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An Optimised Fopid Controller With Dstatcom To Mitigate Power Quality Issues In A Power Grid Connected With Solar Wind Energy Sources

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Abstract— In recent years, the development of renewable energy sources (RESs) and their integration with the conventional power system network have increased significantly. Due to the power grid transformation brought about by the large penetration of RESs such as wind and solar photovoltaic (PV), the operation and control of the interconnected power system has become a challenging task with respect to power quality issues. Power systems connected with renewable energy sources are confronted by power quality issues. In this respect, distribution static synchronous shunt compensator (DSTATCOM) a shunt connected flexible AC transmission system (FACTS), is recognized as a fundamental solution for improving the power quality issues. This paper presents a thorough and state-of-the-art investigation of DSTATCOM with Rock Hyrax Swarm Optimization in fractional order proportional integral derivative (FOPID) controller in wind- and PV-interfaced power systems for enhancing system performance by addressing key power quality issues related to harmonics, voltage regulation, and reactive power compensation. An analysis of FOPID controller is used in DSTATCOM is investigated.
Keywords—Renewable Energy, DSTATCOM, RHSO,Power Grid Integration, Power Quality, UPQC

1 INTRODUCTION

Researchers have turned to renewable power generation from conventional power generation in recent decades. The reason is straightforward that renewable energy generation provide cleaner, smarter power near to the customer's location. Although renewable energy generation-based power currently accounts for a small portion of total power generation, its reliability will improve in the future. Furthermore, generating power at the point of use decreases costs, complexity, and interdependence while greatly improving reliability[1]. Different types of renewable energy sources are integrated to power grid which improves power supply reliability. Power networks powered by non-conventional energy sources are being extensively researched due to their low environmental effect and non-polluting nature. It is critical for a stand-alone to have its own resources for maintaining power quality, namely voltage and frequency values. The voltage changes of the system are determined by the system's reactive power, whereas the frequency is determined by the system's active power. Voltage regulation is accomplished using FACTS-based power electronics converters[2]. Controlling an interconnected hybrid power system is usually a challenging and time-consuming process. Controlling the output power of generating units and achieving power balance is one of the most important control tasks in power systems. Controlling the output power of generating units while establishing the active and reactive power balance ensures that transient variations of system parameters remain within the established limits and the system achieves stability. Wind-powered hybrid systems are extensively employed in rural regions due to their reliability. Induction generators are used in the majority of wind turbines, particularly squirrel cage induction generators for constant speed and double fed induction generators (DFIG) for variable speed and durability. However, disturbances in input wind and load produce mismatches in the generation and consumption of both active and reactive power in the system, influencing the system voltage and frequency directly or indirectly. The variation of reactive power disturbs the system voltage, making it necessary to correct for and regulate reactive power in the hybrid system. The rotor current regulates the active and reactive power of the DFIG, which is controlled by the output voltage of the rotor side converter. DFIG is extensively employed in wind turbines due to its ability to provide electricity at constant voltage and frequency while rotor speed fluctuates. Back-to-back converters are used in the rotor circuit of a DFIG-based Wind Energy Conversion System (WECS) to guarantee decoupled management of stator side active and reactive power[3]. In a hybrid system, the synchronous generator regulates the reactive power need. Because of the unpredictability of wind and the wide range of load, FACTS devices such as SVC, DSTATCOM, UPFC, and SSSC are frequently used for reactive power management and correction.

In the literature, control schemes for reactive power compensation and stability analysis using classical PI, PID controllers, and other optimisation approaches have been developed. For power systems, PID controllers are always more dampening than PI controls. It has received a lot of attention in the literature for reactive power regulation and power quality analysis. Furthermore, in many publications, the design of PID controllers has been done utilizing particle swarm optimization algorithms, Artificial Bee Colony (ABC) algorithms, and so on. Several unique heuristic stochastic search approaches for optimizing PID gains are also given in the literature. A new decentralized resilient optimum MISO PID controller based on matrix Eigen values and the Lyapunov approach was also described by certain researchers in journals. The system parameters and stability are sometimes adversely affected due to the heuristic nature of PI and PID controllers in selecting gains[4]. FOPID controllers, where the order of derivative and integral is not integer, have recently significantly enhanced the performance of traditional PID. FOPID controllers have been used in a variety of engineering applications. Creating aircraft control systems, hypersonic flying vehicles, fractional order time delay systems, weapons systems, and automated voltage regulator systems are just a few examples.The FOPID controller has two extra tuning knobs (parameters) known as k (non-integer order of integrator) and l (non-integer order of differentiator), which provides for more flexibility in system dynamics modification. Many parameters make up the FOPID controller, including proportional gain, integral gain, differential gain, integral order, and differential order[5].

Several methods for upgrading FOPID controllers are widely available in the literature. This research proposes a FOPID controller based on an Imperialist competitive algorithm (ICA) for reactive power adjustment and power quality evaluation in a solar wind microgrid. This Imperialist competitive algorithm (ICA) is a one-of-a-kind evolutionary strategy that is often used to tackle a variety of optimization problems. It is a recently created innovative socio politically motivated optimization algorithm that is inspired by the sociopolitical process of Imperialism. ICA is utilized to solve issues in various applications due to its enhanced efficiency and high convergence[6].

Growing electrical energy demand, as well as the depletion of traditional resources (such as coal, natural gas, and oil), have given new dimensions to renewable energy research and use in urban and rural regions. Renewable energy can now be converted into electrical energy thanks to advancements in power electronics. Traditional energy sources are becoming more costly by the day, and to prevent such excessive energy consumption, renewable-based power grids can be a viable option, since renewable energy has become more affordable owing to cost decreases[7]. Furthermore, renewable energy generation offers a number of advantages, including the capacity to provide electrical energy to rising load demand, economic potential for clean energy, and improved penetration of renewable energy sources into the present power system. Solar and wind energy are viable options since they are in advanced stages of development, and governments are encouraging them through various programs. However, it has been observed that renewable energy sources connected to the power grid, such as solar and wind energy sources, cause power quality concerns such as voltage control, harmonics, imbalanced voltage sag and swells, transients, and voltage interruptions[8]. Several research articles have been published in recent years to address these power quality concerns. It has been observed that the short circuit ratio (SCR in electrical grid is defined as the ration of the short circuit apparent power, and a power grid with SCR between 2-3 is considered a weak grid, and a weak grid can induce power quality issues) of renewable energy sources is lower than that of conventional power plants.Because solar and wind power plants have less SCR, they are less reliable and cause greater power quality issues when integrated with the existing power grid system[9].

Devices like FACTS (Flexible AC Transmission System) have been found to play a crucial role in reducing power quality challenges in renewable energy sources connected to the electrical grid. The Unified Power

Quality Conditioner (UPQC) is one such FACTS device that can effectively address power quality issues in grid-connected renewable energy sources[10]. The UPQC serves as a power conditioner, enhancing power quality on both the power system network's source and load sides. It consists of series and shunt active power filters, which are connected back-to-back on the DC side and share a common DC capacitor. The series component of the UPQC, known as the Dynamic Voltage Restorer (DVR), is responsible for mitigating voltage disturbances originating from the power supply side. On the other hand, the shunt component of the UPQC, known as the Distribution Static Synchronous Compensator (DSTATCOM), works towards addressing current quality issues caused by the load side of a renewable energy source connected to the grid. Figure 1 illustrates the general configuration of the UPQC[11].

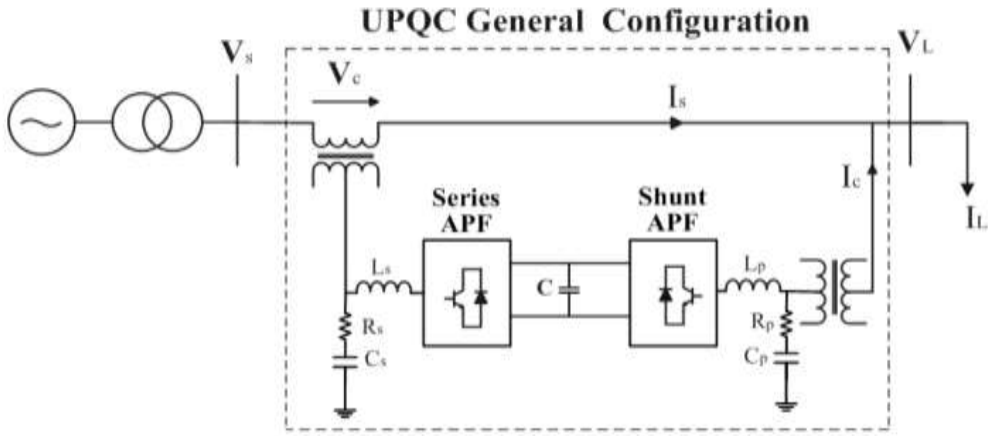

Fig 1: General Configuration of UPQC

A common DC bus connects the UPQC's two IGBT-based VSCs (Voltage source converters), one shunt and one series. The major components of UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers. The main parts of the UPQC system are as follow:

1) Two inverters, one connected across the load and serving as a shunt APF, i.e., DSTATCOM, and the other connected in series with the line and serving as a series APF, i.e., DVR.
2) The network is connected to the shunt inverter via the shunt coupling inductor L. It helps to smooth out the roughness of the current wave form.
3) A common dc link that can be made using an inductor or a capacitor.
4) An LC filter that acts as a passive low-pass filter to minimize the inverter output voltage's high-frequency switching ripples.
5) The series inverter is linked to the network via a series injection transformer. The voltage and current ratings of a series inverter are frequently decreased by selecting an appropriate turn ratio.
6) The UPQC integrated controller's series and shunt APF supplies the compensating voltage reference Vc and compensating current reference Ic.

2 RELATED WORK

Sachin Devassy and Bhim Singh [12] analysed three-phase single stage solar photovoltaic integrated unified power quality conditioner (PV-UPQC) consisting of a shunt and series-connected voltage compensators connected back-to-back with a common dc-link. Apart from adjusting for load current harmonics, the former compensator extracted electricity from the PV array. For better PV-UPQC performance, an improved synchronous reference frame control based on a moving average filter is used to extract the load active current component. In contrast, the subsequent compensator adjusted for grid-side power quality issues such as grid voltage sags/swells. The compensator injects voltage in-phase/out-of-phase with the point of common coupling (PCC) voltage under sag and swell conditions. The proposed system combined the advantages of sustainable energy generation with enhanced power quality. The system's steady-state and dynamic performance are assessed by simulating it in MATLAB-Simulink under a nonlinear load. The system's performance was proven through experiments on a scaled-down laboratory prototype under a variety of disturbances including PCC voltage sags/swells, load unbalancing, and irradiation fluctuation. It was discovered that PV-UPQC attenuated the harmonics induced by nonlinear load and kept the THD of grid current within the IEEE-519 standard limits.

Shuvam Gupta et al. [13] suggested a revolutionary grid-connected solar PV (Photovoltaic) control system that injected active electricity while also improving the power quality of a three-phase distribution grid.A solar PV array, a VSC (Voltage Source Converter), an RC ripple filter, and interface reactors coupled to the three-phase distribution grid and linear/nonlinear balanced/unbalanced loads composed the system.In addition to harmonics avoidance, reactive compensation, and three-phase load balancing, the proposed VSC control pulls the maximum possible power from the PV array using an MPPT (Maximum Power Point Tracking) algorithm. The VSC is regulated using the least sum of exponentials algorithm in addition to the MPPT method. The system performance is experimentally evaluated for various kinds of loads and solar insolation levels on a laboratory prototype and is determined to be within the limitations specified by IEEE 519 and IEEE 929 standards.

Priyank Shah et al. [14] proposed an adaptive filtering technique-based VS-ILSE control method for a single stage three phase grid-connected SPV system in order to improve distribution network power quality. The VS-ILSE control algorithm provides several advantages, including load balancing, power factor correction, and harmonics suppression at the PCC point. According to IEEE-519 and IEEE-929 standards, the total harmonic distortions (THDs) of grid currents and CCP (Common Coupling Point) voltages are well determined.

Nidhi Mishra and Bhim Singh [15] suggested a solar photovoltaic (PV) array supplied to a cascaded H-bridge seven-level converter system, with the perturb and observe (P&O) control method achieving maximum power point tracking (MPPT). The design is for a 5 kW system, and the system's performance was monitored in steady state and dynamic situations using MATLAB/Simulink.The power factor adjustment was accomplished with varied levels of solar insolation. It has kept the THD of the grid current value under the system's 5% limit. Furthermore, it needed a lower switching frequency for system mitigation.

Bhim Singh et al. [16] studied a three-phase wind-solar Micro-Grid (MG) for use in distant and remote places where renewable energy sources like as wind, solar, hydro, and others are abundant. Using a boost converter, the MG turns solar energy into electricity to power loads and charge batteries. The incremental conductance (INC) technique is used to obtain the MPPT. The wind power was converted into alternating current (AC) electrical power by the permanent magnet synchronous generator (PMSG) and used to power the loads. The MG's performance was shown using the NSLMF control scheme to provide power quality solutions such as harmonic suppression, reactive power compensation, load balancing, and voltage regulation. Furthermore, the suggested MG is capable of balancing generation, demand, and storage.

Priyank Shah et al. [17] proposed a hybrid energy storage system (HESS) with a battery and a super-capacitor based on cascaded multilayer STATCOM. A technique for active and reactive power coordination control was also devised. PSCAD/EMTDC was used to create a simulation platform of STATCOM/HESS and wind farm based on these models. The simulation findings revealed that in the situation of random wind and severe power grid disturbances, the problems of wind power fluctuation and low voltage ride through (LVRT) of wind farms connected to the power grid may be successfully handled.

Attila Lendek et al. [18] have described numerous approaches for putting the PV array together. The literature describes MPPT techniques for freestanding systems, hybrid systems with classical MPPT techniques, and hybrid systems with artificial MPPT techniques. The literature compares the complexity level, applicability, and costs of several MPPT approaches such as ripple correlation technique, forced oscillation technique, linearization-based methodology, and intelligent MPPT technique.

Shuvam Gupta et al. [19] have described a fireworks-enhanced P&O (Perturb and Observe) method for global MPPT technique and partial shading identification in SPV system for various shading conditions.

For multifunctional grid interfaced SPV systems, the LMF (Least Mean Fourth) and Jaya optimization algorithms are mentioned in the literature. LMS-LMF (Least Mean Square-Least Mean Fourth) and leaky LMS (Least Mean Square-Least Mean Fourth) algorithms, among others, are presented for improving power quality in distribution networks with D-STATCOM (Distribution Static Compensator) capabilities. When calculating the amplitude of the basic component of load current in steady state, the LMS-based method faced a sluggish convergence difficulty. The variables that cause power loss in grid-connected solar arrays are discussed in the literature.

3 PROPOSED WORK

When associated with a distribution system, all electronics and electrical equipment experience power quality (PQ) concerns. This causes current distortion and voltage collapse, resulting in subpar equipment performance and power losses. Because of the increasing development in the usage of power electronics devices for utility grids and industries, providers must carefully pick a device. Among all controllers, the distribution compensator is the most effective and powerful instrument for dealing with power quality concerns. A distribution compensator is a power device that is used in a shunt design to solve problems with power quality[20]. It maintains voltage stability by managing reactive power, minimizes flicker noise, and performs compensation. The DSTATCOM has two modes of operation: voltage and current. The impact of compensation is determined by the control algorithm used for voltage source inverter (VSI) switching. The performance of the DSTATCOM is determined by the control algorithms that are often employed to create source current. This study provides an overview of contemporary control strategies for DSTATCOM that are available in the literature.

The DSTATCOM is mostly used to compensate for PQ issues. This covers voltage and current quality, harmonic distortion, and load imbalanced issues such as reactive component, unbalance, and neutral current at the PCC. The DSTATCOM may be configured to operate in two modes: single and dual. Two techniques of operation are used in this article. The single mode compensates for either current or voltage, whereas the dual mode compensates for both current and voltage.

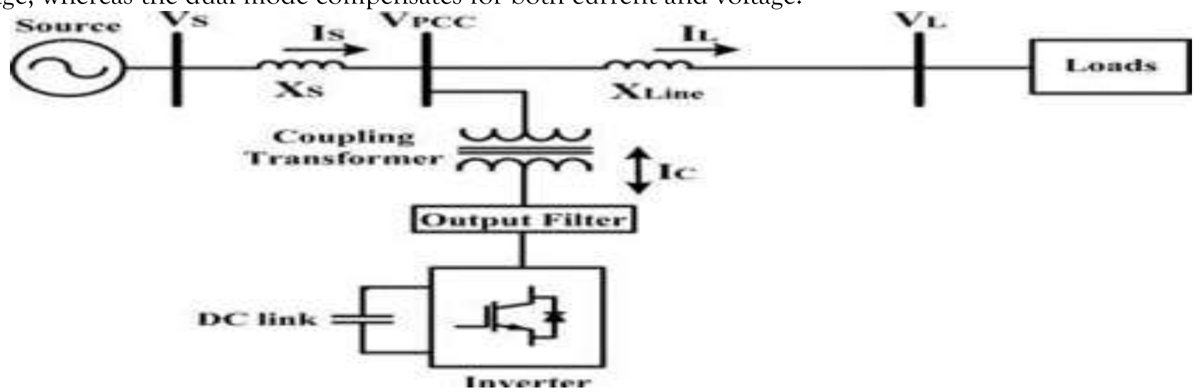

Fig 2 DSTATCOM with power grid

The DSTATCOM is a power device that is in shunt with the power grid. As indicated in Figure 2, its components include VSI, a DC-link device necessary for energy storage, a filter in the output stage, and a coupling transformer. A VSI is used to convert DC voltage stored in energy devices into three-phase AC output voltages[21]. The voltages generated are in phase with each other and linked to the electric grid via a coupling transformer. Control of the active and reactive power flow between the compensator and its grid is provided by employing necessary settings of the magnitude and phase across output of the shunt compensator[22].

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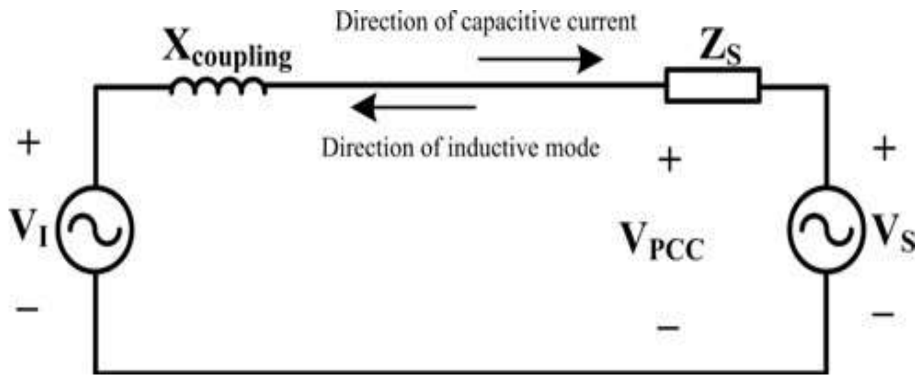

Figure 3 Structure of single phase of shunt compensator

Figure 3 depicts the construction with a single phase shunt compensator. In this case, the variables are: inverter output voltage, coupling impedance voltage drop, voltage of common coupling point (PCC), and source voltage. If =, the Shunt compensator will not interchange any reactive power with its utility grid, and DSTATCOM will not absorb or create reactive power. For >,DSTATCOM operates as if an inductively coupled reactance is attached to its terminal. There is a current flow in the utility grid due to the transformer reactance of DSTATCOM, and the electricity generated is capacitive. If V_1 < V_{PCC}, The DSTATCOM operates in the same way that a capacitive reactance is linked to its terminal. The device absorbs the inductive power in this scenario, and the current flows from the grid to the compensator.

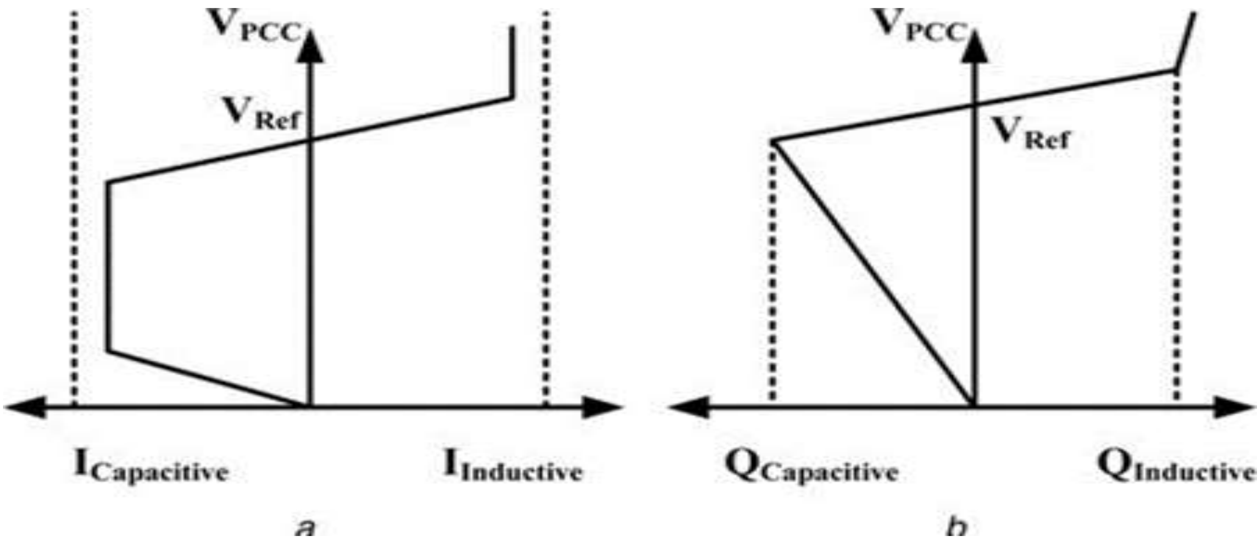

Figure 4 Voltage-current and V-Q characteristics of shunt compensator

Figure 4 depicts the voltage-current and V-Q characteristics of a shunt compensator, exhibiting the exchange of reactive power between the utility grid and the compensator, where Vref is the nominal voltage at the PCC.The phase angle between utility grid voltages and distribution compensator output controls active power flow, resulting in further reduction of losses inside the inverter. It keeps the DC capacitor charged and controls the amount of the DSTATCOM output voltage. Figure 5 depicts the Distribution compensator representation of a vector at the fundamental frequency, demonstrating an inductive to capacitive mode transition and vice versa.

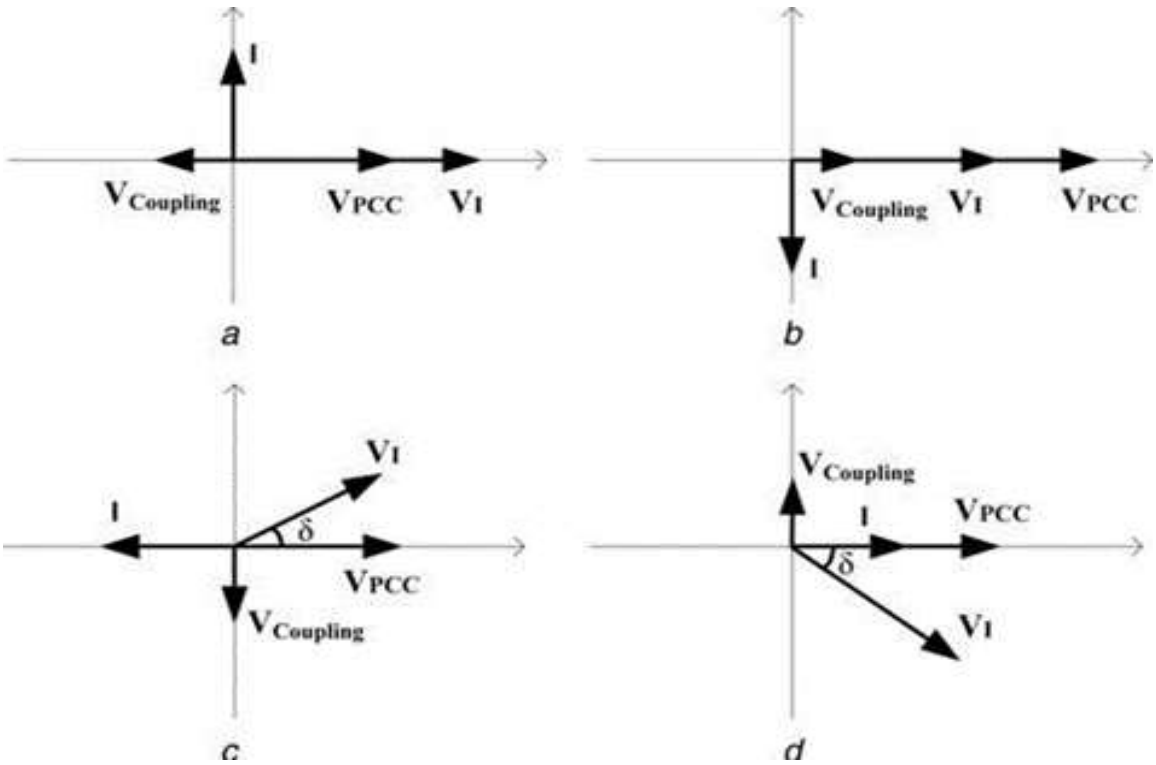

Figure 5: DSTATCOM different modes vector diagrams

(a) Capacitive mode (b) Inductive mode (c) Active powerrelease(d) Active power absorption.

Switching from inductive to capacitive mode is accomplished by altering angle δ= 0 to δ = positive value. The active power from the utility grid is transmitted using a DC capacitor, which also causes a decrease in the DC connection. When angle "" is changed to a negative value from zero, the mode shifts from inductive to capacitive. When active power is transferred from the utility grid to the capacitor, the DC link voltage rises.The active power (P) and reactive power (Q) variation between shunt compensator and its grid can be shown asfollows in (1) and (2).

$$P = \frac{V_{PCC}V_1}{X_{Coupling}} \sin\delta \qquad \text{...................(1)}$$

$$Q = \frac{V_{PCC}^2}{X_{Coupling}} - \frac{V_{PCC}V_1}{X_{Coupling}} \cos\delta \qquad \text{...................(2)}$$

4 SIMULATION AND RESULTS:

To improve the system's performance, Control strategy plays a very important role. Control strategy of DSATCOM may be implemented in three stages:

1)Signals of voltage and current are detected.
2)Compensating directives are developed in terms of voltage and current levels.
3)PWM, hysteresis, or fuzzy logic, proportional-integral-derivative controller (PID)-based control approaches are used to create gating signals for DSTATCOM semiconductor switches.

In second stage derivation of compensating commands are mainly based on two types of domain methods:

(i) Frequency domain methods

(ii)Time domain method.

To extract compensatory directives, frequency domain algorithms based on the Fast Fourier Transform (FFT) of distorted voltage or current signals are used. Because of the huge calculation, time, and latency, this FFT is rarely often used.

DSTATCOM time-domain control systems are based on the immediate derivation of compensating directives in the form of either voltage or current signals. There are mainly two widely used time domain control techniques of DSTATCOM are:

1)The instantaneous active and reactive power or p-q theory,
2)Synchronous reference frame method or d-q theory.

The p-q theory computes instantaneous active and reactive powers, whereas the d-q theory deals with current independent of the supply voltage. To distinguish the fundamental and harmonic values, both approaches transfer voltages and currents from the abc frame to a stationary reference frame (p-q theory) or a synchronously rotating frame (d-q theory).

(I)Different time domain control techniques used are as given below :

1)Instantaneous active & reactive power or 3phase pq theory
2)Synchronous reference frame or 3phase dq theory (SRF)
3)Unit Vector Template Generation (UVTG)
4)One Cycle Control (OCC)
5)Model Predictive Control (MPC)
6)Deadbeat Control
7)Artificial Neural Network (ANN) technique
8)Feed forward & feedback theory
9)Multi Output ADAptive LINear Approach (MO-ADALINE)
10) Proportional-Integral-Derivative controller (PID Control)

A simple controller scheme for DSTATCOM, called as unit vector template generation (UVTG) method uses a phase-locked loop (PLL) to generate unit vector template(s) for single-/three-phase system.

(II)FOPID CONTROLLER: -

The FOPID controller is used in the Distribution Static Synchronous Compensator (DSTATCOM) control structure to generate gating pulses for the converter is efficient to remove power quality issues such as load harmonics, voltage regulation, transients, and to improve load power factor.When compared to the findings mentioned in the linked paper, the method gives a more efficient solution. Because it delivers stability and quick reactions across a wide variety of operating circumstances, a conventional proportional integral derivative (PID) controller is one of the most often used types of controller in industrial applications[23]. Traditional PID controller parameters are simply three: proportional gain constant (KP), integral gain constant (KI), and derivative gain constant (KD). These parameters can be tuned using either traditional or clever ways. Traditional tuning procedures, such as the Ziegler-Nichols, do not produce the greatest results. Intelligent approaches, such as the genetic algorithm (GA), are required to accomplish optimum turning. The GA is based on genetics and natural evolution, and it replicates natural selection's features. The GA elements are equivalent to the chromosome found in deoxyribonucleic acid (DNA). The method searches for the best chromosomes for effectively building the population in the desired solution space. There must be a balance between expanding the search field and finding the optimum option. Each particle in the GA's chosen population corresponds to a solution to the PID parameter optimization. For many years, the classic PID controller has been employed. The majority of the literature focuses on the controlling side of the plant with low error management and less on the peak values of the control signal exiting the PID controller. The derivative kick, which comes from the PID controller's derivative control, is always a balance between overshoot, settling time, and the voltage spike. This voltage spike can be traced to abrupt changes in the setpoint, resulting in an impulse signal from the controller output. The controller's output signal is then sent to control devices such as electric motors, electronics, or control valves, which can be destroyed by such strong voltage spikes.

Several studies have used parallel controller topologies such as the PI-PD, I-PD, and the most recent fractional order proportional integral-derivative (FOPID) controller to alleviate this derivative kick. The PI-PD controller architecture provides strong overall control of the responses of unstable and resonant systems to set point changes[24]. The I-PD is successfully utilized to regulate unstable systems. The I-PD controller, like the PI-PD controller, does not primarily aim to eliminate the derivative or proportional kick. Instead, the removal of the derivative kick is viewed as a consequence of the design. The FOPI-D, on the other hand, disassembles the controller to address the derivative kick by inserting the derivative block into the feedback loop, resulting in a change in the control system's characteristics. The benefits of the fractional order proportional integral derivative (FOPID) over the classic PID controller have attracted attention. The FOPID controller's integral and derivative components employ fractional integral and derivative calculus. This results in five controller parameters for the FOPID controller: Kp, Ki, Kd, and the fractional components: order of fractional integration of and order of fractional derivative of. FOPID controllers improve energy efficiency in controls. Because the fractional operator has memory, it leverages previous states to determine the filtering operation, making plant control more efficient[25]. It also provides more flexible control than a standard PID controller by permitting modifications to the gain and phase parameters using fractional components. The FOPID controller's versatility is important for drives such as permanent magnet direct current motors (PMDC). DC motors are typically employed in applications requiring constant or variable speed drives. DC motors are classified into two types: self-stimulated and externally excited. The DC motor model utilized in this article is an externally stimulated motor whose speed is controlled by armature voltage regulation. For FOPID design, the optimum design using intelligent algorithms is typically used. Aside from the previously stated genetic algorithm, another common technique is particle swarm optimization[26]. The particle swarm optimization (PSO) approach is a population-based academic optimization technique that simulates swarm intelligence, such as that of a school of fish or a flock of birds, and does not rely on the survival of the fittest principle. Each particle in the swarm moves at a constant speed in the search space, and it remembers its optimum position. The best achieved position is compared to the best global position; if it is better than the current global position, the global position is updated with that value, which tends to speed the search for the global value. The PSO and GA optimization design methodologies require an objective function for optimization. The integral of time multiplied absolute error (ITAE), integral of absolute error (IAE), integral of time multiplied squared error (ITSE), and integral of squared error (ISE) are the four single variable objective functions. Among these four objective functions, the ITAE yields less settling and rise times with comparable overshoot . The DC motor speed control is one area of focus in our study. In general, the FOPID controller designed using optimization techniques offers better control performance over the generic PID controller.

The contributions of the paper are listed below:

1. In this research, time-varying fractional order PID controller with DSTATCOM is developed with a purpose to mitigate the power quality issues at the load side of the power grid connected with the renewable energy sources

2. The suggested time-varying derivative FOPID (TVD-FOPID) controller and time varying FOPID (TV-FOPID) controller are optimized using a modified particle swarm optimization technique.

3. The proposed TVD-FOPID controller is validated by evaluating performance indices of different configurations. As a result, the TVD-FOPID controller performs better than the standard FOPID controller. With practically identical performance indices, the TVD-FOPID reduces the control voltage spike by 80%.

(III) Load Harmonic compensation

THD = 0 is for a completely sinusoidal current with no harmonics. Total harmonic distortion (THD) is the number of harmonics on a line in relation to the fundamental frequency of the line, for example, 50Hz. The THD takes into account all of the harmonic frequencies on a line. THD can be correlated with either current or voltage harmonics.Nonlinear loads such as rectifiers, discharge lamps, or saturated electric machines generate harmonic frequencies.When solar wind power plants are connected at the load

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end of the power system network, harmonics are introduced into the system.This is owing to the existence of power electronic switches on the load side of the integrated power system network, which are utilized for AC-DC and DC-AC conversion.Harmonics produces distortions in the sinusoidal waveform and it also produces the heating effect of the equipments at the load end and thus reduces the efficiency of the loading equipments.From the below figure it is clear that the total harmonic distortion(THD) without compensation is 22.25%.

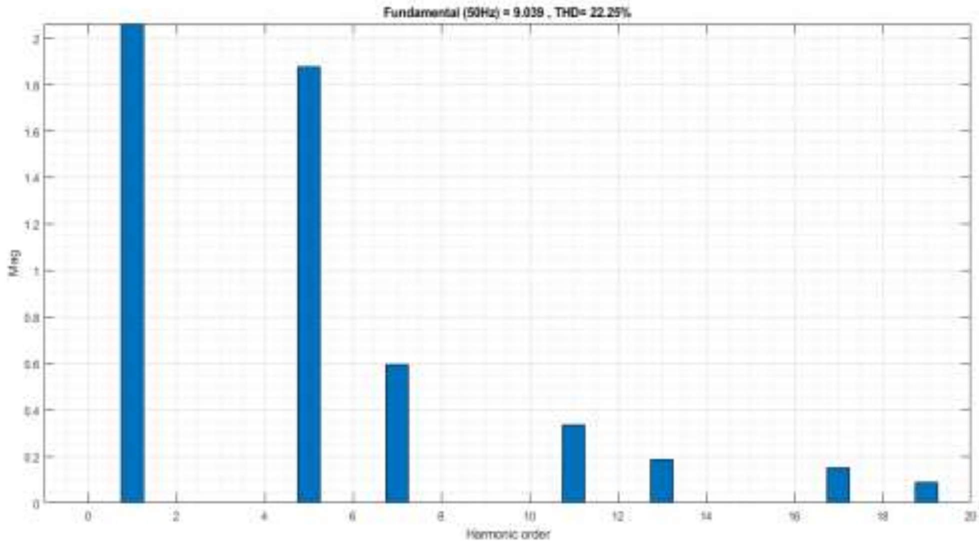

Figure 6 Harmonics without compensation

The UPQC's shunt compensator, DSTATCOM with the efficient FOPID controller, is coupled in shunt with the load side of the power system network to eliminate harmonics at the load side.With the aid of UPQC adjustment, the THD at the load side is decreased to 0.76%, which increases the efficiency of the equipment linked to the load side of the power grid.

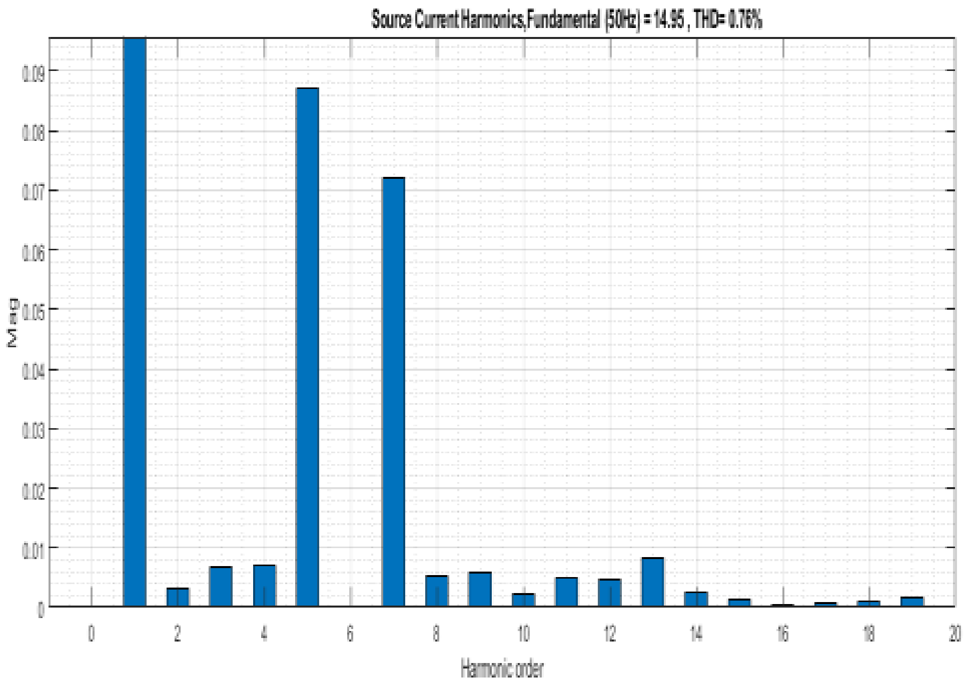

Figure 7 Harmonics with compensation

Figure 7 and 8 shows the three phase load currents with and without load compensations .Figure 7 shows the generation of the load harmonics and figure 8 shows the elimination of load harmonics with the help of the DSTATCOM

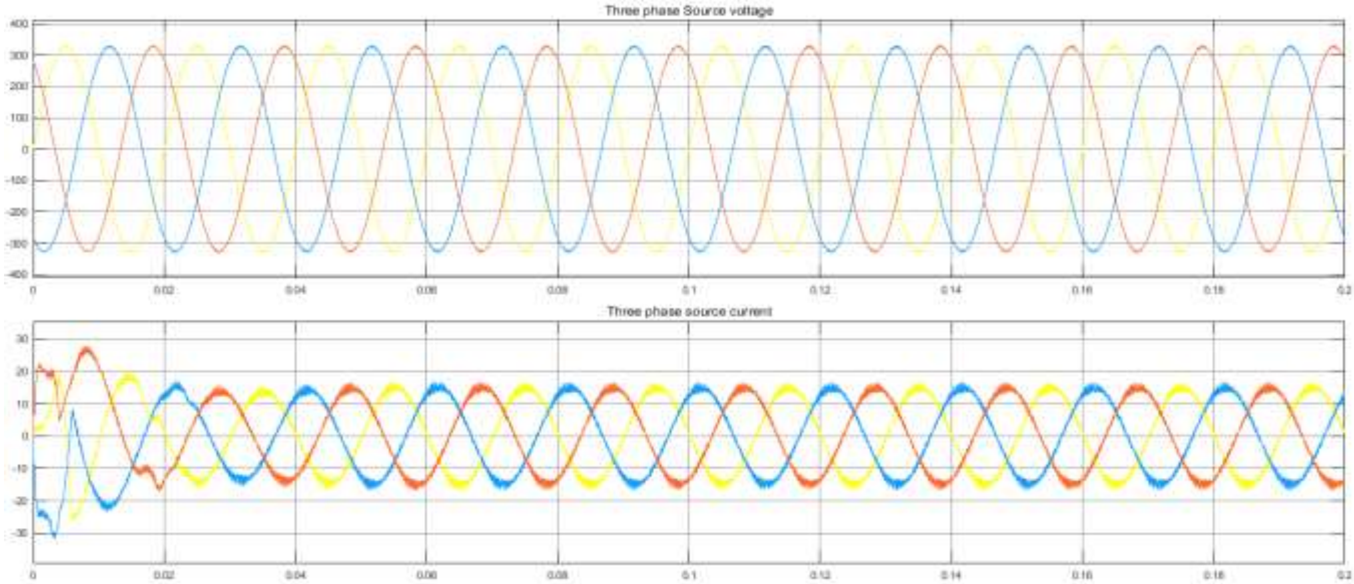

Figure 8 Source voltage and current of the power grid with load compensation

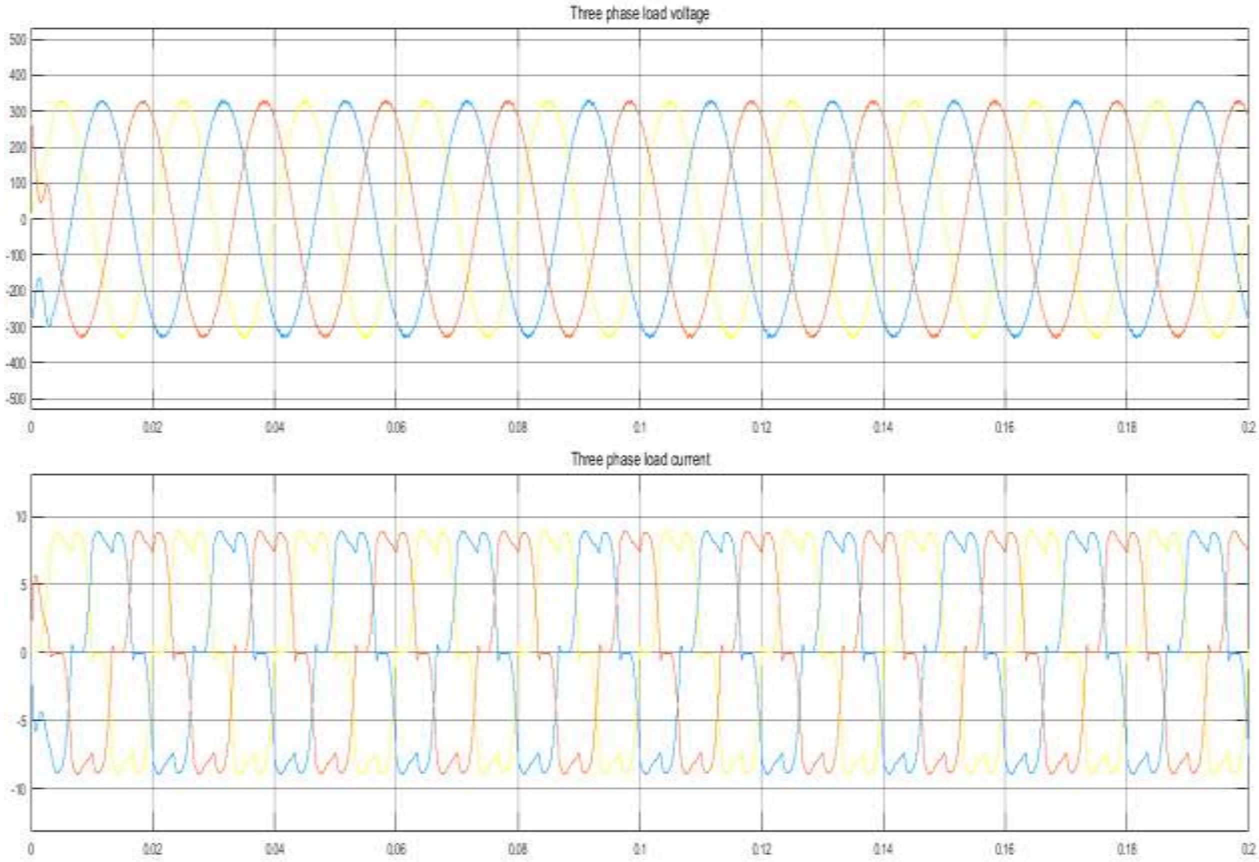

Figure 9 Source voltage and currents without load compensation

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Non-linear loads, such as those that draw current pulses, create current harmonics. Harmonic currents passing across differing system impedances generate voltage harmonics. A voltage drop across the coil of a transformer is caused by the current flowing through it. When current flows in pulses, the voltage follows suit. High voltage distortion is a concern because it acts as a carrier of harmonics to linear loads like motors. Voltage harmonics produce issues (more heat) in the power distribution system and the loads linked to it.

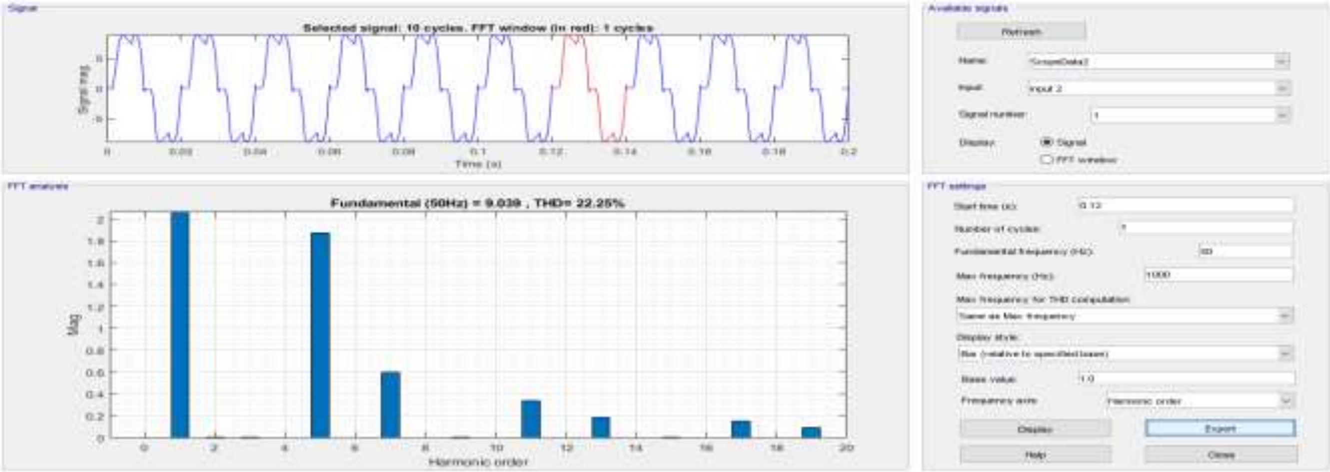

Figure 10 THD without load compensation

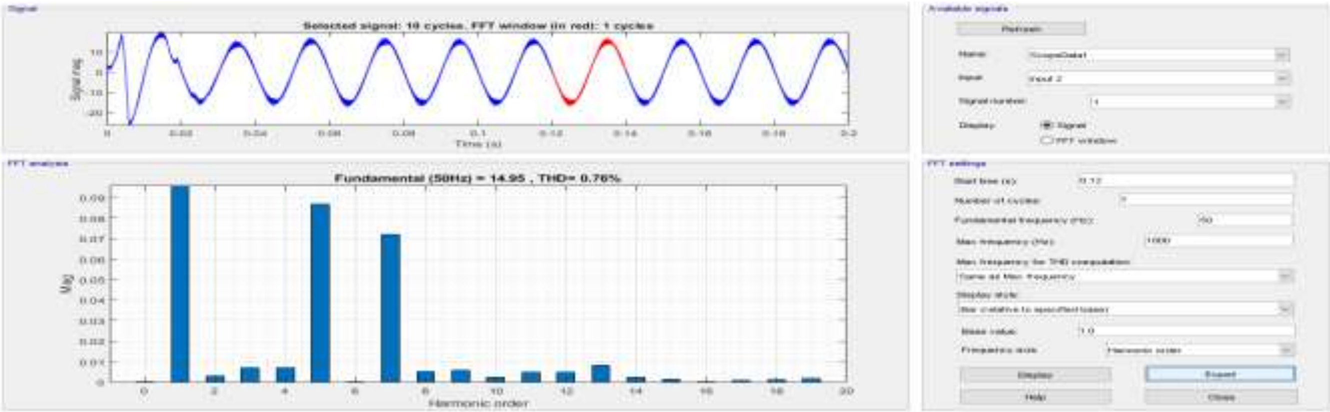

Fig. 11 THD with load compensation

Figure 9 and 10 shows the THD with and without DSTATCOM load compensation at the load side of the microgrid.

(IV)Power factor improvement:*By lowering harmonics on the load side of the power system network, power factor is enhanced.The load power factor is greatly enhanced by regulating the reactive power with DSTATCOM at the load side of the power system network.The fluctuation of three phase voltage and current waveforms shown in the picture clearly illustrates that there is zero phasor displacement between the voltage and current waveforms, which enhances the power factor.*

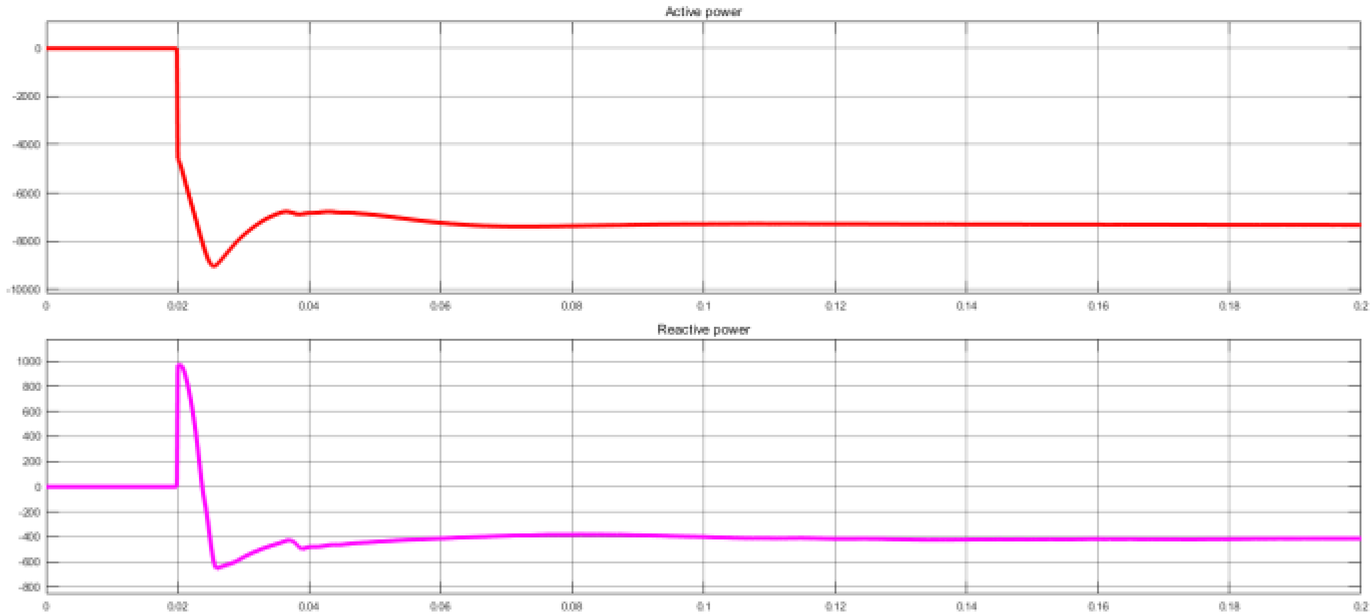

Figure 12 Active and reactive power with compensation

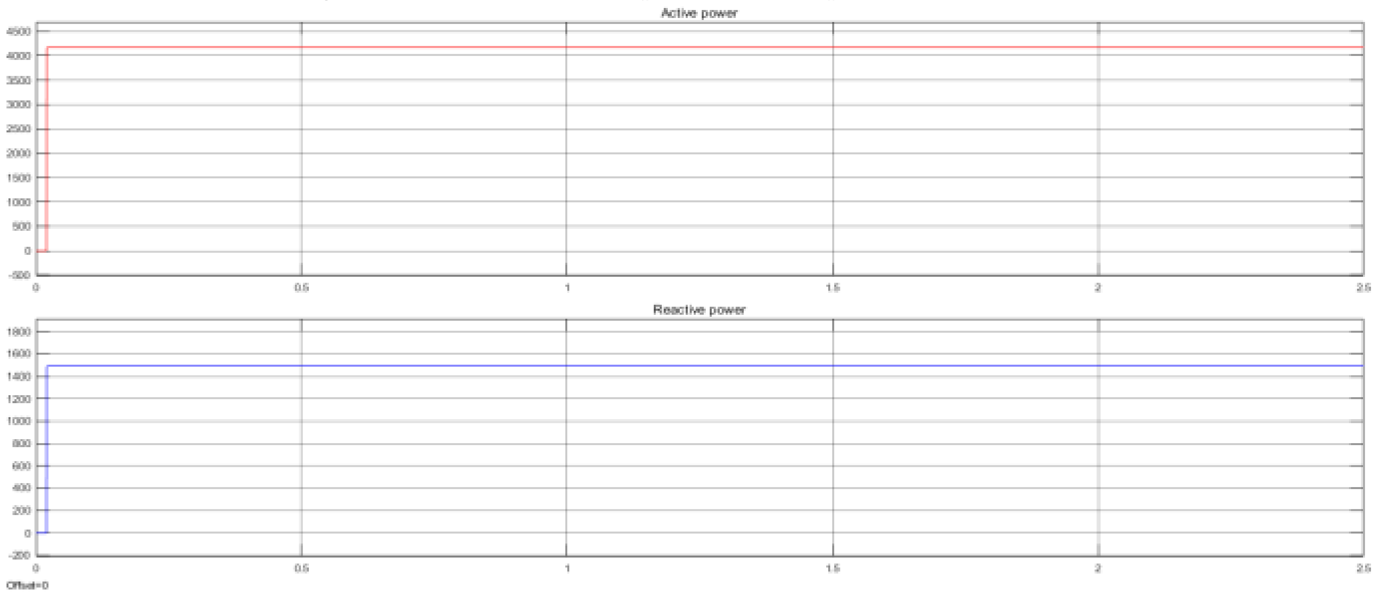

Figure 13 Active and reactive power compensation

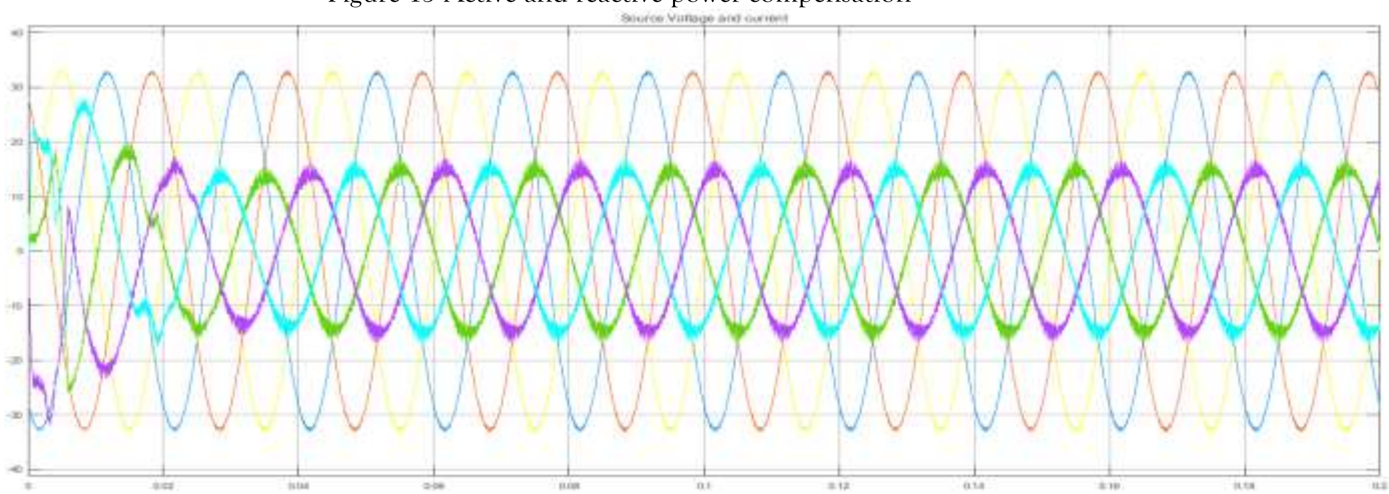

Figure 14 Source voltage and currents with load compensation

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***(V)Zero voltage regulation**:- DSTATCOM efficiently manages reactive power on the power system network's load side.This increases the power factor at the load side of the power system network, which decreases the size of the load current and hence the load side losses.As a result, the voltage regulation power system network improves.Figure 13 depicts the variance of active and reactive power on the power system network's load side.*

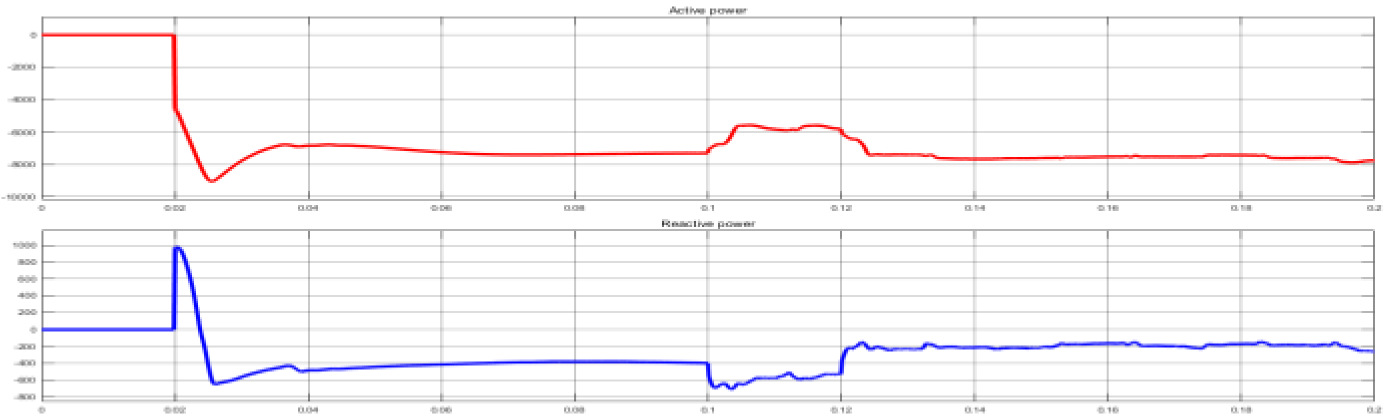

Figure 15 Active and reactive power with load compensation

(VI)COMPENSATION OF LOAD VOLTAGE BALANCING: - Nonlinear loads cause disturbances in voltage waveforms, and the number of harmonics can cause load voltage unbalancing in an integrated power system grid. Unbalanced load voltage lowers efficiency and generates heating in equipment linked to the load side of the power system.Figure 16 shows that there is no load unbalancing up to 1 second.Load unbalancing occurs after 1 second, and the DSTATCOM injects electricity at the load side to balance the grid voltage.

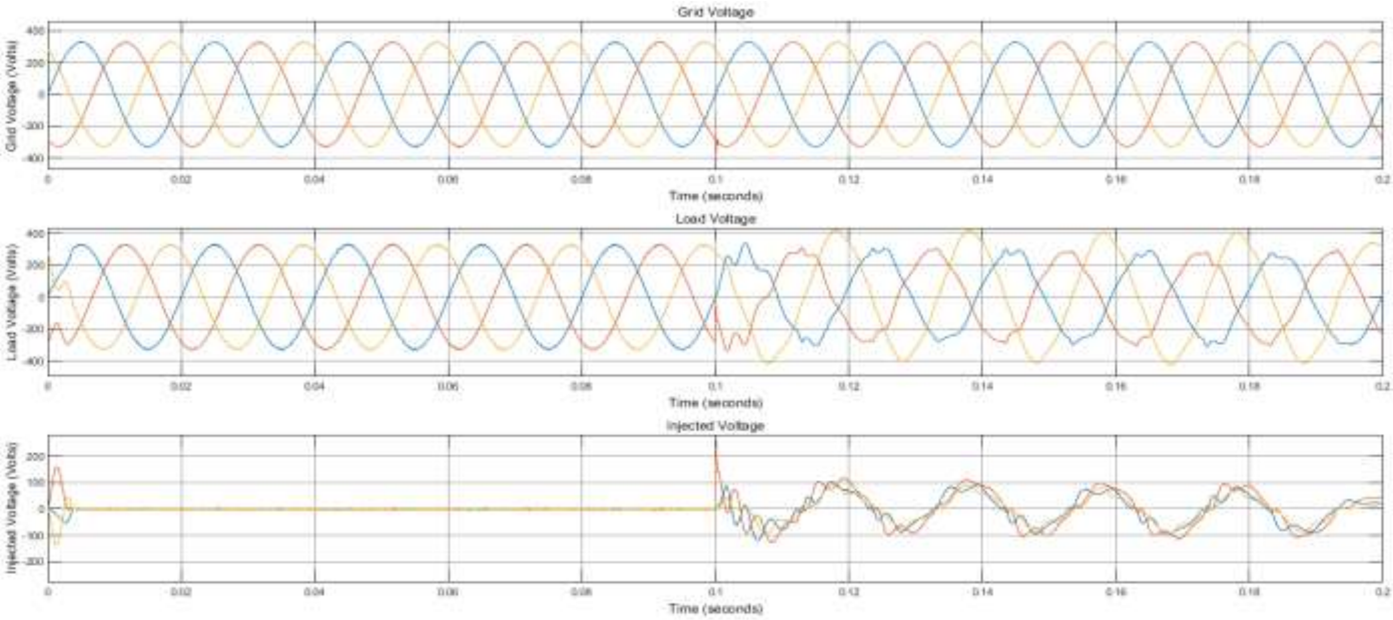

Figure 16 Variation of grid, load and injected voltage

5 Conclusion

Renewable energy technologies are widely used in the power grid because they are environmentally friendly and improve system dependability and stability. Renewable energy resources (RERs) provide a number of challenges in terms of modeling, planning, integration, and control, with renewable energy sources such as solar-wind power plants connected with the power grid. In this study, power quality concerns such as harmonics, unbalanced load voltages, load power factor, and voltage regulation were addressed from the load side of the power grid associated with renewable energy sources such as solar wind power plants. The DSTATCOM with RHSO IN FOPID dealt with these power quality difficulties well. When there is a power quality issue on the load side of the renewable energy power grid, the DSTATCOM injects balanced voltages into the power grid.

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