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Dynamic Voltage Restorer for Power Quality Improvement in Distribution

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Abstract: Power Quality is an essential concern in the modern power system that can affect consumers and utility. The integration of renewable energy sources, smart grid systems and extensive use of power electronics equipment caused myriad problems in the modern electric power system. Current and voltage harmonics, voltage sag, and swell can damage the sensitive equipment. These devices are susceptible to input voltage variations created by interference with other parts of the system. Hence, in the modern age, with an increase in sensitive and expensive electronic equipment, power quality is essential for the power system's reliable and safe operation. Dynamic Voltage Restorer (DVR) is a potential Distribution Flexible AC Transmission System (D-FACTS) 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. The systems' response for load voltage is evaluated for with and without DVR scenarios. It has been noted that the proposed DVR based strategy has effectively managed the voltage distortion, and a smooth compensated load voltage was achieved. The load voltage THD percentage was approximately 18% and 23% with insertion 3rd and 5th harmonics in the supply voltage, respectively. The inclusion of the proposed DVR has reduced THD around less than 4% in both cases.

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I.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 [1]. Renewable Energy Systems (RESs) is used to aid the primary energy demand in solar, Solar thermal, wind energy, etc. The intermittent nature of RESs, harmonics, and reactive power problems halt the power system's performance by originating stability concerns in the power system [2], [3]. The Flexible AC Transmission Systems (FACTS) devices are widely adapted for reactive power compensation, voltage stability, and power quality in distribution grids around the world [4], [5]. However, FACT devices also alter different parameters on the transmission and distribution system [6]. This work presents a study of the power quality and aims at identifying the causes of poor power quality and provide the solutions to these power quality problems. Some equipment like computers, laptops, relays, solid-state devices, adjustable speed drives, and optical devices are known as sensitive equipment. These devices are susceptible to input voltage variations created by interference with other parts of the system.

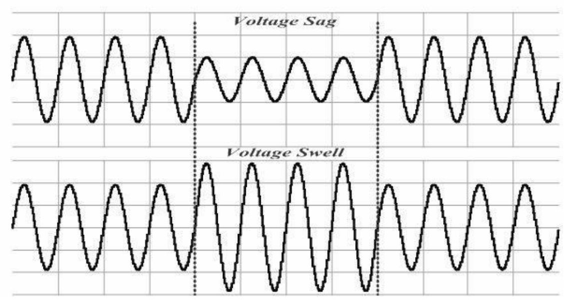

FIGURE 1. Voltage waveform with sag and swell [7].

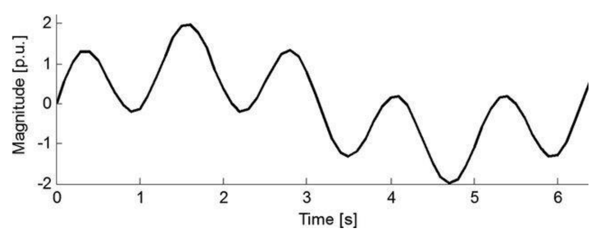

FIGURE 2. Waveform with harmonic content [7].

The main contributions of this research work are summarized below:

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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.

to investigate the power system with the insertion of 3rd and 5th harmonics in the input voltage profile.

to evaluate the performance of the DVR based power system with same 3rd and 5th harmonics insertion by comparing its results with without DVR based system.

II. PROPOSED DYNAMIC VOLTAGE RESTORER

The frequency of the supplied voltage can determine the power supply quality that is a significant indicator of power quality. The voltage sag is interpreted as a drop in the Root Mean Square (RMS) value of the voltage that can happen from 10 ms to 60 seconds with the depth of the falling voltage of 0.9 per unit (p.u) 0.1 p.u of a nominal p.u based on the IEEE standards [22]–[24]. Regular voltage sags are usually checked for the load at the distribution level due to different reasons. The voltage sags are highly unbearable for a few delicate loads in high technology sectors. The load voltage requirements could be maintained by the complicated tasks with a specific frequency and exact value of voltage sag while distortion and oscillation.

Usually, the destruction of the production sector and its downtime is the result of voltage sag that is costly and leads to harsh problems among consumers. A specific amount of energy and voltage is supplied to the distribution system by using electric devices that are also named consumer power devices. The complex problem could be mitigated. As compared to the conventional methods of voltage sags problem solving, the DVR is supposed to be an efficient method to control the voltage sag and

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distortion. In this work, the power system's performance is evaluated by removing voltage sag through a DVR at the distribution level.

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. A DVR connected to a distribution bus is illustrated in Figure 3. 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. Different converter control topologies for droop-controlled converter are presented in [25], [26]. DC voltage source behaves like a device of energy storage given by the DC capacitor, as shown in Figure 4.

To mitigate the problem of voltage drop is not efficiently done by the DVR when there is no voltage sag issue under optimal conditions. DVR will produce a needed controlled voltage of high frequency with the existence of a distribution system, a required phase angle that will ensure that load is perfect and maintained. For keeping the consistency in the load supply of voltage in this situation, the capacitor will be discharged. Here is needed to note that the DVR can absorb and produce reactive power, but an external source of energy is used to provide reactive power injection. The voltage sag detection time and the devices of power electronics shorten the response time of DVR. As compared to the conventional methods of voltage correlation, for example, the tap-changing transformers response time of DVR is less than 25 milliseconds.

B. Construction of DVR

There are two parts of the DVR: one is the power circuit, and the other is the control

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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. The construction and basic Configuration of the DVR are shown in Figure 4 [27].

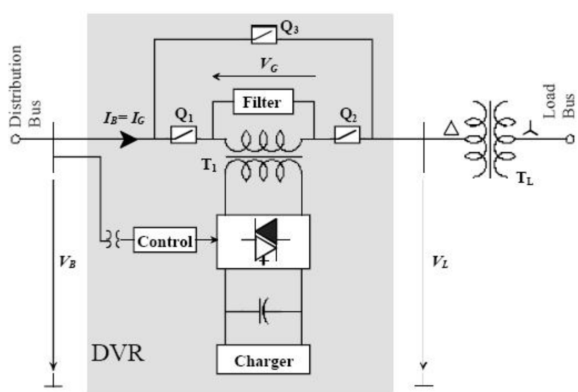


FIGURE 3. Principle design of DVR connected at distribution end [15].

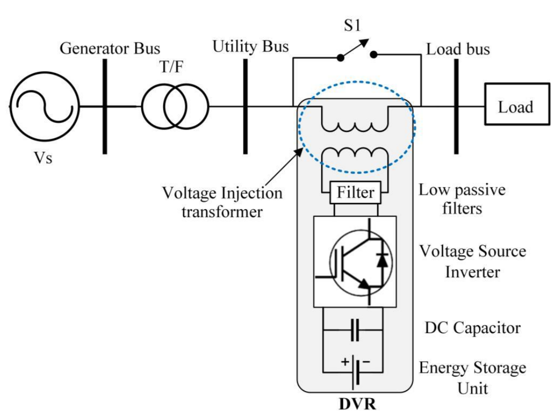
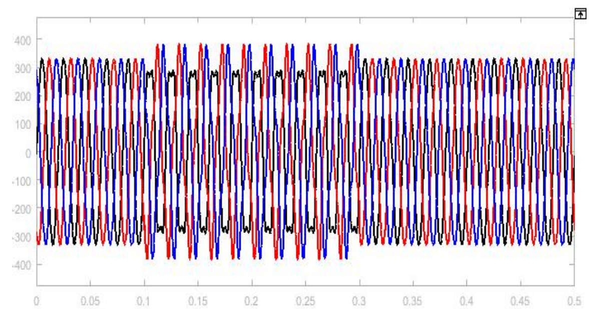
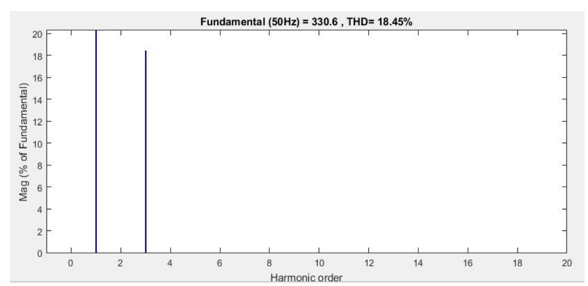


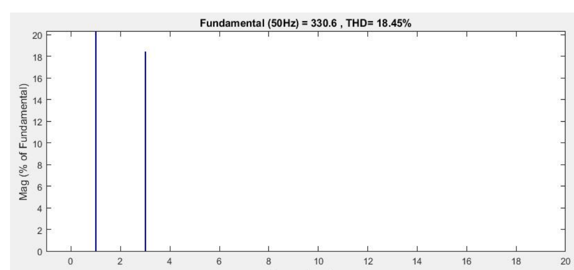
FIGURE 4. Basic Configuration of DVR.

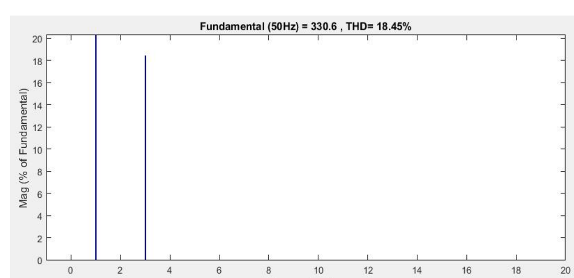
III. GRAPHICAL RESULTS

SCENARIO 1: INJECTION OF 3RD HARMONIC









Above are the results without DVR

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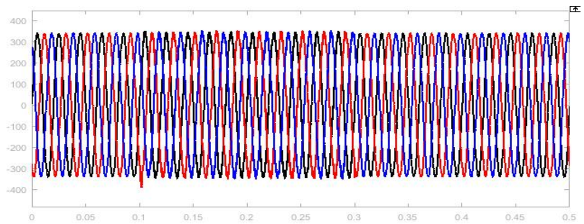
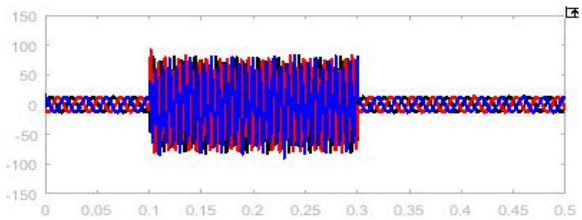
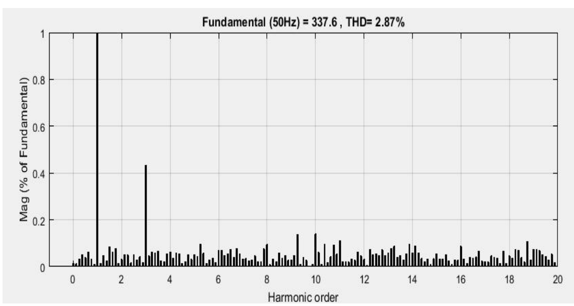
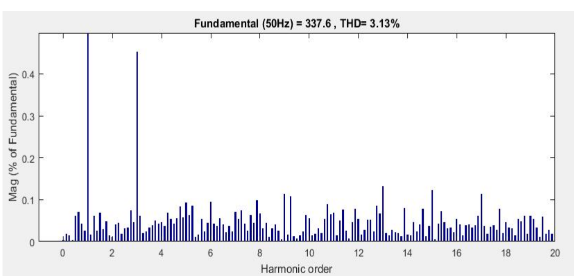
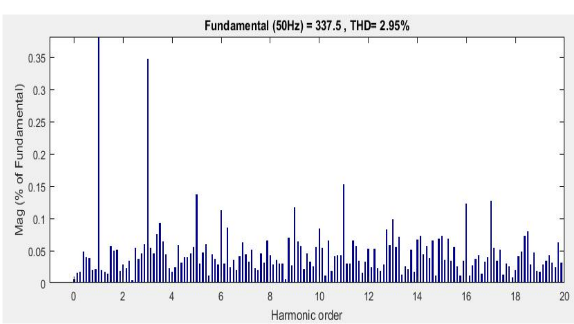




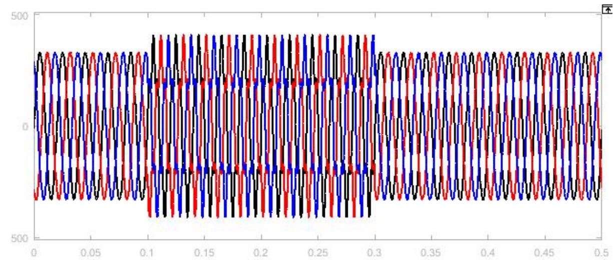


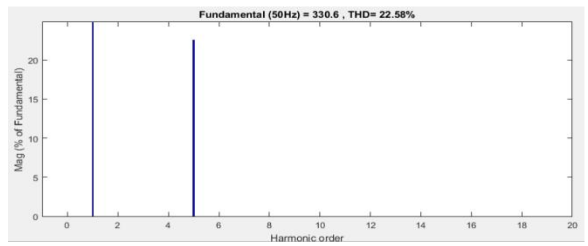


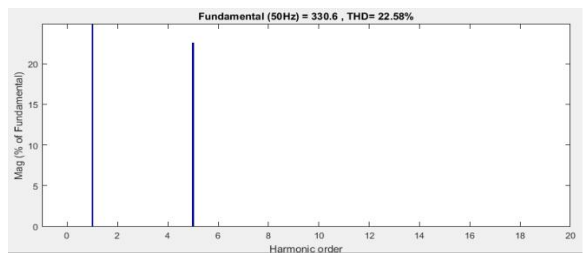


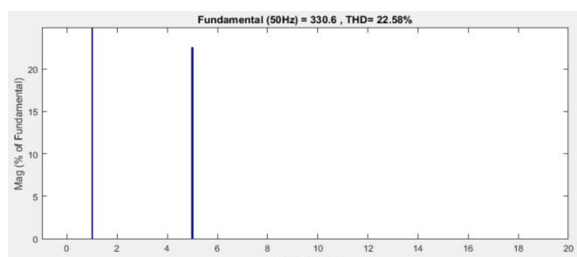
Above results are with DVR

SCENARIO 1: INJECTION OF 5th HARMONIC

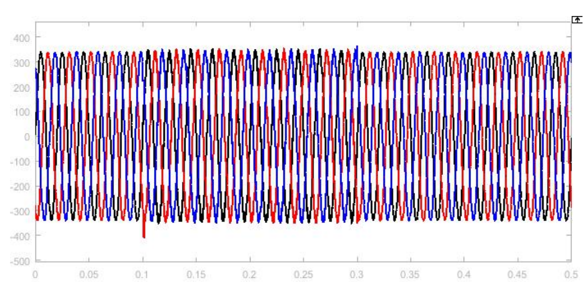


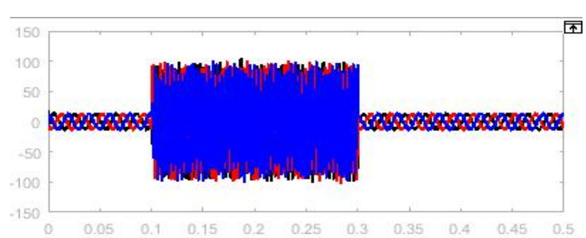


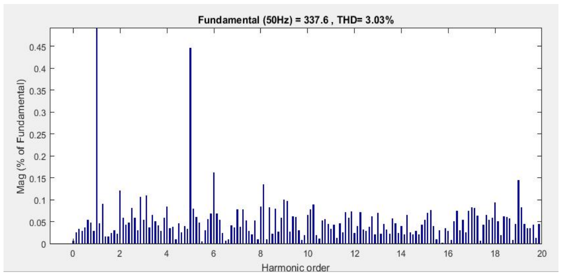


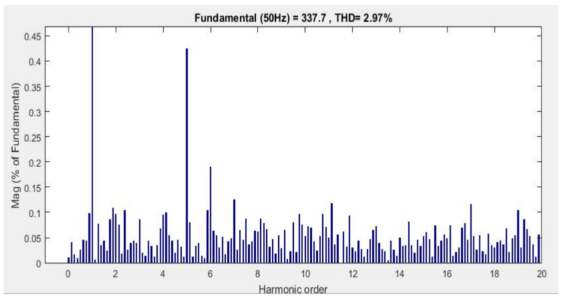


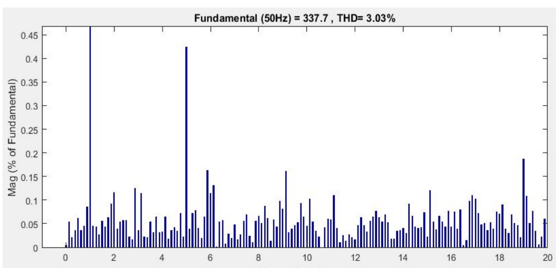
Above are the results without DVR











Above results are with DVR

IV. 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 and power 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. While maintaining the compensation of voltage profile, the THD was reduced to around 4%. Like for scenario 1, the observed THD with DVR case was 2.69%, 2.40%, and 2.69%, and for scenario 2, there were 3.74%, 4.04%, and 3.60% THD in the voltage profile. This improvement and reduction in the THD in load voltage explain the effectiveness of the

DVR based control strategy used in this work. 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 NeuroFuzzy controls for enhancement of power system stability using STATCOM

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