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Total Harmonics Distortion Performance Analysis between Micro-Inverter and Single Phase Inverter Photovoltaic Systems

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Abstract- Before the direct current (DC) input voltage can be turned into alternating current (AC), each of the current topologies of solar micro inverters uses a number of steps. One or more power converters could be built into each of these stages. A transformer, a filter, and a diode rectifier might also be in it. There are a very large number of both active and passive parts. In the scope of this thesis, a brand-new architecture for a solar micro inverter is made. This new micro inverter is made up of a new single switch inverter, which is made by changing the single ended primary inductor DC-DC converter that was already there. This new inverter can take DC power and turn it into a clean sinusoidal waveform. A lot of research is being done on how the new inverter is built and how it works. With the help of a controller, this new inverter can make almost any kind of output waveform. The inverter was found to be able to work in a total of four different ways. The new inverter was designed using a modelling method called "state space averaging." Due to the switching that is built into the circuit, the system is a non-linear fourth order system. This makes the system not follow a straight line. Before the system can be looked at as a linear system, it must be linearized around a certain point. It has been found that the inverter's control-to-output transfer function does not have a minimum phase. To find out about transfer functions, the root locus method is used. From the point of view of control, the presence of right half zero makes it harder to build the structure of the controller. The cell equations are used to make a model of the photovoltaic (PV) cell in MATLAB. The maximum power point tracking (MPPT) method is used to make sure that the PV cell's output power is always at its highest level. This lets the power from the PV cell be used to its fullest potential. The easiest way to solve this problem is to change something and then watch what happens. When you use this new inverter, you don't need the different phases that a traditional solar micro inverter needs. The proposed design of the inverter was confirmed by both simulation and the results of experiments done on the set-up.

Keywords- Microinverter Photovoltaic system Grid-connected inverter PV.

I. INTRODUCTION

The standby power loss and efficiency of the power supply are of major concern .the average efficiency instead of full load efficiency is important for external power supplies such as adaptors.

The challenge for the power supply design is created by the light load and full load efficiency. For offline applications fly back converters are used generally due to its simplicity and low cost. to dissipate the leakage energy when the switch is off an RCD clamp circuit is used. To minimize the voltage spikes across the switch becomes difficult with the presence of well coupled transformer with minimized leakage inductance. This results in usage of a labor Intensive manufacturing process. by reducing the leakage inductance energy loss the efficiency can be improved. The concept of interleaving enables these converter topologies to operate at increased power levels.

The benefits of interleaving include Reduced RMS current in the input capacitors enabling the use of less expensive and fewer input capacitors Ripple current cancellation in the output capacitor, enabling the use of less expensive and fewer output capacitors Reduction of peak currents in primary and secondary transformer windings. Improved transient response as a result of reducing output filter inductance and higher output ripple frequency Separation of heat generating components allowing for reduced heat sink requirements. Improved form factor for low profile solutions Reduced EMI as a result of reduced peak currents.

1. Micro inverter:

Micro inverters can be classified into four categories [8,9], such as: one-stage topology without galvanic isolation; two-stage topology without galvanic isolation; one-stage topology with galvanic isolation; and two-stage topology with galvanic isolation. Figure 1 shows the configuration of each category. In a two-stage topology, it consists of a dc-dc converter that performs the MPPT, and the dc-ac converter has the responsibility of controlling the dc-link and the control of the grid current or properly controlling the output voltage in island mode. In terms of control, the two-stage topology is simple, and the dc-dc converter also extends the operation of the photovoltaic system, leading to a decrease in overall efficiency. One-stage topologies are introduced to reduce power losses and reduce the total system volume.

On the other hand, micro inverters can also be classified by the incorporation of galvanic isolation depending on the electrical policies of each country, as well as the needs of photovoltaic installation. The incorporation of a transformer allows for the isolation of the photovoltaic generation stage and the consumption stage or the grid, with the aim that if panels fail, it does not have direct impact on the grid or on local loads. In addition, the transformer allows reaching high levels of voltage, which is required for integration to the grid; however, it leads to a reduction in efficiency reduction and an increase in the micro inverter's volume [6,8,10].However, there are certain challenges in positioning micro inverters as an attractive alternative on the market such as: to increase reliability and lifespan due to sensitivity to the temperature of the electrolytic capacitors; to increase conversion efficiency considering cutting-edge semiconductors and development of new high-gain converter topologies; and to increase the functionality of the micro inverters, adding some other tasks such as reactive power support and power supply at all times.[17-18]

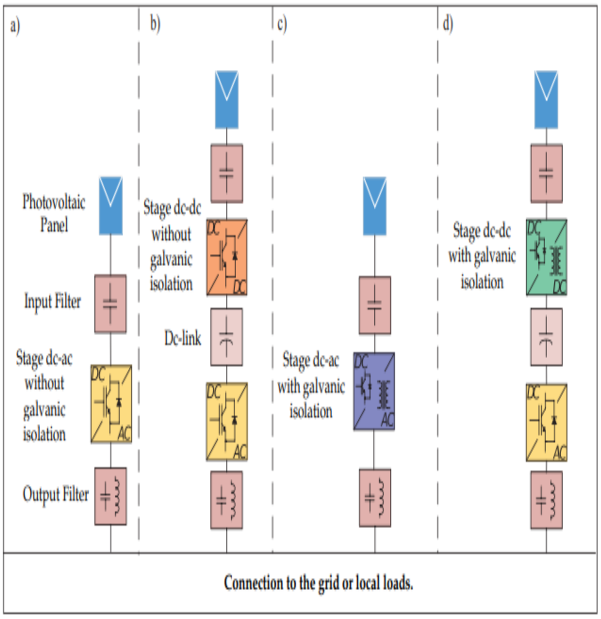

Fig 1. Classification of microinverters. (a) One-stage topology without galvanic isolation. (b) Two-stage topology with galvanic isolation. (c) One-stage topology with galvanic isolation. (d) Two-stage topology with galvanic isolation.

II. RELATED WORK

Diego Rojas et.al.2021 The use of renewable energies sources is taking great importance due to the high demand for electricity and the decrease in the use of fossil fuels worldwide. In this context, electricity generation through photovoltaic panels is gaining a lot of interest due to the reduction in installation costs and the rapid advance of the development of new technologies. To minimize or reduce the negative impact of partial shading or mismatches of photovoltaic panels, many researchers have proposed four configurations that depend on the power ranges and the application.

The micro inverter is a promising solution in photovoltaic systems, due to its high efficiency of Maximum Power Point Tracking and high flexibility.

Aydin Boyar et.al. 2020 The solar energy has become an easily accessible source for electricity generation due to its characteristics preventing pollution, decreasing the carbon emission, and lower manner of maintenance requirements. The most significant components of a photovoltaic (PV) power conversion system is the inverter that can be configured in central, string or micro topologies. Nowadays, the micro inverters which bring advantages and drawbacks are one of the most extensively researched devices. In this study, the micro inverter which is comprised by fly back converter and H-bridge sections is designed and analyzed in terms of reliability and efficiency. The switching control of fly back converter is performed by using Incremental Conductance based Maximum Power Point Tracking (IC MPPT) algorithm while switching pulses of H-bridge are generated with Sinusoidal Pulse Width Modulation (SPWM). Both simulation and implementation of the designed micro inverter have been realized in this study. The input voltage of fly back micro inverter is obtained from a single PV module at 50 V_{dc} whereas output voltage is generated at 220 V_{ac} 50 Hz for single-phase lines. The proposed fly back micro inverter which has LC filter is firstly simulated with MATLAB Simulink software. The efficiency and THD ratio of simulated micro inverter are respectively obtained as 0.35 and 94%. The performance of implemented flyback micro inverter is investigated with LC and LCL filters in terms of output voltage quality. The THD ratios of output voltage are acquired 4.41% and 2.57% with LC and LCL filters while the efficiency of designed flyback micro inverter is measured around 82.3%.

III. PROPOSED WORK

The current state of photovoltaic (PV) energy generation for residential use shows some of the problems that come with the different topologies that are being used. It gives an idea of what needs to be thought about when making a micro-inverter, which is given by the fact that it. From the review, it seems that a single-stage inverter is the best way to connect the PV panel to the utility grid. This inverter would give the power MOSFETs soft switching, which would make for a very efficient and very small solution. The main focus of this chapter is on how the primary circuit architecture works on the inside. The solar panel is an input source that is part of the proposed system. Figure 4.1 is a block diagram of the computer system that is being suggested. The voltage made by the solar photovoltaic panel is sent to the boost converter and used to make the input voltage. A ratio of 1:2 is used by the boost converter to raise the voltage. The three-phase induction motor is the load, and the multilevel inverter with PRBS switching pulse turns DC voltage into AC voltage.

The thesis's most important contribution is that

- The harmonics in the existing and proposed system is analyzed.
- The voltage and current Total harmonics distortion values are measured.

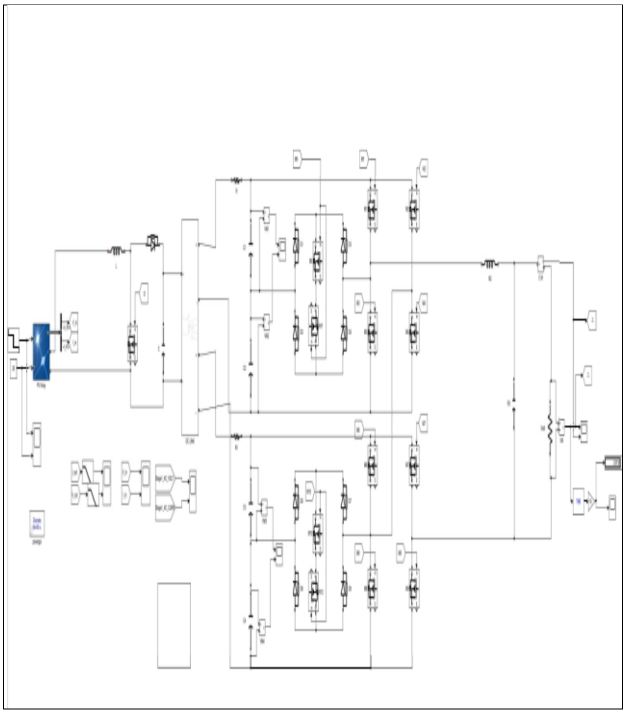

Fig 2. Simulink Model.

Micro inverters, particularly those based on the interleaved fly back converter design, are the primary emphasis. Micro inverter-based solar energy systems are gaining popularity because they are less susceptible to shading and PV cell failure because each solar panel in the system has its own low-power inverter. Micro inverters are referred to as module level power electronics. In these systems, each module is connected to an inverter that is often connected just below the panel. Each panel with a single inverter eliminates the dependence of one module's generation on other modules. Each panel is going to be independent. This type of system is most suited for locations with shadow issues on one or more modules, roofs with varying orientations, etc. In these types of systems, monitoring at the module level is conceivable. It facilitates the simple maintenance of the system. One module or inverter failure would not influence the remainder of the system's generation.

Each module's electrical properties can be monitored, and the data can be transmitted to a database center where performance details can be examined. It is of considerable benefit for solar plant management and maintenance. These micro inverters are more efficient and generate more energy than conventional string inverters. Although they are costly, they are more durable and have a longer lifespan.

This sort of micro inverter system consists of several micro inverters along the branch circuits, each injecting its own current supply and converting DC to AC power. This parallel AC output structure, as opposed to the series DC output structure of a string inverter, offers the benefit of isolating each panel. Reducing or eliminating the output of a single panel has no outsized effect on the output of the complete array. Using MPPT, each micro inverter is able to maintain optimal power for its own module.

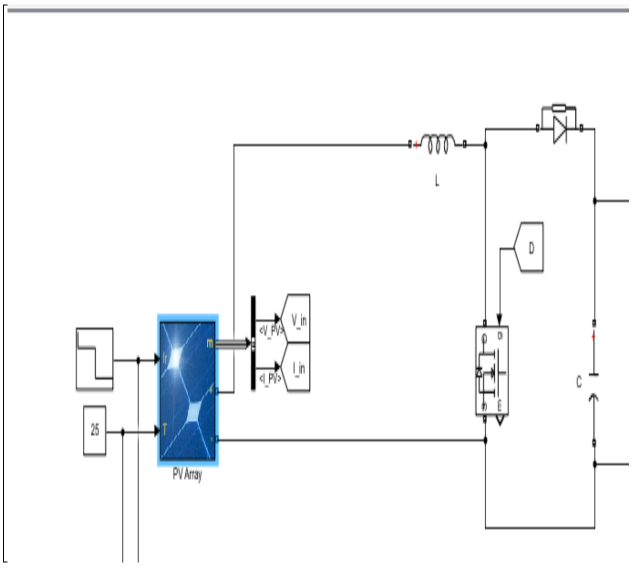

Fig 3. Solar PV panel.

In this type of system, the failure of a single panel or inverter will have negligible effect on the entire system performance. PV module manufacturers and types can be mixed, so long as they are compatible with the micro inverter. Using micro inverters enables PV modules to be managed individually, hence minimizing the risk of a decrease in system power production due to soiling, shading, or PV module problems. In contrast to a single inverter serving a whole string of modules, there is no high-voltage wiring, and inverter failures affect just a small portion of the PV system.

Installs a photovoltaic (PV) array, which is made up of parallel strings of PV modules. Each string is made up of modules that are linked to each other in order. The NREL System Advisor Model (Jan. 2014) has a number of predefined photovoltaic modules that can be simulated. Users can also create their own PV modules that can also be simulated.

Input 1 = Sun irradiance, in W/m2, and input 2 = Cell temperature, in deg.C.

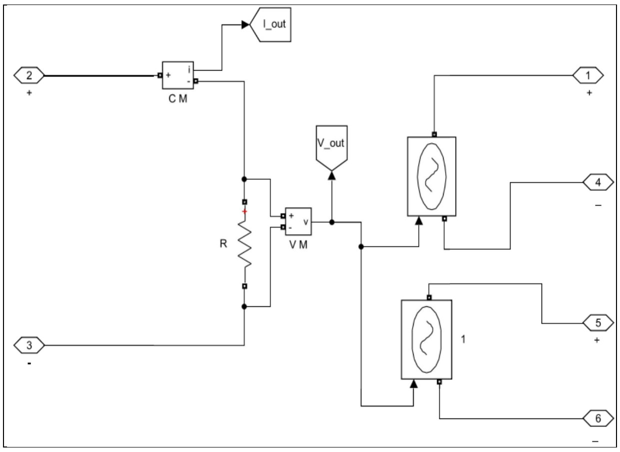

Fig 4. Current controlled source.

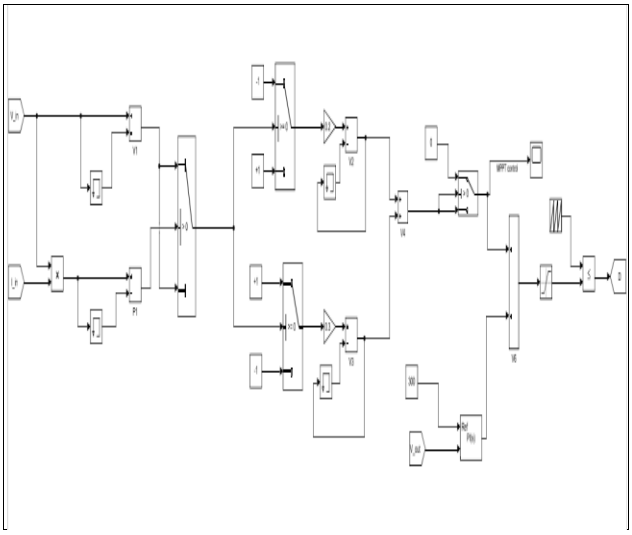

Fig 5. MPPT Controller.

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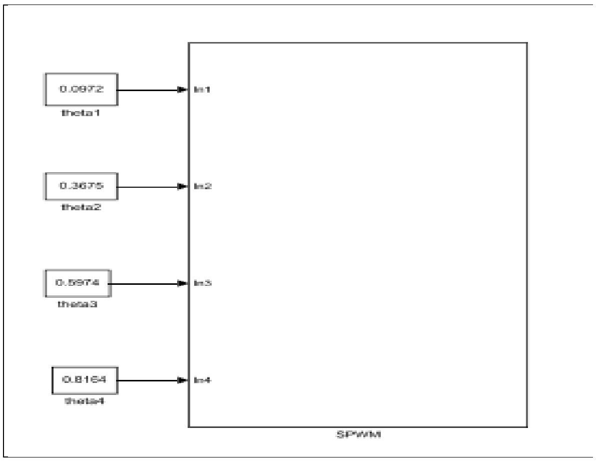

Fig 6. SPWM.

1. SPWM:

An inverter takes an input of direct current and creates an output of alternating current voltage. It does this by employing switching circuits to replicate a sine wave by producing one or more square voltage pulses during each half cycle of the input current. If the distance between each pulse is varied, then the output is said to be pulse width modulated. Each half-cycle of this modulation results in the production of a certain amount of pulses.

The widths of the pulses correspond to the equivalent amplitude of a sine wave during that period of the cycle, and the pulses that are closer to the extremes of the half cycle are consistently narrower than the pulses that are closer to the center of the half cycle. In order to adjust the output voltage, the pulse widths are either magnified or reduced, but its sinusoidal proportionality is preserved throughout the process. Only the on-time of the pulses' amplitudes are altered when using a technique known as pulse width modulation (PWM).

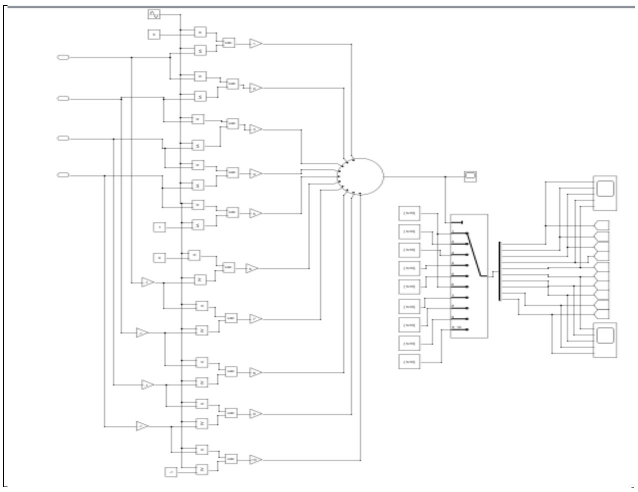

Fig 7. Switching Pulses Subsystem.

IV. SIMULATION RESULT

1. Micro inverter:

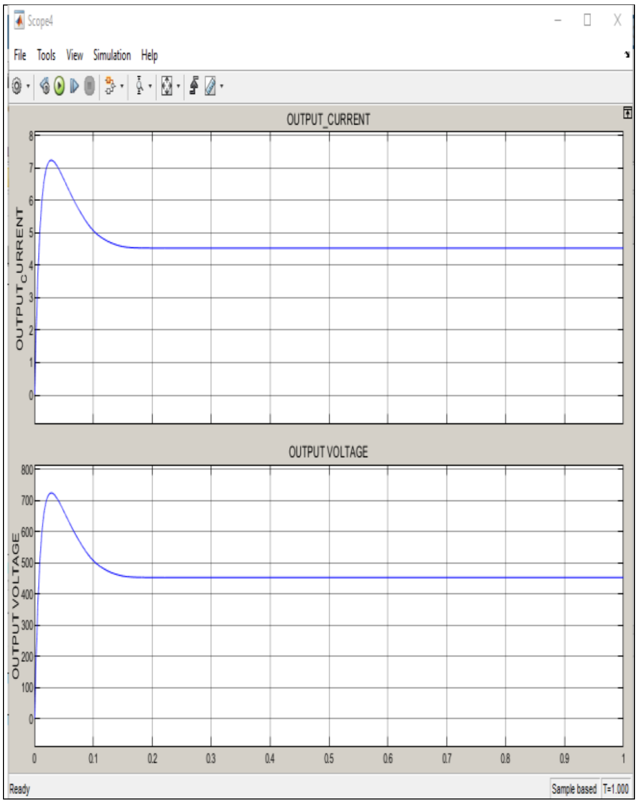

Fig 8. Output current and output voltage results.

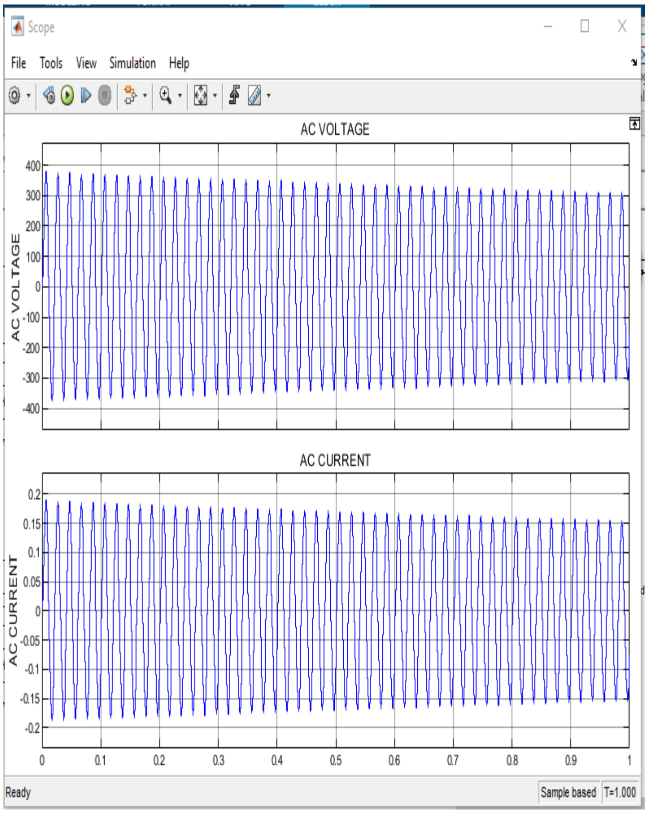

Fig 9. AC current and AC voltage current result.

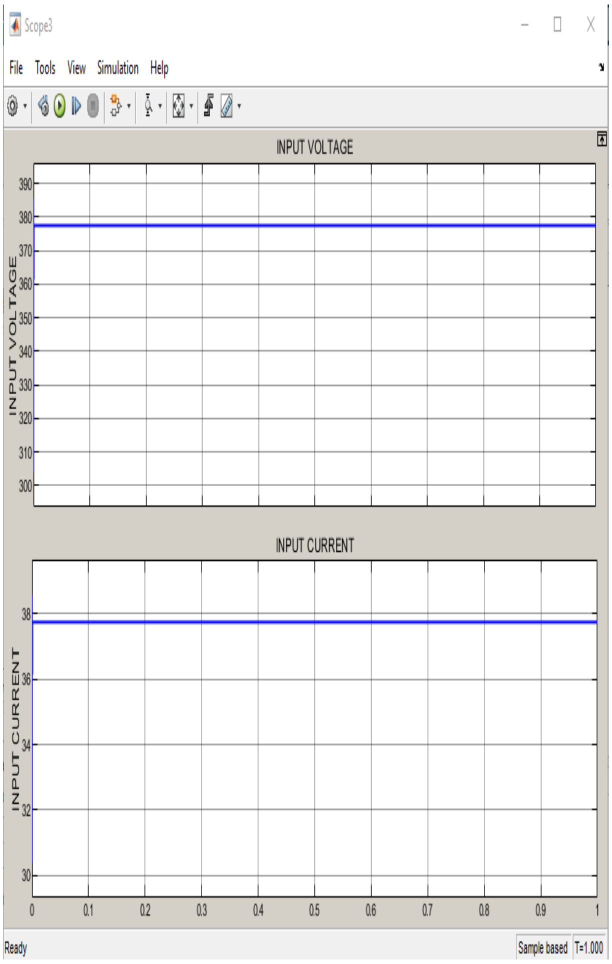

Fig 10. Input voltage and input current.

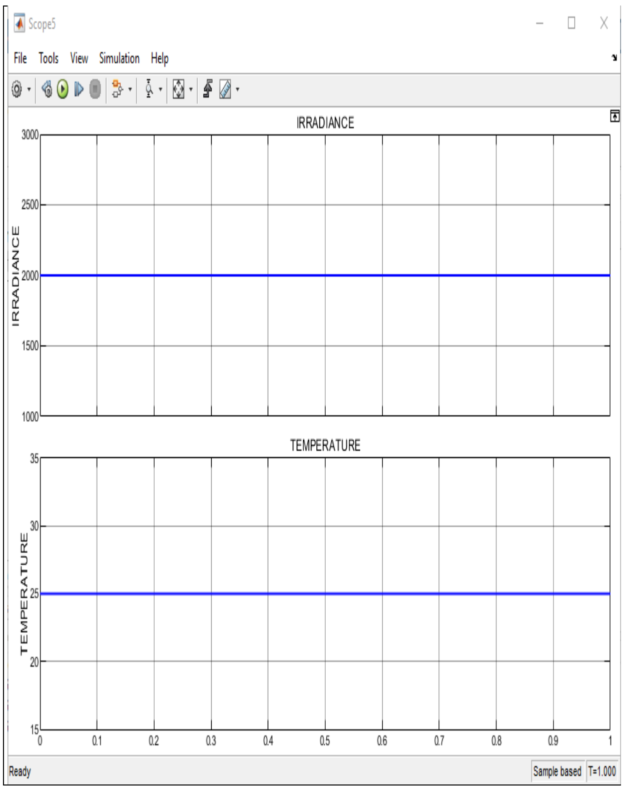

Fig 11. PV temperature and irradiance scope.

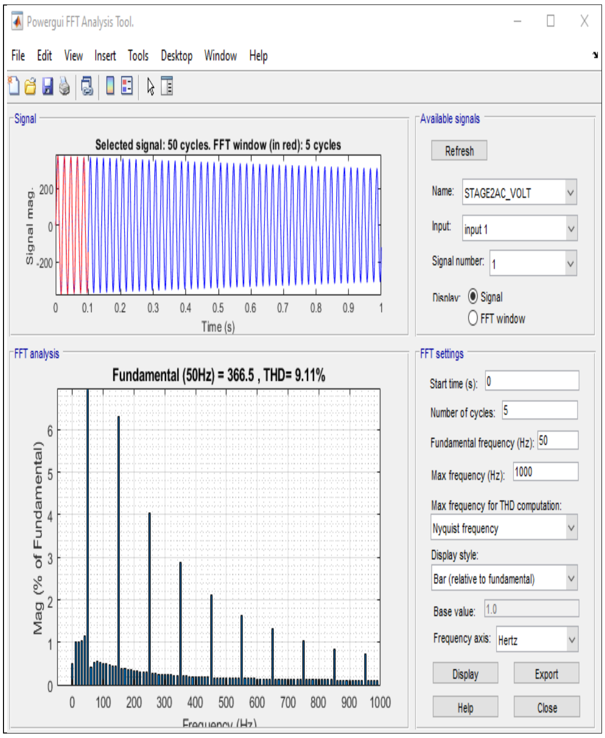

Fig 12. THD performance for multistage Micro inverter.

2. Single Micro Inverter:

The proposed inverter is composed of a DC-DC boost, a DC-AC conversion, voltage and current acquisition, data processing, and an MPPT controller. The block diagram of the system is depicted in figure 13. Maximum power point is tracked using the perturb and observation techniques). In the second stage, the H-bridge topology is employed. Inner current loop and outer voltage loop regulate the amplitude of the inverter's output current. LCL is the output filter type.

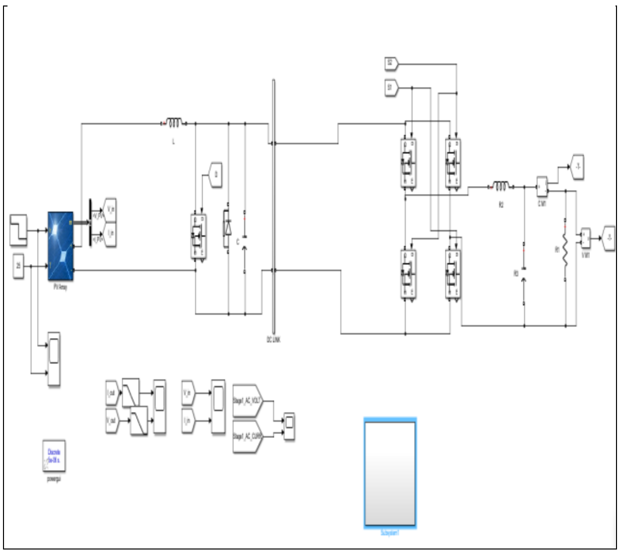

Fig 13. Single Micro Inverter Simulink Model.

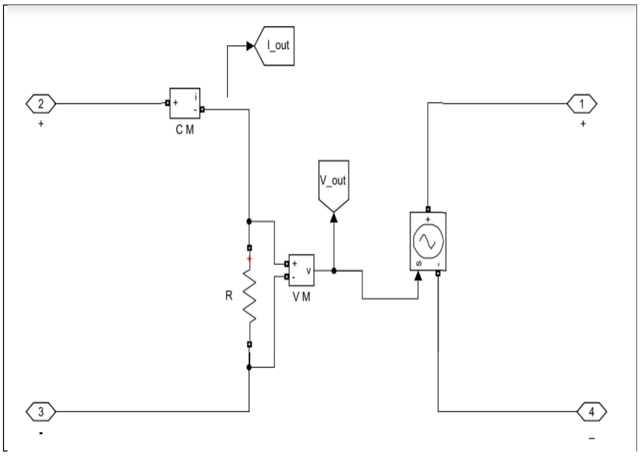

Fig 14. DC link subsystem.

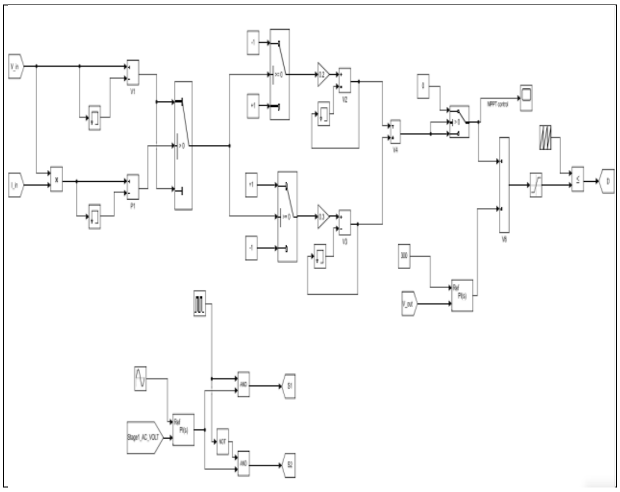

Fig 15. MPPT Controller.

3. Single Micro Inverter:

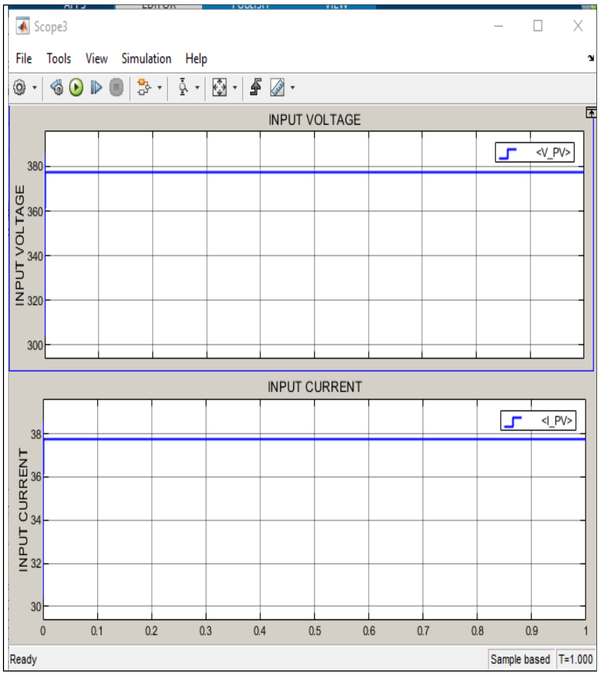

Fig 16. Input voltage and input current.

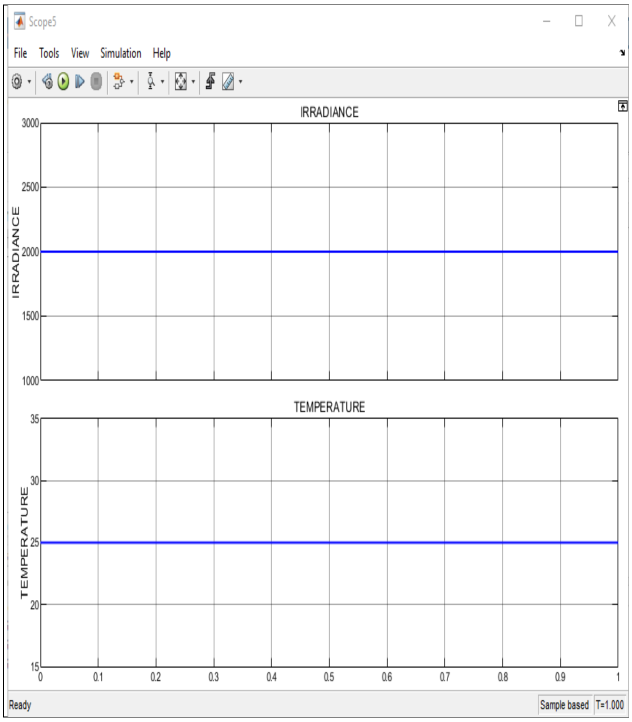

Fig 17. PV temperature and irradiance scope.

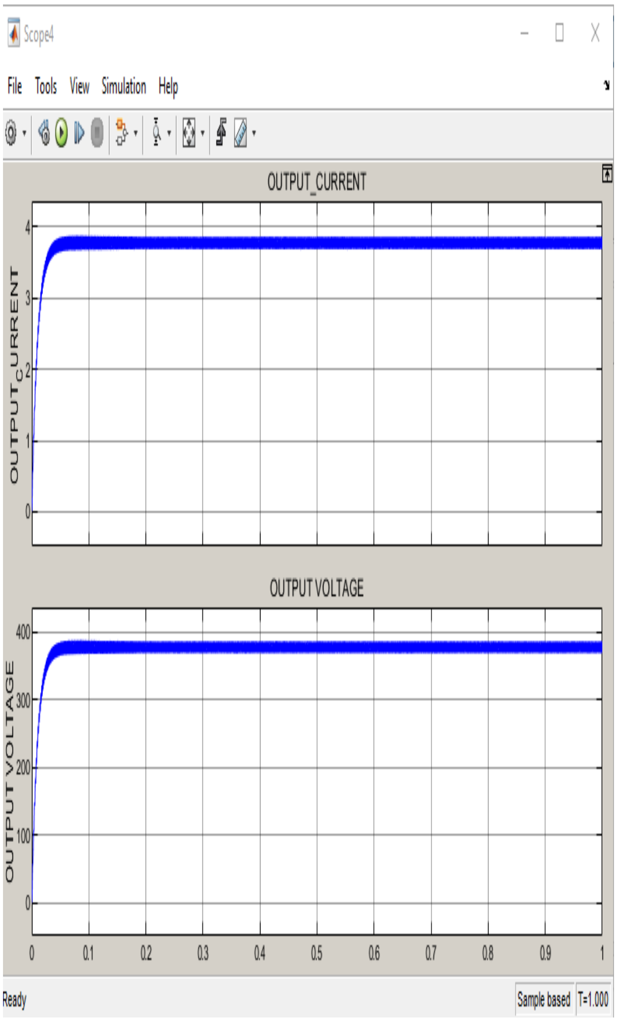

Fig 18. Output current and output voltage results.

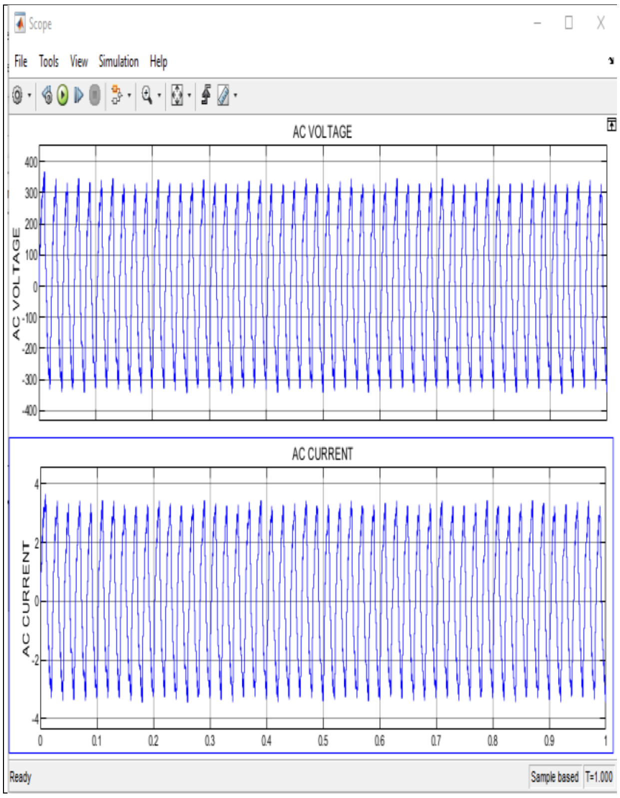

Fig 19. AC current and AC voltage current result.

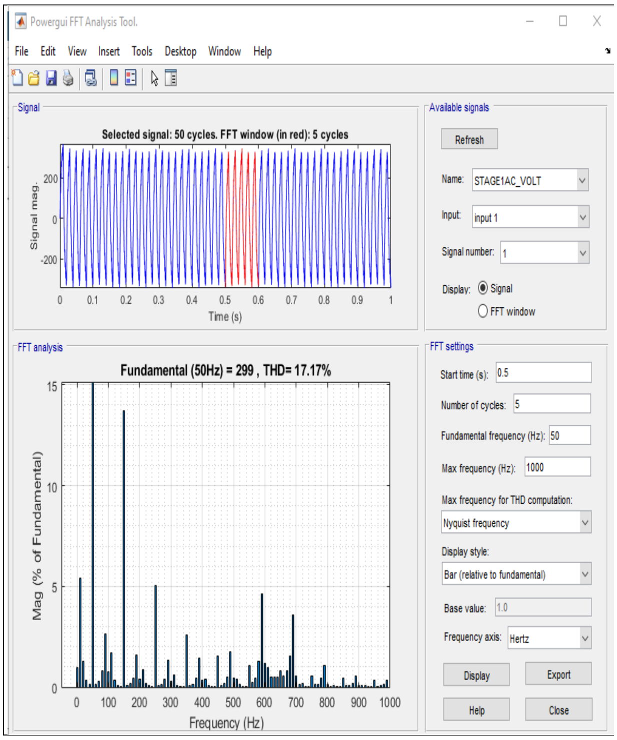

Fig 20. THD performance for multistage Micro inverter.

Harmonics are one of the most dangerous things in the world of power systems. the third harmonics and figures out their THD values. In the current system, an RLE load is used with a multilevel inverter that is driven by a normal switching pulse. Table 1 shows how voltage and current THD are related to each other. A gated inverter system with a normal switching pulse has higher voltage and current harmonics THD values than a system with a pseudorandom switching pulse. Table 1 shows how the values of the harmonics compare to each other.

Table 1. Result Performance of Multilevel inverter and Single phase inverter.

Proposed Approach	THD
Multilevel inverter	9.11
Single phase inverter	17.17

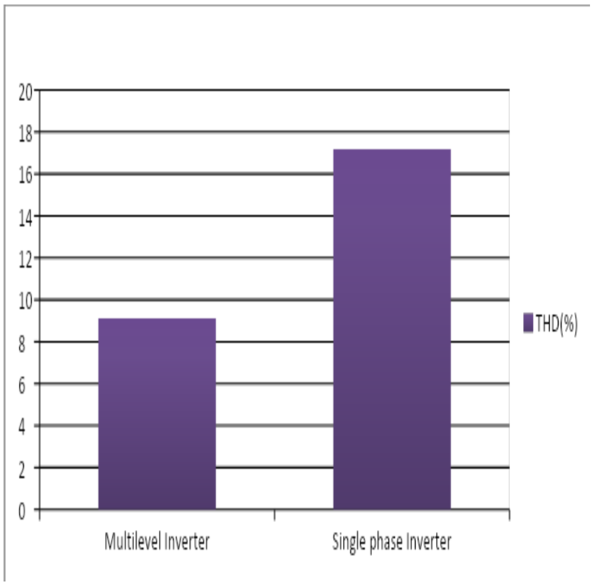

Fig 21. Result Performance of Multilevel inverter and Single phase.

V. CONCLUSIONS

This study looked at how an inverter-fed RLE load responded and worked when it was hit with gated pulses from a pulse generator and a pseudo-random binary sequence from a multilevel inverter. The value of the harmonic made by the system will be changed by the gating pulse. The third harmonics of both systems are looked into, and the results are summed up so that they can be compared.

As things stand right now, both the voltage and current THD values are quite high. On the other hand, the THD value of the voltage and current in the proposed system is much lower than that of the current system. A 460 VAC three-phase induction motor is used to test and check both the current system and the planned system. The RLE load is used to test the current system. The results showed that the suggested system produced output that was more efficient and had a lower THD value than the system that was already in place.

VI. FUTURE SCOPE

Micro inverters are miniature inverters that are only rated to handle the output of a single solar panel. A micro inverter is a device that is used in photovoltaic's and it is a plug-and-play device that transforms direct current to alternating current. The direct current is generated by a single solar module. Because more people are putting solar panels on their roofs to collect and store solar energy, the need for micro inverters is expected to rise in the coming years. The Micro Inverter Industry is expanding at an exceptionally quick rate in the business market.

Micro inverters are being used extensively with solar panels for residential uses. Micro inverters have been used widely in developed countries to increase the use of clean energy. Micro inverters are comparatively more reliable and compact compared to the conventional inverters used earlier for converting direct current generated by a single solar module to alternating current. Micro-inverter technology is an emerging area of photovoltaic (PV) research because it enables solar arrays to function as plug-and-play devices. The majority of studies in this topic examine the arrangement of various DC–DC converters and inverters. The focus is mostly on achieving increased stability, less complexity, and enhanced performance. Our research indicates that the majority of micro inverters are constructed utilizing two-stage power conversion strategies. Less effort is required for single stage power conversion designs.

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