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Analysis of Power Quality Enhancement by DSTATCOM and DVR in Islanded Microgrid

Sagar Yadav, *Vikas Verma,* Himanshu Bhushan and Sachin Singh

Department of Electrical Engineering, Institute of Engineering and Technology, Lucknow, India

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ABSTRACT

In this paper, a Microgrid has been developed consist of renewable energy resources in MATLAB Simulink environment. First, a DVR has been modeled and used in the developed microgrid model. Power quality analysis is carried out with the help of simulation results considering the effect of Dynamic Voltage Restorer (DVR). Also, a MATLAB Simulink model of the DSTATCOM has been developed to compare its performance with DVR. The same DSTATCOM has been used with the earlier developed microgrid model to test its effectiveness. The performance of both DVR and DSTATCOM has been compared in common scenarios related to power quality issues and results are analyzed.

Keywords-DVR (Dynamic voltage restorer) DSTATCOM (Distribution Static synchronous compensator), THD, Power quality, Harmonics, Micro-grid.

INTRODUCTION

An essential advancement in the electrical power system is power generation. Modern society is entirely reliant on the electricity produced by generating plants. The three components of the traditional power system are the generation, transmission, and distribution of alternating current (AC) electricity. The power quality of the system is decreased due to excessive loads, unusual circumstances, or problems on the line, and it is very important to improve its quality [1]. As traditional sources of energy regularly run out, society is forced to consider additional alternatives that can meet the rising need for energy. One such option is the formation of a microgrid using small-scale renewable energy sources to supply a local area. The two unique operating modes for microgrids are grid-connected mode and islanded (autonomous) mode [2], [3]. Different techniques can be used to control distributed energy resources (DER) in microgrids in each mode of operation. DERs based on power electronic converters are typically a microgrid's most important component. In grid-connected mode, the microgrid functions as a current controller and injects power into the main grid by local load and power generation and appropriate market policies [4]. Due to disturbances, such as a breakdown and the subsequent switching occurrences that result from it, preplanned, or resource shores, and due to remoteness, the microgrid may enter an islanded or autonomous mode. Microgrid functions as a voltage controller in islanded operation and oversees voltage regulation, as well as power sharing and balancing. The purpose of power-sharing features is to make sure that each module distributes the load by its rating and the amount of power that is available from its energy source. Grid-forming (master) power converters are always necessary for converters in the islanded mode. Otherwise, there would be no control to maintain the power balance and no voltage control [5]. Due to penetration levels of renewable energy use in the power grid, the old, centralized network faced numerous technical challenges in preserving security and stability by which power quality become poorer [6]. Also due to the non-linear load, there is a disturbance, and harmonics generation in the system occurs which is affect the power quality of the system. To reduce voltage and current harmonics, sag, and swell there are many FACT devices which are shown in Fig.1 [7], [8].

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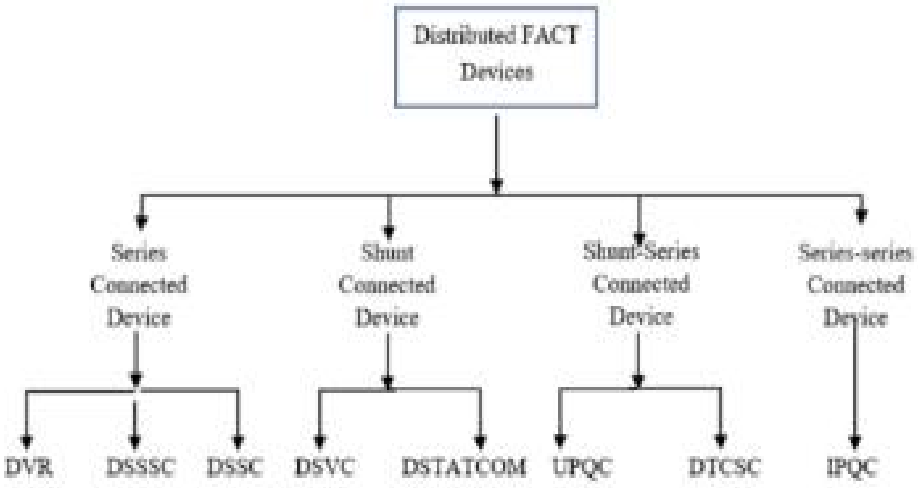

Fig. 1. Distributed FACT devices

In this study, comparison to DVR and DSTATCOM of the same MATLAB Simulink model perform. The DVR is connected in series with the system because it is a series-connected device whereas DSTATCOM connected in parallel with the system. After all, it is shunt-connected device. Both devices are connected to the LV side of the transformer.

TOPOLOGY OF DVR AND DSTATCOM

Due to non-linear loads and complex power electronic devices, there is the majority of automated systems are extremely susceptible to problems with voltage-related power quality, such as harmonics, voltage sag, and swell. To overcome these problems there are many devices in which DVR and DSTATCOM are the most popular to improve power quality problems. Both of the devices use PI-based controller to control the power quality-related problem [9].

A. Structure of DVR

The structure of DVR is shown in Fig. 2, it consists of DC power sources, a Voltage source converter, an Injection transformer, and a Control unit. A power electronic controller used in a DVR protects sensitive electric loads against power quality problems including voltage droop and swell and imbalance issues [10].

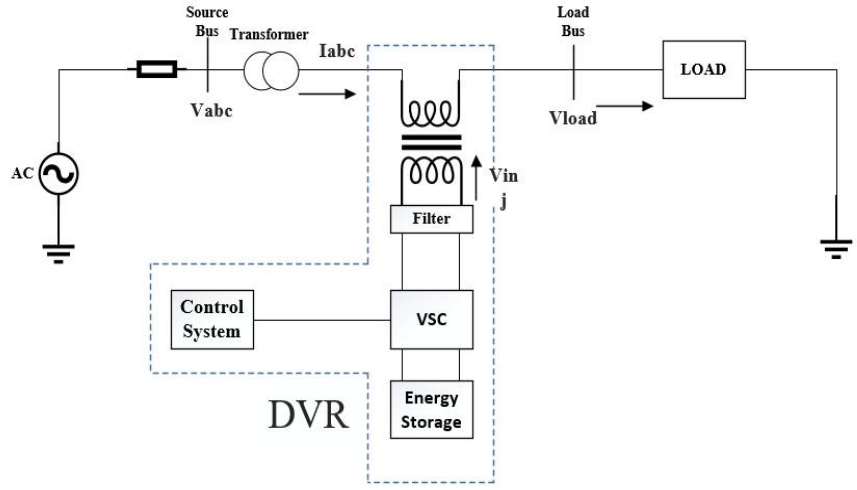

Fig. 2. Structure of DVR

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B. Controlling of DVR

The control scheme of DVR is proportional-integral (PI) based used, it calculates the error, which is the difference between the actual output that was detected and the desired set-point, as well as the integral of that value and known as a weighted sum of the error.

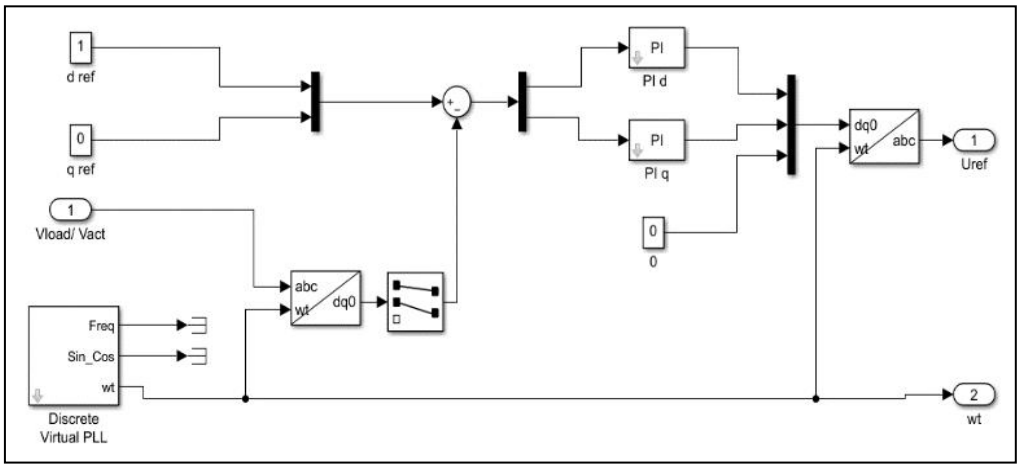

Fig. 3. PI control Simulink of DVR

The steady-state error for a step input is zero thanks to the PI controller's integral term. The difference between Vref and Vabc, as depicted in the PI controller's schematic picture, is the actuating input signal. The desired firing sequence is produced by comparing the controller output at the PWM signal generator. The PI-based controller of DVR have three main parts i.e. the PI control unit, abc-dq0 transform, and discrete virtual PLL [11].

C. Structure of DSTATCOM

A STATCOM is a device with a solid-state VSI architecture that is also required for VAR compensation. This is a power electronics-based shunt device that uses insulated gate bipolar transistors and gate-turn-off thyristors to control the power flow. It is referred to as DSTATCOM when this STATCOM is utilized in the distribution system to regulate reactive power. The structure of DSTATCOM is shown in Fig. 4.

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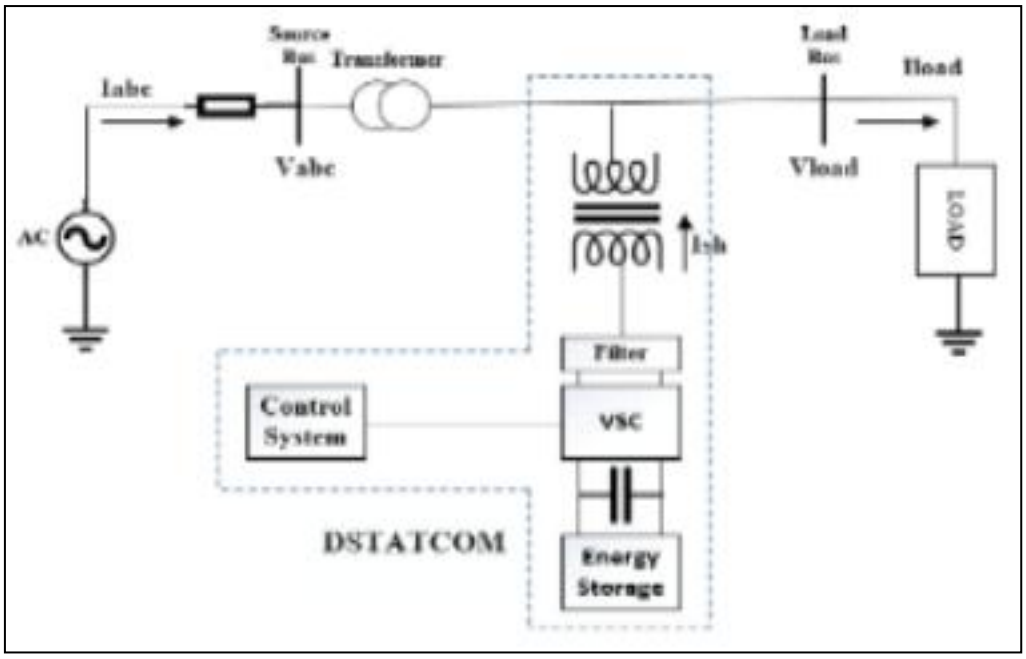

Fig. 4. Structure of DSTATCOM

Its components are a DC capacitor (Energy storing device), one or more inverter modules, an AC filter, a coupling transformer, and a control strategy. Power system issues such as grid stability, power loss, harmonics, and transient voltages are reduced when STATCOM is used [12].

D. Controlling of DSTATCOM

A PI-based controller is used for controlling the DSTATCOM. In contrast to the conventional STATCOM controller, the author used the adaptive PI controller to prevent several issues and errors.

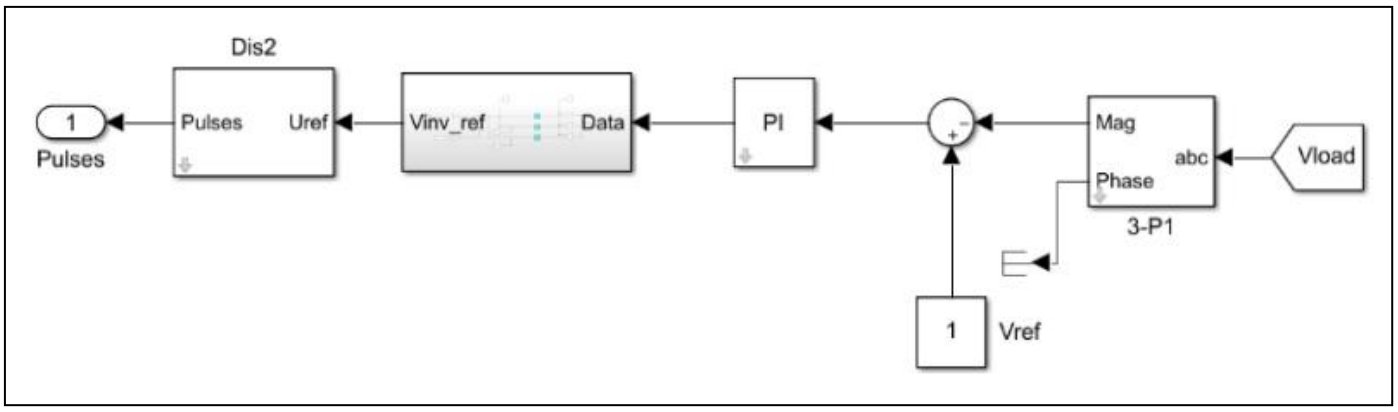

Fig. 5. PI control Simulink of DSTATCOM

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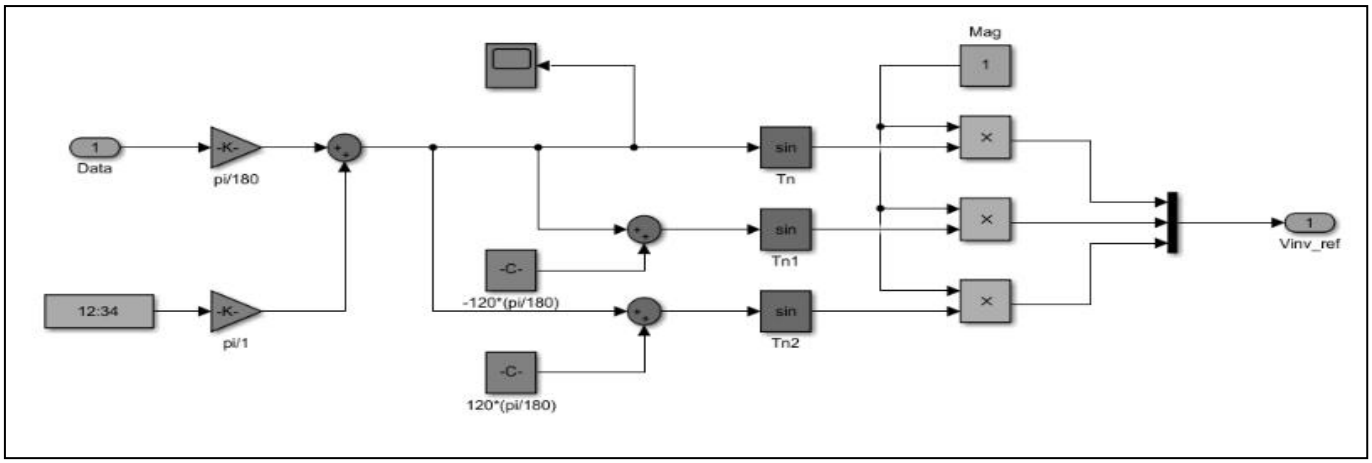

Fig. 6. Subsystem model of DSTATCOM

The PI controller in adaptive PI control decreased mistakes and also self-adjusted the PI control gains when the operational parameters were modified. In Fig. 5. this PI control diagram displays a current regulator in the inner loop and a voltage regulator in the outer loop. First, took the reference voltage from the outside loop and measured the bus voltage. After that, the inner and outer loop's proportional and integral parameters are changed. The permissible voltage error (Kd) is tuned to zero, and the outer loop values are tuned to 1.0 in this controller. [13], [14].

SIMULATION AND RESULTS

E. Simulation Model of Proposed System

DVR and DSTATCOM MATLAB Simulink model connected with the 3-phase system is shown in Fig. 7 and Fig. 9 respectively

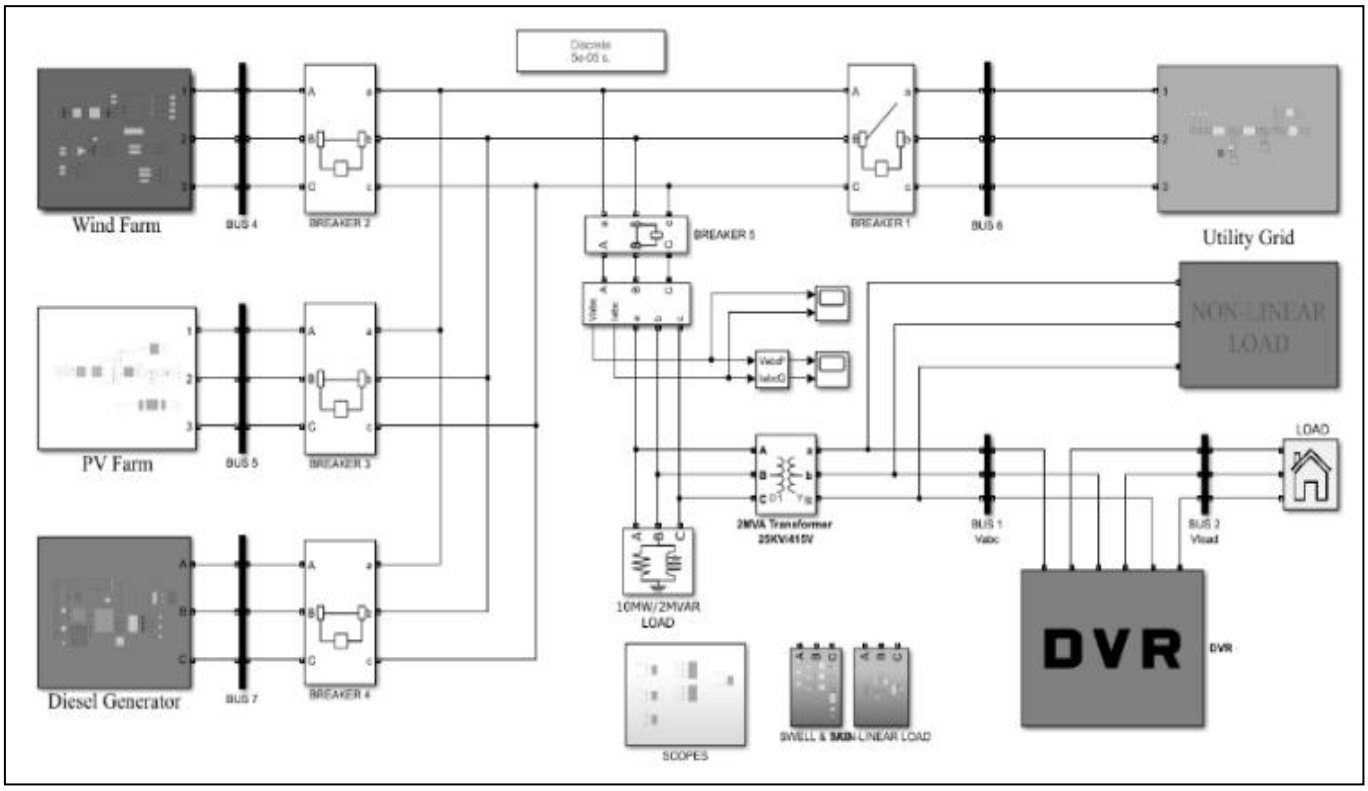

Fig. 7. Simulink model of DVR connected system

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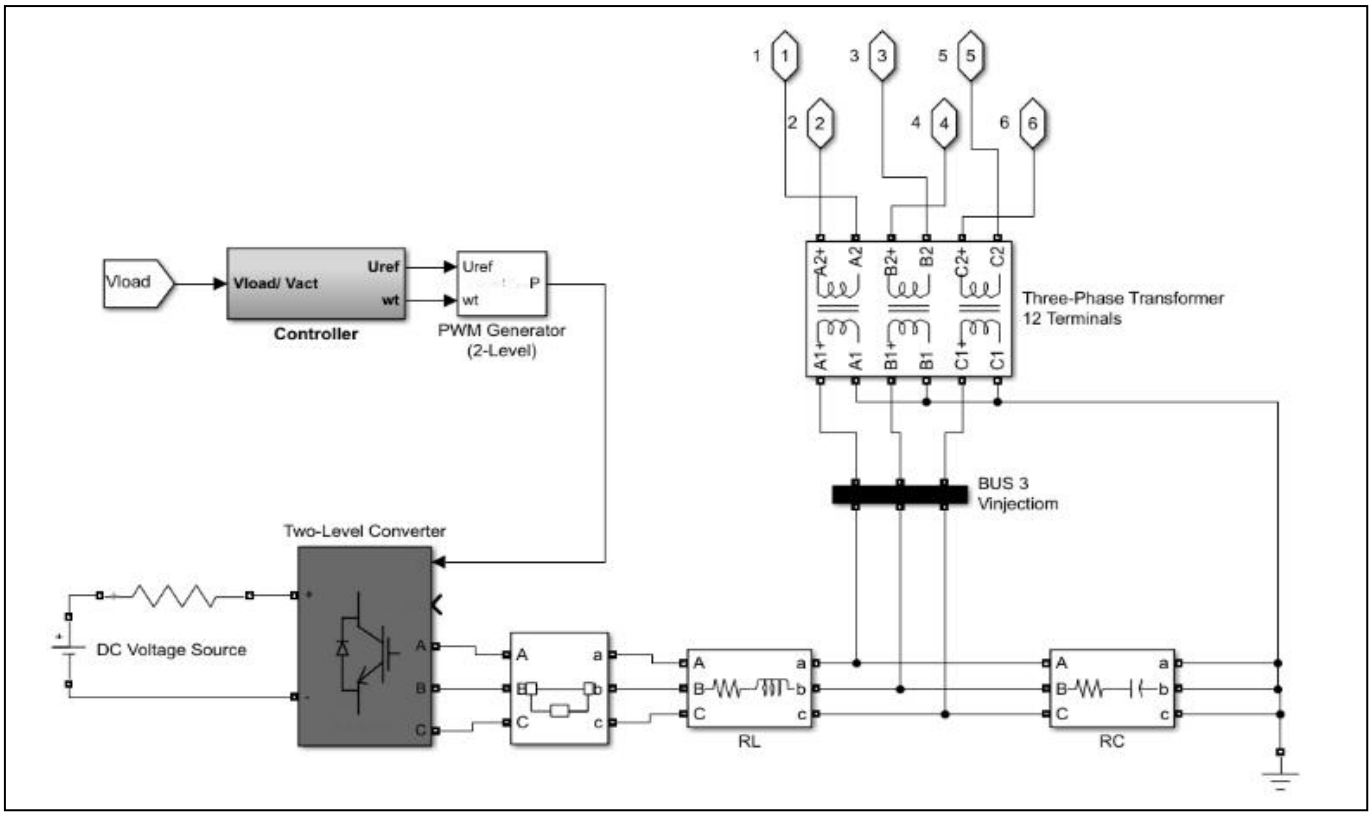

Fig. 8. Simulink model of DVR

In the DVR-connected system shown in Fig. 7 DVR is connected serially with the load bus and source bus. Whereas in Fig. 9 DSTATCOM is connected in parallel with the source bus and load bus.

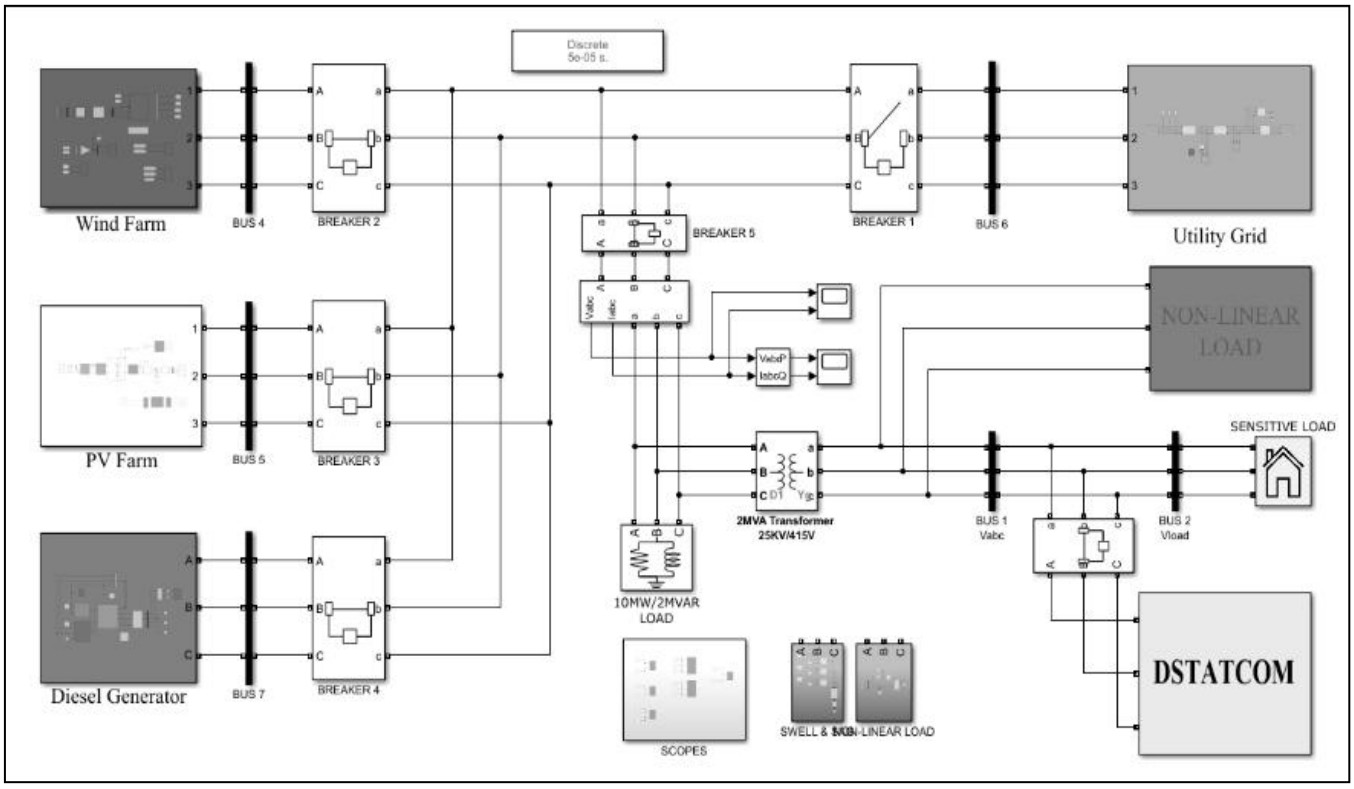

Fig. 9. Simulink model of DSTATCOM connected system

The simulation test has been conducted on both devices DVR and DSTATCOM on the same model to

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analyse the harmonic reduction and THD (Total harmonic distortion) improvement which is generated due to connecting non-linear load on the system for the duration of 0.1 to 0.25 sec.

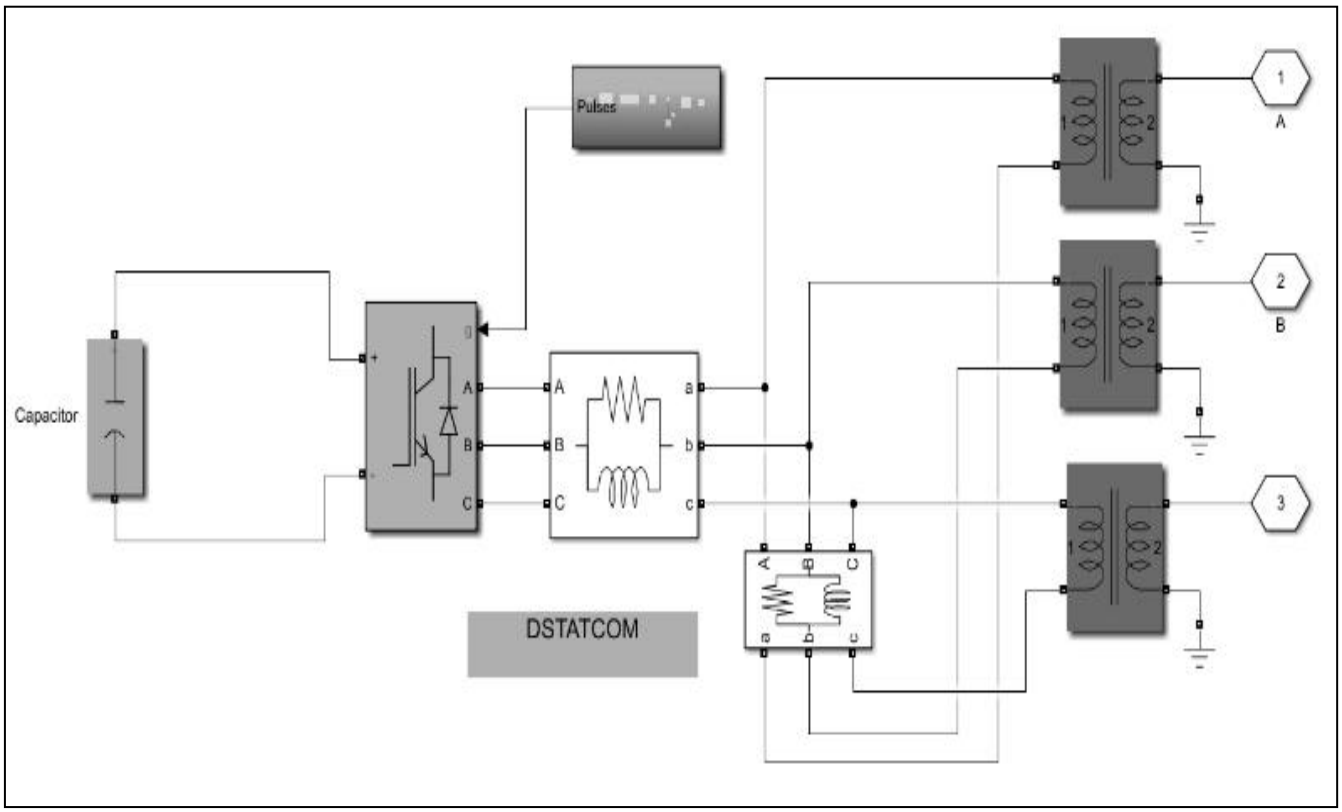
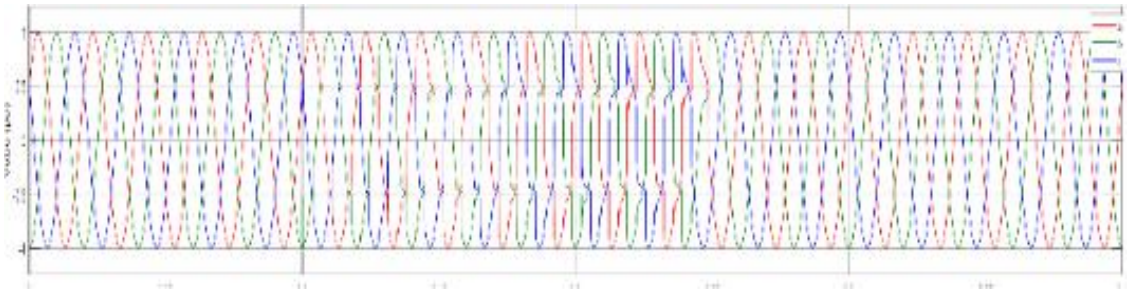


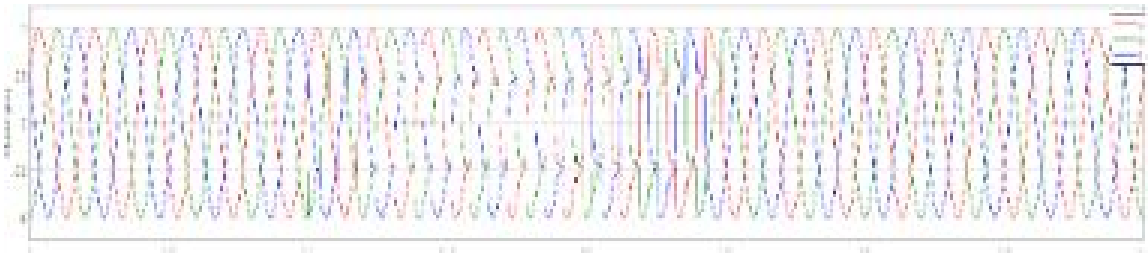
Fig. 10. Simulink model of DSTATCOM

F. Result Obtained Without Using DVR and DSTATCOM

The developed model of microgrid has been simulated with nonlinear load without any FACT device and following results are obtained.



(a)



(b)

Fig. 11. Waveform without using DVR and DSTATCOM (a) Source voltage bus-1 (b) Load voltage

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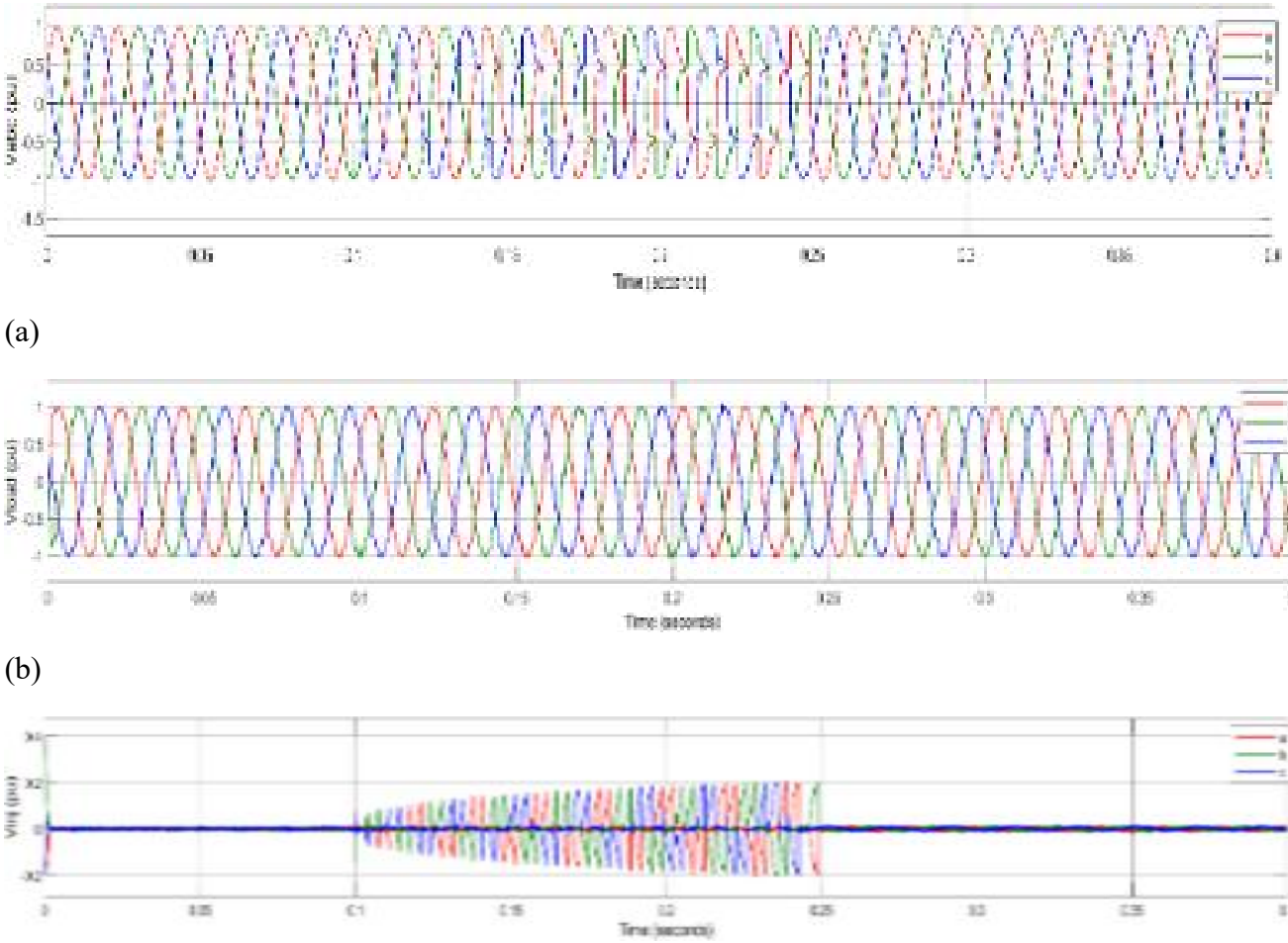
bus2

From the above waveform when non-linear load is connected the harmonics generated in the waveform.

G. Result Obtained by Using DVR

When a non-linear load is connected for the duration of 0.1 to 0.25 sec the following results were found in DVR connected 3-phase system.



(a)

(b)

(c)

Fig. 12. (a) V_{abc} voltage at bus-1 (b) V_{load} voltage at load bus-2 (c) V_{inj} Voltage injected by DVR

From the above waveforms, the voltage at the load Vload side is more uniform as compared to the source side voltage Vabc. It is observed that harmonics are reduced by using DVR.

H. Result Obtained by Using DSTATCOM

When a non-linear load is connected for the duration of 0.1 to 0.25 sec the following results were found in DSTATCOM connected 3-phase system.

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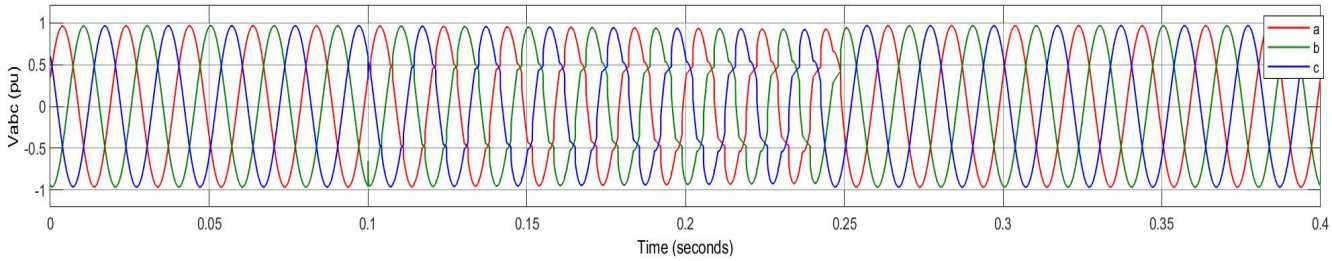
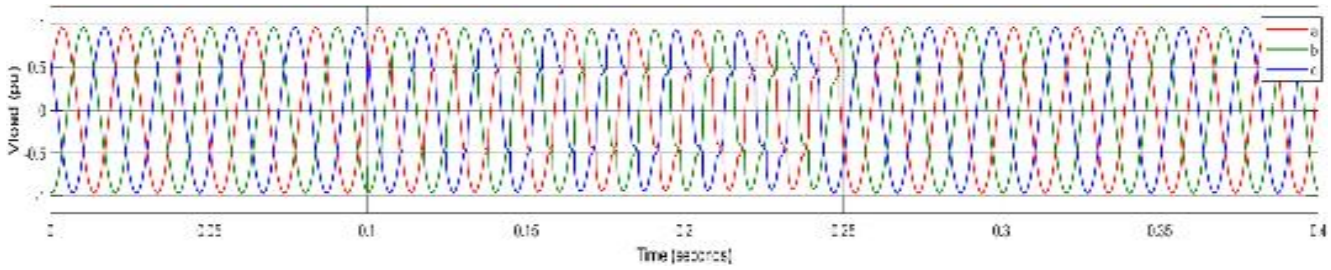
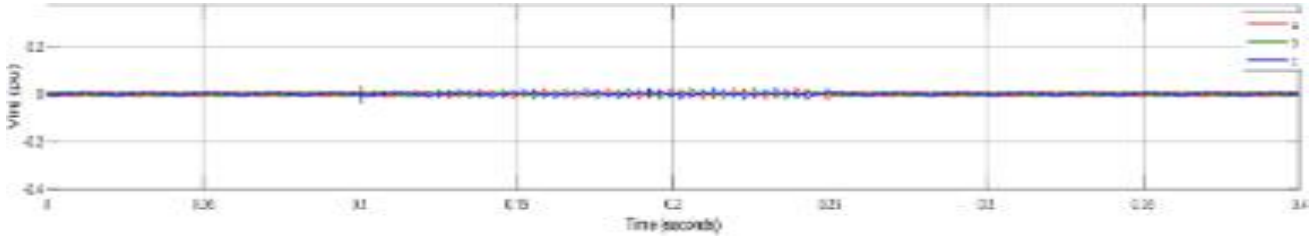


(a)



(b)



(c)

Fig. 13. (a) V_{abc} voltage at bus-1 (b) V_{load} voltage at load bus-2 in DSTATCOM connected system

From the above waveforms, the voltage at the load Vload side is more uniform as compared to the source side voltage Vabc. It is observed that harmonics are reduced by using DSTATCOM.

TOTAL HARMONIC DISTORTION (THD) ANALYSIS

According to IEEE standard 519 from 1992, the total harmonic distortion is a limit below 5% for the voltage level 69KV or below.

The Total Harmonic DISTORTION (THD) for the non-linear connected systems without and with DVR and DSTATCOM is represented below.

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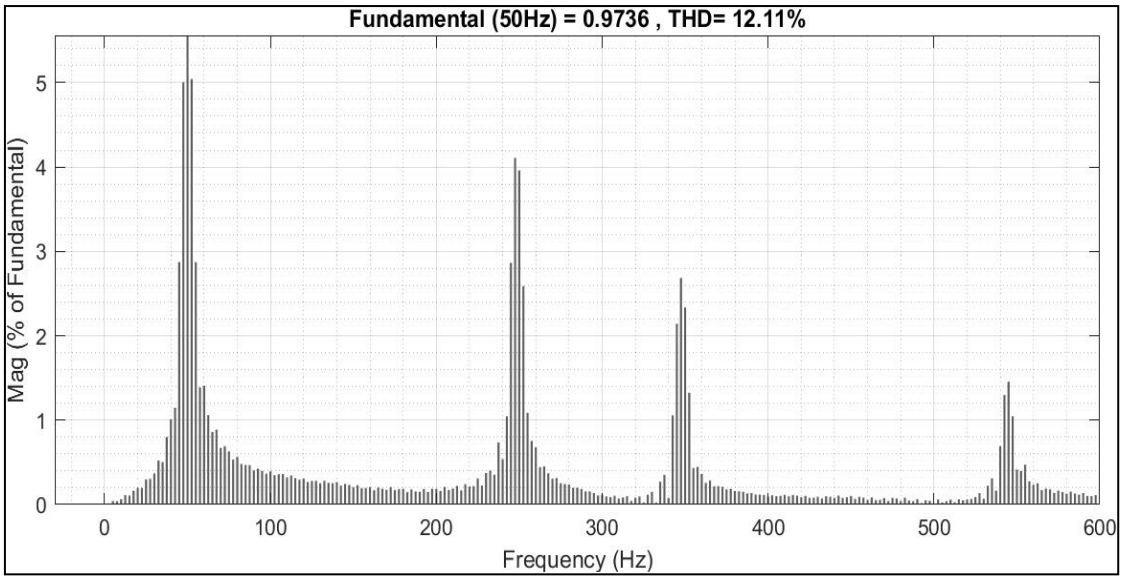

Fig.14. THD of the system without DVR and DSTATCOM

Fig. 14 THD of the system without DVR and DSTATCOM represent the THD of the system without DVR and DSTATCOM is very high 12.11% with is not in the range of IEEE standard.

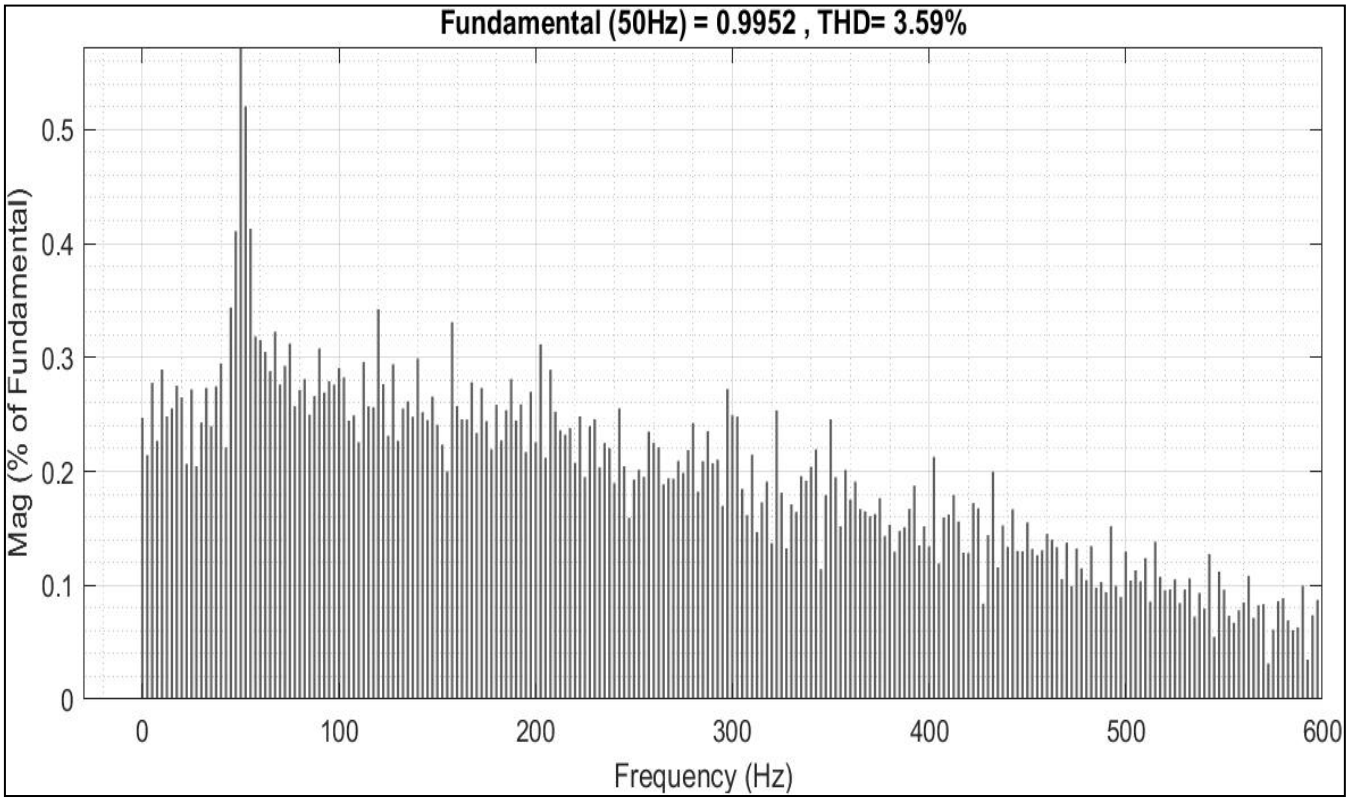

Fig.15. THD of the system with DVR

Fig. 15 THD of the system with DVR represent the THD of the system with DVR (Dynamic Voltage Restorer) is 3.59% which is in the range of IEEE standard.

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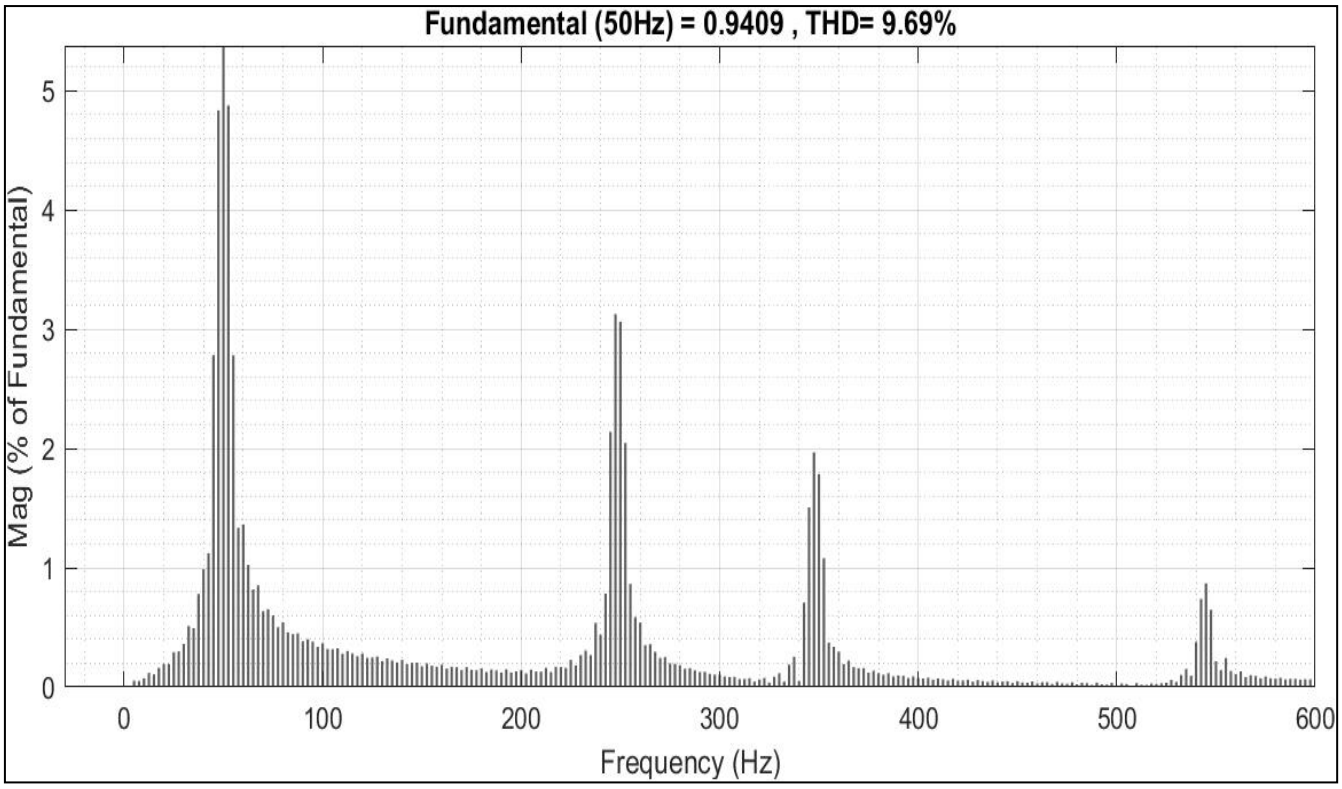

Fig. 16. THD of the system with DSTATCOM

Fig. 16 THD of the system with DSTATCOM represents the THD of the system with DSTATCOM is 9.69% which does not lie the range given in IEEE standards, but it shows the THD improvement of about 2.42%.

ANALYSIS OF TOTAL HARMONICS DISTORTION

Total Harmonic Distortion	
Operation	*THD (%)*
Without DVR and DSTATCOM	12.11
With DVR	3.59
With DSTATCOM	9.69

CONCLUSION

The MATLAB Simulink platform is used to perform the test analysis of DVR and DSTATCOM on the same Simulink model. By observing and testing both DVR and DSTATCOM, harmonics, and Total harmonic distortion it is found that the performance of DVR is better than the performance of DSTATCOM. The harmonic reduction in the DVR is more as compared to the DSTATCOM. Also, in the THD analysis of both DVR and DSTATCOM it is found that the THD improvement of DVR is better than the DSTATCOM.

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