Power Flow Analysis Across a Load Feed by Two Synchronized Voltage Source Inverters In Solar Power PV-System

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Abstract

As of now, the utilization of solar energy to control the grid area is quickly expanding. We have plenty of solar energy because it is provided by nature. For shrewd energy systems, solar energy with decentralized energy generation is suitable. Within the proposed plan there are two distinctive frameworks that are coordinated at the point of common coupling (PCC). The potential exists for inverter interface sources to be sent to direct the voltage at the point of common coupling (PCC) of each inverter interface source. For this synchronization between the two-voltage source inverter's output is accomplished utilizing PLL. To realize the Greatest control from the PV Board, the greatest control point following (MPPT) Calculation is utilized. Since a PV cluster gives a DC voltage as an output, this DC voltage is changed over to AC utilizing H-Bridge full-wave inverter topology. At last, a control stream investigation is examined along a load that is fed by two voltage source inverters. One is the solar control inverter and the moment inverter is utilized in an ups-based energy capacity framework. As the power generation of the solar system shifts all through an entire day, the power stream analysis is discussed in three different scenarios i.e. when load is greater, less, and when rise to generation of PV-system.

Keywords—MPPT, BOOST Converter, PLL, VSI, Power Flow

1 Introduction

These days, economic power sources, for example, wind, solar energy, wave tidal, and energy components, expect basic parts in energy locale. The more prominent portion of the sustainable power sources are included like wind turbines that are AC sources with varying frequency. Wind gas turbines are the sources of high-frequency AC sources. Then comes DC sources like solar PVs. The electronic circuits to convert DC power into AC power are called inverters. They anticipated to interface these sustainable power sources with the framework [1]. In spite of the reality that maintainable power sources are exceptionally well known, there are still many challenges faced by the inverter control for organized joining. For occurrence, the feasible power sources, for illustration, wind control, and PV boards are not consistent energies in different breeze conditions or sunshine conditions; the current implanted into the framework to be idealized sinusoidal to keep organize steady and arrange pleasing [1]; the Grid variation ((frequency variation or voltage variation), in spite of the truth that they are small, also impact the grid soundness.

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With the developing solar-based industry and energy prerequisite, the network joining of PV sources furthermore turns out to be uncommonly conspicuous. Since sunlight is an uncontrollable resource, the temperature is a vital factor for generating the energy from a photovoltaic (PV) system, while ensuring the maximum power point tracking (MPPT) systems, the role of electronic converters is primary one for the transformation of DC power to grid required AC power.

In this paper, a power stream investigation and technique based on two tied inverters is created based on distinctive methodologies of quantity of load vs. capacity of generation. The essential point of this power stream consideration is to investigate the behavior and flow of power in this particular situation when there's more generation as compared to load requests. One inverter is based on a settled DC voltage source and this inverter's output voltage will act as the reference for the second inverter's output voltage. PV panels will act as a discontinuous voltage source for the moment inverter. These two inverters contribute their powers to a single load and power flow behavior in examined utilizing distinctive load scenarios. A common topology of tied PV systems has two controls taking care of stages, counting a DC/DC converter and a DC/AC converter. The DC/DC converter, more regularly than not a lift converter, converts the fluctuating DC voltage from the PV source into a stable DC voltage output. At that point, the DC/AC converter changes over the steady DC voltage control into the AC electrical framework. Currently, there are a number of PV arrays connected to respective DC-to-DC converters, which especially share a common DC bus to improve the system further. In grid-connected PV systems with two-stage configurations, the MPPT functionality is typically incorporated into the control strategy of the DC/DC converter.

This study focuses on a distinctive framework for the analysis of power flow in which two synchronized voltage source inverters are utilized for managing the variability in the power requirement at the load side for a solar power system. Unlike, the approaches used traditionally, the proposed model uniquely combines an uninterrupted power supply (UPS) inverter with a solar inverter to maintain synchronization and enhanced adaptability of load using a Phase Lock Loop (PLL). This work involves optimization of internal resistance for controlling and stabilizing DC link voltage and incorporates the latest models like VSI-CSI transitions, which in fact are mitigating real-world challenges, such as harmonic distortion, transient stability, and the fluctuation of power from PV panels. Therefore, this work proposes an innovative design that insights into enhancing the efficiency and minimizing harmonic distortion in solar-powered applications, which are increasing drastically.

1.1 Maximum Power Point

Photovoltaic framework systems contain PV panels and a framework tie inverter, without batteries. The sun-oriented sheets control an extraordinary inverter that changes the DC voltage from the PV panels particularly into AC energy to facilitate the Grid. Any power made by PV subtracts from what you employ from the power organization. On the occasion that you just make more power than what you utilize, it infuses any overflow within the Grid. This fragment has each PV inverter for tie systems. MPPT or Most Extreme Power Point Following may be a calculation that joins charge controllers utilized to partition the foremost extraordinary available power from the PV module beneath particular conditions. The voltage at which the PV module can make the most extraordinary control is known as the "top powerpoint" (or peak voltage). The most prominent power changes depend upon the sun-based radiation, the encompassing temperature, and the temperature of the solar cell. Figure 1 represents the MPPT algorithm.

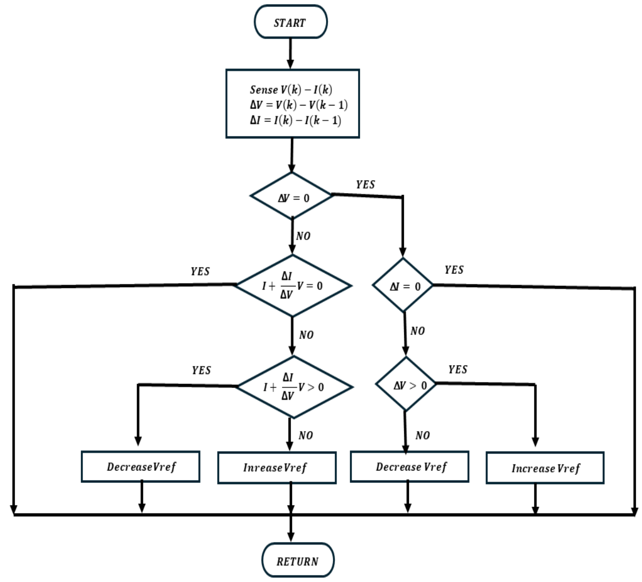

Fig. 1: MPPT algorithm

The primary function of MPPT control is to extract the maximum available power from the PV module by operating it at the optimal voltage corresponding to the maximum power point.

MPPT checks the abdicate of the PV module, considers it to be the battery voltage, and subsequently, the MPPT controller determines the maximum power the PV module can generate under given conditions. It then optimizes this power by converting it to the most suitable voltage for efficiently charging the battery or supplying the connected load to induce the foremost exceptional current within the battery. It can in addition control a DC stack especially associated with the battery. MPPT is more viable beneath these conditions:

- Cold climate, cloudy or foggy days: Ordinarily, the PV module works best at chilly temperatures and MPPT is utilized to expel the most prominent power available from them.

- When the battery is significantly discharged: MPPT can remove more display and charge the battery in case the condition of charge of the battery decreases.

1.2 Uninterruptible Power Supply

An uninterruptible power supply (UPS) system is used to safeguard sensitive electrical loads across a wide range of applications. With the advent of the internet, the amount of critical automated equipment in use has grown significantly. Because of sensitive utilities and loads, it became the need of time to adopt UPS systems for a reliable supply of power. Many multinational organizations that were purely relying on automated networks switched to UPS systems to make power failure a cornerstone in this modern technology era.

According to requirements, the UPS is installed upstream of the load. This is customized to protect the needs output end (Nasiri, 2011). Usually, a UPS is comprised of electronic components that rectify the signals. It also inverts the power. The converted power is stored in batteries. Electronic filters are designed for UPS to remove the noise and distortion at the power output stage. This is also accomplished using different electronic switches. The role of these switches is to activate the UPS in case of external power failures.

The UPS network and its important usefulness isn't another development. Truth be told, the usefulness of UPS has continued as before for a very long while (a standard content still alluded to by numerous is Price (1989)), yet the expanded request has enhanced the effectiveness and forcefully diminished expenses of UPS networks.

1.3 DC-DC Converter

The DC voltage between the input and the output is reduced by the buck converter. The movement of the circuit depends upon the conduction condition of the MOSFET The current through the inductor increases and the diode pieces.

Since the current through the inductor can't alter suddenly, the diode must pass on the display with the objective that it switches and starts driving. The energy is traded from the inductor to the capacitor, which causes a reduction within the inductor current. For working in uncontrollable conduction mode in the event that the inductor current accomplishes zero and in consistent conduction mode on the off chance that the inductive current is never zero.

The circuit has two working cutoff points. For a PWM obligation cycle D, when it reaches 0, the output voltage is equivalent to zero, and when D reaches 1, the output voltage is equivalent to Vin. Between these limits, the output voltage in persistent conduction mode is given by:

$$V_{out} = D.V_{in} \tag{1}$$

1.4 Phase Locked Loop (PLL)

A phase detector, a voltage-controlled oscillator (VCO), and a low-pass filter (LPF) are the three main components of PLL. The phase detection section is provided with the input signal Vi having frequency Fi making the detector work as a comparator. This comparator compares the frequency of the input signal with the frequency of the signal provided by the feedback section, called Fo. This detector block yields a signal comprising a DC component associated with Fi+Fo. This signal is then given to the LPF to eliminate the distortion and unwanted noise components. Thus, the final output consists stable DC level linked to Fi-Fo. The resulting voltage, Vf, is a dynamic characteristic of the PLL.

1.5 LCL Filter

An LCL channel as shown in Figure 4 is ordinarily set between the inverter and the network to constrict the exchanging frequency harmonics delivered by the grid-connected inverter.

2 LITERATURE SURVEY

Power generation utilizing solar photovoltaic (PV) frameworks is broadly recognized as a low-emission, non-exhaustible energy source that can address supportability issues within the energy segment (Fthenakis, 2009). Solar energy is for the most part separated into two categories: utility, commercial scale, or little scale (Reichelstein and Yorston, 2013).

In future energy framework scenarios, solar energy is by and large considered a major source of power (Komiyama and Kraines, 2008), with solar energy being the biggest source of power generation within the year 2100 (Nakicenovic, 2000).

The primary impediment to the large-scale sun-powered era is the verifiably higher taken toll compared to routine vitality sources (Kumar Chinnaiyan et al., 2013). In arrange to tackle the energy of the sun, a solar cell where photovoltaic transformation takes put needs framework adjust components (BOS) to control, change, and transmit the power created (Kalogirou, 2014).

Systems for uninterruptible control supply (UPS) secure profoundly delicate hardware in clinics, airplane terminals, and data storage units to ensure continuous power supply, when power failure occurs in customary networks. There is a continuous advancement in the solar power sector and UPS. There is a dire need for cheaper solar cells, to take the generation of solar energy at an extended level.

Certain progressed plans of UPS have also been created for large-scale applications expending much power (i.e., huge information centers) to extend change efficiencies in arranging to spare power (Nasiri, 2011). An ordinarily arranged topology based on grid-tied PV frameworks has two powers managing out procedures, counting a DC/AC converter and a DC/DC converter, see Zhong and Hornik (2013). As a rule, a boost converter is utilized within the DC/DC converter, which comes about consistent DC voltage bus from the variable DC voltage power of the PV source, see Femia et al. (2008); Pilawa-Podgurski and Perreault (2013); Deo et al. (2015); Montoya et al. (2016). At that point, consistent DC voltage control changed over to an AC electrical network by the DC/AC converter. In a few cases, for the disentanglement of the framework design, multiple PV sources in conjunction with DC/DC converters share a common DC bus. To control two-phase preparation in grid-tied PV frameworks, an MPPT work is ordinarily joined into the DC/DC converter control. In most writing the DC/AC converters are utilized for controlling bus voltage, e.g., in Femia 2005); Deo et al. (2015); Montoya et al. (2016); Liu et al. (2015). And for the generation of voltage reference and current reference from the DC-bus voltage direction, is ordinarily carried out by the proportional-integral (PI) controller, at this point, voltage or current controllers are used in DC/AC converters to facilitate effective integration with the AC grid. Furthermore, there are many possible designs for adding the blocks of DC/AC inverters into the grid. These methods include vector control, as investigated by Prodanovic and Green (2003) and Trinh and Lee (2014), as well as droop control techniques, as discussed by Kim et al. (2011) and Nejabatkhah and Li (2015).

Zhong et al. (2017) work on various synchronous machines (VSM) control, including those by Beck and Hesse (2007) and Zhong and Weiss (2009, 2011), as well as Zhong (2016), have contributed significantly to this field. More recently, a robust power flow control method based on an uncertainty and disturbance estimator (UDE) has been developed for DC/AC converters, as demonstrated by Wang et al. (2016a, b). This approach enables the smooth stabilization of the two types of powers termed the real and reactive ones, taking into account the assumed uncertainties like powerpoint deviations, output impedance, the coupling effect, and external disturbances including DC voltage fluctuations, and grid voltages. Additionally, this method eliminates the need for a separate synchronization unit in grid-connected operations.

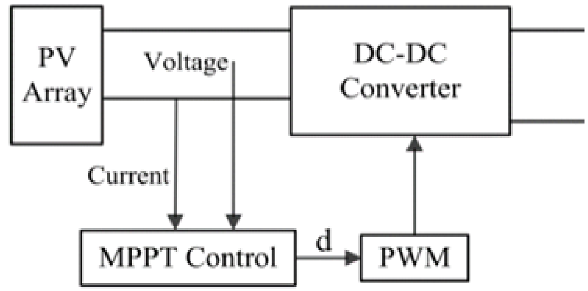

Fig. 2: Incremental conductance algorithm

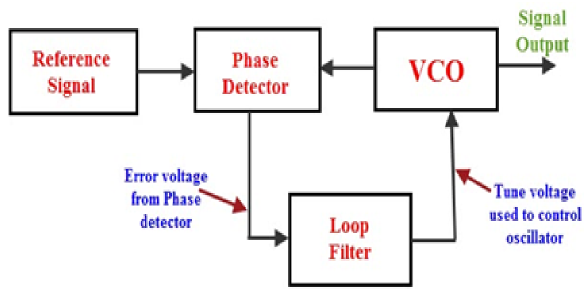

Fig. 3: Synchronization of Inverters

3 SYSTEM SIMULATION MODEL

Our recreation demonstrates comprise of MPPT, boost converter, PLL, and two voltage source inverters.

The incremental conductance algorithm is utilized for the most extreme power point following appeared in Fig 1. So, the most extreme power accomplished by utilizing the MPPT is nearly 2000 watts. The boost Converter is utilized to extend the voltage of the DC bus. The boost converter is controlled by the door signal (PWM beat) which is created by the MPPT by shifting the obligation cycle in the incremental conductance algorithm shown in Fig 2. PLL is utilized for the synchronization of both inverters. Essentially, PLL could be a negative input system where an oscillator-generated signal is phase and frequency locked to a reference signal. Here in our work, the reference signal is the AC signal created by UPS based inverter. The basic working guideline of the PLL is to identify the phase distinction between the input and output signal controlled by the loop frequency.

In this paper the power flow analysis is discussed in three different scenarios, i) when the load is greater than generation, ii) when the load is less than gener-

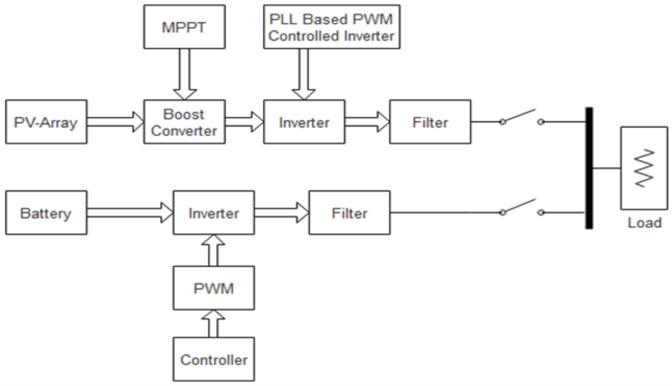

Fig. 4: System Block Diagram

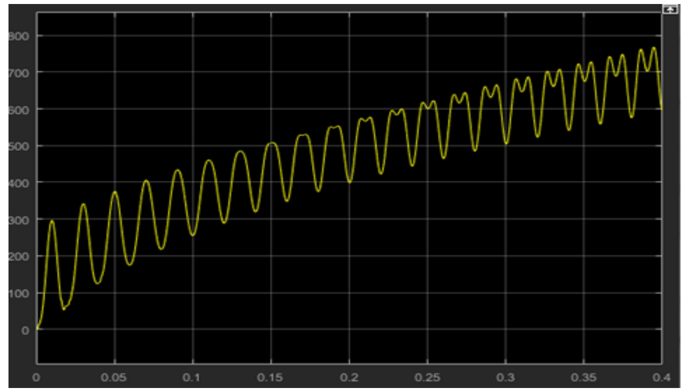

Fig. 5: DC link of PV side

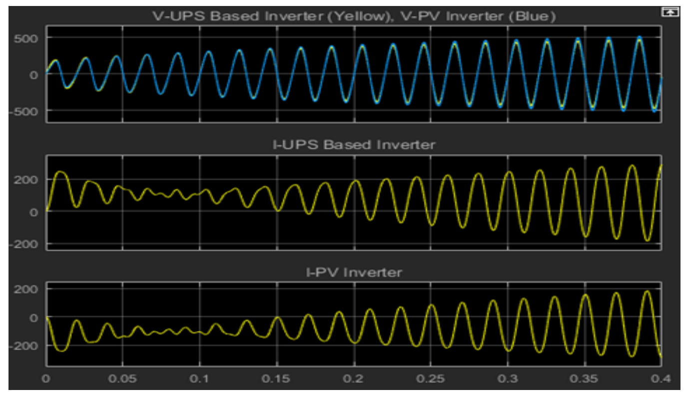

Fig. 6: Voltage and Current curves

ation, and finally iii) when the load is equal to generation. This study is performed because the generation of the PV system varies over a whole day. So, the main purpose of this case study is to determine the power flow in the system through the power converters drawn by the load when the power is unbalanced in the system. Generally, the battery bank directly connects to the DC link at the PV generation side and is controlled by the charge controller but in our system model, an independent battery bank is used to feed the power to load. It could be the source of independent commercial battery banks just like Lithium-Ion batteries or any other. The System block diagram is shown in Figure 4.

Most inverters, in addition to the power input from the PV module, accept auxiliary control input to operate a standby generator, which is used to supply power when the battery voltage drops to a minimum level. A special type of inverter, known as the grid-connected inverter, includes synchronization circuitry that enables the generation of sinusoidal waveforms in alignment with the utility grid. Once this type of inverter becomes part of the grid, it can produce AC power. Grid-tied inverters in solar power systems are generally controlled by utility companies offering net metering. Certain inverters are also equipped with a built-in AC transfer switch, which allows them to receive power from an AC-powered backup generator. In such setups, the inverters contain specific components designed to direct power from the generator to the load.
In our system dc source is used for a battery-based inverter. By using the ideal DC source at a UPS-based inverter system there is a problem. The problem is that the DC source-based UPS system enforces the power flow towards the PV-based inverter. Because of this, the DC link of the PV side disturbs as shown in Fig 5.

Also, the currents and voltages shown in Fig. 6 are unstable. To overcome this problem the internal resistance of the IGBTs is increased which is being used in PV inverter. After increasing the internal resistance, we will be able to get the required voltage of the DC link, the figure shown in Fig 7.

At both inverter sides LCL filtering process is used to filter the signal and convert it to a pure sine wave. The individual output voltages and currents are shown in section IV during MATLAB simulation. The parameters which are being used throughout the simulation are given in Table I.

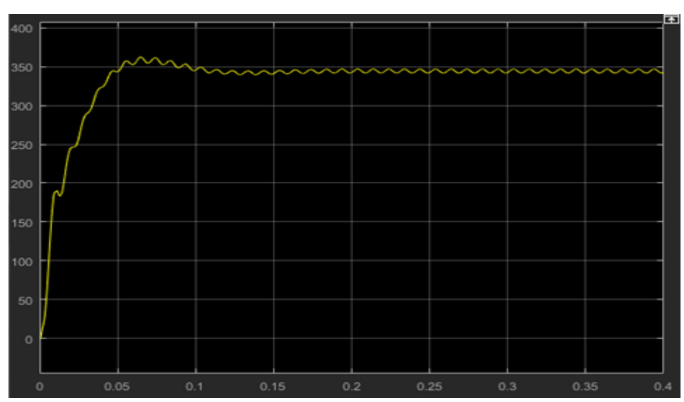

Fig. 7: Required voltage of DC link

TABLE 1: SIMULATION PARAMETERS

L1, L3	17.7e-4 H
L2, L4	5.7e-4 H
C1, C2	10e-6 F
Irradiance of PV-Array	1000 W/m2
Temperature	25 deg.C
No. of Parallel String	4
Series modules / String	2
DC Bus Link	350 V
Internal R of PV-Inverter	0.6 ohm
Internal R of UPS-Inverter	Default 1e-3 ohm
Power Generated By PV	2000 W
Carrier frequency (PWM)	3000 Hz
System Frequency	50 Hz
System Voltage Vmax	300 V

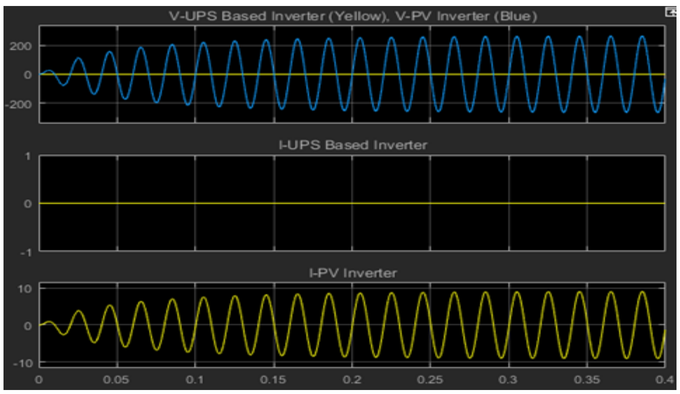

Fig. 8: Output voltage

4 SYSTEM SIMULATION RESULTS

The individual output of voltages and currents are shown in Figures 8 and 9. Figure 8 shows when UPS UPS-based inverter is absent and Fig. 9 shows when only the load is fed by UPS UPS-based inverter.

Hence the load capability is to draw the 10A current in both scenarios. Figure 10 shows when both are in tied form in this case voltage will remain the same because they are in parallel, here voltage is synchronized by PLL and the current drawn capability will be 10A.

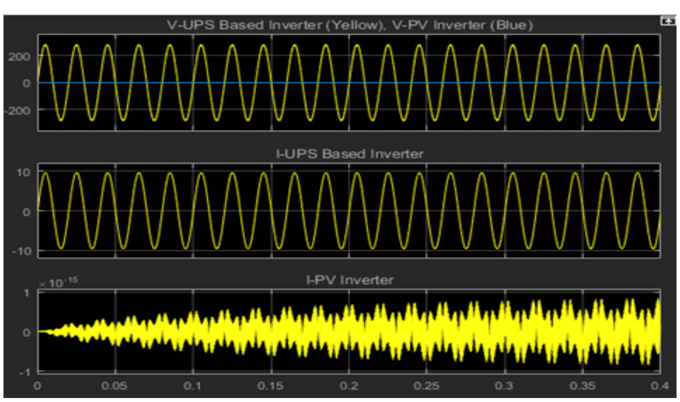

Fig. 9: Output current

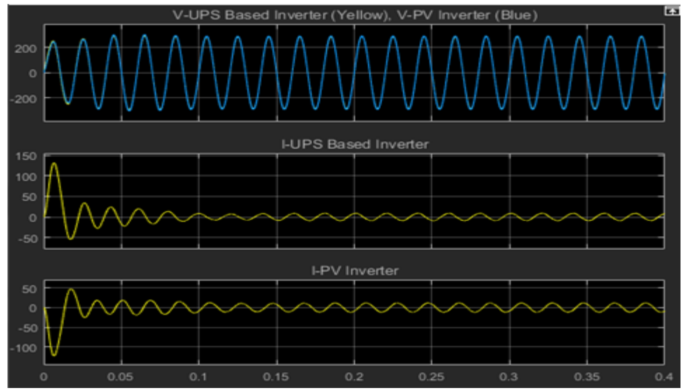

Fig. 10: Voltage and current waveforms

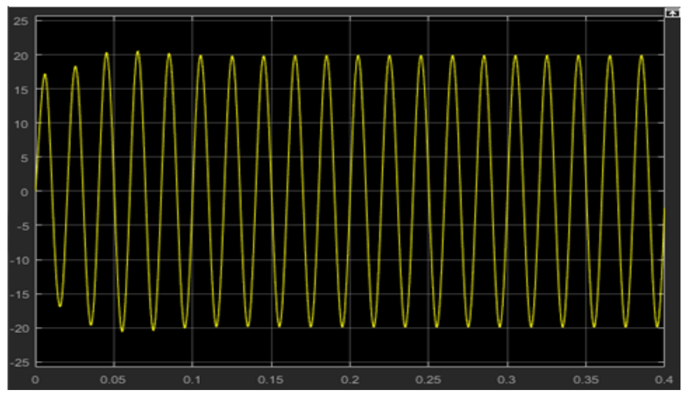

Fig. 11: Transients in Load Current

Now the three different cases are discussed, i) when load is greater than generation, means the power generation of PV solar system is 2000W and load power is 4000W then the current drawn across the load is 20A. In MATLAB due to this excess of power generation, it increases the load current shown in Fig 11.

Similarly, ii) when the load is less than the generation means load power is 1000W and the generation is 2000W then the current drawn across the load is 5A shown in Fig 12. and finally iii) when power generation is equal to the load power it draws the normal rated current 10A shown in Fig 13. A very important factor that we examined during the whole simulation is that as we were using the ideal DC source which has infinite internal resistance, therefore it was showing a high impedance.

As in our simulation, we used voltage source analysis we get the sharp peaks or currents shown in Fig 10. To overcome it VSI based current source is simulated. [9,10] The inductor is connected to the DC link. After inserting the inductor the voltage and the compensating current are shown in Figure 14.

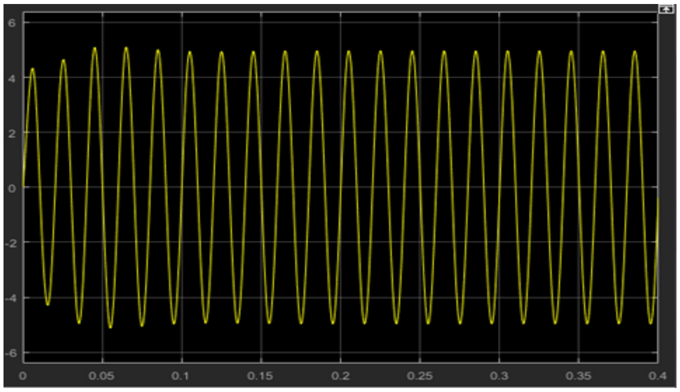

Fig. 12: Transients in Load current when load power is less than generated power

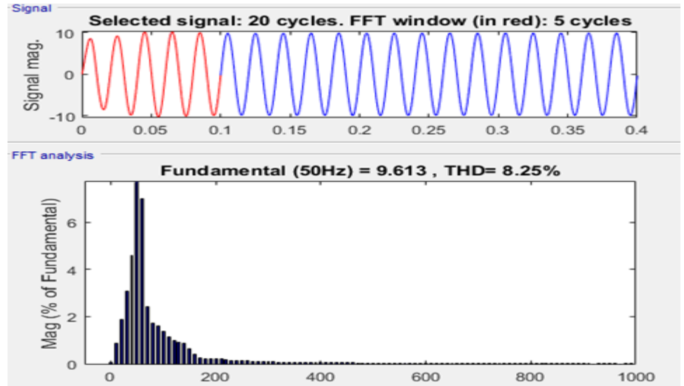

Fig. 15: THD analysis for VSI

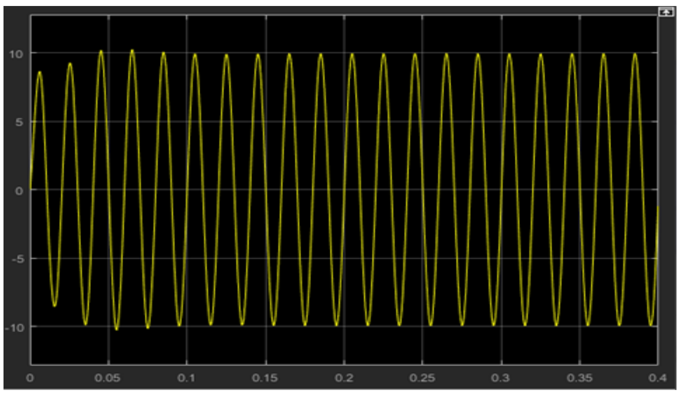

Fig. 13: Transients in Load current when load power is equal to generated power

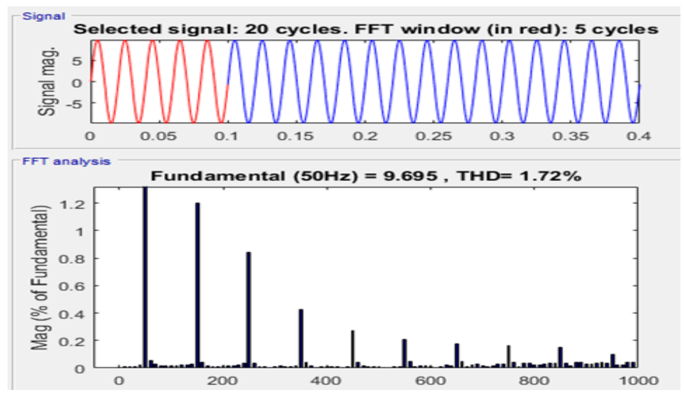

Fig. 16: THD analysis for CSI

Finally, FFT analysis is performed to calculate the total harmonic distortion in both cases using VSI and CSI and it is found that a significant difference in THD. The THD in the load current while using VSI was 8.25% for 5 cycles at 50 Hz. But in the case of CSI, it reduces to 1.72% for 5 cycles at 50 Hz. Figures 15 and 16 show THD analysis for VSI and CSI respectively.[11]

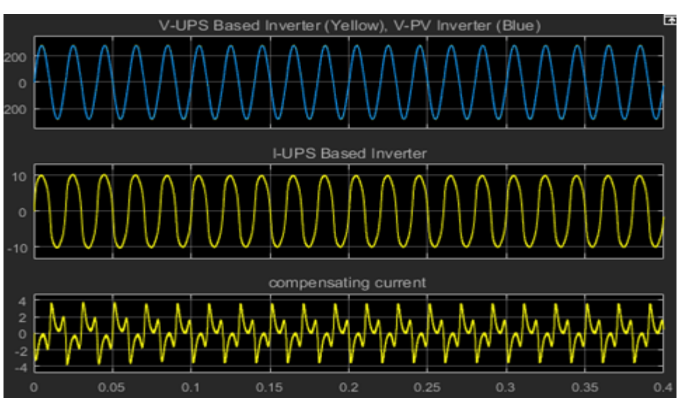

Fig. 14: Effect of inductance on voltage and current

In comparison with the state of the art, and with existing solutions, the approach and method proposed in this study distinguishes in several ways with numerous additional features. The traditional system PV systems usually rely on single and unsynchronized inverter which generates harmonic distortion, and instability with variability in the load. The proposed work utilizes two synchronous inverters; one is for solar and the other is for UPS, and with PLL configuration. The inclusion of internal resistance helps in increasing the stability of DC link voltages, and the VSI to CSI transition increase illuminates the effects of harmonic distortion. The massive reduction in the total harmonic distortion from 8.25% to 1.72% ensures the excitation with superior quality of power in low irradiance conditions and load variations. The proposed method improves the reliability, adaptability, and efficiency of the system as compared to the existing methods and approaches. This innovation contributes to lining the proposed design, the well suited for decentralized solar power applications.

5 FUTURE DIRECTIONS

To improve the stability of voltage source inverters under dynamic load conditions, more studies can concentrate on refining synchronization algorithms. Using cutting-edge control techniques, such as adaptive controllers or machine learning, may enhance system responsiveness and lower energy losses. Furthermore, investigating hybrid systems that incorporate other renewable energy sources, like wind, may offer guidance on how to create grid-tied systems that are more resilient and dependable. Last but not least, carrying out large-scale simulations and real-time implementation studies in a range of weather and grid situations could confirm the suggested approaches and guarantee wider application in a variety of operational scenarios.

6 CONCLUSIONS

In this paper, the power flow analyses are discussed across the load feed by two voltage source inverters when the load varies. One inverter is based on PV-system and the other is based on UPS. PLL has a great impact on controlling and synchronizing the voltage phases. It is found that the current varies across the load as the power generation changes throughout the whole day. Also, it is analyzed that the THD in the load current while using VSI was 8.25% for 5 cycles at 50 Hz. But in the case of CSI, it reduces to 1.72% for 5 cycles at 50 Hz.

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