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Investigating the Use of DVRs in Power Systems for Voltage Harmonic Compensation

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Abstract: Of all the categories, energy distribution networks are the most closely examined and tested since they serve as the primary conduit between the energy sector and consumers. It is crucial to keep an eye on the energy level throughout the distribution phase as a result. However, power distribution networks continue to face common issues such as harmonics, capacitor switching, power outages, and voltage breakdown, all of which impair sinusoidal waveforms and reduce the strength and quality of the network. Employing power appliances, such as customized power appliances, is one way to solve issues with energy quality. The Dynamic Voltage Restorer (DVR) is one such device. Which is integrated with both distribution and network networks. Every DVR in a distribution network is under control. It can simultaneously modify the voltage amplitude and phase in the network by introducing voltage into the system. It takes the form of three-phase syncing and injections to make up for the difficulty of energy quality. This article gives information on each DVR's control in distribution networks and looks at how DVRs have been used recently for power compensation

***Index Terms* - Power Quality, Distribution Networks, Dynamic Voltage Restorer (DVR), Control Systems (PWM)**

INTRODUCTION

The distribution phase because it is seen as the most important link between the energy sector and the customers. As a result, it is important to address energy quality towards distribution. However, harmonics, capacitive switching, and dynamic voltage sag and swell are a few instances of sinusoidal wave power outages that can seriously impair power quality and network stability. Some users are affected by the above interruptions, which also affects other users and network devices. In addition, due to various issues, the network may be disrupted for vulnerable customers. As a result, distribution businesses have a responsibility to provide reliable and high quality energy to their customers. This requires the use of network-based power quality controls. This can be done with custom power tools, which are powerful power tools that reduce interference. Dynamic voltage recovery, here model and prototype, is an example of such a device. Also, its effects on the distribution network interruption are being examined. After discussing the need for DVR appointment, the structure, operating principle and control method are explained. There are many DVR control systems we know of, including current sinusoidal controllers, current lines according to the fast power principle, and related reference structures. Because it successfully eliminates all harmonic components, negative sequences, zero current line, and other current load disturbances, the fast power principle was selected with the new modifications. Models of networks with unequal linear and indirect loads (such as input engines and electric arc furnaces) are simulated before the DVR and tested for a variety of interventions to brighten the DVR performance. The DVR serves as a powerful remedy for voltage oscillations based on current three-phase imbalance, active power compensation, and voltage sag and simulation data. People often examine and evaluate the distribution component, in which case it is recognized as an important link between the power business and consumers. As a result, it is important to address fuel quality in the distribution sector. However, distribution networks are vulnerable to interference from sinusoidal waves, including swell, harmonics, and capacitive switching, as well as dynamic voltage sag. These factors all lower the quality and power of the network. Certain clients disrupt other users and network devices in the manner described above. Furthermore, if given specific risks, the network may be disrupted for affected customers. As a result, it is the duty of distribution companies to give their clients dependable, premium energy. Therefore, it is the duty of distribution companies to offer their clients dependable, premium energy. Tools for network power management must be used for this. Electronic devices known as power demands can be used to increase distraction. Dynamic voltage restoration, designed and modified here, is an example of such a machine. Also, its effects on the distribution network are being studied. The DVRs they encounter are specified because of the structure, operating system, and control system they require to use them. There are many DVR control systems known to us, including current sinusoidal controllers, current line and sync reference structures based on the fast power principle. In this case the fast power principle with novel modifications was chosen due to the fact that it successfully removes all harmonic components, current-load distortion, miss-sequence, and zero current line. The light is on when using a DVR. Before DVR, different kinds of interference were tested and input engines and electric arc furnaces, two examples of unequal and indirect loads, were simulated and designed into networks. The DVR functions as a potent compensation for voltage sag, voltage spikes, active power compensation, and three-phase imbalance based on the simulated data.

DVR SYSTEM OPERATION PRINCIPLES

Finding power outages and restoring the network's power supply is the DVR's main goal. For radial distribution systems, the voltage sag can be computed using a separator model. The situation is shown in Figure 1. This method indicates that the error in current carried by the loads in the error path is much smaller than the error in current. At the standard integration point (PCC), the load and the error are provided. The voltage sag is not equal, as evidenced by the phase angle jump that characterizes it. [1-5]

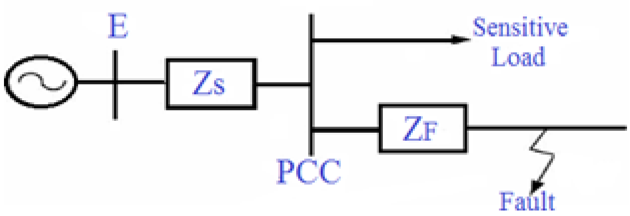


Figure 1. Model of voltage Divider for Voltage Sag

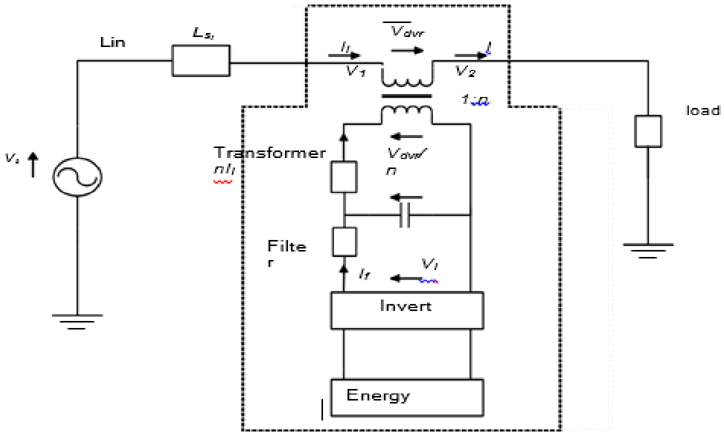


Figure 2. DVR-equipped Distribution System

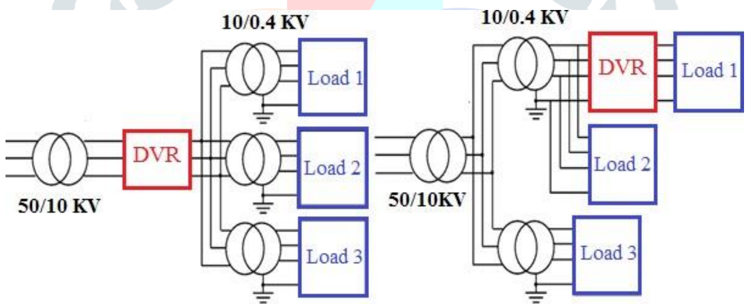


Figure 3. DVR Location in Distribution Networks

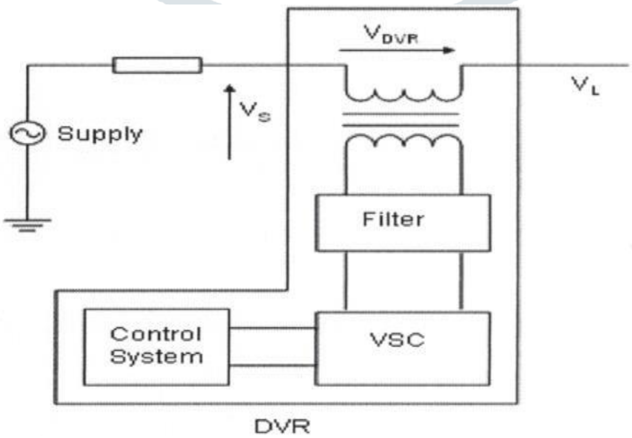


Figure 4. The actual DVR schemes

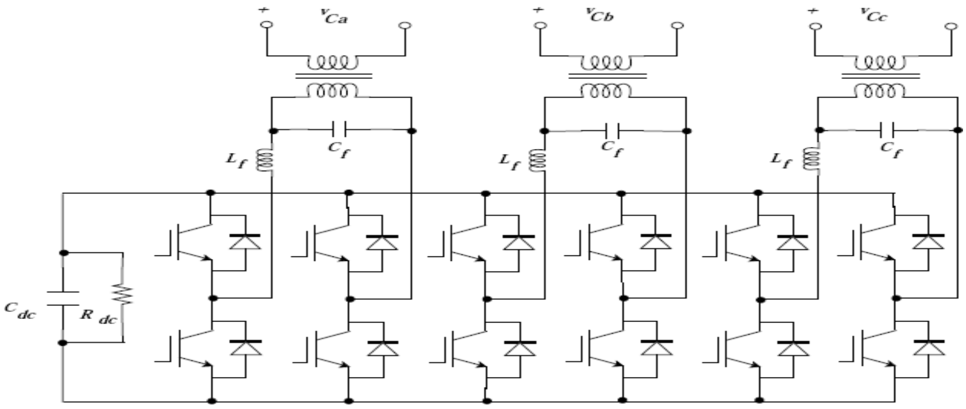


Figure 5. DVR's Configuration and Structure

To fix major errors, the DVR may need to maximize effective power. The energy storage system should be used to achieve this goal. Powerful banks have recently been used in the construction of DVR systems. Once the problem is fixed and the system returns to normal, the DVR detects and saves the power used on the network. Power banks are classified based on system parameters such as load and power dissipation, based on their energy storage capacity. The injection transformer connects the DVR in between the distribution lines for the series. Actually, a three-phase transformer's main side ought to be built to support the full current line. The initial voltage level is the highest voltage that a DVR is capable of injecting into a circuit.

Power output waves will be generated by switching to Pulse Width Modulation. When the voltage drops to a very low point, a power storage device installed in the DVR is used to adjust the voltage. The term "ideal restoration" refers to the fact that the voltage supply is inseparable. Actually, the active power needs to be moved from the DVR to the distribution system after it has adjusted for the high voltage fluctuations. When it comes to a DVR that has infinite power storage, the line voltage doesn't fluctuate in any way. However, the DVR's stored power is likely to be trapped if the DC connector's capacity is restricted. For instance, at solid voltages, the stored power is lost because the DVR is unable to maintain a constant load voltage when the DC connection voltage drops. Therefore, for DVR, the injected power loss is significant. Other techniques for introducing DVR-reduced voltage into a distribution system have been documented in the literature [6]. The configuration and layout of the DVR are shown in Figure 5.

Techniques for Voltage SAG Compensation

The most commonly used methods of compensation are, among other things, the replacement of above-ground current by the use of underground cables, increasing the area of equipment, and supplying affected loads from two or more points. To disassemble, disassemble the limit reactor. To reduce the load affected by the various lines. Reduction period with installation of immediate protection devices as well as voltage sag compensation. The first six possibilities include network maintenance, human resources, and existing repair and maintenance costs, but they focus solely on power limits and cannot be improved. In 1998, Hingorani Energy Issues compared energy quality improvements and customer requirements. A few examples of these factors are the power of the DVR, varying loads, and varying voltage sag. There are load steps that are more prone to jump. The control system is therefore dependent on the load factors. The DVR injects voltage in three different ways depending on the type of load and how sensitive it is to amplitude and phase flexibility. [7]

METHOD OF IN-PHASE COMPENSATION (IPC)

The voltage sag in the IPC method allows the injection voltage to be split into phases. Consequently, during adjustment, the load voltage and source voltage are in phase. Phase overflow at the load voltage will occur if there is a phase jump in the supply voltage drop voltage. As seen in Figure 6's phase diagram, the only thing that stays constant in such a situation is the voltage's magnitude.

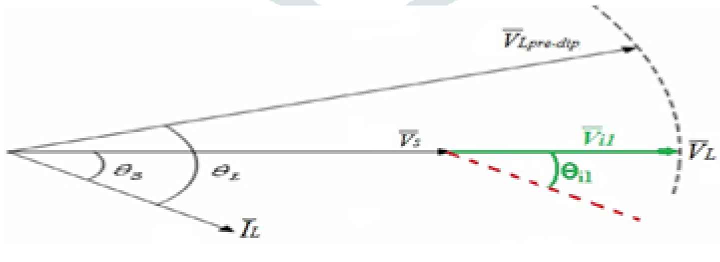


Figure 6. Phase diagram of the IPC controller

The following formulas can be used to determine the apparent and active energy, phase, and injection voltage magnitudes:

$$Si = ILVi = IL(VL - VS) \quad (3)$$

$$Pi = ILVi\cos\theta s = IL(VL - Vs)\cos\theta s \quad (4)$$

$$Vi = VL - Vs \quad \Theta i1 = \Theta s \quad (5)$$

DPC Compensation Method

Another issue is that certain loads skip certain parts. Thus, the voltage phase must naturally shift to phase voltage prior to the voltage drop. As a result, the DVR must inject a voltage equal to the difference between the network voltage during SAG and the pre-SAG load voltage, which is similar to the voltage after SAG. The PDC approaches depicted in Fig. 7, can explain this. By maintaining the amplitude and phase of the load voltage, this solution outperforms the power level. The injection voltage's can be found using the following formulas:

Phase Advanced Compensation Method (PAC)

To lower the injection power, the injection voltage and source voltage must be adjusted differently. The injectable energy is found to be zero and s = 0, indicating that VL and IL are in phase, using Pi2 arithmetic. Reducing the power supplied to the DVR during compensation is the aim of this procedure. As illustrated in Fig. 8, the load voltage's phase VL oscillates in a circle with a diameter of [8]. It is crucial to remember that loads that are prone to phase changes cannot be handled by the prior method. The large amplitude of the injected voltage is another drawback of this technique. In these kinds of circumstances, it is possible to produce effective and tangible energy. This formula can also be used to determine the type and amount of injected energy. The DVR should enter voltage with VS and IL in phase when VL.Cos>VS, according to previous statistics. If the VL.CosVS Pi3 is negative, on the other hand, the active force needs to be adjusted to zero without being adjusted to zero. Stated differently, the active force compensates for the voltage sag. As a result, the injected voltage corresponds to the current load. The input value [9-13] is used to calculate its zero flow rate.

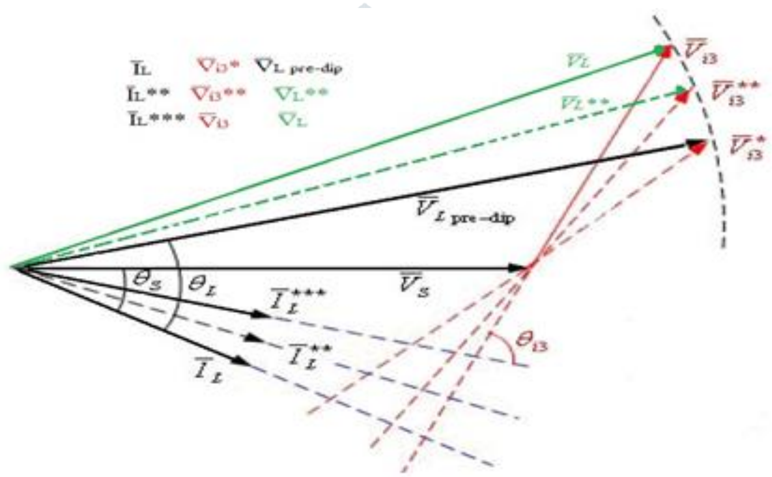
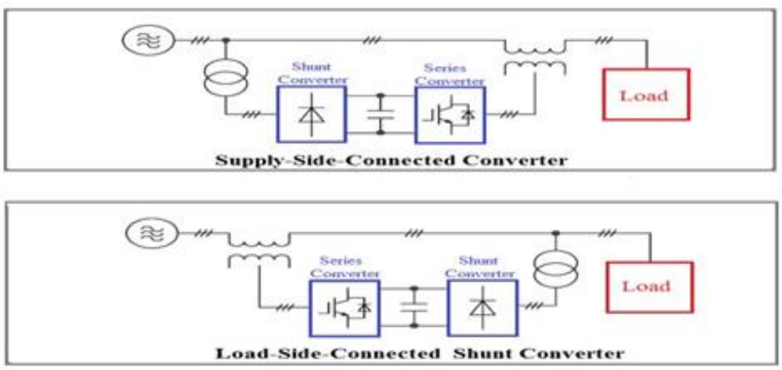


Figure 8. Phasor's Diagram of Fuzzy logic Method

Distinct DVR Types

Two varieties of DVRs exist. There are two choices for the power supply: Two types of DVRs exist: 1) ones that have a power storage system, and 2) ones that don't. (Figure 9) In the first, power is produced by a capacitive battery or batteries; in the second, a network linked to a load or supply is used [14].



Control Strategy

The response time and voltage compensation sag techniques are determined by the DVR architecture, which makes it a crucial component of the control system design. The DVR is used to inject control circuits that lower control signal parameters like amplitude, frequency, phase shift, etc. Control signals are used by current inverters to produce injection voltage. There are two types of DVR control systems: closed loop and open loop. The closed loop approach is extremely laborious and ineffective, despite its excellent performance. This is a description of the open loop method. The values are obtained and constant. This number is declining. The error signal is caused by the difference between the voltage drop and its levels before and after the sag (Vqerror, VD error). Necessary pulses are available to replace the inverter. The following result was obtained, in contrast to the transformation given earlier and using the same angle as determined by the SPLL. In fact, DVRs require knowledge of the power supply phase and size. The SPLL method is used to determine the power source range. A positive, negative and zero voltage sequence is generated when a single phase downstream error occurs, which leads to phase measurement errors. Figure 10 shows the DVR control strategy [15-16].

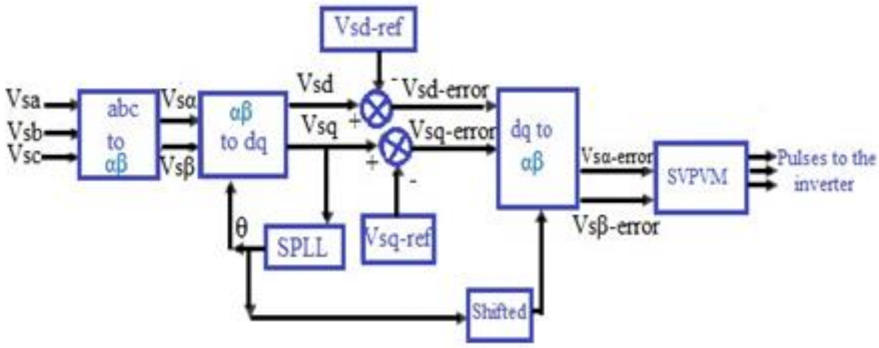


Figure 10. Control System Block Diagram

It should be mentioned that the injection transformer's flexible impact is removed by using the shift block. The acquisition of simulation shows that DVR can correct for errors related to short circuits as well as single-phase short circuits.

THREE-PHASE DVR AND ITS MANAGEMENT

Three-phase DVRs are covered in this section. It can protect the steady voltage of the medium load from harmonics, oscillations, voltage sag, and other unbalanced conditions. Through a star connection, the main section of the transformer is connected to three single-phase inverters, creating a three-phase inverter. The chain to line and the opposing side are connected. The minimum value of a three-phase transformer is 10kVA, and its conversion rate is 1: 5. This shows that 20% of the nominal voltage can be injected by the inverter. Below the switch frequency of 20 kHz (single pole switch), the inverter uses sinusoidal PWM. Converters transform DC energy into the volume of liquid they can store. [17-19]

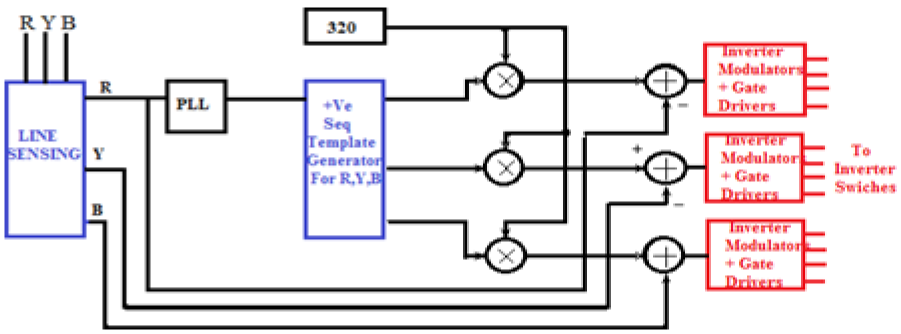


Figure 11. Block Diagram of a DVR's Control Strategy

The R-load load voltage gradually decreases due to PT and PLL locking. The net phase sinusoidal wave is constantly connected to the positive generator when aligned with R (referring to the all pass filter). It produces a series of waves of uniform propagation as can be seen. The desired amplitude increases such a pattern (320V load voltage). Under these models, the actual loading voltage provided by the sensor circuit is reduced, which allows the flexible module to make reference signals. The DC component acts as a power supply or converter. The simulation of the SIMULINK simulation system is shown in Figure 12.

This subsystem's positioning block, which shows the over-modulation inverter limit, is set to 65 volts. The previous model's inverter power model is only used to define the concepts; it is compatible with the proper regulated voltage. The filter is installed at the inverter outlet, and the end of the inverter is intended for a voltage source that is well-controlled. The third does not include the PWM switch, but it makes up for the loss of the inverter. The first produces a more hopeful and optimistic result under dynamic conditions; for instance, it demonstrates that the output voltage does not exhibit an abrupt phase variation even at the input. Of course this does not happen. Multiple specific delays, as well as inverter filter response time, effectively transmit rapid voltage fluctuations toward the input, at least slightly.

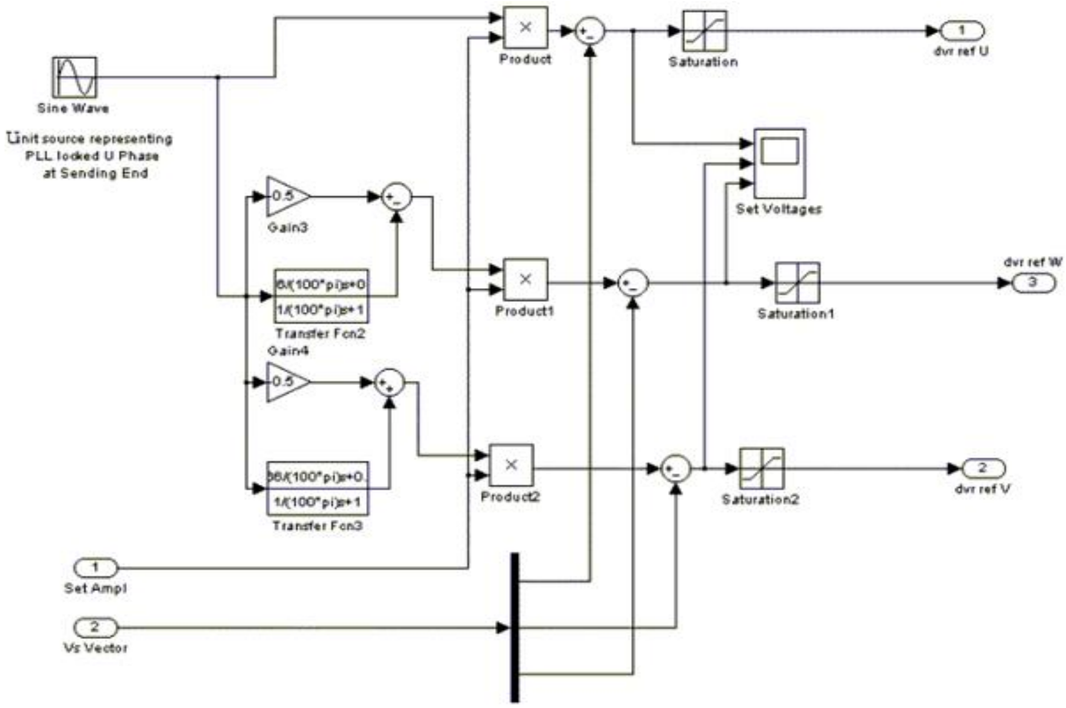


Figure 12. The inverter's reference block

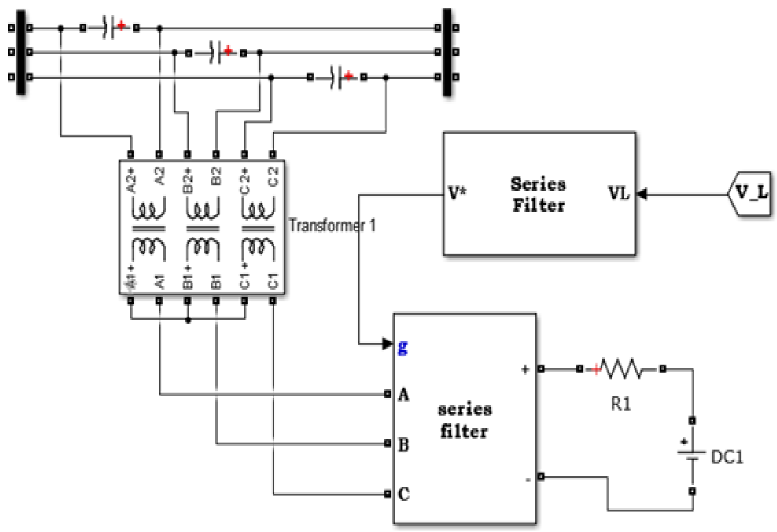


Figure 13. Performance and Schematics of a Simulated DVR

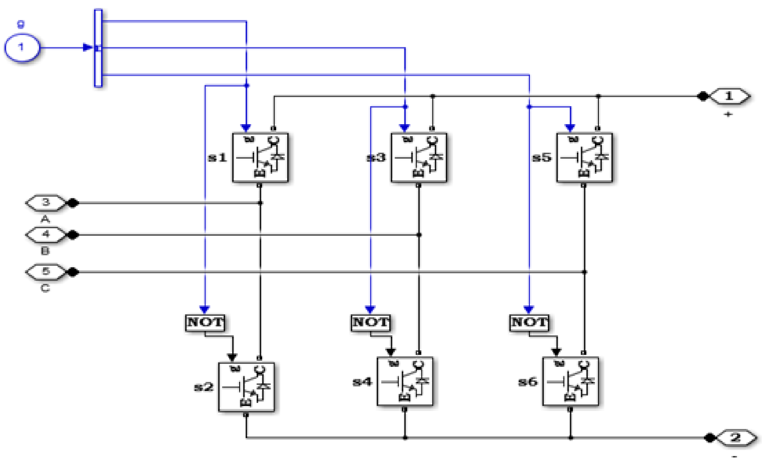


Figure 14. DVR's Power Circuit

The current strength has no effect on the first type's performance because it lacks barriers everywhere. The inverter output filter incorporates a harmonic reduction after the harmonic load currents are exceeded, and the system does not adjust to the right of the inverter in the absence of feedback control, which is how loading harmonics affects output power. 2 in) is regarded as zero. The converter overflows and cuts the output below one another if the contraction, swelling, blink, or harmonic content is too high. The result is a distorted output voltage. However, simulations show that the deviation is less than 10%, even though the SAG sources bring the voltage power up to 100V. Clips are available in all three models. Controlling the DVR is not a difficult issue and in fact, feed control is based on the knowledge of the field. The biggest disadvantage is that it is difficult to find a sufficient DC side power source that can withstand prolonged sinking, swelling or blinking all day long (like an arc furnace). You'll need a charger if it's a battery. According to some researchers, the charging force ought to be applied to inverters only in the form of tiny swells or dents that are managed by a voltage injection at a 90-degree angle. On the other hand, this makes controlling a certain level challenging.

When it comes to AC-DC diode rectifiers, the DVR can only tolerate the swelling because the energy is absorbed by the swelling converter and then dumped onto the DC side (also known as the "in phase injection method"). Mentioned in this instance). We are therefore getting closer to a "Unified Power Quality Conditioner" and it must be a bilateral converter based on an AC-DC converter. - It can no longer just be DVR, it can easily be UPQC. The simplified formulation of the DVR in the distribution network is shown in Figure 13. The most common use of DVRs is to correct voltage sag and swelling in distribution systems [20]. Figure 14 shows the DVR power circuit.

Conclusions

As previously said, the presence of essential loads in the network necessitates the prevention of power outages, which is necessary. The structure of DVRs as a fundamental answer to the problem of power outages, as well as substantial changes in energy quality as defined by IEC and IEEE standards, are discussed in this article. Simultaneously, The significance of DVR in enhancing these facets was highlighted. Simulations show that active power, unequal voltage, positive voltage distortion, voltage sag, and eventually voltage rises in the distribution network can all be sufficiently compensated for by the DVR.

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