality. Flexible A transmission systems (FACTS) is an idea developed based on power electronic controllers, which controls the values of different electrical parameters. FACTS technology makes use of high speed thyristors for switching in or out transmission line components for the required performance of the system. There are different types of FACTS devices namely shunt connected devices and series connected devices [1].

Dstatcom is a shunt connected FACTS device. It is a reactive source that can be controlled and it is capable of absorbing or generating reactive power. Dstatcom consists of coupling transformer, voltage source converter, DC energy storage device and necessary control circuits [8].

The dstatcom can provide compensation in both inductive and capacitive mode. The V-I characteristic of dstatcom is shown in figure. By using dstatcom we can control the effect of voltage sag also.

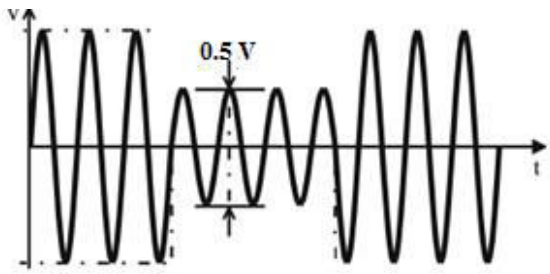

Figure-1. Graphical representation of voltage sag.

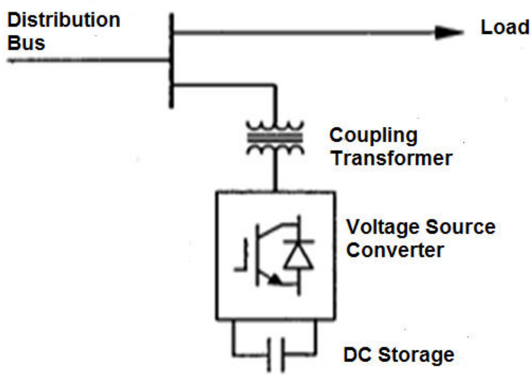

Figure-2. Block diagram of Dstatcom.

Intelligent control techniques provide a method of approximate reasoning that is similar to human decision making process. They have fast response time and high range of operating conditions. Fuzzy logic provides a formal idea for presenting and implementing human knowledge about how to control a system [3]. The fuzzy logic controller is shown below.

Fuzzification part converts crisp input values into fuzzy values. The knowledge base consists of a database

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of the plant. It gives all the required definitions for the fuzzification process .Rule base represents the controlling system of the network. It is represented as a set of if-then rules. Inference applies fuzzy reason to rule base to obtain the output. Defuzzification process converts fuzzy output to crisp values.

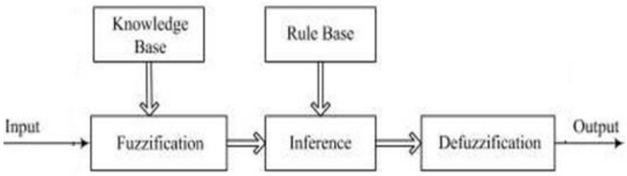

Figure-3. Fuzzy logic controller.

2. DSTATCOM CONTROL SCHEME

Dstatcom is controlled by means of PWM generator. The test system output is compared in an error detector and its output is fed to a fuzzy logic controller. The controller will take necessary control actions and the controller will output an angle δ which is phase modulated by the following equations [5].

$$V_A = \mathrm{Sin}\ (\omega t+\delta) \tag{1}$$

$$V_B = \mathrm{Sin}\ (\omega t+\delta-2\pi/3) \tag{2}$$

$$V_C = \mathrm{Sin}\ (\omega t+\delta+\pi/3) \tag{3}$$

The phase modulated signals are fed to PWM generator and the pulses from PWM generator will control the operation of DSTATCOM during voltage sag.

3. DESIGN of FUZZY LOGIC CONTROLLER

The fuzzy logic controller designed here consists of two inputs, namely error and change in error, and an output. Seven linguistic variables are selected. The linguistic variables are NEB, NEM, NES, ZE, POS, POM and POB. Triangular shaped membership functions are chosen for the inputs and output. A rule base with strength of forty nine rules is created by interconnecting different variables. Fuzzy logic controller is implemented by using fuzzy logic toolbox of Matlab Simulink. The rule base for inputs and output using different linguistic variables are given in the table below:

Table-1. Fuzzy logic rulebase.

de / e	NEB	NEM	NES	ZE	POS	POM	POB
NEB	NEB	NEB	NEB	NEB	NEM	NES	ZE
NEM	NEB	NEB	NEB	NEM	NES	ZE	POS
NES	NEB	NEB	NEM	NES	ZE	POS	POM
ZE	NEB	NEM	NES	ZE	POS	POM	POB
POS	NEM	NES	ZE	POS	POM	POB	POB
POM	NES	ZE	POS	POM	POB	POB	POB
POB	ZE	POS	POM	POB	POB	POB	POB

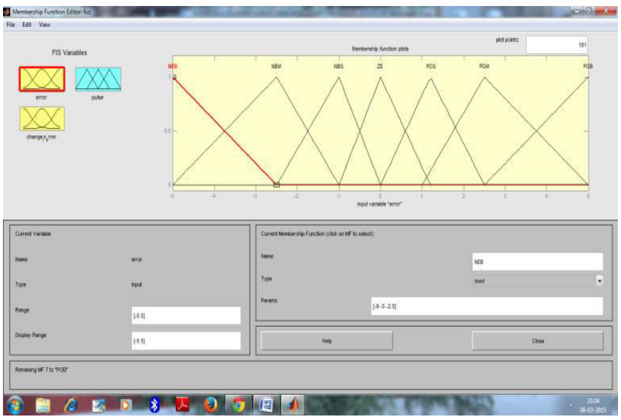

Figure-4. Membership function for input.

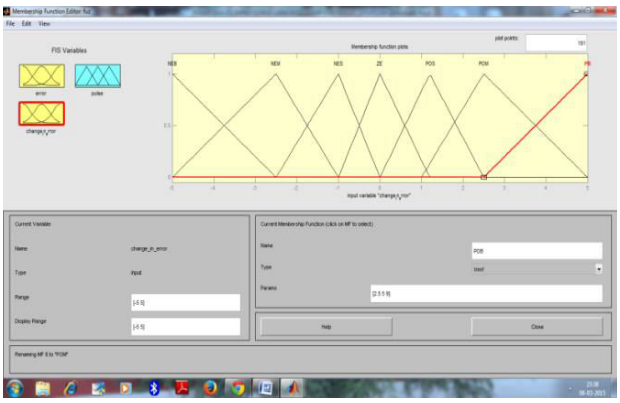

Figure-5. Membership function for input2.

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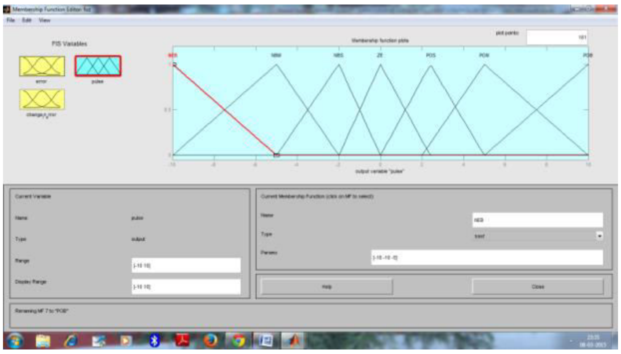

Figure-6. Membership function for output.

4. OPTIMIZATION USING PSO

Particle swarm optimization (PSO) is one of the optimization techniques which can be used with fuzzy logic controller in order to optimize the performance of fuzzy logic controller. Here we optimize the fuzzy rules of fuzzy logic controller to get the optimized results. In PSO the initial population of the system is selected in a random manner and reaches the optimal solutions by updating the different generations. In PSO, the potential solutions, called particles, move through the problem space by following the recent optimum particles [9].

Every particle monitors its coordinates in the problem space, which are related with the best fitness value it has reached so far. The best fitness value is also stored and that value is called pbest. Similarly another best value that is taken by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbours of the particle. This position is called fbest. When a particle takes all the population as its adjacent neighbours, the best value is a global best and is called gbest. The genetic algorithm process can be explained by the following steps

a) Initialization each particle in the population, and take X(i) and V(i) randomly

b) Evaluate the objective function of X(i) and calculate the value of fitness(i)

c) Initialize Pbest (i) with a copy of X(i)

d) From the values of fitness (i) select best value and keep it as the new fbest

e) Choose the particle with the best fitness value from all the particles in the population as the gbest

f) For each particle calculate velocity of the Particle and update the value of particle position

g) Check the selected gbest value is right or wrong

h) Repeat the process from step 2 until maximum iteration is reached

The new optimized rule base of fuzzy logic controller is given in Figure-8.

5. TEST SYSTEM

Test system consists of a 250kv source which is connected to the input of a three phase three winding transformer. The output terminals of three phase tree winding transformer are fed to two branches of 11kv each. In one of the branches Dstatcom is connected for the compensation of voltage sag is connected. In the second feeder we connected linear and varying loads. Different faults are introduced into this branch and the test results are analysed.

Table-2. Optimized fuzzy logic rule base.

de / e	NEB	NEM	NES	ZE	POS	POM	POB
NEB	NEB	NEB	NEB	NEM	NES	NES	NES
NEM	NEB	NEM	NEM	NES	NES	NES	NES
NES	NES	NES	NES	NES	NES	NEM	NEM
ZE	NES	NES	ZE	ZE	ZE	ZE	ZE
POB	POS	POS	POS	POS	POS	POS	POS
POM	POS	POS	PO	POM	POM	POM	POB
POB	POS	POS	POM	POM	POB	POB	POB

6. SIMULATION RESULTS

The system is simulated using Matlab Simulink Sim Power Systems toolbox.

A three phase fault is applied for a time range 0.85s-0.9s with a fault resistance of 0.66Ω. The system is simulated for 1s. In the first case no Dstatcom is placed for the compensation of voltage sag. In the second case Dstatcom with PI controller is introduced in the system. In the third case fuzzy controlled Dstatcom is operated during the time of fault. In the last stage particle swarm

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optimized fuzzy logic controller is provided. A subsystem block is also provided in simulink model to generate the PWM control signals. Matlab Simulink test model and the simulation results are shown below. During fault in the system without dstatcom voltage sag occurs and there is no control over the system. When PI controlled dstatcom is placed in the system voltage sag is mitigated. Fuzzy controlled dstatcom provides much more improvement in voltage sag mitigation. The optimization of fuzzy controller gave much more improved result. From the various figures given below we can analyse the performance of different controllers.

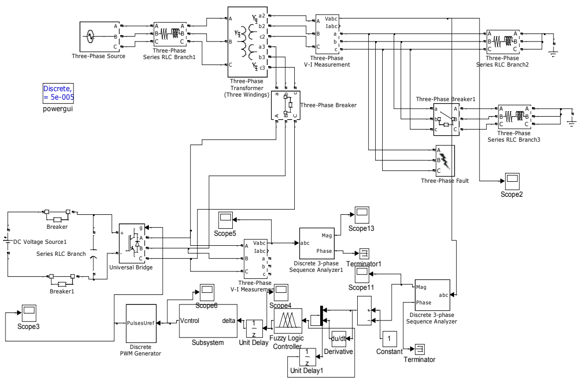

Figure-7. Simulink model of the test system.

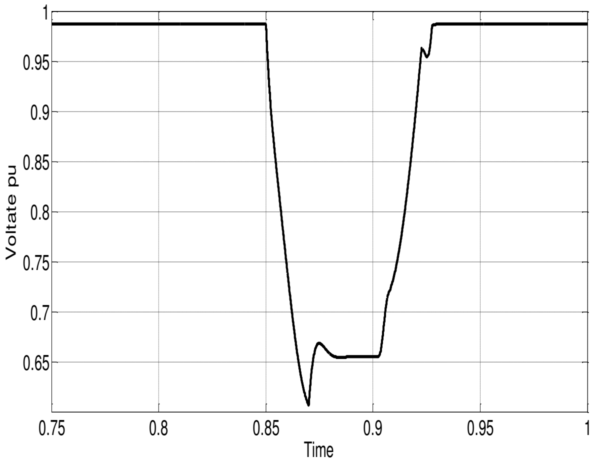

Figure-8. Output of the system without Dstatcom in the system.

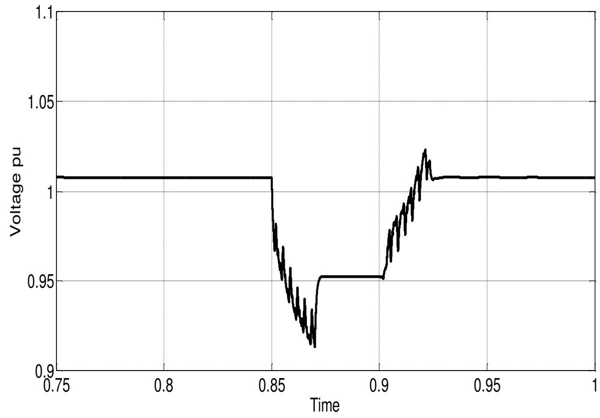

Figure-9. Output of the system with PI controlled Dstatcom in the system.

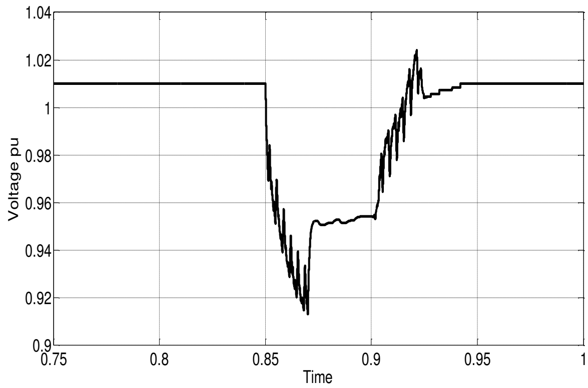

Figure-10. Output of the system with fuzzy logic controlled Dstatcom.

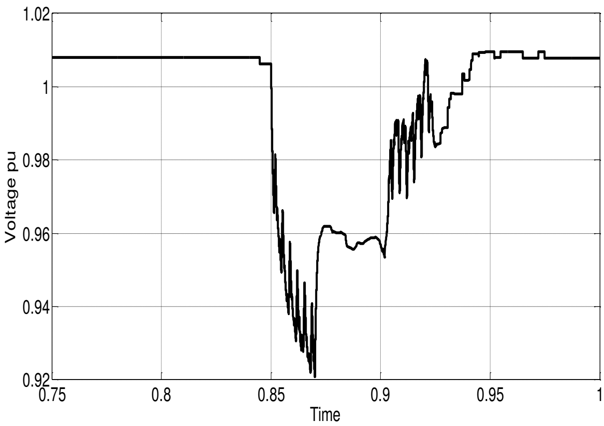

Figure-11. Output of the system with particle swarm optimized fuzzy logic controlled Dstatcom.

7. CONCLUSIONS

From the test results we can see the performance of fuzzy controlled DSTATCOM is better than the performance of PI controlled Dstatcom. The magnitude of voltage output of Fuzzy controlled Dstatcom is higher than that of PI controlled Dstatcom and it is further increased by PSO optimization. PSO optimized fuzzy controlled Dstatcom can perform well in voltage sag mitigation. A combination of different intelligent control techniques can be applied for the control of Dstatcom. The performance of DSTATCOM can be further improved by the application of hybrid optimization techniques.

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