A REVIEW PAPER ON DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY IMPROVEMENT

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Abstract:

The problem of voltage sags and Swells and its severe impact on sensitive loads is well known. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is one of the most efficient and effective modern custom power devices used in power distribution networks. This paper described DVR principles and voltage correction methods for balanced and/or unbalanced voltage sags and swells in a distribution system. Simulation results were presented to illustrate and understand the performances of DVR under voltage sags/swells conditions. The results obtained by simulation using MATLAB confirmed, which significantly affect the quality of power supplies.

Introduction:

A s a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. Aparl from nonlinearl oads, some systeme vents, both usual (e.g. capacitors witching, motor starling) and unusual (e.g. faults)c ould also inflict power quality problems [3]. The consequencoef power quality problems could range from a simple nuisancef licker in the electricall amps to loss of thousandso fdollars due to production shutdown. A power quality problem is defined as any manifested problem in voltage/currenot r leading to frequency deviationst hat result in failure or misoperation of customer equipment 13-41

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state

. A typical duration of sag is, accordingt o the standard,l 0 ms to I minute. Voltage sag can cause loss of production in automated processes sincev oltage sagc an trip a motor or cause its controller to malfunction. Voltage swell, on the other hand,i s defineda s a suddeni ncreasing of supplyv oltage up I l0% to 180% in rms voltagea t the network fundamental frequencyw ith duration from 10 ms to 1 minute. Switching off a large inductive load or energizing a large capacitorb ank is a typical system event that causes swells t I] To compensate the voltage sag/swell in a power distribution system, appropriate devices needt o be installeda t suitable locations. Thesed evices are typically placed at the point of common coupling tPCCI which is defined as the point where the ownership of the network changes. The DVR is one of the custom power devices which can improve power quality, especially, voltage sags and voltage swells. As there are more and more concerns for the quality of supply as a result of more sensitive loads in the systemc onditions, a betteru nderstanding of the devices for mitigating power quality problemsi s important. This would allow us to make use of the functions of such devices in a better way with efficient control techniques. Hence, in this paper an attempt is made to understand the functionso f DVR with the help of MATLAB.

2.POWER QUALITY PROBLEMS:

2.1 Sources and effects of power quality problems:

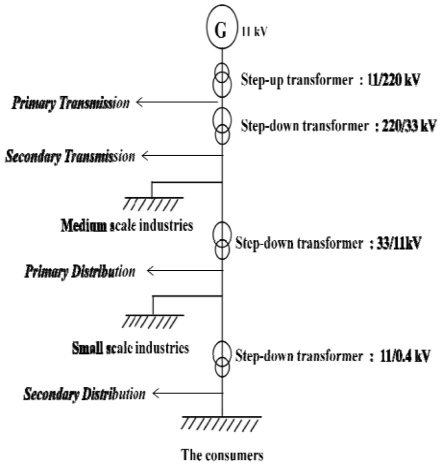


Fig. 2.1 Single line diagram of power supply system

Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

Voltage sag: Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.

Voltage swell: Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in voltage value.

Voltage transients: They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.

Harmonics: The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

Flickers: Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects

3. Dynamic Voltage Restorers A DVR is a device that injects a dynamically controlled voltage V,,,(4i1n series to the bus voltage by means of a booster transformer as depicted in Figure L There are three single phase booster transformers connected to a three phase converter with energy storage system and control circuit [8]. The amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V1@. This means that any differential voltage caused by transientd isturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the mediumv oltage level through the booster transformer. The DVR works independently of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most practical cases, a more economical design can be achieved by only compensating the positive- and negative sequence components of the voltage disturbance seen at the input of the DVR. This option is reasonableb ecause for a typical distribution bus conhguration, the zero sequence part of a disturbancew ill not pass through the step down transformersb ecause of infinite impedancef or this component. For most of the time the DVR has,v irtually, "nothing to do," except monitoring the bus voltage. This means it does not inject any voltage (V,,ift) : 0) rndependent of the load current. Therefore, it is suggestedto particularly focus on the losseso f a DVR during normal operation. Two specificf eatures addressing this loss issue have been implemented in its design, which are a transformer design with a low impedancea, nd the semiconductodr evices used for switching. An equivalent circuit diagram of the DVR and the principle of series injectionf or sagc ompensation is depicted in Figure2 . Mathematically expressed, the injection satisfies:.

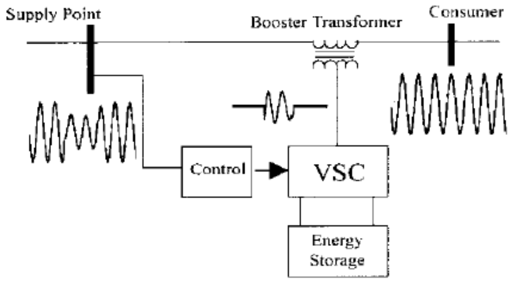


Fig. 1 Schematic diagram of DVR System.

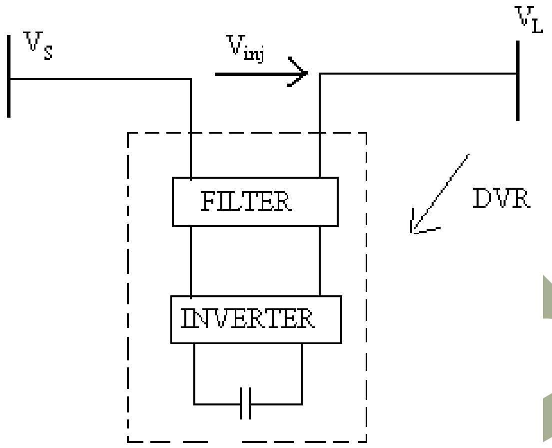


Fig.2 block diagram for series compensation

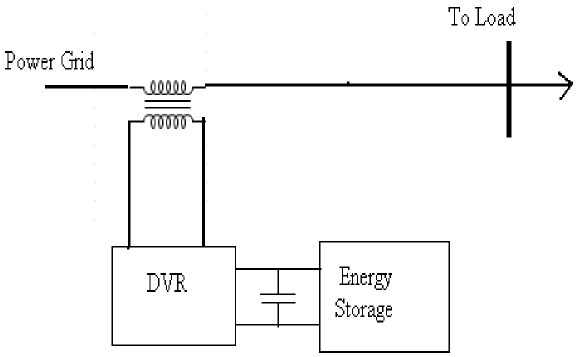


Fig.3 configuration of dvr

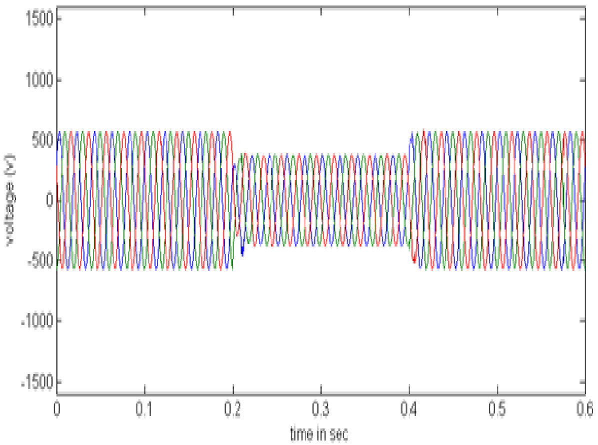
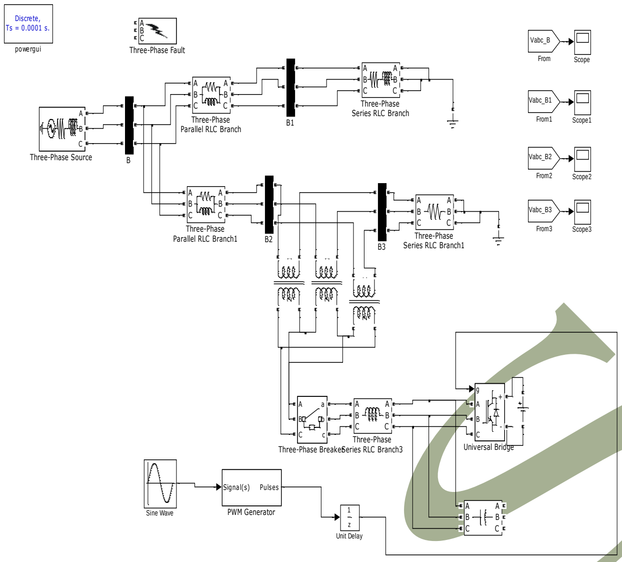


fig.4 balanced voltage sag

4. Modeling of DVR in MATLAB The compensation of voltages ag/swell can be limited by a number of factors, including finite DVR power rating, loading conditions, power quality problems and types of sag/swell. lf a DVR is a successful device, the control is able to handle most sags/swells and the performancem ust be maximized according to the equipment inserted. Otherwise, the DVR may not be ablet o avoid tripping and evenc ause additionald isturbances to the loads. The control strategy should be able to compensate for any of voltage sag/swell and consider the limitation the DVR. transformer are neglected.W hen the voltage sagso ccur, the actual source voltage vector V5ft) is moved to Vs.-r(t).To restoret he load voltage vector V/t), an injected voltage vector V1,,1(its) provided by the DVR. A similarc ompensation strategyc an be drawn in the form of a phasor diagram for voltases well as well.

Figure 4 shows the basic control scheme and parameters that are measured for control purposes. When the grid voltagei s at its normal level the DVR is controlled to reducet he losses in the DVR to a minimum. When voltage sags/swellsa re detected,t he DVR should react as fast as possible and inject an ac voltage to the grid. It can be implemented using a feedback control techniqueb ased on the voltage reference and instantaneousv alues of supply and load voltage.T he control algorithm produces a three-phase referencev oltage to the seriesc onverter that tries to maintain the load voltage at its referencev alue [0]-[2].. The MATLAB/Simulink environmenti s a useful tool to implement this study because it has many tool boxes that can be used in this work and is easy to understand. In Figure4 , the supplyv oltage is connected to a transformation block that convefts stationary frame to crp-frame. Output of this block is connected to a phase lock loop (PLL) and anothert ransformation block that converts a,B-framet o rotating frame (dq), which detects the phase and changest he axis of the supply voltage.T he detection block detectst he voltage sag/swell.I f voltages ag/swell occurs,t his block generates the reference load voltage. The injection voltagei s also generated by difference between the referencel oad voltage and supply voltage and is appliedt o the VSC to produce the preferred voltage,w ith the help of pulse width modulation (PWM).

FIG shows simulink diagram for voltage sag



5. Simulation results In order to understand the performance of the DVR along with control, a simple distribution network as shown in Figure 5, is implemented. Voltage sags/swellsa re simulatedb y temporary connectiono f differenti mpedances at the supply side bus. A DVR is connected to the system througha seriest ransformer with a capability to inserta maximum voltageo f 50oho f the phase- to-ground system voltage. Apart from this a series filter is also used to remove any high frequency components of power. The load consideredi n the study is a 10 MVA capacity with 0.9 p.f., lagging.

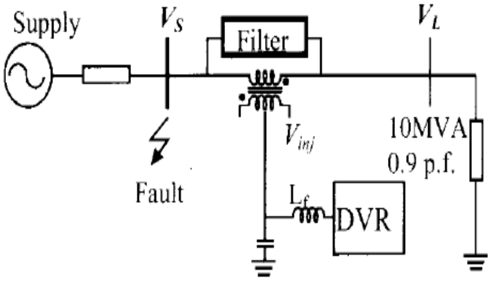


Fig. 5 Simple distribution network with DVR.

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5.1 Voltage Sags : Voltage sags are one of many power quality related problems the industrial process sector has to face , though sags are one of the most severe. Voltage sags are defined as short duration reductions in the rms supply voltage that can last from a few milliseconds to a few cycles, with typical dip depths ranging from 0.9pu to 0.5pu of a 1pu nominal. It has been shown that year on year voltage sags cause extensive disruption to the industrial process sector in terms production loss which make them a particularly important area

First, a caseo f symmetricals ag is simulated by connecting a three-phaser eactance to the busbar. The results are shown in Figure 6. A 30% voltage sag is initiated at 400 ms and it is kept until 550 ms, with total voltage sag durationo f 150 ms. Figure 6 (a), (b) and (c) show the serieso f voltage components injected by the DVR and compensated load voltage, respectively. As a result of DVR, the load voltage is kept at 1.00 p.u. throughout the simulation, including the voltage sag period. Observe that during normal operation,t he DVR is doing nothing. It quickly injects necessary voltage componentst o smootht he load voltage upon detectinga voltages ag. In order to understand the performance of the DVR under unbalanced conditions,a single- line-ground (SLG) fault at supplyb us bar at 400 ms is simulated.A s a result of SLG fault. an unbalancedv oltage sag is created immediately after the fault as shown in Figure 7 (a), the supply voltage with two of the phase voltages dropped down to 80%. The DVR injected voltagea nd the load voltagea re shown in Figure 7 (b) and (c), respectively.A s can be seen from the results, the DVR is able to produce the required voltage components for different phases rapidly and help to maintaina balanced and constanlto ad voltagea t 1.00 p.u.

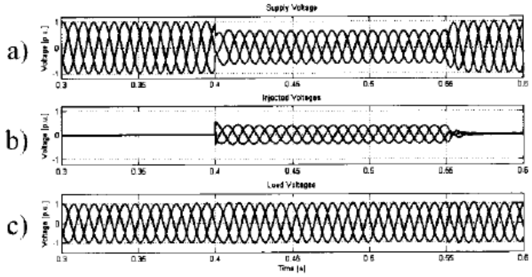

Fig. 6 Simulation result of DVR response to a balanced voltage sag.

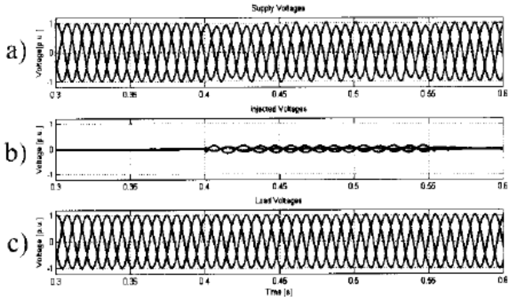

Fig. 7 Simulation result of DVR response to an unbalanced voltage sag.

5.2 **Voltage Swells**: Next, the performance of DVR for a voltage swell condition is investigated. Here, voltage swell is generated by energizing of a large capacitor bank and the corresponding supply voltage is shown in Figure 8 (a). The voltage amplitude is increaseda bout l25o/oo f nominal voltage. The injected voltaget hat is produced by DVR in order to coffect the load voltagea nd the load voltage,a re shown in Figure 8 (b) and (c), respectively. As can be seen from the results, the load voltage is kept at the nominal value with the help of the DVR. Similar to the caseo f voltages ag, the DVR reacts quickly to inject the appropriate voltage component (anti phase with the supply voltage or negative voltage magnitude) to correct the supply voltage. The performance of the DVR with an unbalanced voltage swell is shown in Figure 9. In this case, the unbalanced voltage swell is created by partly rejecting the load. This results in an unbalancedv oltage swell wheret wo phase voltagesa re equal and the other phase voltagei s slightly highert hat the first two phases voltages. The anti phase unbalanced voltage component injectedb y the DVR to correct the load voltage is shown in Figure9 (b) and the load voltagei given in Figure 9(c). Notice the constant and balanced voltage at the load throughout the simulation, including during the unbalanced voltages well event.

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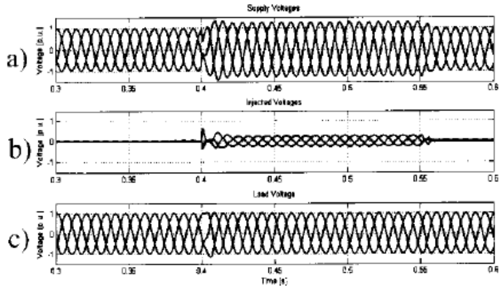

Fig. 8 Simulation results of DVR response to a balanced voltage swell.

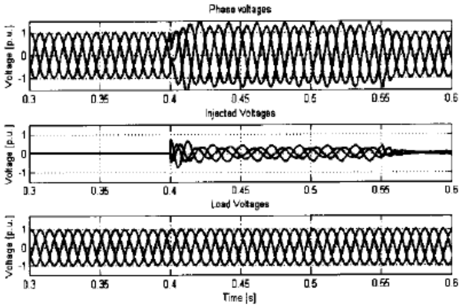

Fig. 9 Simulation result of DVR response to an unbalanced voltage swell.

6. Conclusion

In this paper, performance of a DVR in mitigating voltage sags/swells is demonstrated with the help of MATLAB. The DVR handles both balanced and unbalanced situations without any difficulties and injectst he appropriate voltage component to correct any anomaly in the supply voltage to keep the load voltage balanceda nd constant at the nominal value. In the case of a voltage sag, which is a condition of a temporary reduction in supply voltage, the DVR injects an equal positive voltage component in all three phasesw, hich are in phase with the supply voltaget o correct it. On the other hand,f or a voltages swell case,which is a condition of a temporary increasei n supply voltage, the DVR injects an equal negative voltagei n all three phases, which are anti-phase with the supply voltage. DVR is a cost effective solution for improvement of power quality.

7. References

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