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Analysis of Voltage Source Inverter with Photovoltaic Renewable Energy Source for Improving Power Quality in Solar

K. Hazee Shabbeer Basha[1], S. Solomon Raj[2], S. Sivakumar[3], M. Padmarasan[4], G. Laxmaiah[5], K. Bharath Raj[6]

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Abstract: Power quality analysis are based on converter technique and grid connected linear, nonlinear loads. Power quality Contains different issues: stability, reliability, and THD (Total harmonic distortion). In the existing Perturb and Observe (P&O) algorithm technique and Cascaded Multilevel Inverter (DC-AC) methods have low distortion and power losses. So, to overcome problems the Power point maximum tracking based Incremental Conductance (IC) algorithm and Voltage Source Inverter (VSI) are to improve the energy generated by the cause of voltage distribution. The input source is a photovoltaic (PV) power generating unit of fundamental power generation calculated based on irradiance temperature. MPPT tracks the input voltage and produces maximum power output within particular conservation environments. The IC algorithm controls the MPPT output for proper pulse width modulation and regulates the interlope control. The DC–DC converter operates both bucks and boost for given proper conversion technique in inverter and output load. A voltage Source Inverter (VSI) converts DC to AC, which operates the switching operation based on pulse width modulation; the switching operation of the duty cycle continues to move in the opposite direction from that of the interruption when the whole system is at the right opposite end of the Power point maximum tracking for the positive structure working directions. The output result gains better maximum output voltage, reduces harmonics distortion and improve power quality.

Keyword: *MPPT (Maximum Power Tracking), Incremental Conductance (IC), Voltage Source Inverter (VSI), Photovoltaic.*

1.Introduction

An inverter is an electronic device that converts direct current from an energy source solar panel into alternating current. This conversion is necessary when equipment or devices require AC power, but the available power source is DC. An inverter is often used in a variety of applications, including powering home appliances, electronics, and off-grid. The main function of a power inverter is to change the voltage and waveform of the electrical output. Inverters can produce a changed sine wave, a clean sine wave, or other waveforms depending on the specific application requirements. Pure sine wave inverters are preferred for sensitive electronic devices because they provide clean and stable current similar to grid distribution.

[1]*Assistant Professor, Department of Computer Science and Engineering, Madanapalle Institute of Technology and Science, Andhra Pradesh 517325. Email: khsb1987@gmail.com*
[2]*Associate Professor, Department of Mechanical Engineering, Chaitanya Bharathi Institute of Technology(A), Gandipet, Hyderabad-75, Telangana, India. Email: solomonraj_mech@cbit.ac.in*
[3]*Associate Professor, Department of Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Saguthala R&D Institute of Science and Technology, Avadi, Chennai, Tamil Nadu, India – 600062. Email:siva.carthick@gmail.com*
[4]*Associate Professor, Department of Electrical and Electronics Engineering ,Panimalar Engineering College, Poonamallee, Chennai, Tamil Nadu Email:padmarasanmathi@gmail.com*
[5]*Professor, Department of Mechanical Engineering Chaitanya Bharathi Institute of Technology, Hyderabad, India, Email:glaxmaiah_mech@cbit.ac.in*
[6] *Assistant Professor, Department of Physics, Girraj Govt College, Nizamabad, Telangana-503001.Email. kbraju111@gmail.com*

VSI Inverter is a kind of power electronic converter that customs multiple DC voltage sources to produce a multilevel output voltage waveform. The concept of multilevel inverters is to connect several power cells or H-bridge inverters in series to achieve a stepwise approximation of a sine wave. Each H-bridge inverter contributes to the total output voltage, generating part of the waveform. By adjusting the modulation of each inverter, the combined output can be very similar to a sine wave shape.

The multilevel structure can improve efficiency and reduce switching losses compared to traditional inverters that operate at higher switching frequencies. Multilevel inverters are used in renewable energy systems, motor drives, FACTS (flexible alternating current transmission systems), and other high-power applications where high-quality voltage waveforms are important. A voltage source inverter (VSI) is an electronic device that converts direct current (DC) current into alternating current (AC). This procedures power electronic switching devices such as isolated bipolar gate transistors (IGBTs) or Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) to switch the DC voltage on and off rapidly.

VSIs are frequently recycled in many applications, such as motor drives, renewable energy systems, and UPS sources. The main function of a VSI is to yield a variable frequency AC output from a fixed DC voltage source. DC voltage is usually obtained from a rectifier circuit that converts AC power from a power source or DC source. VSIs provide precise control of the output voltage, which is important in applications such as motor drives, where the speed of the motor can be controlled by adjusting the frequency of the AC output. VSIs are widely used in variable-speed motor drives to control the speed and torque of AC motors. Inverters are used in renewable energy systems (such as solar and wind drive) to convert direct current electricity shaped by solar panels or other power generation source into alternating current electricity that is used in power grids. VSIs are also used in UPS systems to provide a stable AC power supply during power outages.

1.1 Objective

- To produce an efficient power source and better power-producing system using Photovoltaic (PV)
- To track the power maximum after PV and control the buck/boost operation using Power point maximum tracking and Incremental Conductance (IC) algorithm.
- To decrease the voltage fluctuations and regulate the output power, use a voltage source inverter (VSI).

To reduce switching losses in each stage of switching operation and operating condition in VSI.

2. Previous Research Work

2.1 Voltage Source Inverter (VSI)A predictive modified control current approach is proposed for a voltage source inverter (VSI). The technique replaces the conventional model predictive controls selected zero vectors with two active vectors, V1 and V4, during specific time intervals (T1 and T2) within a single sampling period (Ts). The harmonic performance and reduced common mode voltage (CMV). The effectiveness of the suggested switch scheme is estimated through mathematical simulations conducted by. The results indicate a significant improvement, with the Total Harmonic Distortion (THD) decreasing from 3.57% to 3.38%, reflecting a 19% enhancement. Additionally, there is a decrease in the collective mode voltage from ±Vdc/2 to ±Vdc/6 [1].

Power quality is a major worry in VSI-based systems grid-linked renewable source arrangements and manufacturing efforts, with PWM method selection impacting total harmonic distortion (THD) and power damage. Current PWM methods frequently have substantial THD and power loss concerns. PWM approaches, the proposed hybrid PWM methodology delivers much reduced filtered voltage THD (Total et al.) at 0.89% and filtered current THD at 0.69%. Under filter-free conditions, however, the proposed hybrid PWM approach achieves reduced THDs of 45.77% for inverter output voltage and 12.50% for current, outperforming current PWM strategies. Furthermore, as compared to current PWM performances, this hybrid PWM process efficiently minimizes switching and conduction power damages in the Voltage Source Inverter (VSI). [2].

One possible strategy is to use a robust control design technique, which leads to the selection of a continuous gain that reduces the closed-loop transfer function's norm under parametric insecurity. In contrast to a gain-arranged controller, which can respond to changes in system dynamics, a constant gain robust controller cannot. Another issue with steering control is nonzero rudder offset state error. [3].

With the limits of double-loop voltage control, a more optimum solution in the form of a single-loop Proportional Integral (PI) is provided. When applied to a single-segment VSI track feeding resistive, inductive, and nonlinear loads, this controller, developed from the PR controller, improves dynamic responsiveness and provides a clean sinusoidal waveform. The suggested system's performance is evaluated using a single-loop PI controller for a single-phase VSI circuit with an LC filter, with a target output voltage of 230 V (RMS) at 50 Hz. Notably, the system maintains a steady-state inaccuracy of 1.067% while achieving a low voltage Total Harmonic Distortion (THD) of 0.039%. Based on a switching occurrence of 5 kHz and a resonance rate of recurrence of 1.1 kHz, transfer utilities are calculated. [6].

Impedance network inverters strive to deliver the benefits of a two-stage system while reducing the number of power conversions and addressing the difficulties associated with traditional inverters. Examines many impedance network inverters and emphasizes their fundamental structures in terms of solar applications. Evaluating acceptable control mechanisms for impedance source inverters in terms of mathematical performance and complexity examine the essential control strategies for linking network voltage and inverter output current, as well as the obstacles and future path. [9]. In addition, the suggested power converter layout allows better use of the voltage across the DC bus than a standard ANPC converter. The proposed inverter incorporates a high-frequency transformer to address the voltage balance issues encountered by typical ANPC inverters. Galvanic isolation is one benefit of the proposed magnetic-connected power exchange. [11].

The PV energy conversion is expanding in both residential and business environments. Power inverters are necessary for these PV systems to interface with the electrical utility. The material in this scenario aims to improve equipment performance by using a modelling PV inverter to address the power disturbance. Disturbance-observation regulators for the DC-link voltage and the current inverter output make up the control system. [12].

Harmonic distortion, Electromagnetic Interference (EMI), and high dv/dt are all introduced by this method. Because two-level inverters have limits, multilayer inverters (MLIs) are finding preference in MLIs create output voltages with many levels by using several DC voltages as supplies, resulting in a smoother waveforms. The diode-clamped multilevel inverter (DC-MLI), cascaded H-bridge multilevel inverter (CHB-MLI), and flying-capacitor multilevel inverter (FC-MLI) are all notable MLI types that may be simulated using the power system CAD (PSCAD). Higher-level arrangements, such as the five-level FC-MLI, provide benefits such as lower power dissolution, lower the presence of harmonics and lower total harmonic distortion (THD), as demonstrated by a reduction from 28.88% (three levels) to 18.56% (five levels). [13].

A voltage source inverter (VSI). QZSI also provides grid-connected single-stage PV transformer less systems with improved conversion characteristics. Due to the lack of galvanic isolation in these systems, the Common-Mode Voltage (CMV) created inverter output voltages' Pulse Width Modulation (PWM) allows leakage current to travel through their parasitic capacitances linked. As a result of this current, PV systems may have major security difficulties. Many PWM solutions for QZSI have been presented in recent years, and the bulk of these PWM systems exhibit leakage current features. In this work, closed-form methods for calculating effective CMV and leakage current were established. [16].

A three-phase or single-phase modular cascaded H-bridge multilevel photovoltaic (PV) amplifier that is connected to the grid. A distributed maximum power point tracking controlling technique is used by both single-phase and three-phase multi-level inverters. This strategy enables the independent management of each DC-link voltage to enhance PV module performance and optimize solar energy collection. PV imbalances in three-phase grid-connected systems may lead to unequal supplied power, which may lead to unequal grid current. [20]

2.2 Cascaded multilevel inverter

N repeating units and a Level Boosting Circuit (LBC) combine to form MLI, which generates 4n + 7 voltage levels as opposed to 2n + 3. A comparative is performed to determine the superiority of the generated MLI. The feasibility of the proposed MLI is examined with a 1.3 kW photovoltaic. With regard for a 15-level MLI structure, the closed-loop control system allows for maximum power tracking, DC-link voltage balancing, proper MLI functioning, and injection of a harmless sinusoidal grid electrical current during any dynamic fluctuations. [4].

The 3L-SI-NPCI2 demonstrates the working value, dynamic performance, output filter design, and leakage current effects of asymmetric filter inductors. As a result, for some configurations, leakage current, serious issues with transformer-less PV inverters, can be reduced. Furthermore, those topologies have several advantages over two-level ones, such as low distortion, limited voltage transient dv/dt, higher output voltages with the same device evaluations, small size demands for filter variables high system performance, and lower common-mode voltages that are substantial. [5].

Asymmetric multilevel inverter employs fewer switches and drivers than a conventional construction. The durable analogy concerns traditional inverter topologies with comparable construction. MLI has a suitably basic design and is simple to expand for a range of output levels. MLI is designed for a 15-level output with an accurate and superior sinusoidal waveform using seven switches, three DC resources, diodes that reduce ON state semiconductor switching devices; total harmonic distortion (THD) metric used evaluate MLI's outputs. [7].

The passive LC decoupling methodology eliminates the double-frequency oscillation on the DC connection. However primary DC-link capacitor and the LC circuit may occur; this may be reduced by employing active damping approach. Furthermore, the proposed SOSMC ensures high DC-link voltage stability, upright steady-state dynamic performance (voltage variation and resolving interval), and high precision, all of which are beneficial to MPPT switch in relations of rapid dynamics. A detailed parameter optimal SOSMC design is offered. [8].

Other recent converters were pitted against the switched-diode multilevel converter, and a novel DC offset nearest level modulation approach was also introduced. When compared to standard Closest Level Modulation (NLM) and modified NLM control systems, this recommended DC offset solution provides low voltage Total Harmonic Distortion (THD) and RMS yield electrical energy. The proposed DC offset modulation technique, which employs unique switching capacitor-diode multilevel converters, was built and evaluated using an FPGA Spartan 3E controller. [10].

In grid-connected photovoltaic plants, inverters are critical in converting electrical drive from DC to AC already solar electricity is released into the grid. Because of its particular characteristics, such as its capacity to tolerate high voltage and create a staircase sinusoidal voltage at its output, the inverter is linked to the primary winding of the high-frequency magnetic link. Using magnetic-link (no voltage step-up) technology, galvanic isolation is assured, and several power sources may be created, balanced, and isolated from a single source. The rectifier unit generates an isolated DC foundation for the H-bridge by converting improve-frequency AC control into DC voltage. [14].

The foundations of the reduced switch count constructions include bidirectional switches, modified forms of the buildings' polarity and level generation-based structures, reduced switch count structures, and hybrid topology structures. In comparison to 48 switches in CHBMLI, a 3 nine level inverter requires 24 switches, with eight switches in each phase. For both symmetric and asymmetric DC voltage supply, this Total Harmonic Distortion (THD) level is examined utilizing PWM approaches. The THD results of the proposed MLI are compared to those of existing reduced switch topology architectures. [15] - [17].

The switches have a Common Emitter (CE) setup and are bidirectional. Additionally, a specific-driver circuit is employed to regulate the switches. Consequently, there are now just 10 instead of 14 gadgets. In order to provide 27 levels of output voltage, 14 switches are needed. Six unidirectional switches make up the reduced design of the proposed asymmetric multiple-level inverter four bidirectional switches, and five DC sources. Internal conduction frequencies for positive and negative load flows are separate. These configurations provide independent current control. [18].

The Harmonic Elimination Pulse Width Modulation (SHE-PWM) technique manage the directions of PV-based 5-level and 7-level CHB-MLI. Using a P&O MPPT regulator, the boost converter gives or creates the highest power feasible to be transferred to the proposed inverter. This controller runs the switch at a higher switching frequency, causing the switch to enter a duty cycle and provide the greatest potential output power. Within the boost converter, an IGBT switch, a capacitor, an inductor, and a diode are all connected. A capacitor in this boost converter removes any ripples in the amplitude of the output voltage. [19].

A critical characteristic from the featured data and minimise the dimensionality of features, the Vector Space Bag of Words (VSBW) approach is applied. In addition, a weighted feature matrix is utilised to identify the various sorts of intrusions utilising a novel classification method known as Boosted Variance Quantization Neural Networks (BVQNNs). During categorisation, a Multi-Hunting Reptile Search Optimisation (MH-RSO) method is used to determine the probability value for making the best decisions while expecting incursions [20].

Furthermore, the primary goal of sign language recognition technology is to facilitate communication between the deaf and the dumb. For hand gesture detection in traditional works, a variety of image processing techniques are used, including segmentation, optimisation, and classification. However, it takes more time and restricts the main issues of inefficiently processing huge dimensional information [21].

2.3 Problem statement

- Low reliability and improved power quality in grid linked Photovoltaic systems using Common-Mode Voltage (CMV).
- The accuracy is low in Maximum Power Tracking and booting conversion using perturbation observation (P&O)
- Small voltage regulation while operating pulse width modulation using Active neutral-point-clamped (ANPC).
- High switching losses in grid-connected inverters when compared to the convolutional Method in each switch control technique.

3. Materials and Method

Two distinct cascaded multilevel inverters—a voltage source inverter (VSI) and a comparative analysis using total harmonic distortion, or THD—are analyses. The functions of an inverter are to convert DC power to AC, control the effective output voltage, and shape the waveform of the AC electrical output. For solar power applications, an inverter's dependability and efficiency are crucial characteristics. They are designed to maintain a photovoltaic system continually working at or close to its maximum power point. High-switching-frequency inverters run on semiconductor power sources that switch at frequencies of at least 20 kHz.

3.1 Cascaded Multilevel Inverter

The input source consists of PV modules, a DC/DC converter, a Cascaded Multilevel DC/AC power inverter, and a grid-connected output. Every PV array string has a maximum power point tracking DC/DC Buck/Boost converter installed. The weather continuously affects the power output of the PV modules since the total amount of irradiance varies throughout the day. The Perturb and Observe method is used to calculate the PV array's maximum power. The PV array's DC power is enhanced using a DC-DC boost converter and DC bus capacitors.

$$\mathrm{NL} = 2\mathrm{s} + 1 \qquad (1)$$

Each cascaded inverter may create three different voltages by opening the corresponding switches: +Vdc, 0 Vdc, and –Vdc. This lookup table makes it simple to identify which switches are on and off at specific times, which makes it simple to create a switching pattern. For example, S1 and S3 will be activated, and the diode will be forward-filtered to obtain the V1 voltage as a result. Switches that are turned on are represented in ones in the lookup table, while switches that are turned off are represented in zeros. The diode will stop current backflow because it is a unidirectional component

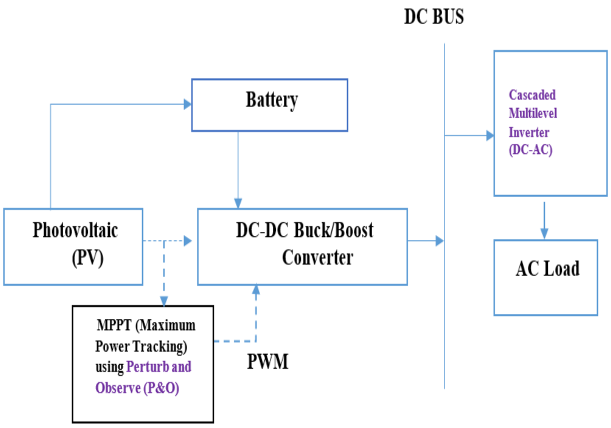

Fig 1. Cascaded Inverter with Photovoltaic System

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Table 1. Comparison and analysis of different multilevel inverter

	Algorithm Technique	**Level of Inverter**	**THE**
1	Nine-Level Active Neutral Point Clamp Inverter [11]	Predictive Control Technique	13.99%
2	Modular Cascaded H-Bridge Multilevel inverter (MMC) [20]	Distributed MPPT Control Scheme	4.2%
3	Cascaded Multilevel Inverter (CMI) [12]	Perturbation-Observation (P&O)	3.23

3.2 Propose Method of Voltage Source Inverter (VSI)

A Voltage Source Inverter (VSI) is a scheme that changes a unidirectional voltage pattern a bidirectional voltage output or a converter that converts a voltage from DC to AC mode. A reliable voltage source inverter continues a constant voltage through the operation. A voltage source inverter is a caused electrical device that operates on the pulse width modulation concept. It accepts DC electricity and converts it to AC power using complex circuitry.

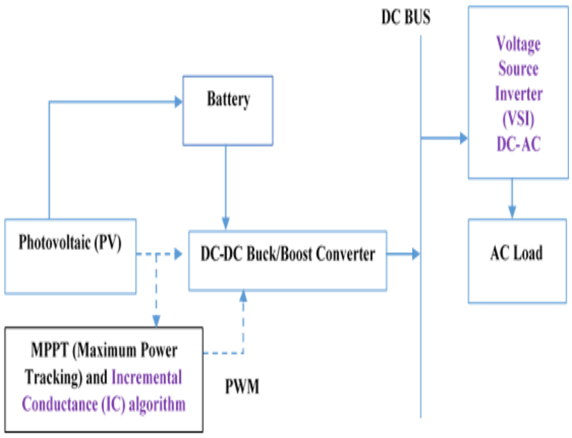

Fig 2. Voltage Source Inverter (VSI) with Photovoltaic System

The alternating current waveform is created via the switching action. Depending on the application, 3phase VSI may include six switches such as IGBTs, MOSFETs, and GTOs. In this situation, the feedback devices linked across switches S1 through S6 will return the collected power from the induction load to the DC supply. If the necessary gate signals are provided to the switches, three-phase VSI receives DC power as input and converts it to AC power. To maintain the harmonics, a large capacitor is sometimes installed at their input terminals and fed back to the DC source.

Switching the DC voltage on and off at a high frequency creates a waveform that mimics AC. This waveform is subsequently filtered and bent to generate a clean and steady alternating current output. Harmonic Injection increases the quality of the output waveform, and predefined harmonic components are added. Whatever approach is put to use, it is critical to properly control the switching transitions to prevent harming the VSI or linked devices.

Table 2 comparison analysis of different inverter and controller technique.

	Algorithm Technique and compare with inverter technique	**Converter Technique**	**THE**
1	Lyapunov theory [9]	DC-AC Inverter	5%
2	second-order sliding-mode control (SOSMC) [8]	single-phase grid-connected PV inverter	2.06%
3	Power point maximum tracking and Incremental Conductance (IC) algorithm **[proposed Method]**	Voltage Source Inverter (VSI) DC-AC	1.42%

4. Result and Discussion

The MATLAB simulation is based on a PV, Voltage source inverter for input voltage power system is generated by the solar panel. By using a buck-boost converter, the solar array's final voltage is increased to the necessary amount. When compared to other DC-to-DC the buck/boost gains an output including a PWM operation and a shorter operational duty cycle. Because the irradiance raises the cell temperature, the lowest DC voltage will be observed at high ambient temperature and high irradiance; this impact outweighs the rise in ideal voltage brought on by a rise in irradiance at constant cell temperatures and Dynamic and responsive power control the base of the VSI inverter management.

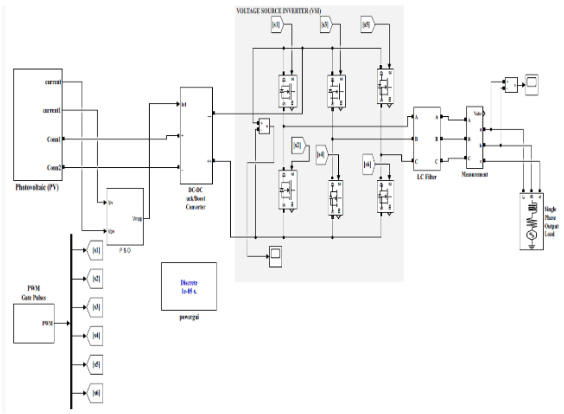

Fig 3. Simulation output-based PV input source and Voltage Source Inverter (VSI) are developed using Mat-lab Simulink.

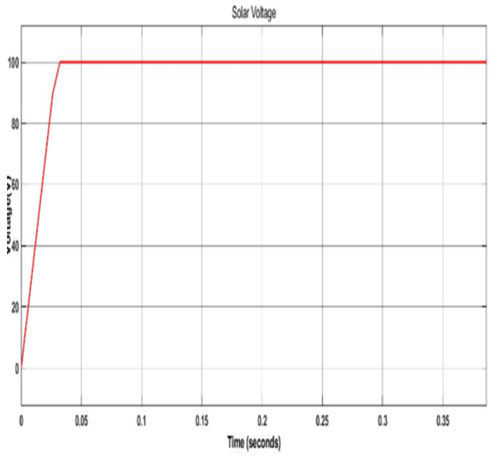

Fig 4. Voltage output waveform of PV The figure 4 shows 4 PV output voltage that generated input is 100 V gain from Temperature 25 and irradiance 500.

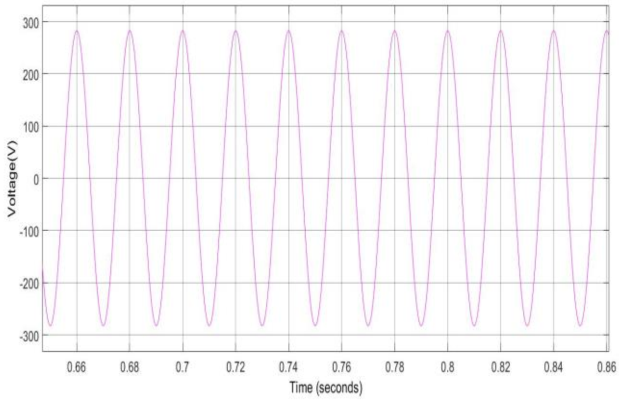

Fig 5 Single phase Output waveform of VSI

Figure 5 shows the output waveform is 230V achieved from the DC-AC inverter

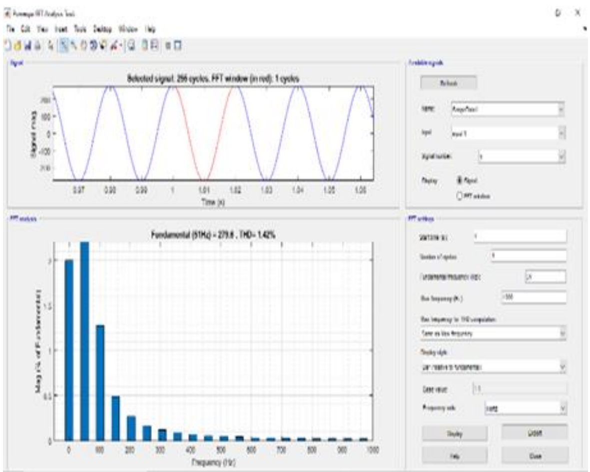

Fig 6 THD output taken from single-phase inverter output

Figure 6 measures the THD result by 1.42 %, which was obtained by calculating the distortion level using voltage. A signal pattern that is an integral multiple of the reference signal is referred to as a harmonic here. Subsequently, it can instead be described as the ratio of the signal's wavelength to the reference signal's value.

5. Conclusion

The photovoltaic renewable energy source-based grid power system is an analysis of Voltage Source Inverter (VSI) DC-AC. In this suggested approach, the THD may still be eliminated with the use of controls that maintain the magnitude and fundamental voltage, as well as the Incremental Conductance (IC) algorithm method controller. An MPPT is essential to adjust the output voltage level because the solar array's output is somewhat low. In this suggested approach, the THD may still be decreased with the use of controls to maintain the magnitude and fundamental voltage, as well as the Incremental Conductance (IC) algorithm method controller. When compared to the Cascaded Multilevel Inverter (CMI) THD 3.23%, the proposed THD output is 1.42 % is improved. Comparing two different inverters with buck-boost converter and solar, have been examined and modeled using real time data.

5.1 Future scope

In the future, CNN (Convolutional neural Network) based MPPT will track the maximum power, and a buck-boost converter will increase the output voltage at the outflow of the output current. The CNN-powered inverter controls and evaluates grid power and PV array strength, which serves as the input for the neural network's 2-layer function approximation. The data is inferred by the neural network, which sends it to layer 1. After being processed, the output of layer one is converted into data in the opposite direction and given to the control system, where it serves as the input for the layer. The THD output and switched inverter control system examine the measured values and generate a pulsing output.

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