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Power Quality Improvement Using DSTATCOM For IEEE 9 Bus System

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ABSTRACT- The rapid rise of people is causing significant issues in the electricity system by increasing energy consumption or load demand. In Power System, there are several problems cause of overloading issues, dangerous blackouts, voltage fluctuations, and collapse. A system's voltage profile will be better as a result of improved reactive power compensation, raising the system's overall power quality. In this paper, the power quality analysis examined case study i.e. Standard IEEE 9 bus system describes the During-fault, and Post-fault conditions using DSTATCOM device carried out with MATLAB software. The pre-fault condition is accomplished using the power flow study by the Newton-Raphson method, and the influence of a three-phase balanced fault has been deliberated during-fault conditions. The IEEE-9 bus system was first examined using standard test data, and subsequently the same system was examined using D-STATCOM. The system's reactive power compensation, voltage profile, and line losses with and without D-STATCOM are all investigated.Also this paper presents a comparative analysis of IEEE 9 bus system power quality analysis using D-STATCOM device with respect to without DSTATCOM device to improve system performance.

KEYWORDS- FACTS device, D-STATCOM, Transient Stability, and IEEE 9 Bus System.

I. INTRODUCTION

Power systems are often divided into three stages: generation, transmission, and distribution. The first stage is the Generation, where synchronous Generators are often used to produce electrical power. Transformers then increase the voltage range before the power is transferred to decrease the line voltage & current, hence reducing the losses associated with the transfer of power. Transformers are used to step down the voltage after the transmission so that it can be distributed appropriately. Power systems are designed to offer continuous power while maintaining voltage stability. Short circuits that may occur between transmission line phase conductors or between a phase conductor and ground are caused by undesirable phenomena like as lightning, accidents, or other unexpected events and are referred to as faults. As a result of a fault, one or even more generators may be significantly affected., which would cause instability between supply and demand. If the issue continues & is still not resolved within a specified period of time, it could seriously harm the equipment, which could result in a power loss and outage. In order to prevent the fault energy from spreading to other areas of the system, antifouling equipment is compartmented to observe faults and clear/separate faulted components of the power system as rapidly as possible.

Simulink is an interactive platform that may be used to model and simulate many different dynamic systems. Blocks make building systems simple, and they also make displaying results quickly.

MATLAB-simulink is employed for studying the effects of non-linearity of the system and hence is an ideal research technique.

It is being used for research projects in a variety of fields, including the power system. In this research paper, the time domain simulation method is used. This study models the multi-machine, a 9 bus system in MATLAB /Simulink and performs a transient stability analysis with a bus fault as the focus.

II. POWER SYSTEM STABILITY

Power system stability refers to the ability of an electric power system to return to a condition of operating equilibrium after being subjected to a physical disturbance for a given initial operating condition, with most system variables bound so that practically the entire system is unaffected. Due to the high complexity of power system designs & behavior, the stability phenomenon is a single issue linked to numerous forms of instabilities affecting the power system. A thorough investigation of power system stability requires a comprehensive understanding of classification in order to properly understand stability. Stability is categorized according to the type of system instability it causes (voltage & frequency instability), the size of the disturbance (small & large disturbance), and the period of stability (short & long term). Alternatively, there are two major categories of stability i.e. steady -state and dynamic. The system's capacity to transition among operating points when there are only minor load fluctuations is known as steady-state stability. In the literature, power system dynamic stability is stated as a class of rotor angle stability to indicate if a system can continue to operate steadily in the presence of frequent interruptions.

III. TRANSIENT STABILITY

The power system is in steady state if the generation of the system is equal to the load plus transmission loss. The system's frequency, voltage, current, and power flows are stable, and the generating units run at synchronous speed. When a severe disturbance occurs, such as a three-phase fault, loss of load, loss of generation, etc., the power balance is disrupted and the rotors of the generating units accelerate or decelerate.. The system may split into smaller systems or one or more machines may stop sustaining synchronism before returning to a steady state condition In the first case, the system is described as stable, while in the second, it is described as unstable.

IV. FACTS CONTROLLERS

A FACTS system is defined by the IEEE as "a power electronic-based system and associated static equipment that permit management of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."

FACTS controllers are classified into four types:

- Series Controller
- Shunt Controller
- Combined series-series Controller
- Combined series-shunt Controller

Table 1. Comparison between FACTS controller

Name	Type	Controller Used	Purpose
SVC	Shunt	Thyristor	Voltage control
SSSC	Series	GTO	Power flow control
STATCOM	Shunt	GTO	Voltage control
UPFC	Shunt & Series	GTO	Voltage & Power flow control
TCSC	Series	GTO	Voltage control
TCPAR	Shunt & Series	GTO	Control power flow

A. Static VAR Compensator (SVC)

This is a kind of electrical equipment used in high voltage transmission networks to supply quick reactive power. As demonstrated in fig. 1, an SVC is composed of fixed capacitors (FC) tuned to filters, Thyristor Switched Capacitors (TSC), Thyristor-Controlled Reactors (TCR), and/or TSCs. A stationary reactor and a bi-directional Thyristor valve help compensate for a TCR. TCR reactors typically have an air core, and glass fibre insulation, and are impregnated with epoxy coating.

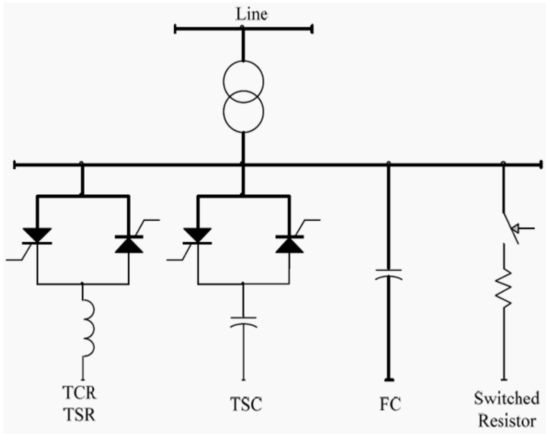

Figure 1. Line Diagram with SVC Model

SVCs have a quick immediate response to changes in the system voltage, which gives them a significant advantage over straightforward mechanically-switched compensation schemes. To make the most of the reactive power adjustment, These can offer in the system quickly when needed, and are frequently run very close to their zero-point. In comparison to dynamic compensation schemes like synchronous condensers, they are typically more affordable, have a larger capacity, and are faster, efficient, and dependable.

B. Static Synchronous Compensator (STATCOM)

A static synchronous compensator (STATCOM), well-known as a static synchronous condenser , with a shunt connection whose output current (capacitive or inductive) is controllable without reference to the ac system voltage.

As seen in fig. 2, STATCOM is made up of a coupling transformer, a voltage source converter, and a DC energy storage device. It can interchange reactive power through the transmission line due to its small energy storage device, or small DC capacitor. When this DC capacitor is replaced by a DC battery system or the other Dc power source, the controller can interchange both real and reactive power with the transmission network, increasing its operating region from 2-4 quadrants.

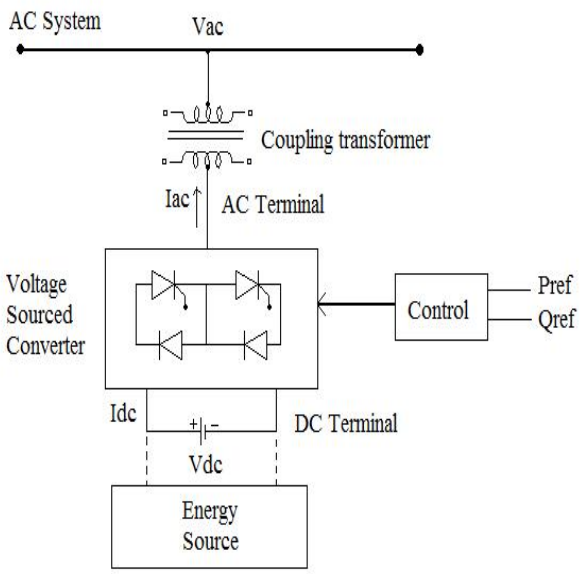

Figure 2. STATCOM Model

C. D-STATCOM

Reactive loads, such as fans, pumps, and other devices, have consumed a significant amount of power in modern distribution systems. These loads demand lagging power factor currents, which increases the distribution system's reactive power burden. Unbalancing has an impact on the functioning of Transformers and Generators, while excessive reactive power demand results in higher feeder losses and a reduction in the distribution system's ability to transfer active power. DSTATCOM delivers reactive power as required by the load for reactive power correction, so the source current stays at the unity power factor (UPF).

The load current's primary frequency component that is acquired using these methods is present in the reference source current that is utilized to determine the DSTATCOM's switching. A STATCOM for the load current's actual fundamental frequency component, which is derived using these methods. While a DSTATCOM is employed at the distribution or load end to optimise power factor and regulate voltage, a STATCOM at the utility side primarily handles essential reactive power and provides voltage support. A DSTATCOM can also be used as a shunt active filter to remove imbalances or distortion in the ac mains or supply voltage. A DSTATCOM is such a versatile device, thus any control algorithm's primary goal should be to make it as flexible as possible.

- It is efficient during high real-power exchange and necessitates a large voltage level.
- It results in significant real and reactive power losses.
- It can cause hazardous momentary over voltages as a result of load rejections.
- It necessitates greater equipment for the transformers and cable.
- Any compensation plan's primary goal is to be quick to react, flexible and easy to Considering transmission along a large power angle and a significant voltage magnitude gradient, reactive energy will never be balanced. Transfers should be reduced in favor to Reactive power for a variety of reasons.

V. BASIC PRINCIPLE OF DSTATCOM

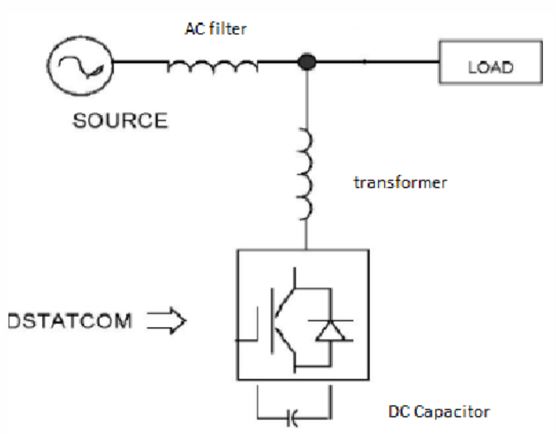

Figure 3. Basic Principle of DSTATCOM (Distribution Static Compensator)

As seen in Fig. 2, A DSTATCOM comprises a two-level Voltage Source Converter (VSC), a DC energy storage unit, and a coupling T/F shunt-connected to the distribution system through an interface inductor. The VSC transforms the storage device's DC voltage into a set of 3-ϕ A.C. output voltages. Such outputs are coupled to the A.C.system in phase with the reactance of the coupling transformer. The phase & magnitude of the DSTATCOM output should be appropriately adjusted. Effective regulation of active and passive "reactive power" transfers between the DSTATCOM as well as the ac grid. Such a setup enables the instrument to produce or absorb controlled active and electrical inertia The VSC's AC terminals are the Point of Common Coupling is tied to (PCC) through a filter, or perhaps an inductance or the coupling's leakage inductance transformer as depicted in Figure 3.

The major component for storing reactive energy is a DC capacitor, which is attached to the DC side of the converter and carries the converter's input ripple current. This capacitor can be charged by the converter or by a battery source. If the VSC output voltage and the terminal alternating voltage are both equal, no reactive power is supplied to the system.

If the output voltage is greater than the AC terminal voltage, the DSTATCOM functions in capacitive mode, and vice versa.

VI. CONTROL ALGORITHM

Any compensation plan's primary goal is to be quick to react, adaptable, and simple to implement. The following steps are where a D-STATCOM's control algorithms are mostly implemented:

- System voltage and current measurements, as well as signal conditioning
- Compensating signal calculation
- Generation of switching device firing angles

VII. STANDARD IEEE 9–BUS POWER SYSTEM

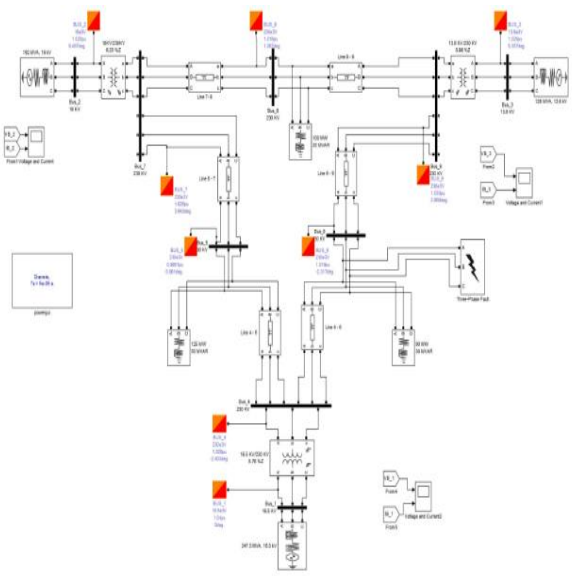

Figure 4: IEEE 9 bus power system without "D-STATCOM"

Fig.4 MATLAB model of the “IEEE 9” bus power system without “D-STATCOM”. The system is set up utilizing the data of the standard 9 bus system.

VIII. SIMULATION RESULTS

The proposed model performance is simulated and analyzed in MATLAB software. The simulation outcomes were firstly obtained for the system in which D-STATCOM is not implemented both in considerations of voltage & current waveforms which are shown in Figures 5 and 6.

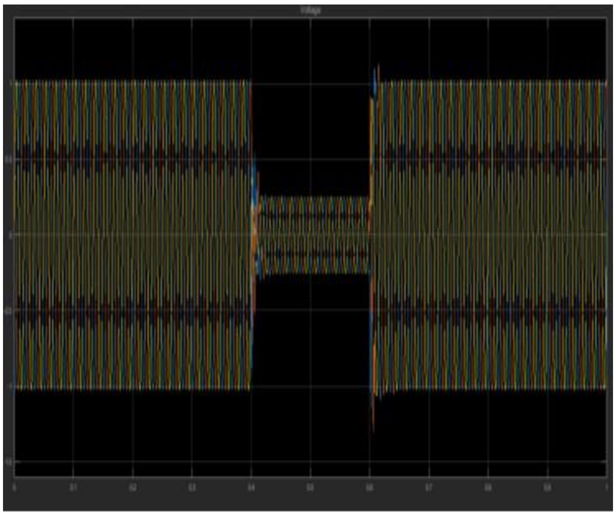

Figure 5: Waveform of voltage in case of 3-ϕ fault “without D-STATCOM”

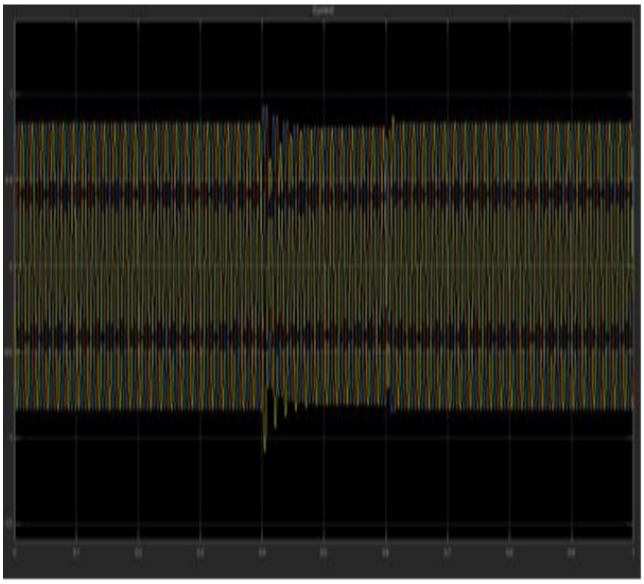

Figure 6. Waveform of Current in case of 3-ϕ fault “without D-STATCOM”

Figure 5and 6, represent the waveform of voltage &current in the power system with three phase faults without D-STATCOM. After analyzing the voltage waveform in figure 5, it is observed that with the introduction of faults in voltage from 0.4s to 0.6s, its amplitude decreases drastically. While when faults are introduced in the current waveform from 0.4s to 0.6s(as shown in figure 6), the amplitude of the current increases or swells. Almost 90% of the voltage sag occurs when faults are introduced for 0.2s. However, since custom power device deals with electronic elements, harmonics and distortion will appear in the system.

In addition to this, the impact of the total harmonic distortion (THD) on voltage and current is depicted for the model in which D-STATCOM is not implemented. The waveforms obtained for the THD in terms of voltage and current are shown in Figures7 and 8.

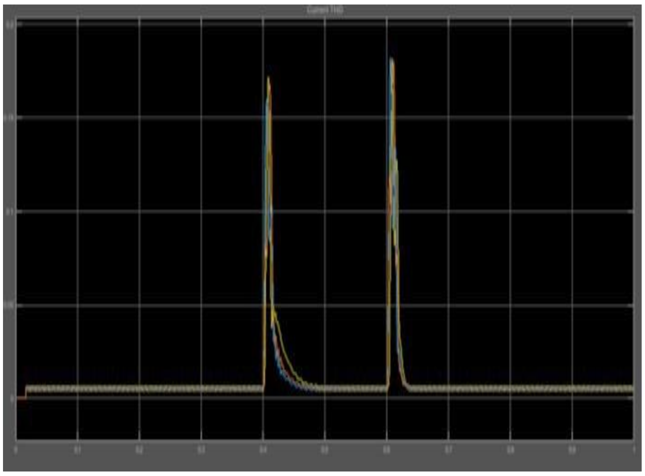

Figure 7:Impact of THD on voltage in three-phase fault without D-STATCOM

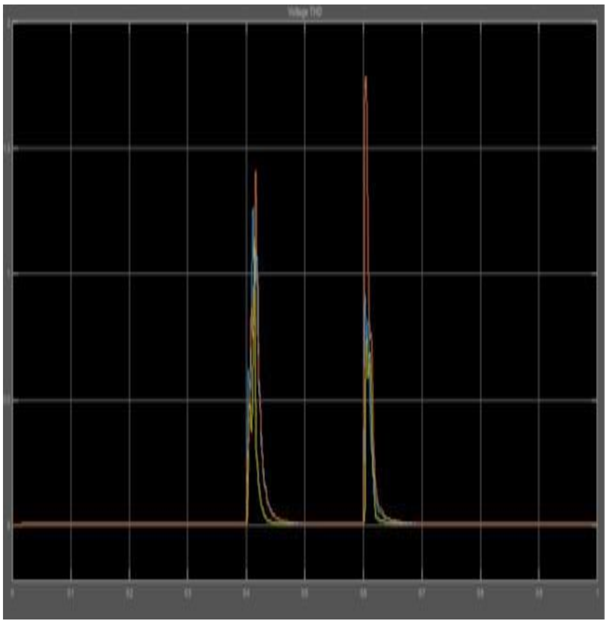

Figure 8: impact of THD on current in three-phase faults without D-STATCOM

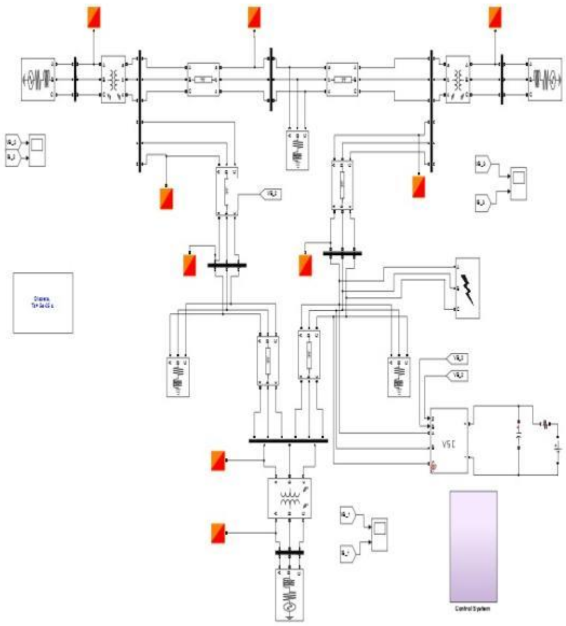

Figure 9: IEEE 9–bus power system with D-STATCOM

This system is set up by the MATLAB SIMULINK program Bus nos. 7 and 8 are connected with a shunt FACTS device i.e. D-STATCOM. 3-generators, 3-transmission lines, 3-transformers, and 3-loads make up the system. Generators 2 and 3 are connected to synchronized machines. Additionally, the synchronous machines of generators 2 and 3 are linked to the power system stabilizer. The source bus is bus 1, the generator or voltage bus is bus 2 and bus 3, since the generators have direct access to these buses, and the load buses are bus 4, 5,6,7,8, and 9.

The performance of the proposed model is then simulated & analyzed in the "MATLAB" software for the system in which D-STATCOM is implemented. The simulation results were obtained when it comes to voltage and current waveforms which are shown in Figures10 and 11.

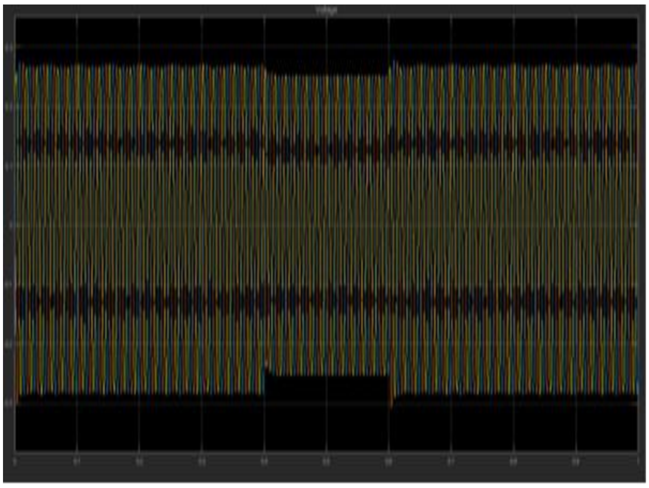

Figure 10: Waveform of voltage in case of a 3-ϕ fault with D-STATCOM

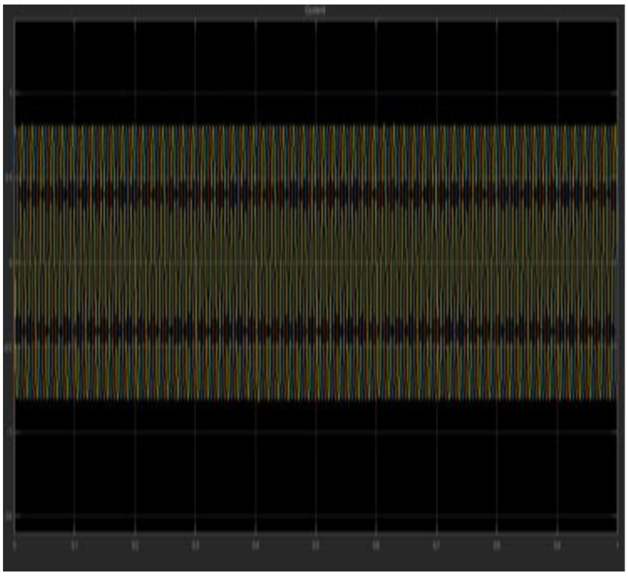

Figure 11: Waveform of Current in case of 3-ϕ fault with D-STATCOM

Figure 10 &11, represent the voltage and current waveform for 3-ϕ faults when D-STATCOM is implemented.After analyzing the waveform of voltage, it is seen that the distortion is minimum or we can say almost negligible when faults are introduced in it for 0.2s i.e., from 0.4 to 0.6s. Also, the impact of total harmonic distortion on the current waveform is negligible as shown in figure 11. With the introduction of the D-STATCOM the voltage at load points is improved. This occurs because D-STATCOM can quickly absorb or produce reactive power, which reduces voltage sags. Because the D-STATCOM &system's AC output voltage is directly coupled with the coupling transformer of the electricity network, the interchange of active and reactive power between the D-STATCOM & the existing system can be made easily.

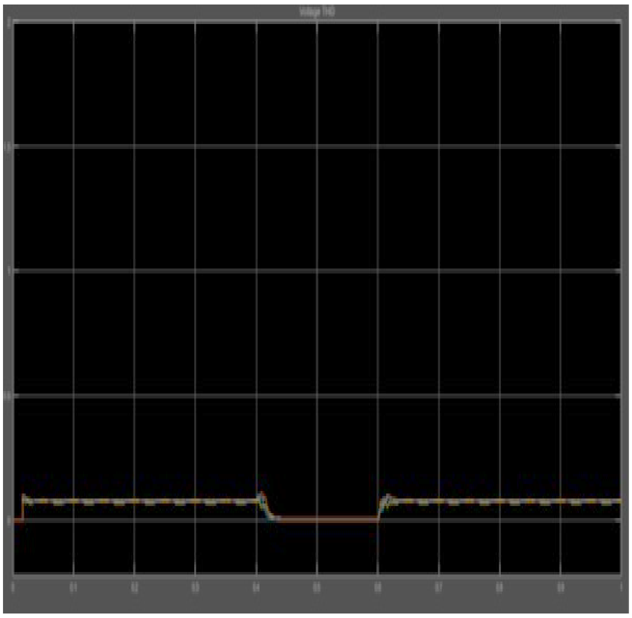

Figure 12: Impact of THD on voltage in three-phase faults with D-STATCOM

The impact of the total harmonic distortion (THD) on voltage and current is analyzed for the model in which D-STATCOM is implemented. The waveforms obtained for the THD in terms of voltage &current are shown in Figures12 and 13.

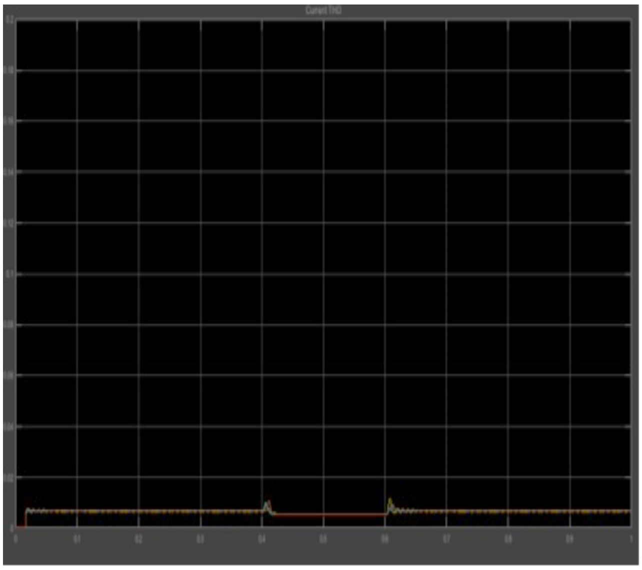

Figure 13: Impact of THD on current in three-phase faults with D-STATCOM

Figure 12 and 13,illustrate the waveform of voltage& current in the power system with 3phase faults with the implementation of D-STATCOM. From the two figures, it has been determined that THD occurred in voltage is very least.

IX. CONCLUSION

To conclude, it is possible to demonstrate and confirm that the D-STATCOM device is capable of resolving the voltage sags issue.While the plan cannot fully adjust for voltage drop, it is still permissible since the output voltage after compensation is still within the nominal value's allowed range. To compare IEEE 9 bus system for power analysis using D-STATCOM device with respect to without DSTATCOM device to enhance system performance.Also, the effect of total harmonic distortion (THD) on the current waveform is negligible using D-STATCOM and the voltage at load points enhanced. This is because D-STATCOM can easily absorb or supply reactive power, which reduces voltage sags. In this paper, the distribution system is the only location where the issue exists, and D-STATCOM is more effective because it just deals with the distribution system. Meanwhile the “Distribution Static Compensator”, deals with an IGBT-powered power electronic device, harmonic distortion will definitely result. The use of an LC passive filter helps eliminate the harmonics.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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