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E-Mail :
editor.ijasem@gmail.com
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# Design & Analysis of High-Level Inverter with EANFIS Controller

**SHIAK MD NOOR UL AMEEN[1], SHAIK WAZEED[2]**
[1]PG Student, Dept of EEE, SITS, Kadapa.
[2]Assistant Professor, Dept of EEE, SITS, Kadapa.

***Abstract –***
A PV array's output power is maximized by using the maximum power point tracking (MPPT) technique, which also improves the system's stability and reliability. The maximum output of a PV module changes with the temperature and amount of solar radiation. Using a Maximum Power Point Tracker (MPPT), photovoltaic (PV) systems continuously extract and deliver as much power as they can. A DC-DC Converter and a controller are components of an MPPT. Many different MPPT algorithms have been proposed, but most of them have drawbacks in terms of efficiency, accuracy, and adaptability. Conventional controllers cannot give the optimal response due to the nonlinear current-voltage characteristics of PV modules and the nonlinearity of DC-DC converters because of switching in large parameter changes and line transients. To track a PV system's maximum power point, the authors designed and modeled a fuzzy/P&O controller. The proposed method shows improved performance in terms of oscillations about the maximum power point, speed, and sensitivity to parameter variation. The PV system's performance was assessed using a variety of test scenarios that included signals for temperature and solar irradiance variables. The MATLAB/Simulink simulation results showed that the proposed method worked well at the operating point in terms of settling time, power loss, and oscillations.

***Keywords –*** EANFIS controller, Control voltage, Harmonics, Multilevel inverter.

## I. INTRODUCTION

Photovoltaic (PV) system will be one of the most promising renewable energy systems in the near future. The costs of the installed PV systems are continuously decreasing worldwide because of falling component average selling prices. Based on the statistics of the PV power plants 2017 industry guide report, the global PV system installations reached 355 GW at the end of 2017 and the cumulative market growth reaches 73%. Several factors affect the high penetration of the PV systems into electricity networks, such as environmental concerns, clean energy, increase in fuel price, political issues, and PV system cost reduction. In addition, installations of the MW PV power plants take only a few months. Increasing energy demand and the need to find clean and cheap alternative energy sources have led to extensive research in renewable energy sources (RES). The growth in the RES market is also directly related to the development of power electronics. Among several types of RES the photovoltaic (PV) energy source has benefits such as high efficiency, reliability and a long life. In addition, it is also characterized by low cost, freedom from moving components and also easy and quick to setup.

Now a days, power generation from solar system is widely applicable in various fields like micro grids, fact devices, distributed generation systems. Such kind of transformer-less PV grid linked scheme is attractive due to their cost effectiveness, tiny size and reliability. Use of MLI in PV grid connected system to synthesize preferred output voltage from various level of DC input voltages. MLI produces stepped resultant voltage as clean sine wave to show minimization of THD. Traditional MLI topologies need separate driver circuits, individual DC sources for every stepped output. Especially in high power applications, failure of certain inverter portion contributes whole switching loss and power rating of inverter topology enhanced through reduction of switching frequency. But this condition leads to rise of current THD and which is very difficult to minimize. These findings say that, minimization of switches, DC sources and gate drivers improves voltage levels. Raise in voltage level results better power quality with considerable reduction in size, THD and cost. This motivates us to make use of high level MLI with an optimized switching scheme for addition of PV grid connected scheme. The system work uses 27 level inverter with reduced switch topology to get better reliability with low harmonics.

## II. MAXIMUM POWER POINT TRACKING TECHNIQUES

In order to extract the maximum PV available power at certain atmosphere and load conditions, maximum power point tracking has to be used. As can be seen in Fig.1, the direct connection of the load to the PV source results in the operating point of the PV source being the intersecting point of I-V curve with the load impedance line. However, this point may not be at the location where the PV panel generating the maximum power.

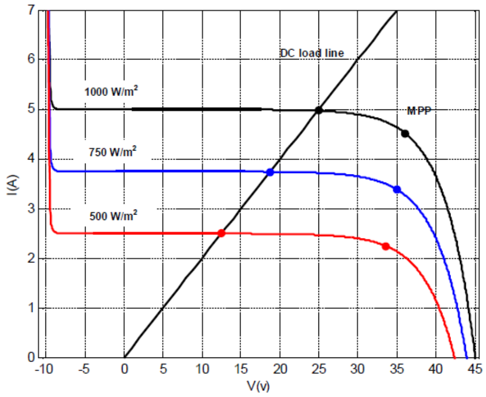


Fig.1: I-V PV characteristics and load line.

As illustrated in Fig.1, the load line crosses the PV I-V characteristic curves under different irradiance levels at several points. The load impedance at these points is always 5 Ω, while the PV impedances at MPP are 8 Ω at 1000 W/m2, 10.36 Ω at 750W/m2 and 15 Ω at 500W/m2. To achieve the maximum PV power delivered to the load, the load impedance has to be equal to the PV impedance at MPP points and if that condition cannot be obtained by direct load connection, power converters have to be used. Power-converters have not only been used to convert the supplied electric power from one form to another suitable to the load requirements, they can also be used to match the impedances of the PV panel at MPPs with that of the load so that the maximum PV power can be delivered. Even though implementing the MPPT increases the system complexity with regard to the use of digital computing techniques and additional transducers, many benefits can be gained such as high system efficiency hence the total cost can be reduced in some cases by 15% and the efficiency improved by 16% in the worst case. Also, the system is able to generate the maximum possible power regardless of the irradiance and temperature levels. Finally, employing the MPP control can be beneficial for other aspects for example, realizing storage element charging/discharging control so its life time can be extended. This chapter gives a thorough and comprehensive review on the existing MPPT schemes. Their operating principles and features are reviewed along with their limitations. Overall, the MPPT consists of three parts - a power converter, a controller (voltage or power feedback controller) and a MPPT algorithm. The latter represents the core of MPPT technique which continuously monitors the PV power and then consequently controls the power converter in order to ensure that the load works at the maximum possible PV power. With respect to the controller, the voltage-

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feedback control is mostly used to maintain the PV terminal voltage varying about that corresponding to the MPPs. The simple voltage-feedback controller diagram is shown in Fig.2.

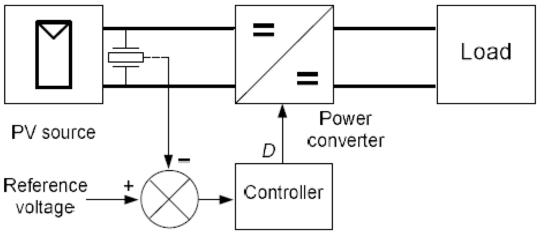


Fig.2: Simple MPPT system with voltage-feedback controller.

It can be noticed that in this scheme the reference voltage, i.e. the voltage corresponding to MPP has to be known and set according to predetermined measurements or the data sheet of the PV source, so this technique is called the constant reference voltage MPPT. However in practice it is difficult to obtain the reference voltage values due to changes of weather condition and data sheet may not be available. To avoid the dependency of this technique to the predetermined reference voltage, an improvement is made in order to make it more flexible specifically with respect to the atmosphere changes. The regular changes in the reference voltage due to the changes of irradiance and temperature levels are basically rely on the PV open circuit voltage which is close to the MPP PV voltage (*V*mpp is almost 68% to 77% of *V*oc). For every time period, the PV source and load are disconnected regularly, so the open circuit voltage can be sampled. In 1998 this method with the open-circuit voltage measurement was chosen to be used in the integrated maximum power point tracker for PV panels. As a result of repeatedly reset the PV source to its open-circuit voltage (PV output power is equal to zero), considerable amount of energy is lost also the system needs some time to settle down again after each interrupt. Because of that in a pilot model or separated reference solar cell was used instead of interrupting the main PV power flow. Although the pilot model idea improves the system operation and increases the total extracted PV power, the main drawback is that the mismatching between the reference solar cell and the main PV panel may occur due to, for example, dust falling on the reference cell not on the main PV panel and any other different conditions differing between them. If this mismatching is neglected, incorrect information about the MPP voltage may be obtained, resulting in inaccurate or even erroneous control. Overall, the constant reference voltage technique is a simple and inexpensive MPPT method to implement, but it may not respond to the irradiation and temperature variations correctly. Even though it has been developed to overcome the mentioned problem, it is an inaccurate and unreliable MPPT method. Artificial intelligence has been used to find the desired reference voltage, for instant in the artificial neural networks were trained in order to predict the proper reference values in different load and atmospheric situations. As a result, the PV MPP tracking is improved. However, using the ANN needs a large number of predetermined information patterns in order to improve its feed-forward response and that requires quite long training time especially in the on-line training also it will be difficult to reduce the total squared error so inaccurate reference values are still produced. However, smaller pattern numbers results in the ANN method not being able to respond accurately to the new patterns which it had not been trained to deal with, hence it cannot lead to high performance MPPT. Another simple method uses the power-feedback controller, instead of using the PV voltage as a control variable, the PV power is used to maintain the maximum PV extracted power. This strategy is characterized by the fact that the MPP is actually achieved independently of any PV source characteristics or predetermined

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reference values. Also, it is able to track the PV MPP efficiently regardless of any atmospheric changes, Fig.3 shows the simple power-feedback MPPT.

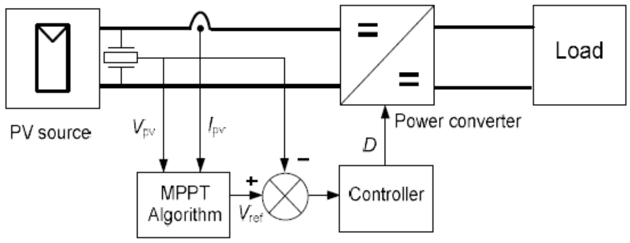


Fig.3: Simple MPPT system with power-feedback controller.

There have been many MPPT algorithms in the literature. The most commonly used power feedback MPPT algorithms are Perturbation and Observation (P&O), Hill-Climbing (HC) and Incremental Conductance (IncCond) due to them being efficient, simple and easy to implement.

## III. SYSTEM MODELING

The system work uses 27 level inverters with reduced switch topology to get better reliability with low harmonics. This inverter performance completely relies on EANFIS controller which is the combination of ANFIS and Emperor Penguin Optimization (EPO) algorithm & Optimized Technique. Working procedure of ANFIS will be optimized by EPO & Optimized Technique to make us easy to grip transferring position of MLI and make less harmonic controller voltage.

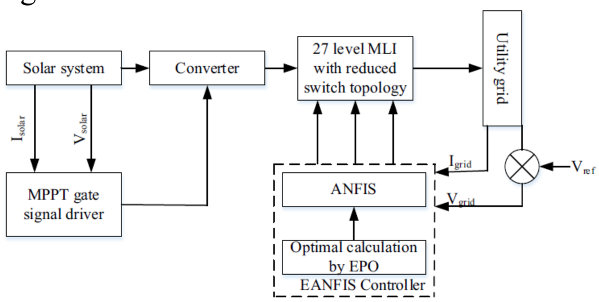


Fig:4. System design with ANFIS controller

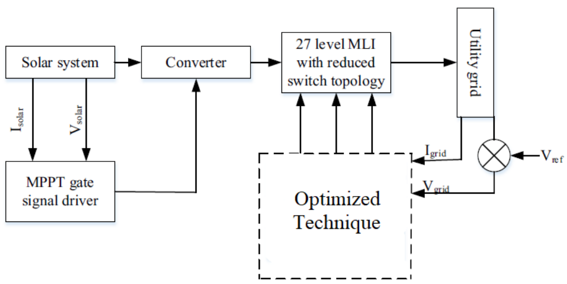


Fig:5. System design with Optimized Technique controller

Main concept of EPO based on huddling characteristics of emperor penguins. While comparing with other met meta-heuristic algorithms, EPO provides efficient result by means of computational complexity, time and space complexity. This is the main reason to select EPO for optimizing ANFIS & Optimized Technique controller in our system work. Diagrammatic flow of system work given in Fig.4, 5. Solar fed to 27 level MLI with minimize switch topology. Data required for EANFIS obtained by solving harmonic equations by considering various modulation indices. THD evaluated from output voltage

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generation of EANFIS & Optimized Technique controlled MLI. Main focus of EANFIS & Optimized Technique controller is to make inverter to harmonic free output voltage similar to grid voltage. Here, essential of filter circuit to improve inverter output because of generation of harmonic less output at inverter side. Thus, system EANFIS & Optimized Technique controllers perform better in THD and reduce design complexity of whole system.

To monitor the multilevel inverters input voltage a novel controller is used and the grid voltage as reference magnitude to be employed by ANFIS with EPO algorithm & Optimized Technique. From a conventional phase-locked loop (PLL) the stage angle grid of reference voltage is obtained to ensure the grid synchronization. Solar based radiation information is gathered on a level surface. If the PV cluster is introduced confronting the sun they created control from PV framework could be expanded significantly.

## IV. SIMULATION RESULTS

The system work will be implemented in Simulink working environment. Resultant outcomes like inverter output, controller output and THD analysis will be compared with recently developed existing works. Our system work is compared with existing controllers. Figures display the system model of Simulink.

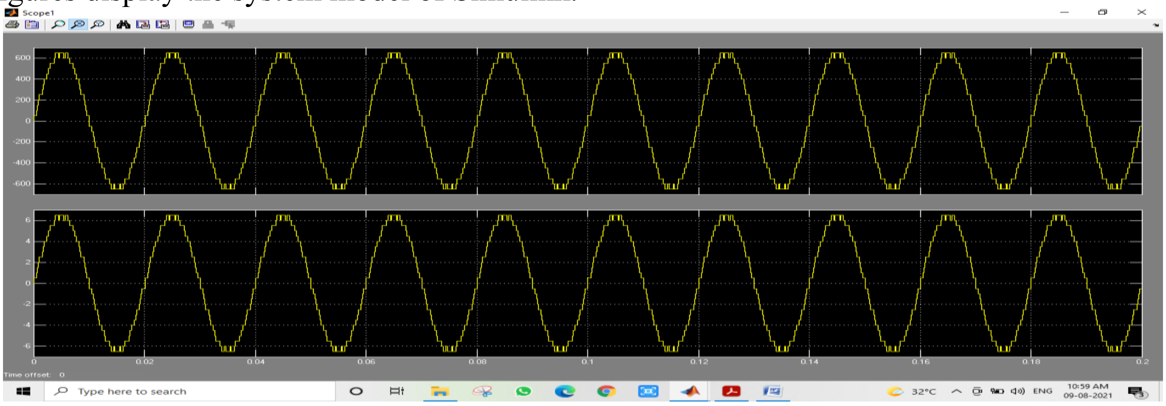

Fig.6: inverter voltage and current

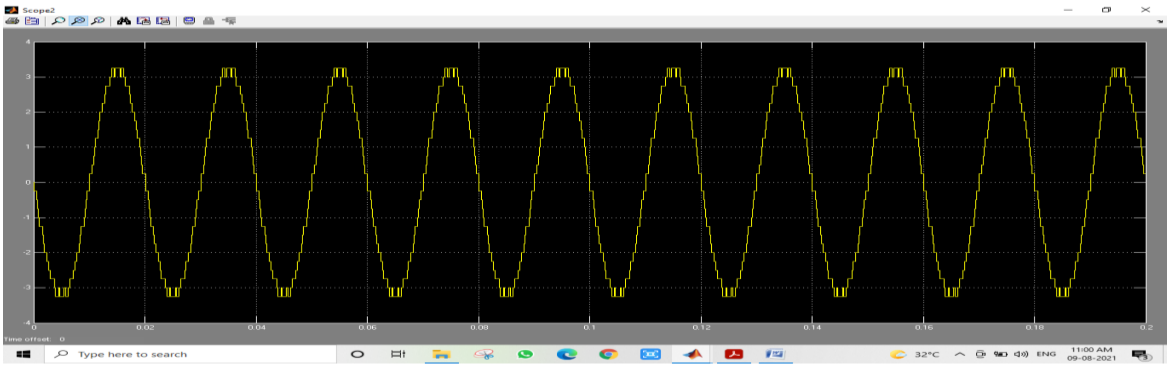

Fig.7: grid current

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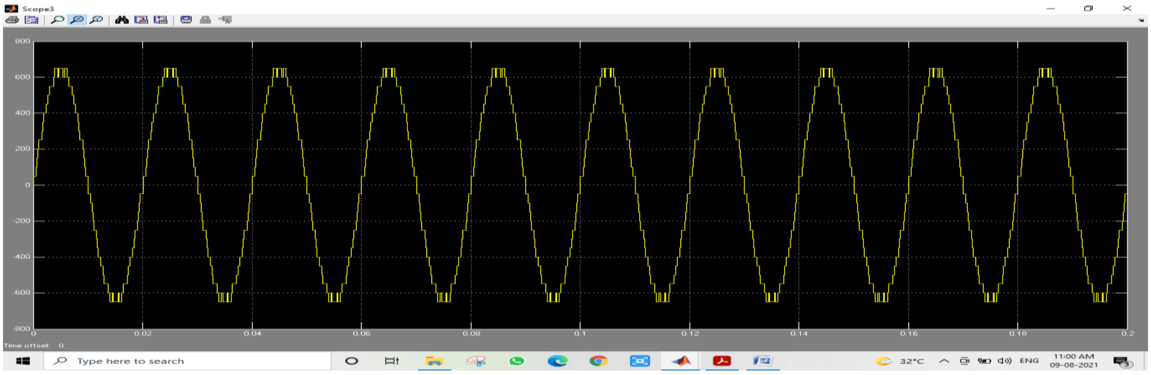

Fig.8: grid voltage

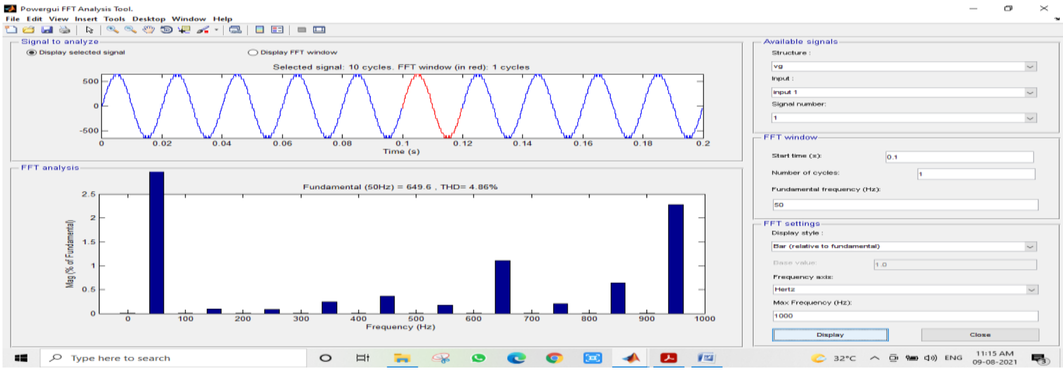


Fig.9: THD at grid voltage.

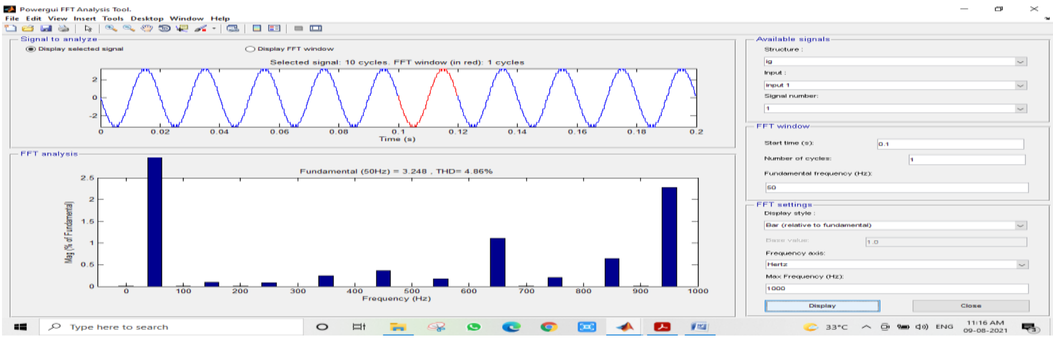


Fig.10: THD at grid current.

Figure 6 shows the performance of existing controller of inverter current and inverter voltage. By varying controller, the inverter current and inverter voltage performance are taken. By using this controller we does not get the stable inverter current and inverter voltage performance. Figure 7, 8 shows the performance of existing controller of grid current and voltage. By varying controller, the grid current and voltage performance are taken. By using this controller we do not get the stable grid current and grid voltage. Figure 9, 10 shows the performance of THD waveform for the yield voltage at the load side. By using existing controller the THD value of load side is 4.86%.

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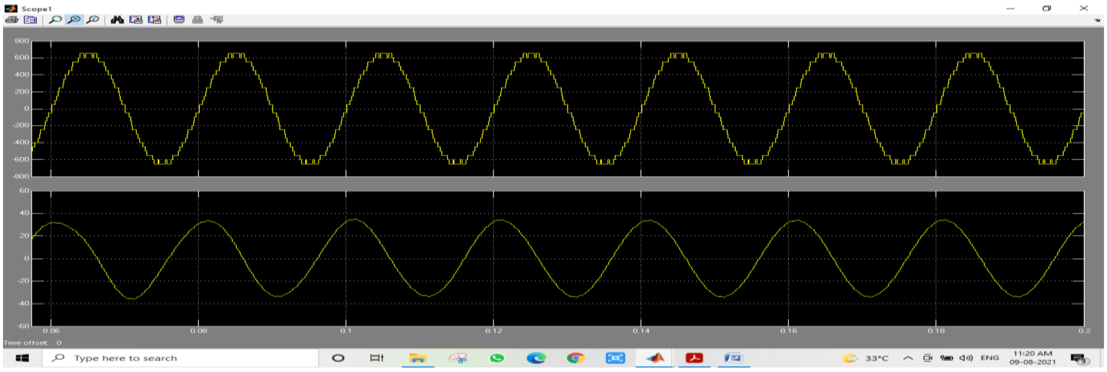


Fig.11: inverter voltage and current

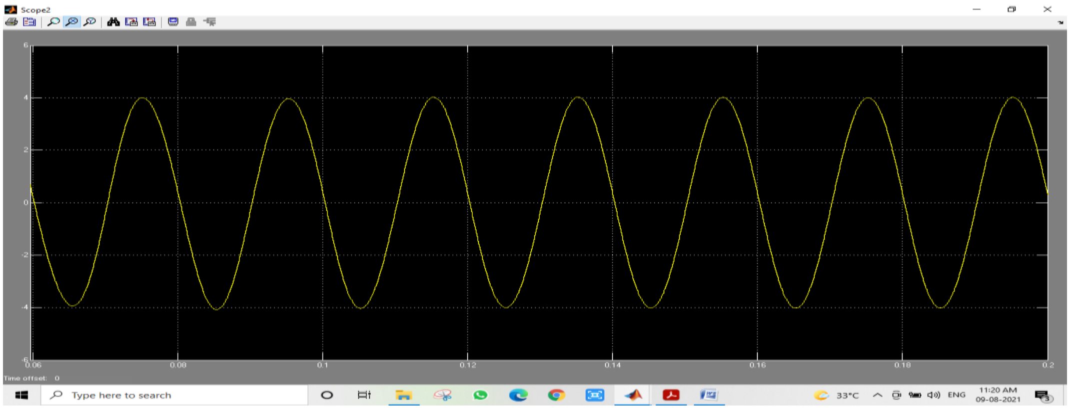


Fig.12: grid current

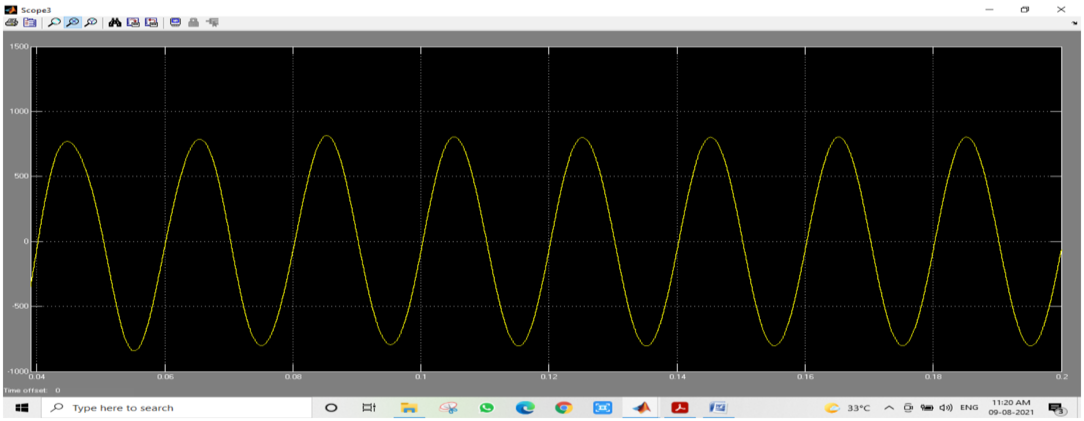


Fig.13: grid voltage

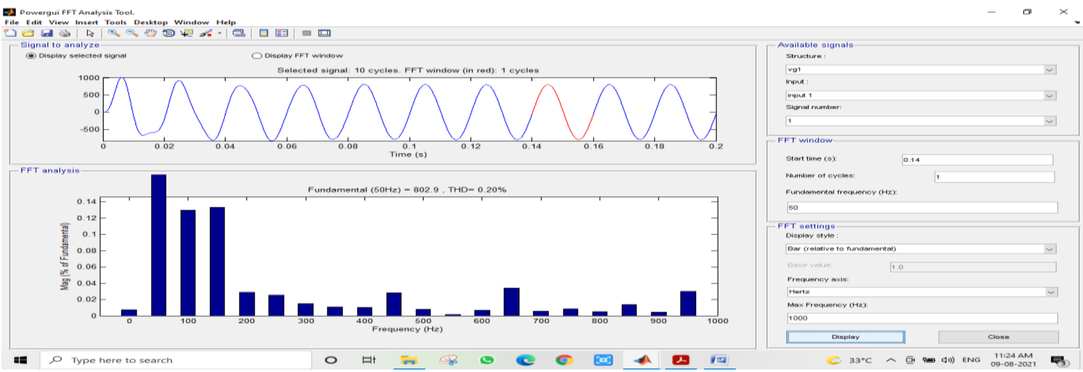


Fig.14: THD at grid voltage.

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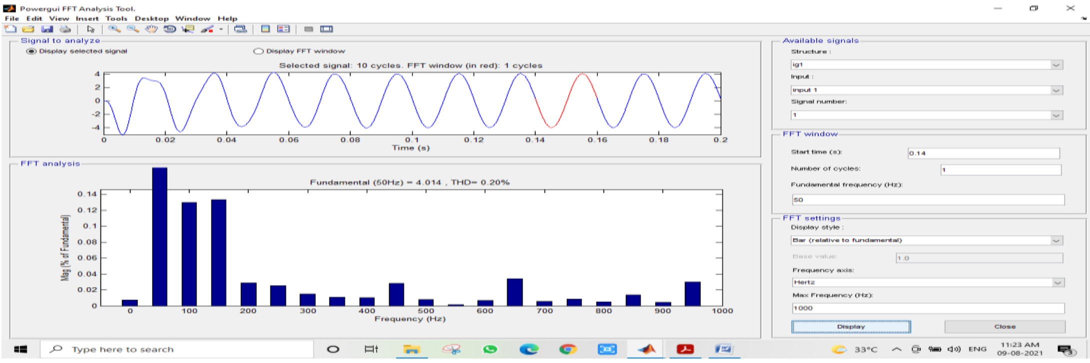


Fig.15: THD at grid current.

Figure 11 displays the performance of inverter current. By varying Optimized Technique controller, the inverter current performance are taken. By using this controller for tuning the purpose of the inverter we got stable inverter current. Our system method give better result give better results compared with others. Figure 11 gives the performance of inverter voltage. By varying Optimized Technique controller, the inverter voltage performance are taken. By using this controller for tuning the purpose of the inverter we got exact inverter voltage. Our system method give better result give better results compared with others. Figure 12 shows the performance of grid current. By varying Optimized Technique controller, the grid current performance are taken. By using this controller for tuning the purpose of the inverter we got exact grid current. Our system method give better result give better results compared with others. Figure 13 shows the performance of grid voltage. By varying Optimized Technique controller, the grid voltage performance is taken. By using this controller for tuning the purpose of the inverter we got exact grid voltage. Our system method give better result give better results compared with others. Figure 14, 15 shows the performance of THD waveform for the yield voltage at the load side. In the system system the THD value in load side is 0.20%.

## CONCLUSION

In this project solar fed to 27 level MLI with minimize switch topology. Data required for EANFIS & Optimized Technique obtained by solving harmonic problems by considering various modulation indices. THD evaluated from output voltage generation of EANFIS & Optimized Technique controlled MLI. Main focus of EANFIS & Optimized Technique controller is to make inverter to harmonic free output voltage similar to grid voltage. The system work has implemented in Simulink platform. The expected outcomes like inverter current and voltage, grid current and voltage and THD analysis will be compared with recently developed existing works.

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