Voltage Quality Improvement using DVR with Novel Control Strategy

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Abstract - *Voltage sag, swell and harmonic distortion are the key power quality concerns addressed by the distribution network. The presence of non-linear loads and renewable energy sources like solar, wind etc. is the reason for power quality issues. These necessitates the need for the development of a power quality conditioner to compensate the effects of these power quality problems. Hence a Dynamic Voltage Restorer is developed and deployed to improve power quality by decreasing harmonics and adjusting for voltage swell and sag. A two-stage energy conversion device connects the PV system to the PCC (Boost converter and inverter) system. The incremental inductance approach is used to extract maximum power from solar energy. DVR control is achieved by regulating the load voltage under a variety of unexpected working conditions. Artificial Neural Network controller based DVR is carried out. The simulation results show that the Artificial Neural Networks based DVR with a THD of 2.84 % outperforms the PI-based controller THD of 4.48%.*

Key Words: Voltage sag, Voltage swell, Harmonics, Dynamic Voltage Restorer, PI controller, Artificial Neural Network (ANN)controller.

1.INTRODUCTION

The Electrical energy generated is insufficient to meet our country's increased demand. As a result of the reduction in conventional energy sources of supply, research into alternative energy sources has begun. The two common nature of non-conventional energy sources are accidental variability and existence of static converter will cause power quality issues. These characteristics can create phenomena voltage sag and swells, including flickers, voltage sag and swells, high voltage and low voltage ride-through, harmonics, poor power factor, and power quality issues, fault ride-through, which are among the top concerns of utility companies. Understudy, the Dynamic Voltage Restorer (DVR) is incorporated into a power grid associated to a PV plant to handle solar energy's intermittency and variability, as well as grid failures lead by voltage sags and swell at the Point of common connection (PCC). The suggested DVR control technique handles a proportional integral controller(PI), an Artificial Neural Network(ANN)controller, and an in-phase compensation approach. The describe DVR and the electric system are evaluated in various fault scenarios.

Power quality issues have become a major problem to the modern power system. These power quality issues mainly include voltage quality disturbances. Voltage sag, swell and harmonic distortions are the most commonly occurring voltage quality disturbances. There are various reasons for the cause of voltage sag and swell. Sudden appearances of short circuit or fluctuations in load are some of them.

1.1 Literature survey

Many papers have been reported for the power quality issues. A Fuzzy Logic based Dynamic Voltage restorer is proposed in [1]. A PID based control strategy for Power quality improvement is presented in [2]. In [3] PV system is used as energy source for DVR instead of using battery. Made comparison Artificial neural network(ANN)over Hysteresis voltage control technique(HVCT). [4] provides an overview of the DVR control architecture as well as its modelling. It demonstrates that DVRs can effectively restore voltage. The basic construction and operation of DVR are demonstrated. DVR compensating techniques are explored in detail. In [5] PV source injected to DVR instead of using DC source or energy storage unit with the desire of encounter the voltage sag and harmonics. The incremental conductance technique is selected for MPPT. The DVR minimizes harmonics from load voltage accurately. The THD cut down under the SLG fault condition with DVR. The author not going to discuss about the voltage swell. In [6] different control techniques for Voltage Source Inverter (VSI) are introduced. Various control schemes are demonstrated and explored. The effectiveness of various strategies is assessed and contrasted. [7] presents a controller for DVR all right to increase the performance of OFF-grid hybrid RES. The suggested controller adjusts the voltage between the DVR and the load in order to reduce system disruption and hence increase system performance. The results of a comparison of PSO-tuned PI and Intelligence technologies for controlling DVR are presented. In [8] presents, the DVR technique was used to adjust for voltage sag and voltage swell in a PV grid-connected scheme. The fault analysis is complete is done, and a PI controller approach for compensation of voltage sag and swell has been discussed in this paper. In [9] controller's is used to adjust the injected DVR voltage in order to enhance the voltage profile at both the PCC and the load during abnormal operating circumstances. The CS optimization technique is utilized to identify the ideal parameters of the two PI controllers introduced by minimizing the ISE between the load voltage and a reference voltage under various abnormal operating scenarios. [10] deliberate the DVR control method by PI controller with the series control module and shunt control module to enhance the power system quality. The suggested control technique can be done using single-phase compensation system or three phase compensation modules, build upon the required voltage sag and voltage swell condition. [11] presents two promising controllers like PI controller and Park transformation controller to mitigate the voltage sag. Compare to PI controller, Park transformation controller gives better results. [12] presents the studies on fuzzy polar controller for reducing the voltage sag and swell. The results show that fuzzy polar controller is better than PI controller. The simulation of discrete PWM based PI control and Hysteresis voltage controller (HVCT)for Dynamic Voltage Restorer using MATLAB has been presented in [13]. PV system is considered as input source to the DVR. Novel control strategy is used to mitigate the power quality issues like voltage sag, swell and harmonics [14]. [15] presents a fuzzy control-based DVR approach for compensation of voltage sag and voltage swell. Section 2 comprises of proposed system. Section 3 comprises simulation studies.

2. PROPOSED SYSTEM

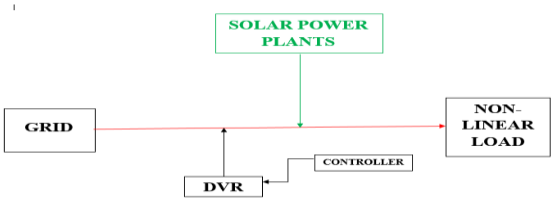


Fig-1: Proposed System Block Diagram

2.1 Dynamic Voltage Restorer:

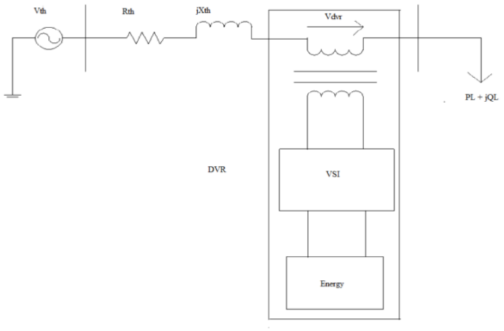


Fig-2: Shows a DVR's schematic diagram.

The main principle of the DVR is to maintain the constant load voltage during sag or swell conditions. Dynamic voltage restorer gives an economical solution to compensate the voltage sag and swell as well as other power quality issues compared to other custom power devices. The block diagram shows in Figure 2 the components of Dynamic voltage restorer (DVR) which is kept in between the grid and Non-linear load where it mainly consists of 4 components like voltage source inverter, injection transformer, filter, energy storage element, controller among them control system is the brain of the DVR which detects the voltage sag and swell that occurs at the time of the power transmission from supply to load and then activates the Voltage source converter (VSC) to generate required voltage waveform of magnitude and phase angle in order to calibrate the essential voltage sag or swell that is occurred.[3] The voltage source inverter(VSC)converts the DC voltage from the energy storage system to a regulated three phase AC voltage during voltage disturbances to keep the load voltage at the desired level. In this investigation, inverter side filtering is featured. The high-order harmonic currents are interrupted from getting within the sequence transformer using this filtering system, lowering the voltage urgency on the transformer.

2.2 Solar Power Plant:

Photovoltaic cell is a device which converts visible light in to direct current, solar panels or arrays can be formed by connecting the PV cell in series or parallel as per the requirement. The major advantage of using photovoltaic is it is eco-friendly, and the solar energy is unlimited. Once the PV module is installed it provides energy at essential cost with minimal maintenance. It is composed of five solar forms of 100kW each. The solar forms are interfaced to the distribution grid through a three phase PWM inverter. The PV array used in this simulation examine comprises of seven (7) modules in series line and forty-seven (47) parallel strings are used generate 100 kW at 1000 W/m2 solar irradiation and 380V output DC voltage. The Incremental Conductance (InC) technique is used in this study, which can be thought of as an upgraded variant of the famous P&O algorithm. This method was recommended to handle immediately changing climatic circumstances. All the five solar forms connected to 30KV distribution grid parallel. The specification details of PV panel shown in the Table 1.

Table-1: Specifications of PV panel

Sl.no	Parameters	Specifications
1	Maximum power/panel(P_{max})	305 W/panel
2	Maximum voltage(V_{max})	54.7V
3	Maximum current/panel(I_{max})	5.58 A
4	Irradiation	1000W/m^2
5	Cell temperature	25°C
6	Ns and Np	7 and 47
7	Each plant output power	100kW
8	Total output power	5 Farms =500kW

2.3 Proportional Integral Controller

The PI controller's general characteristic modelling equation is as follows:

$$y(t)=Kpe(t)+Ki\int e(t)dt \qquad (1)$$

y(t) is the controller's output, while e(t) is the error signal. The feedback PI controller has the advantage of being developed in such a way that the steady state error is zero. The plant is controlled by the feedback controller, which uses a weighted sum of the errors and the integral of that value. The proportional response is obtained by accumulate the error by the proportional gain constant, Kp. The donation of the integral terms is proportional to the error size and period. To get the accumulated offset that was previously rectified, multiply the error by the integral gain, Ki, and then integrate it with 58. The values of Kp and Ki have a big impact on the PI controller's performance. For each of the quadrature phases ‘d' and ‘q,' two PI controllers were employed individually. For the d-controller, Kp and Ki are 40 and 154, respectively, and for the q-controller, they are 25 and 260. All of the gains are used to fine-tune the error signal d and q, ensuring that it is durable and responsive to system disruptions.

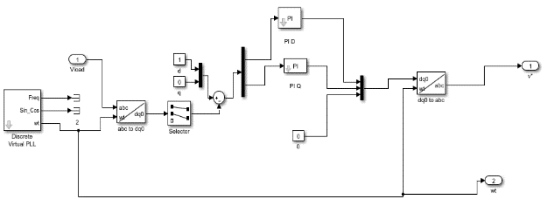


Fig-3: Simulink model PI controller for DVR.

2.4 ANN Controller:

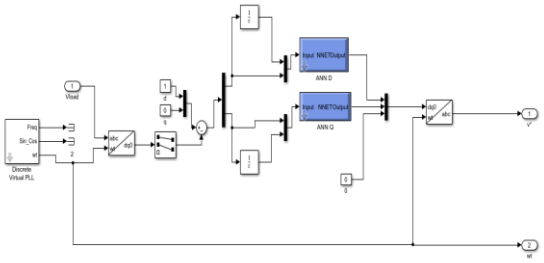


Fig-4: Simulink model of ANN controller for DVR.

The DVR control based on ANN is shown in Figure 4 The controller's main function is to detect voltage disturbances, inject the voltage difference, and then return to standby mode once the disturbances have been erased. The phase lock loop (PLL) in this method tracks the sensitive load voltage.

$$V_d=\frac{2}{3}\left[V_{SLa}\sin\omega t+V_{SLb}\sin(\omega t-\frac{2\pi}{3})\right.$$
$$\left.+V_{SLc}\sin(\omega t+\frac{2\pi}{3})\right] \quad (2)$$

$$V_q=\frac{2}{3}\left[V_{SLa}\cos\omega t+V_{SLb}\cos\omega t\frac{2\pi}{3})\right.$$
$$\left.+V_{SLc}\cos(\omega t+\frac{2\pi}{3})\right] \quad (3)$$

$$V_0=\frac{1}{3}[V_{SLa}+V_{SLb}+V_{SLc}]=0 \quad (4)$$

According to Equations (2), (3) and (4) the three phase load voltage across the sensitive load (VSL) is transformed to Vd, Vq, and Vo using park transformation (4). The benefit of turning abs phases into dq0 components is that the zero sequence component can be separated. The d-q components can be easily regulated in the nonappearance of a zero sequence component. They are compared to reference signals Vd-ref, Vq-ref to generate the error voltage. Vde is the inequality in d-reference and sensitive load voltage acquired by abc-to-dq0 transformation, and similarly q component error voltage (Vqe) is the inequality in q-reference and sensitive load voltage obtained by abc-to-dq0 transformation. The modulating signals for the IGBT pulses are generated by the controllers' outputs Vd* and Vq*.

$$V_a^*=V_d\sin\omega t+V_q\cos\omega t \quad (5)$$

$$V_b^*=V_d\sin(\omega t-\frac{2\pi}{3})+V_q\cos(\omega t-\frac{2\pi}{3}) \quad (6)$$

$$V_c^*=V_d\sin(\omega t+\frac{2\pi}{3})+V_q\cos(\omega t+\frac{2\pi}{3}) \quad (7)$$

The dq0-to-abc transformation is applied to these output signals. Equations (5), (6), and (7) explain how to convert dq components to abc phases in the nonappearance of a zero sequence component (7). The zero sequence component has been deactivated. These voltages (Vabc*) are utilized to improve the performance of the Dynamic Voltage The dq0-to-abc transformation is applied to these output signals. Equations (5), (6), and (7) explain how to convert dq components to abc phases in the nonappearance of a zero sequence component (7). The zero sequence component has been deactivated. These voltages (Vabc*) are utilized to improve the performance of the Dynamic Voltage Restorer by generating pulses in the voltage source inverter.

3. SIMULATION RESULTS AND ANALYSIS:

The DVR regulates the voltage about a 30 kV distribution grid system associated to bus B2 and has a 4MVA power rating. One feeder supplies electricity to a resident load attached to bus B3, which depicts a plant that is constantly consuming oscillating currents and, as a result, creates voltage flicker. The DVR injects an adequate voltage to adjust the voltage of the buses B1&B3. This voltage carry is accomplished by the coupling transformer's reactance, which produces a secondary voltage that is in phase along the primary voltage (grid side). During a simulation time of three seconds, the simulation scheme examined in this case study abide of establishing two types faults of 0.3 second length each. As illustrated in Figure 7, the first type of fault is a swell voltage that occurs at intervals of the duration from 0.8 seconds and 1.1 seconds, and the second type of fault is a voltage sag that occurs at intervals of the duration from 1.25seconds and 1.55 seconds. The swell voltage defect is modelled as a 20% rise in nominal voltage, whereas the sag voltage is modelled as a 10% reduction in nominal voltage.

Table-2. The simulation parameters.

Sl.no	System Parameters	values
1	Supply voltage and frequency	30kV, 50Hz
2	Load	R_L=60ohm, L_L=0.15 mH
3	DC supply	70kV
4	Filter	$C_{F=}100\mu F$
5	DVR	4MVA

3.1 Modelling of Test System in Mat-Lab Environment.

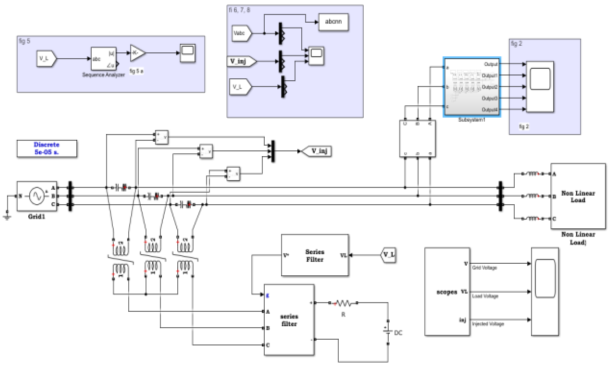


Fig-5: Modelling of TEST SYSTEM in MATLAB environment.

DVR is connected in between grid and nonlinear load through injection transformer and filter. Five PV forms are connected to distribution grid through DC-DC converter and inverter, all the five PV forms are connected in parallel. Each solar plant generates 100KW and output voltage is 380V. PV farm of 500 kW connected to grid shown in the figure 5 below. Each power plant operates in different irradiation at 25°C.

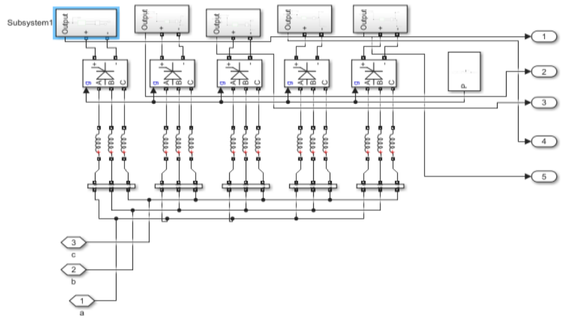


Fig-6: Grid connected Photovoltaic farm

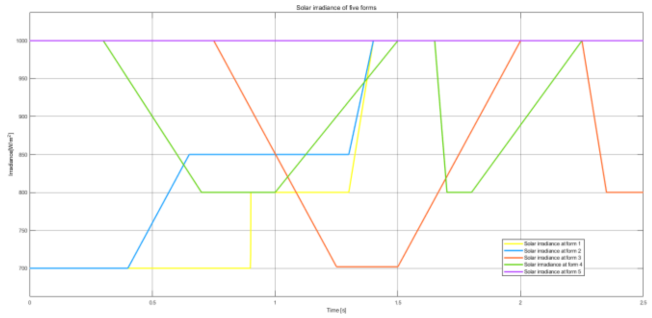


Fig-7: A temperature of 25°C, the solar irradiances of the five solar photovoltaic farms were measured.

3.2 Case studies

[1]. Voltage Swell Condition

[2]. Voltage Sag Condition

[3]. Combined voltage Swell and voltage Sagcondition.

The DVR injects a compensating voltage when the voltage swell/raise occurs at 0.8 second, and the steady state is reached after a transient of around 0.11 second, as shown in Figure9.

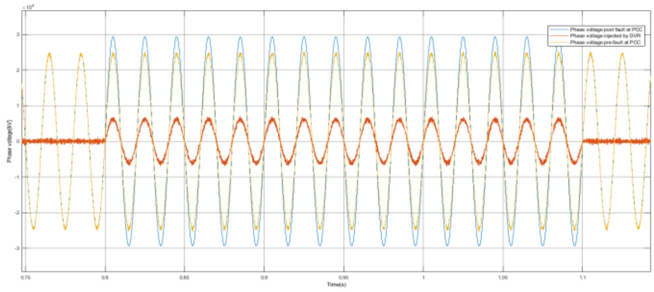


Fig-8: Phase voltage during voltage swell

The grid voltage at the Point of common Connection achieves steady state after 2 cycles, or roughly 0.03 seconds, current the scenario of voltage sag/dip happening at 1.25 sec, as shown in Figure 10.

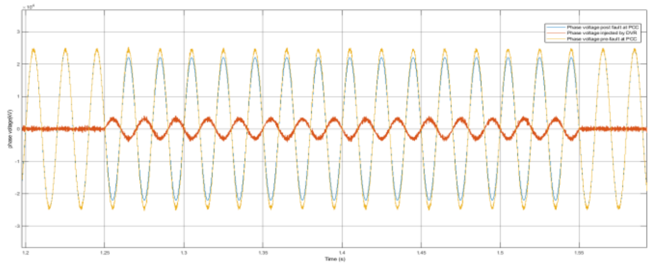


Fig-9: Phase voltage during voltage sag

The dynamic voltage restorer(DVR) is in mode of standby at the time of normal operation. As shown in Figures 8,9and 10 when a voltage swell/raise arise, the controller identifies the system failure and the DVR injects the required voltage.

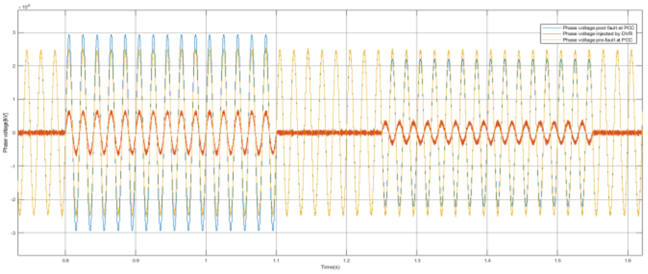


Fig-10: Waveforms for voltage sag and voltage swell

Figures 11,12 and 13 show the active power and reactive power capabilities. When the DVR is not in operation, we can witness slight abandon and swaying in the active power in Figure 11 and during the swell fault, although the oscillations are totally suppressed during the DVR is turn on, as seen in Figure 12. The grid voltage produces a strong transient lasting 9 cycles when a sag fault occurs without DVR, which is entirely damped when DVR is used, as seen in figure 12.

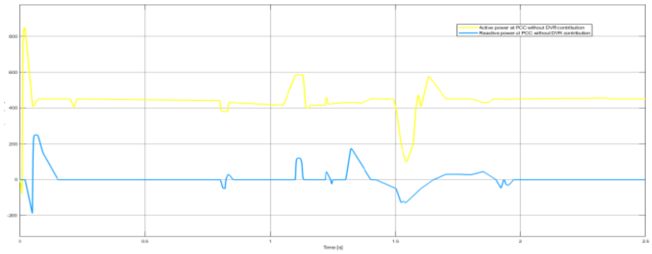


Fig-11: Active and Reactive power without DVR

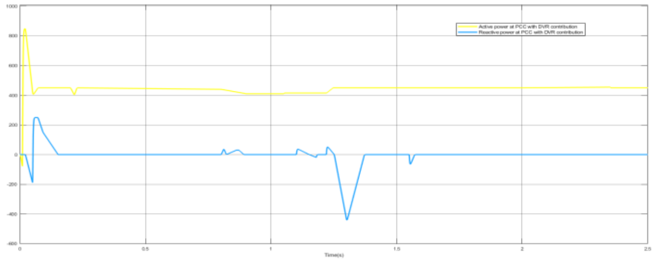


Fig-12: Active and Reactive power with DVR

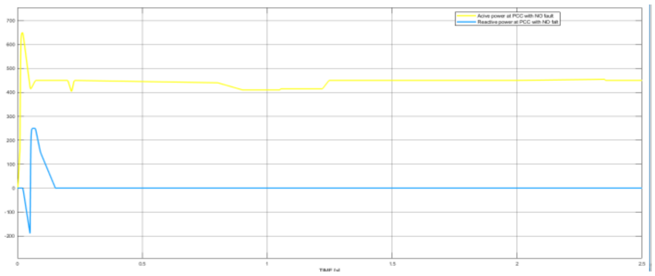


Fig-13: Active and Reactive power without fault

The reactive power (blue wave-form) flow at the Point of common connection at the time both faults, as shown in Figures 11,12 and 13 at that time the voltage swell/raise fault, the waving of reactive power are very crucial than during the sag fault, where the overshoots are lesser in amplitude with the DVR donation. When a voltage sag fault occurs, the movement of reactive power rises in magnitude, direction, and duration without the DVR. The reactive power reveals a high abandon at 1.39 seconds, analogues to an inoculation of +181.2 kVar, after a brief oscillation at the commencement of the fault. At 1.535 seconds, the reactive power dropped to -139.1 kVar, and after numerous oscillations, the system's natural activity was renewed finally of the sag fault at 1.957 seconds, as opposed to the situation with DVR donation, when the oscillations were entirely saturated at 1.69 seconds.

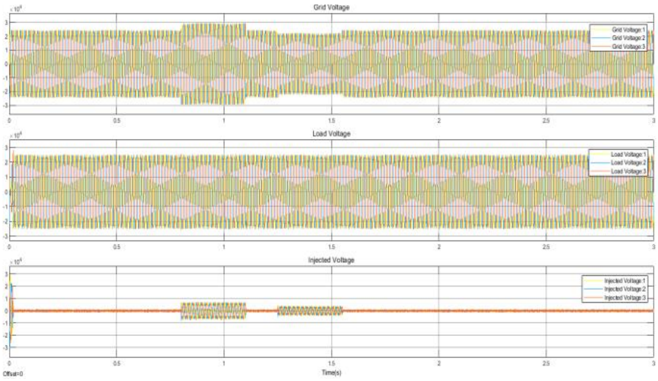
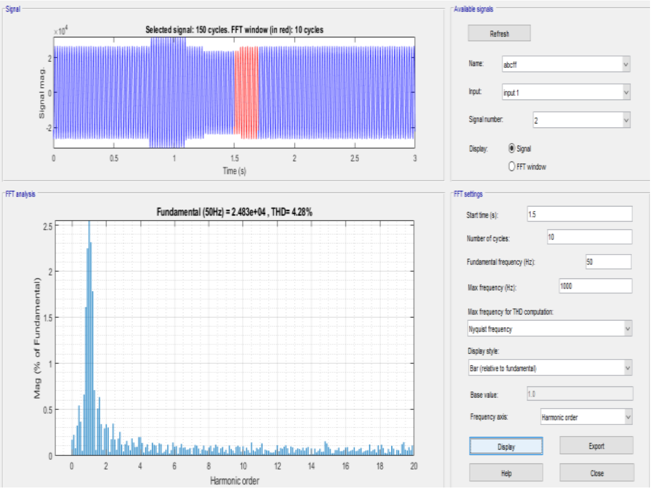
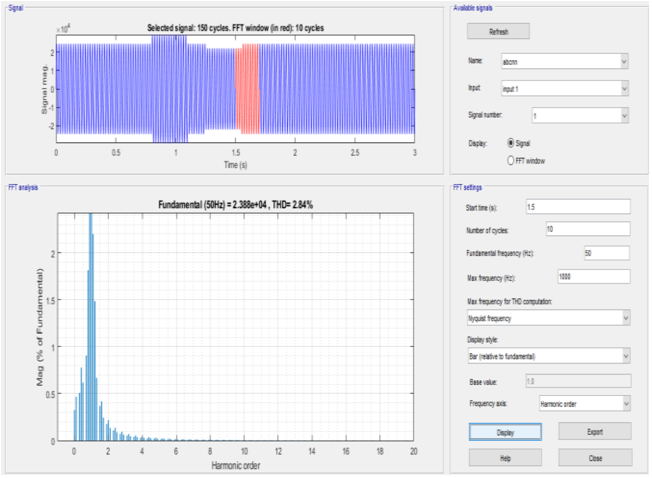


Fig-14: Performance of DVR with ANN Controller.



Name: abcff
Input: input 1
Signal number: 2
Display: ● Signal ○ FFT window
Start time (s): 1.5
Number of cycles: 10
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order

Fig-15: THD graph for PI Controlled DVR.



Name: abcnn
Input: input 1
Signal number: 1
Display: ● Signal ○ FFT window
Start time (s): 1.5
Number of cycles: 10
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order

Fig-16: THD graph for ANN Controlled DVR.

Figure 15and 16 show the values of THD with PI controller and ANN controller respectively. It can be seen that with PI controller the THD is 4.28% and with ANN controller it is 2.84%. Use of ANN controller gives the better value of THD thereby increasing the system performance.

Table-.3: Load Voltage THD Analysis.

Sl.No	**System**	**THD in %**
1	Without controller	24.98%
2	With PI controller	4.28%
3	With ANN controller	2.84%

In this section two different controllers viz., PI controller and ANN controller have been used to analyze THD value. These controllers are used to give signals to VSC in case of fault condition. From the analysis it can be concluded that the use of ANN controller provides lower value of THD thereby increasing system performance.

4. CONCLUSION

Power quality issues have become a major problem to the modern power system because of high penetration of renewable energy sources(solar) and nonlinear loads These power quality issues mainly include voltage quality disturbances like Voltage sag, swell and harmonic distortions. A literature review on different aspects of power quality is conducted. Based on the literature survey the research objectives are defined. In this work DVR based power quality enhancement is presented. Detailed Modelling of the solar PV cell and boost converter discussed. Simulation studies in MATLAB is conducted to assess the performance of the proposed controller. From the results it is observed that with ANN based DVR the THD is 2.48%, against PI controller-based DVR the THD is 4.28%. In comparison to the PI controller and ANN controller is the best method for solving the power quality issues related to sag and swell

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