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Design of Artificial Intelligent Technique based Controller for DVR

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Abstract:
The increased use of power electronic components results in power quality issues like voltage sag/swell, harmonics, flickers and so on. The major power quality issue faced in a distribution network is voltage sag. To overcome this voltage sag, numerous voltage restorers have been proposed. Among those, DVR is considered as a unique device for voltage sag compensation because of its fast response. This work proposes a new controller for DVR using ANFIS topology so as to optimize its performance. The performance of proposed DVR is examined using MATLAB software under different fault conditions for a standalone system. The simulation results indicate that the proposed DVR has higher efficiency and rapid voltage sag compensation in comparison with the traditional one.
***Keywords**: Sag, DVR, ANFIS.*

INTRODUCTION

The increase use of greater number of electrical and electronic equipment's causes a deviation in the power quality of the electrical system. Faults occurring in the transmission lines may result in voltage sag/swell in the system. Apart from this, under heavy load condition, a significant voltage drop may occur. These above said problems can determinate the power quality of the system. Hence, many topologies have been introduced to mitigate the power quality issues generated by voltage sag and swell. Among those, DVR is considered as a most efficient one. Hence, to improve the performance of the DVR, a controller has to be designed. The most common choice of controller for DVR is PI controller. However, this controller may not exhibit satisfactory performance when it is subject to varying system. Hence, to solve this problem, AI based controllers are introduced. Among those, FVC requires an expert to formulate rules. Hence, this work proposes an ANFIS controller to convert to control the parameters of a DVR.

DVR is a solid state device, which injects voltage in the system so as to regulate the voltage on the load side. Its primary function is to boost up the voltage on the load side and thus presents power disruption on the load side. The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system as shown in Figure 1.

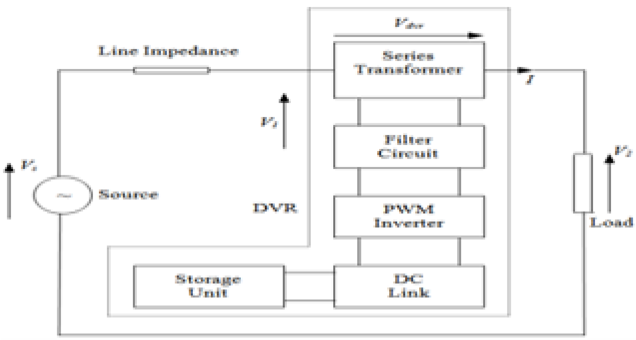

Figure 1. General configuration of the DVR.

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Transformer

It couples the compensating voltage injected by the DVR into the distribution network.

Filter

The main function of the filter is to limit the harmonic voltage present generated by the VSI, with in the permissible level.

VSI

A simple three phase VSI is integrated in this work, to generate a sinusoidal voltage.

Energy storage device

The DC supply provides a real power requirement of DVR during compensation

Design of ANFIS controller

ANFIS is an association of Fuzzy and Neural Network. In ANFIS, Neural Network learning methods enhance the parameters of a Fuzzy Inference System (FIS).ANFIS network structures comprise five discrete layers and are depicted in figure 2. It comprises of two inputs and one output.

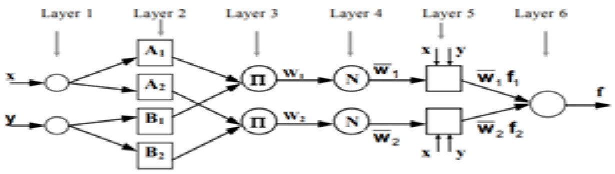

Figure 2. Architecture of ANFIS.

In the above figure, each circle and square represents a fixed node andan adaptive node respectively. The rule base of this system has two if –then rules (Takagi-Sugeno'stype)and are depicted as:

Rule 1 : *if* y_1 *is* A_1*and* y_2 *is* C_1;
then $z_1= a_1y_1+b_1y_1+c_1$
Rule 2 : *i f* y_1*is* A_2*and* y_2 *is* C_2;
then $z= a_2y_1+b_2y_2+c_2$
and its function is stated below

Layer 1

Every node of this layer is considered as an input node and through this externally applied signals are conveyed to other layers.

Layer 2

In layer 2, a generalized bell membership function is implemented and its degree is calculated as follows.

$$\mu_A(x) = gbell(x; a_i, b_i, c_i) = \frac{1}{1+\left|\frac{x_i - c_i}{a_i}\right|^{2b}}$$

$a_{i,}$ $b_{i,}$ c_i- Parameter set.
c- Center of the function,
a-Half of the width and
b - Controls the slopes at the crossover points.

Layer 3 (Fuzzification Layer)

The output obtained from this layer is the product of all input signals.

$$w_i = \mu A_i(x).\mu B_i(y), i = 1,2$$

Layer 4

Here, each node computes its firing strength. It is the ratio of the ith rule's firing strength to the summation of whole rule's firing strengths.

$$\overline{w_i} = \frac{w_i}{w_1 + w_2}, i = 1,2$$

The output obtained in the layer is called normalized weight.

Layer 5(Rule Consequent Layer)

The nodes in this layer is an adaptive in nature with a node function.

$$\overline{w_i}\, fi = \overline{w_i}(p_x + q_i y + r_i)$$

$\overline{w_i}$ - normalized weight from layer3

Layer 6 (Rule Inference Layer)

The node present in this layer calculates the complete output.

Overall output = $\sum_i \overline{w_i}\, fi = \frac{\sum_i w_i\, fi}{\sum_i w_i}$

Thus the design of an ANFIS controller implemented in this work is discussed above and the fuzzifier section comprises of two inputs namely, the error signal(e) / change in error signal(ce). Gaussian membership function is chosen as Membership functions. Thus they are characterized into seven functions viz. Negative Big (NBig), Negative Medium (NMed),Negative Small (NSma), Zero (ZE), Positive Small (PSma),Positive Medium (PMed) and Positive Big (PBig). Thus the inputs given to the ANFIS controller are fuzzified using these fuzzy sets. The rule base explained in table 1 is used for decision making and it includesof 49 (IF-THEN) rules.

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Table 1. ANFIS Rules.

Δe/e	NBig	NMed	NSma	ZE	PSma	PMed	PBig
NBig	NBig	NBig	NBig	NMed	NMed	NSma	ZE
NMed	NBig	NBig	NMed	NSma	NSma	ZE	PSma
NSma	NBig	NMed	NSma	NSma	ZE	PSma	PMed
ZE	NMed	NSma	NSma	ZE	PSma	PSma	PMed
PSma	NMed	NSma	ZE	PSma	PSma	PMed	PBig
PM	NSma	ZE	PSma	PSma	PMed	PBig	PBig
PBig	ZE	PSma	PMed	PMed	PBig	PBig	PBig

Here the neural network comes into existence and is utilized for selecting appropriate rule. Once an appropriate rule is designated, a control signal required to achieve the optimal output is generated. Thus the defuzzifier section comprises a signal which in turn controls the switching states of the converter switches. The input neurons, viz., the change in error and error, influences the hidden layer of NN. Thus, in this proposed topology, the optimum rules are obtained at the 4th hidden layer. Hence, 4 hidden layers are chosen in this work. Thus the defuzzified output is considered as an output neuron. This defuzzified output generates the firing pulse of the converter. Figure 3 shows the ANFIS training Flowchart of the controller.

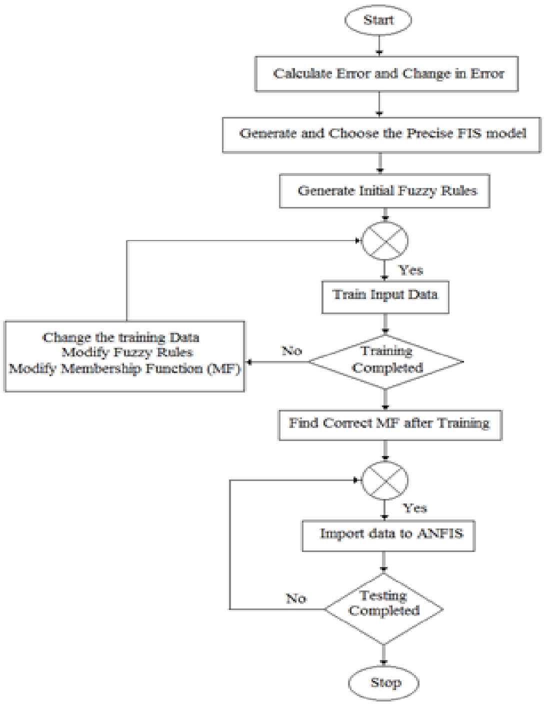

Figure 3. ANFIS training Flowchart.

II.RESULTS AND DISCUSSIONS

In order to verify the performance of the proposed in voltage sag mitigation, a simple distribution network was simulated using MATLAB. A DVR was connected to that system using a series transformer. In this mode, in-phase compensation method is utilized. The parameter of the system designed for testing is shown in Table-1.

The input-output data pairs for training the ANFIS were generated using the conventional PI controller. ANFIS structure with Sugeno model containing 49 rules have been considered. Hybrid learning algorithm method was used to adjust the parameter of membership function. All the variables' fuzzy subsets for the inputs ε and Δε are defined as with triangular membership function. The membership functions and initial universes of the inputs generated by ANFIS training are illustrated in Figure 4. The output variable Y given by ANFIS training is a vector of constants.

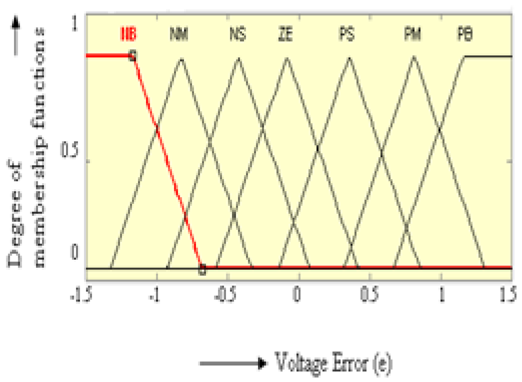

Figure 4.1a Membership functions (*e*)

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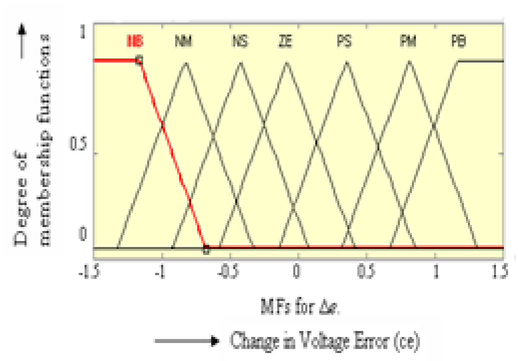

Figure 4.1b Membership functions (Δ*e*)

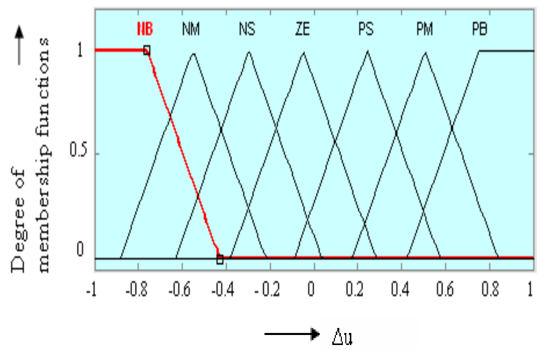

Figure 4.1c Membership function (Δu)

A DVR is connected to the system through a series transformer with a capability to insert a maximum voltage of 80% of the phase to ground systevoltage.

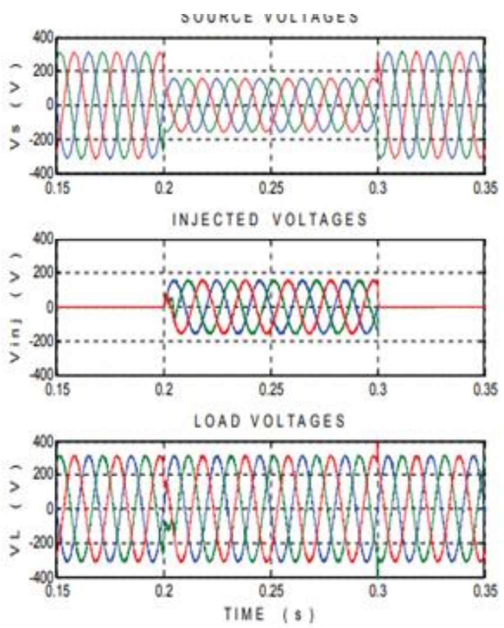

Figure 5. Simulation result of DVR response to a balanced voltage sag.

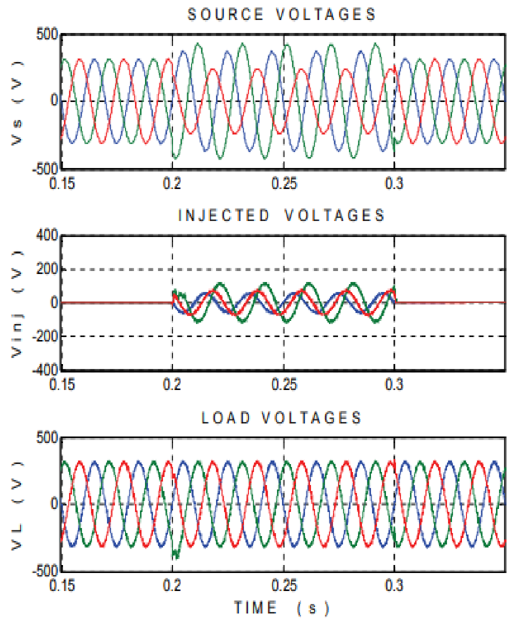

Figure 6. Simulation result of DVR response to unbalanced voltage.

Table 2.Comparison of Distorted voltage, Injected voltage and Load voltage for different controllers under balanced sag condition.

Type of Controller	% of sag	Distorted voltage			Injected voltage (volts)			Load voltage (volts)		
		A	B	C	A	B	C	A	B	C
PI controller	50	225	415	350	165	0	40	390	415	390
ANFIS controller		225	415	350	190	0	65	415	415	415

COMPARATIVE ANALYSIS

For the case of balanced voltage sag compensation represented by Figure 5, the load voltage is kept at the nominal value with the help of the DVR. The DVR reacts quickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage.

At the end Three-phase unbalanced voltages condition is investigated to confirm the performance of the DVR under the proposed controller. According to figure 6, the DVR is able to produce

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the required voltage components for different phases rapidly and help to maintain a balanced and constant load voltage. As a result, the performance of DVR under the proposed ANFIS controller in mitigating voltage sag and voltage unbalance is evident from table 2.

IV. Conclusion

This work formulated a new controller topology (ANFIS controller) for DVR. From the obtained results, it could be observed that the proposed DVR improves the performance of the DVR and the sag indices are within the recommended IEEE Standard 512-1992. The work may be extended to study the feasibility of application by optimizing ANFIS controller.

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