Modeling and simulation of Dynamic Voltage Restorer with improved power quality features

GONNURI CHARAN SAI ARJUN, PG STUDENT, HELAPURI INSTITUTE OF TECHNOLOGY AND SCIENCE, JNTUK, AP, INDIA.
CH KOTESWARA RAO, HOD, HELAPURI INSTITUTE OF TECHNOLOGY AND SCIENCE, JNTUK, AP, INDIA.

ABSTRACT

The series-connected DVR will inject three-phase compensating voltages via the three-phase injection transformer or three single-phase injection transformers with the main supply through the three-phase injection transformer or three single-phase injection transformers. The injection transformer raises the voltage of the filtered VSI output voltage to the level chosen by the user. In addition, the transformer separates the DVR circuit from the rest of the distribution system. The capacity of the voltage source inverter (VSI) and the parameters for the link filter that connects the injection transformer and the inverter are critical in the design of the DVR because they determine how much power can be converted. Within the scope of this research project, a novel Dynamic Voltage Restorer (DVR) topology has been developed. Smaller capacities and filter values for the voltage source inverter (VSI) and the link filter will result in improved compensation capabilities for voltage harmonic, swell and sag mitigation under different fault scenarios, as will the link filter's values. The switching harmonics may be eliminated by using the new RLC filter design. Inductance reduces the capacity of the direct current supply voltage when the amount of inductance is modest. With its great efficiency and capacity to increase the quality of voltage, the new DVR architecture has the potential to revolutionize the industry. The outline architecture of the RLC filter parameters for the particular model has been described, as well as the RLC filter parameters for the general model. It is possible to construct and simulate the new DVR with the suggested controlled Dynamic Voltage Restorer architecture using the MATLAB software. The control system exhibits excellent control dynamics and has a low amount of transient current overshoot at startup. It is possible to get decent simulation results under transitory performance.

INTRODUCTION

The three-phase comp will be injected by the DVR that is linked in series. Because the intensity of sensitive loads in power systems is increasing on a daily basis, power quality concerns are becoming more important in today's world. Extreme power quality issues such as voltage swell, voltage sag, harmonics, flicker, and so on have been identified and documented. Sagging voltage is often caused by failures on the load or supply side, improper operation (e.g., electrical motor beginning, electrical heaters coming on), and other factors. Consequently, the DVR is preventing voltage sag by injecting voltage into the system. Power quality issues arise as a result of the introduction of numerous non-linear loads, such as diode bridge rectifiers, adjustable speed drives (ASD), switched mode power supplies (SMPS), laser printers, and other similar devices, among other things. As previously mentioned, voltage sag is defined as a fall in RMS voltage from 0.1pu to 0.9pu over a short period of time, typically 0.5 cycles to a few cycles. In most cases, problems occurred in distribution systems that experienced a voltage fall of 40 percent to 50 percent of the rated voltage for less than 2 seconds or less. Since the aforementioned power quality issues have an impact on sensitive loads, it is vital to minimise their consequences. Aside from that, new power electronic devices are being created, which are referred to as bespoke power devices. The distribution static compensator (D-STATCOM), the unified power quality conditioner (UPQC), and the dynamic voltage restorer are examples of such devices (DVR). The DVR is the ideal method for restoring the voltage at the output terminals of the load. It occurs when the quality of the supply voltage is degraded. As a result of an adequate injection of voltage in series with the grid voltage, the DVR can correct for voltage fluctuations while maintaining the rated load voltage under balance mode conditions. DVRs are typically comprised of three components: an inverter, an injection transformer, and an energy storage device.

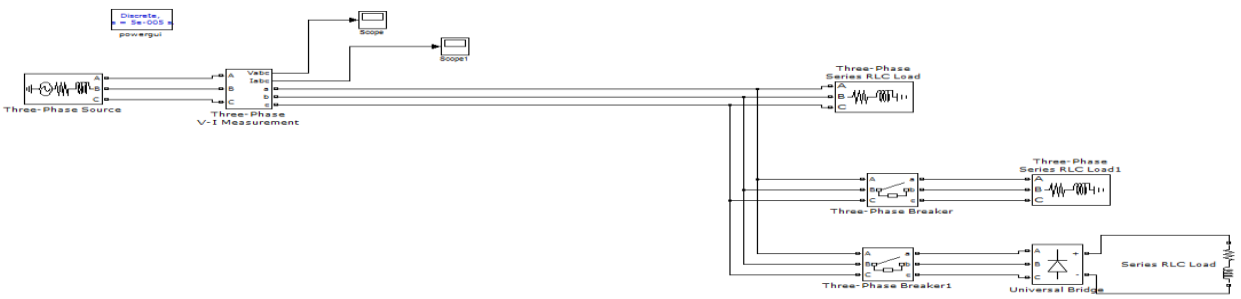
A novel inverter architecture is being designed with the goal of injecting voltage with appropriate control over the magnitude and phase angle, keeping the constant load voltage, and avoiding voltage disturbances at the load voltage. Typical DVR system model A power electronic switching device, coupled in series with the load voltage bus, that injects a dynamically regulated voltage into the load voltage bus is seen in Figure 1. This voltage may be used to mitigate the impact of a voltage bus failure on a sensitive load. DVR is a piece of equipment that is used to recover a voltage or improve the voltage quality on the load side, and it is installed in series with the source and the load to accomplish this. DVRs are connected in series with distribution systems in order to protect sensitive equipment from being damaged by a voltage spike. Essentially, the DVR's primary duty is to detect the occurrence of voltage dips on the power system channel and then inject the necessary voltage to correct for the voltage drop that has been detected. As a result, the DVR is put in close proximity to the sensitive load that is being secured. Based on the kind of interference or event that occurs in the system, the DVR responds by producing injection voltage derived from the DC energy storage unit, which is then transformed to alternating current voltage by the voltage source inverter (VSI) and then back to DC voltage. The dq0 transformation or the Park transformation are used to configure the controller on the DVR.

This method will provide information on the depth of the voltage drop as well as the phase shift along with the starting point and end point of the voltage drop by using ensating voltages through a three-phase injection transformer or three single-phase injection transformers in conjunction with the main supply and the three-phase injection transformer. The injection transformer raises the voltage of the filtered VSI output to the desired level while simultaneously isolating the DVR circuit from the rest of the distribution system. The capacity of the voltage source inverter (VSI) and the parameters for the link filter that connects the injection transformer and the inverter are critical in the design of the DVR because they determine how much power can be converted.

Within the scope of this research project, a novel Dynamic Voltage Restorer (DVR) topology has been developed. Smaller capacities and filter values for the voltage source inverter (VSI) and the link filter will result in improved compensation capabilities for voltage harmonic, swell and sag mitigation under different fault scenarios, as will the link filter's values. The switching harmonics may be eliminated by using the new RLC filter design. Inductance reduces the capacity of the direct current supply voltage when the amount of inductance is modest. With its great efficiency and capacity to increase the quality of voltage, the new DVR architecture has the potential to revolutionise the industry. The outline architecture of the RLC filter parameters for the particular model has been described, as well as the RLC filter parameters for the general model. It is possible to construct and simulate the new DVR with the suggested controlled Dynamic Voltage Restorer architecture using the MATLAB software. The control system exhibits excellent control dynamics and has a low amount of transient current overshoot at startup. It is possible to get decent simulation results under transitory performance.

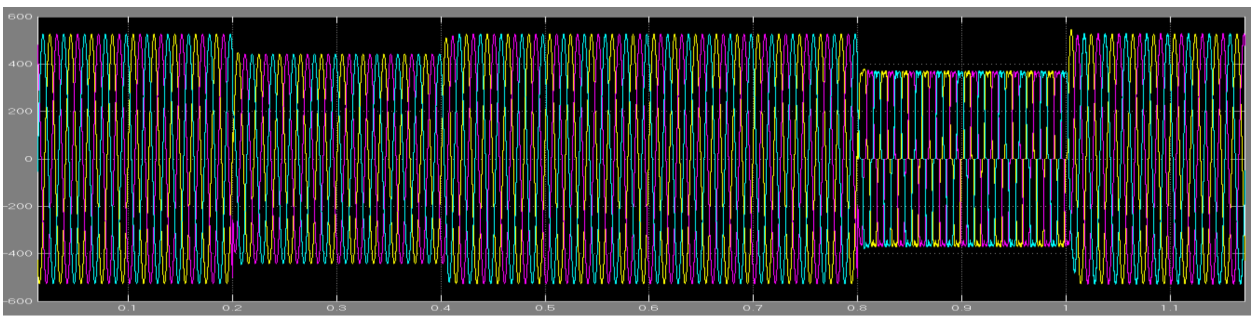
SIMULATION CIRCUIT WITHOUT DVR

Dynamic Voltage Restorer (DVR): The conventional circuit configuration of the DVR is shown in Figure 1. Dynamic voltage restorer is a series connected device is used for mitigating voltage disturbances in the distribution system (Lee, et al., 2004). The DVRs can be used and are already in operation (W.E. Brumsickle, et al., 2001). DVR maintains the load voltage at a nominal magnitude and phase by compensating the voltage sag/swell, voltage unbalance and voltage harmonics presented at the point of common coupling (Mahesh, et al., 2008; Jowder, et al., 2009; Ramachandaramurthy, et al., 2004). These systems are able to compensate voltage sags by increasing the appropriate voltages in series with the supply voltage, and therefore avoid a loss of power. In 1994, L.Gyugyi (Patent No. 5329222) proposed an apparatus and a method for dynamic voltage restoration of utility distribution network. This method uses real power in order to inject the faulted supply voltages and is commonly known as the Dynamic Voltage Restorer (Gyugyi, et al., 1994). The DVR should capable to react as fast as possible to

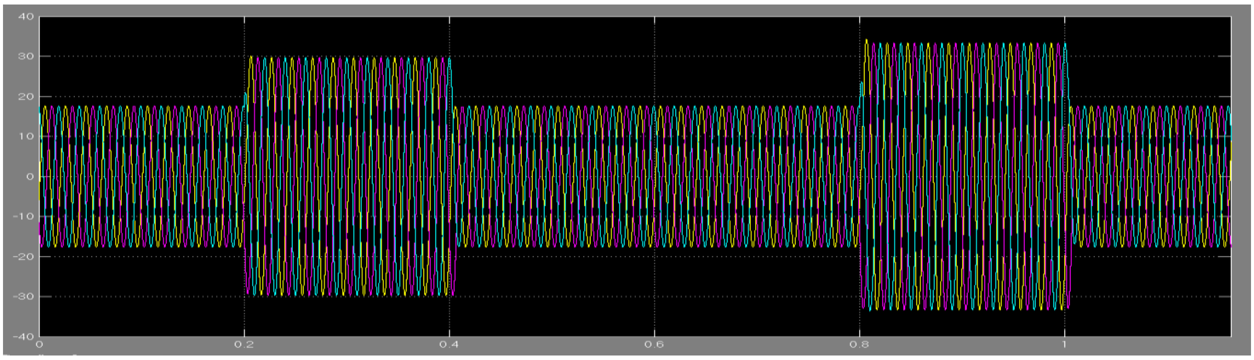


Circuit without DVR

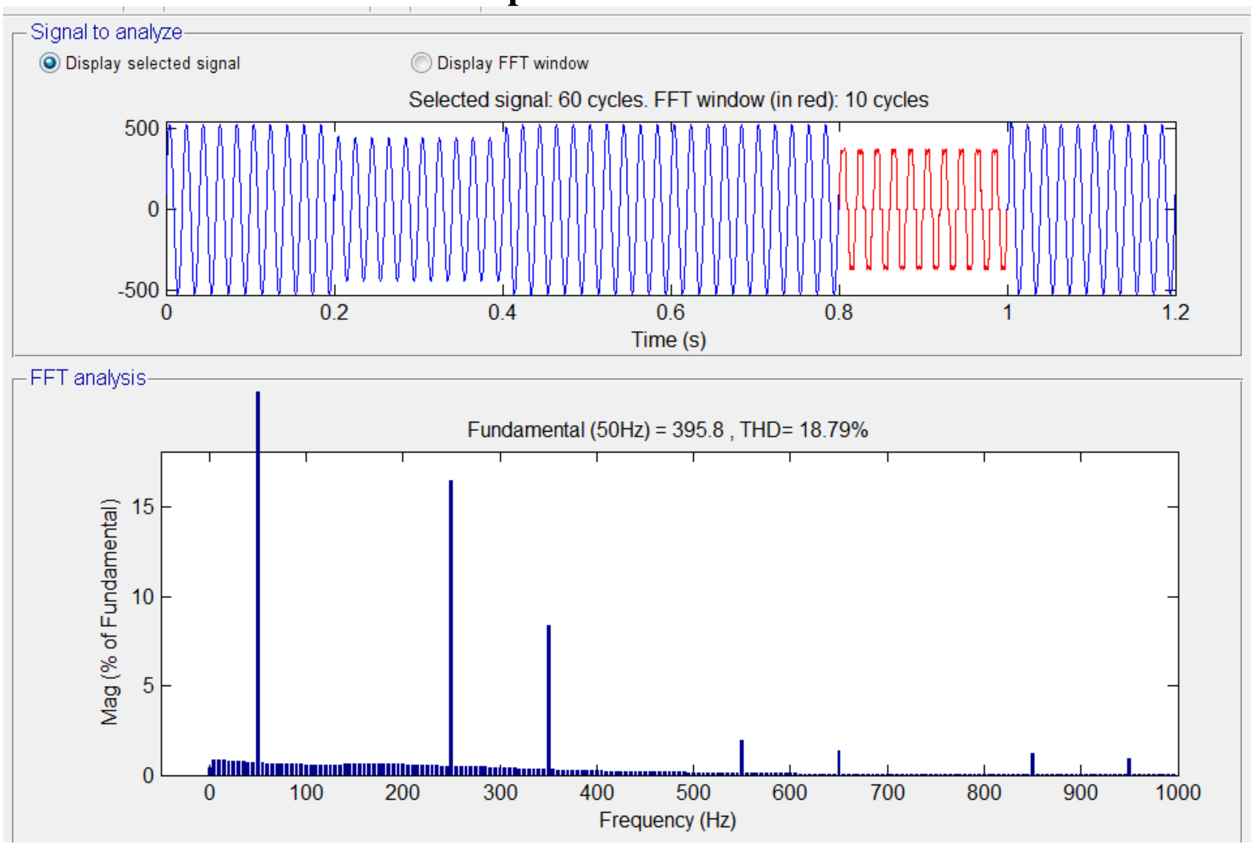
S



Voltage profile without DVR

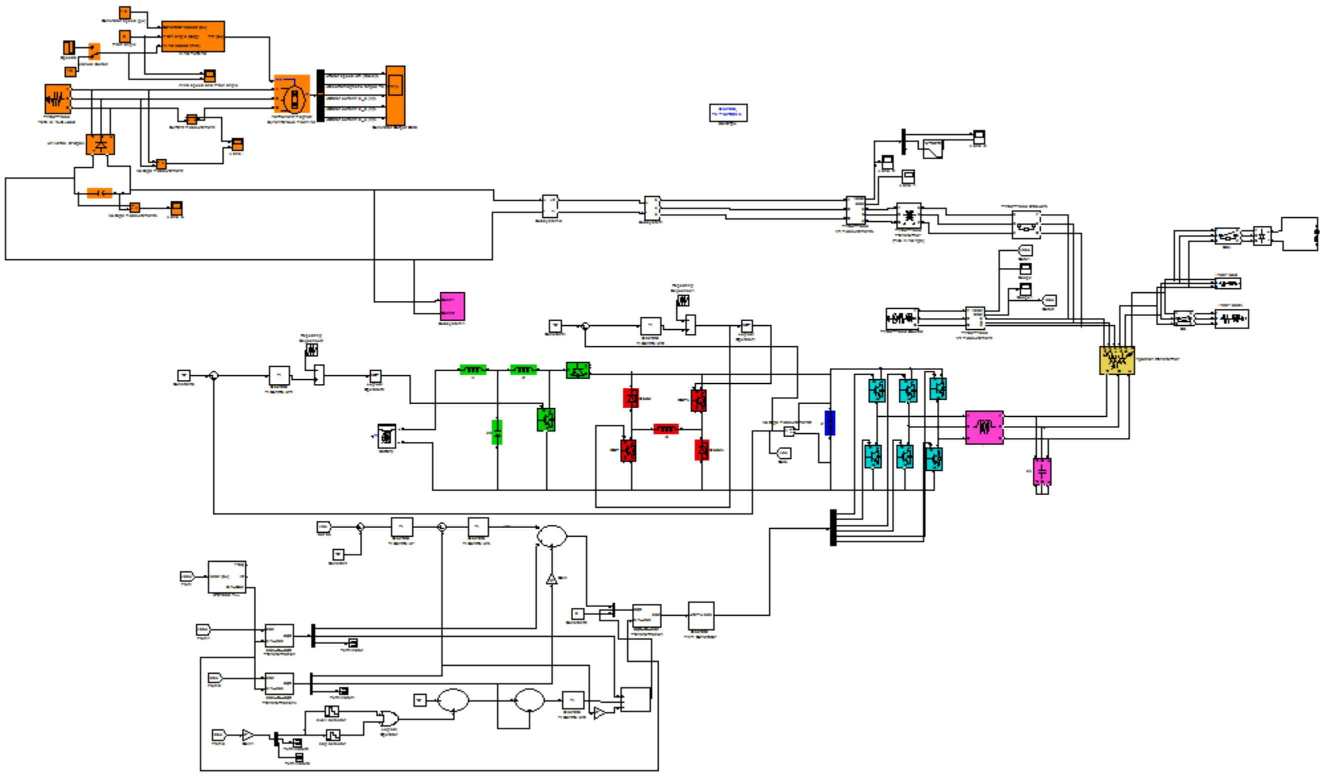


Current profile without DVR



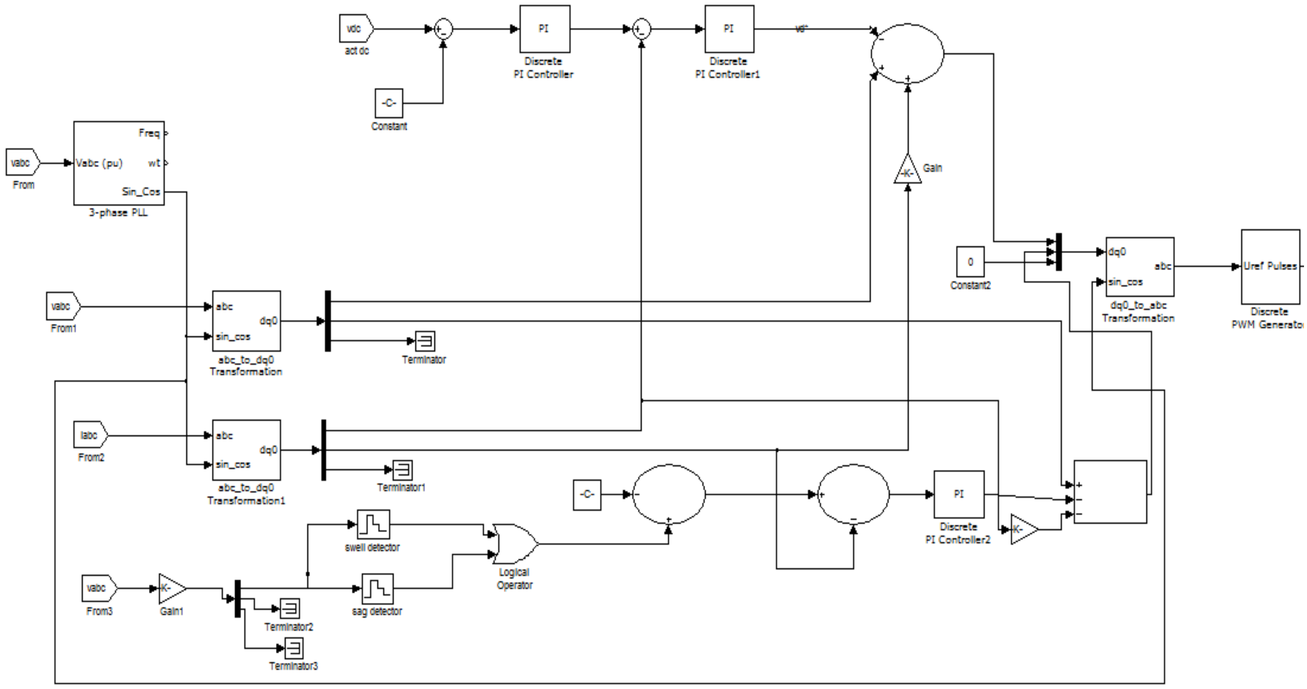
Total harmonic distortion

SIMULATION CIRCUIT WITH DVR



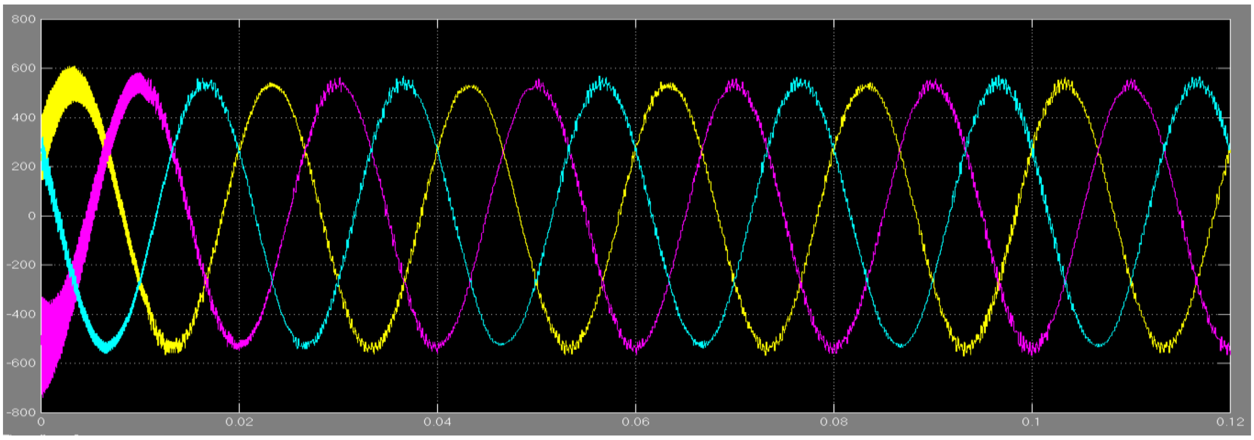
Total circuit configuration with existing controller

DVR can be applied for medium voltage (Li, et al., 2007; Toodeji, et al., 2009; Meyer, et al., 2008) and in low voltage application (Muni et al., 2004). The DVR components has been discussed in (Zhan, et al., 2002;Chun, et al., 2003; Zhan, et al., 2003). The DVR system consists of two (2) important components namely a power circuit and a control unit. A comprehensive literature survey of DVR including power circuit, control unit and its application in electrical distribution system is discussed. Power circuit of DVR basically consists of a voltage source inverter, a seriesconnected injection transformer, an inverter output passive filter, and an energy storage device that is connected to the dc link (Boonchiam, et al., 2006; Ezoji, et al., 2009; Banaei, et al., 2006; Ghosh, et al., 2002; Nguyen, et al., 2004) as follows. • Series Voltage Injection Transformers • Energy Storage • Passive Filters • Voltage Source Inverter (VSI) • By Pass Switch Power Circuit of a DVR is shown in Figure 2. In DVR the control circuit is used to derive the parameters (magnitude, frequency, phase shift, etc) of the control signal that has to be injected by the DVR. Based on the control signal, the injected voltage is generated by the switches in the power circuit (Zhan, et al., 2002; Kim, et al., 2005).

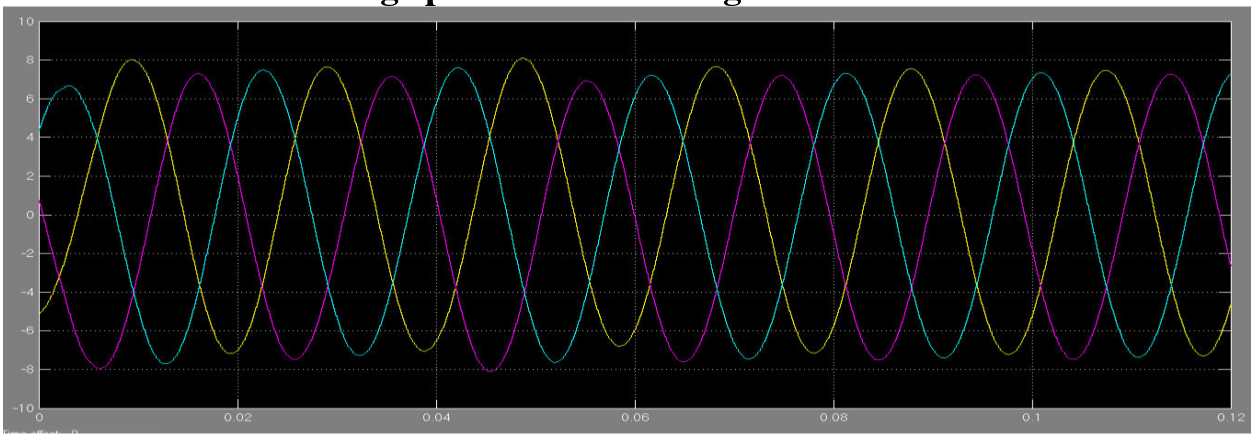


Simulink diagram for existing controller

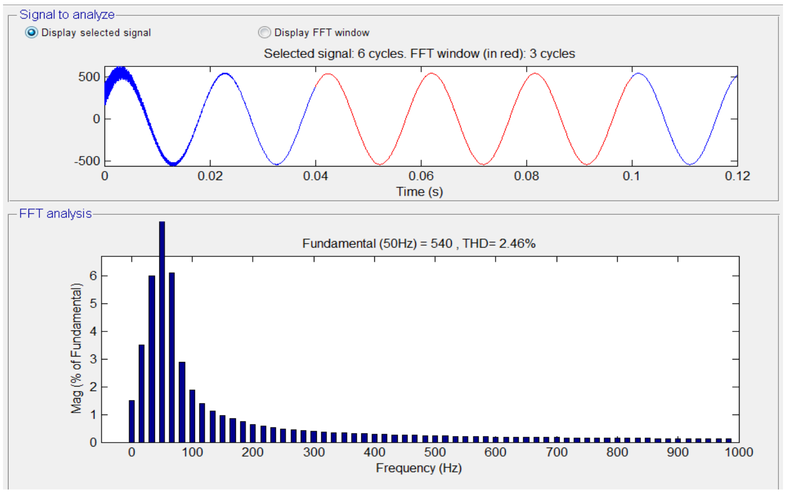
In a three-phase system, either three single-phase transformer units or one three phase transformer unit can be used for voltage injection purpose (Zhan, et al., 2000).The injection transformer comprises of two side voltages namely the high voltage side and low voltage side. Normally the high voltage side of the injection transformer is connected in series to the distribution system while power circuit of the DVR can be connected at the low voltage side. The basic function of the injection transformer is to increase the voltage supplied by the filtered VSI output to the desired level while isolating the DVR circuit from the distribution network. The transformer winding ratio is pre-determined according to the voltage required in the secondary side of the transformer (generally this is kept equal to the supply voltage to allow the DVR to compensate for full voltage sag (Zhan, et al., 2001). A higher transformer winding ratio will increase the primary side current, which will adversely affect the performance of the power electronic devices connected in the VSI. Three single phase or three-phase voltage injection transformers can be used for a three-phase DVR. In this case the high voltage of the injection transformer is connected to the distribution line and for single phase DVR one single-phase injection transformer can be connected (Zhan, et al., 2001). The single phase transformers can be used to inject the compensating voltages separately when three phase inverter is used. To evaluate the performance of the DVR the rating of the injection transformer is an important factor that need to be considered due to the compensation ability of the DVR is totally depend on its ratingThe DVR performance is totally depend on the rating of the injection transformer , since it limits the maximum compensation ability of the DVR (Wang, et al., 2006; Banaei, et al., 2006). In (Loh, et al., 2004; Graovac, et al., 2001) ,discussed multilever inverter topology is used in DVR allowing the direct connection of the DVR to the distribution system without using injection transformer.



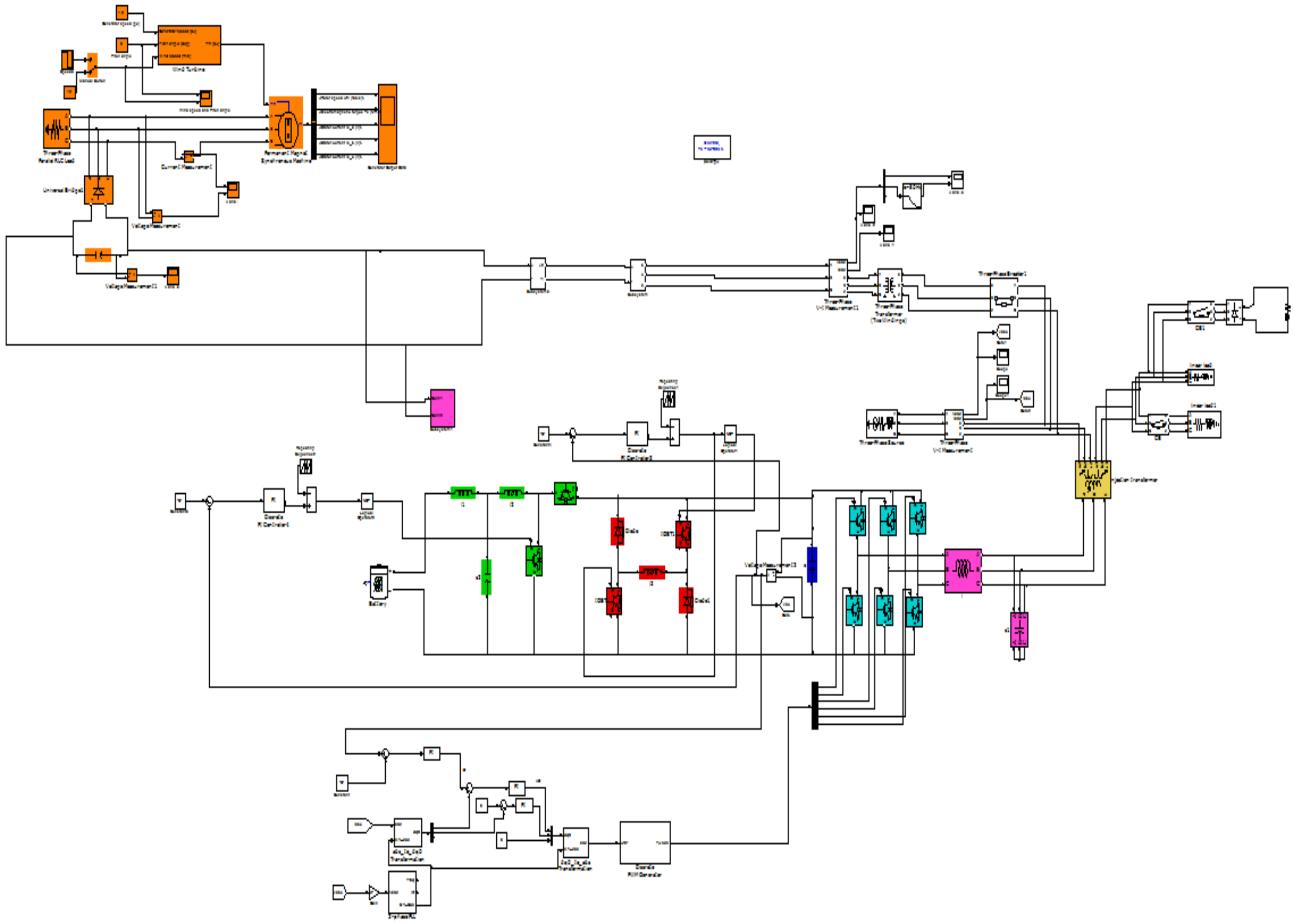
Voltage profile with existing controller



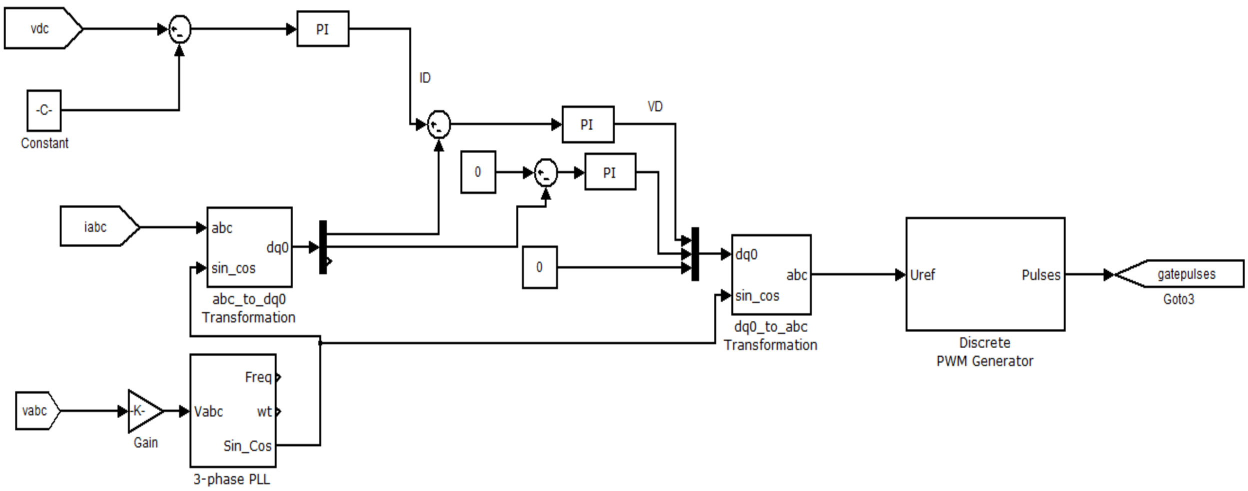
Current profile with existing controller



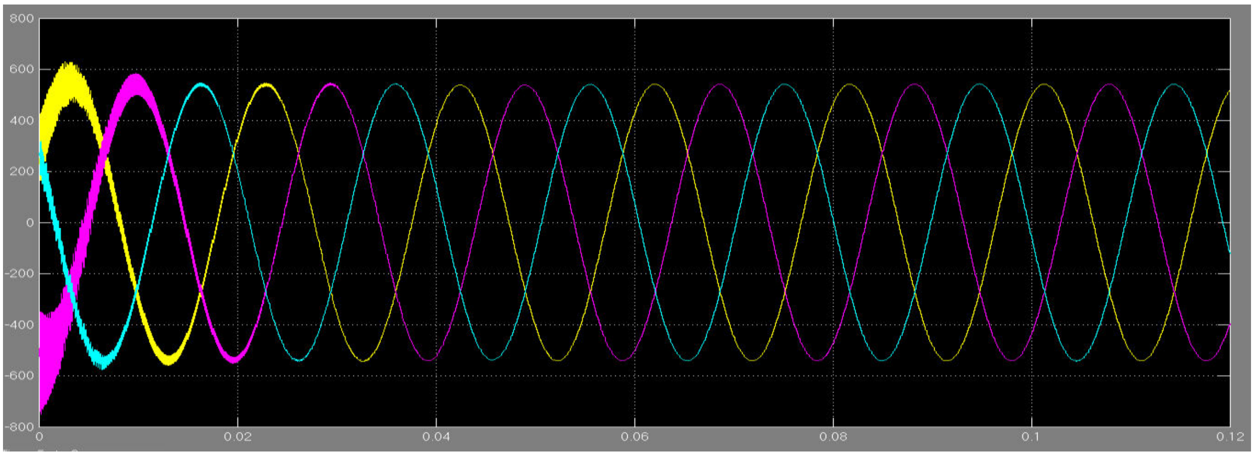
Total harmonic distortion existing controller



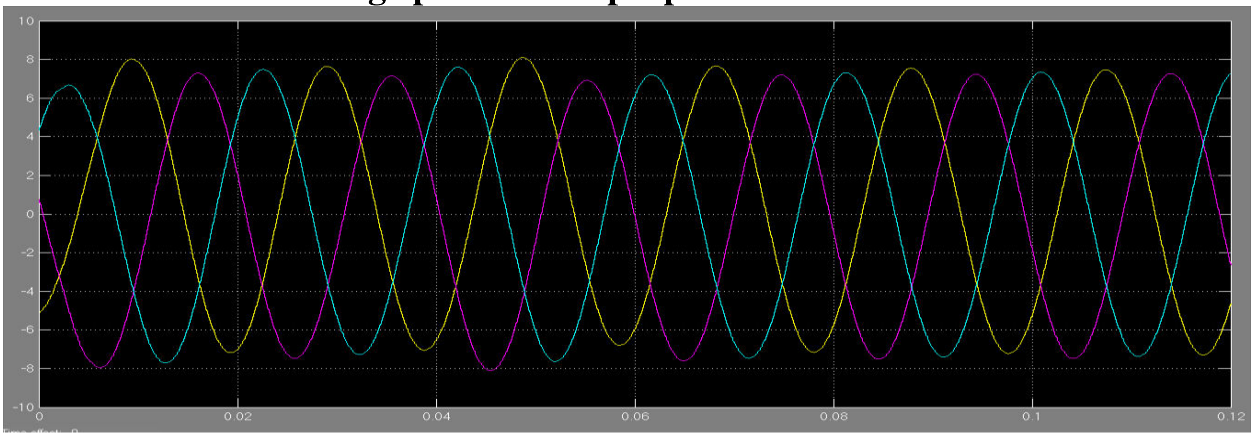
Total circuit with proposed controller



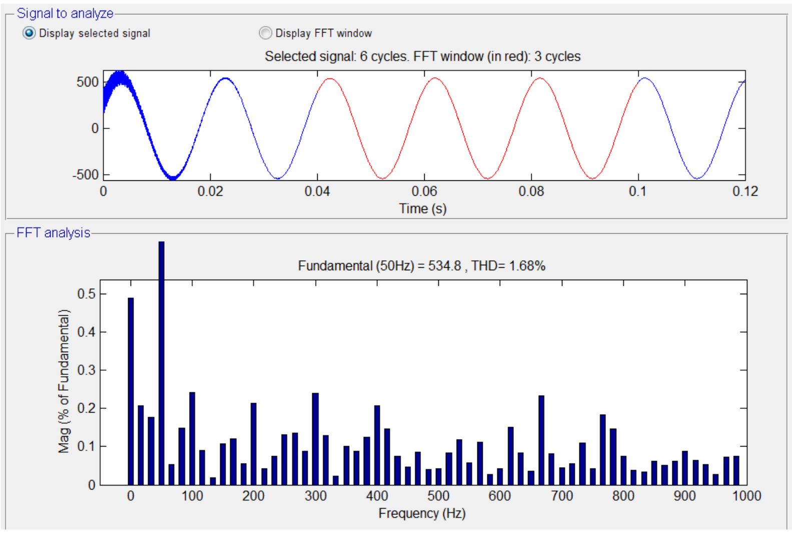
Simulink diagram for proposed controller



Voltage profile with proposed controller



Current profile with proposed controller



Total harmonic distortion proposed controller

CONCLUSION

According to the simulation findings, the suggested DVR is capable of rectifying power quality interference. The DVR control block will detect any voltage disturbances that arise and will act as a compensation. either a three-phase injection transformer or three single-phase injection transformers. The injection transformer boosts the filtered VSI output voltage to the required level. Additionally, the transformer separates the DVR circuit from the distribution network. The capacity of the voltage source inverter (VSI) and the values of the link filter connecting the injection transformer to the inverter are critical in the DVR's design. This research project proposes a novel Dynamic Voltage Restorer (DVR) structure. The voltage source inverter's (VSI) capacity and link filter values are small, which enhances the compensation capabilities for voltage harmonic, swell, and voltage sag mitigation under various fault conditions. The new RLC filter is capable of removing switching harmonics entirely. When the inductance value is tiny, the capacity of the dc supply voltage is lowered. The new DVR structure is very efficient and capable of improving voltage quality. We have offered an overview architecture of the RLC filter settings for the given model. MATLAB is used to model and simulate the new DVR with its proposed controlled Dynamic Voltage Restorer topology. The control technique offers a low transient current overshoot and an excellent control dynamics. The simulation findings are satisfactory for transient performance.

REFERENCES

[1] C. Tu, Q. Guo, F. Jiang, H. Wang, and Z. Shuai, “A comprehensive study to mitigate voltage sags and phase jumps using a dynamic voltage restorer,” IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 2, pp. 1490–1502, 2020.

[2] A. P. Torres, P. Roncero-Sanchez, and V. F. Batlle, “A two degrees of freedom resonant control scheme for voltage-sag compensation in dynamic voltage restorers,” IEEE Transactions on Power Electronics, vol. 33, no. 6, pp. 4852–4867, 2017.

[3] S. Priyavarthini, A. C. Kathiresan, C. Nagamani, and S. I. Ganesan, “Pvfed dvr for simultaneous real power injection and sag/swell mitigation in a wind farm,” IET Power Electronics, vol. 11, no. 14, pp. 2385–2395, 2018.

[4] Y. Zhang and C. Qu, “Direct power control of a pulse width modulation rectifier using space vector modulation under unbalanced grid voltages,” IEEE Transactions on Power Electronics, vol. 30, no. 10, pp. 5892–5901, 2014.

[5] C. Meyer, R. W. De Doncker, Y. W. Li, and F. Blaabjerg, “Optimized control strategy for a medium-voltage dvr¡ a theoretical investigations and experimental results,” IEEE Transactions on Power Electronics, vol. 23, no. 6, pp. 2746–2754, 2008.

[6] F. Jiang, C. Tu, Q. Guo, Z. Shuai, X. He, and J. He, “Dual-functional dynamic voltage restorer to limit fault current,” IEEE Transactions on Industrial Electronics, vol. 66, no. 7, pp. 5300–5309, 2019.

[7] A. dos Santos, T. Rosa, and M. T. C. de Barros, “Stochastic characterization of voltage sag occurrence based on field data,” IEEE Transactions on Power Delivery, vol. 34, no. 2, pp. 496–504, 2018.

[8] J. L. Sosa, M. Castilla, J. Miret, J. Matas, and Y. Al-Turki, “Control strategy to maximize the power capability of pv three-phase inverters during voltage sags,” IEEE Transactions on Power Electronics, vol. 31, no. 4, pp. 3314–3323, 2015.

[9] S. Choi, J. Li, and D. M. Vilathgamuwa, “A generalized voltage compensation strategy for mitigating the impacts of voltage sags/swells,” IEEE Transactions on Power Delivery, vol. 20, no. 3, pp. 2289–2297, 2005.

[10] M. Castilla, J. Miret, A. Camacho, J. Matas, and L. G. de Vicu na, “Voltage support control strategies for static synchronous compensators under unbalanced voltage sags,” IEEE Transactions on Industrial Electronics, vol. 61, no. 2, pp. 808–820, 2013.

[11] J. Wang, Y. Xing, H. Wu, and T. Yang, “A novel dual-dc-port dynamic voltage restorer with reduced-rating integrated dc¨cdc converter for wide-range voltage sag compensation,” IEEE Transactions on Power Electronics, vol. 34, no. 8, pp. 7437–7449, 2019.

[12] A. Parre ˜ nno Torres, P. Roncero-S˜ nanchez, J. V˜nazquez, F. J. L ˜ nopezAlcolea, nd E. J. Molina-Mart˜ ninez, “A discrete-time control method for fast transient voltage-sag compensation in dvr,” IEEE Access, vol. 7, pp. 170 564–170 577, 2019.
[13] V. Valouch, M. Bejvl, P. ˇ Simek, and J. ˇ Skraml˜ ik, “Power control of grid-connected converters under unbalanced voltage conditions,” IEEE Transactions on Industrial Electronics, vol. 62, no. 7, pp. 4241–4248, 2014.
[14] M. Pradhan and M. K. Mishra, “Dual p- q theory based energyoptimized dynamic voltage restorer for power quality improvement in a distribution system,” IEEE Transactions on Industrial Electronics, vol. 66, no. 4, pp. 2946–2955, 2019.
[15] T. A. Naidu, S. R. Arya, and R. Maurya, “Multiobjective dynamic voltage restorer with modified epll control and optimized pi-controller gains,” IEEE Transactions on Power Electronics, vol. 34, no. 3, pp. 2181–2192, 2018.