Rachid DEHINI [1], Abdesselam BASSOU[2], Benachaiba CHELLALI [2]

University (center) of Relizane , ALGERIA, (1),Department of Electrical Engineering Faculty of the sciences and technology Bechar (2)

Generation of voltage references using Multilayer Feed Forward Neural Network.

***Abstract**. Among the dynamic voltage restorer (DVR) objectives, the protection of sensitive loads against voltage swell/sag voltage, as well as correction of unbalanced problems. The DVR acts as a voltage source, which is connected in series with a sensitive load and controlled to generate the required compensation voltages. Many researches were presented in literature to identify the voltage disturbance; one of them is Synchronous Reference Frame (SRF) method. This paper provides a DVR with identification method based on artificial neural network - the (MLFFN) Multilayer Feed Forward Neural Network. To investigate this novel method performance, it is confronted with the conventional (SRF) method. All of the studies have been carried out using the simulation with the MATLAB Simulink Power System Toolbox. The results of simulation study of new DVR detecting method presented in this paper are found quite satisfactory to eliminate the voltage disturbance from utility voltage.*

***Streszczenie**. Przedstawiono dynamiczny układ przywracania napięcia DVR jako zabezpieczenie przeciw zapadom napięcia. Układ działa jako źródło napięcia połączone w szereg z obciążeniem. W artykule opisano metodę identyfikacji wykorzystującą sztuczne sieci neuronowe. Przedstawiono też symulacje systemu. (**Sterowanie wytwarzaniem napięcia kompensującego zapady napięcia z wykorzystaniem sztucznych sieci neuronowych**)*

Keywords: DVR, Power Quality, Voltage Sag, Voltage Swell, MLFFN, SRF.
Słowa kluczowe: jakość energii, zapady napięcia, napięcie referencyjne.

Introduction

Owing to the rapid technology proliferation in industrial control processes, as well as the large uses of sophisticated electrical apparatus, the high power quality is required by manufacturing factories and commercial electrical consumers [1]. Therefore electrical Power utility should continually provide the flow of energy at their customers, with maintaining nearly sinusoidal voltage at frequency of 50/60 Hz, symmetrical voltage and a constant rms value [2].

The major power quality problems interested by industries are Voltage sag and swell [3], these problems occur in the whole plan or in a large part of it, caused by the Faults at either the transmission or distribution level. The existence of voltage sag can cause damaged product, lost production, restarting expenses and danger of breakdown [4], but voltage swells can cause over heating tripping or even destruction of industrial equipment such as motor drives.

In recent years, owing to the rapid improvement in power semiconductor device technology that makes high-speed and high-power switching devices. Usable for the voltage sag or swell mitigation modern power electronic technology, Dynamic voltage restorer (DVR) has been considered as an effective solution for this issue, it has been widely used. DVR is a series custom power device, which has excellent dynamic capabilities. It is composed of a voltage source inverter VSI, an inverter output filter, and an energy storage device that is connected to the DC link [5].series-connected transformer. The transformer is placed between the supply and the VSI. The functioning of (DVR) is to inject a dynamically controlled voltage in series with the supply voltage through the three single-phase transformers to correct the load voltage ,as shown in figure1. Generally, the effectiveness of (DVR) depends on three design criteria: (i) design of power inverter; (ii) energy Storage Devices (iii) methods used to obtain the reference voltage. The presented work was oriented mostly on latter criterion.

Nowadays, some methods based on artificial intelligence have been applied In order to improve processing detecting time of voltage disturbances. The past decade has seen a dramatic increase in interest Artificial Neural Networks (ANNs) which is characterized by its learning ability and high speed recognition but simple structure, the (ANNs) have been applied in many uses in the power electronic part of both machinery [6] and filters devices [7] where it have justified their effectiveness. The results obtained with ANNs are often better than those of traditional methods. Indeed, as a result of their capacities to optimize simultaneously their weights and biases in an on-line training process, they are able to adapt themselves to any system.

In this paper, a detection method using artificial neural network (ANN) is presented which can be utilized in disturbances detection from distorted wave. This method can precisely obtain the reference voltage of each phase. The learning rate can be regulated in a wide range with little affection on the performance and it has a simple structure and theory. The performances of the Neural Method are evaluated under simulation and are compared to SRF theory.

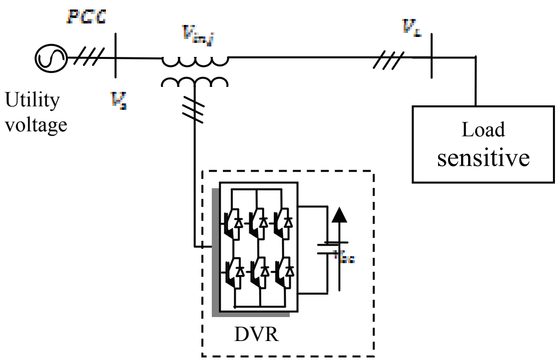

Fig.1.DVR's circuit configuration

The power flow Study in the DVR

The DVR is controlled in such a way that the voltage across the load is always sinusoidal and equal to a desired value. Therefore, the voltage injected by the DVR is equal to the difference between the supply voltage and the ideal desired voltage across the load.

In what follows, the load voltage is considered in phase with the supply voltage. This is done by injecting a voltage in phase or in phase opposition with the source voltage respectively. In cases of voltage sag or voltage swell, this leads to a bidirectional power flow (DVR-Network) through the booster transformer. The voltage injected by the DVR must be positive or negative, according to the source voltage amplitude, voltage swell or sag. On account of this, the reactive power is absorbed or supplied by the DVR.

In this study, the load used has been assumed nonlinear with a power factor equal to 0.97. The equivalent DVR single phase circuit is presented in Figure2 below.

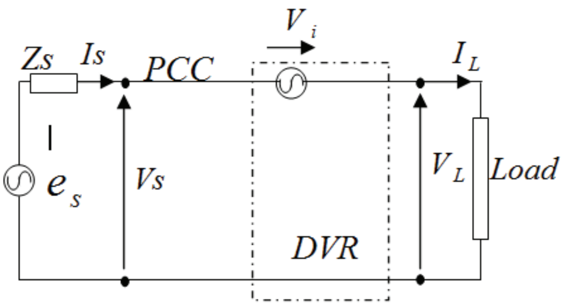

Fig.2. Equivalent Circuit of a DVR

with: e_s, I_s: the supply current and voltage respectively, V_s: the voltage at the point of common coupling (PCC) A, I_L, V_L: the load current and voltage respectively, V_i: DVR inserted voltage.

V_L is taken as phase reference and $\cos\varphi_L$ the power factor corresponding to the load, it can be said that :

(1) $$v_L = v\angle 0°$$

(2) $$i_L = I_L\angle -\phi_L°$$

(3) $$v_s = v_L(1+k)\angle 0°$$

where k is the voltage fluctuation factor at the point of common coupling (PCC) A, defined by:

(4) $$k = \frac{V_s - V_L}{V_L}$$

The inserted voltage by DVR equals:

(5) $$v_i = v_L - v_s = -k v_L\angle 0°$$

Supposing that DVR is without losses, the active power required by the load equals that of the joining point. This power can be expressed as follows:

(6) $$P_s = P_L$$

(7) $$V_s I_s = V_L I_L \cos\varphi_L$$

(8) $$V_L(1+k)\cdot I_s = V_L\cdot I_L \cos\varphi_L$$

(9) $$I_s = \frac{I_L}{1+k}\cos\varphi_L$$

Equation (9) shows that the source voltage depends on both the k, $\cos\varphi_L$ factor and the load current I_L.

The apparent power absorbed by the DVR can be written as:

(10) $$S_i = v_i I_s$$

(11) $$P_i = V_i\cdot I_s\cdot\cos\varphi_s = -k\cdot V_L\cdot I_s\cdot\cos\varphi_s$$

(12) $$Q_i = V_i\cdot I_s\cdot\sin\varphi_s$$

Q_i = 0, the DVR maintains the unit power factor on the load side:

(13) $$P_i = V_i\cdot I_s = -k\cdot V_L\cdot I_s$$

Normal operation

In normal operation, the DVR does not exchange any active or reactive power with the electrical network.

The below vector diagram illustrates the normal operation.

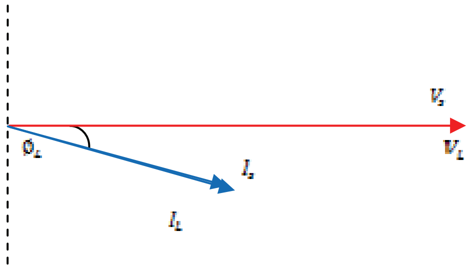

Fig.3.Vector diagram representing the operating conditions during the normal operation

Voltage sag case

In voltage sag case: VS<VL, and according to equation (4), where k <0, it signifies that the DVR injects an active power to electrical network (P i) ,with a view to compensate the power injected by the DVR towards the load,. On the other hand, at the voltage sag time, the DVR absorbs reactive power (Q i) through the booster transformer .The below vector diagram illustrates the voltage sag case:

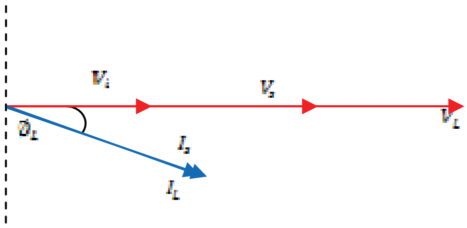

Fig.4.Vector diagram representing the operating conditions during voltage sag

Voltage swell case

In voltage swell case: VS>VL, where k >0, it signifies that the DVR absorbs an active power (Pi) from the electrical network. Concerning the reactive power, during the voltage sag time, the DVR absorbs reactive power (Q i) through the booster transformer.

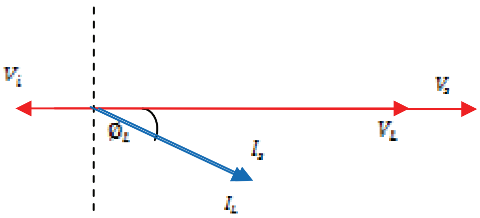

Fig.5.Vector diagram representing the operating conditions during swell voltage

Reference Source voltage Generation

Synchronous Reference Frame (SRF) Method

In order to generate the references voltages ($v^*_{ca}, v^*_{cb}, v^*_{cc}$), the synchronous reference frame (SRF) method is used, which is founded on the instantaneous values of the source voltage (v_{sa}, v_{sb}, v_{sc}) [8]. When a disturbance occurs (abnormal condition) and supply voltage deviates from nominal value, they are spotted by estimate the deference between the d-voltage of the supply and the d-reference value. The control algorithm produces a three phase reference voltage. This reference voltage is fed through a controller and then the switching signal is generated to switch the power switching devices of the VSI such that the DVR will indeed to produce the reference voltage required by the system. Finally, maintaining the load voltage at its reference value. This method can be used to compensate all type of voltage disturbances, voltage sag/swell, voltage unbalance and harmonic voltage; nevertheless only voltage sag/swell are studied in this paper. The difference between the reference voltage and the injected voltage is applied to the VSI to produce the load rated voltage as shown in figure 6.During the normal operating condition (without sag or swell conditions) DVR operates in a low loss standby mode. During this condition the DVR is said to be in steady state.

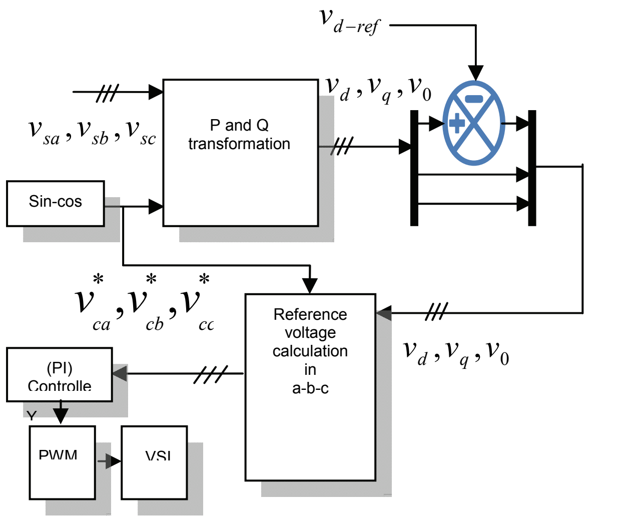

Fig.6 .Control of the injected voltage using conventional PI controller (CPI)

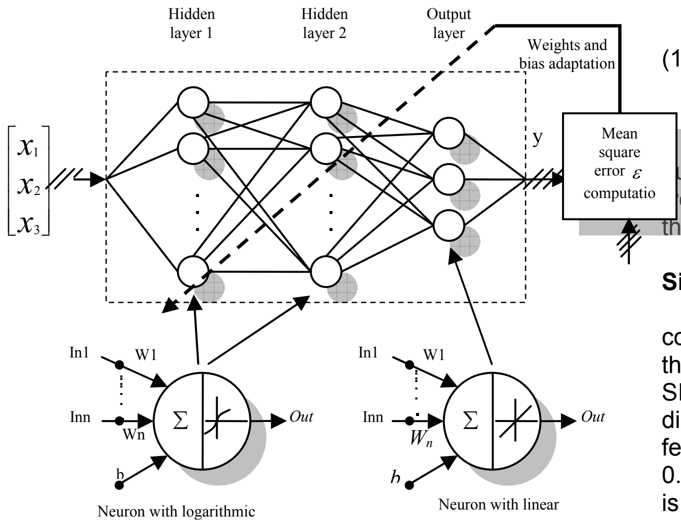

Fig.7. Neural network for (SRF theory) modelling

MLFFN Based Control Algorithm

Nowadays, one of the most popular topologies in use is The MLFFN Multilayer Feed Forward Neural Network [9-10]. This network consists of a set of output neurons and one or more of intermediate neurons, known as hidden layers. Firstly, the piece of information feeds through the network by the input layer, passes across the hidden layers and finally moves out via the output layer. A three layer MLFFN interconnected by weight matrices W and bias vectors b which are the free parameters, the block diagram is illustrated by the Figure 7.

In order to modify W and b, the ANN uses the training, in such a way that the ANN approximates there function to the system function, the ANN minimizes ε the difference between the actual output y and the reference function.

Each input in the input column vector x is weighted with an appropriate W. The sum of the weighted inputs and the bias forms the input to the transfer function f.

The activation vector a is determined as:

(14) $$a = \sum (w \cdot x + b)$$

Neurons can use any differentiable transfer function f to generate their output. In this case the tan-sigmoid transfer function tansig function is used in input layer and the hidden layer.

(15) $$\tan sig(a) = \frac{2}{1+e^{-2a}} - 1$$

on the other hand the output layer use the linear transfer function purelin .

(16) $$purelin(a) = a$$

In this work the least mean square error (LMS) algorithm is used to supervise training, in which the learning rule is provided with a set of desired network behaviour:

(17) $$\{x_1, y_1\}, \{x_2, y_2\}, \ldots\ldots\{x_n, y_n\}$$

Here x is an input to the network, and y is the corresponding target output. As each input is applied to the network, the network output is compared to the target. The error is calculated as the difference between the target output and the network output. The mean of the sum of these errors is calculated as:

(18) $$\varepsilon = \frac{1}{n}\sum_{k=1}^{n} e(k)^2$$

(19) $$\varepsilon = \frac{1}{n}\sum_{k=1}^{n} (y(k) - y'(k))^2$$

where y' is the network output, y is the target utput.The objective of The LMS algorithm is to adjust the eights and biases of the linear network so as to minimize this mean square error.

Simulation and Results

To prove the effectiveness of the abovementioned control methods in providing continuous voltage regulation, the test system is modeled and implemented in MATLAB SIMULINK. The test system comprises a 380V, 50Hz distribution system, represented by a Thevenin equivalent, feeding a load with 104.4 kVA and the power factor about 0.95. To provide the voltage necessary by the load, a DVR is connected to the 380V by transformer .this later is modeled as a linear element. The transformer winding's resistances and core saturation effect were neglected. A 4.4 mF capacitor on the dc side provides the DVR energy storage capabilities.

In simulation, it is assumed that during the period of 0.2 s≤t≤0.4s, voltages sag is created with a decrease about 0.5 (p.u.) from its reference value by a remote three phase fault of the supply voltage is occurred. Moreover, the three-phase unbalanced voltages swell starts at t = 0.6s and ends at t = 0.8s, during this fault, the phase A, B and C voltages increase to 1.5 (p.u.), as illustrated in figure 8(a).

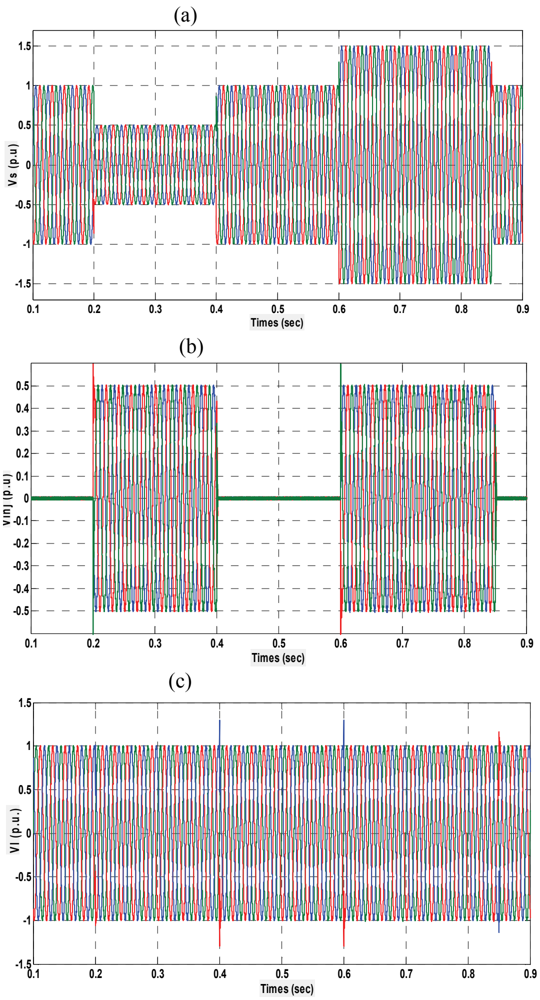

Fig .8. Simulation result of DVR response to a balanced voltage sag/swell with SRF method :(a) Supply voltages,(b) injected voltage,(c) load voltage.

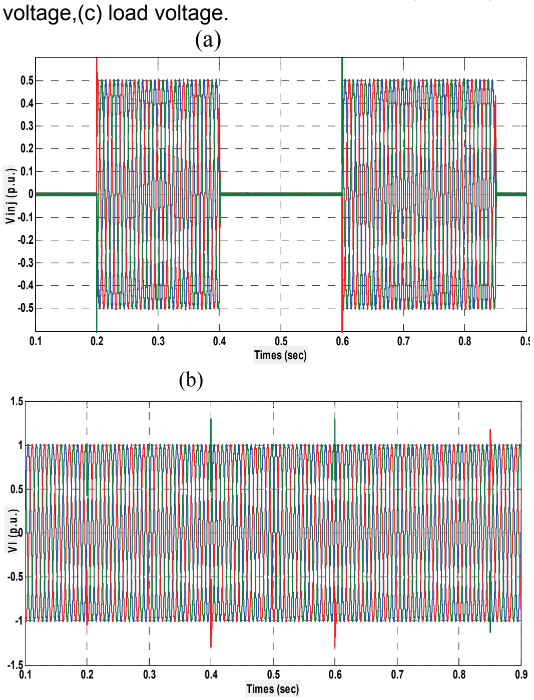

Fig .9. Simulation result of DVR response to a balanced voltage sag/swell with (MLFFN) method :(a) injected voltage,(b) load voltage.

In simulations the two different identification methods were used .Because of the (ANNs) capacities to optimize simultaneously their weights and biases in an on-line training process; this approach improves the (DVR) performance. The compensation result can be seen in Figure 8and 9.

Conclusions

The mathematical derivation of the SRF theory has been employed to demonstrate the behaviour of DVR. An Adaline based identification technique has resulted in considerable improved performance of DVR. The Adaline based technique utilizes LMS algorithm to calculate the weights and biases, and all the calculations are performed online therefore the algorithm is able to generate reference voltage components in case of sag and swell voltage. MATLAB based results have verified the effectiveness of these identification algorithms.

ACKNOWLEDGMENT

The authors express thanks to all Laboratory staff of Power Quality and Artificial Intelligence, Bechar University, for their kind technical assistance.

REFERENCES

[1]. N. S. Sakthivel Murugan, A. Nirmalkumar , T. Vijayakumar, 2009.Implementation of H Bridge Inverter Based DVR Using Atmel 89c2051. International Journal of Computer and Electrical Engineering, 1(4),pp: 443-448.
[2]. S.Deepa,S.Rajapandian,2010.Voltage Sag Mitigation Using Dynamic Voltage Restorer System.International Journal of Computer and Electrical Engineering, 2(5): 821-825.
[3]. A.Ramasamy, V.K.Ramachandaramurthy, R.K. Iyer, L.Z. Liu, 2007. Control of Dynamic Voltage Restorer using TMS320F2812.9th international conference.electrical power quality and utilization,Barcelona,9-11 october,pp: 1 – 6.
[4]. Y.Yun,l. W.Bu,h.Z.Cheng,x. Mao , 2009. Modeling and simulation of Dynamic Voltage Restorer based on super capacitor energy storage. International Conference on Electrical Machines and Systems, Wuhan, 17-20 Oct,pp: 2064 - 2066.
[5]. H.Ezoji, A. Sheikholeslami, A.G.samani, M.Fazlali1, M.Rezanezhad, 2009. A New Control Method for Dynamic Voltage Restorer with Asymmetrical Inverter Legs Based on Fuzzy Logic Controller.24th International power Systems Conference (PSC2010) ,Tehran, 8 - 10 Nov. 2010,pp: 1-10.
[6]. M. Ahmed, 2004.Sliding Mode Control For Switched Mode Power Supplies', Doctor of Science Thesis, Lappeenranta University of Technology, Finland.
[7]. R.Dehini, A.Bassou, Brahim.Ferdi, 2009.Artificial Neural Networks Application to Improve Shunt Active Power Filter.International Journal of Computer and Information Engineering (IJCIE).3(4),pp: 247-254.
[8]. C.Benachaiba, B.Ferdi, 2008. Voltage Quality Improvement Using DVR. Electrical Power Quality and Utilisation, Journal. XIV (1), pp: 39-46.
[9]. W.Danesh, N. Muktadir, S.Bhowmick, S.Alam, 2011. A Review of Neural Networking Methodology to Different Aspects of Electrical Power Systems. International Journal of Science and Advanced Technology.1 (1) ,pp:1-7.
[10]. M.V Rajesh, R .Archana, A .Unnikrishnan, R. Gopikakumari, Jeevamma Jacob,2008. Evaluation of the ANN Based Nonlinear System Models in the MSE and CRLB Senses. World Academy of Science, Engineering and Technology.48(34),pp:211-215