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# Design of Dynamic Voltage Restorer for Power Quality Improvement

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## ABSTRACT

Solutions for customers with delicate loads and quick voltage regulation are essential. Protect important loads from supply-side voltage disturbances with a power electronic converter-based Dynamic Voltage Restorer (DVR). In the case of severe sag and swell, DVR is a well-known, low-cost therapy option. On the basis of its maximum voltage injection and active power contribution, a DVR's mitigation ability is determined. Standard DVRs use batteries as their DC input, but batteries are cumbersome, expensive, and hazardous to dispose of after they've been used. This limits compensation for DVRs. It is recommended to increase the DVR's VA rating by 1.5 times by increasing the DC connection voltage to 1.5 times the micro grid voltage regulation and quality improvement methods are proposed in this study. As a series voltage compensator, these solutions incorporate a Dynamic Voltage Restorer (DVR) for regulation, quality improvement, and reduction of harmonic distortion. Continuous adjustment of the DVR output voltage is proposed to reduce harmonic distortions while minimizing network bus voltage changes. As a result of this strategy, the peak demand voltage loss is compensated for. In constant impedance loads, voltage rise reduces network demand, resulting in lower branch currents and losses

**Keywords:** Dynamic voltage restorer; AC Supply; Micro grid; Voltage injection; Active power contribution; Quality improvement.

## 1. Introduction

Voltage disruptions in electric power distribution networks are increased by DVR, a CPD (DNs). Series-linked devices, such as DVRs, are utilised in distributed networks to minimize voltage disturbances [1]. A voltage source inverter, an injection transformer in series with another transformer, an AC filter, a controlling unit, and a storage unit are all components of the DVR [2]. A boosting transformer can be used whenever there is a voltage imbalance or voltage variation in the distribution network and the fundamental principle of operation is to supply the necessary voltage in series with the distribution network. DVR can also do sag and swell mitigation, harmonic mitigation, and power factor correction in addition to VV and VU mitigation. Representation of DVR recording system layout is depicted in Figure 1.

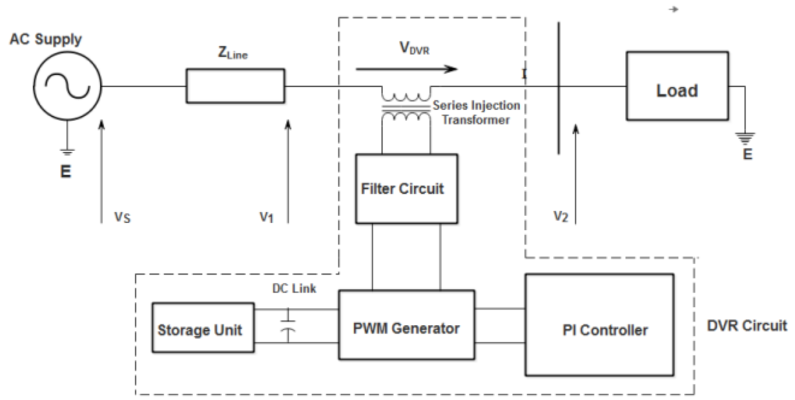


**Figure 1.** Block diagram of the Dynamic voltage restorer

Disruptions in the secondary electric power distribution network include harmonics, voltage sags, and other power quality issues. Unbalanced voltage and voltage volatility cause severe interruptions in secondary networks. CPDs

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have only lately been proposed as a full solution to these problems [3]. DVR is a standout CPD tool. Modern-day CPDs like DVRs are employed in electric distribution networks because they are effective, effective, and efficient. It's only been around for a short time.

With the DVR, a completely new type of advanced solid-state power electronic device has been proposed, one that can supply the distribution system with the voltage it needs while also controlling the voltage at the load side within an acceptable standard voltage range of 5% of the nominal voltage value. In most cases, a boosting transformer is used at the point of power transfer link to connect DVR to distribution networks between the essential load feeder and the power supply. Voltage harmonic reduction, fluctuations reduction, overvoltage and under voltage mitigation, and fault current reduction are all capabilities of a dynamic voltage restorer in addition to the usual voltage imbalance mitigation and compensation for voltage variation. The DVR will supply an appropriate amount of electric potential sequentially to the source voltage to ensure its safety [4]. According to the specific circumstances at hand, either galvanic isolation or a float-at-the-source voltage for the voltage source converter are necessary, depending on what is required. There are two types of converters that can be used: transformer-connected converters and transformer-less connected converters, often known as direct connected converters. The use of transformer-connected converters is on the rise.

Application of Dynamic Voltage Restorer (DVR) in the power system for voltage quality enhancement, as well as SRF controlled DVR implementation for the mitigation of sag, surge, and voltage harmonic distortion when an induction motor is utilised as a source of load [5]. To reduce voltage sag, voltage swell, and voltage harmonics, a new control for DVR has been proposed Distributed generation (DG) integrated DVR with SRF theory and a new control approach have been developed to suppress voltage sag and harmonics.

## 2. Methodology

There may be an impact on the DVR reference voltage's transient estimated value due to line current transients generated by load and PV connections and disconnections. As a result, the transient response could see severe overshoots, and even the network itself could become unstable as a result. At the output of the Low Pass Filter, the estimated reference voltage is likewise filtered by the other methods outlined above (LPF) [6-12].

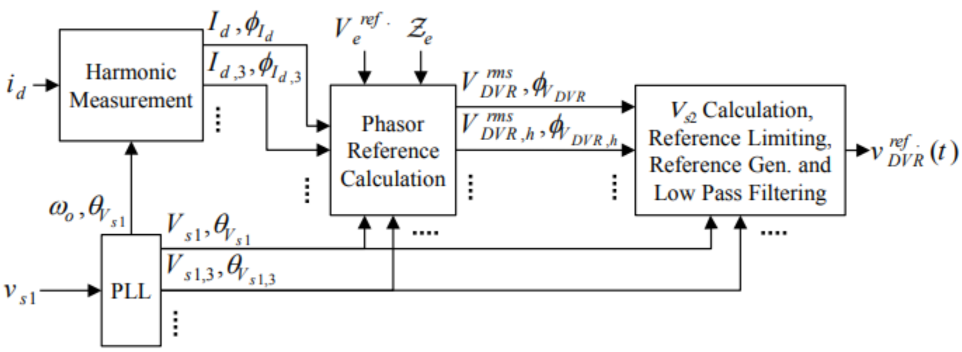


**Figure 2.** Reference voltage generation block diagram of DVR

Nonlinearity in the control loop necessitates the inclusion of this additional filtering due to the limited output voltage and mathematical restrictions. The LPF, which removes nonlinear responses and smooth out the loop's functioning, sets a bandwidth limit for the reference generation loop [13-17]. The SOGI damping coefficient, k, and the LPF cut-off frequency must be adjusted to the right levels in order to provide some filtering while retaining a desired response time. Figure 2 shows the schematic for computing the reference voltage.

## 3. Shunt Compensation of Voltage Regulation

Similar to the VSC illustrated in Figure 3, D-STATCOMs can be used to achieve a variety of goals by injecting or absorbing reactive power, as shown in Figure 3. Additional applications for this device include power factor correction and current harmonic elimination, as well as voltage regulation [18]. The load flow analysis can be performed in the presence of D-STATCOM by starting with the conventional load flow analysis. Adding the current injection from D-STATCOM bus to the current injection from the bus results in an increase in current injection.

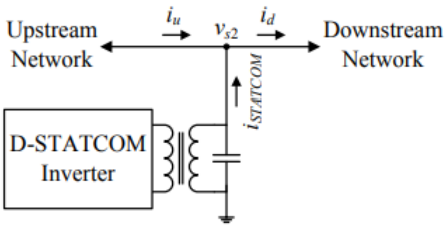


**Figure 3.** D-STATCOM Shunt voltage compensation

Depending on the application, a DVR can either inject or absorb actual or reactive electricity to control voltage sag. As illustrated in the diagram, DVR self-sufficiency is achieved by injecting reactive power in quadrature with the fundamental frequency of the injected voltage. A system's voltage injection capability (inverter and transformer rating) as well as energy storage optimization should be taken into consideration while designing control mechanisms.

As soon as an error in the terminal voltage arises, the SRF control algorithm injects the correct magnitude of voltage to keep the load end voltage balanced. It can accurately diagnose both symmetrical and unsymmetrical sag and swell concerns. The DVR's input DC voltage and the magnitude of the load voltage are used as inputs to this algorithm, which estimates the direct and quadrature axis voltage [19]. The DVR controller generates error voltage when the load voltage falls below 10% of the reference load voltage. This voltage is utilised to generate the PWM waveform for VSI. Figure 4 shows a state-space representation of the proposed SRF theory for controlling DVR.

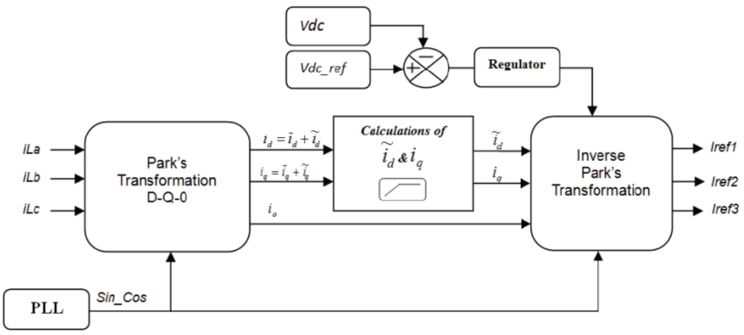


**Figure 4.** Block diagram of SRF Based compensation algorithm

SRF theory and a typical boost converter are used in the overall schematic layout of the DG integrated DVR. In this design, the abc/dq transformation block receives the source voltage as an input, and the PLL block also receives the same voltage. Information on sin and cos can be found in the PLL block [20-22]. abc/dq blocks accept this value as an input, as follows: Based on the two inputs, this transformation block delivers information about Vd and Vq. Vdact and Vqact are compared to the genuine parameters in the preceding section, which are listed here. A frequent practise is to compare the quadrature axis to 0 P. U As an input, a PI controller receives the error. The PI controller output once again provides an input to the dq/abc block, as well as PLL information. Using the pwm generator's gate pulses as an input, this block creates the gate pulses that the inverter then uses to transform the pulse information to voltage for output to the inverter. As long as you have a simple boost converter, the output of PV can be used to power the DVR.

## 4. Results

At 11 kV and 50 Hz, the generator in this test system generates power. When the DVR is activated, the test system is used to record the results. When the load side generates voltages, these voltages are fed into the controller system. The power circuit generates the appropriate AC output voltage through the utilization of the DC power system. A PI controller and a PMW generator are employed to offer feedback in the control section.

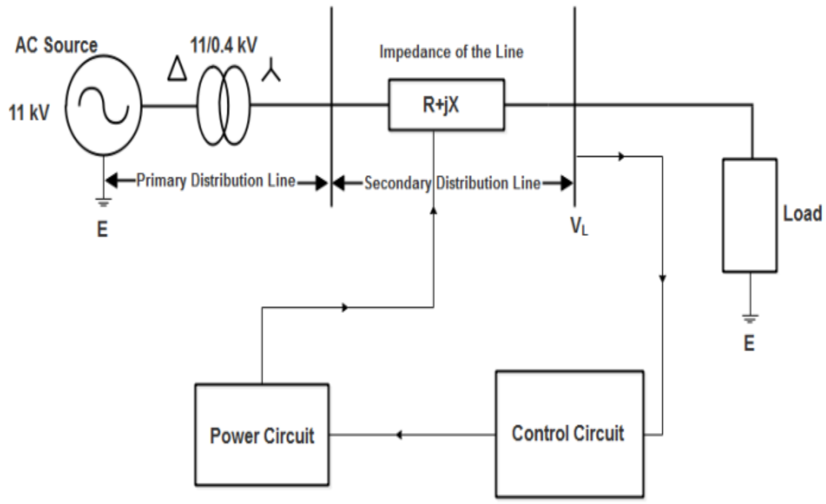


**Figure 5.** Proposed block diagram of DVR test system

Figure 5 shows the operation of a dynamic voltage restorer in conjunction with a distributed generation system (DGS). Distributed generation is the term used to describe the photovoltaic system in this context. For the DVR to obtain the correct voltage from the PV system, a boost converter is used in conjunction with the PV system. The dynamic voltage restorer is linked to the line in series with this device, and it is powered by the line voltage. An alternating current (AC) converter converts the output of a PV system to alternating current (AC), while also correcting voltage.

It is usual method to employ a capacitor to provide voltage support for the converter in a digital video recorder. In this particular instance, photovoltaic systems are being employed to power the voltage source converter of the DVR system. The switches of the voltage source converter are activated by the use of a control circuit. As long as the power system has a DVR connected to it, the source voltage will remain at a constant level throughout the day. The integrated DVR from DG is illustrated in the subsystem diagrams.

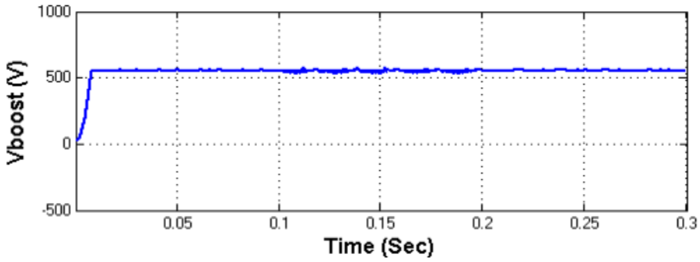


**Figure 6.** DG Output

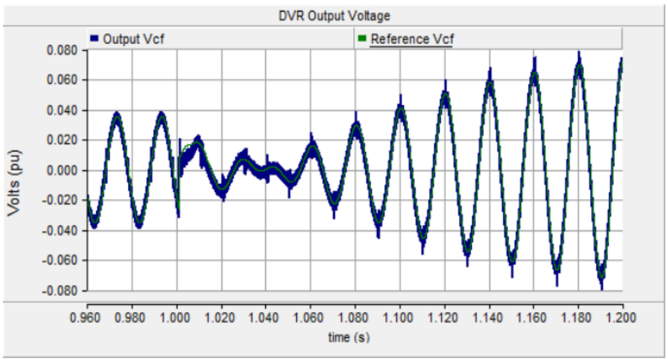


**Figure 7.** Output Voltage and Reference voltage

The output voltage of the system is depicted in Figure 7. The magnitude of the voltage is 200 volts in this case. As illustrated in Figure 8, the DG output is 550V.

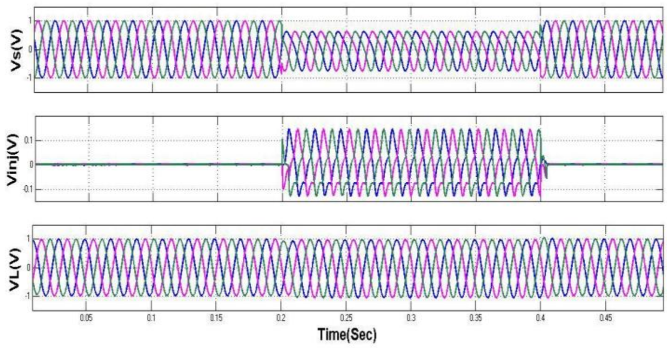


**Figure 8.** DVR Output voltage of both Swag and Swell

When confronted with challenges such as voltage swell, the DVR's behaviour is represented in Figure 9. As shown in Figure 9 (a), the DVR injected voltage for all three phases (Vinja, Vinjb, and Vinjc) during an event swell during which the DVR was enabled can be seen. By looking at the injected voltage Vinja in figure 9 (b), it can be seen that it is $150^{o}$ behind the line-neutral voltage source V0ab, suggesting that it is out of phase with the $180^{o}$ in the line-neutral voltage source V0ab. A steady amount of load voltage is thus maintained as a result of this technique. This is seen in Figure 9(c), which depicts how the proposed DVR successfully compensates for concerns about voltage sag and swell, which are correctly adjusted in a precise and effective manner.

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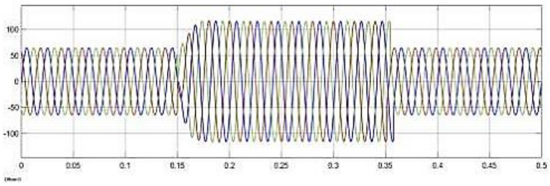
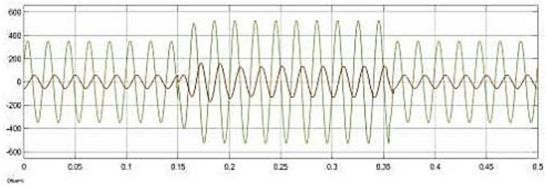
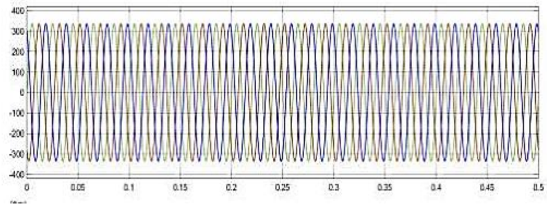


(a)



(b)



(c)

**Figure 9.** Simulated results of injected voltage and compensated load voltage during the Swell

## 5. Conclusion

An integrated DVR topology design was demonstrated in this chapter to increase the voltage supply of a distribution system. A bidirectional buck boost DC-DC converter was designed and modelled for the incorporation of a DC input for DVR in this project. A FL controller was used to demonstrate the functionality of the proposed DVR in a distribution system for the problems of voltage sag and swell events. In this chapter, it is said that the results of the DVR simulations will be thoroughly examined. Researchers found that integrating DVR improved the DVR's compensating capabilities by keeping a steady DC input voltage and also provided active power support for the micro grid, according to the findings. Using distributed generation integration, the dynamic voltage restorer is examined in this chapter. The DVR is powered by the DG system. Photovoltaic systems are considered to be dispersed generation. In general, the output voltage of the PV system is very low and does not match the requirements of the DVR. An efficient DC-DC converter with a high gain has been used to increase the voltage of the solar panel system. In this research, a DC-DC converter based on SRF theory and a proposed control mechanism for voltage harmonic compensation during sag are modelled and analysed in simulation.

**Declarations**

**Source of Funding**

The study has not received any funds from any organization.

**Competing Interests Statement**

The authors have declared no competing interests.

**Consent for Publication**

The authors declare that they consented to the publication of this study.

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