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POWER QUALITY IMPROVEMENT OF UNBALANCED DISTRIBUTION SYSTEM USING ANFIS BASED D-STATCOM

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ABSTRACT

In this paper to address well known power quality issues such as voltage swell, voltage sag of unbalanced distribution system, a ANFIS based D-STATCOM is proposed. The performance of proposed ANFIS based D-STATCOM is tested on 13-bus IEEE test feeder, a D-STATCOM is placed at bus no-632.The performance of proposed ANFIS based D-STATCOM is compared to D- STATCOM with PI control mechanism using MATLAB-simulink.

KEYWORDS: A ANFIS based D-STATCOM is proposed, MATLAB-simulink.

INTRODUCTION

Now a day's power quality is a more serious problem for consumers and power companies. The power quality issues such as voltage swell and voltage sag leads to economic impact on consumer utility sectors like induction furnaces and process control of bulk manufactures.[1-4] An Electrical distribution system is a connection between utility sector and Power Company, to provide quality of supply to consumer by maintains good voltage profile at consumer premises.[5]

Causes of Power quality problems in Electrical distribution system

- Sag and swell, which varies from 10% to 90% of the rated voltage.
- Harmonic distortion in distribution system due to harmonic currents.
- Due to lower power factor causes heating of electrical equipment, results heating losses.
- It also causes vibration and noise in machines and malfunction of the sensitive equipment.
- Due to unbalanced voltages.

There are two methods to resolve power quality problems. The first approach is from source side and second approach is from load side to diminish well known power quality problems such as voltage swell and voltage sag.

If there is sudden increase in the load then the voltage in the line decreases rapidly due to the decrease in the terminal voltage at the receiving end or the utility side. This sudden change in the terminal voltage appears as sag.

If there is a sudden decrease in the load then the voltage in the line increases rapidly due to the increase in the terminal voltage at the receiving end or the utility side. This sudden change in the utility side terminal voltage appears as voltage swell in the line.[8]

There are different ways to enhance power quality problems in transmission and distribution systems. D-STATCOM is a suitable custom power device to address the power quality issues of an unbalanced distribution system and efficient device to resolve power quality issues, D-STATCOM consisting of a Voltage Source Converter (VSC) and a shunted DC link capacitor.[9-10] A D-STATCOM is reactive source, generating and absorbing reactive power. In this paper a 13-bus unbalanced distribution system is considered to address power quality problem and a D-STATCOM is connected at bus number 632.

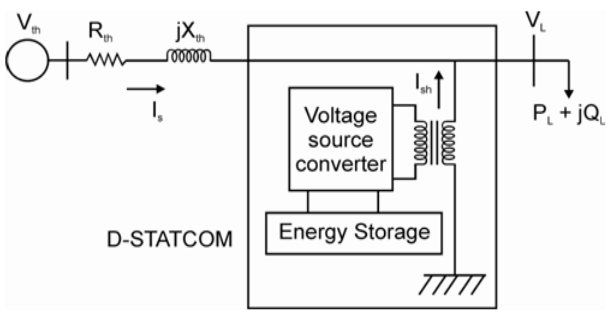

Fig. 1: Block diagram of D-STATCOM.

This paper is organized as follows the D-STATCOM with PI control mechanism is discussed in section II. The D-STATCOM with ANFIS control mechanism is discussed in section III. In section IV simulation results are presented where, the performance of D-STATCOM with ANFIS control technique is compared to PI control mechanism. Finally conclusions are given in section V.

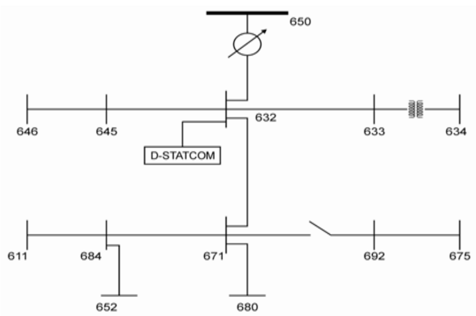

Fig. 2: IEEE-13 bus unbalanced distribution system with D-STATCOM.

Conventional Control of D-Statcom

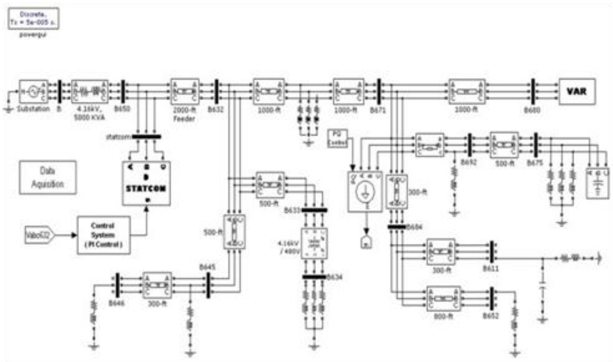

Fig. 3: 13-Bus unbalanced Distribution System with D-STATCOM with PI Control Mechanism.

D-Statcom with Anfis (Adaptive Neuro Fuzzy Inference System) Control Mechanism

An Adaptive Neuro – Fuzzy Inference System (ANFIS) is a kind of artificial neural network based on fuzzy inference system. The concepts of neural networks and fuzzy logic combined together in a single structure to capture the benefits of FLC and ANN. Its inference system corresponds to a set of fuzzy IF – THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be a universal estimator. In the building of intelligent system FLC and ANN are the paired tools in the development of adaptive structure. NNs structure is quite capable of handling raw data.FLC deals higher level linguistic rules obtained from expert knowledge of system engineers. However due to the opaque structure of ANN and lack of learning ability of FLC structure, now a day's users are facing more problems while in implementation.[17]

Integrated neuro-fuzzy systems can combine the parallel computation and learning abilities of neural networks with the human-like knowledge representation and explanation abilities of fuzzy systems. As a result, neural networks become more transparent, while fuzzy systems become capable of learning.

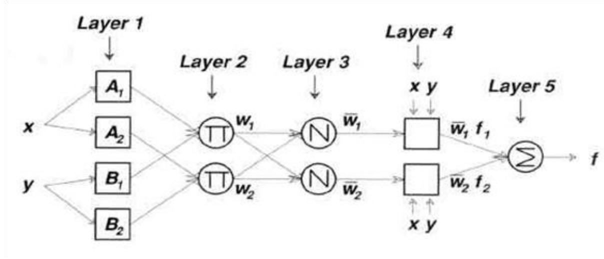

Fig. 4: Equivalent ANFIS architecture using the Tsukamoto fuzzy model.

The structure of ANFIS is similar to a multi-layer neural network, which consists of input and output layers, and three hidden layers that represent membership functions and fuzzy rules.[17]

Layer-1: This is called the input layer. Neurons in this layer simply pass external crisp signals to *Layer* 2.

Layer-2: This is called the fuzzification layer. Neurons in this layer perform fuzzification.In Jang's model, fuzzification neurons have a bell activation function.

Layer-3: This is known as rule layer. Each neuron in this layer corresponds to a single Sugeno-type fuzzy rule. A rule neuron receives inputs from the respective fuzzification neurons and calculates the firing strength of the rule it represents.

Layer-4: This is called output membership layer. Neurons in this layer represent fuzzy sets used in the consequent of fuzzy rules.

Layer-5 is the defuzzification layer. Each neuron in this layer represents a single output of the neuro-fuzzy system. It takes the output fuzzy sets clipped by the respective integrated firing strengths and combines them into a single fuzzy set.

Learning of the Anfis Model

An ANFIS uses a hybrid learning algorithm that combines the least-squares estimator and the gradient descent method.

In the ANFIS training algorithm, each epoch is composed from a forward pass and a backward pass. In the forward pass, a training set of input patterns (an input vector) is presented to the ANFIS, neuron outputs are calculated on the layer-by-layer basis, and rule consequent parameters are identified.[17]

The rule consequent parameters are identified by the least-squares estimator. In the Sugeno-style fuzzy inference, an output "***y***" is a linear function. Thus, given the values of the membership parameters and a training set of P input-output patterns, we can form P linear equations in terms of the consequent parameters as.

$$\begin{cases} y_d(1) = \bar{\mu}_1(1) f_1(1) + \bar{\mu}_2(1) f_2(1) + \cdots + \bar{\mu}_n(1) f_n(1) \\ y_d(2) = \bar{\mu}_1(2) f_1(2) + \bar{\mu}_2(2) f_2(2) + \cdots + \bar{\mu}_n(2) f_n(2) \\ \vdots \\ y_d(p) = \bar{\mu}_1(p) f_1(p) + \bar{\mu}_2(p) f_2(p) + \cdots + \bar{\mu}_n(p) f_n(p) \\ \vdots \\ y_d(P) = \bar{\mu}_1(P) f_1(P) + \bar{\mu}_2(P) f_2(P) + \cdots + \bar{\mu}_n(P) f_n(P) \end{cases}$$

In the matrix notation, we have.[17]

$\boldsymbol{y}_d = \mathbf{A}\,\boldsymbol{k}$,

Where $\boldsymbol{y}_d$ is a $P \times 1$ desired output vector and $\boldsymbol{k}$ is an $n\,(1 + m) \times 1$ vector of unknown consequent parameters

$\boldsymbol{k} = [k_{10}\, k_{11}\, k_{12} \ldots k_{1m}\, k_{20}\, k_{21}\, k_{22} \ldots k_{2m} \ldots k_{n0}\, k_{n1}\, k_{n2} \ldots k_{n\,m}]^T$

As soon as the rule consequent parameters are established, we compute an actual network output vector "y" and determine the error vector "*e*"

$\boldsymbol{e} = \boldsymbol{y}_d - \boldsymbol{y}$

The BPA is used in the backward pass and according to the chain rule antecedent parameters are updated and error signals are propagated. The optimization of antecedent parameters and consequent parameters are optimised as suggested by Jang.[17]

SIMULATION RESULTS

In this work a D-STATCOM with ANFIS control mechanism have been proposed to improve power quality (voltage swell, voltage sag) of 13-bus IEEE distribution system. Simulations are performed using MATLAB SIMULINK. The performance of proposed D-STATCOM with ANFIS control technique is compared to D-STATCOM with PI control technique.

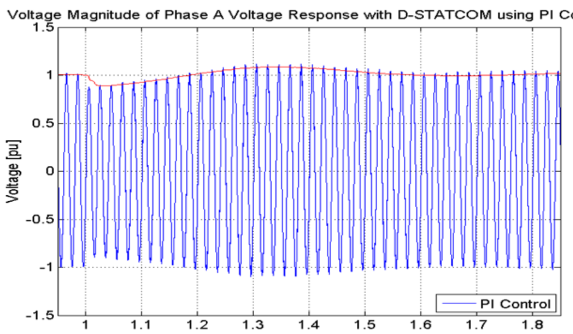

Fig. 6: Illustrates mitigation of voltage sag of phase-A from load side using D-STATCOM with PI control mechanism.

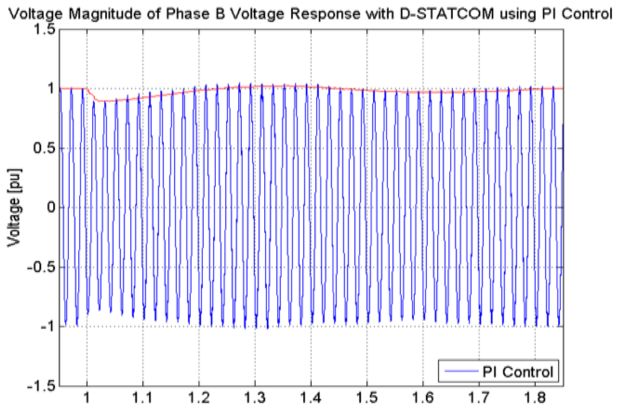

Fig. 7: Illustrates mitigation of voltage sag of phase-B from load side using D-STATCOM with PI control mechanism.

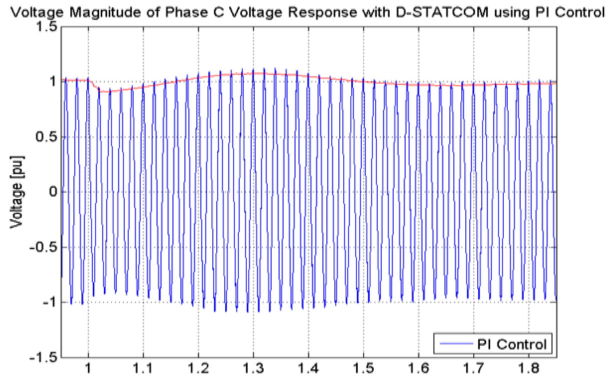

Fig. 8: Illustrates mitigation of voltage sag of phase-C from load side using D-STATCOM with PI control mechanism.

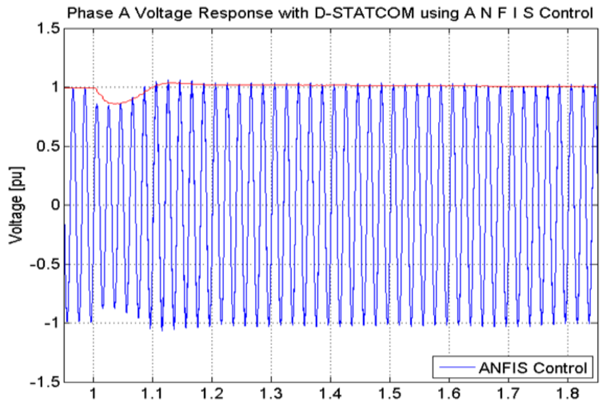

Fig. 9: Illustrates mitigation of voltage sag of phase-A from load side using D-STATCOM with ANFIS control mechanism.

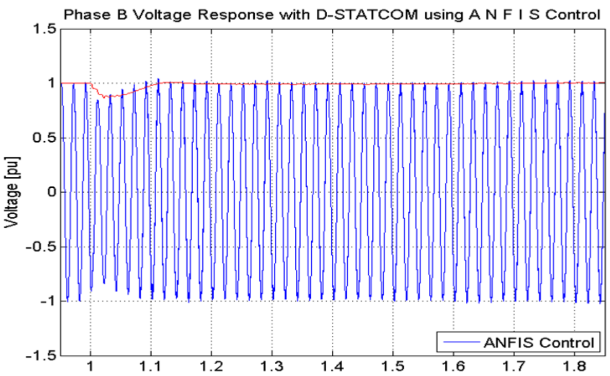

Fig. 10: Illustrates mitigation of voltage sag of phase-B from load side using D-STATCOM with ANFIS control mechanism.

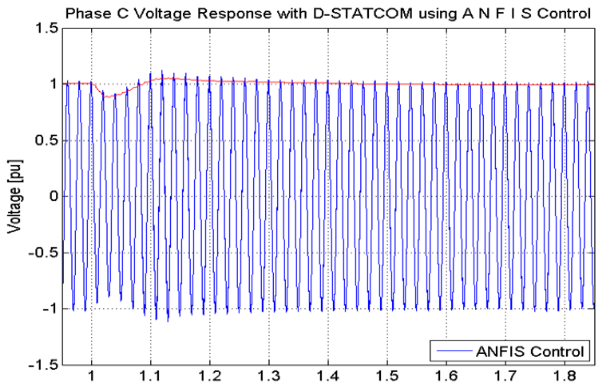

Fig. 11: Illustrates mitigation of voltage sag of phase-C from load side using D-STATCOM with ANFIS control mechanism.

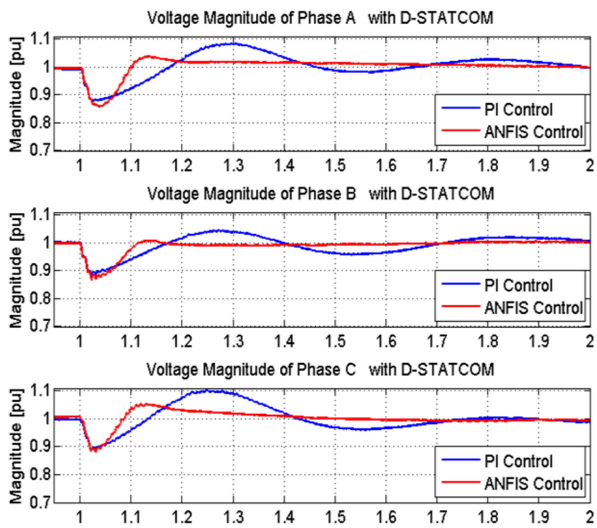

Fig. 12: Illustrates mitigation of voltage sag of phase A, B, C from load side using D-STATCOM with PI & ANFIS control.

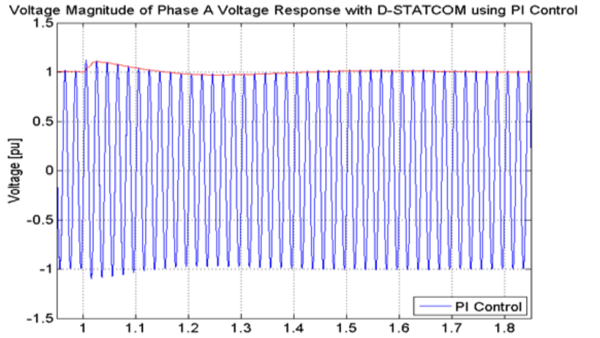

Fig. 13: Illustrates mitigation of voltage swell of phase-A from source side using D-STATCOM with PI control mechanism.

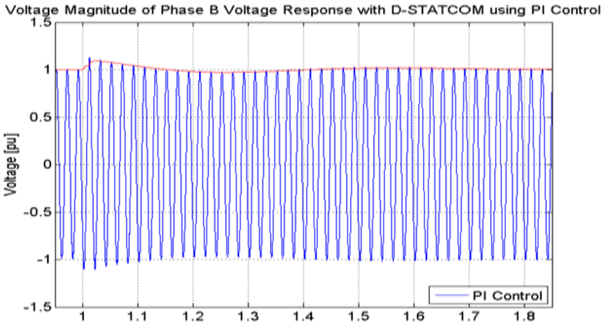

Fig. 14: Illustrates mitigation of voltage swell of phase-B from source side using D-STATCOM with PI control mechanism.

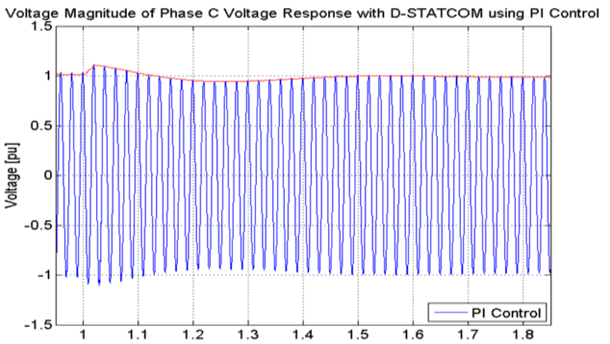

Fig. 15: Illustrates mitigation of voltage swell of phase-C from source side using D-STATCOM with PI control mechanism.

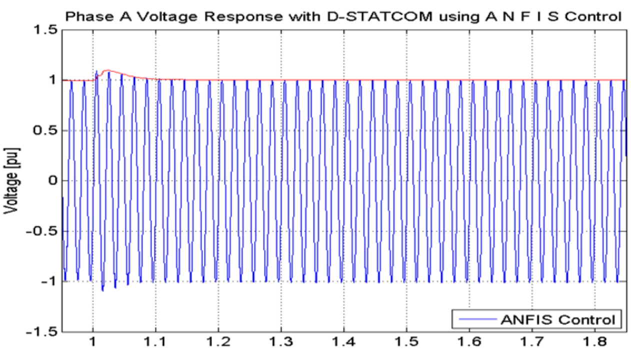

Fig. 16: Illustrates mitigation of voltage swell of phase-A from source side using D-STATCOM with ANFIS control mechanism.

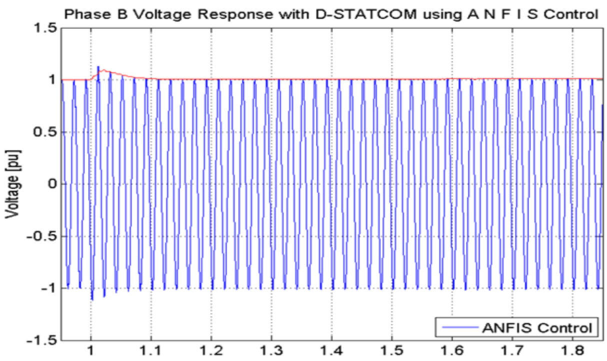

Fig. 17: Illustrates mitigation of voltage swell of phase-B from source side using D-STATCOM with ANFIS control mechanism.

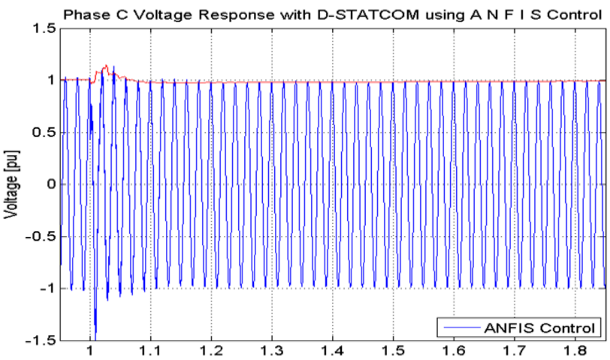

Fig. 18: Illustrates mitigation of voltage swell of phase-C from source side using D-STATCOM with ANFIS control mechanism.

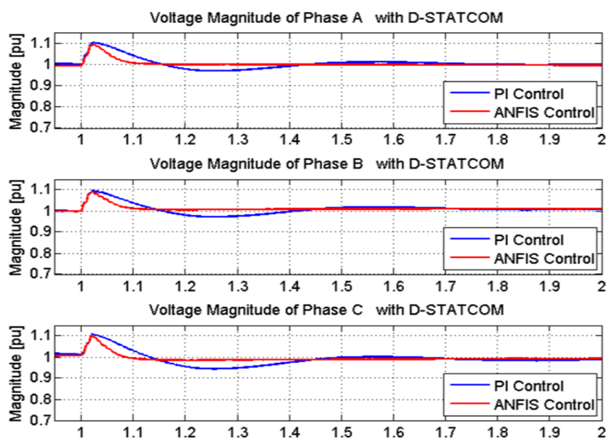

Fig. 19: Illustrates mitigation of voltage swell of phase A, B, C from source side using D-STATCOM with PI & ANFIS control.

CONCLUSION

In this paper for enhancement of power quality of distribution system a 13- bus system is considered. An ANFIS control based D-STATCOM is introduced at bus number-632 of 13-bus IEEE test feeder system. The performance of proposed method is compared with PI based D-STATCOM. Simulation results revealed that the proposed adaptive control methodology based D-STATCOM can tackle power quality issues such as voltage sag, voltage swell at all busses effectively. An ANFIS based D-STATCOM is quite capable of suppressing voltage swell and voltage sag compared to PI based D-STATCOM.

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