POWER QUALITY IMPROVEMENT USING DYNAMIC VOLTAGE RESTORER

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ABSTRACT
In the modern power system, power quality is a crucial topic that can have an impact on utilities and customers. Numerous issues in the contemporary electric power system were brought on by the integration of renewable energy sources, smart grid technologies, and increasing usage of power electronics equipment. The delicate equipment can be harmed by voltage harmonics, voltage sag, and voltage swell. These devices are vulnerable to input voltage changes brought on by system interference. Power quality is therefore crucial for the efficient and secure operation of the power system in the present period, with a growth in delicate and expensive electronic equipment. A prospective Distribution Flexible AC Transmission System (D-FACTS) is the Dynamic Voltage Restorer (DVR).device widely adopted to surmount the problems of non-standard voltage, current, or frequency in the distribution grid. It injects voltages in the distribution line to maintain the voltage profile and assures constant load voltage. The simulations were conducted in MATLAB/Simulink to show the DVR-based proposed strategy's effectiveness to smooth the distorted voltage due to harmonics. A power system model with a programmable power source is used to include 3rd and 5th harmonics.

INTRODUCTION
Electrical Energy is invisible, a universal commodity that is immediately available in most of the world, and it has now been recognized as everyday consumer need. Renewable Energy Systems (RES) is used to aid the primary energy demand in solar, wind energy, etc. The intermittent nature of RES, harmonics, and reactive power problems halt the power system's performance by originating stability concerns in the power system.
The power system is divided into the following parts as generation, transmission, distribution, and by using other transmission line power systems is fed to different loads on the distribution side. Power quality plays a vital role in the power system when variable power is supplied to the load. Subsequently, the domestic and industrial customers with delicate loads are affected by the poor quality of power. Even there is various type of load on the distribution side, but poor power quality affects the sensitive loads more than others. causes voltage sag, transient, swell, and high distorted voltage with harmonic and Total Harmonic Distortion (THD) due to the occurrence of the faults. When the faults occur in the power system that causes a large current drawn from the power system, a short duration reduction RMS voltage appears, commonly known as voltage sag or Dips.

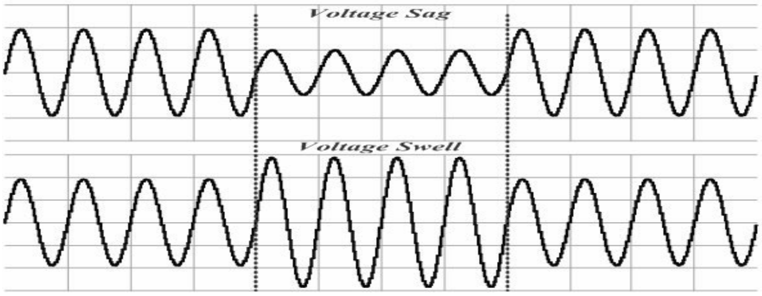

FIGURE 1. Voltage waveform with sag and swell.

Voltage swell is defined as the increase in the voltage value from its fundamental value, e.g., during the half-cycle to 1-minute time, the change in voltage from 10 to 80 %. There are different types of voltage swell, including i. Instantaneous swell, ii. Momen- tary swell, and iii. Temporary swell.Overheating and destruction of electrical instruments and insulation breakdown are consequences of voltage swells. Figure 1 shows the voltage swell in voltage profile. Harmonic distortion is the problem of voltage produced by the variation in fundamental frequencies by three times, for example, 50Hz fundamental frequency when multiplying with three as 3 50 150Hz. That is the 3rd harmonic of the fundamental frequency, as Figure 2 shows the waveform with harmonic content.

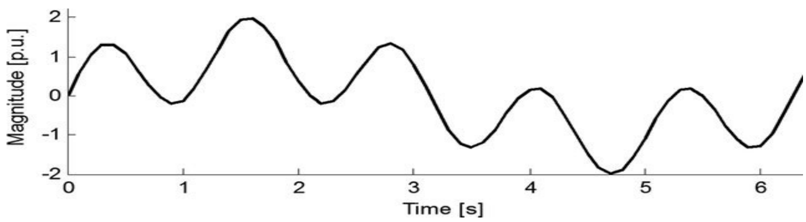

FIGURE 2. Waveform with harmonic content.

The main contributions of this paper are summarized below:

• to decrease the THD lower than 5% by mitigating the problem of distorted voltage due to sags, swell or, harmonics.

• to access and analyze the performance of the suggested model with the use of MATLAB / SIMULINK along with the use of DVR and without it too.

LITERATURE REVIEW OF DVR

The transmission and distribution system problems were addressed in some countries using the FACTS and D-FACTS devices. As per IEEE recommendations, FACTS can be expressed as“AC transmission systems containing static and power electronics-based controllers to increase power transfer capability and more immeasurable controllability.’’ Today, electricity demand has risen considerably while the development of generation and transmission systems is notadequate by the limited resources, economic issues, and some environmental limitations. The present transmission system cannot be easily extended due to limited resources. Therefore, the expansion in transmission capacity is a viable solution. DVR is used on the distribution feeder to protect the load from faults due to the voltage sags and voltage swells. DVR is mounted in series with the load, and a battery energy storage system (BESS) is connected with a transformer and inverter are also connected with DVR, which compensate the active and reactive power requirement for the reduction in voltage sags and voltage swells.DVR is the FACTS device, which compensates the disturbances like the voltage sags, swells, and voltages harmonics from the loads. DVR injects the voltages in series with the transmission linesrequired for robust and adaptive control. The DVR is embedded with the energy storage system (ESS).

PROPOSED DYNAMIC VOLTAGE RESTORER

A.PRINCIPLES OF DVR OPERATION

A DVR is consists of GTO or IGBT based Voltage Source Inverter (VSI), an energy storage instrument,a capacitor bank, and an injection transformer. The DVR is also called solid-state power electronic switching device. The practical guideline of the DVR as it works by methods for an injecting transformer; a control voltage is created by a forced commuted converter, which is in arrangement to the bus voltage.

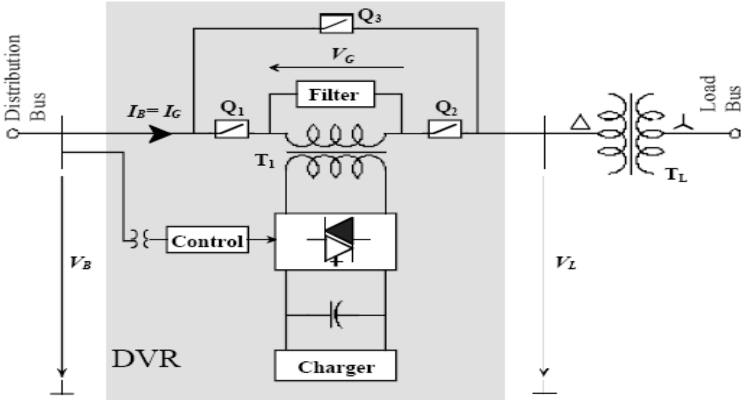

FIGURE 3. Principle design of DVR connected at distribution end.

B.CONSTRUCTION OF DVR

There are two parts of the DVR: one is the power cir- cuit, and the other is the control circuit. The control signal consists of magnitude, phase shift, the frequency that are complex parameters of it, and injected by the DVR system. In the power circuit, the switches are used to generate a voltage-dependent on control signals. Additionally, this section will describe the fundamental structure of the DVR by the power circuit.

1)ENERGY STORAGE UNIT

Different devices are used to store energy like Flywheels, Lead-acid batteries, Superconducting Magnetic energy storage (SMES), and Super-Capacitors. While the occur- rence voltage sags, the storage unit provides the required real power as it is its primary function. The compensation capability of DVR is defined by the active power produced the device of energy storage. Instead of using other storage devices, the devices of the high response time of charging and discharging are being used that are lead batteries.

2) VOLTAGE SOURCE INVERTER

The use is of Pulse-Width Modulated VSI (PWMVSI) widespread. A DC voltage has been created through a device of energy storage, as discussed in the previous section. A VSI is the source of the conversion of voltage from DC-AC voltage. At the time of sag occurrence, a step-up voltage injection transformer of the DVR power circuit has been used to increase the magnitude of voltage. So, a minimum voltage value with VSI is enough.

3) PASSIVE FILTERS

The use of low passive filters in this method in which the PWM inverted pulse waveform converted into a sinusoidal waveform. In VSI for the achievement of this conversion, it is compulsory to remove high-value harmonic components while DC-AC transformation, and it will also change the compensated output voltage. A passive filter is an essential source in voltage inverter. If we put the filters on the inverter side, it can overcome maximum value harmonics from passing through the voltage transformer. So, the stress on the injection transformer is also decreased by it. When the filter is placed in the inverter side and causes phase shift and voltage drop in inverted, that is the disadvantage of the filter. Thus, by putting the filter on the load side, this problem can be solved. The secondary side of the transformer permits the high valued harmonics currents because the transformer with high values is necessary.

4)VOLTAGE INJECTION TRANSFORMERS

There are two sides of the voltage injection transformer, as one is the primary side linked with a distribution line in a series. The other one is the secondary side that is connected with the power circuit of DVR. For the three-phase DVR, one 3-phase transformer or three single-phase transformers could be used, but for one phase DVR, only one single-phase transformer is allowed. The ‘‘Delta-Delta’’ type connection is being used at the time of contact between 3 phase DVR and three single-phase transformers. Usually, the amount of voltage that is supplied by the filtered VSIoutput to a needed range also simulates the DVR circuit from the transformation network caused by the setup transformer. According to the required voltage at the secondary side of voltage, pre-examined and significant values are winding ratios.The parts of inverter circuits areaffected by the high cost of windingratio with high-frequency.

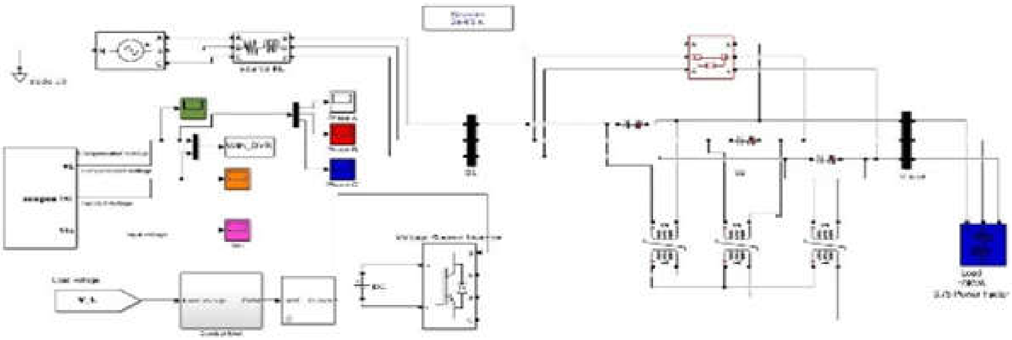

FIGURE 6 Simulink model of the test system with DVR.

currents—the primary side current with high-frequency ratios of high windings that could affect the parts of the inverter circuit. The value of the transformer is an important reason when determining the working efficiency of the DVR. The significance of the winding ratio of the injection transformerconcerns on the upward distribution transformer. If there should arise an occurrence of a Δ-Y association with the grounded unbiased, there won’t be any zero-grouping current streaming into the auxiliary during an unbalancedeficiency or an earth shortcoming in the high voltage side.

TABLE: THD% of test system with and without DVR.

PHASES	HYSTERESIS OF THD (%)		PWM OF THD (%)	
	WITHOUT DVR	WITH DVR	WITHOUT DVR	WITH DVR
PHASE(A)	18.49	2.69	22.56	4.06
PHASE(B)	18.49	2.40	22.56	3.55
PHASE(C)	18.50	2.69	22.57	3.74

GRAPHICAL RESULTS AND DISCUSSION

A.INTERNAL CONTROL OF DVR

At the normal level of the supply voltage, to provide the lower number of losses in the conversion circuits, the DVR should be controlled in thetransformer and the filtering circuits. When the voltage unbalance, or distorted voltage is detected in the system, then the required injected voltages are supplied to the test system through the installed DVR. Depend upon the voltage (Vref), the instantaneous value of the supply voltage (Vsupply), the whole process is accomplished by the feedback control technique.The reference voltages (Vref) are extracted by the control algorithm from the supply and the load voltages when the gate pulses provide the VSI to regulate the load voltage at the control algorithm’s reference voltage.

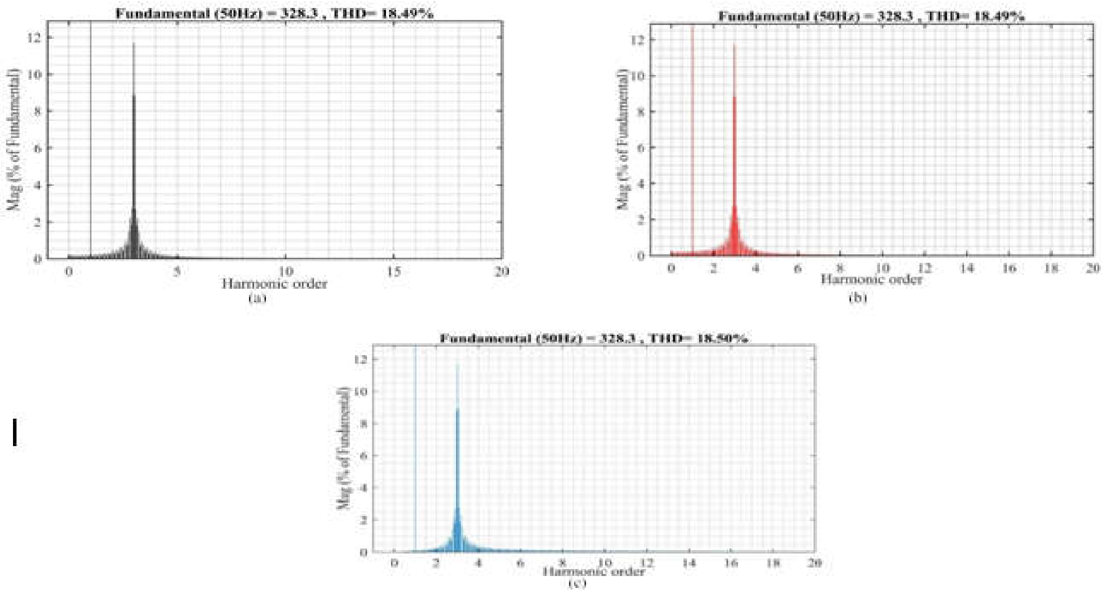

FIGURE: Without DVR (Scenario 1): (a) THD in Phase A (b THD in Phase B (c) THD in Phase C.

415V load and 50Hz frequency to a 3-phase supply system. The single line diagram of the test system without DVR is shown in Figure 7. It shows that the test system contains a Three-Phase, a programmable voltage source, an RL source, and a sensitive active and reactive load is connected with it.

CONCLUSION

DVR is proposed as the most noteworthy device to enhance the quality of power and proved to be a useful and well-performing device. Through the platform of MATLAB/ Simulink, a simulation of DVR with a power circuit is carried out by structure and modeling of the control circuit andpower system with a sensitive load. The DVR is implemented with the test system and investigated with and without DVR. A programmable voltage source is used to supply a distorted voltage with first with 3rd harmonic content and then with 5th harmonic insertion in the supply voltage. The proposed DVR based control strategy was effective in compensation of the distorted load voltage and maintained a better steady and smooth voltage profile with very less harmonic content in it. To maintain the load voltage normal and steady at the optimal range, the correction of any problem in voltage supply is possible when the DVR injects the suitable voltage component into it.

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The application of control strategy based on soft computing like adaptive NeruoFuzz controllers for power quality improvement is a promising future perspective of this research. Authors have already implemented Type-2 Neuro- Fuzzy controls for enhancement of power system stability using STATCOM.

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