ISSN: 2583-5637 (Online)

International Journal of Inventive Research in Science andTechnology Volume 2, Issue 6, June 2023

DVR BASED POWER QUALITY ISSUES MITIGATION A REVIEW

Ankita Parihar[1],Vasant Acharya[2]

Email- pariharankita999@gmail.com[1],vasantacharyatitc@gmail.com

[1]M.Tech Scholar, Department of Electrical and Electronics Engineering, Technocrats Institute of Technology, Bhopal, India
[2]Professor, Department .of Electrical & Electronics Engineering, Technocrats Institute of Technology Bhopal,India

ABSTRACT

Power Quality is an essential concern in the modern power system that can affect consumers and utility. The integration of renewable energy sources, smart grid systems and extensive use of power electronics equipment caused myriad problems in the modern electric power system. Current and voltage harmonics, voltage sag, and swell can damage the sensitive equipment. These devices are susceptible to input voltage variations created by interference with other parts of the system. Hence, in the modern age, with an increase in sensitive and expensive electronic equipment, power quality is essential for the power system's reliable and safe operation. Dynamic Voltage Restorer (DVR) is a potential Distribution Flexible AC Transmission System (D-FACTS) device widely adopted to surmount the problems of non-standard voltage, current, or frequency in the distribution grid. It injects voltages in the distribution line to maintain the voltage profile and assures constant load voltage. The simulations were conducted in MATLAB/Simulink to show the DVR-based proposed strategy's effectiveness to smooth the distorted voltage due to harmonics.

KEYWORDS:-***DVR, D-FACTS, THD, POWER QUALITY, MATLAB,VOLTAGESAG,VOLTAGE SWELL.***

1. INTRODUCTION

Electrical Energy is invisible, a universal commodity that is immediately available in most of the world, and it has now been recognized as everyday consumer need . Renew- able Energy Systems (RESs) is used to aid the primary energy demand in solar, Solar thermal, wind energy, etc. The intermittent nature of RESs, harmonics, and reactive power problems halt the power system's performance by originating stability concerns in the power system . The Flexible AC Transmission Systems (FACTS) devices are widely adapted for reactive power compensation, voltage stability, and power quality in distribution grids around the world. However, FACT devices also alter different parameters on the transmission and distribution system.

This work presents a study of the power quality and aims at identifying the causes of poor power quality and provide the solutions to these power quality problems. Some equipment like computers, laptops, relays, solid-state devices, adjustable speed drives, and optical devices are known as sensitive equipment. These devices are susceptible to input voltage variations created by interference with other parts of the system. The power system is divided into the following parts as generation, transmission, distribution, and by using other transmission line power systems is fed to different loads on the distribution side. Power quality plays a vital role in the power system when variable power is supplied to the load. Subsequently, the domestic and industrial customers with delicate loads are affected by the poor quality of power. Even there is various type of load on the distribution side, but poor power quality affects the sensitive loads more than

others.

There are many applications where the sensitive load has an increasing demand, like in hospital's operation theatres, semi- conductor systems in processing plants, database systems, instruments to control air pollution in crowded areas, precise and accurate equipment are required by data processing, and service providers. If the power system causes the dips and distorted voltages, these devices may fail, and such a device's failure leads to wastage of a significant amount of money. Therefore, the distribution side is dependent on power quality. Electrical characteristics are set by the power system that does not disturb the system's performance and perform its function in a controlled manner.

In this Synopsis , voltage swell and distorted voltage with high harmonics in it are discussed .When the load voltage being disturbed, it causes voltage sag, transient, swell, and high distorted voltage with har- monics and Total Harmonic Distortion (THD) due to the occurrence of the faults. The vulnerability of voltage sags and harmonics problems is mostly to the delicate instruments. Few problems occur in the result of voltage sag that may also cause disturbance of torques in the motors, device burning, misfiring in the device, etc. The harmonic is an essential issue for power quality to be solved effectively

2. LITERATURE REVIEW

The transmission and distribution system problems were addressed in some countries using the FACTS and D-FACTS devices. As per IEEE recommendations, FACTS can be expressed as [9], AC transmission systems containing static and power electronics-based controllers to increase power transfer capability and more immeasurable controllability.'' Today, electricity demand has risen considerably while the development of generation and transmission systems is not adequate by the limited resources, economic issues, and some environmental limitations. The present transmission system cannot be easily extended due to limited resources. Therefore, the expansion in transmission capacity is a viable solution. Transmission lines are not being fully utilized due to some limiting factors affecting the loading capability of the trans- mission line. These factors are perceived as the thermal limit, dielectric, and stability. FACTS controllers can control power and enhance the usable capacity of present lines. The FACTS controllers enable the power to flow through line under nor mal conditions and when subjected to faults and allow a line to transport power close to its thermal ratings [10], [11].

DVR is used on the distribution feeder to protect the load from faults due to the voltage sags and voltage swells. DVR is mounted in series with the load, and a battery energy storage system (BESS) is connected with a transformer and inverter are also connected with DVR, which compensate the active and reactive power requirement for the reduction in voltage sags and voltage swells [12].

For the voltages stability, DVR injects voltage into the distribution system, the DVR to the system through the transformer. DVR is the FACTS device, which compensates the disturbances like the voltage sags, swells, and voltages harmonics from the loads. DVR injects the voltages in series with the transmission lines and injects a small amount of voltages in normal conditions.But, when a disturbance occurs, DVR calculates the voltages required to protect the load through the sinusoidal pulse width modulation (SPWM). Then after those voltages are injected in the system to maintain the situation. In the steady-state, DVR either absorbs or delivers the active or reactive power, but when a disturbance occurs, DVR delivers or absorbed the active or reactive power from the dc-link [13]. Martiningsih et al. have recommended the installation of DVR are PT DSS power plant, the DVR acts as a compen- sator and connected in series with the distribution line. The proposed PI-based DVR is competent in restoring the power quality restraint. [14]. Eltamaly et al. have proposed a DVR based strategy for mitigation of voltage sag through DVR to enhance the power systems quality. To degradation in the performance of electrical equipment. The results determine that DVR compensate sag/swell adequately and implement proper voltage adjustment [15].

3. METHODOLOGY

The frequency of the supplied voltage can determine the power supply quality that is a significant indicator of power quality. The voltage sag is interpreted as a drop in the Root Mean Square (RMS) value of the voltage that can happen from 10 ms to 60 seconds with the depth of the falling voltage of 0.9 per unit (p.u) 0.1 p.u of a nominal p.u based on the IEEE standards . Regular voltage sags are usually checked for the load at the distribution level due to different reasons. The voltage sags are highly unbearable for a few delicate loads in high technology sectors. The load voltage requirements could be maintained by the complicated tasks with a specific frequency and exact value of voltage sag while distortion and oscillation.

Usually, the destruction of the production sector and its downtime is the result of voltage sag that is costly and leads to harsh problems among consumers. A specific amount of energy and voltage is supplied to the distribution system by using electric devices that are also named consumer power devices. The complex problem could be mitigated. As compared to the conventional methods of voltage sags problem solving, the DVR is supposed to be an efficient method to control the voltage sag and distortion. In this work, the power system's performance is evaluated by removing voltage sag through a DVR at the distribution level

4. PRINCIPLE OF DVR OPERATION

A DVR is consists of GTO or IGBT based Voltage Source Inverter (VSI), an energy storage instrument, a capacitor bank, and an injection transformer. The DVR is also called solid-state power electronic switching device. A DVR connected to a distribution bus. The practical guideline of the DVR as it works by methods for an injecting transformer; a control voltage is created by a forced commuted converter, which is in arrangement to the bus voltage. Different converter control topologies for droop-controlled converter are presented. DC voltage source behaves like a device of energy storage given by the DC capacitor, as shown in Figure 1.

To mitigate the problem of voltage drop is not efficiently done by the DVR when there is no voltage sag issue under optimal conditions. DVR will produce a needed controlled voltage of high frequency with the existence of a distribution system, a required phase angle that will ensure that load is perfect and maintained. For keeping the consistency in the load supply of voltage in this situation, the capacitor will be discharged. Here is needed to note that the DVR can absorb and produce reactive power, but an external source of energy is used to provide reactive power injection. The voltage sag detection time and the devices of power electronics shorten the response time of DVR. As compared to the conventional methods of voltage correlation, for example, the tap-changing transformers response time of DVR is less than 25 milliseconds.

5. CONSTRUCTION OF DVR

There are two parts of the DVR: one is the power cir- cuit, and the other is the control circuit. The control signal consists of magnitude, phase shift, the frequency that are complex parameters of it, and injected by the DVR sys- tem. In the power circuit, the switches are used to generate a voltage-dependent on control signals. Additionally, this section will describe the fundamental structure of the DVR by the power circuit. The construction and basic Configuration of the DVR are shown in Figure

1) ENERGY STORAGE UNIT

Different devices are used to store energy like Flywheels, Lead-acid batteries, Superconducting Magnetic energy stor- age (SMES), and Super-Capacitors [28]. While the occur- rence voltage sags, the storage unit provides the required real power as it is its primary function. The compensation capability of DVR is defined by the active power produced the device of energy storage. Instead of using other storage devices, the devices of the high response time of charging and discharging are being used that are lead batteries. The rate of discharge determines the internal space available for the storage of energy, and this discharging rate is based on a chemical reaction .

2) VOLTAGE SOURCE INVERTER

The use is of Pulse-Width Modulated VSI (PWMVSI) widespread. A DC voltage has been created through a device of energy storage, as discussed in the previous section. A VSI is the source of the conversion of voltage from DC-AC voltage. At the time of sag occurrence, a step-up voltage injection transformer of the DVR power circuit has been used to increase the magnitude of voltage. So, a minimum voltage value with VSI is enough.

3) PASSIVE FILTERS

The use of low passive filters in this method in which the PWM inverted pulse waveform converted into a sinusoidal waveform. In VSI for the achievement of this conversion, it is compulsory to remove high-value harmonic components while DC-AC transformation, and it will also change the compensated output voltage. A passive filter is an essential source in voltage inverter. That is why it uses either on the side of low voltage like the inverter side of the injection transformer and side of high voltage like load side.

If we put the filters on the inverter side, it can overcome maximum value harmonics from passing through the voltage transformer. So, the stress on the injection transformer is also decreased by it. When the filter is placed in the inverter side and causes phase shift and voltage drop in inverted, that is the disadvantage of the filter. Thus, by putting the filter on the load side, this problem can be solved. The secondary side of the transformer permits the high valued harmonics currents because the transformer with high values is necessary

4) BY-PASS SWITCH

DVR is a series-connected device. The current pass through the inverter if the fault exists in the downstream causes a fault current. For the protection of the inverter, the By-pass switch is being used. Commonly, to bypass the inverter cir- cuit, a crowbar switch is used. Whenever the current is in the range of parts of the inverter, the crowbar would detect the scale of the current and deactivate it in the end. On the other side, it will allow bypassing the components of the inverter if the current is high .

5) VOLTAGE INJECTION TRANSFORMERS

There are two sides of the voltage injection transformer, as one is the primary side linked with a distribution line in a series. The other one is the secondary side that is connected with the power circuit of DVR. For the three-phase DVR, one 3-phase transformer or three single-phase transformers
could be used, but for one phase DVR, only one single-phase transformer is allowed. The ‘‘Delta-Delta’’ type connection is being used at the time of contact between 3 phase DVR and three single-phase transformers [31].

Usually, the amount of voltage that is supplied by the filtered VSI output to a needed range also simulates the DVR circuit from the transformation network caused by the setup transformer. According to the required voltage at the sec- ondary side of voltage, the pre-examined and significant values are winding ratios. The parts of inverter circuits are affected by the high cost of winding ratio with high-frequency currentsth, the primary side current with high-frequency ratios of high windings that could affect the parts of the inverter circuit. The value of the transformer is an important reason when determining the working efficiency of the DVR.

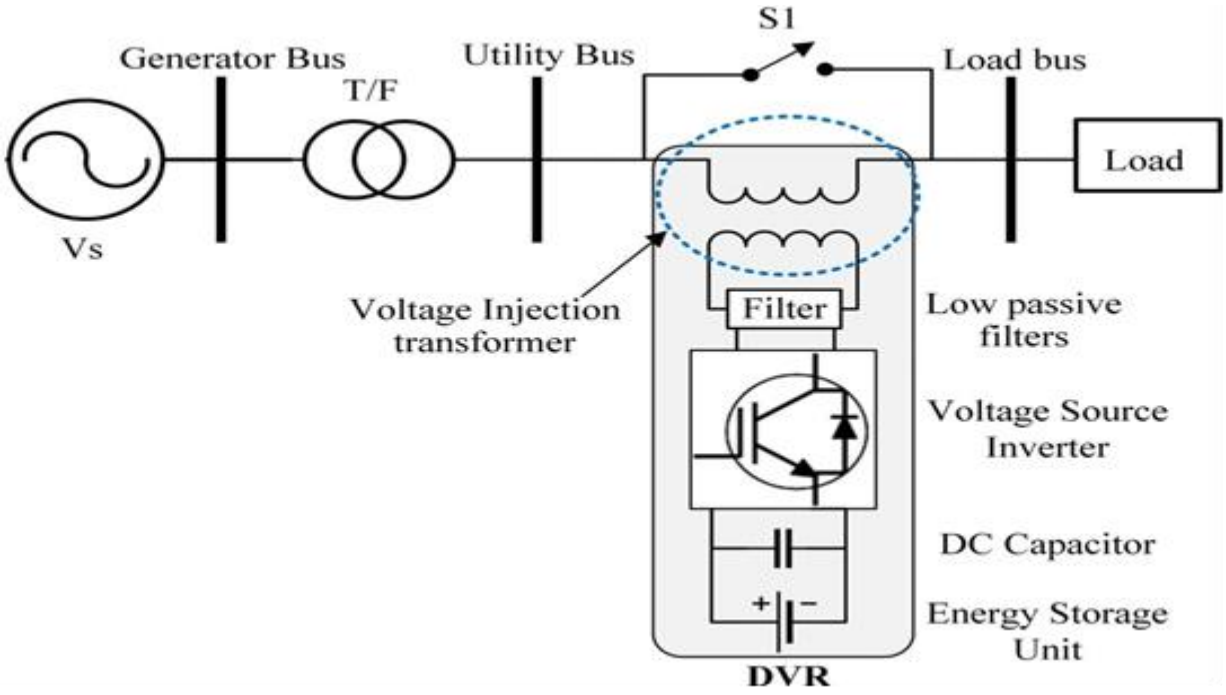

Figure 1 –Components of DVR

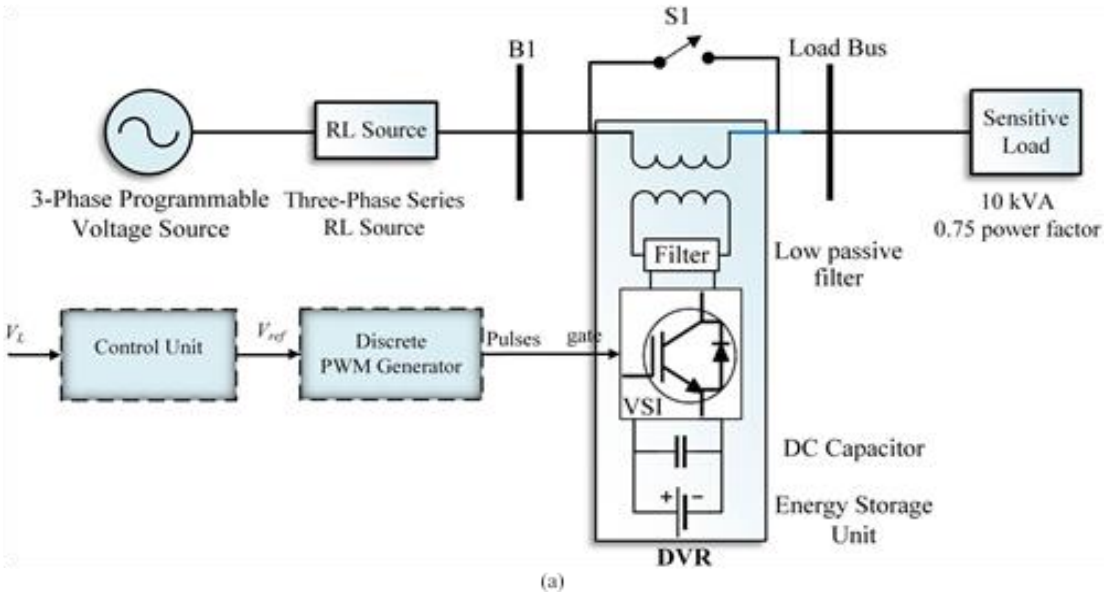

Figure 2- Single Line Diagram of Test system with DVR

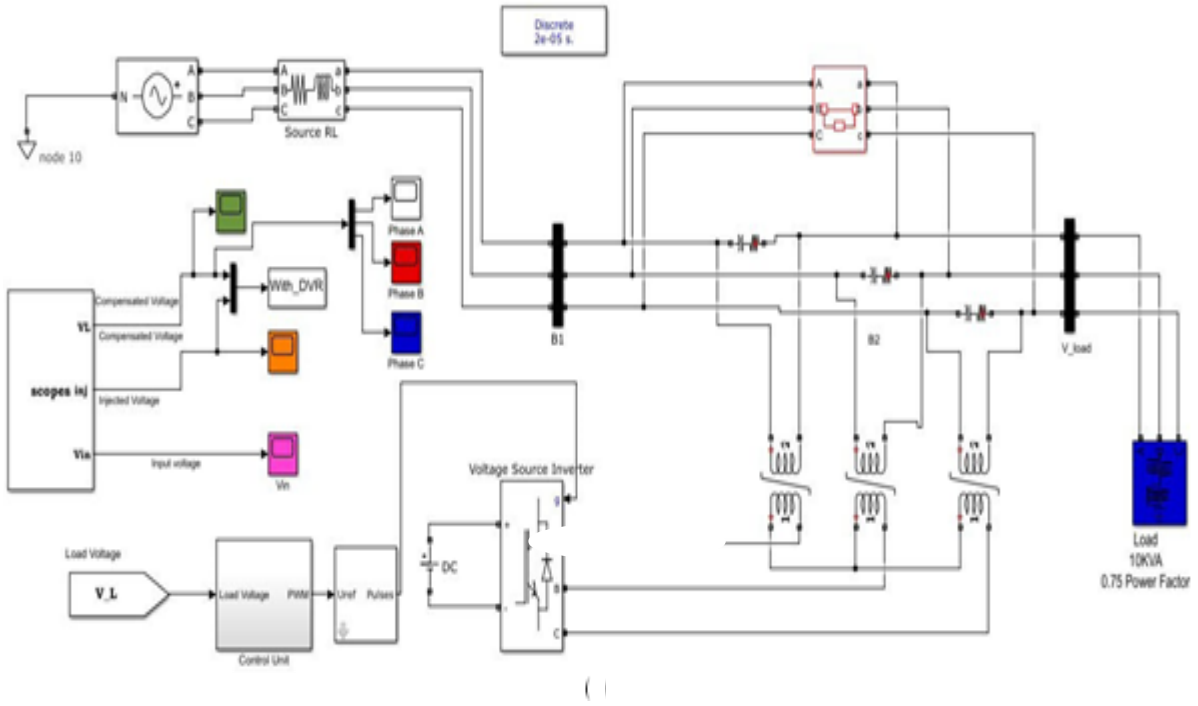

Figure 2 Simulation Model of Test System With DVR

Parameters and values of test system.

Supply Voltage 415 V

Frequency 50 Htz

Load Power Factor 0.74

Converter IGBT (3 arms ,6 pulse)

Load Reactive Power 7.5 KW

Load Active Power 6.6 KVA

In the test System, the 3rd harmonic voltage is inserted into the supply voltage programmable source. The 3-phase sensitive with this distortion in all three phases. Figure 1 Shows that the insertion causes a distortion in voltage profile and load voltage has observed a distorted voltage (VLoad) with a disturbing waveform, and some swell in it. The VRMS phase to phase peaks reaches to near 460 V mag- nitude in voltage profile. The disturbance in the voltage profile may lead to failure or malfunctioning of sensitive equipment.

To maintain the THD distortion under the IEEE limit and improve the power quality, DVR with a control system is implemented. The load voltage with DVR, along with the control system, is shown in Figure 2. The compensation in the load voltage (VLoad) can be seen in all three phases of voltage. This is accomplished with the automatic connection, and the injection of the voltage occurs when the breakers of the circuit open in the presence of the DVR. A significant reduction is seen from t 0.1 to 0.3 sec for the voltage swell as well as the high magnitude of harmonics is removed, and voltage profile is back to normal in all the three cases with a slight flicker at 0.1 sec or 0.3 sec only. A smaller spike has been observed at 0.1 and 0.3 sec. To maintain the power quality, DVR has injected the voltage into the distribution line, the injected voltage for all three phases are shown in Figure 1.
The DVR used the electronic device, transistor, and diodes to protect from the error, convert voltage from AC to DC, correct the voltage in load, and control the flow of the power. Then during operating, the generation of the harmonics takes place through the inverter that is PWM. Then the small amount of effect will occur on the load the supply of the utility, reduction in the harmonics occur.

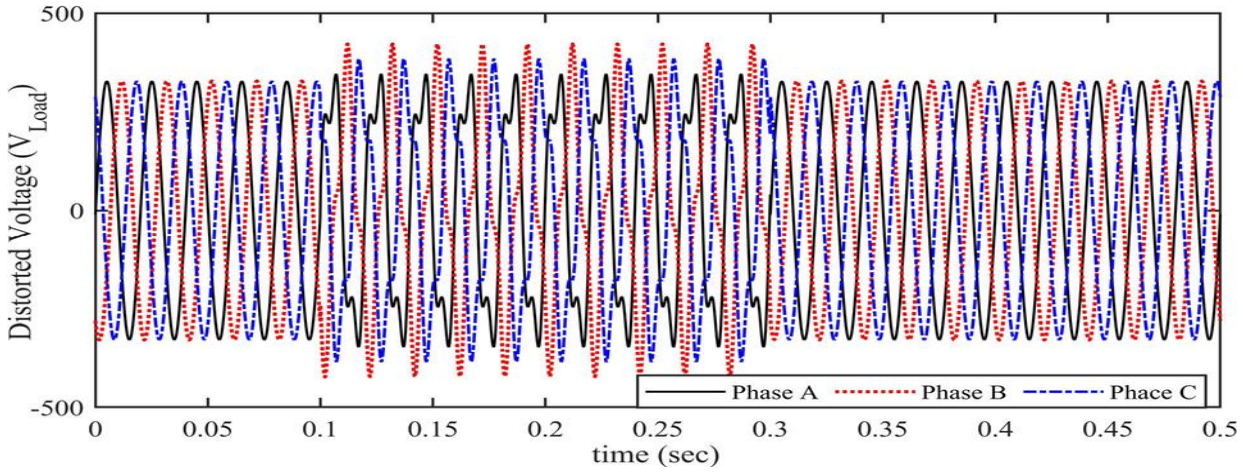

Figure 1 Distorted signal (VLoad) in test system without DVR

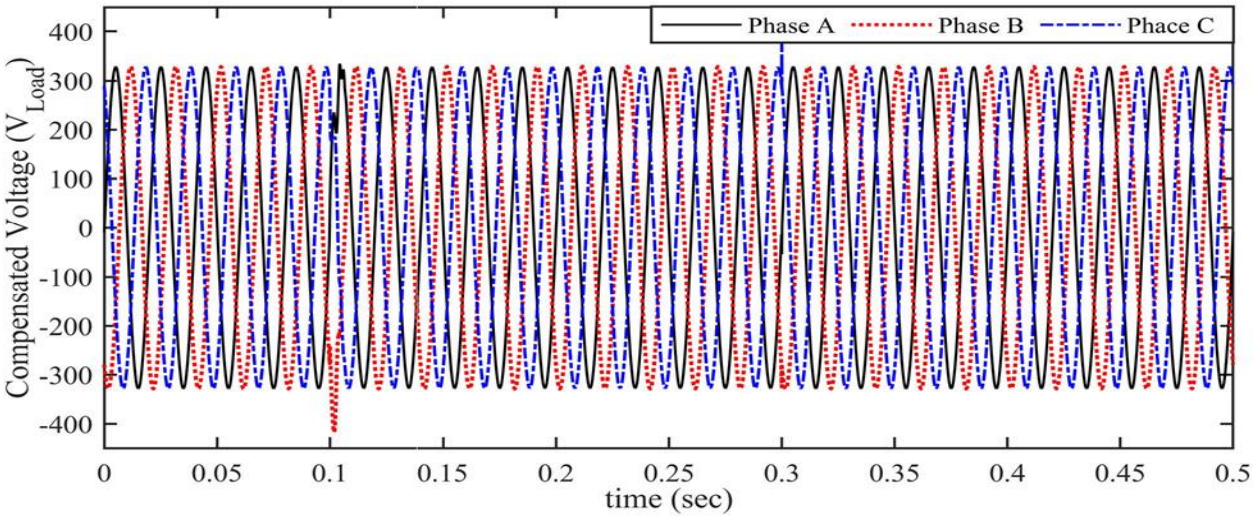

Figure 2 Compensated signal (VLoad) in test system With DVR

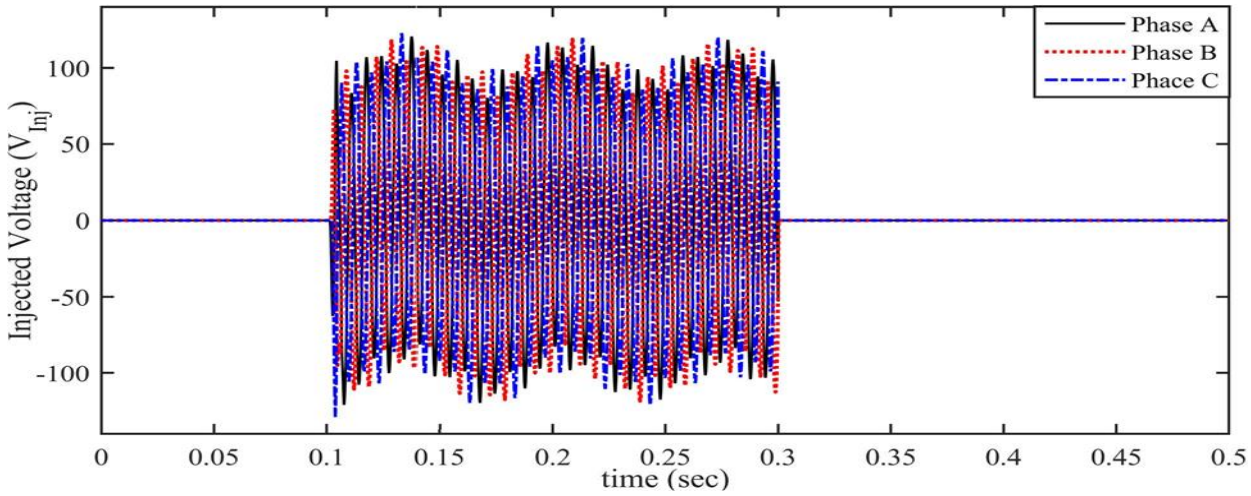

Figure 3 Injected voltage (Vinj) by DVR in all three phases

Conclusion

DVR is proposed as the most noteworthy device to enhance the quality of power and proved to be a useful and well-performing device. Through the platform of MATLAB/ Simulink, a simulation of DVR with a power circuit is carried out by structure and modeling of the control circuit and power system with a sensitive load. The DVR is implemented with the test system and investigated with and without DVR. A programmable voltage source is used to supply a distorted voltage with first with 3rd harmonic content and then with 5th harmonic insertion in the supply voltage. The proposed DVR based control strategy was effective in compensation of the distorted load voltage and maintained a better steady and smooth voltage profile with very less harmonic content in it. To maintain the load voltage normal and steady at the optimal range, the correction of any problem in voltage supply is possible when the DVR injects the suitable voltage component into it. While maintaining the compensation of voltage profile, the THD was reduced to around 4%. the observed THD with DVR case was 2.69%, 2.40%, and 2.69%, This improve- ment and reduction in the THD in load voltage explain the effectiveness of the DVR based control strategy used in this work. The application of control strategy based on soft comput- ing like adaptive Neruo Fuzz controllers for power quality improvement is a promising future perspective of this research. Authors have already implemented Type-2 Neuro- Fuzzy controls for enhancement of power system stability using STATCOM**.**

References

[1] N. Khan, S. Dilshad, R. Khalid, A. R. Kalair, and N. Abas, ‘‘Review of energy storage and transportation of energy,’’ Energy Storage, vol. 1, no. 3, Jun. 2019, doi: 10.1002/est2.49.

[2] M. A. Basit, S. Dilshad, R. Badar, and S. M. S. ur Rehman, ‘‘Limitations, challenges, and solution approaches in grid-connected renewable energy systems,’’ Int. J. Energy Res., vol. 44, no. 6, pp. 4132–4162, May 2020, doi: 10.1002/er.5033.

[3] A. Kalair, N. Abas, A. R. Kalair, Z. Saleem, and N. Khan, ‘‘Review of harmonic analysis, modeling and mitigation techniques,’’ Renew. Sustain. Energy Rev., vol. 78, pp. 1152–1187, Oct. 2017, doi: 10.1016/j.rser.2017.04.121.

[4] F. H. Gandoman, A. Ahmadi, A. M. Sharaf, P. Siano, J. Pou, B. Hredzak, and V. G. Agelidis, ‘‘Review of FACTS technologies and applications for power quality in smart grids with renewable energy sys- tems,’’ Renew. Sustain. Energy Rev., vol. 82, pp. 502–514, Feb. 2018, doi: 10.1016/j.rser.2017.09.062.

[5] A. M. Sharaf and A. A. Abdelsalamy, ‘‘A novel facts based dynamic volt- age compensation scheme for smart electric grid stabilization and efficient utilization,’’ in Proc. 24th Can. Conf. Electr. Comput. Eng. (CCECE), May 2011, pp. 000042–000047, doi: 10.1109/CCECE.2011.6030405.

[6] A. R. Kalair, N. Abas, A. Kalair, Q. U. Hasan, and N. Khan, ‘‘Impact of FACTS devices on transmission and distribution system,’’ J. Active Passiv. Electron. Devices, vol. 14, no. 4, pp. 287–305, 2019.

[7] M. Büyük, M. Inci, and M. Tümay, ‘‘Performance comparison of voltage sag/swell detection methods implemented in custom power devices,’’ Rev. Roum Sci. Techn.-Électrotechn. Énerg, vol. 62, no. 2, pp. 129–133, 2017.

[8] Y. W. Li and J. He, ‘‘Distribution system harmonic compensation methods: An overview of DG-interfacing inverters,’’ IEEE Ind. Electron. Mag., vol. 8, no. 4, pp. 18–31, Dec. 2014, doi: 10.1109/MIE.2013.2295421.

[9] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York, NY, USA: Wiley, 2000.

[10] Y.-H. Song and A. Johns, Flexible ac Transmission Systems (FACTS), no. 30. Edison, NJ, USA: IET, 1999.

[11] K. Habur and D. O’Leary, ‘‘FACTS-flexible alternating current trans- mission systems: For cost effective and reliable transmission of electrical energy,’’ Siemens-World Bank Doc., Erlangen, Germany, Draft Rep., 2004, p. 46. [Online]. Available: http://www.academia.edu/ download/41305916/facts_siemens.pdf

[12] W. Frangieh and M. B. Najjar, ‘‘Active control for power quality improve- ment in hybrid power systems,’’ in Proc. 3rd Int. Conf. Technol. Adv. Electr., Electron. Comput. Eng. (TAEECE), Apr. 2015, pp. 218–223, doi: 10.1109/TAEECE.2015.7113630.

[13] S. Agalar and Y. A. Kaplan, ‘‘Power quality improvement using STS and DVR in wind energy system,’’ Renew. Energy, vol. 118, pp. 1031–1040, Apr. 2018, doi: 10.1016/j.renene.2017.01.013.

[14] W. Martiningsih, U. Y. Prakoso, and Herudin, ‘‘Power quality improvement using dynamic voltage restorer in distribution system PT. DSS power plant,’’ in Proc. MATEC Web Conf., vol. 218, Oct. 2018, p. 01003. [Online]. Available: https://www.matec-conferences.org/articles/matecconf/pdf/ 2018/77/matecconf_iciee2018_01003.pdf, doi: 10.1051/matecconf/ 201821801003.

[15] A. M. Eltamaly, Y. Sayed, A.-H. M. El-Sayed, and A. N. A. Elghaffar, ‘‘Mitigation voltage sag using DVR with power distribution networks for enhancing the power system quality,’’ IJEEAS J., vol. 1, no. 2, pp. 2600–7495, Oct. 2018.

[16] K. K. Ali, M. Talei, A. Siadatan, and S. M. H. Rad, ‘‘Power quality improvement using novel dynamic voltage restorer based on power elec- tronic transformer,’’ in Proc. IEEE Electr. Power Energy Conf. (EPEC), Oct. 2017, pp. 1–6, doi: 10.1109/EPEC.2017.8286166.

[17] L. Yan, X. Chen, X. Zhou, H. Sun, and L. Jiang, ‘‘Perturbation compensation-based non-linear adaptive control of ESS-DVR for the LVRT capability improvement of wind farms,’’ IET Renew. Power Gener., vol. 12, no. 13, pp. 1500–1507, Oct. 2018, doi: 10.1049/iet-rpg. 2017.0839.

[18] A. Benali, M. Khiat, T. Allaoui, and M. Denai, ‘‘Power quality improve- ment and low voltage ride through capability in hybrid wind-PV farms grid-connected using dynamic voltage restorer,’’ IEEE Access, vol. 6, pp. 68634–68648, 2018, doi: 10.1109/ACCESS.2018.2878493.

[19] M. Danbumrungtrakul, T. Saengsuwan, and P. Srithorn, ‘‘Evaluation of DVR capability enhancement-zero

active power tracking technique,'' IEEE Access, vol. 5, pp. 10285–10295, 2017, doi: 10.1109/ACCESS.2017.2706275.
[20] A. I. Omar, S. H. E. Abdel Aleem, E. E. A. El-Zahab, M. Algablawy, and Z. M. Ali, ''An improved approach for robust control of dynamic voltage restorer and power quality enhancement using grasshopper opti- mization algorithm,'' ISA Trans., vol. 95, pp. 110–129, Dec. 2019, doi: 10.1016/j.isatra.2019.05.001.
[21] V. Verma and R. Gour, ''OLTC-DVR hybrid for voltage regulation and averting reverse power flow in the micro-grid with intermittent renewable energy sources,'' in Proc. IEEE Ind. Electron. Appl. Conf. (IEACon), Nov. 2016, pp. 81–87, doi: 10.1109/IEACON.2016.8067360.
[22] S. P. Mishra, B. Biswal, J. P. Roselyn, and D. Devaraj, ''Simulation and analysis of DVR for mitigating voltage sags and swells,'' Procedia Eng., vol. 64, pp. 341–350, 2013, doi: 10.1016/j.proeng.2013.09.106.
[23] S. Khalid and B. Dwivedi, ''Power quality issues, problems, standards & their effects in industry with corrective means,'' Int. J. Adv. Eng. Technol., vol. 1, no. 2, p. 1, 2011.
[24] IEEE Recommended Practice for Monitoring Electric Power Quality, Standard 1159-1995. Accessed: May 16, 2020. [Online]. Available: https://standards.ieee.org/standard/1159-1995.html
[25] R. Wang, Q. Sun, D. Ma, and Z. Liu, ''The small-signal stability analysis of the droop-controlled converter in electromagnetic timescale,'' IEEE Trans. Sustain. Energy, vol. 10, no. 3, pp. 1459–1469, Jul. 2019, doi: 10.1109/TSTE.2019.2894633.
[26] W. Rui, S. Qiuye, Z. Pinjia, G. Yonghao, Q. Dehao, and W. Peng, ''Reduced-order transfer function model of the droop-controlled inverter via jordan continued-fraction expansion,'' IEEE Trans. Energy Convers., vol. 35, no. 3, pp. 1585–1595, Sep. 2020, doi: 10.1109/TEC.2020.2980033.
[27] S. M. Deshmukh and B. Dewani, ''Overview of dynamic voltage restorer (DVR) for power quality improvement,'' Int. J. Eng. Res. Appl., vol. 2, no. 6, pp. 1372–1377, 2012.
[28] A. Kalair, N. Abas, M. S. Saleem, A. R. Kalair, and N. Khan, ''Role of energy storage systems in energy transition from fossil fuels to renew- ables,'' Energy Storage, p. e135, Feb. 2020, doi: 10.1002/est2.135.
[29] M. Mani Sankar and S. B. L. Seksena, ''A cost effective voltage sag compensator for distribution system,'' Int. J. Syst. Assurance Eng. Man- age., vol. 8, no. S1, pp. 56–64, Jan. 2017, doi: 10.1007/s13198-015- 0373-3.
[30] N. Van Minh, B. Quoc Khanh, and P. Viet Phuong, ''Comparative sim- ulation results of DVR and D-STATCOM to improve voltage quality in distributed power system,'' in Proc. Int. Conf. Syst. Sci. Eng. (ICSSE), Jul. 2017, pp. 196–199, doi: 10.1109/ICSSE.2017.8030864.
[31] S. S. Rao, P. S. R. Krishna, and S. Babu, ''Mitigation of volt- age sag, swell and THD using dynamic voltage restorer with photo- voltaic system,'' in Proc. Int. Conf. Algorithms, Methodol., Models Appl. Emerg. Technol. (ICAMMAET), Feb. 2017, pp. 1–7, doi: 10.1109/ICAM- MAET.2017.8186668.
[32] V. K. Ramachandaramurthy, C. Fitzer, A. Arulampalam, C. Zhan,
M. Barnes, and N. Jenkins, ''Control of a battery supported dynamic voltage restorer,'' IEE Proc.-Gener., Transmiss. Distrib., vol. 149, no. 5, pp. 533–542, Sep. 2002.
[33] M. Vilathgamuwa, A. A. D. Ranjith Perera, and S. S. Choi, ''Performance improvement of the dynamic voltage restorer with closed-loop load voltage and current-mode control,'' IEEE Trans. Power Electron., vol. 17, no. 5, pp. 824–834, Sep. 2002, doi: 10.1109/TPEL.2002.802189.
[34] N. Abas, A. Kalair, N. Khan, and A. R. Kalair, ''Review of GHG emissions in Pakistan compared to SAARC countries,'' Renew. Sustain. Energy Rev., vol. 80, pp. 990–1016, Dec. 2017, doi: 10.1016/j.rser.2017.04.022.
[35] H. B. Khalil and N. Abas, ''Smart grids: An approach to integrate the renewable energies and efficiently manage the energy system of pakistan,'' in Proc. 5th Int. Conf. Comput., Commun. Netw. Technol. (ICCCNT), Jul. 2014, pp. 1–7, doi: 10.1109/ICCCNT.2014.6963060.