



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



---

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

---

**Volume:** 12    **Issue:** VI    **Month of publication:** June 2024

**DOI:** <https://doi.org/10.22214/ijraset.2024.62925>

[www.ijraset.com](http://www.ijraset.com)

Call:  08813907089

E-mail ID: [ijraset@gmail.com](mailto:ijraset@gmail.com)

# Simulation and Analysis of Dynamic Voltage Restorer with PI Controller under Different Fault Condition

Budhraj<sup>1</sup>, Dr. M.K. Bhaskar<sup>2</sup>, Manish Parihar<sup>3</sup>

Electrical Engg. Department, M.B.M. University, Jodhpur (Raj)

**Abstract:** *This document gives formatting instructions for authors preparing papers for publication in the Proceedings of an IEEE conference. The authors must follow the instructions given in the document for the papers to be published. You can use this document as both an instruction set and as a template into which you can type your own text.*

*The demand for quality power has become a challenging issue for industrial area and consumers. Among them voltage unbalance is considered as the major affecting problem leads to degradation in performance of electrical equipments. FACTS devices used for compensation are the best method to overcome such problem. Among them DVR considered the most efficient and cost effective. In a control system of the DVR main consideration includes: detection of the start and finish of the sag, voltage reference generation, transient and steady-state control of the injected voltage, and protection of the system. In this work, the simulation model of nonlinear load connected power distribution system with Dynamic voltage Restorer controlled by PI Controller has been developed using Matlab/Simulink. In this case we simulate three fault likewise: Three-line to ground fault, Double-line to ground fault and Single-line to ground fault with two different PI controller to study the THD.*

**Keywords:** *PI Controller, DVR, FACTS devices, Power Quality, THD*

## I. INTRODUCTION

With thousands of load centres and hundreds of producing stations connected by extensive power transmission and distribution networks, modern electric power systems are dense networks. Due to significant energy and economic costs, power quality is a key problem in today's industry. Many power quality issues, including voltage sags, swells, and harmonics, as well as the loss of sine waveform purity, are caused by a growing number of sophisticated electrical and electronic devices, such as computers, programmable logic controllers, and variable speed drives. These devices are highly sensitive to disturbances and non-linear loads at distribution systems. One of the worst disruptions to industrial equipment is thought to be voltage sags.

Using a dynamic voltage restorer (DVR) is another power electronic approach for voltage management. One type of specialized power equipment for dependable distribution power quality is the DVR. In order to compensate for fluctuations in voltage, they employ a range of voltage boost methods utilizing solid state switches. DVRs are mostly used for vulnerable loads, where variations in system voltage might have a negative impact on performance.

The DVR is a simple, flexible, and reliable solution for voltage sag problems. In a couple of milliseconds, it may restore the voltage and avoid the load from losing power. The primary function of the DVR is to identify voltage sags and use an injection transformer to inject the missing voltage in series with the bus.

The DVR's output voltage waveform has excellent stability and uniformity. Harmonic adjustment and voltage transient mitigation are features of the DVR. A DVR can be implemented using a variety of circuit topologies and control approaches. Apart from compensating for voltage sags and swells, DVRs can have additional functionalities including line voltage harmonics correction, minimizing voltage transients, and fault current restrictions. An Injection/Booster transformer, a Harmonic filter, a Voltage Source Converter (VSC), a DC charging circuit, and a Control and Protection system make up the overall DVR setup.

## II. DYNAMIC VOLTAGE RESTORER

The basic operation principle of DVR is measuring the missing voltage by using control unit and injecting the dynamically controlled missing voltage in series to the line and providing the load voltage unchanged during sag. The phase angle and amplitude of the injected voltage fluctuate during sag. As a result, the distribution network and DVR will be able to govern the interchange of active and reactive electricity.

An injection transformer, a bank of capacitors for energy storage, and a GTO or IGBT make up a DVR, a solid state power electronics switching device. The load depicted in Fig. 1 is connected in series with a distribution system. Using an injecting transformer, the DVR's main concept is to inject a regulated voltage produced by a forced commuted converter in series with the bus voltage. This voltage is controlled by a DC to AC converter using a sinusoidal PWM approach.

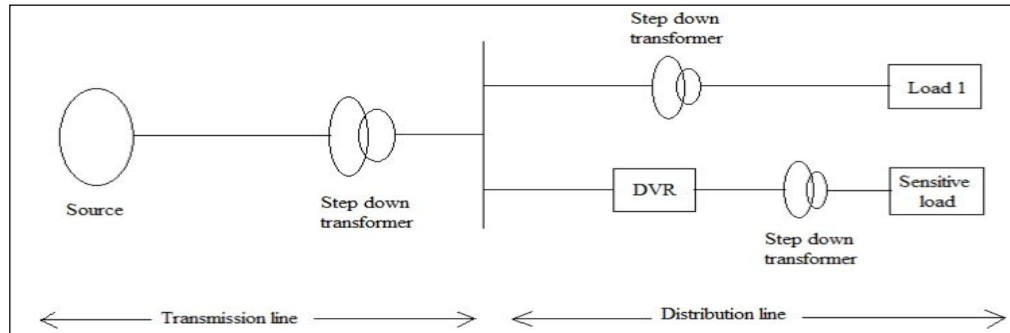


Fig. 1 Location of DVR

The DVR only injects a little voltage during regular operation to make up for device losses and the injection transformer's voltage drop. Nevertheless, in order to maintain output voltage to the load when the distribution system voltage drops, the DVR control system measures and synthesizes the required voltage by injecting a controlled voltage into the distribution system at a certain magnitude and phase angle. This allows it to reach the critical load. It should be mentioned that while the DVR can generate or absorb reactive power, the active power injection for the device has to come from an external energy source or energy storage system. The very quick reaction time of the DVR is restricted by the voltage sag detection time and power electronics components. About 25 ms is the predicted reaction time, which is significantly smaller than some of the more conventional techniques for voltage adjustment, including tap-changing transformers. The primary factors taken into account in a DVR's control system are protection of the system, transient and steady-state regulation of the injected voltage, and voltage reference generation and sag start and end detection.

A controller is a device that is needed to operate or control the DVR only in the event of a malfunction. The linear load voltage is sensed and sent via a sequence analyzer. The benefit of the ABC to DQO transformation is the removal of zero sequence components from the ABC components. There is a different PI controller for the d- and q-coordinates. As shown in fig. 2, the Proportional-integral controller is a feedback controller that is controlled by the summation of the error and integral of those values.

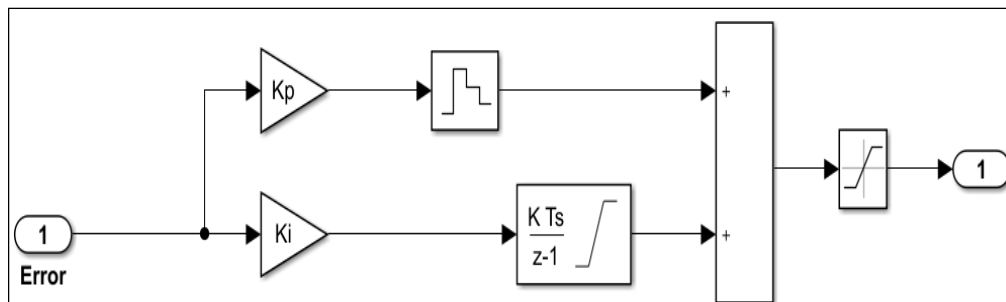


Fig. 2 PI Controller

The PI controller's input is the difference between the real voltage (F2 voltage) and the reference voltage. There are 1 and 0 p.u. as the reference voltages for the d- and q-coordinates, respectively. There are 40 and 154 proportional and integral gains in the d-coordinate PI controller, respectively. The q-coordinate PI controller has a proportional gain of 25 and an integral gain of 260. The PI controller converts its output to a three-phase voltage, which is then fed into a standalone PWM pulse generator. To turn on the IGBT switches, the generated pulse is received by the VSI.

### III. SIMULATION AND RESULTS

The simulation work being done in MATLAB/SIMULINK is presented in this paper. An analysis of the simulation's output to demonstrate DVR's effectiveness and efficiency.

Parameter	Values
Power Supply voltage Frequency	3-Phase, 400V, 50Hz ,
Step down Transformer	11KV /400V, r1= r2= 0.0003 pu , L1=L2= 0.001pu,
Linear load	Active power= 1.5KW, Reactive power= 100VAR
DC voltage	200V DC
Injection Transformer & Ratio	1.5kva, 1:10, r1= r2= 0.00001 pu, x1=x2= 0.0003 pu
PI controller	KPd=40, kId=154 ; KPq=25, kIq=260 ;
LC filter	L=6mH C=20μF
DVR switching frequency	Fs = 2250 (Hz)

The DVR is modelled and simulated using the MATLAB and its Simulink and Sim Power System toolboxes. The MATLAB model of the DVR connected system is revealed in fig. 3, fig. 4, fig. 5.

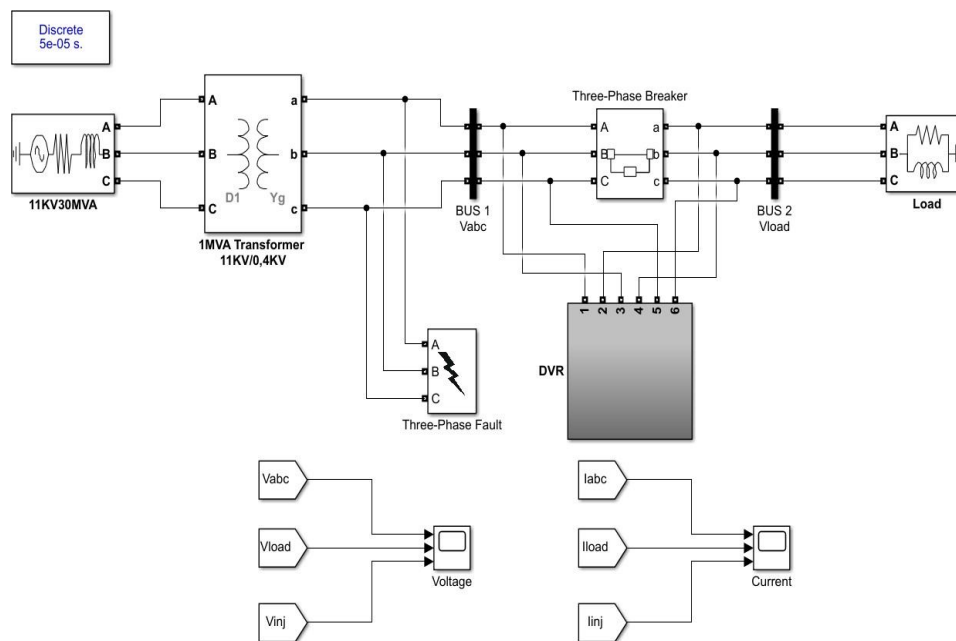


Fig.3 Simulink model of test system

A three-phase voltage source of 11kV has been employed and it is step down to 400 through a three phase delta connected transformer. Intentional fault has been created in all the phase using a three phase fault block. In this distribution system take a RL load, fault time 0.03 to 0.07 sec.

As demonstrated, a two-level converter was used to convert DC to AC. To give the load the proper voltage for operation, a 12-terminal 3-phase transformer has been employed. As mentioned, the controller subsystem is responsible for generating the pwm signal for the DC to AC converter. In the next section all the two type of controller is discussed. The PI controller's general characteristic modelling equation is as follows':

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

y(t) is the controller's output, while e(t) is the error signal. Among the benefits of developing the feedback PI controller this way is that the steady state error is zero. The feedback controller is in control of the plant, which uses a weighted sum of the errors and the integral of that value.

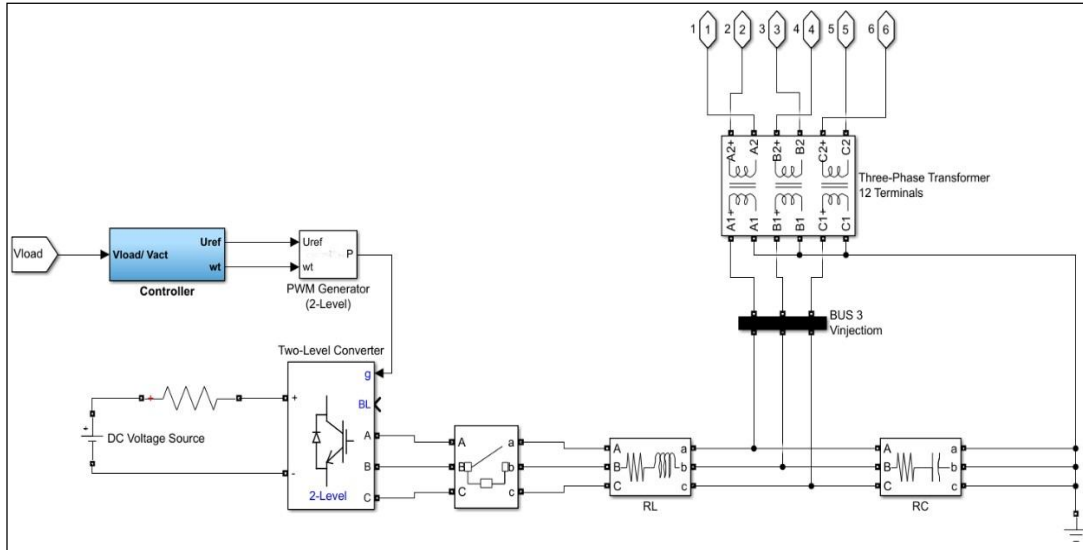


Fig.4 Internal view of DVR

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. The values of  $K_p$  and  $K_i$  have A significant 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, values of  $K_p$  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.

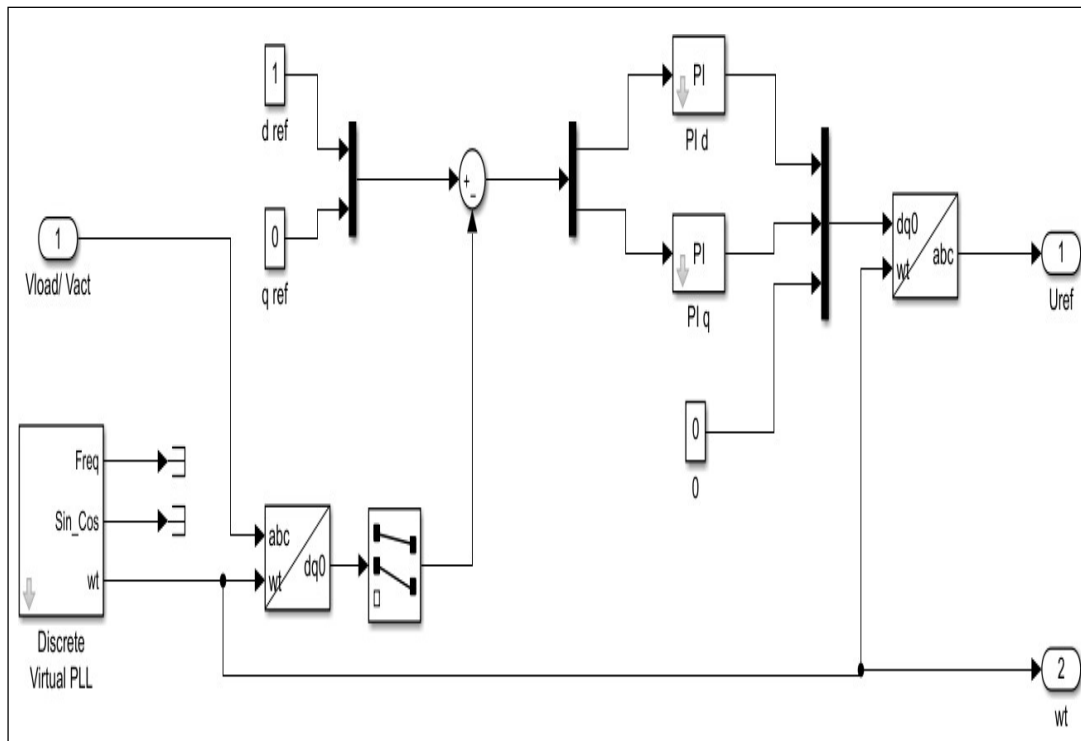


Fig. 5 DVR with PI Controller

A Park transformation in the abc to dq0 block converts a three-phase (abc) signal into a rotating reference frame (dq0). The angular location of the spinning frame is given by the input wt, in rad. PI controllers have been used to identify errors, as seen in the figure. Using the dq0 to ABC block, this error signal is reverse converted to the injected voltage signal.

In this case we simulate three fault likewise: Three-line to ground fault, Double- line to ground fault and Single-line to ground fault with PI controller to study the THD. All Three faults simulated with PI controllers has been discussed in this.

Case 1: Three line to ground fault with PI controller: Whenever a three-line to ground fault (TLGF) occur while causing the voltage to drop below its normal levels. From 0.03 to 0.07 seconds, the entire fault duration is 0.04 seconds. Figure 6 depicts the source, load, and injected voltages in a TLGF situation.

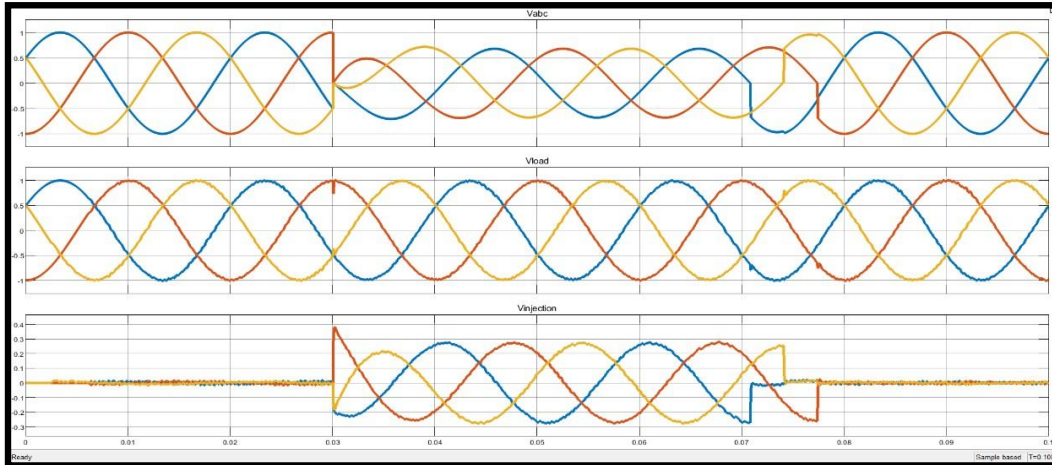


Fig. 6 : Three line to ground fault with PI controller

The FFT analysis of the sensitive load voltage reveals that the load voltage is a perfect sinusoid with an extremely low THD of 2.00% as shown in figure 7.

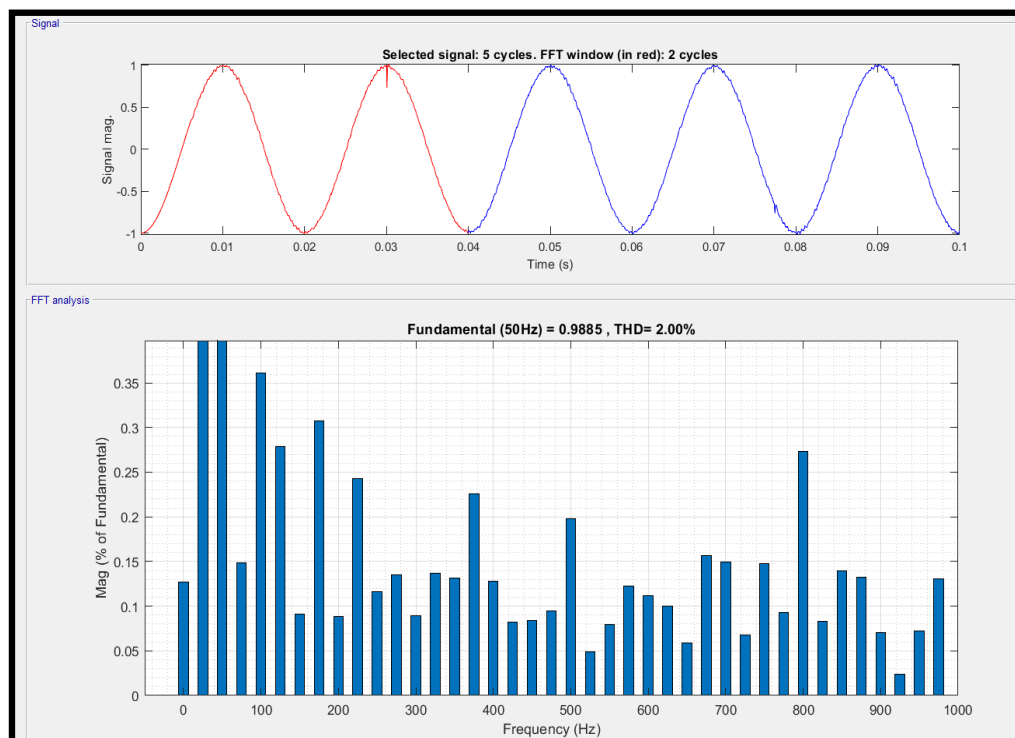


Fig.7 : THD analysis for three line to ground fault with PI controller

Case 2: Double line to ground fault with PI controller: Fig. 8 displays the source voltages, load voltages, and injected voltages observed during this DLGF event. Phase A and B are both affected by a double-line to ground fault (DLGF), which drops the voltage compared to its nominal levels. The fault persists for a total duration of 0.04 seconds, specifically from 0.03 seconds to 0.07 seconds.

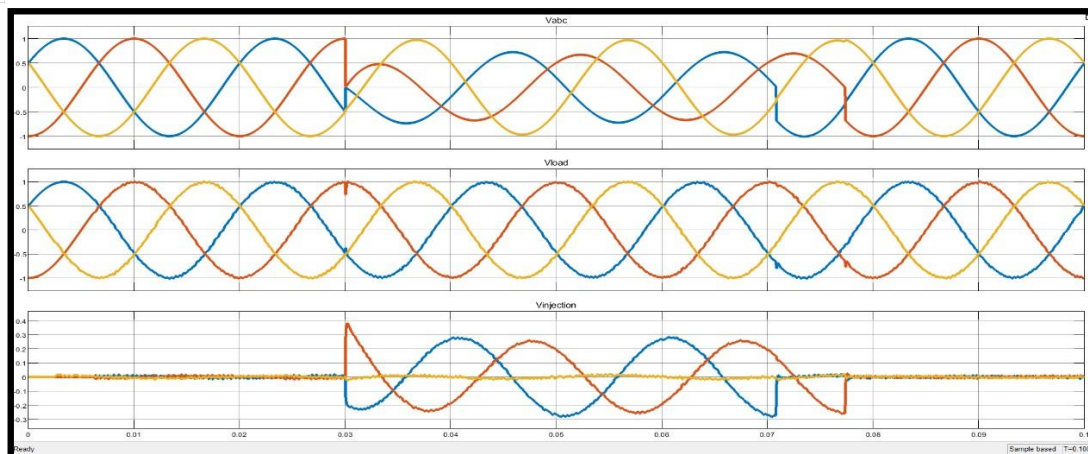


Fig.8 : Double line to ground fault with PI controller

An FFT analysis of sensitive load voltage using a PI-based DVR reveals a THD of around 2.06 %.

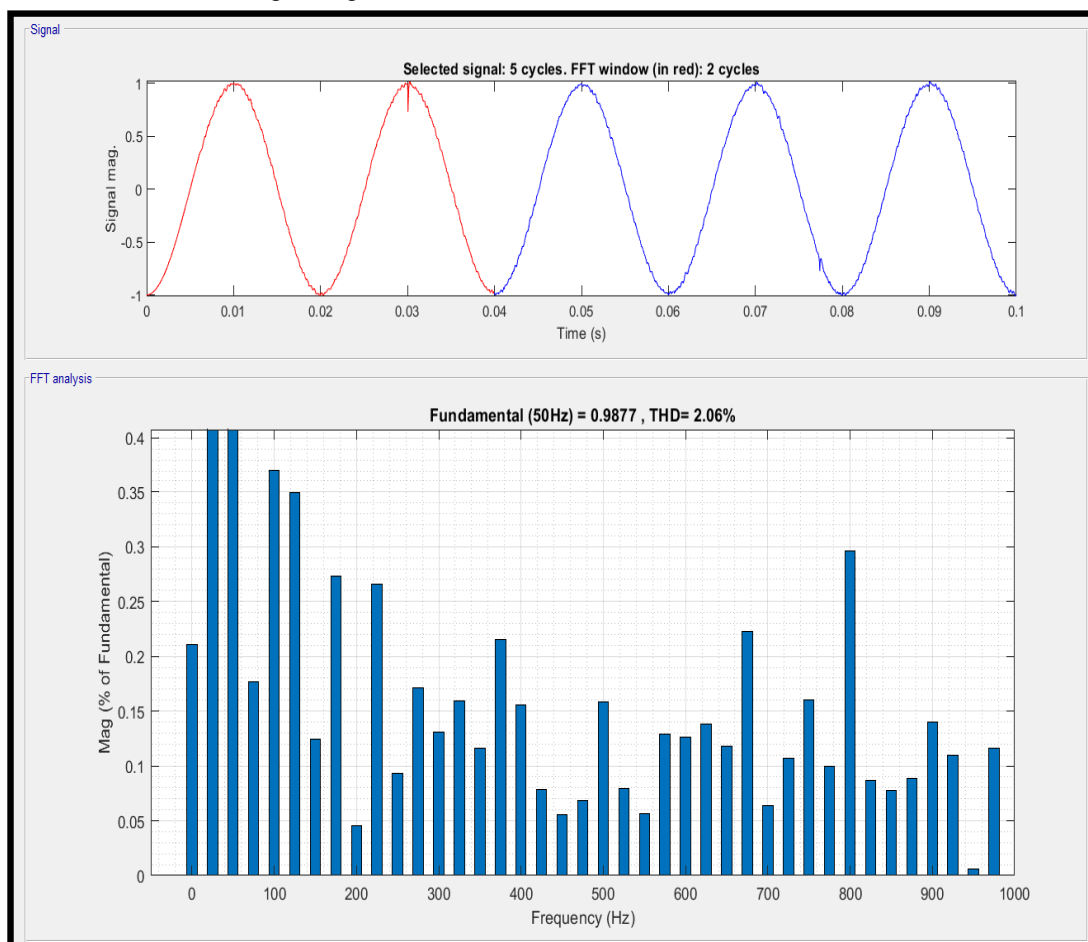


Fig. 9 : THD analysis for Double-line to ground fault with PI controller

Case 3: Single-line to ground fault with PI controller: The source voltage, load voltage, and injected voltage waveforms of the DVR under a single line to ground failure scenario can be seen in Figure 10. A SLGF happens, which causes the voltage to drop below its nominal levels. The whole fault duration, from 0.03 to 0.07 seconds, is 0.04 seconds. Using a PI controller, the voltage sag is rectified by injecting the necessary voltage that is absent during the fault situation.

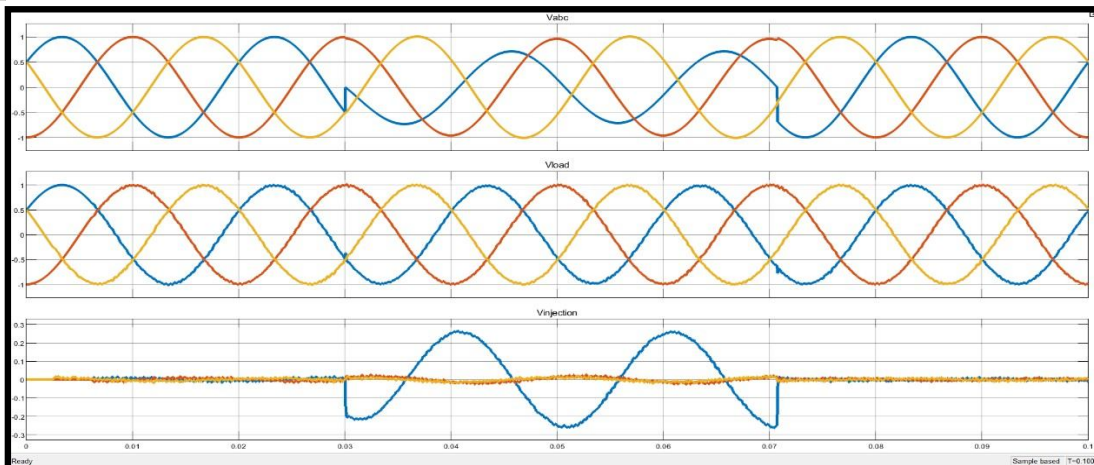


Fig. 10 : Single-line to ground fault with PI controller

The FFT analysis of the sensitive load voltage reveals that the load voltage is a perfect sinusoid with a very low THD of 1.73%.

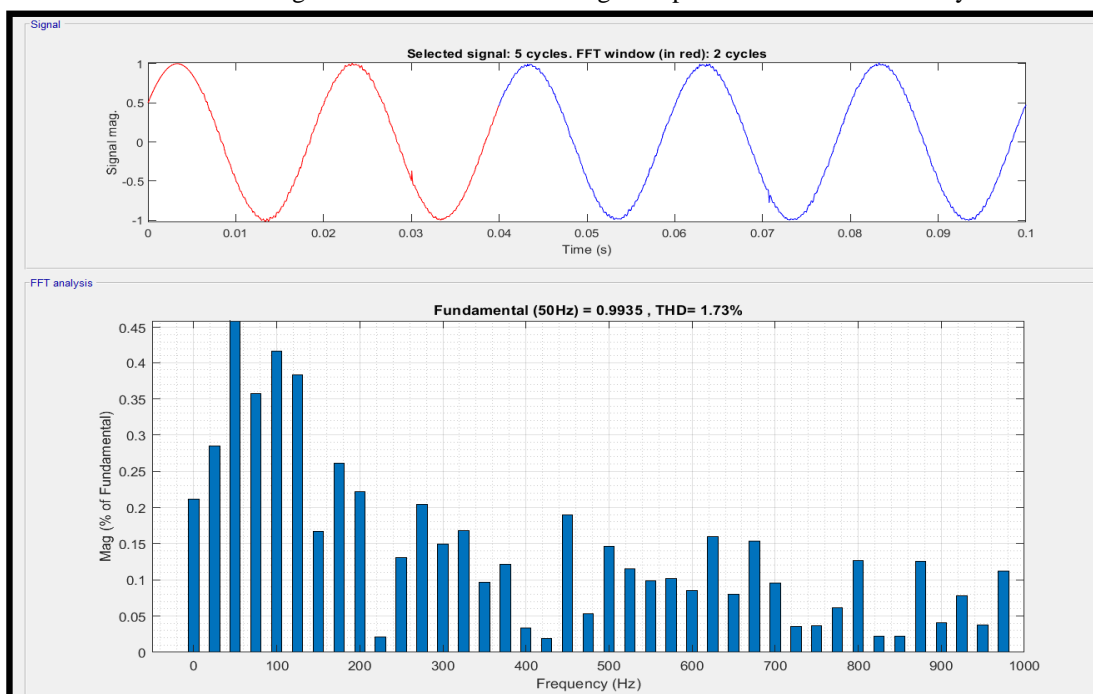


Fig. 11: THD analysis for Single-line to ground fault with PI controller

TABLE I  
THD WITH PI CONTROLLER

Faults	THD (%) with PI Controller
Three-Line to Ground Fault (L <sub>L</sub> L <sub>L</sub> G Fault)	2.00 %
Double-Line to Ground Fault (L <sub>L</sub> L <sub>G</sub> Fault)	2.06 %
Single-Line to Ground Fault (L <sub>G</sub> Fault)	1.73 %

The investigation leads to the conclusion that using an PI controller improves system performance by lowering THD values.



#### IV. CONCLUSIONS

Quality power has become a difficult problem for consumers, Among them is the imbalance of voltage and is thought to be the main factor for electrical device performance to decrease. Using FACTS devices for compensation is the most effective way to deal with this kind of issue. DVR is said to be the most economical and efficient of them all. To demonstrate the efficacy of DVR in mitigating various errors, MATLAB is utilized to model a basic distribution network. In this work, a simulation model of a nonlinear load linked power distribution system with a dynamic voltage restorer controlled by a PI controller is built using Matlab/Simulink. The study's conclusions show that the recommended DVR system effectively corrects for voltage sag brought on by single-, double-, and three-phase line to ground faults as well as harmonics generated by nonlinear loads.

#### REFERENCES

- [1] A.Karthikeyan, Member IEEE, D.G.Abhilash Krishna, Tejaswini A, Aeshwrya Sweta Panda,Laxmi Prasanna R, "A Comparative Study of PI and PDF Controllers for DVR Under Distorted Grid Conditions" Proceedings of the National Power Systems Conference (NPSC) - 2018, December 14-16, NIT Tiruchirappalli, India.
- [2] Abdul Hameed Soomro, Abdul Sattar Larik, Mukhtiar Ahmed Mahar, Anwar Ali Sahito, "Simulation-based Analysis of a Dynamic Voltage Restorer under Different Voltage Sags with the Utilization of a PI Controller" Engineering, Technology & Applied Science Research, Vol. 10, No. 4, 2020, 5889-5895.
- [3] B.Gopal, Pannala Krishna Murthy, "Power Quality Improvement Using DVR Control Designed with ANN-Fuzzy in MATLAB" webology (ISSN: 1735-188X) Volume 17, November 1, 2020.
- [4] Brahim Ferdi, Samira Dib, Brahim Berbaoui, Rachid Dehini, "Design and Simulation of Dynamic Voltage Restorer Based on Fuzzy Controller Optimized by ANFIS" International Journal of Power Electronics and Drive System (IJPEDS) Vol. 4, No. 2, June 2014, pp. 212~222 ISSN: 2088-8694.
- [5] C. K. Sundarabalan and K. Selvi, "Power Quality Enhancement in Power Distribution system using Artificial intelligence based Dynamic Voltage Restorer" International Journal on Electrical Engineering and Informatics - Volume 5, Number 4, December 2013.
- [6] Chandan kumar, Pradipta Ghosh, Saibal Chatterjee, "Enhancement of Power Quality by mitigating of sag and swell problem in power system using DVR" IFAC Papers On Line 55-1 (2022) 131–137.
- [7] DAYNIS TOPPO, "Implementation of DVR for Power Quality Improvement using Matlab/Simulation" International Journal of Scientific Engineering and Technology Research Volume.04, IssueNo.01, January-2015, Pages: 0042- 0047.
- [8] Dr. S.Sathiyaraj, Dr. Anandhi Dynamic "Voltage Restorer for Power Quality Improvement in Distributed Power System by ANFIS Controller" IJEDR 2019 | Volume 7, Issue 4 | ISSN: 2321-9939.
- [9] G. Deva dasu, Dr. M. Sushama, "A Novel Approach of Inverter Topology of DVR for Mitigation of Voltage Sags and Voltage Swells" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 15 (2018) pp. 12115- 12123.
- [10] H.P. Tiwari and Sunil Kumar Gupta, "Dynamic Voltage Restorer against Voltage Sag" International Journal of Innovation, Management and Technology, Vol. 1, No. 3, August 2010 ISSN: 2010-0248.
- [11] I. V. CHANDANA, YEDUKONDALU PAKALA, "Modeling, Simulation and Analysis of a Dynamic Voltage Restorer with PI, Fuzzy & Neural Controllers under Different Fault Conditions" International Journal of Scientific Engineering and Technology Research Volume.04, IssueNo.51, December-2015, Pages: 10926-10933.
- [12] Jain Shilpa Pavan, Dr. Bhupendra R. Parekh, Makawana Mukund kumar M, "Power Quality Improvement using Dynamic Voltage Restorer" 2018 JETIR November 2018, Volume 5, Issue 11, (ISSN-2349-5162).
- [13] K V R Chong, "Design and simulation of dynamic voltage restorer (DVR) for power quality improvement" 16th Eureka 2021 International Engineering and Computing Research Conference, Journal of Physics: Conference Series- 2222 (2022) 012003, doi:10.1088/1742-6596/2222/1/012003.
- [14] Manish Singh Chauhan, Prof. Parikshit Bajpai, "DEVELOPMENT OF PI/ PID AND NN CONTROLLER FOR THE THREE PHASE DYNAMIC VOLTAGE RESTORER IN MATLAB/SIMULINK" IRJMETS, Volume:04/Issue:12/December- 2022.
- [15] Mbuli, N. Dynamic Voltage Restorer as a Solution to Voltage Problems in Power Systems: Focus on Sags, Swells and Steady Fluctuations. Energies 2023, 16, 6946. <https://doi.org/10.3390/en16196946>, Published: 4 October 2023.
- [16] Priyanka Kumari, Vijay Kumar Garg, "Simulation of Dynamic Voltage Restorer Using Matlab to Enhance Power Quality in Distribution System" International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 4, Jul-Aug 2013, pp.1436-1441.
- [17] R. Navya Pragna, L. Prameela Rani, K. Ramya, T. Krishna Mohan, "DYNAMIC VOLTAGE RESTORER USING PI & FUZZY LOGIC CONTROL" 2019 IJRAR March 2019, Volume 6, Issue 1, (E-ISSN 2348-1269, P- ISSN 2349-5138).
- [18] Choudhary, Priti, M. K. Bhaskar, and Manish Parihar. "Decision Tree Based Fault Classification for Transmission Line Analysis."
- [19] S. Ezhilarasan, G.Balasubramanian, "Dynamic Voltage Restorer For Voltage Sag Mitigation Using Pi With Fuzzy Logic Controller" / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 3, Issue 1, January -February 2013, pp.1090-1095.
- [20] S.T.V. Saranya, K. mallikarjuna, "Power Quality Improvement using Dynamic Voltage Restorer with Hybrid Fuzzy Control Technique" International Journal of Research, Volume 04 Issue 02 February 2017.
- [21] Sandesh Jain, Prof. Shivendra Singh Thakur / Prof. S.P Phulambrikar, "Improve Power Quality And Reduce The Harmonics Distortion Of Sensitive Load" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 [www.ijera.com](http://www.ijera.com) Vol. 2, Issue 6, November- December 2012, pp.806- 815.
- [22] Sanjay Haribhai Chaudhary, Gaurav Gangil, "Analysis, Modeling and Simulation of Dynamic Voltage Restorer (DVR)for Compensation of Voltage for sag-swell Disturbances" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e- ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 3 Ver. I (May – Jun. 2014), PP 36-41.
- [23] Saurabh Sahu, Neelesh Kumar, "MITIGATION OF POWER QUALITY PROBLEMS USING DYNAMIC VOLTAGE RESTORER (DVR)" International Journal of Electrical Engineering & Technology (IJEET) Volume 6, Issue 8, Sep-Oct, 2015, pp.86-98.



- [24] Shubham Yadav, Manish Chandrakar, "Power Quality Improvement using "Artificial Neural Network Controller based Dynamic Voltage Restorer" International Journal of Scientific Research in Science, Engineering and Technology Print ISSN: 2395-1990 | Online ISSN: 2394-4099 ([www.ijraset.com](http://www.ijraset.com)) doi : <https://doi.org/10.32628/IJSRSET>.
- [25] Srinivas Bugata, D Danalakshmi, V Agnes Idhaya Selvi, "A Comparative Analysis of Different Controllers for DVR to Mitigate Harmonic Distortion" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278- 3075, Volume-8 Issue-6, April 2019.
- [26] Sudheer Kasa, Sudha Ramasamy "Photovoltaic Fed Dynamic Voltage Restorer with Voltage Disturbance Mitigation Capability Using ANFIS Controller" INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH S. Kasa and S.Ramasamy , Vol.6, No.3, 2016.
- [27] Viswaprakash Babu , S. Sathik Basha , Y. Mohamed Shuaib , M. Manikandan , S. Syed Enayathali "A Novel Integration of Solar Fed Dynamic Voltage Restorer for Compensating Sag and Swell Voltage in Distribution System Using Enhanced Space Vector Pulse Width Modulation (ESVPWM)" Universal Journal of Electrical and Electronic Engineering 6(5): 329-350, 2019, DOI: 10.13189/ujeee.2019.060504.
- [28] Saud Nashwan Abdulazeez, "DESIGN OF ADAPTIVE CONTROLLER FOR REGULATING THE VOLTAGE BY A DYNAMIC VOLTAGE RESTORER DVR" M.Sc., Electrical and Computer Engineering, Altınbaş University, 26/04/2019.
- [29] [www.wikipedia.org/wiki/Total\\_harmonic\\_distortion](http://www.wikipedia.org/wiki/Total_harmonic_distortion)
- [30] N. P Transmission, FACTS CONTROLLERS IN POWER TRANSMISSION.
- [31] C. Sankaran "Power Quality", CRC Press 2002
- [32] MINAXI L. PATEL, Prof. SANJAY R. VYAS Literature Review of "Modelling And Simulation of Dynamic Voltage Restorer For Power System Distribution Networks" Volume : 4 | Issue : 11 | November 2014 | ISSN - 2249- 555X.
- [33] Apurva Vashishth, Balvinder Singh "A Review For Voltage Sags And Swells Mitigation By Dynamic Voltage Restorer" International Journal of Innovative Science and Research Technology ISSN No: - 2456- 2165 , Volume 1 , Issue 3 , June – 2016.



10.22214/IJRASET



45.98



IMPACT FACTOR:  
7.129



IMPACT FACTOR:  
7.429



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24\*7 Support on Whatsapp)