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Optimal DSTATCOM placement in radial distribution system using fuzzy-ANFIS

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Paper aim is to obtain voltage control with optimal DSTATCOM placement to decrease the total cost of voltage regulators and losses. This algorithm makes the initial selection, installations and buck-boost setting of the DSTATCOM which provides a smooth voltage profile along the network. It is also used to obtain the minimum number of the initially selected DSTACOM, by moving them in such way as to control the network voltage at the minimum possible cost. Software using MATLAB™ has been developed and implemented using back track algorithm, fuzzy logic and ANFIS (Artificial Neuro Fuzzy Inference system) results are compared.

Keywords: *Optimum placement, DSTATCOM, fuzzy, ANFIS*

1.0 INTRODUCTION

Consumer awareness regarding reliable power supply has been growing day by day. Power quality is most common concern for power utilities as well as for consumers. Today, the world needs increased amount of quality power for its growing population and industrial growth. Voltage sag is a frequently occurring power quality problem. Voltage sag has been defined as reduction in the Root Mean Square (RMS) voltage in the range of 0.1 to 0.9 per unit (p.u.) for duration greater than half a cycle and less than one minute [1]. It may be caused by faults, increased load demand and transitional events such as large motor switching [2-3].

In industrial areas, it has been observed that under certain critical loading conditions, the distribution system experience voltage collapse. Due to this phenomenon, system voltage collapses periodically urgent reactive compensation needs to be supplied to avoid repeated voltage collapse [4]. FACTS Controllers help in increasing the operational efficiency of power systems without affecting the reliability of supply [5-8]. DSTATCOM can enhance the power distribution capability and thus extend the steady state stability limit [9]. The modern and conventional control techniques based DSTATCOM can provide optimal performance for the nominal operating condition and nominal system parameters. However, a modern Distribution system has become large, wide load changes and complex, it is difficult to achieve voltage stability through conventional methods.

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 [10-11], genetic algorithm [12], and differential evolution [13]. 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

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with the adaptive capabilities of neural networks to achieve improved performance [14-15]. Compared to a standard fuzzy logic controller, a control system based on this concept can be trained without significant expert knowledge.

2.0 METHODOLOGY

The entire frame work to solve the optimal DSTATCOM placement problem includes the use of numerical procedures which are coupled to the Back Tracking Algorithm (BTA), FES (Fuzzy Expert System) and ANFIS (Artificial Neuro- Fuzzy Inference System). First a vector based load flow calculates the power losses in each line and voltages at every bus. Voltages and real power losses calculated by placing The DSTATCOM. Obtained voltage and power losses are given as inputs to the BTA, FES and ANFIS which determines optimal position of voltage regulator i.e DSTATCOM.

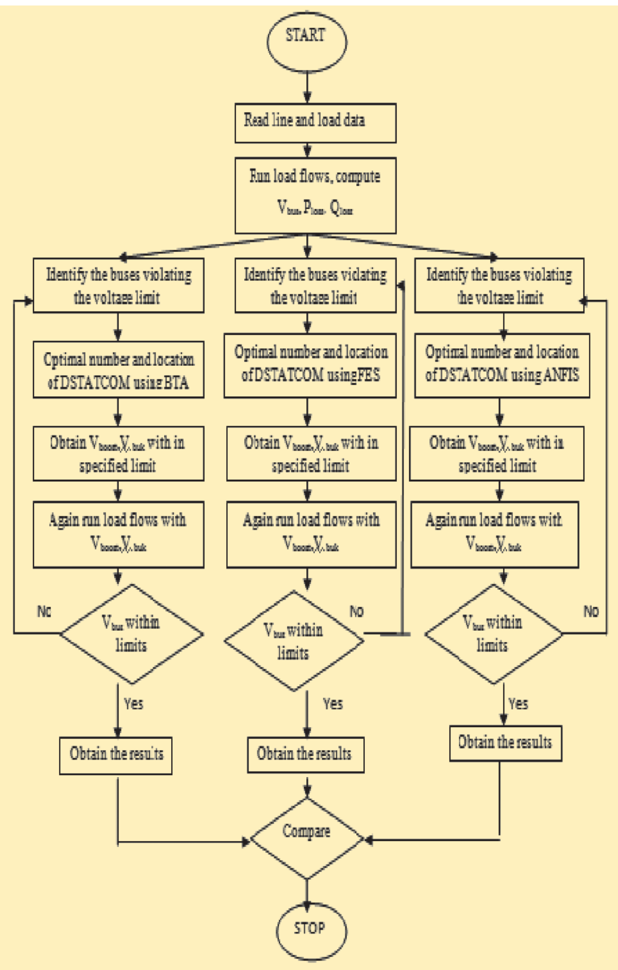

FIG. 1 METHODOLOGY

3.0 FUZZY EXPERT SYSTEM

The entire frame work to solve the optimal DSTATCOM placement problem includes the use of numerical procedures which are coupled to the fuzzy. First a vector based load flow calculates the power losses in each line and voltages at every bus. The voltage regulators are placed at every bus and total real power losses is obtained for each case. The per unit voltages at every bus and the power losses obtained are the inputs to the FES with Mamdani which determines the bus most suitable for placing DSTATCOM without violating the limits. The FES (Fuzzy Expert System) contains a set of rules which are developed from qualitative descriptions. In a FES, rules may be fired with some degree using fuzzy interfacing for determining the suitability of DSTATCOM regulator placement at a particular bus, a set of multiple antecedent fuzzy rules have been established. Inputs to the rules are the voltages and power loss indices and the output consequent is the suitability of the DSTATCOM placement. The rules are summarized in the fuzzy decision matrix in Table 1 given below. L=Low, LN=Low Normal,N=Normal, HN=High Normal, H=High.

TABLE 1

RULE BASE FOR FUZZY INTERACE SYSTEM

AND		VOLTAGE				
		L	LN	N	HN	N
POWER LOSS	L	L	LM	LM	L	L
	LN	M	LM	LM	L	L
	M	HM	M	LM	L	L
	HN	HM	HM	M	LM	L
	H	H	HM	M	LM	LM

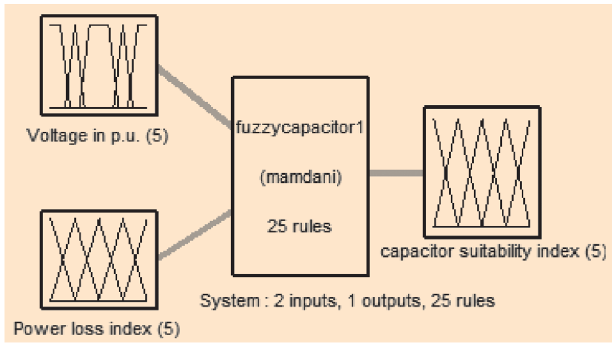

FIG. 2 FES WITH MAMDANI INTERFACE SYSTEM

FES have two inputs and one output, the input consisting of 5 membership functions and output fuzzy consists of 5 membership functions. Where the input 1, voltage is in the range [0.7 1.1], input 2, power loss is in the range [0 1] while the output variable is in the range [0.7 1.1] shown in Figure 2.

4.0 ARTIFICIAL NEURO FUZZY INFERECE SYSTEM (ANFIS)

ANFIS represent fuzzy dynamic models or fuzzy systems. This brings a two fold advantage. First, any model-based technique (including a nonlinear one) can be applied to the fuzzy dynamic models with tuning. Second, the controller itself can be considered as a fuzzy system. Since the fuzzy model of the nonlinear process is usually based on a set of local linear models which are smoothly merged by the fuzzy model structure, a natural and straight forward approach is to design one local controller for each local model of the process consist of two input and one output, only the output in the form of a constant and not range shown in Figure 3.

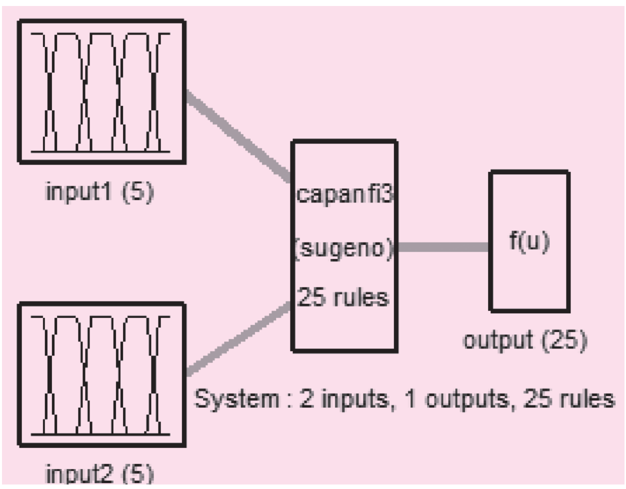

FIG. 3 ANFIS INPUT AND OUTPUT MEMBERSHIP FUNCTION

5.0 TEST CASE

Considered IEEE 47 bus Radial Distribution System, For the positioning of DSTATCOM. The upper and lower bounds of voltage are taken as ±5% of base value. The DSTATCOM are of 11 kV, 200 MVA with 32 steps of 0.00625 p.u. each.

5.1 A back tracking algorithm

Load flow solution for 47 bus practical RDS without and with DSTATCOM is shown in Figure 4-11. From Figure 4 it is found that all bus voltages except bus 1 violate the lower limit of 0.95 p.u. Ideally, Figure 5 shows DSTATCOM are to be installed at all buses except at bus 1. However, in practice, it is not economical to have more number of DSTATCOM at all buses to get the voltages within specified limits and hence by applying back tracking algorithm the required optimal number of DSTATCOM regulators are 3 i.e at 2, 9, 27. And that will maintain the voltage profile within Tolerence limits is shown in Figure 7.

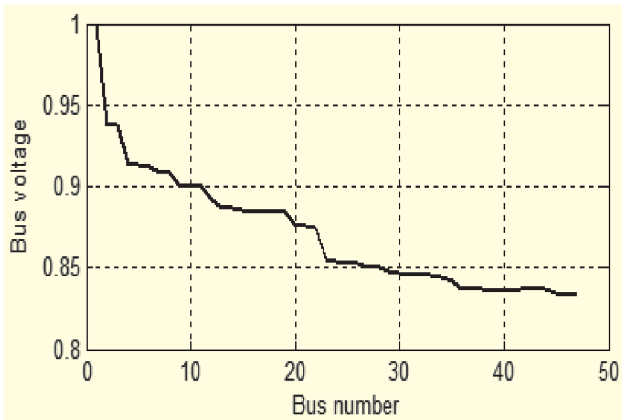

FIG. 4 BUS VOLTAGE BEFORE DSTATCOM PLACED

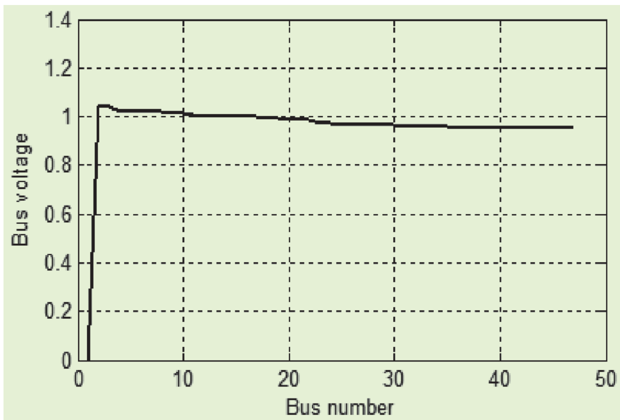

FIG. 5 BUS VOLTAGE AFTER INSERING DSTAATCOM AT ALL BUSES EXCEPT AT BUS1

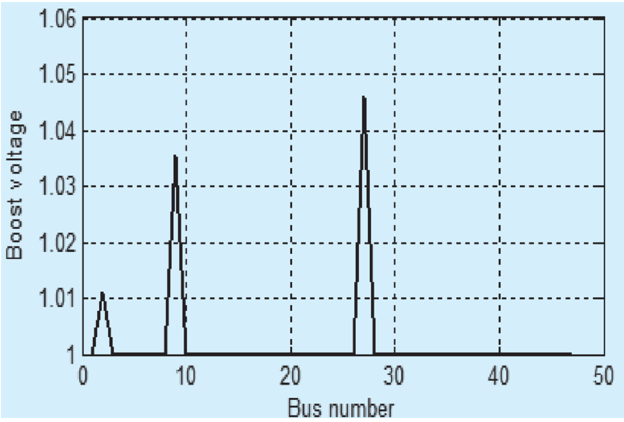

FIG. 6 BOOST VOLTAGE AT 2, 9, 27

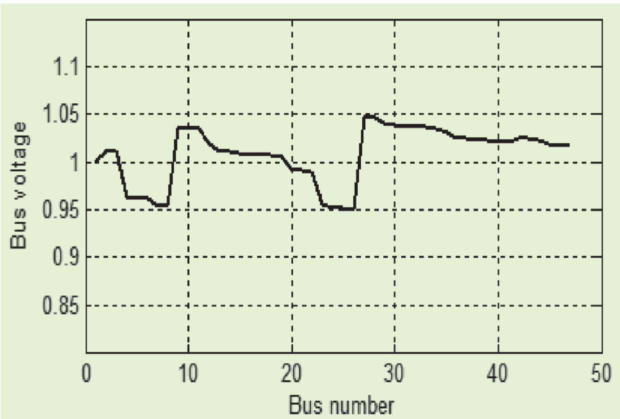

FIG. 7 BUS VOLTAGE WITH BTA INTERFACE SYSTEM

5.2 A fuzzy expert system

By applying FES the required optimal number of dstatcom for 47 bus radial distribution system is at one i.e at bus number 2. It is sufficient to maintain the voltage magnitude within limits as shown in Figure 8.

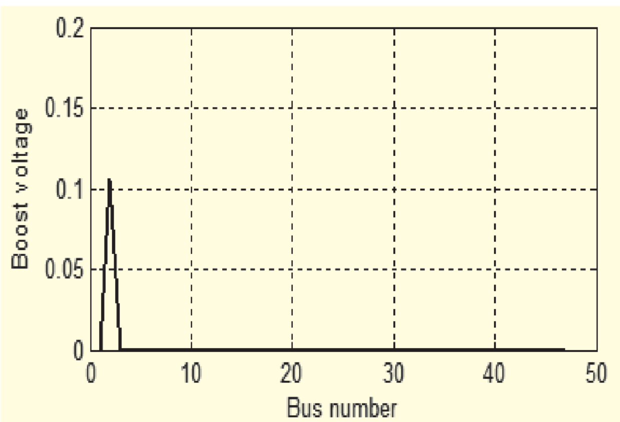

FIG. 8 BOOST VOLTAGE

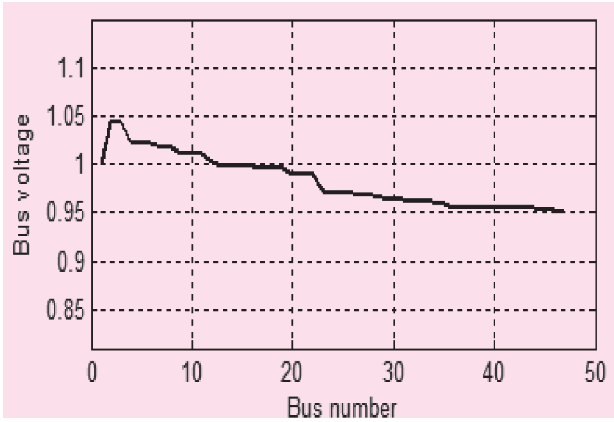

FIG. 9 BUS VOLTAGE WITH FES

C ANFIS

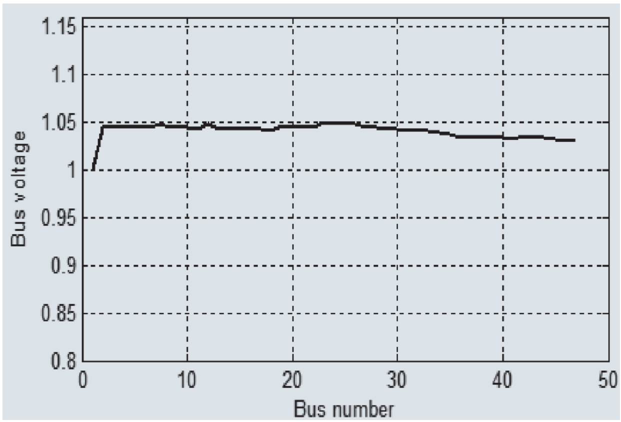

FIG. 10 BUS VOLTAGE WITH ANFIS

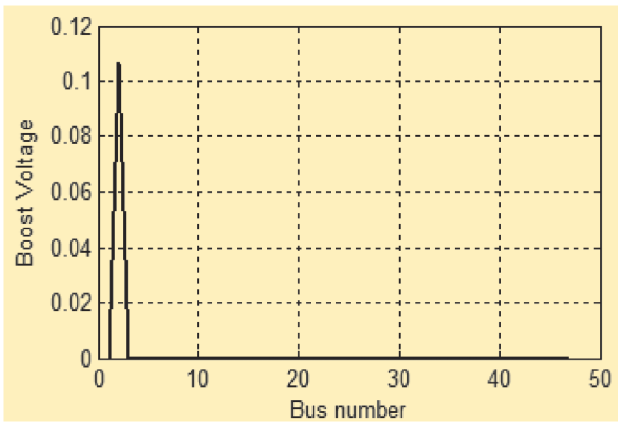

FIG. 11 BOOST VOLTAGE WITH ANFIS

By applying ANFIS the required optimal number of dstatcom for the test system is one i.e at bus number 2. It is sufficient to maintain the voltage amplitude within Tolerence limits and when compared to Fuzzy Expert System ANFIS maintained good voltage level shown in figure 10.

4.0 CONCLUSION

This paper presents a fuzzy-ANFIS control technic based voltage control for optimal DSTATCOM placement with MATLAB™ results and performance is satisfactory in mitigating voltage sags

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