

FUZZY LOGIC CONTROLLER BASED D-STATCOM FOR VOLTAGE SAG MITIGATION

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Abstract: The transmission system has poor reliability and more power fluctuations due to insufficient reactive power support into the network. Distributed Static Compensator (DSTATCOM) is highly efficient component for this issue which improves power quality and dynamic performance of the system. The main power quality issue is voltage sag because of which there are considerably much economic and component losses. This paper presents fuzzy logic-based controller which mitigates voltage sag and total harmonic distortion (THD) into the system. This programmable fuzzy logic controller can be used both into linear and non-linear loads efficiently. The performance of the fuzzy logic controller used with the DSTATCOM is been analyzed at the transmission side by using 3- Φ . The issues resolved are been studied are done and control strategies are been tested by using MATLAB/Simulink.

Keywords: Distribution Static Compensator (DSTATCOM), Fuzzy Logic Control, Total harmonic distortion (THD), Voltage sag.

1. INTRODUCTION

In the present century the power electronics-based equipment has been utilized in industrial and domestic process. Because of the growth of technologies, reliability, stability and power quality of power transmission is fundamental. To satisfy the developing power demands, present day power system has become a complex network. These power electronic components have maintained the power quality issues into the network. A good power system should have a dependability and reliability for uninterrupted transmission of power with a constant voltage without any harmonics into the network. Power system usually has many power qualities issues which generally affects the industries and also customers. The present century has affected the automation of various industries which includes personal computers and power electronics components for example, customizable speed drives.

1.1 D-STATCOM

The most important power quality issue is voltage sag because of its frequency of occurrence is high into the power system. It emerges as a tough challenge to eliminate this power quality issue. Due to faults in connecting heavy loads like start-up motors and consumer installations voltage sag happens every time. The importance of this presented work would show the voltage fluctuations which results in voltage sag that damage consumer's appliances and equipment and also mitigate the voltage sag by the use of custom power device such as D-STATCOM. We use D-STATCOM because it is of its quick action to the fluctuations and also small in size. Voltage sag mainly has been caused due to short circuit faults onto the utility system.

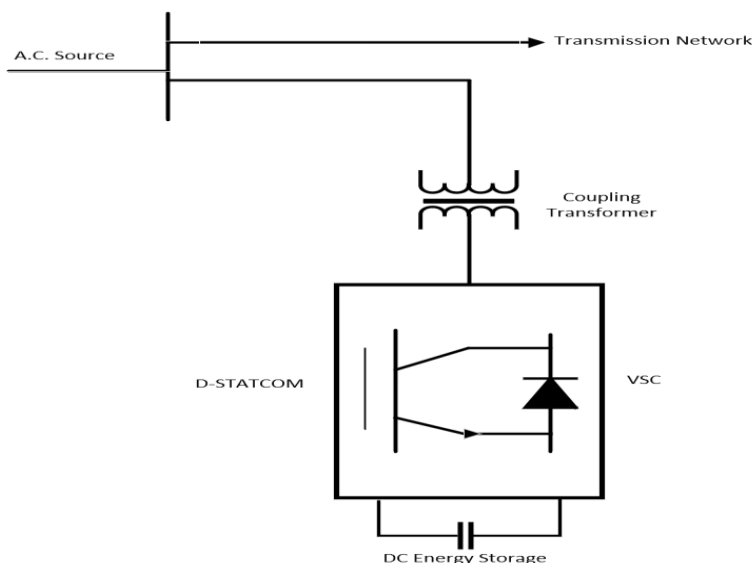


Fig. 1.1 Basic Configuration of D-STATCOM

A coupling transformer, mainly VSC and a DC energy storage device are been connected in shunt with AC system in the D-STATCOM. The configuration of D-STATCOM been shown in fig. 1.13. For efficient controls of reactive and active power exchanges between AC system and D-STATCOM a proper adjustment is needed of phase and magnitude of D-STATCOM output voltage. By the use of indirect controlled converter, a continuous voltage regulation is provided into D-STATCOM.

Reactive power importance in the power system:

- The amount of reactive power would result into collapse of voltage.
- As transformer, transmission lines, motors and energy storage devices on the power grid (especially inductors and capacitors) require reactive power.
- For the production of magnetic fields electric motor would require reactive power for its operations.
- Grid balance should be protected to prevent voltage issues.

The need for reactive power:

- Requirement of reactive power is felt for various electro-mechanical systems and loads.
- Voltage sags happens when there is no reactive power into the system.
- For measurement of active power of the network reactive power is much needed.

Limitations of reactive power:

- The ability for the delivery of real power is closely related to the reactive power source.
- It would be profitable when the production of reactive power is close where it is much needed.
- Reactive power is delivered efficiently when the area of need is in better position. Closest to the area would be delivered more reactive power as compared to the area of long distance.

For the compensation of the reactive power the shunt compensator is consequently very much utilized. A synchronous 3- Φ optional voltage been generated through the D-STATCOM which is a static synchronous generator which has the principle voltage at immediate voltage source. The voltage amplitude of D-STATCOM would be controlled for the development of the reactive power to impact to line voltage V_t and the injection of reactive voltage relies upon the terminal voltage of the transmission network and the output terminal of the convertor (VSI). Between compensator and utility grid for the exchange of reactive power there can be three potential methods. The DC energy storage device changes the DC into three phase voltages and when these DC sources is changed over with active power source for example fuel cells, battery, supercapacitor etc. As D-STATCOM is skilled for trading both real and reactive power.

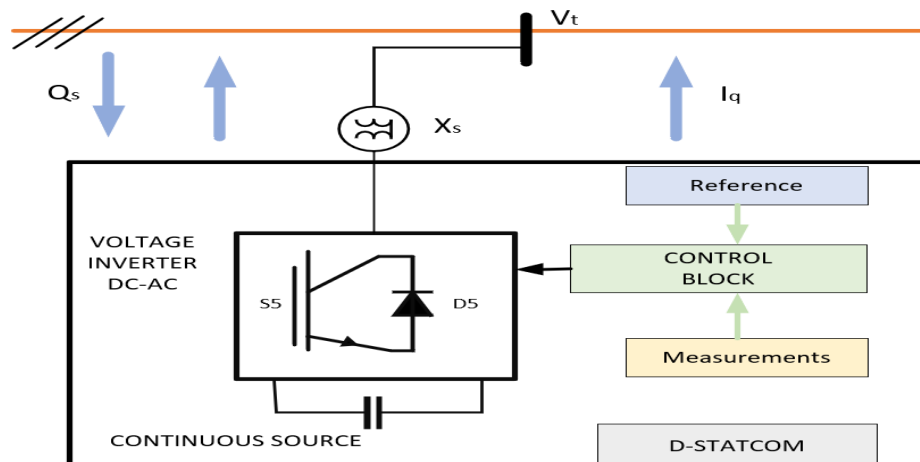


Fig. 1.2 Operation of D-STATCOM

1.1.1 Voltage Source Inverter (VSI)

It can be seen that stimulation of the (Voltage source inverter) VSI through dc voltages supplied of lower impedances at input. Here the load current would be freed from the output voltage. For high and low power applications VSIs are been mainly utilized. For example, ac-dc converters, traction, motor drives and UPS. Due to the capacitor in the VSI the estimation of output voltage variations is moderately low yet it's hard to limit the current due to capacitor.

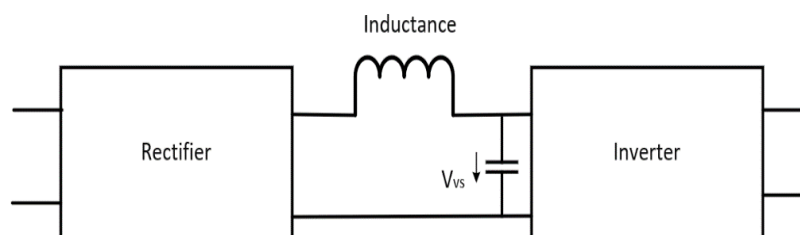


Fig. 1.3 Circuit Configuration of VSI

Power Electronic device inverter consisting of switching devices like: Integrated Gate Commutated Thyristor (IGCT), Metal Oxide Semiconductor Field Effect Transistor (MOSFET), Gate Turn-off-Thyristor (GTO) and Insulated Gate Bipolar Transistor (IGBT) this would create a voltage which is sinusoidal in nature at necessary phase angle, magnitude and frequency. The fundamental work of the inverter would be a change over the DC voltage which is been provided through energy storing devices into the ac voltages. In the D-STATCOM step up voltage infusion transformer is utilized. The most common VSI types are Single-phase and Three-phase bridge inverters as shown in Fig. 1.4.

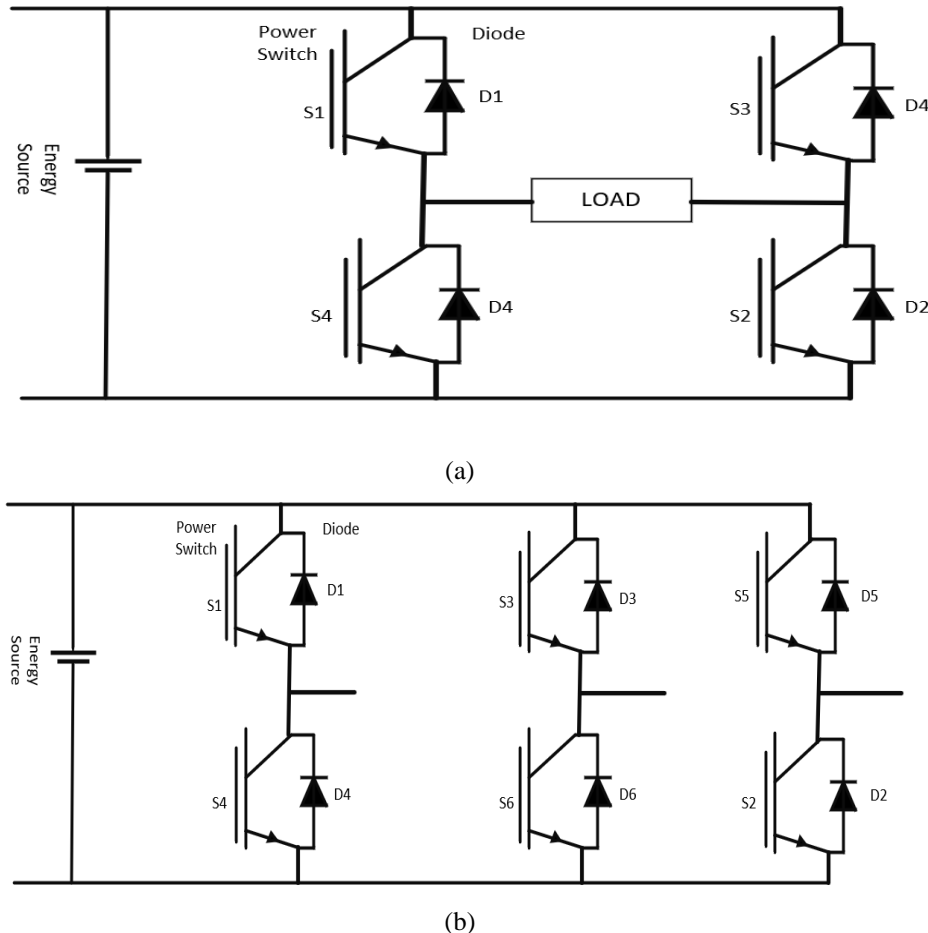


Fig. 1.4 (a), (b) Single Phase and Three Phase Inverter Respectively

2. SYSTEM MODELLING AND SIMULATION

The PWM method under system disturbances, to keep the voltage magnitude being constant at the point when sensitive loads are associated then this type of control system is being introduced. The RMS voltage been estimated into the control system at the load points. This VSC switching system method provides a great response and effortlessness which depends on the sinusoidal PWM procedure. The amplitude modulation index (M) could be defined as

$$M = \frac{A_c}{A_r}$$

Here, A_r = rectangular reference signal of amplitude

A_c = triangular carrier wave

M = amplitude modulation index

The main advantage of this process is the addition of the basic element, improved harmonics features and reduced number of switching losses. Here modulation index (M) would be controlled by the rms output voltage (V_o) and also the peak amplitude (A_r) is been controlled by M .

$$M = \frac{f_c}{f_o}$$

$$V_o = V_s(S_1 - S_4) \quad (\text{Instantaneous output voltage})$$

2.1 Fuzzy Logic Controller (FLC)

To overcome the losses brought by the traditional PI controller, and to improve the transient conduct and consistent response, a hybrid system consisting of Fuzzy Logic Controller based D-STATCOM is designed. To overcome the complex nature of the system, fuzzy based design is beneficial. The fuzzy based design manages the way which profoundly deals to lower the computation and ways to support and addition of artificial intelligence which manages human like problem solving behavior. It can be visualized that basic PI controllers

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are more prone to changes in the energy storage system boundaries and which makes the whole system more complicated. In presented technique, for calculation purpose Mamdani based fuzzy logic controller is been taken. Architecture of Fuzzy Logic contains generally four parts”.

Rule Base: For the decision-making system the rule base gives if-then standards as well as logics given to the consumer, for better linguistic data manipulation. For the tuning and development of the fuzzy controllers there are many efficient strategies present in the modern world. Some of these advance methods weakens the fuzzy rules.

2.1.1 Fuzzification

The crisp numbers in the fuzzy sets are been transformed from the incoming inputs. These inputs crisp in nature are the main input for the system and with the use of sensors controls the system for any function, for example to control the rpm, pressure, frequency and temperature of the machine.

Inference Engine: This sets out the priority or sequences of the certain rules for the fuzzy inputs to act on accordingly. Therefore, here controlling actions are been configured for the gathered acting principles.

2.1.2 Defuzzification

There are various defuzzification methods for the utilization into the system and the best fit technique with minimal error is taken into consideration. Here after the fuzzy input sets are followed through inference the sets get the fresh estimation of the fuzzy.

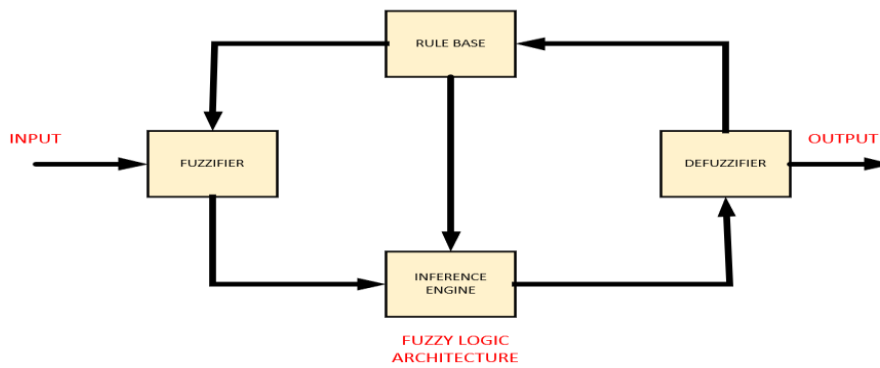


Fig. 2.1 Fuzzy Logic Architecture

The inverter controlling is been done by the rule base designed into the FLC. The change in error (ΔE) and error (E) are been related to the seven membership functions combined with the linguistic variables which are been put together from the sum of 49 rules in the FLC. The membership levels are in the scope of 0 to 1 for the linguistic variables. For the controlling of PWM generator the FLC crisp output is being used. By the use of this method the reaction of the system is improves and also the calculation time. The table below shows all the 49 rules arranged for the system which are based on ΔE and E.

Table 6.1 Rule base for fuzzy logic controller

ΔE \ E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PMPB	PB	PB	PB	PB

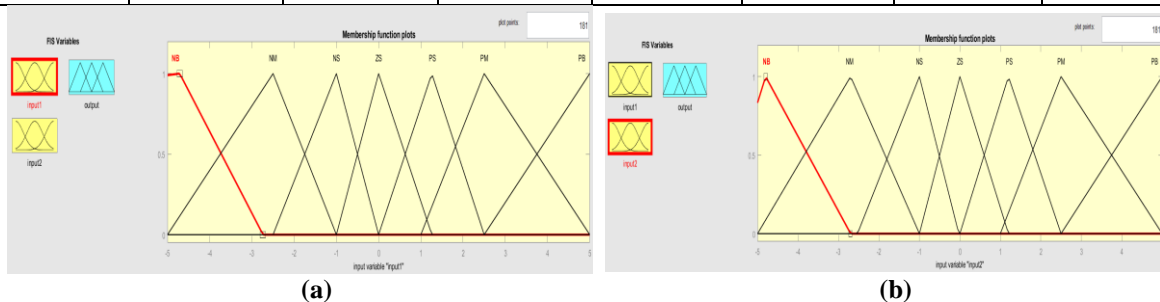


Fig. 2.2 (a), (b) Change in Error (ΔE) and Error (E) FIS Editor Respectively

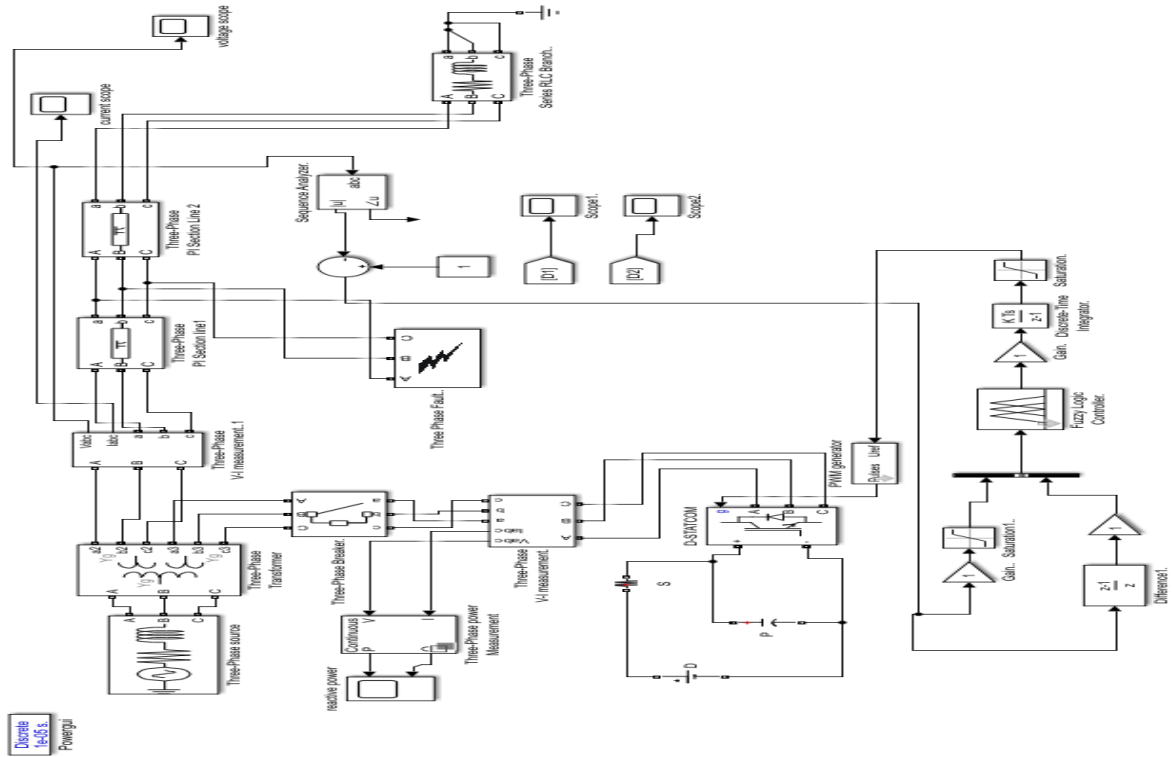


Fig. 2.3 Simulink Model of D-STATCOM

3. SIMULATION RESULTS

For voltage sag 3- Φ fault is created at point A. Since the duration of the sag relies upon the fault resistance hence, faults of various resistance are made. This case comprises of line voltage waveform and line current waveform, line voltage magnitude and Total Harmonic Distortion (THD) of the line voltage. The system's load parameters are considered as $R= 0.33 \Omega$ and $L = 0.52 \text{ H}$. D-STATCOM of 21kV energy device is considered examined as under:

A 3- Φ fault is made at point A via a transition time of 0.2s to 0.3s for the resistance of 0.70Ω D-STATCOM is not been connected to the system, which would cause voltage sag 34%. After D-STATCOM is connected, voltage sag improves to 4.6%. THD spectrum of the load voltage improves from 42.42% to 2.06%.

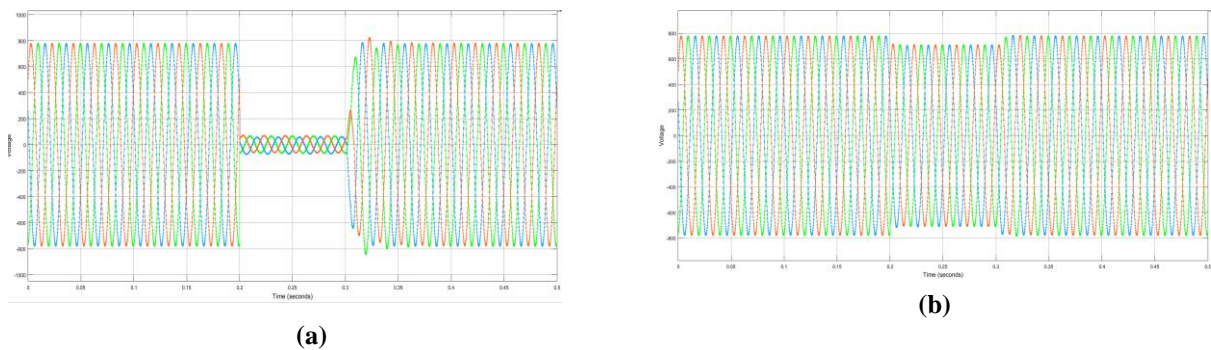


Fig. 3.1 (a) (b) 3- Φ line Voltage without and with D-STATCOM Respectively

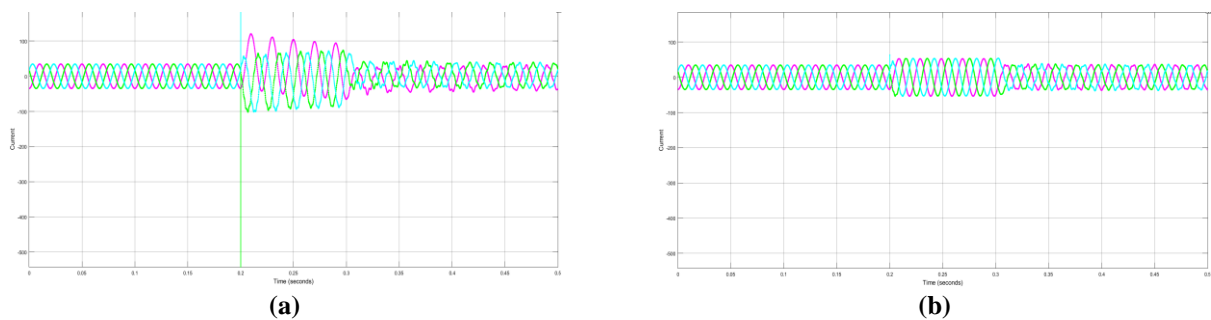


Fig. 3.2 (a), (b) 3- Φ Line Current without and with D-STATCOM Respectively

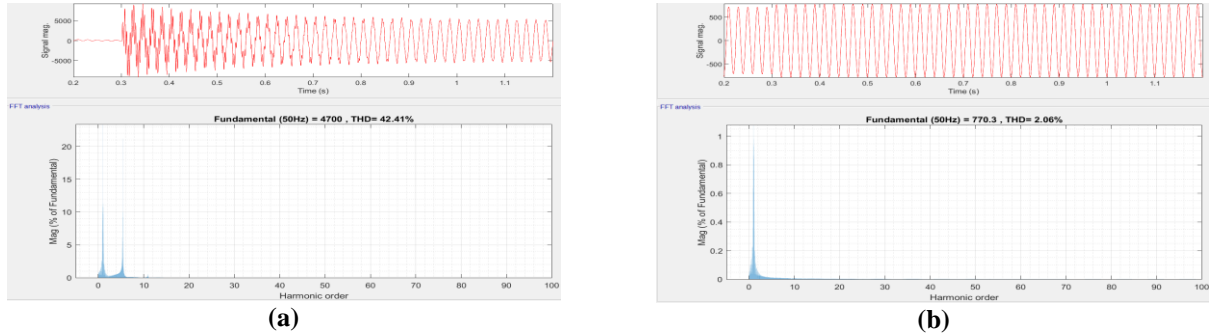


Fig. 3.3 (a), (b) THD of Load Voltage without and with D-STATCOM Respectively

CONCLUSION

The results from analysis of the above three phase to ground fault condition validate that the D-STATCOM successfully mitigate the voltage sag considerably. For long duration voltage sag is suited to compensate about 25.6% to 4.5% sag and 22% to 2.78% with a decent efficiency. Thus, the proposed DSTATCOM design finds its utility in distribution system particularly. From analyzing the 3- Φ faults in the transmission system it would be concluded that D-STATCOM is an excellent custom power device for the mitigation of voltage sags and total harmonic distortion into the interrupted system. By the use of this model there are excellent performance on the load side components, improved reliability and stability and good voltage profile. From this proposed work the ultimate aim is to preserve the power system for the economic losses for industries and consumers and also to rectify all the power quality problems present in the power network. Here we have fulfilled the mitigation of voltage sag into the network.

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