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Improvement of Voltage Profile using ANFIS based Distributed Power Flow Controller

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Abstract: *It is customary for the power industry to maintain the voltage at a desired nominal value. The fluctuations in Voltage can be regulated if reactive power is maintained properly. A new device, DPFC, derived from UPFC, controls the reactive power flow at a faster rate. This paper presents a new controlling technique for the Distributed Power Flow Controller (DPFC) . A Neuro Fuzzy controlling technique is proposed for the fast controlling of DPFC. Also the results are compared with existing PI controlling technique. An IEEE 4 bus Transmission system with DPFC at load bus is simulated in MATLAB/SIMULINK.*

Keywords: *DPFC, PI Controller, Power Quality, Neuro-Fuzzy Controller, Voltage Sag, Voltage Swell.*

I. INTRODUCTION

The performance of electrical networks can be improved with the management of reactive power. Also reactive power compensation is the best method of maintaining good power quality. The concept of FACTS technology is concerned with the management of reactive power. A Flexible AC Transmission System incorporates power electronics and controllers to enhance Controllability. Proper control of reactive power also results in maintaining the voltage profile i.e., voltage quality of the transmission system. As engineering technology is advanced in computing, communication, microprocessors & microcontrollers, electronic devices, new FACTS Concepts have come up with increased reliability. To reduce the cost of reactive power control through FACTS devices, D-FACTS technology is proposed in the previous work. To regulate the controlling action of D-FACTS device, Distributed Power flow Controller, firstly a Conventional PI controller is proposed. To improve the rate of convergence of controlling action of the DPFC a soft computing technique is proposed in this paper[11].

Distributed Power Flow Controller is a Distributed Flexible AC Transmission system device. The large size Capacitor in UPFC, a FACTS device, is replaced with smaller size with distributed technology which in turn reduced the cost of the new DPFC[1]. The structure of DPFC is given in the below figure 1.

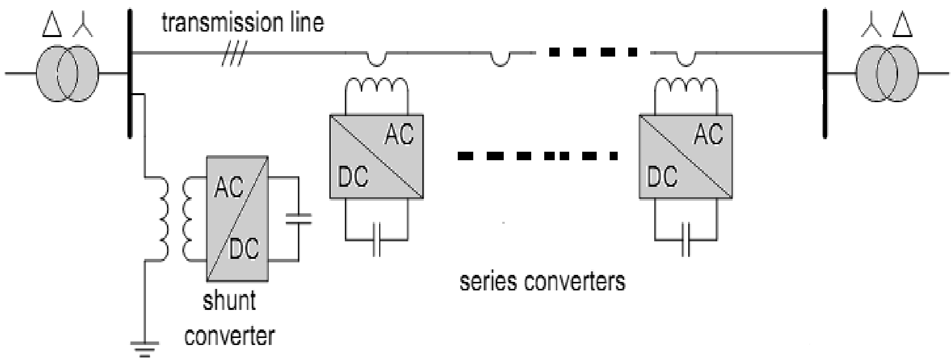

Fig 1: DPFC Structure.

An IEEE standard 4 bus system as shown in figure 2 is used for the simulation. DPFC is proposed to connect at load bus as the variations in load is the main cause for the variations in magnitude of voltages in the entire transmission system. Analysis is done with conventional PI controller and with Neuro – Fuzzy controller.

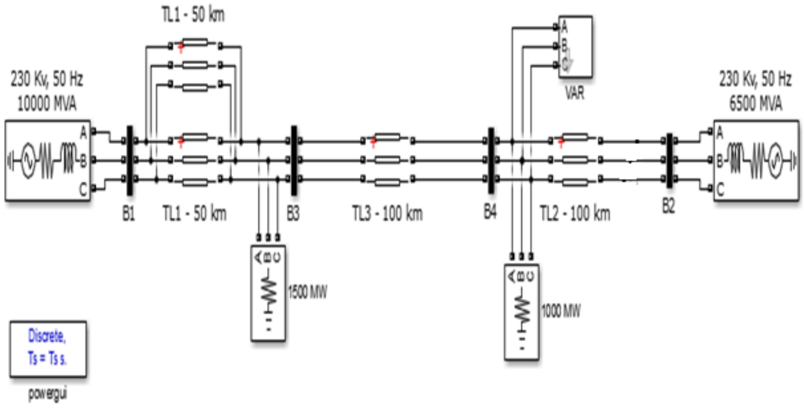

Fig 2: IEEE 4 bus system

II. PI CONTROLLER

A Conventional PI controlling technique is used to improve the performance of the DPFC. The improvement in voltage profile of the transmission system is observed with DPFC and without DPFC.

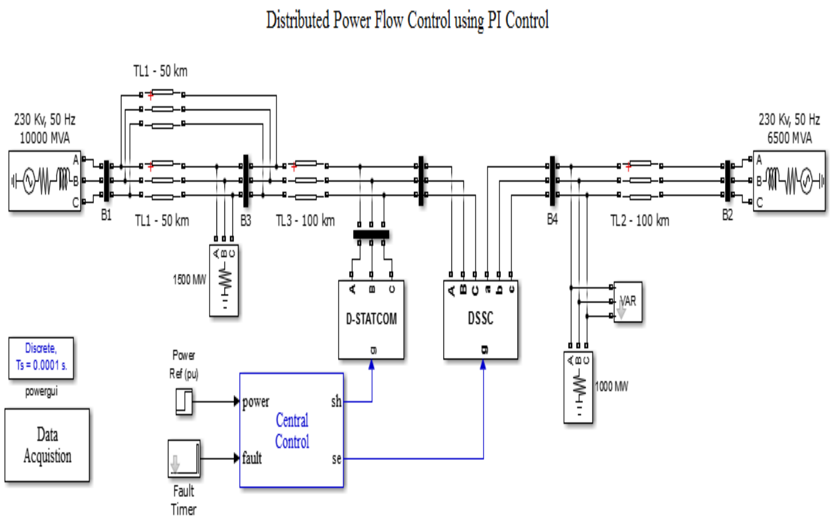

Fig 3: Transmission system with DPFC at load Bus

It is observed that the voltage profile of load bus is improved from 0.8 to approximately to the nominal value with the introduction of DPFC.

III. ADAPTIVE NEURO – FUZZY INFERENCE SYSTEM

There are several intelligent technologies available for the fast controlling actions of big data of any big network, like power system, in which the data is uncertain and imprecise. A hybrid intelligent system is one which combines at least any two intelligent technologies like neuro – fuzzy inference system, a combination of neural networks and fuzzy logic[13].

Fuzzy logic and neural networks are natural complementary tools in constructing intelligent systems. Neural Networks are low level computational structures nd deals with raw data and fuzzy logic is a high level computational technique that deals with reasoning, using linguistic information. The combination of neural network and fuzzy system combines the parallel computation and learning abilities which results in more transparent neural networks and increased learning capability of fuzzy systems[13].

The structure of neuro – fuzzy system is similar to multi layer neural network. A neuro-fuzzy system has input and output layers, and three hidden layers that represent membership functions and fuzzy rules as shown in figure4.

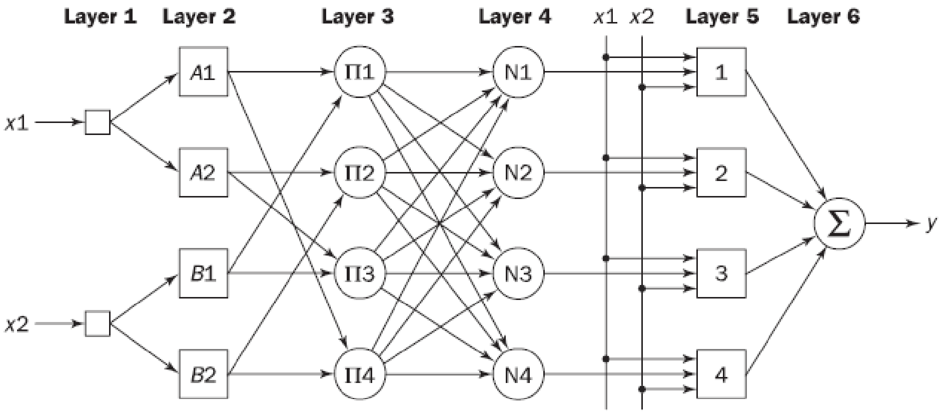

Fig 4: Structure of Neuro – Fuzzy inference Sytem

Layer 1 is the input layer, transmits Crisp data to the next layer

$$y_i^{(1)} = x_i^{(1)}$$

Where x_i is the input and y_i is the output of input neuron i in first layer
Layer 2 is the fuzzification layer, neurons in this layer perform fuzzification..

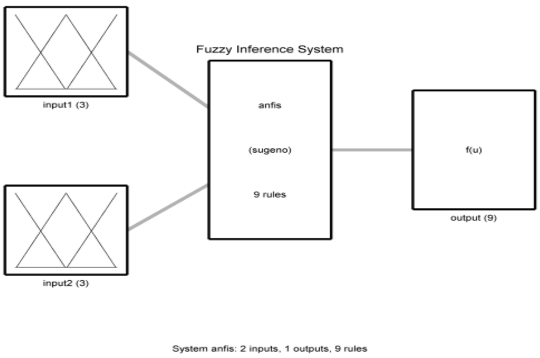

Fig 5: Fuzzy inference system

Layer 3 is the fuzzy rule layer, neurons in this layer receives inputs from fuzzification neurons and calculates the firing strength of the rule. The output of a neuron in layer 3 is obtained as

$$y_i^{(3)} = x_{1i}^{(3)} \times x_{2i}^{(3)} \times \ldots.. \times x_{ki}^{(3)},$$

where $x_{1i}^{(3)}$, $x_{2i}^{(3)}$, …., $x_{ki}^{(3)}$ are the inputs and $y_i^{(3)}$ is the output of fuzzy rule neuron i in this layer.
Layer 4 is the normalization layer; each neuron receives inputs from neurons in rule layer and calculates normalized firing strength of the given rule.

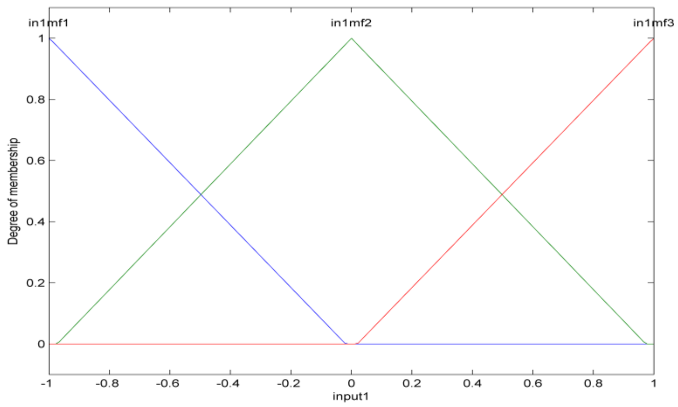

Fig 6: Fuzzification and rule evaluation

Layer 5 is the defuzzification layer, a neuron in this layer calculates the weighted consequent value of a given rule.
Layer 6 is a summation neuron, calculates the sum of outputs of all defuzzification neurons and produces overall output[12].

IV. RESULTS

The output voltages of load bus in the IEEE 4 bus system is observed without DPFC, with PI controlled DPFC and ANFIS based DPFC. To show that voltage quality in turn power quality is improved, different situations like voltage sag, voltage swell are created. Then Controllers are introduced. The output waveforms for both sag and swell mitigation are given below.

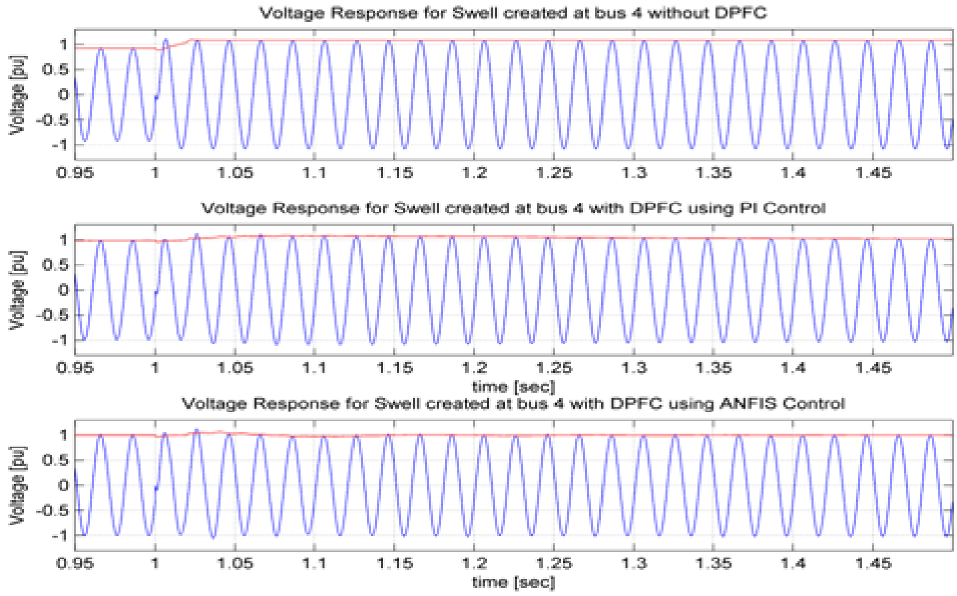

Fig 7: Mitigation of Voltage Swell

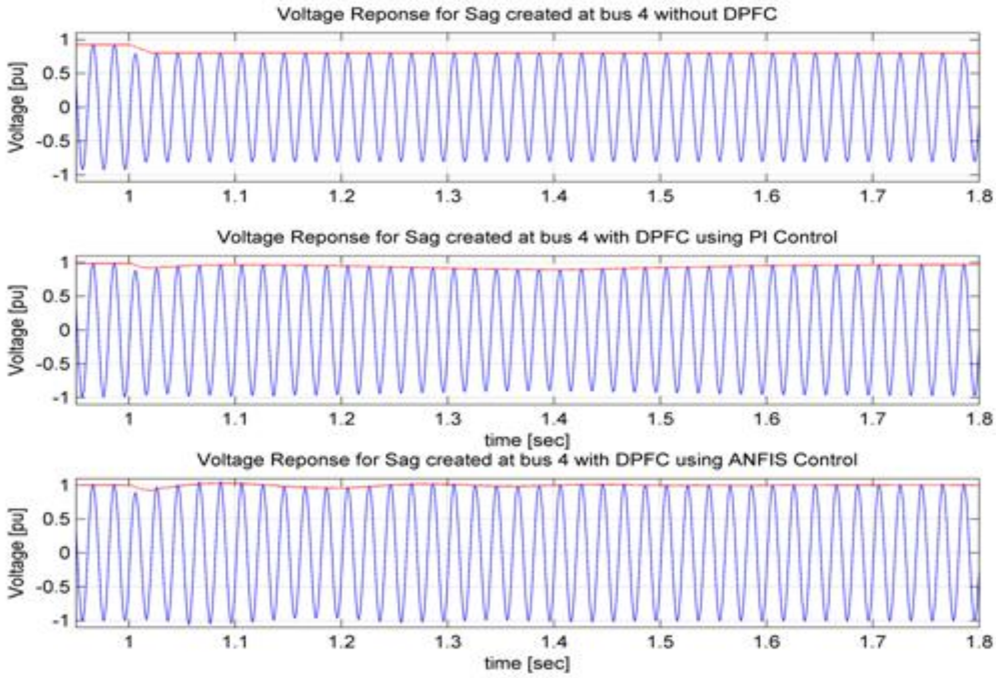

Fig 8: Mitigation of Voltage Sag

It is observed that the results are better with PI controller and the convergence made fast with the introduction of ANFIS technology. The waveforms of active power supplement for both sag and swell are also given here.

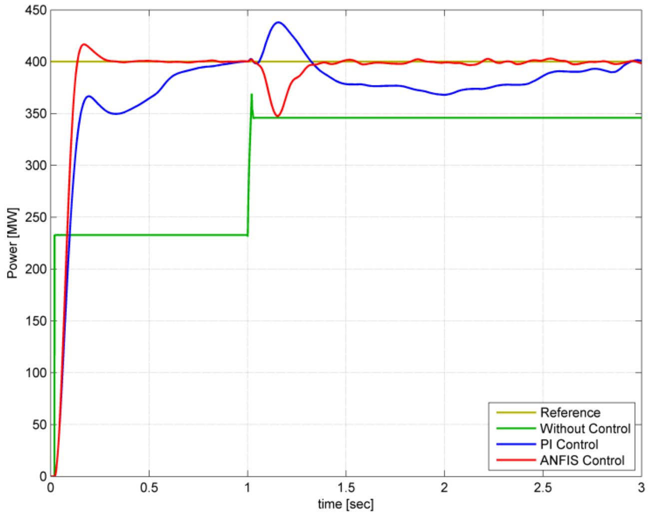

Fig 9: Power Flow Control during Swell

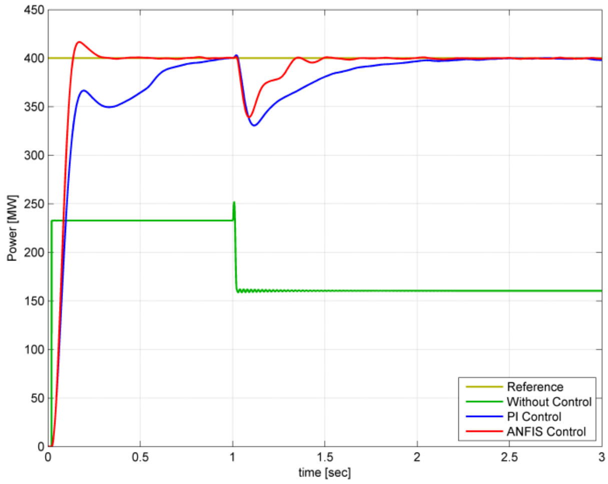

Fig 10: Power Flow control during Sag

The improvement of power flow under normal working conditions is also observed, as given in Figure 11, and it is noted that with the ANFIS technology it is improved and maintained at the required value.

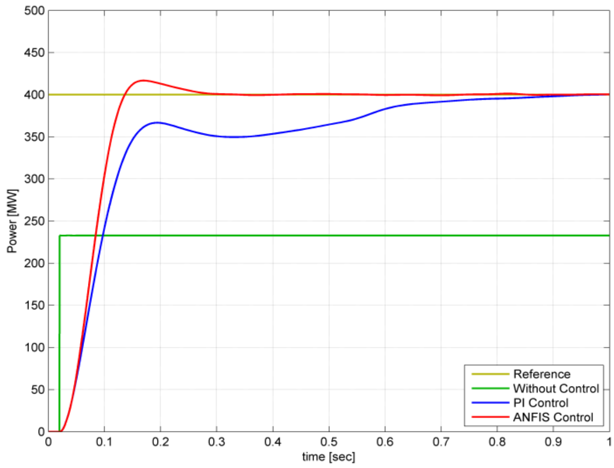

Fig 11: Power response with DPFC with PI and with ANFIS controls

V. CONCLUSION

The dynamic problem of maintenance of voltage at the nominal per unit value became a great task in the operation and performance of the power transmission system. A new D-Facts device, DPFC is proposed in the previous work, but the convergence is low. The proposed Soft Computing technique, adaptive neuro fuzzy inference system, improved the convergence rate of the DPFC in improving the voltage profile of the transmission system. It also maintained good power flow control during all periods including voltage sag, swell and normal working conditions very effectively.

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