

# Enhancing power quality of ANN controller based Photo Voltaic source injected DVR

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## Abstract

The DVR is a series connected FACTS controller used to compensate voltage disturbance in distribution systems. The main purpose of the DVR is to examine the load voltage waveform regularly if any disorder happens, the equilibrium or excess voltage is injected to the load voltage. The most important advantage of the DVR is observance the users all the time on-line with high quality stable voltage maintaining the permanence of production. In this dissertation, a Photovoltaic voltage injected with an ANN control method for DVR that protects a sensitive load, to counter voltage sag under uneven loading conditions (linear, non-linear) is presented. DVR along with other parts of the distribution system are simulated using MATLAB/ SIMULINK.

**Keywords:** DVR, sag, swell, ANN.

## 1. Introduction

In recent times, power quality troubles become a main alarm of industries due to defeat in terms of time and prosperity. Hence, there are forever stipulate for good power quality, which certainly results in diminish of power excellence problems like voltage sag, swell, harmonic, disturb and flicker. preferably, the best electrical provide would be a even magnitude and frequency sinusoidal voltage waveform. Voltage support at a load can be attained by reactive power insertion at the point of universal coupling. The general process for this is to mount mechanically switched shunt capacitors in the primary incurable of the distribution transformer. The mechanical switching may be on a agenda via signals from a supervisory control and data acquisition (SCADA) system, with several timing schedule or with no switching at all. The drawback is that elevated speed transients cannot be remunerated. Sometimes unbalances are not corrected within the limited time enclose of mechanical switching devices.

A DVR is the power electronics-based apparatus that is associated in series with the feeder of sensitive loads between the supply and load buses [1]. DVR regularly consist of three single-phase Voltage Source Inverters, an energy storing unit, passive harmonic filters, injection transformers and a control scheme which itself comprises three parts: an estimation unit, a compensation strategy and a switching pattern, enables the DVR to inject three-phase controllable voltages of required amplitudes and phase angles to maintain the load bus voltage in required waveform during voltage sags [2-4]. By using a single phase DVR with direct AC/AC converter in order to moderate harmonics and controls DVR when the frequency changes [5-7]. Mitigation of voltage sags by means of DVRs mostly depends on protectecting load characteristics. There are three conservative voltage sag compensating strategies, each having distinctive advantages. They are known as in-phase,

pre-sag and optimized energy [8-9]. In some control schemes, for the DVR, the booster voltage for the pre-sag compensating scheme is obtained by comparing the amplitude of the positive sequence component with its reference value and using the dismissal angle that is tracked via a Phase-Locked Loop (PLL) feedback [10-12]. Using optimized control strategy, dropping the needed addition voltage of the DVR and also to mitigate the transient distortions at the load side [9]. DVR has been used to take from battery [13-15]. In order to realize voltage parameter with low down total harmonics distortion (THD) for mutually voltage and current, it uses the control technique enhancement of a three-phase inverter using direct quadrature-zero (d-q-0) controllers based on MATLAB simulation for DVR application [16-17]. Using a DVR, a most cost effective solution method is used to mitigate the voltage sag and swell caused by sensitive loads. The PI controller method such as improper tuning of  $K_p$  and  $K_i$  values which will lead to increase in settling time of the system stability and the continuous usage of controller with fixed PI parameters leads to reduce the life time of DVR [18-20]. In order to get better the real power of the inverter under any disturbances, a DVR is used as three phase four wire based on super capacitor. The organizer used in this system is d-q-0 transformation process and Proportional Integral. DVR is a group of custom power devices for given that dedicated distribution power quality [21-25]. They utilize series as well as shunt inverter for both the active and reactive power recompense.

This paper introduces Dynamic Voltage Restorer together with photovoltaic (PV) system with the purpose of mitigate the voltage sag and harmonics happening in distribution system shown Fig. 1. A projected dq0 based PI controller beside with PV can be used by replacing the predictable DC source controller for DVR. Here, the MATLAB/SIMULINK replica based simulated results were accessible to validate the efficiency of the future real power injected Control method all along with the PV for DVR over usual methods.

The Performance of the PV array is connected to DVR in order to improve the power quality problem. Solar photovoltaic systems are used to make use of the energy of sun in power production during recent years. PV systems require MPPT techniques to capitalize on the energy by reason of non-linear PV characteristics. The most generally used MPPT techniques are P&O and INC technique.

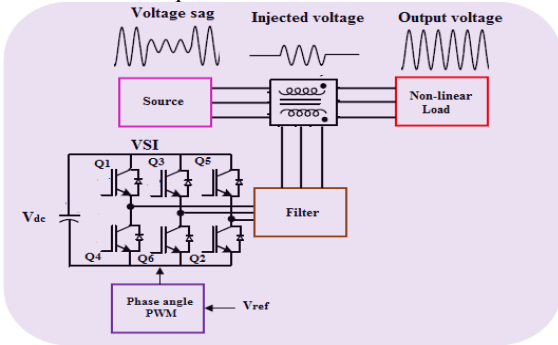


Fig. 1: Block diagram of proposed DVR system

- Pg - Power from source
- PL - Power to load
- Psh - Power from DVR
- PPV - Power from PV

To mitigate the voltage derange issue caused by the high penetration of photovoltaic systems into the low down voltage distribution networks using a single phase energy storage system. In this projected system, voltage unbalance can be improved using a DVR with rooftop photovoltaic cells. In order to improve the good organization of the photovoltaic with MPPT technique is implemented in this system. The Dynamic Voltage Restorer (DVR) is a series connected device similar to a SSSC is shown in Fig.2.

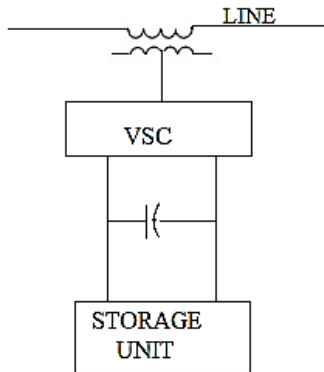


Fig. 2: Dynamic voltage restorer

## 2. PV system

Photovoltaic (PV) is a system of converting lunar energy into DC current electricity using semiconductor resources that reveal the photovoltaic consequence. A photovoltaic organization employs solar panels collected of a number of solar cells to supply functional solar power. The irradiance and temperature are the inputs of the system. The voltage is considered varying from zero to open circuit voltage (Voc) corresponding to the variation in current from short circuit current (Isc) to zero current. Fig.3 shows the plots of V-I characteristics at various module temperatures (T=00, T=25° C, T=50 ° C, T=75° C) and various irradiance (1000, 800, 600, 400, 200W/m2) at constant temperature (T=25°C) respectively. The amount of sunlight incident on the PV cell increases with the increase in solar irradiation and hence power would increase for the same voltage value. Conversely, an increase in temperature decreases open circuit voltage and hence the efficiency of the PV cell is reduced

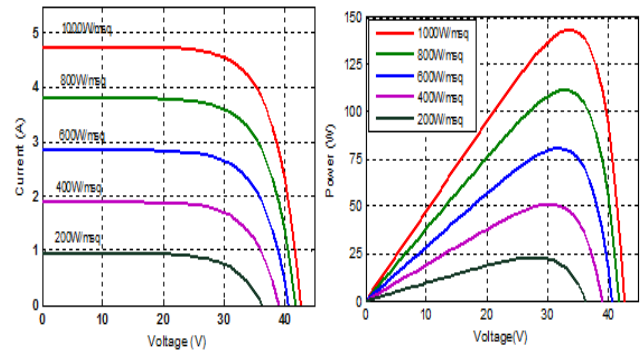


Fig. 3: IV and PV characteristics of solar panel

## 3. INC MPPT algorithm

The incremental conductance (INC) technique has discussed by many authors, Liu et al (2008) Safari et al (2011) and Mai et al (2011). This process MPPT by comparing the solar collection incremental ( $\Delta G$ ) and instant conductance ( $G$ ), the procedure of this method is explain in the flowchart in Fig. 4. This algorithm overcomes the drawbacks of the P&O scheme by tracking MPP under changing atmospheric state. This method focuses straight on power variations of the PV array. This system tracks the MPP by compare the solar array INC ( $\Delta G = dI_{pv}/dV_{pv}$ ) and instant conductance ( $G = I_{pv}/V_{pv}$ ). The PV panel voltage and current are deliberate at fixed sampling intervals and fed to the regulator to evaluate the PV panel power. The PV system INC is knowable by measuring small changes in PV voltage and current. i.e where  $dP_{pv}/dV_{pv} = 0$ , as illustrated in Equation (1).

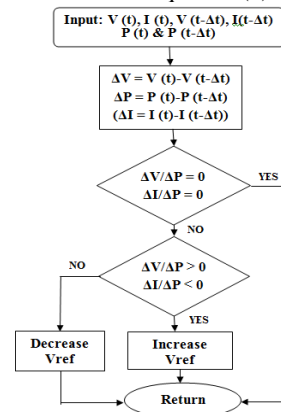


Fig. 4: Incremental conductance algorithms

$$\left. \begin{aligned} \frac{dP_{pv}}{dV_{pv}} = 0 & \quad \frac{I_m}{V_m} = -\frac{\Delta I_{pv}}{\Delta V_{pv}} & G = \Delta G \\ \frac{dP_{pv}}{dV_{pv}} > 0 & \quad \frac{I_m}{V_m} > -\frac{\Delta I_{pv}}{\Delta V_{pv}} & G > \Delta G \\ \frac{dP_{pv}}{dV_{pv}} < 0 & \quad \frac{I_m}{V_m} < -\frac{\Delta I_{pv}}{\Delta V_{pv}} & G < \Delta G \end{aligned} \right\} \quad (1)$$

The plan of this algorithm is to track the voltage functional point at which conductance is equal to change in conductance. Hence, it works under varying solar irradiance and temperature. The INC process requires more calculations than P&O method and meeting is slow. The INC method used to have difficult analog implementation, but it is easier at the present time with micro controllers' stage. on the other hand, the INC system requires additional calculations than P&O process and thus slows downwards the sampling speed. ultimately, the unacceptable value of the incline of the PV power versus voltage curve rarely occurs active improvements in narrative of this method focuses on modifying the action size of the algorithm. However, the high

difficulty of the process requires high sampling correctness and fast control speed, which may result in a elevated cost system.

### 4. ANN algorithm

The operation of this method is explained in the block drawing and structure is shown in Fig.5 the developed ANN configuration is a multilayer-perceptron configuration together with an input layer, a hidden layer and output layer. The input layer collected of two nodes in the input that are; the foundation voltage and the DC capacitor voltage, the hidden layer is composed of twenty nodes whose function is activated sigmoid. The output layer is calm of one node that is the best possible gate control signal. The function of the weighted sum of the inputs plus bias is the output of a neuron as follows:

$$y = f(w_{ij}x_{ij}) + b_j \tag{2}$$

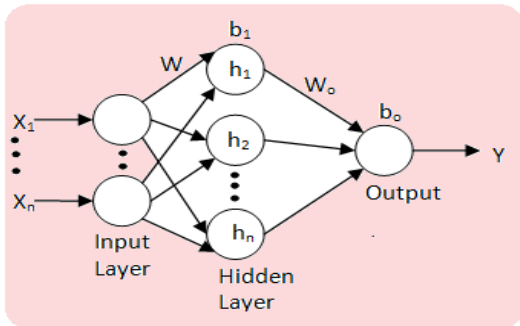


Fig. 5: ANN

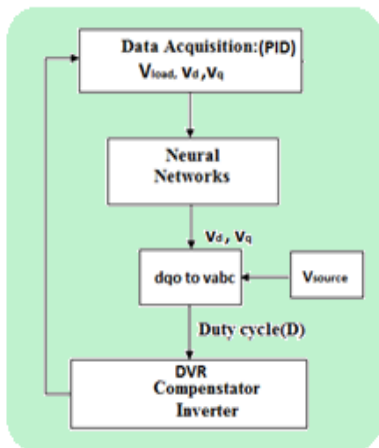


Fig. 6: ANN systems

Fig.6 ANN DVR organization of inverter control system. In this work, information set consists of 1200 patterns of system input and out voltage, which has alienated into two sub-databases, 71%, of the samples are used to train the ANN, and the rest 29% are second-hand to test and authenticate the network. The performance is measured by the mean- square error as shown in Fig. 7 and Equation (3).

$$e = \frac{1}{p} \sum_{i=1}^p \|y^{(i)} - v^{(i)}\|^2 \tag{3}$$

Where, p= number of training information ; y = ANN output vector; v = required output  
For a set of contribution parameters, a well-trained ANN would give as an output, the orientation voltage that is very close to the desired value, giving an error more or less zero. Each neuron \$a\_j\$ computes a weighted sum of its n inputs \$V\_k, k = 1, 2, \dots, n\$, and generates an output as shown in Equation (4).

$$a_j = \tan sig \left( \sum_{k=1}^n w_k v_k + bias \right) \tag{4}$$

The tan sigmoid function of the important weighted sum that regularly has a bias connected with it that can be considered as an additional input gives the output.

\$W\_k\$= synapse weight related with each one of the n inputs. The plan of the manage system is to keep up voltage scale at the point where a sensitive load is related under system disturbances.

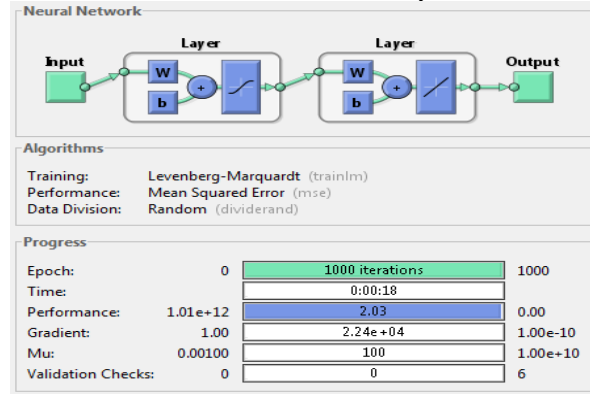


Fig. 7: ANN training structure

The harmonics are produced in the load terminals by resources of 6 pulse converters with fixed firing angle are related to the main drive non linear load which is alike to the sensitive load. Voltage sag is warped at the load terminals via a 3 phase mistake. The above voltage trouble are sensed independently and passed through the succession analyzer. The control format of the general arrangement typically consists of a voltage modification method which determines the mention voltage that should be injected by DVR ,which is in this work consists of PWM with ANN algorithm. The regulator input is an error signal obtained from the reference voltage and the rate of the injected voltage. The control of the proposed DVR is based on ANN regulator shown in Fig.8. The PWM signal generator that controls the DVR inverter to produce the necessary injected voltage. The performance of ANN controller is well documented for improvements of both momentary and steady State performances.

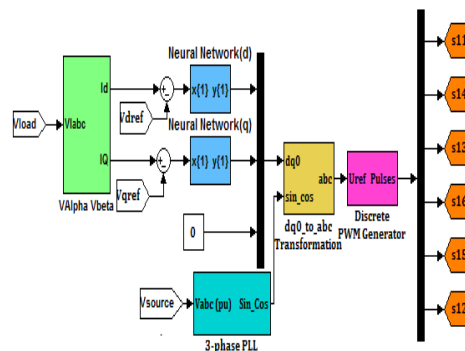


Fig. 8: ANN organizer

### 5. Parameters of DVR test system

The System parameters are scheduled in Table 1. The System comprises of 11000V, 60 Hz generator, feeding transmission lines through a 3 phase system. In this test system, 2 similar loads with dissimilar feeders are considered. One of the feeders is linked to the DVR and the other is retained as it is. This test system is analyzed under SLG fault condition. The proposed system constitution of the DVR is composed of a 98V, 60 Hz generation system, feeding two transmission lines through a 3- winding inductive filer connected. The micro turbine scheme output is the three phase voltage further convert and supply to the DC link of DVR. To verify the working of DVR for voltage compensation,

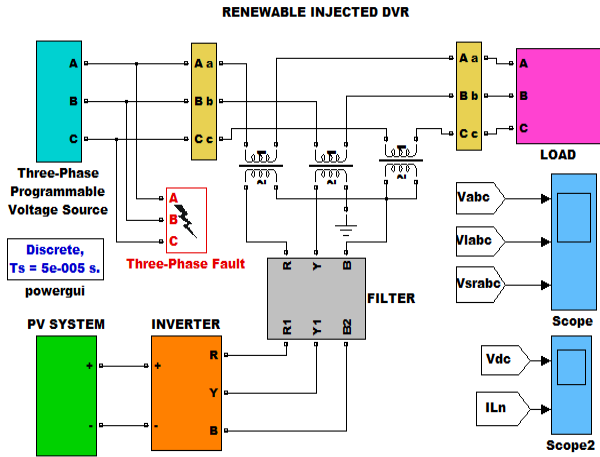
both linear & nonlinear loads is associated at the distribution end. The DVR is replicated to be in process only for the heavy load condition.

**Table 1:** Parameters of DVR

S.No.	Parameters	Values
1	Source Voltage	100V
2	No. of bridge arms	3
3	Transition time	0.25 to 0.3 sec
4	Snubber resistance	0.1 mΩ
5	Breaker resistance	0.0001Ω
6	Line frequency	60Hz

### 6. Simulation results

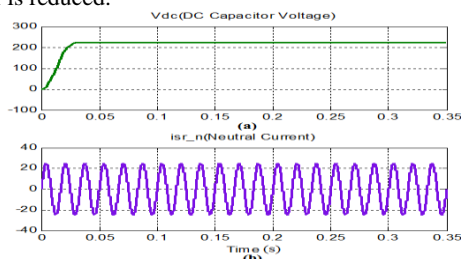
In one feeder DVR is connected ANN controller simulation, detailed control system shown in Fig.8. In one feeder DVR is connected in series with line and the other feeders is kept as it is. The system performance is investigated for compensating the load voltage in distribution networks under Single line to ground fault condition. Three cases of different load conditions are considered to study the collision of DVR in the distribution system. Different cases are scheduled below: Third order harmonics, sag and 3 phase fault with non-linear load Seventh order harmonics, sag and 3 phase fault with non-linear load



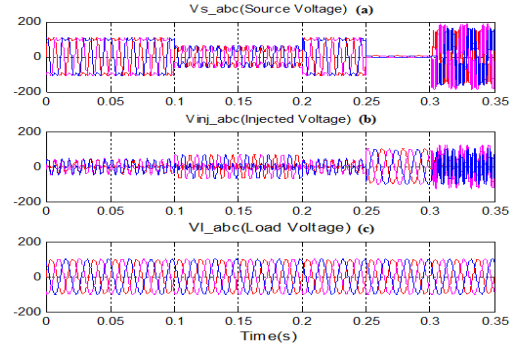
**Fig. 9:** Simulation model of DVR test system

#### Case 1

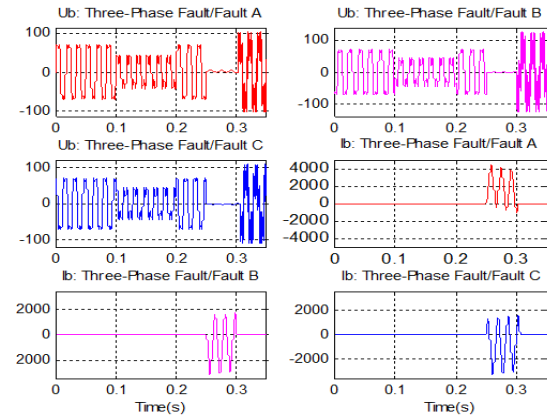
Single line ground fault is deliberate for the test system delivering non linear load. Here the defect resistance is 0.001 ohm and the ground resistance is 0.002 ohm. The fault is shaped for the duration of 0.255s to 0.31s. The PV out voltage and inverter load current shown in Fig. 10. The output power for the load voltage without and with reimbursement are shown in Figs.11 (a)–(c), single phase voltage and current reproduction output of harmonic ,sag and fault shown in Fig.12. The ANN guarded PV injected real power frequency spectrum of source voltage. Injected voltage and load voltage with compensation is shown in Figs.13-15. The output wave shapes that the voltage in the phase where error is created is growing during the fault duration in the uncompensated feeder. When DVR is associated in the system the unbalancing condition is reduced.



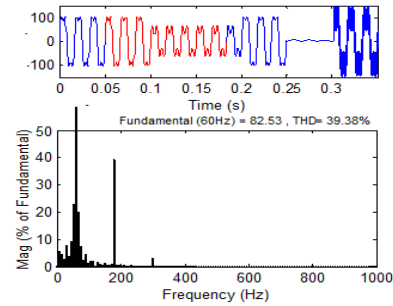
**Fig. 10:** (a) PV voltage (V), (b) load current (A)



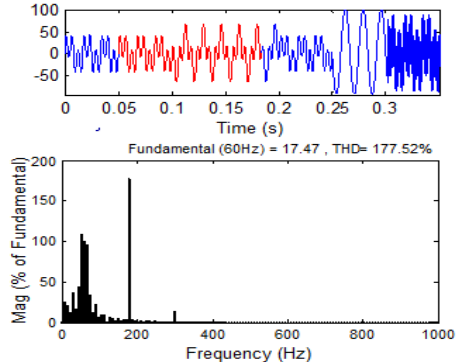
**Fig. 11:** (a) source voltage, (b) injected voltage (c) load voltage



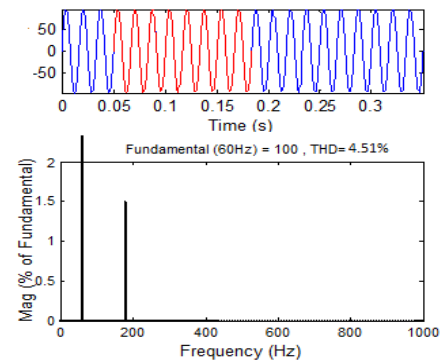
**Fig. 12:** (a) single phase source voltage, fault current(ABC phases)



**Fig. 13:** Frequency spectrum source voltage



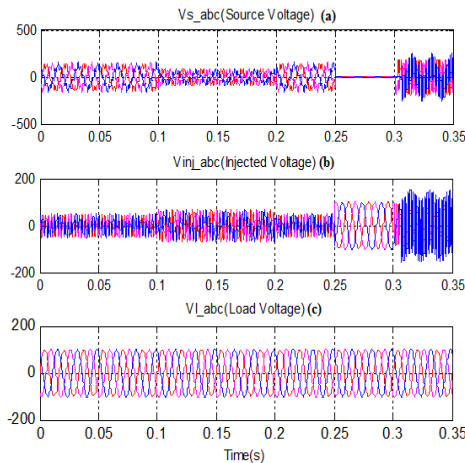
**Fig. 14:** Frequency spectrum injected voltage



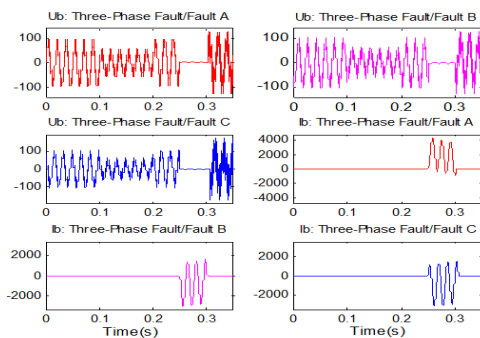
**Fig. 15:** Frequency spectrum load voltage

**Case 2**

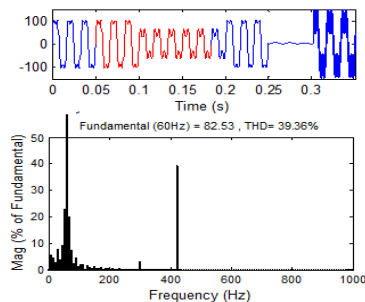
single phase ground fault imperfection is considered for the test scheme delivering non-linear load. Here the fault resistance is 0.002 ohm and the ground resistance is 0.0021 ohm. The fault is created for the duration of 0.252s to 0.31s. The output waves for the load voltage, injected voltage and load voltage with compensation are shown in Fig.16,(a)–(c) With ANN regulator Fig.17 single phase simulation yield view of harmonics, sag and fault configuration. Fig.(18)-(20) frequency spectrum with and without compensation of source voltage, injected voltage and load voltage. The output wave shape that the voltage in the phase where slip-up is created is increasing in the fault duration in the uncompensated feeder. When DVR is associated in the system the unbalancing is condensed



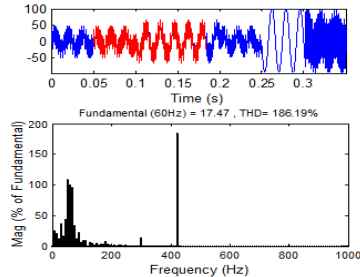
**Fig. 16:** (a) source voltage, (b) injected voltage (c) load voltage



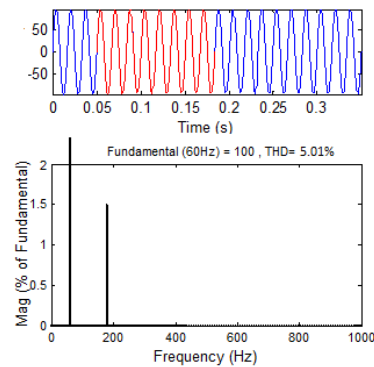
**Fig. 17:** (a) single phase source voltage, fault current (ABC phases)



**Fig.18:** Frequency spectrum source voltage



**Fig. 19:** Frequency spectrum injected voltage



**Fig. 20:** Frequency spectrum load voltage

**Comparison of thd levels for different types of loads**

The judgment of THD levels for dissimilar types of loads under a single phase ground fault state with or without DVR is shown in Table 2. It is clear from the THD examination that DVR efficiently removes harmonics from load voltage and makes it even.

**Table 2:** THD Levels

Description	THD %		
	Source voltage	Injected voltage	Load voltage
Case1	39.38	177.52	4.51
Case 2	39.36	186.19	5.01

Here, imitations are executed on the DVR test system using MATLAB/SIMULINK. The system performance is investigated for compensating the load voltage in distribution networks under single line to Ground fault condition. Three cases of dissimilar load states are considered to revise the impact of DVR in the distribution system.

**7. Conclusion**

In this paper, performance analysis of the DVR has been simulated by ANN controller method for changing linear and non-linear load conditions. The DVR has been control voltage under varying load situation and unbalanced load condition. The THD reduces under the SLG fault condition with DVR. The DVR reduces harmonics from load voltage very efficiently. Hence, it is sophisticated that DVR has a enormous possibility in getting better power quality in distribution systems.

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