

# DESIGN AND ANALYSIS OF PV BASED DVR USING CONVENTIONAL AND ARTIFICIAL INTELLIGENT TECHNIQUE BASED CONTROLLERS

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**Abstract:** The rapid technological development all around the world roots huge demand for power. This in turn leads to increased utilization of fossil fuels for power generation. Hence, global warming becomes high and in turn affects the environmental condition. So now a days, a numerous Renewable Energy Sources (RES) such as Solar, Biomass, wind etc., comes into existence. Among the various Renewable Energy Sources (RES), solar energy plays a vital role in power generation. While instigating this solar energy into a grid, various power quality complications such as voltage sag, voltage flicker, transient and harmonics occurs. Hence in order to overcome these complications, Dynamic Voltage Restorer (DVR) affords a best solution. Henceforth, this work proposes a Multi-level inverter based DVR system for enhancement of power quality. Apart from this, it also investigates the performance of the proposed DVR with both conventional and artificial intelligent controller. It implements a PSO based MPPT technique to track maximum power from the solar system. From the results, it is concluded that the proposed DVR with neural controller provides the best results and the Total Harmonic Distortion (THD) of the proposed technique oveys the IEEE standards.

**Keywords:** PV based DVR, Multi-level Inverter, Fuzzy controller, Neural controller.

## 1. INTRODUCTION

The rapid development in technology leads to an increase in demand for power. As this demand goes on increasing each and every moment, there arose a need to find alternative to this problem. As a result of this, renewable energy based power generation system is hosted as an alternate foundation to meet out power demand. Although various Renewable Energy Sources (RES) like wind, tidal etc., are available, solar energy is deliberated as a major resource because in nature, it is available in large quantities. Apart from that, it is eco-friendly when compared with the other renewable energy sources such as tidal, biomass, wind and fuel cell etc.,

This Solar based power generation system transforms the light from the sun into electrical energy. This is carried out with the assistance of Photovoltaic cell or solar cell. These solar cells

which are used for conversion of light energy into electrical energy may be either connected in series or in parallel. This type of arrangement form, solar units/ arrays. It is popularly known as PV panel. Conversely, only about 30-40% of radiation from the sun is renewed into electrical energy. So, to acquire more energy from the sun, Maximum Power Point Tracking (MPPT) technique is implemented. In general, electronic based MPPT system was instigated to acquire the power from the sun. Analogues to this electronic MPPT system, there are several algorithms such as Perturbation and Observation algorithm, Incremental Conductance algorithm, Hill climb algorithm etc., are employed to obtain maximum amount of energy from the solar panel. At the same time, when this solar system implemented for generation of power, various power quality disputes such as voltage sag, voltage flicker, transient and harmonics are generated. Among these, major one is the

Voltage sag and is mainly by rapid switching of large loads and also due to other faults such as single line to ground faults, line to line faults etc. Henceforth to overwhelmed this problem, Dynamic Voltage Restorer (DVR) offers a best solution. By injecting a voltage and power into the system, the voltage sag is completely vanished by DVR. The main purpose of this device is to safeguard the sensitive loads from voltage sag and to compensate the rise or fall in the supply voltage. Hence this work proposes a PV based DVR to alleviate the problems such as voltage sag and swells etc.,

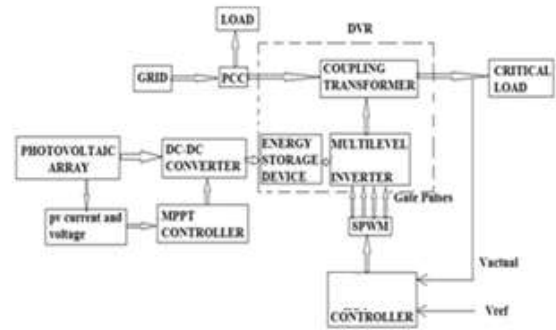
Thus, the proposed PV based DVR system comprises a PV system, DC-DC boost converter, Voltage source inverter and Series injection transformer. The Voltage Source Inverter (VSI) along with series injection transformer is tailored to inject voltage in to the system.

In this proposed topology, VSI plays a vital role. It converts DC voltage from the solar panel into AC voltage which in turn is injected into line for compensation. This might is carried out with injection transformer. Thus the injected voltage should be in such a way to reduce harmonics. This can be achieved with the help of multi-level inverters.

Hence this work proposes a Multi-level inverter based DVR system for power quality improvement. Apart from this, it analyses the performance of the proposed DVR with both conventional and artificial intelligent controller. It implements a PSO based MPPT technique to track maximum power from the solar system.

## 2. PROPOSED APPROACH

Figure 1 signifies the block diagram of the proposed system.



**Figure 1. Block diagram representation of the proposed system**

The power injected on the PV panel is maximized using MPPT technique. Hence to derive maximum power from the solar system, a huge number of conventional algorithms are utilized. However, these conventional methods exhibit a continuous oscillation under steady state condition. This in turn leads to a reduced output power of a PV module and it also unable to track the speedy changes occurring in the conditions of weather. Hence in order to override these complications, Particle Swarm Optimisation (PSO) technique based MPPT tracker is designed. In accordance to the output obtained from the PV module, the initialization of PSO changes and proceeds to search for a fresh MPP.

### 2.1 PSO Algorithm

**Step 1:** Set a population, positions and velocities and define the maximum number of iteration  $m$ ,

$$t = 1, C_1, C_2, \omega_{\min}, \omega_{\max}, r_1, r_2$$

**Step 2:** Estimate the fitness function  $F_T$ , thus the fitness function should be formulated is in such a way acquire maximum power from solar system.

**Step 3:** Catch the  $P_{best}$  and  $G_{best}$  value according to its position.

**Step 4:** Based on the positions  $P_{best}$  and  $G_{best}$ , revise the velocities of the particles.

**Step 5:** Then update the position of the particles using the formulae given below.

New position = Old position + Updated velocity

**Step 6:** Repeat the steps 2 and 3 to find out the succeeding particles new position.

**Step 7:** While a stopping criterion or maximum numbers of iterations is reached, goto step 8.

Otherwise, increment  $t=t+1$  and go back to step 4.

**Step 8:** End.

## 2.2 Design of controllers

In order to maintain the DVR performance, Controllers are implemented.

### PI Controller

Thus the performance of the proposed DVR is studied by implementing PI controller. These PI controllers are found be very sensitive to the changes in the system constraints. Hence to tackle this condition, an artificial intelligent technique based controllers like Fuzzy and Neural controllers are instigated.

### Fuzzy logic Controller

The Fuzzy Logic Controller (FLC) is advantageous over conventional controller because the gains of the system are fixed. Apart from this, the fuzzy logic based controller contributes quick response to nonlinear system and there will be no overshoot. At the same time, FLC does not involve any mathematical derivations and human based one.

Thus the fuzzy logic controller deliberated in this methodology is described by

- The input and output variables of the system are formulated through seven fuzzy sets namely NB, NM, NS, ZE, PS, PM, PB.
- Triangular membership function ( $\mu$ ) is effected because of its uncomplicatedness and easy execution.
- Implication is executed with Mamdani-type min-operator
- Defuzzification is effected using centroid method of defuzzification.

However, the membership functions of the FLC considerably affect the quality of controller. Hence, while using FLC, to acquire a higher accuracy, a fine tuning method is required. So as to overthrow this problem, Neural Controllers are agreed.

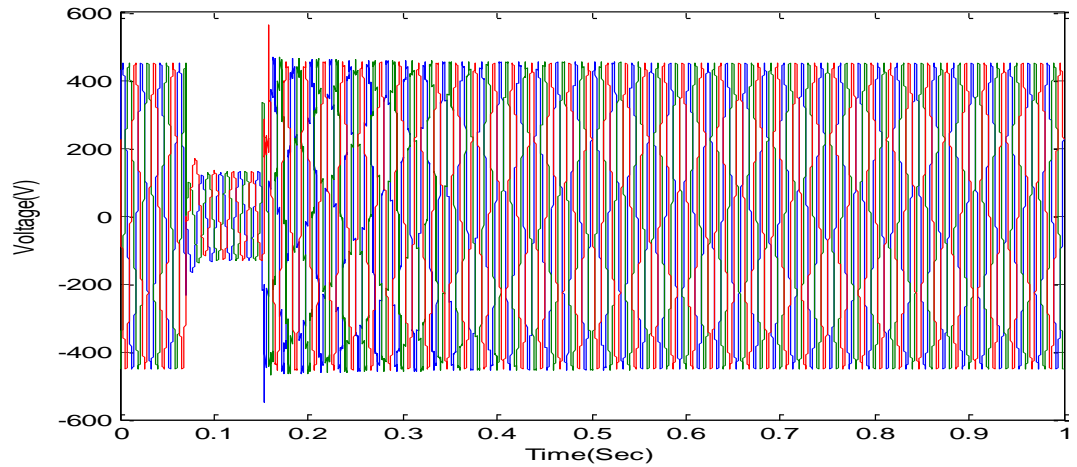
### Neural Controllers

Neural network affords an optimum solution to the tuning problem. However, no organized technique is assumed for the selection of design parameters.

Thus the designed neural controller is characterized by tansigmoid for transfer function of hidden layer and for the design of output layer, linear transfer function is personalized. Back propagation algorithm is employed in this projected topology. Feed forward architecture is applied in the back propagation algorithm.

## 3. SIMULATION RESULTS AND DISCUSSION

The simulation results are carried with the MATLAB software. Thus, this simulation is carried about one second with 75% of sag. This sag is applied at 0.1 second and it lasts for 0.3 seconds. Consequent to the sag, there was a fall of 100Volts.



**Figure 2.uncompensated voltage of the proposed system**

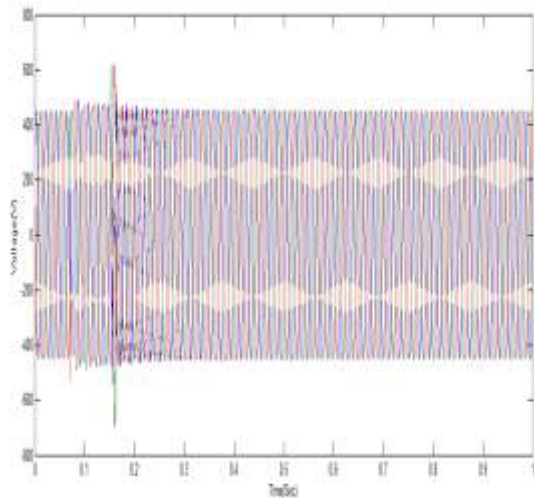
Figure 2 shows the performance of proposed system without DVR for 75% of sag. To Mitigate these issues; the proposed controller injects the voltage in the system.

Thus the performance of the projected topology is studied under various load condition such as

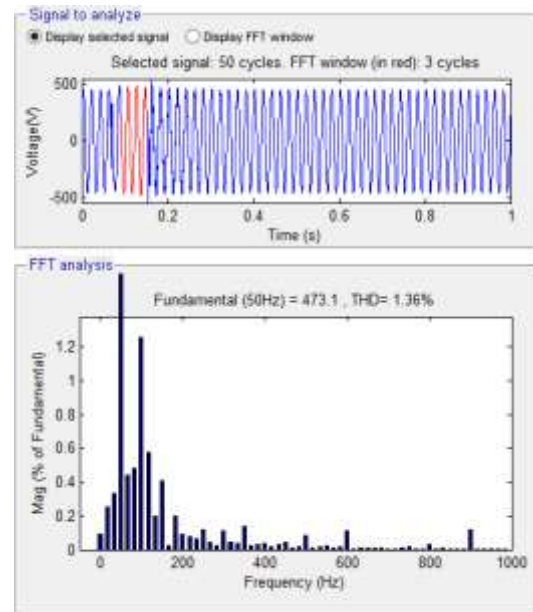
- i) Linear load condition
- ii) Nonlinear load conditions.

**Case I**

Figure 3 shows the line voltage after compensation of DVR with neural controller and the FFT analysis of the proposed topology under linear load.



**Figure3a. Compensated Line Voltage of the proposed DVR with PSO based MPPT algorithm and 5 - level inverter under Neural controller**



**Figure 3b. FFT Analysis of the proposed DVR with neural controller**

Figure 3 shows the load voltage of the system with DVR and it is inferred that there is no impact of sag in the line voltage. Thus the

proposed DVR, compensates the voltage sag by injecting required voltage.

Table 1 represents the load voltage, power factor and total harmonic distortion (THD) of the proposed system by implementing three different controllers such as PI controller, Fuzzy Controller and Neural Controller.

**Table 1 THD Analysis for both conventional and artificial intelligent controllers**

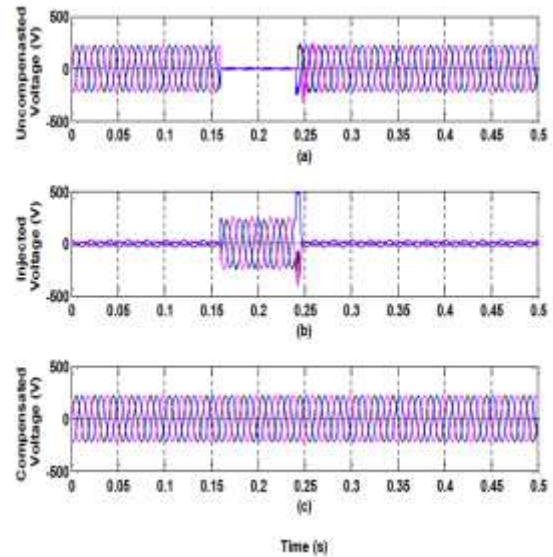
Controller Type	Voltage	THD	Power Factor
Conventional PI Controller	390	3.5	0.86
Fuzzy Controller	428	1.53	0.95
Neural Controller	430	1.36	0.96

From the results, it is concluded that the THD of the DVR with neural controller shown in figure 3b indicates that THD is improved to 1.36% from 12.67%. In addition, the result indicates that there is a significant improvement in load power factor also. The time taken to renovate the voltage of the system is also found to be significant and it is around only 2 milliseconds. Hence, from the table, it may be concluded that the proposed DVR with Neural controller provides the best results when compared to other controllers namely PI and Fuzzy controller.

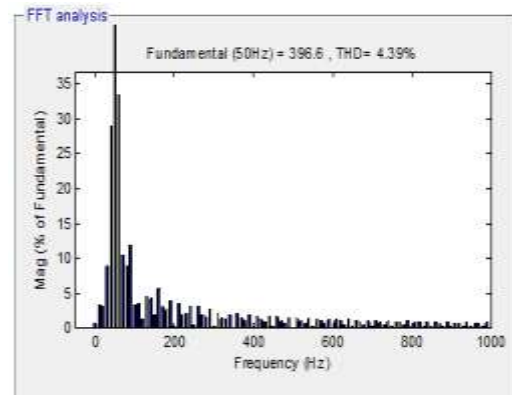
## Case II

In this section, the performance of the DVR is analyzed under non-linear (rectifier) load condition. Whenever a fault is hosted in the system, the proposed DVR acts speedily and shoots up the voltage. Thus the system restores its normal condition quickly. Figures 4a to 4c show the performance of DVR under 3 phase fault. Figure 4b represents the voltage injected by the DVR during compensation. The spectrum

analysis for total harmonic distortion is given in Figure 5. From the figure 5, it is observed that the Total Harmonic Distortion (THD) is within permissible limits.



**Figure 4. Performance of DVR under 3phase fault (a) uncompensated voltage (b) Injected voltage by DVR (c) Compensated voltage**



**Figure 5. THD of load voltage for DVR with neural controller**



**Table 2 THD Analysis for both conventional and artificial intelligent controllers with DVR**

Controller Type	Voltage in Volts	THD in %	Power Factor
PI Controller	390	7.9	0.87
Fuzzy Controller	422	5.68	0.92
Neural Controller	430	4.39	0.96

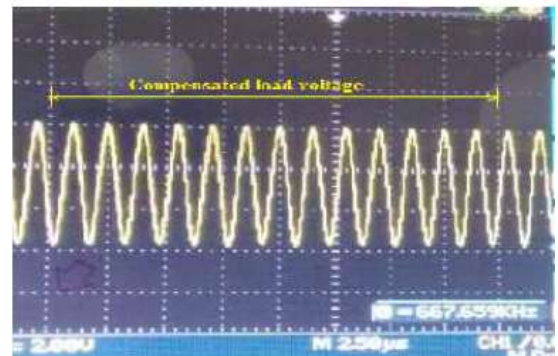
From the results shown in table 2, it is concluded that the THD of the DVR with neural controller shown in figure 3b indicates that THD is improved to 4.39%. In addition, the results indicate that there is a significant improvement in load power factor also. From the results, it is proven that the time taken to bring back voltage is also found to be significant and it is around only 2 milliseconds. Hence, from the table, it may be concluded that the proposed DVR with Neural controller provides the best results when compared to other controllers namely PI and Fuzzy controller.

#### 4. HARDWARE DESCRIPTION AND RESULTS

Hence in order to examine the performance of the proposed DVR, a proto type model of a single phase, 24W, 12Volts AC system is fabricated. Figure 6 shows the experimental set up of the proposed system. The PIC micro controller 16F887 controls the gating signal of the circuit.



**Figure 6. Experimental set of the proposed system.**



**Figure 7. Load Voltage compensated by DVR**

The voltage compensated by the DVR is shown in the Figure 7. From the figure, it is concluded that, load maintains the voltage level. Therefore, from the experimental waveforms, it is concluded that the designed DVR system is capable to compensate the voltage sags quickly.

#### 5. CONCLUSION

In this work, a Multi-level inverter based DVR system for power quality improvement is proposed. It analyzed the performance of the proposed DVR with both conventional and artificial intelligent controller. A PSO based MPPT technique is tailored to track maximum power from the solar system. From the results, it is also proven that all the proposed DVR with neural controller satisfactorily provides the best results and the THD of the proposed methodology comply with the IEEE standards.

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