World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Comparative analysis of Dynamic Voltage Restorer based on PI and ANN Control strategies in order to improve the voltage quality under Non-linear loads.

Arjun Joshi [1,*], Gaganambha [1], Dharshan B G [1], Varsha V [1], Shamala N [1], Spoorthi S N [1] and Reshma [2]

[1] *Department of EEE, Vidya Vikas Institute of Engineering & Technology, Mysuru, Karnataka, India.*
[2] *Department of EEE, Sapthagiri NPS University, B. lore Karnataka, India.*

World Journal of Advanced Research and Reviews, 2024, 22(03), 292–303

Publication history: Received on 25 April 2024; revised on 03 June 2024; accepted on 05 June 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.3.1706

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. 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%.

Keywords: 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. 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.

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

* Corresponding author: Arjun Joshi

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.

2. Proposed system

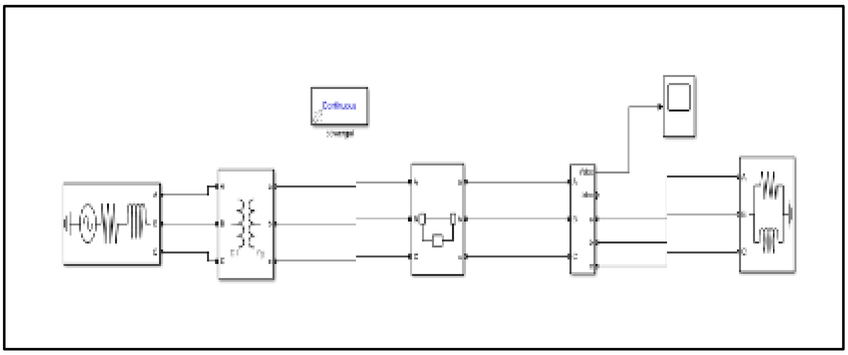

Figure 1 Proposed System without any fault

In the above system there is a generator i.e. Three phase source directly connected three phase parallel **RLC** load. In between three phase source and load there is three phase breaker for open /Close the complete circuit without any fault. Figure 2. 3-phase wave form in PU Value 1.

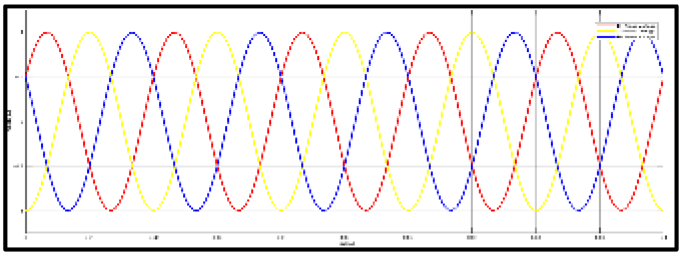

Figure 2 3-Phase wave form without any fault.

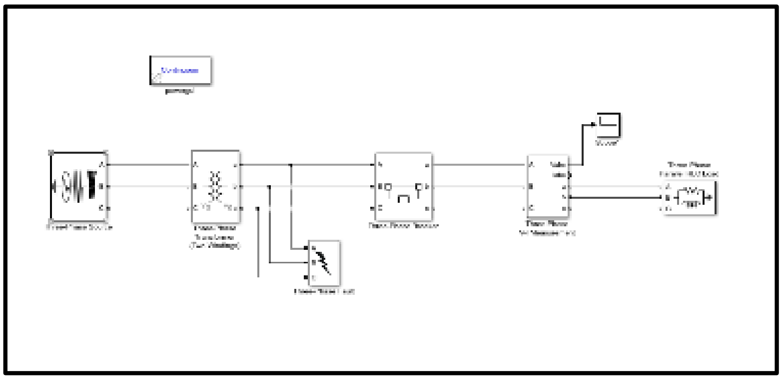

Figure 3 Proposed System Block Diagram

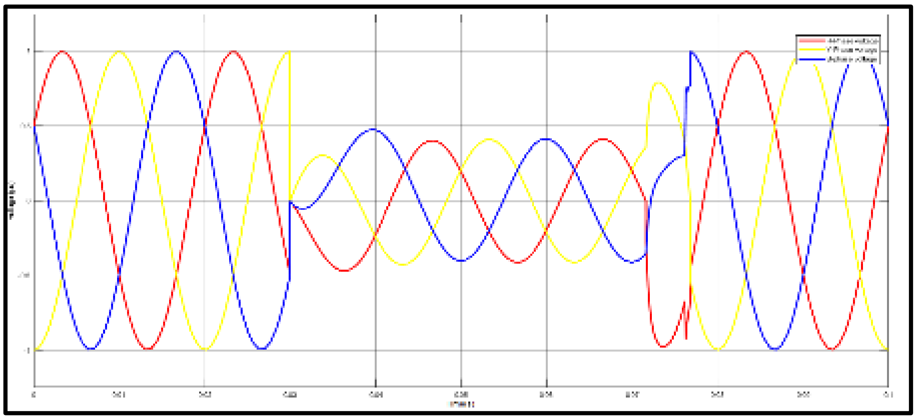

Figure 4 3-Phase fault wave form with fault

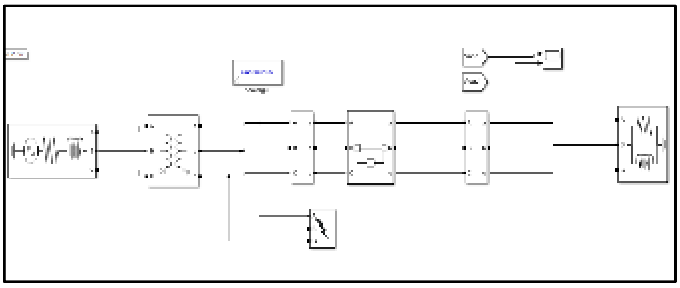

Figure 5 Proposed System gives both grid and load voltage.

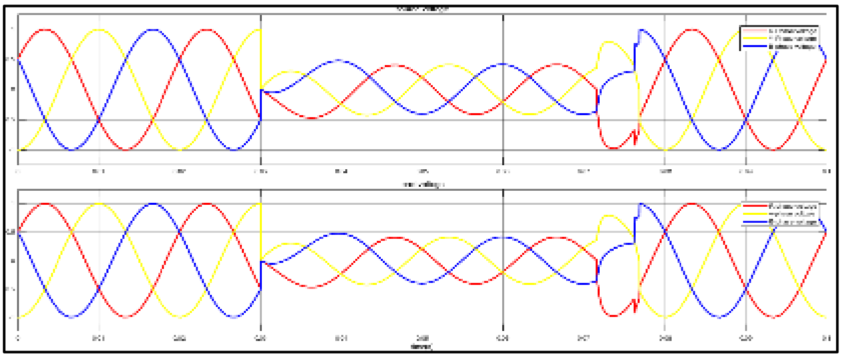

Figure 6 3-Phase wave form gives both grid and load voltage

Three phase fault block will going use for create a Sag artificially this paper presents dynamic voltage restorer (DVR) test systems using MATLAB Simulink for minimizing voltage sag by two promising controlling strategies: Control using PI controller and ANN controller. The first control method uses PI controller where the magnitude of Figure1 shows Proposed System Block Diagram. The proposed DVR control technique employs a PI controller and ANN controller and an in phase compensation scheme. The designed DVR and electric system are evaluated under various fault conditions.

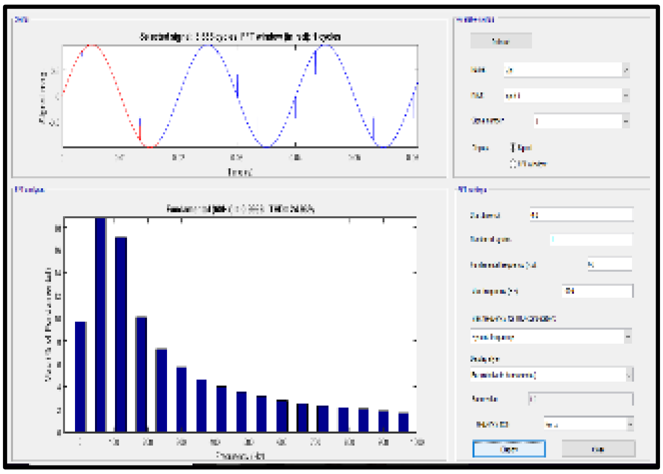

Figure 7 THD graph for without any DVR

Without DVR the system will give 24.93% THD, this percentage is not acceptable this should reduce to less than 5% with help of PI and ANN controller.

2.1 Dynamic voltage restorer

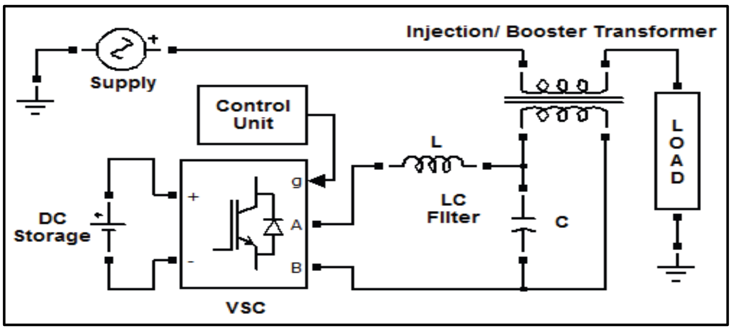

Figure 8 DVR's schematic diagram.

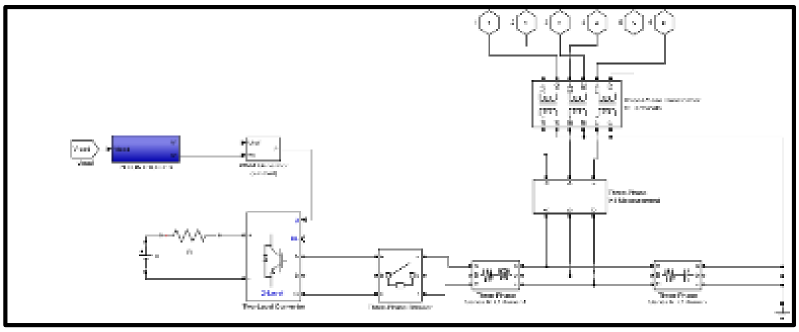

Figure 9 Simulink Model of DVR

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 7 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 Proportional integral controller

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

$$(t)=K(t)+Ki\int e(t)dt \quad (1)$$

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, K_P. 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, K_i, and then integrate it with 58. The values of K_P and K_i 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, K_P and K_i 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.

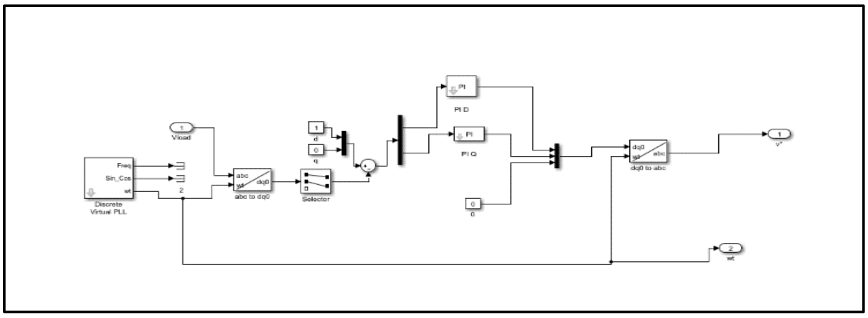

Figure 10 Simulink model PI controller for DVR

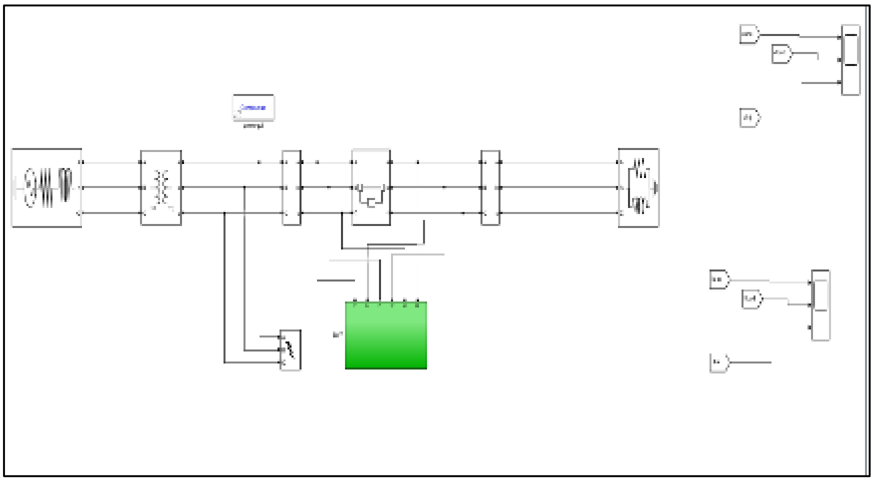

Figure 11 Simulink model DVR with PI controller

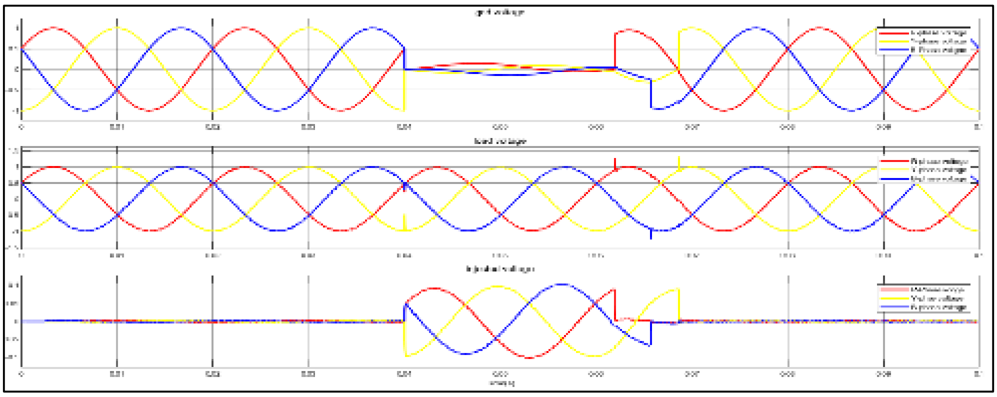

Figure 12 3-Phase wave forms

First wave form = Grid voltage; Second wave form=load voltage; Third wave form=Injected voltage

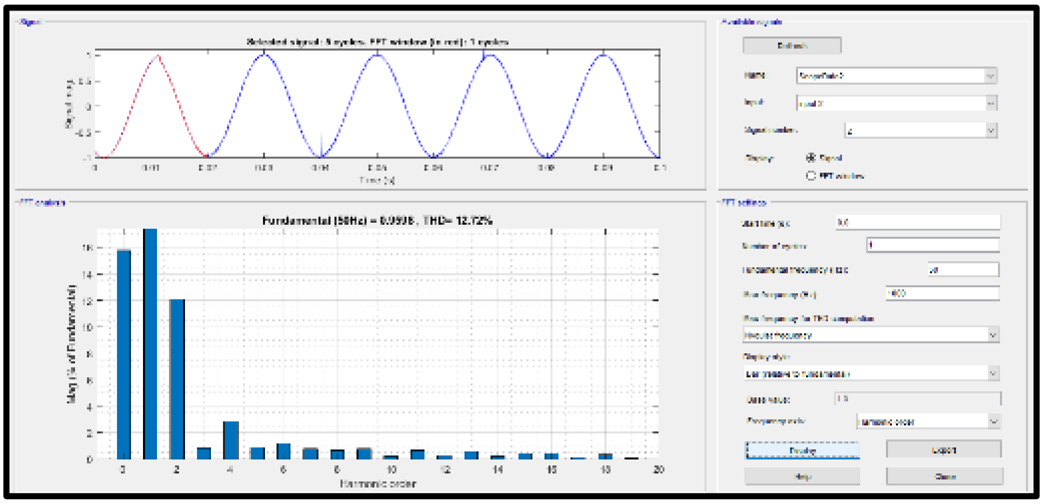

Figure 13 THD graph for with DVR and PI controller

DVR under PI controller it will going give 12.72% THD compare to with any DVR THD will get improve with DVR with PI Controller.

2.3 Proposed system with NON linear Load.

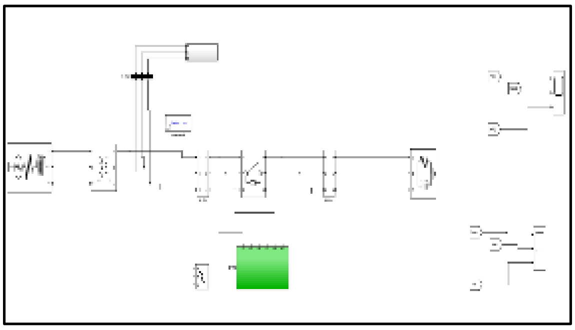

Figure 14 Proposed system with NON linear Load.

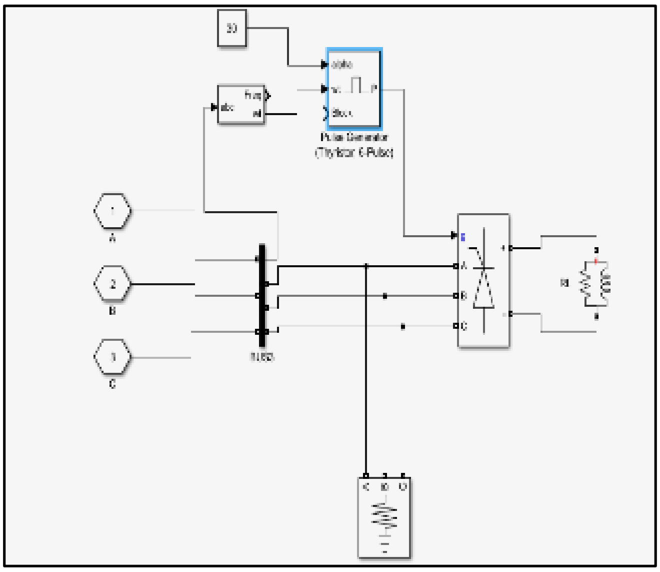

Figure 15 Simulink Model of Nonlinear load.

Increasing non-linear loads cause various undesirable effects and power quality problems. The use of power converters, electronic equipment's and other non-linear loads are rapidly increasing in industry and also by consumers. This equipment's draw non-linear currents from the AC mains as compare to traditional loads such as motors and resistive heating elements. This leads to the distortion of power system voltage and current and other problems. Here, the power quality with nonlinear load is studied and total harmonic distortion (THD) is calculated under this condition by using Fast Fourier Transform (FFT) method.

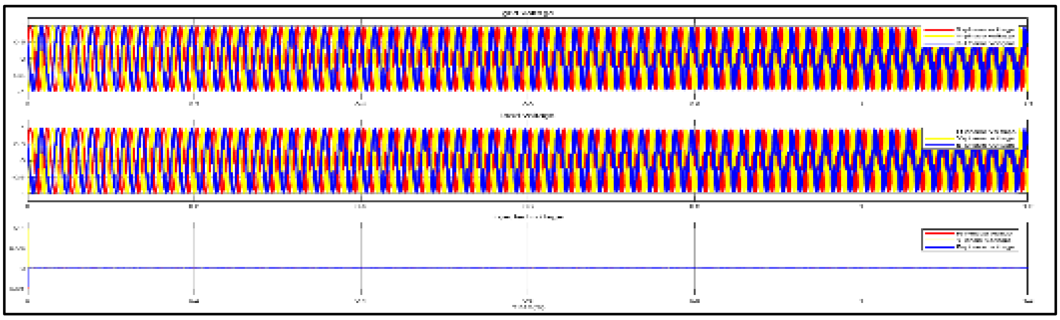

Figure 16 Wave form without DVR for Nonlinear load.

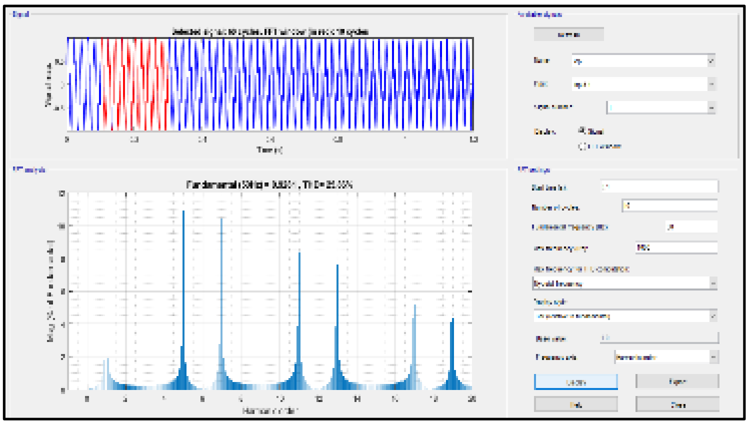

Figure 17 THD graph for without DVR for Nonlinear load.

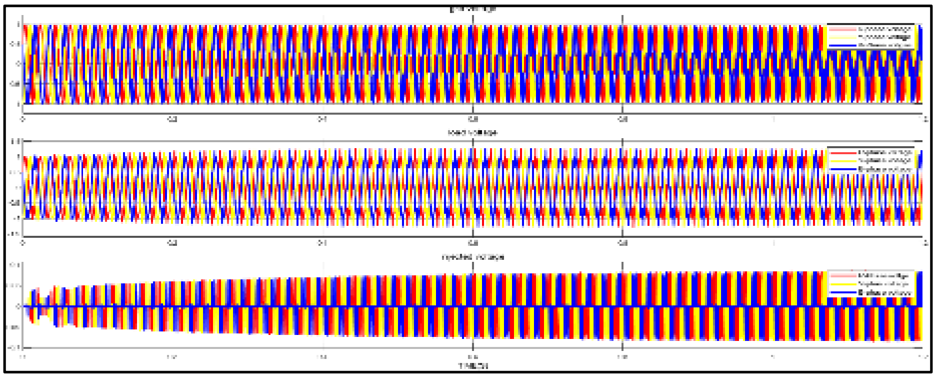

Figure 18 Wave ae form with draw for Nonlinear load

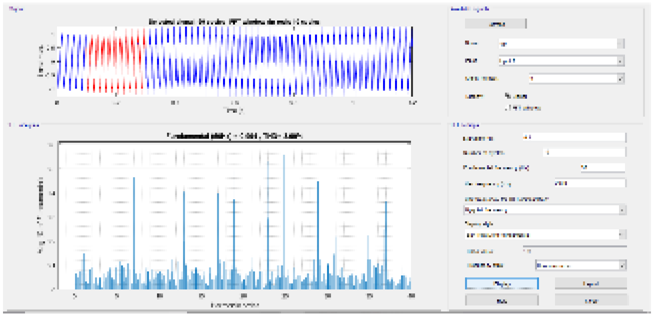

Figure 19 THD graph for without DVR for Nonlinear load.

2.4 ANN controller

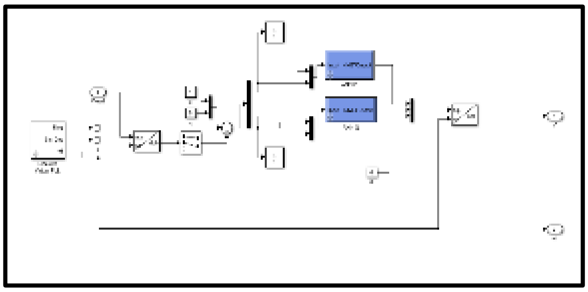

Figure 20 Simulink model of ANN controller for DVR

The DVR control based on ANN is shown in Figure 3.8. 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.

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

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

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

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*.

$$V_a^* = V_d \sin \omega t + V_q \cos \omega t \tag{5}$$

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

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

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 Restorer by generating pulses in the voltage source inverter.

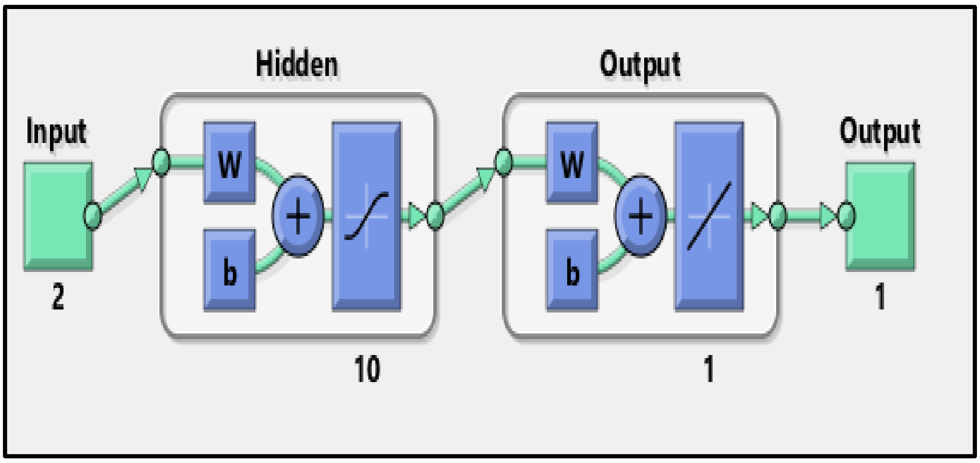

Figure 21 Simulink model of ANN controller for DVR.

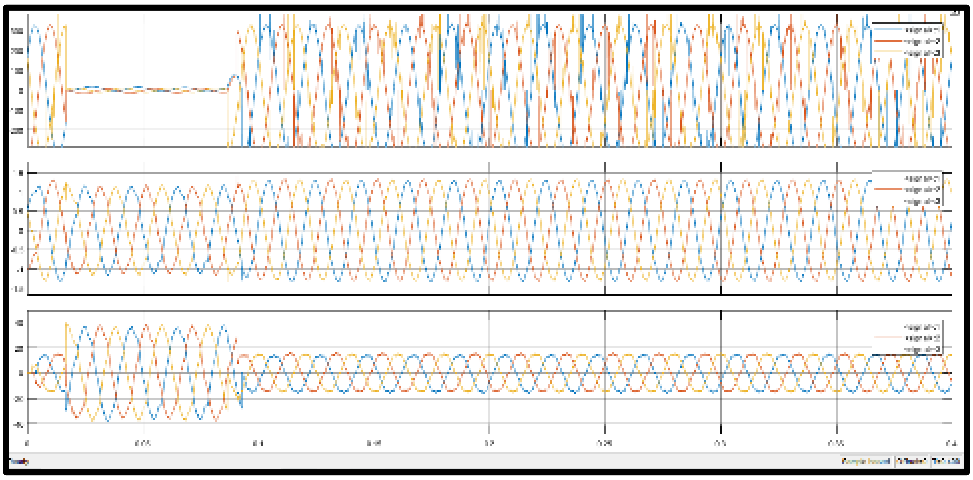

Figure 22 Wave form with ANN controller

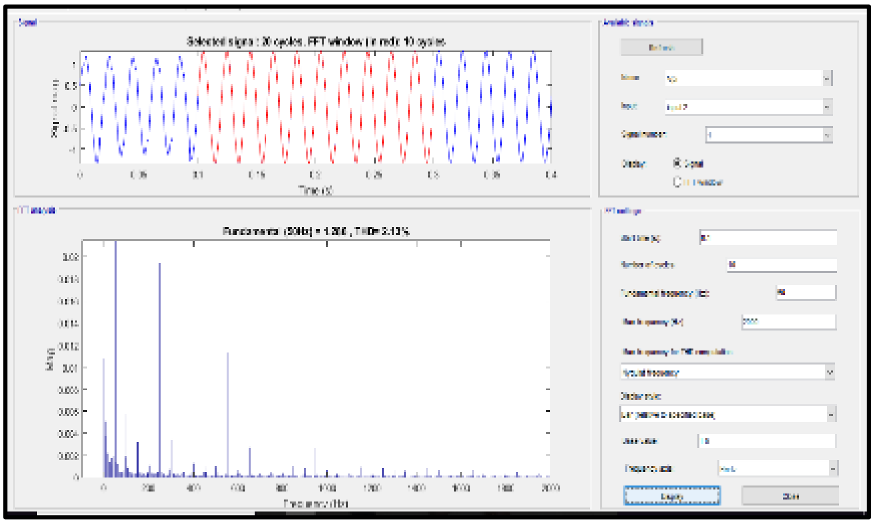

Figure 23 THD graph for with ANN controller

3. Simulation Results and discussion

The DVR regulates the voltage about a 440 V 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 B1andB3. 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 8, 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 1 The simulation parameters

Sl.no	System Parameters	Values
1	Supply voltage and frequency	440V, 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

Table 2 Load Voltage THD Analysis.

Sl.No	System	THD in %
1	Without controller	24.98%
2	With PI controller	4.28%
3	With Nonlinear load without DVR	25.86%
4	With Nonlinear load with DVR-PI	3.99%
5	With ANN controller	2.13%

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 2.18%, against PI controller based DVR the THD is 12.72%. In comparison to the PI controller and ANN controller is the best method for solving the power quality issues related to sag and swell.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Benali Abdelkrim, Khiat, Mounir Denai, Mouloud, "Voltage profile and power quality improvement in photovoltaic farms integrated medium voltage grid using dynamic voltage restorer," International Journal of Power Electronics and Drive Systems, vol.11, no.3, 2020.

[2] M. S. Haque Sunny, E. Hossain, M. Ahmed and F. Un-Noor, "Artificial Neural Network Based Dynamic Voltage Restorer for Improvement of Power Quality," IEEE Energy Conversion Congress and Exposition, pp. 5565-5572,2018.

[3] A. M J, S. N and M. S. Shashikala, "Power Quality Enhancement using Dynamic Voltage Restorer (DVR) by Artificial Neural Network and Hysteresis Voltage Control Techniques," Global Conference for Advancement in Technology, pp.1-6, 2019.

[4] Sathish Babu P, Kamaraj N "Performance Analysis of DVR Using ANN Controller for Voltage Quality Enhancement," Applied Mechanics and Materials, pp. 356–61, 2014.

[5] RAMESH T. "Enhancing power quality of ANN controller based Photovoltaic source injected DVR." International Journal of Engineering and Technology, p. 155-160, 2018.

[6] Thana, H.S., Ruban Deva Prakash, "Use of neural network-based DVR for the reduction of power quality issues in composite micro-grid," Ambient Intel Human Compute 12, pp 6285–6294 ,2021.

[7] Wael S. Hassanein, Marwa M. Ahmed, M. Osama abed el-Raouf, Mohamed G. Ashmawy, Mohamed I. Mosaad, "Performance improvement of off-grid hybrid renewable energy system using dynamic voltage restorer," Alexandria Engineering Journal, Vol 59, Issue 3, pp 1567-1581, 2020.

[8] T Sridevi, Y Suri Babu, "Mitigation of Voltage Sag and Swell in A Grid Connected PV System by Using Dynamic Voltage Restorer," International Journal of Creative Research Thoughts, Vol 6, pp.659-665, APRIL 2018.

[9] Mohamed I. Mosaad, M. Osama Abed El-Raouf, Mahmoud A. Al-Ahmar, Fahmy M. Bendary, "Optimal PI controller of DVR to enhance the performance of hybrid power system feeding a remote area in Egypt, Sustainable Cities and Society," Vol 47,2019.

[10] A. Mohamed Eltamaly, Y. Sayed Mohamed, A. Mustafa El-Sayed and A. N. Abd Elghaffar, "Enhancement of Power System Quality Using PI Control Technique with DVR for Mitigation Voltage Sag," Twentieth International Middle East Power Systems Conference, pp.116-121, 2018.

[11] M. Faisal, M. S. Alam, M. I. M. Arafat, M. M. Rahman and S. M. G. Mostafa, "PI controller and park's transformation based control of dynamic voltage restorer for voltage sag minimization," 9th International Forum on Strategic Technology, pp.276-279, 2014.

[12] Pujiantara, Margo, Heri, P.M. Ashari, Mochamad, Hiyama, "Voltage Sag Correction Using Dynamic Voltage Restorer Based Fuzzy Polar Controller," Second International Conference on Innovative Computing, Information and Control, 2007.

[13] G. S. Dua and R. Kaur, "Enhancement of Power Quality in distribution network using DVR," Annual IEEE India Conference, pp. 1-6, 2015.

[14] Syed, Suraya, Sujatha, P. Kumar, "Contemporary Control of DG Integrated DVR for Sag, Swell and Harmonic Mitigation," International Journal of Electrical and Computer Engineering, VL – 8, 2018.

[15] A. Yagavi and P. V. Manitha, "Compensation of Voltage Sag/Swell by Fuzzy Control Based Efficient Power Electronic Module," International Conference on Inventive Research in Computing Applications, pp.559-564, 2015.

Author's short biography

Arjun Joshi Received the B.E. degree in Electrical and Electronics Engineering in the year 2019 from SDM institute of technology ujire and post-graduation degree in Power System Engineering from The National Institute of Engineering (NIE), Mysuru in the year 2021.he is working as Assistant professor in department of Electrical and Electronics engineering at Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka. He has 2.8 years of teaching experience. He published 8 International Journals. His research interest includes Power System Operational Planning and Control, Distribution System Network Reconfiguration, Service Restoration, Distribution System Automation and Distribution Generation, electric vehicle technologies, power quality,EVs.

a