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DISTRIBUTED GENERATION HYBRID SYSTEM POWER QUALITY BY USING DSTATCOM

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Abstract
The main aim of this project is Distributed Generation hybrid system power quality by using Distributed static synchronous compensator DSTATCOM. In the present days power quality is the major issue in the transmission and distribution systems. Facts devices are best solution for mitigate the power quality problems. In this project harmonics are the main power quality problem because of nonlinear loads, this is mitigated by shunt controller device namely DSTATCOM. In this paper DSTATCOM is functioning in voltage control mode using renewable power sources i.e., photovoltaic (PV) and wind system for dc generation. The combination of pv and wind along with eliminates the need of battery and dc link voltage regulation control. It is observed that DSTATCOM operate successfully providing the sinusoidal source currents in the presence of nonlinear/unbalanced loads. The instantaneous symmetrical component theory (ISCT) is used for the operating the DSTATCOM. This proposed system is simulated by MATLAB/SIMULINK environment.
Key words: Distributed static synchronous compensator (DSTATCOM), photovoltaic (PV), wind system, power quality, nonlinear loads

I. INTRODUCTION

Distributed generation (DG) systems based on renewable energy sources (RES) are currently emerging as an alternative to conventional large and decentralized power plants connected to long-distance transmission / distribution networks [1], [2]. DG RES-based systems can be added to new electric power systems (EPS) to meet rising power demands, reduce power transmission costs , improve system reliability due to increased demand, and reduce harmful environmental impacts from polluting energy sources such as oil, coal , and natural gas.

Because of the low environmental impact and abundance, primary RES, such as solar and wind, have been widely used in the proliferation scenario of DG systems [2], [3]. Special attention should be paid to generating electricity by means of photovoltaic (PV) systems connected to the utility grid, since they can involve small, medium and large-scale generating systems.

When connected to a single or three-phase EPS, PV systems are intended to inject energy from PV arrays [4]–[17] into the grid, which may consist of one or more series or parallel-connected solar panels. Once the PV array generates energy in the form of dc current, an inverter stage is required, i.e., at least one power converter should be used between the PV array and the grid [4]–[11]. By contrast, if the voltage in the PV array's dc bus is not high enough to supply the inverter stage's dc bus, a boost dc – dc converter [12]–[14] has to be used. The PV systems can therefore be classified as single- or double-stage power converter systems. In a single-stage PV system, the dc – ac converter [9] necessarily performs maximum power point tracking (MPPT), [10] whereas in a double-stage PV system, this task is usually performed by a dc – dc converter boost [14]. Regardless of the topology of the PV system, the dc-bus voltage control inverter executes the power balance between the PV system and the power grid. In other words, to ensure that the power generated by the PV array is equal to the power injected into the grid plus system losses, the dc-bus voltage controller must increase or decrease the amplitude of the inverter sinusoidal current references, so that the power balance remains.

You can highlight the functionalities of PV systems in several applications. This is because, in addition to injecting active power into the grid[3]–[13], PV systems can simultaneously perform some type of power line conditioning[14] and subsequently improve power quality (PQ) indicators, which are linked to the following indexes: line utilization factor [power factor (PF) and fundamental PF], harmonic pollution factor, and unbalance factor for loads.

PV systems have similarly acted in [14] as parallel active power filters (P-APF), compensating for reactive power, and suppressing current harmonics generated by nonlinear loads. PV systems were employed in [15] to operate integrated with Unified Power Quality Conditioners (UPQC) [16].

Although the main role of UPQC systems is to perform series – parallel compensation, so that they can simultaneously act as APF series, compensating for the mains voltages, as well as acting as P-APF, compensating the load currents, in [21] the experimental results of the single-stage PV system integrated with UPQC only perform the function of a dynamic voltage restorer. In this case, only the grid voltage disturbances are offset. A dual-stage PV system integrated with the UPQC, named SPV-UPQC-P, was evaluated in [17] using computer simulations only. However, this system only offsets the reactive load power and grid voltage imbalances. Therefore the suppression of grid voltage as well as load current harmonics was not considered. Another application is presented in which the PV system is integrated with the UPQC. In this application, the system can function as a grid forming in an acmicrogrid[19], since different types of DG sources (PV, wind, and others), as well as energy storage systems, can be used as grid forming units in an insulated microgrid. Transients / disturbances, however, could be observed in the voltages that fed the load when the system was transferred from the grid-connected mode of operation to the grid-islanded mode. This is because the UPQC parallel converter needs to change its control mode from source of current to source of voltage. The same effect occurs when the system returns to operate in the grid-connected mode, since the parallel converter as the current source must be controlled again.

The system named PV-UPQC was presented in [18]. It can operate in both three-phase three wireand three-phase four-wire EPS. Since the parallel converter is controlled by voltage so that balanced and regulated voltages can be supplied to the load, when the system operates as grid forming in an acmicrogrid there is no need to change its control mode. In other words, voltage in both grid-connected and grid-islanded modes is controlled by the parallel converter. On the other hand, the aforementioned system can also operate in an acmicrogrid either as grid feeding or grid supporting[19], since the parallel converter control mode can also be switched to operate from voltage source to current source.

On the other hand, studies relating to stability analysis, detailed study of active and apparent power flows, and mainly the sizing and protection of the power converters that make up the PV-UPQC system, were not addressed. This paper presents further research advances and contributions, as follows.

1) A comprehensive study involving the power flow through the PV-UPQC system is carried out in order to obtain an overall understanding of the system operating under several operating modes. This study represents a useful and important methodological tool for properly designing the power converters. It is supported by an extensive number of sizing curves and allows effective sizing of power converters for the designer.

2) A strategy to avoid series and parallel power converters exceeding power ratings is implemented. This strategy is needed to prioritize the power flow through the converters, as the PV-UPQC system simultaneously performs grid active power injection (energy generated from the PV system) as well as power line conditioning.

3) An analysis of the PV system's stability is carried out. In the context of a UPQC, the study involving the ability of the series and parallel converters to remain stable even when disturbances occur in both the load currents and grid voltages has never before been addressed in the literature and appears to be an important and necessary subject to be discussed. Additionally, it is checked if different grid impedance characteristics affect the system stability or not.

4) The PV-UPQC system is also tested in grid-insulated use. This operation mode allows the exploration of new aspects relating to the PV-UPQC system's multifunctionality.

This paper proposes a combined PV and wind energy systems to generate and maintain dc-link voltage of VSI for DSTATCOM. Amongst various control algorithms listed in the literature ISCT scheme is used for control the VSI. Further, the satisfactory dc voltage regulation and effective load compensation proves the efficacy of hybrid dc-link VSI based DSTATCOM.

II. EXISITNG PV-UPQC SYSTEM

Fig. 1 displays a three-phase, single-stage PV-UPQC power circuit. The series and parallel converters are composed of NPC inverters of three stages. The inverter series is connected to the grid by means of three coupling transformers connected to L filters in series, represented in series by Lscabc inductances with their respective internal resistors Rscabc. The parallel inverter is connected to the common coupling point 2 (PCC2 through LC filters represented by the inductances Lpcabc in series with their respective internal resistances Rpcabc, in addition to the capacities Cpabc. The dc bus consists of the condensers Cdc1 and Cdc2 connected in parallel to the PV array consisting of a string with 20 series-connected PV panels.

The PV system's operating voltage is calculated by the MPPT algorithm, called perturbs and observes (P&O) [16]. Therefore, the maximum dc-bus voltage amplitude is approximately 600 V, enabling the PV system to operate in MPP under standard test conditions (STC). The minimum, on the other hand

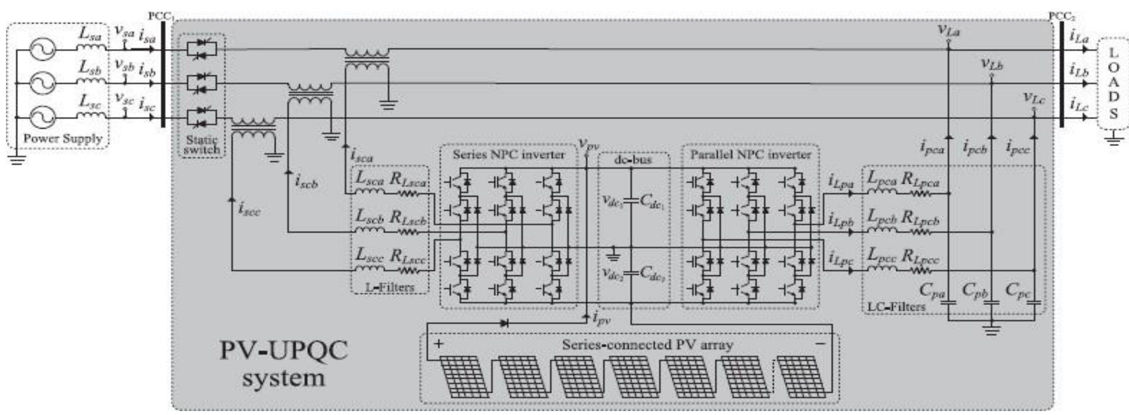

Fig. 1.The PV-UPQC framework's power circuit structure

Device operating voltage (v to dc min) is set at 460 V, i.e. when this voltage is reached, the PV system works outside the MPP. Under unfavourable conditions the PV-UPQC configuration acts as a traditional UPQC, i.e. while the PV is under maintenance or at night. The minimum dc-bus voltage in this situation is set at 460 V.

PV-UPQC System Control Strategy

The PV-UPQC structure is regulated by information floods that are synchronized with grid voltages. These streams are controlled by a blueprint converter, which is intended as a sensible, sinusoidal current source for the strategy converter. Now a high impedance course is taken between grid and weight for consonant streams in the store that suggests that the blueprint transformer acts like a symphonic insulator. As the grid streams are sinusoidal in conjunction with grid stress, no reactive intensity and music in the grid (PCC1) is created. A high PF is thus obtained irrespective of the weight imbalance payment. The voltage controller dc-transport modifies the adequacy of grid streams to achieve a power stream equilibrium including the grid, the PV frame and the heap. In addition the repaid grid streams can be tested in detail at the local level in phase or phase restriction with grid voltage.

The PV-UPQC frame output voltages will also be matched to the grid voltages in process. The different voltages are regulated by an equivalent converter, i.e. a voltage sinusoidal source. In order to stimulate the creation of these voyages through the equality converter, a low impedance path is thus taken for the store symphonious streams. As the structure yield voltages are controlled to be sine-sided, balanced and handled, any disturbing effect present in the grid is noticeable through the transformers in the course of operation, such as voltage noises, voltage imbalances, and voltage hangs / swells.

The remuneration technique used in the PV-UPQC framework is recognized as a twofold pay method and it is illustrated in depth in, where are dissected the focal concentrations over traditional pay systems used to monitor most UPQCs implemented in the work.

This paper demonstrates the figures in the organized reference plot (SRF), which demonstrates the tales used for transmitting the references for the grid streams (plan NPC inverter), yield voltages (identical NPC inverter) and the dc transport voltage (MPPT-P&O).

A. System Control Strategy PV-UPQC

The PV-UPQC system's input currents are controlled to synchronize to grid voltages. A series converter controls those currents, so the series converter acts like a balanced sinusoidal current source. A high impedance path for the harmonic load currents is thus created between grid and load, meaning that the series converter acts as a harmonic isolator. Since the grid currents are sinusoidal and are in phase with the grid voltages, the grid (PCC1) has no flow of reactive power and harmonics. Thus, in addition to load unbalance compensation a high PF is obtained. The dc-bus voltage controller adjusts the grid currents amplitude to achieve the power flow balance involving the grid, the PV system, and the load. In addition, the compensated grid currents may be in phase or phase opposition to the grid voltages, as discussed in detail in the following section.

The PV-UPQC system's output voltages are also controlled to synchronize and be in phase with the grid voltages. A parallel converter controls the respective voltages, i.e., the parallel converter acts like a sinusoidal voltage source. Therefore a low impedance path is created for the harmonic load currents to facilitate the flow of these currents through the parallel converter. Since the system output voltages are controlled to be sinusoidal, balanced, and regulated, any disturbance present in the grid, such as voltage harmonics, voltage unbalances, and voltage sags / swells, will appear through the series coupling transformer terminals.

The compensation strategy used in the PV-UPQC system is known as a dual compensation strategy and is described in more detail in [25]–[27], where the advantages over conventional compensation strategies[28] used to control most UPQCs presented in the literature are discussed.

In this paper, in the synchronous reference frame (SRF), the algorithms used to generate the references of grid currents (series NPC inverter), output voltages (parallel NPC inverter), and dc-bus voltage (MPPT-P&O) are implemented. 4(a) to (b).These respective algorithms, the converter mathematical modelling, the voltage controllers (parallel inverter and dc bus), as well as the current controllers (series inverter) are detailed in [24]. In [30] the phase-locked loop scheme used for synchronization and phase-angle detection of the utility is presented.

B. The PV-UPQC Operating Modes

The PV-UPQC system's multifunctionality can be underlined by its number of operating modes (OPMs), as described below.

1) OPM 1: In OPM 1, the grid is connected to the PV-UPQC system without the connected load. In this case, it injects all the power generated by the PV system into the grid (operating as a conventional DG system).

2) OPM 2: In OPM 2, the PV-UPQC system is connected to the grid using the connected load and without PV array power generation. The system only performs power line conditioning in this case, since it operates as a conventional UPQC (grid supporting [19]).

3) OPM 3: In OPM 3, the PV-UPQC system is connected to the power grid using the PV array for both load and power generation. The system performs power line conditioning in this case, and supplies grid / load power. The energy surplus is injected into the grid if the power generated by the PV system is greater than the energy demanded by the charge. If lower, all the energy generated is sent to the load.

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4) OPM 4: In OPM 4 the PV-UPQC system is disconnected from the grid (insulated operating mode) with both the PCC2 load (see Fig. 1) and the PV array power generation. In this case, the series converter operation is inhibited, and the load is fed through the voltage-controlled parallel converter by the power produced from the PV array. The system may act as a grid forming for a given application [19] provided a storage energy system is present

5) OPM 5: In OPM 5 the PV-UPQC system is disconnected from the grid (insulated operating mode) with both the PCC2 load and the PV array power generation. In this case, the series converter operation is inhibited and the load is fed by the parallel converter, which is currently controlled (grid feeding [19]). Not addressing this operation mode in this paper.

III. PROPOSED SYSTEM

In a three-phase four wire distribution system, the DSTATCOM is integrated near the PCC as a PQ-mode to compensate for all current-related issues such as eradication of current harmonics, reactive power exchange, load-balancing, neutral current elimination and power factor correction etc. To drive the balanced non-linear load and the sudden interrupted load the DSTATCOM is interfaced into a three-phase distribution system. It includes various elements such as, DC-link condenser as Cvdc, 3-phase voltage source inverter (VSI) as PQ-VSI is designed by IGBT switches, RLabc circuit line-interfacing filter, sensing elements, reference current generator, gate-pulse switching circuit, etc. Figure 2 illustrates the block diagram of the proposed DG-integrated DSTATCOM topology for the three-phase 4-wire distribution system at PCC. By using signal analyzers, the significant control strategy provides the optimum switching states to DSTATCOM by sensing accurate values of load and source parameters.

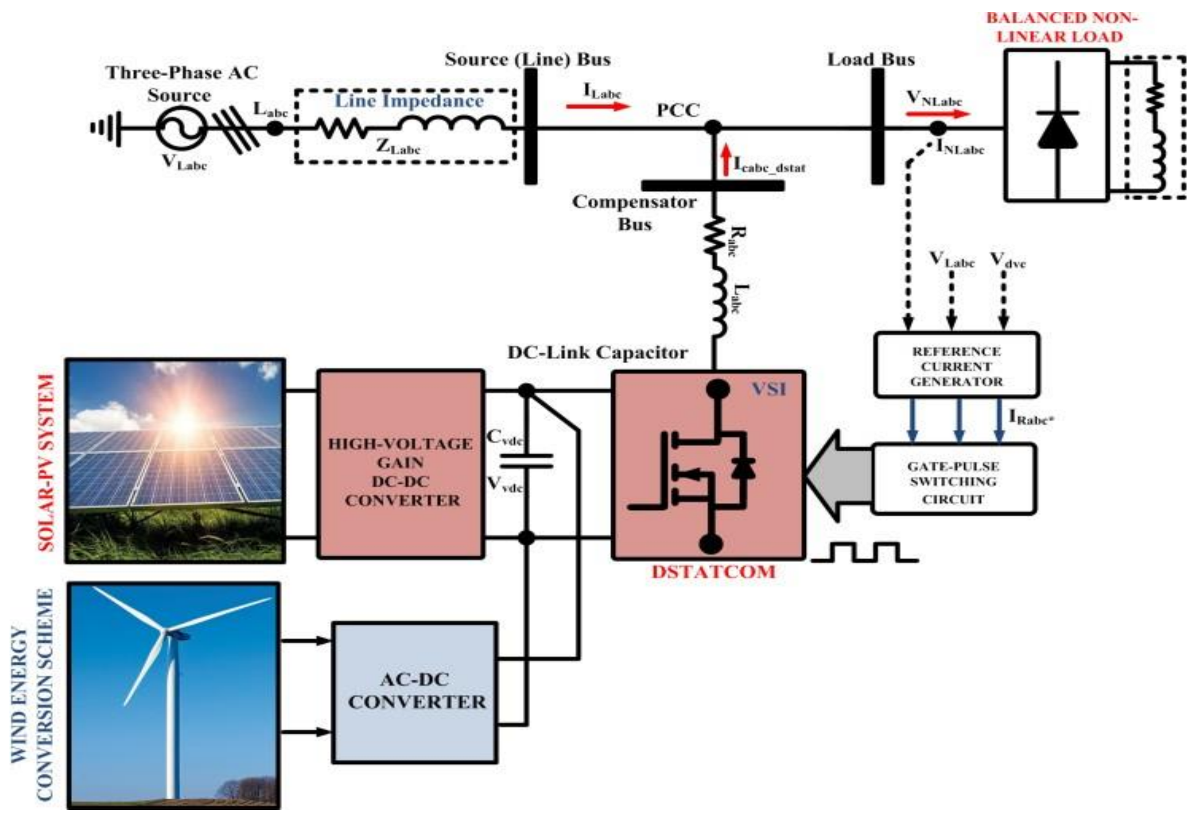

Fig.2 Block Diagram of Proposed DSTATCOM Topology with DG Integration Scheme

The DG scheme generally requires additional source as a Battery Energy Storage System (BESS), but additional charging management schemes are required. Renewable energy plays an important role in DG schemes over the BESS, in that SPV-Wind is the major power producer as the scheme for CO generation. The SPV-Wind is the primary source of VSI, commonly built into the DC-link capacitor Cdc by using DC-DC converter with high voltage gain. This boost converter transforms the low-level SPV-Wind voltage into the high-level voltage required to drive the STATCOM VSI, and supports the constant DC-link voltage Vdc. Typically, the appearance of DSTATCOM is taken from the active-filtering technique working at the PCC level of the distribution system based on the current injection methodology in phase.

IV. RESULTS

EXISTING RESULTS

In this section, the proposed strategy developed to prevent the parallel NPC inverter's over-power rating is tested using numerical simulation using the MATLAB / Simulink tool. In such tests the size of the parallel converter is defined to process a maximum apparent Spcmax power = 3 kVA. Fig 8.1 shows the PV-UPQC system SIMULINK circuit diagram. Figure 4 shows grid voltages (v_{sabc}), figure 5 shows grid currents (i_{sabc}), figure.6 shows charging voltages (vLabc), figure.7 shows parallel converting currents (i_{pccabc}). Fig 8 shows currents of load (i_{Labc}). The DC connection voltage and the pv power are shown in Figure 9 and 10.

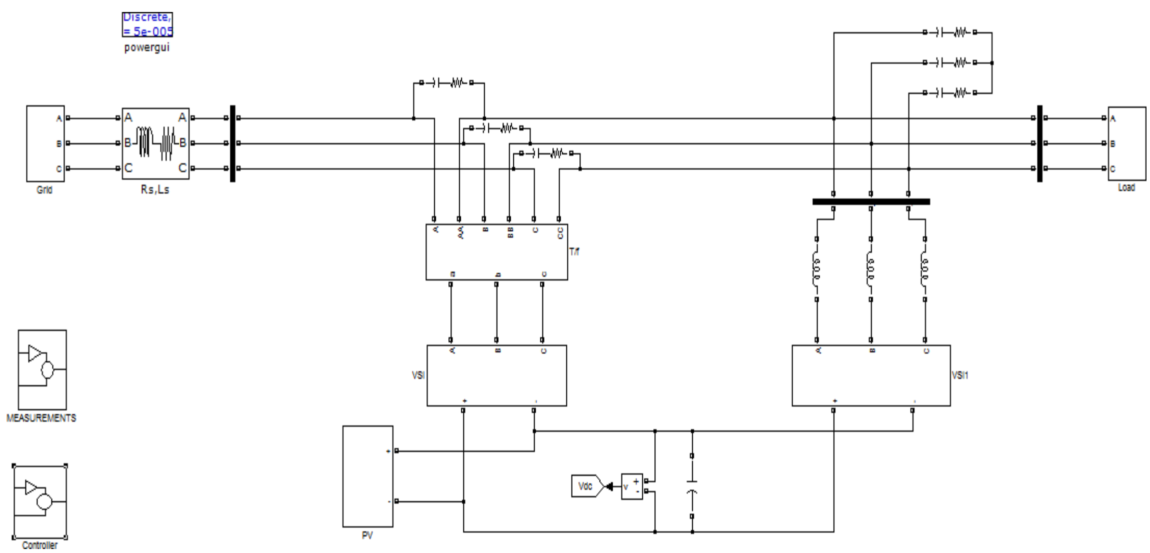

Fig 3 MATLAB/SIMULINK Circuit diagram of the PV-UPQC system

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CASE 1: PV-UPQC PERFORMANCE WITHOUT THE POWER LIMITATION ALGORITHM OF THE PARALLEL NPC INVERTER

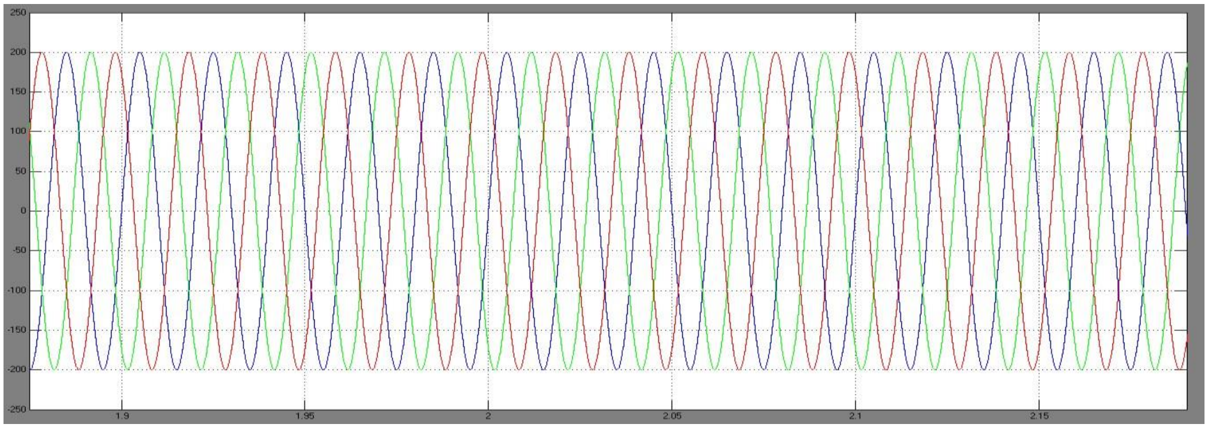

Fig.4 Grid voltage

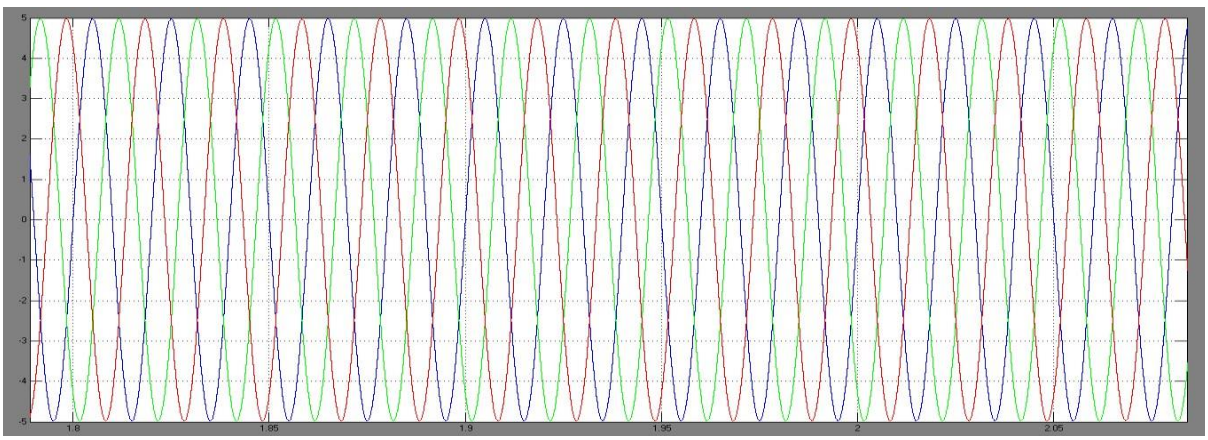

Fig.5 Grid current

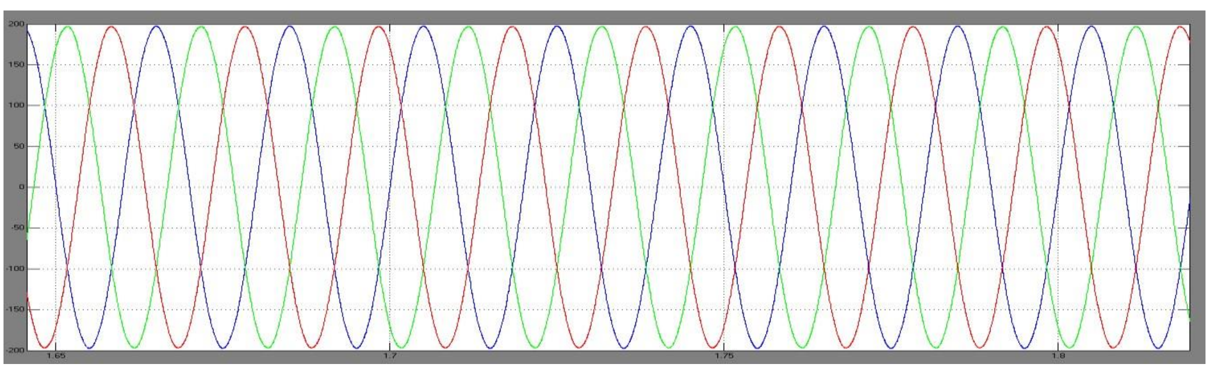

Fig.6 Load voltage

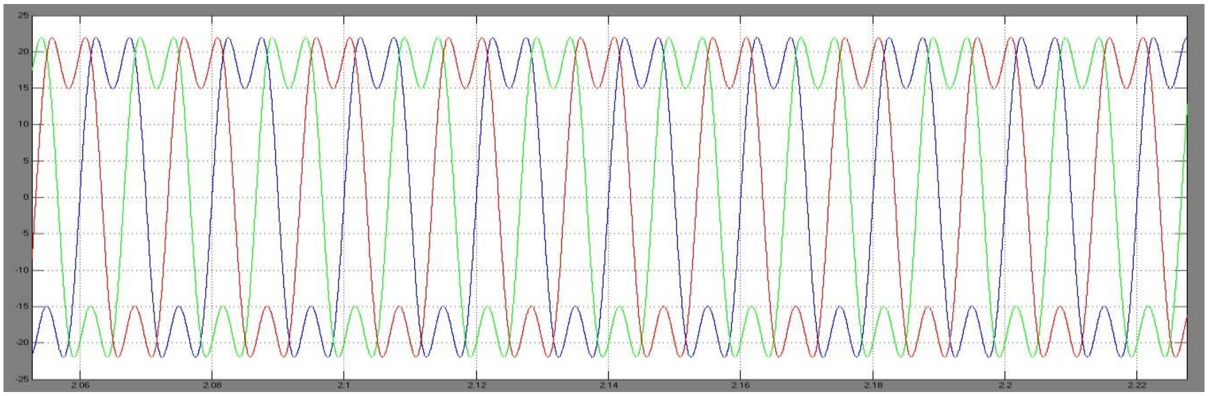

Fig.7 Parallel converter currents

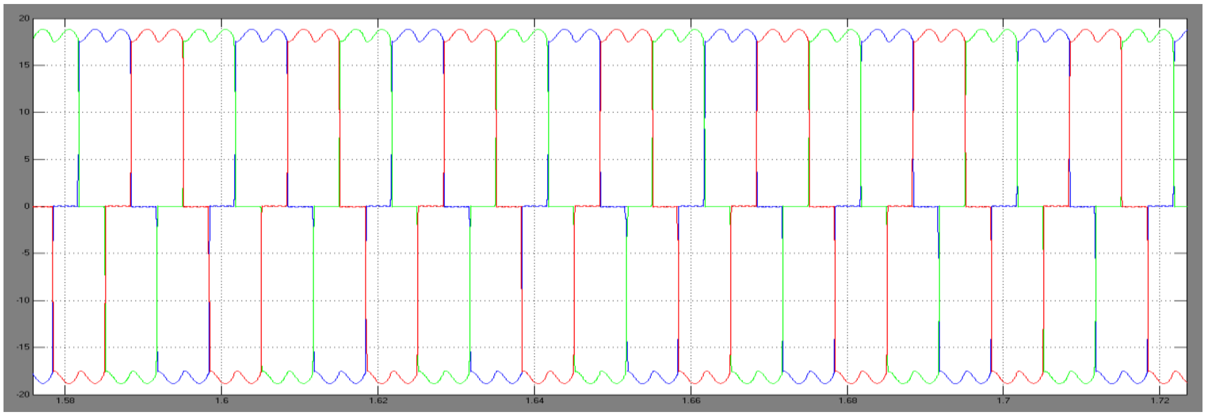

Fig.8 Load currents

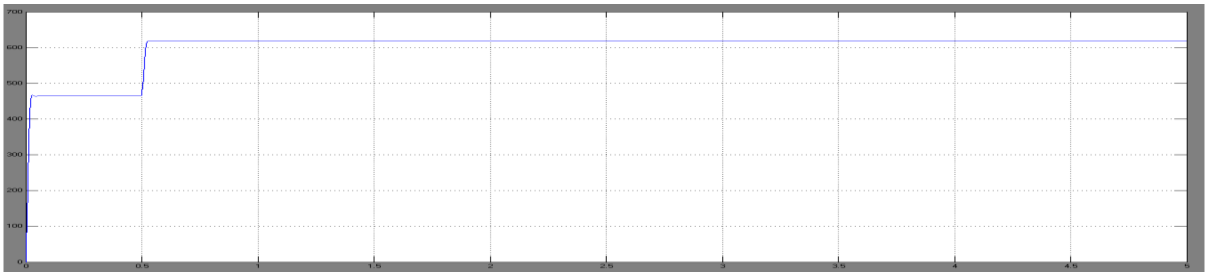

Fig.9 Dc link voltage

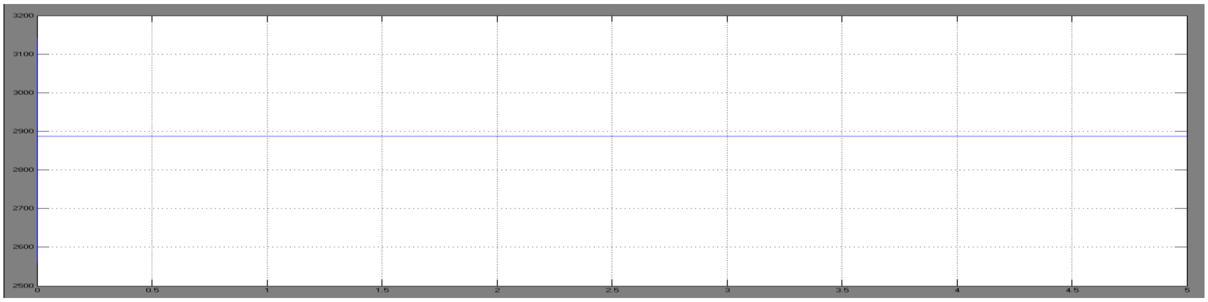

Fig.10 PV Power

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EXTENSION RESULTS (PV-WIND WITH DSTATCOM)

The proposed control scheme is simulated using SIMULINK in power system block set which is shown in figure .11 and the PV-WIND connected DSTATCOM subsystem is shown in figure.12

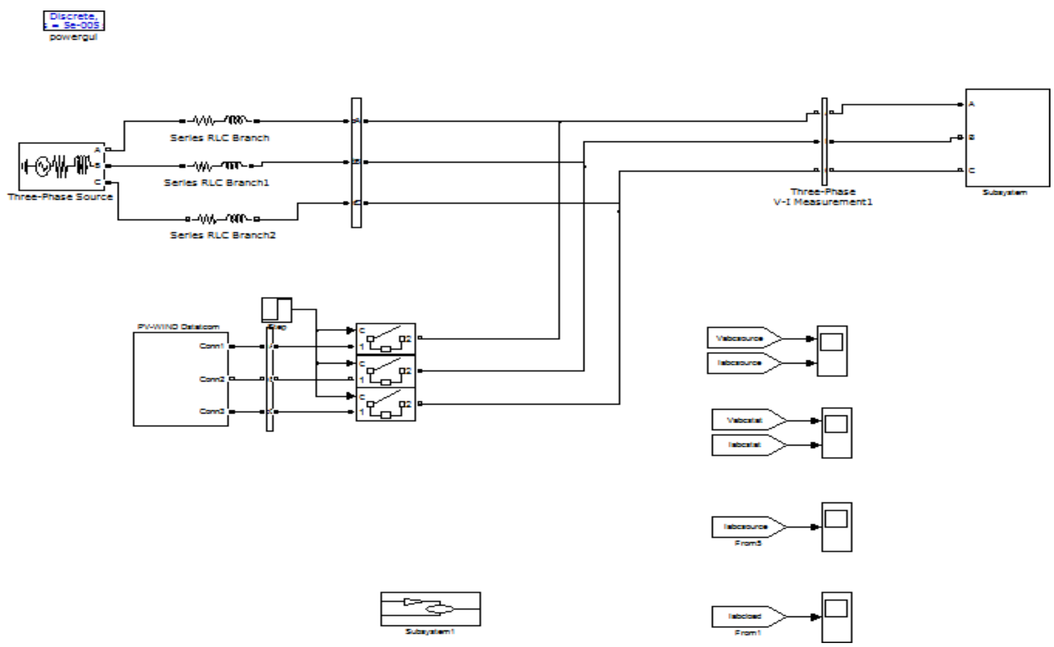

Fig 11 MATLAB/SIMULINK circuit diagram of PV-WIND with DSTATCOM

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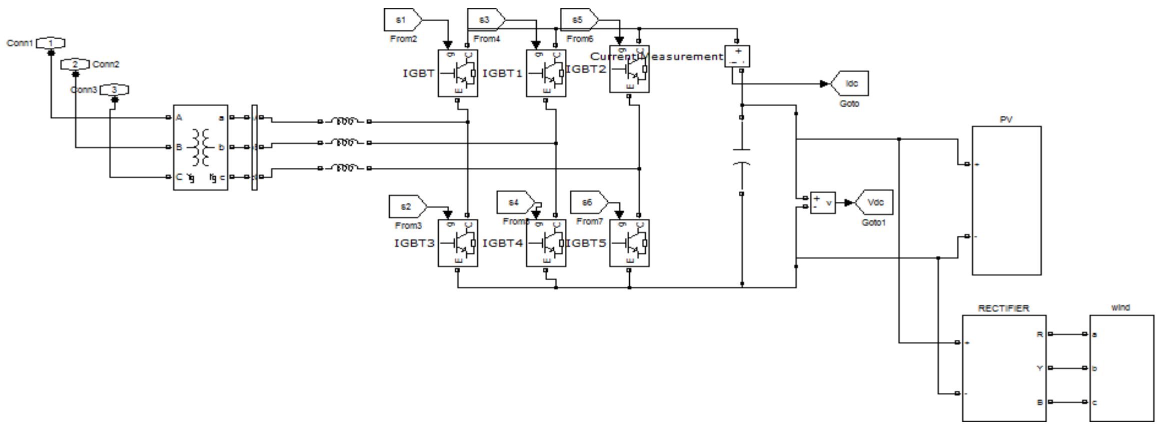

Fig 12 PV-WIND connected DSTATCOM subsystem

The below figure 13 shows the source voltage & current, fig .14 shows the Dstatcom voltage & current, and fig 8.20 shows the load current. By observing the fig.15 in source current after 0.1 sec DSTATCOM is activated and it compensated the source currents as shown in figure

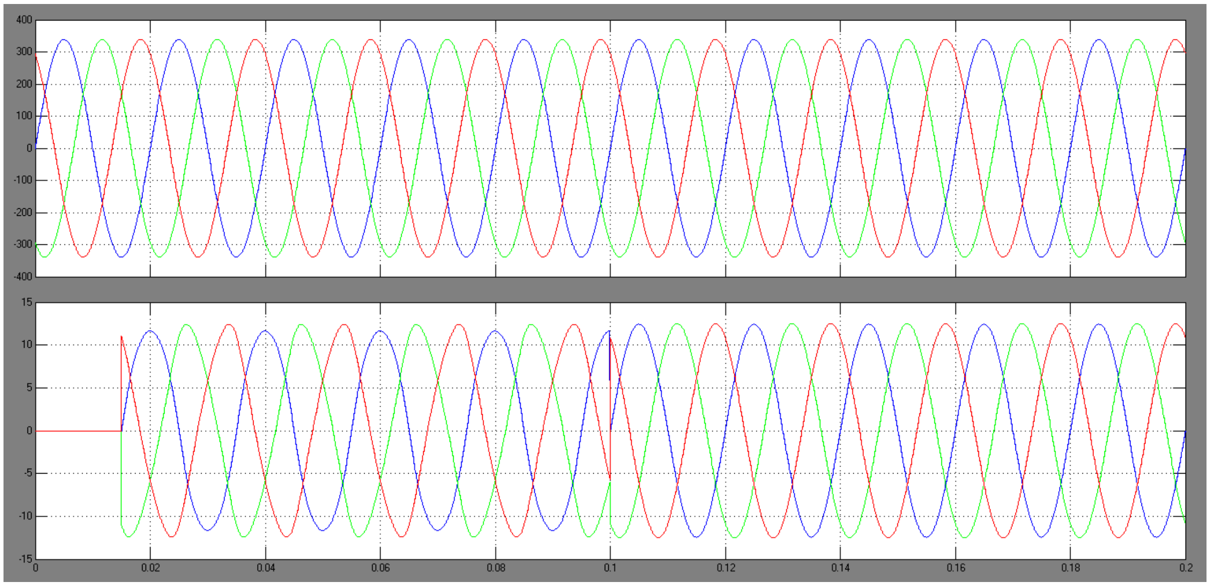

Fig .13 Source voltages and current

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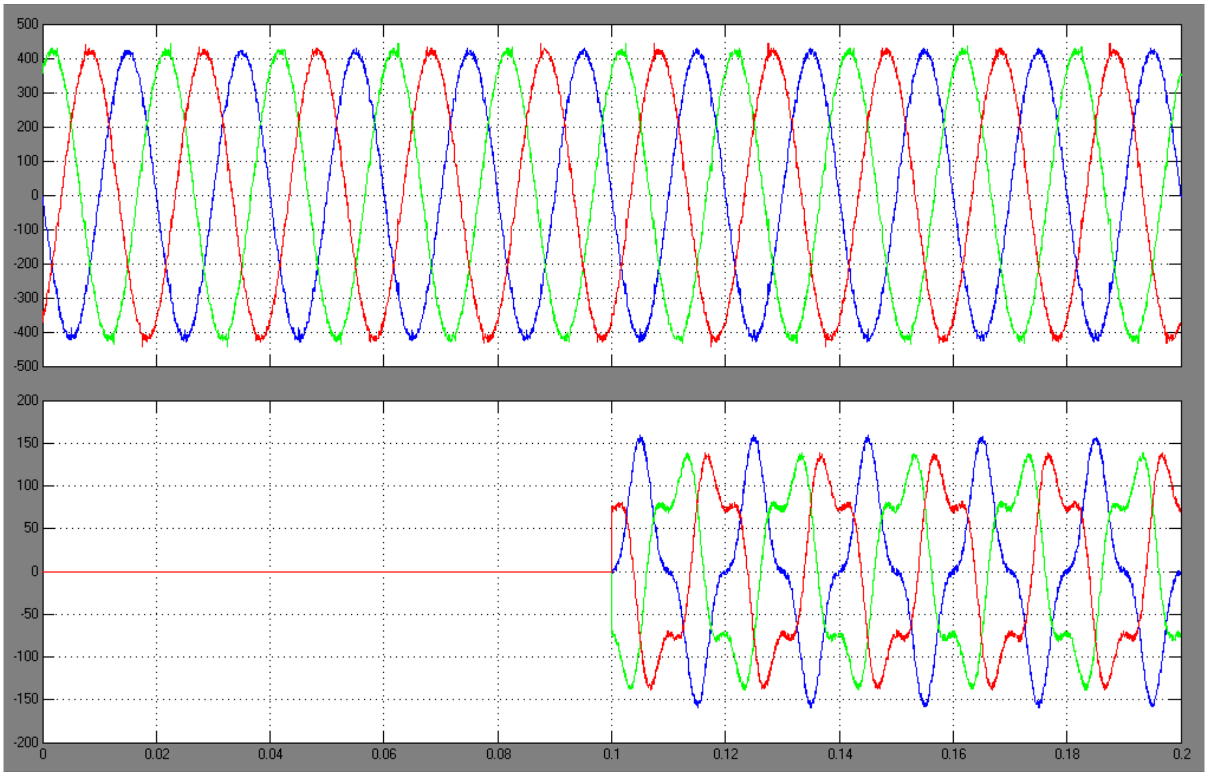

Fig .14 DSTATCOM voltages and current

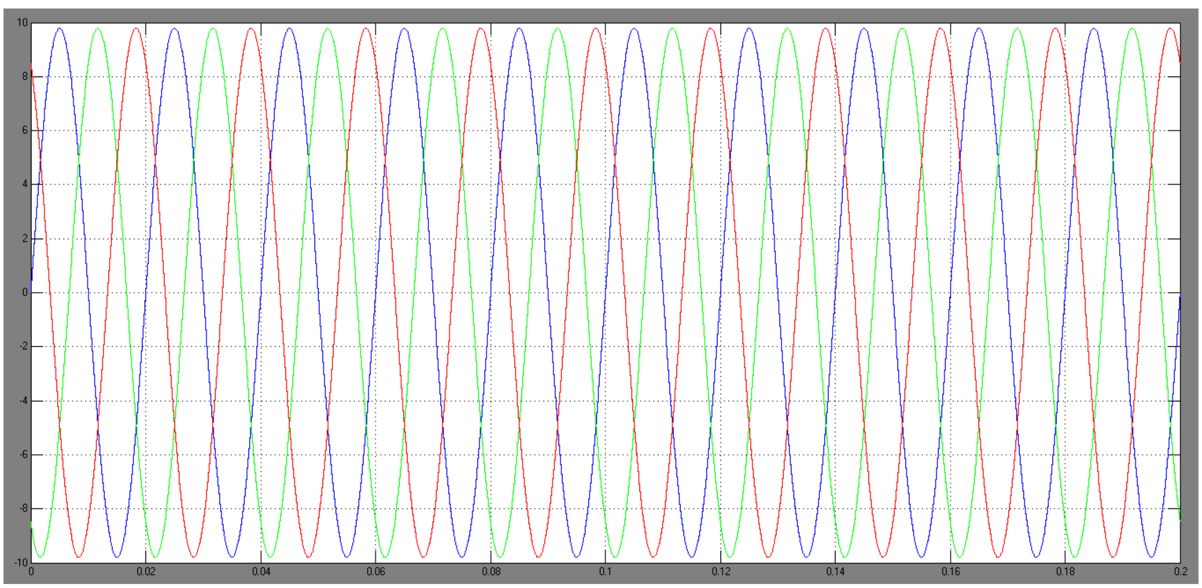

Fig.15 Load voltage

Figure 16 indicates the THD% source current without compensation is 4.46% and the figure .17 indicates the THD% of source current with compensation is 0.40%

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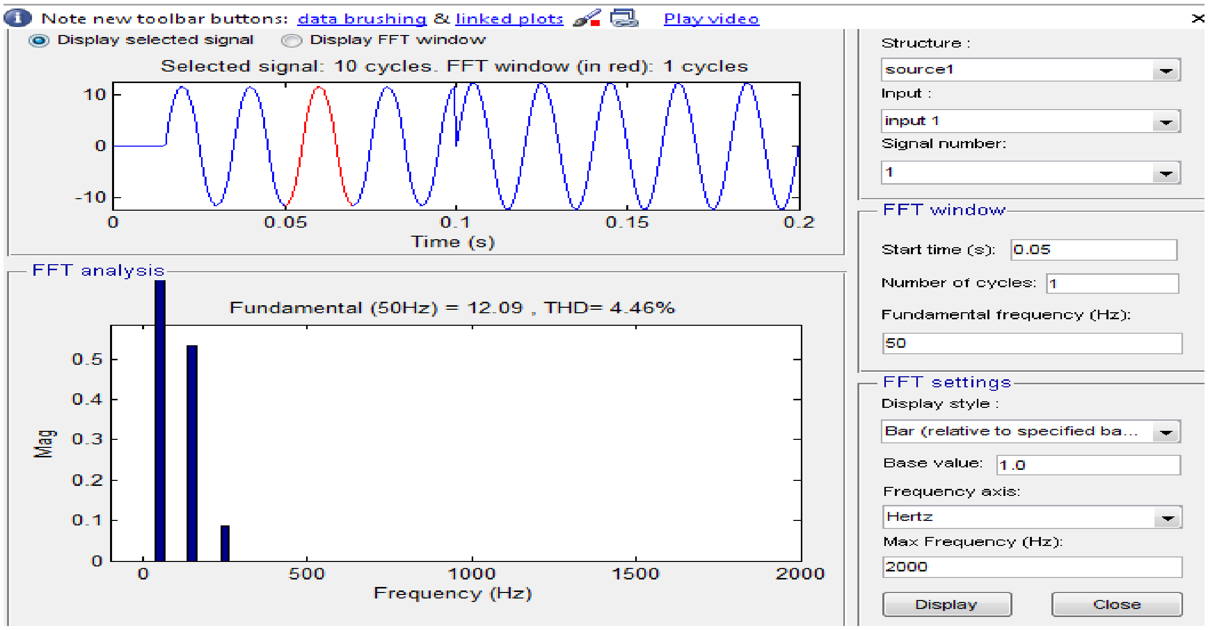

Fig. 16 FFT analysis without DSTATCOM (THD=4.46%)

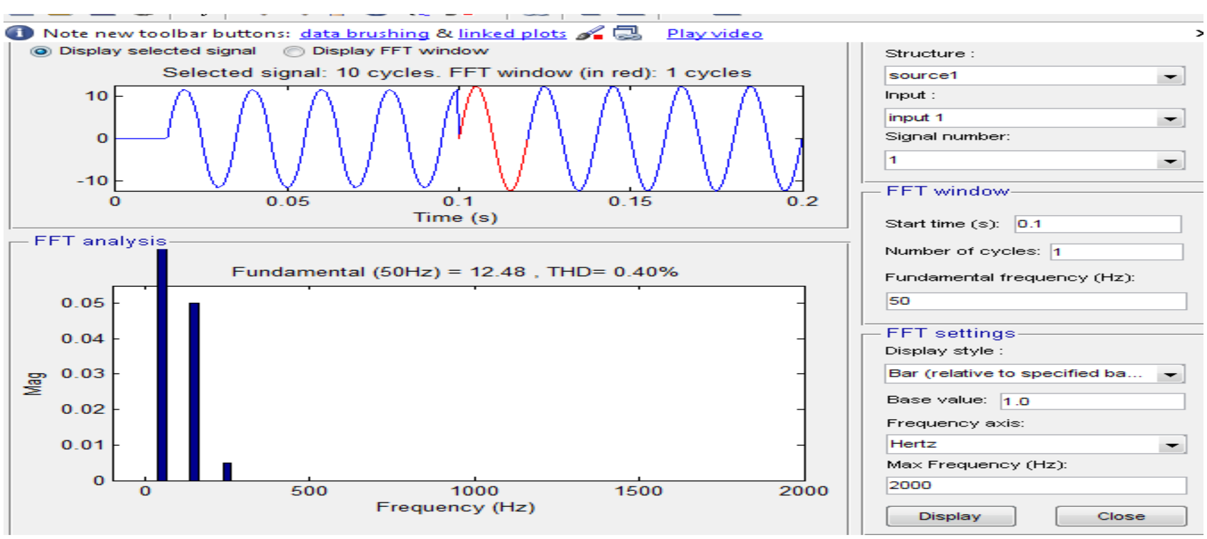

Fig. 17 FFT analysis with DSTATCOM (THD=0.40%)

CONCLUSION

In this endeavour PV based UPQC is proposed. When the DG system is placed between grid and either ac loads or ac microgrid, the UPQC operates as a bidirectional interface. The DG system performs active power-line conditioning in grid-connected mode, while injecting the energy generated by the PV array into the grid. The system can act as an ac grid forming in insulated operation via a parallel inverter, whether there is an energy storage system present. A complete study involving the power flow through the PV-UPQC is mandatory in order to get an overall understanding of the operation of the system and properly design the power converters.

In the extension we present the renewable energy sources based FACTS device (i.e., PV-WIND DSTATCOM) based control scheme for power quality improvement in grid connected system with nonlinear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It has a capability to cancel out the harmonic parts of the load current. The PV-WIND connected DSTATCOM device gives the good performance.

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