IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⋇ Impact Factor 7.105 ⋇ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.96147

DESIGN AND SIMULATION OF DVR USED FOR VOLTAGE SAG/SWELL MITIGATION AT DISTRIBUTION SIDE

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Abstract: The Dynamic Voltage Restorer (DVR) is a potential Distribution Flexible AC Transmission system (D-FACTS) has been introduced to protect sensitive loads from voltage sags and other voltage disturbances in addition to this, it mitigates current harmonics distortion. Dynamic voltage restorer is a series connected power electronic based FACT device. It is considered as one of the most efficient and effective solutions. DVR is in smaller size and has a fast dynamic response to the disturbance introduced by the load or fault.

This work contains power quality improvement (majorly focusing on the mitigation of voltage sag and swell) using DVR. A simulink model of DVR has been modeled in MATLAB software. Simulation results carried out by MATLAB/Simulink to investigate the performance of the proposed method's effectiveness to smooth the distorted voltage.

IndexTerms: Distributed generation power system, renewable energy resources, energy storage systems, PV system, grid-connected systems.

I. INTRODUCTION

Power stations produce the most effective quality of sinusoidal waveform. The event of fault, the use for various types of non- linear loads and application of power electronics devices causes the deflection from ideal sinusoidal waveforms. Customers need pure sine waves at symmetrical voltage and 50 Hz frequency and with an unbroken rms value to continue the assembly. These above demands can be satisfied by eliminating them. The power quality problems are sags in voltage, phase shifts, interruptions, swells, harmonics and transients[2]. The majority usage of non-linear loads, like changing speed drives, PCs, UPS systems, etc generate harmonics which is a big problem in commercial and industrial level of the power systems. These harmonics interfere with impedances of the system and which produces voltage harmonics that affect the non linear loads Considering that the provided voltage's peak value or zero crossing determines how they are controlled, both are impacted by the harmonic distortion.

Power quality is one of the main issues in the energy sector because these issues affect both electricity suppliers and consumers [3]. Electronic devices are sensitive loads against harmonics. sensitive apparatus, such as that found in chemical or semiconductor industries, might malfunction or stop working due to voltage sag and swell, while still producing an excessive current imbalance that could trip breakers or

explode fuses. These negative effects can cost the consumer a lot of money and might include everything from minor quality changes to loss and equipment damage. Although various other ways can also reduce sags in voltage and swells in voltages, using a tailored power device is seen to be the most effective approach. The phenomenon of voltage sag is the most dangerous cause because sensitive loads are particularly susceptible to sudden variations in voltage. Within the distribution system, voltage sags typically happen relatively quickly. Swells are frequently caused by system events such as turning off an excessive inductive load or activating an excessive capacitor bank. A supply voltage fluctuation in magnitude, with or without a phase shift, causes voltage sag. After a specific amount of time, the voltage returns after temporarily dropping to a lower value.

Roadside voltage sags may result from short-term increases in current from contact faults, motor starting, and transformer energizing. Even though they only last a moment or two, such events can seriously harm a variety of equipment.

The magnitude of the remaining voltage and the length of the sag are used to characterize voltage sags. Damaged goods, lost output, restart costs, and the risk of a breakdown can all add up to several dollars when there is voltage sag. Voltage sags must be reduced, and power quality must be improved. Utilizing DVR is one novel strategy (VSC connected serial between the provision system and also the sensitive load). Recently, DVR was designed or made to protect delicate loads from voltage sags and different disturbances in voltages. It also currently reduces harmonic distortion. The Dynamic Voltage Restorer is intended for heavy loads that range in magnitude [0-50] MVA. DVR is significantly more efficient

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and cost-effective than UPS for greater power sensitive loads when the energy storage abilities of UPS become quite expensive a LV level and a MV level are frequently used to execute the DVR. The DVR could also be a network of linked personal power equipment. Because of the advantages of series compensation over shunt compensation (like DSTATCOM) in terms of power rating required for typical voltage stiff systems, it has been used as a final solution[7].
The voltage sag issues can also be quickly, adaptably, and effectively resolved with the DVR. DVR can quickly restore the load voltage, preventing any power outages from occurring. When a voltage sag or swell is detected, the DVR's main operating principle is to inject a proper voltage serial with the available power using an injection transformer. The DVR is also capable of functions like harmonic compensation and power factor correction in addition to compensating for voltage sags and swells. The VSI, Inverter Output Filter, Energy Device Connected to the DC Link, Protection System, and three phase Transformer make up the majority of the DVR.
In the business world, the DVR is now able to minimize the effect of voltage sags on delicate loads. DVR may be accessible for tangency functioning under typical steady-state conditions or may inject a tiny voltage to compensate for the drop occurring due to transformer impedance. The DVRs, however, operate primarily in standby mode so that their series-connected inverters can even be knowledgeable about catching any load voltage harmonics at steady state condition, as doing so may improve their capacity to provide advantages to the grid. The DVR enters the injection mode, also known as the mode when voltage injection begins, as soon as sag is detected in the circuit. For compensation, three single-phase ac voltages are injected serially with the necessary magnitude, phase, and harmonic resonance. In order to restore the quality of the voltage waveform to the load when a voltage disturbance occurs, the DVR injects the real and reactive both power depending upon the need and the control unit of the inverter. The voltage sags caused by a defect or a non-linear load are addressed in the transmission network and distribution network. Reactive power can be used by the DVR to resolve minor disturbances, and actual power can be used to resolve greater disturbances.
The DVR provides the control signal for PWM by comparing the source voltage distortion and its pre-fault value in order to recover the missing voltage details about the necessary voltage to be inserted and how long it should last during sag is provided by the control unit. The DVR is controlled using a sinusoidal pulse width modulation method. PWM makes use of solid-state power electronic switching devices. Harmonics may be present in the output of an inverter (a semiconductor device), and we use the inductor to filter out the harmonics or minimize the harmonics to smooth the voltage waveform. The technique used to dampen out the harmonics must keep the THD of the leftover voltage at the availability side within limitations and, as a result, the injected voltage within standards-established limits. In order to recover the entire system from the voltage sags problem which causes the damage of the equipment the DVR must inject the required voltage and active power to the PCC point to restore the load voltage as required. Due to the DC link's limited ability to store energy, it I required to reduce energy input from the DVR. In order to improve the ability quality issues in distribution systems including voltage sags/swells, harmonic distortion, and imbalanced voltages, this study describes the DVR
The DVR Power Circuit
DVR consists mainly of 4 parts;
1. DC energy storage Unit
2. Voltage Source Inverter (VSI)
3. low pass filter
4. Voltage injection transformer

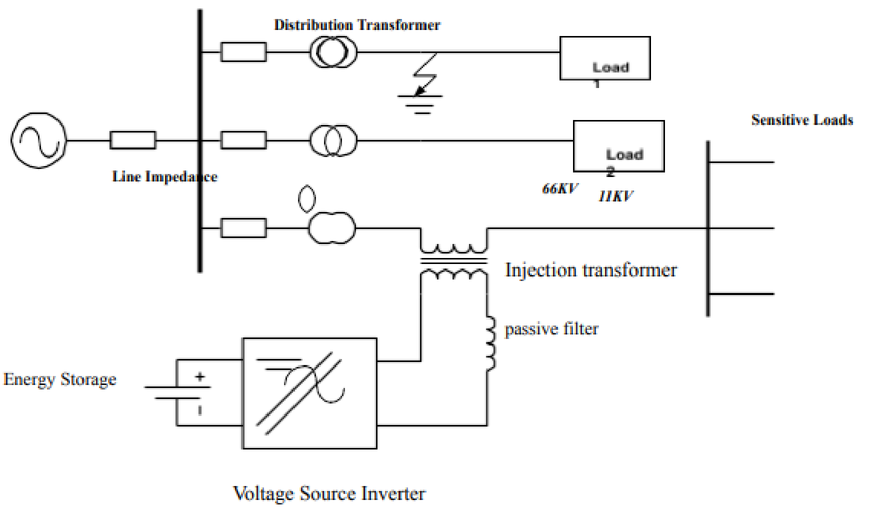

Figure 1: The common grid connected DVR circuit

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Energy storage

The necessary energy can be drawn from the grid itself to compensate for load voltage during sag. This technique is used to improve performance when the DVR's grid is poor. In this process, either a fixed or variable DC voltage is used. When the DVR is connected to a solid grid, no energy storage solution uses the leftover voltage on the supply side or load side to provide the system with the required power. Because it is constantly fed from a corrected constant load voltage, the DC link voltage in the load side connected type is practically constant. Energy storage is required to maintain active power to the load during deep voltage sags. Flywheels, lead-acid batteries, super-capacitors, and superconducting magnetic energy storage are among the energy storage alternatives (SMES). Flywheels, which include rotating components, undergo ac-ac conversion. The DVR's capacity to correct for the grid system is defined by the active power supplied by the energy storage device. Lead acid batteries are common energy storage system components because of their quick charging and discharging times. The rate of discharge determines how much internal space is available for energy storage and a chemical reaction forms the basis of this discharging rate.

Voltage Source Inverter (VSI)

The energy storage device's DC voltage is changed into a three phase AC voltage via a voltage source inverter Before it reaches the main system. The ac voltage is then transferred via a 3-phase 12 terminal transformer to increase the input voltage. Due to the usage of step up transformers, the VSI's rating is often low voltage and high current. It primarily comprises switching devices, of which there are four main categories: IGBT, GTO thyristors, MOSFETs, and IGCT, IGBTs. The various switching device types each have benefits and drawbacks.

II. THE DVR OPERATION MODES

Using a control device to inject the continuously controlled missing voltage in series to the line while keeping the load voltage constant, the DVR works by monitoring the missing voltage during sag. The injected voltage's phase angle and amplitude change during sag. The distribution system and

DVR can interchange active and reactive power under control thanks to the changeable angle and amplitude.

The DVR’s operation can be classified into 3 modes

1. Protection mode.
2. Standby mode.
3. Injection mode.

IV. DVR COMPENSATION STRATEGIES AND CONTROL

For voltage sag/swell removal from the distribution line, the compensation control methods of DVR is the mechanism used to monitor the source voltage and synchronize it with the pre-sag source voltage. In addition to the magnitude shift, voltage sags frequently involve a jump in the phase angle. The chosen control method is determined by how sensitive the load is to changes in voltage waveform size, phase, or wave shape. Additionally, the size of the energy storage device, the rating of the inverter and the transformer should be taken into account for selecting a suitable control method for a specific load. When the Grid is operating normally, the source voltage (Vs) is known as the pre-sag voltage. The supply voltage (Vsupply) and load voltage (Vload) will both be the same in this case because the DVR is not introducing any electricity into the system. The supply voltage can shift in magnitude and phase angle during voltage sag, which is shown by the symbol Vsag.

V. SIMULATION RESULTS AND DISCUSSION

The simulation model has been performed in MATLAB Simulink

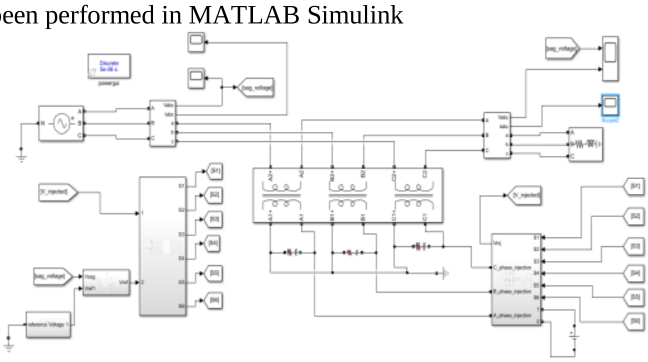

Fig 2 : Simulink model of DVR connected to Grid with control and inverter circuit

IARJSET

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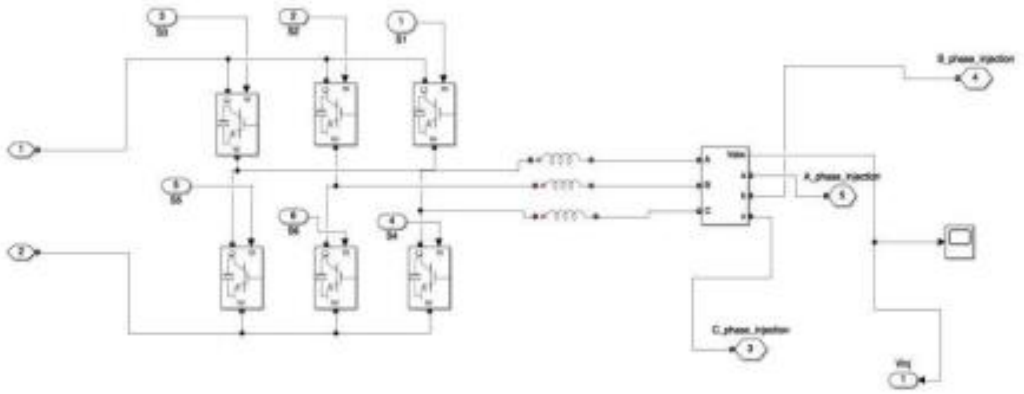

Fig 3: Inverter circuit of DVR

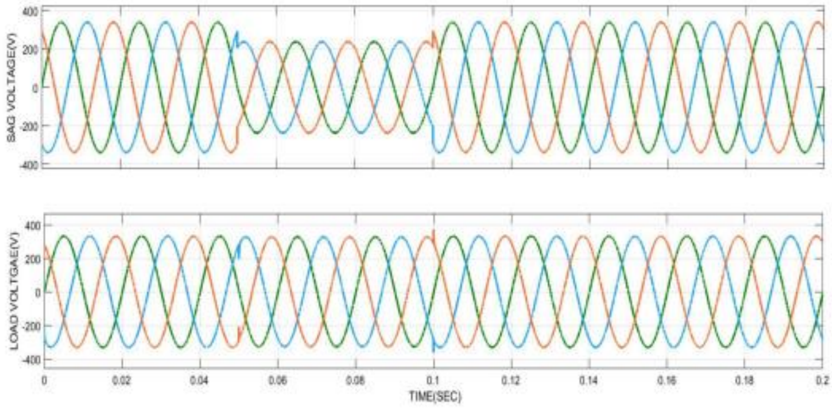

Fig 4 Sag voltage vs time and load voltage vs time waveform

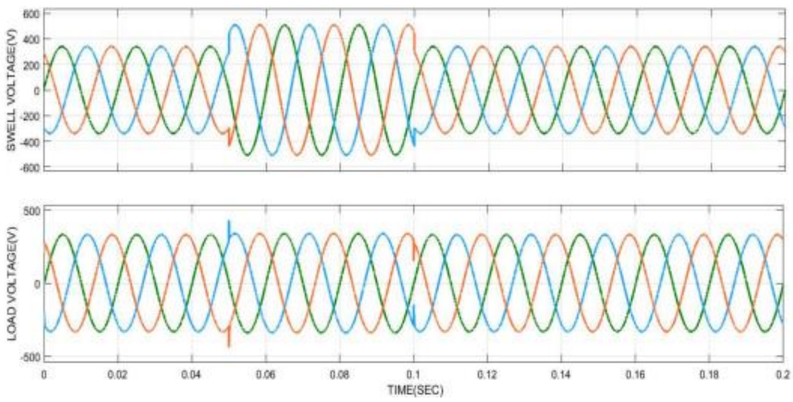

Fig 5 : swell voltage vs time and load voltage vs time waveform

In the first waveform (Fig 4), the sag voltage is being created for 0.05 to 0.1sec with the help of three phase programmable voltage source and the sag in voltage waveform is compensated by the DVR circuit with proper control mechanism of inverter(using PQ theory) which has shown in the load voltage vs time waveform in Fig 5. So basically the DVR is injecting the required voltage in the Grid.

In the second Waveform (Fig 5), the swell voltage is being created for 0.05 to 0.1 sec with the help of three phase programmable voltage source and the swell in voltage waveform is compensated by the DVR circuit with proper control mechanism of inverter (using PQ theory) which has shown in the load voltage vs time waveform in (Fig 5). So basically the DVR circuit absorbing the extra voltage due to swell.

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VI. CONCLUSIONS

The DVR used in the power circuit is working properly in the MATLAB environment. A programmable voltage source is used to create voltage sag and swell in the circuit. by using the suitable control strategy the modeling of proper working simulation has been created in Simulink. As from the graph shown the mitigation of voltage sag and swell is happening in the circuit.

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