


ANN Controller Based Single phase Inverter in Smart City

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Abstract: Solar-grid integration is a method for incorporating large amounts of photovoltaic (PV) supply to the grid. Advanced inverter technology, smart grids technology, islanding detection technology, solar-grid forecasting technology, grid-plant protection technology and are all part of solar-grid synchronization technology. Many methods are used to control inverters, including sinusoidal pulse width modulation, selective harmonic suppression pulse width modulation, space vector width modulation. Among control methods, pulse width modulation is the most popular. PWM inverters are used for two different switching techniques: bipolar and unipolar. The primary goal of this paper is to create an inverter that will convert a solar DC power source to an AC power source that can be used to power a load or connected directly to the utility grid. In this work, the control of inverter output voltage is done without the need for any user intervention, but only with the intervention of an AI technique, and it is compared to existing methods.

Keywords: Single phase inverter, Artificial neural network controller, Smart grid, Renewable energy

1. Introduction

Single phase inverters are electronic devices used to convert direct current (DC) power into alternating current (AC) power, typically with a single-phase sinusoidal waveform. They discovery submissions in different fields, including renewable power generation systems, uninterruptible power supplies, and home appliances. This review aims to submit a brief of the available state of education and development in single-phase inverters. With the rapid advancements in power electronics technology and decreasing costs, single-phase grid converters are increasingly being utilized in various applications, particularly in industrial settings [1]. These converters require synchronization with the grid voltage waveform, which frequently experiences random changes, to ensure their effective operation.

However, these dynamic systems are susceptible to various random factors such as load switching processes, harmonic signals in the grid, and other instabilities caused by electrical equipment. Consequently, continuous monitoring of grid variables is necessary to ensure that the voltages are appropriate for proper operation of the controlled converter drivers. This becomes especially crucial when RES are integrated into the power grid, as their use of power electronics converters can adversely impact grid synchronization

As a result, extensive research has been conducted worldwide over the past decade to understand and manage the behavior of schemes incorporating RES particularly during abnormal constant state and momentary conditions, such as grid operating failures grid synchronization is a critical task in power electronic circuit systems when connecting RES to the utility [2]. The voltage magnitude and frequency of the grid determine which solar sources and wind systems should be attached or removed to maintain system stability. Power converters in RES must precisely find grid voltages at the point of common coupling (PCC) to activate safety disconnection algorithms when grid parameter limits are exceeded. This requirement also governs the dynamic requirements for reliable grid connectivity of

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renewable energy sources. To meet regulatory standards, grid synchronization algorithms executed in grid-integrated converters essential detect grid variables with minimal comeback time and phase-angle error.

Grid integration and Power Quality: Grid-connected single-phase inverters play a crucial role in renewable energy systems, especially for solar photovoltaic (PV) installations [3]. Research has focused on grid integration techniques, including maximum power point tracking (MPPT), compensation of reactive power and synchronization with the utility grid. Power quality problems, such as harmonic distortion and total harmonic distortion (THD), have been extensively studied to ensure compliance with grid codes and standards.

Efficiency and Power Electronics: Efficiency improvement is a significant concern in single-phase inverter design. Various techniques, such as soft switching, high-frequency operation, and advanced power electronic devices, have been investigated to enhance the overall efficiency of single-phase inverters. Switching losses, conduction losses, and heat dissipation are critical factors in achieving high.

Efficient Topologies and Control Strategies: Numerous inverter topologies have been projected and considered in the literature [4]. The furthest common ones contain pulse-width modulation techniques, full-bridge inverters, half-bridge inverters and multilevel inverters. Different control strategies, such as voltage control, current control, and hybrid control, have also been investigated to improve the performance of single-phase inverters efficiency.

Size and Weight Reduction: Energies have been finished to decrease the scope and weight of single-phase inverters, particularly for portable and consumer electronic applications. Miniaturization techniques, advanced power semiconductor devices, and thermal management strategies have been explored to achieve compact and lightweight designs while maintaining performance and reduction [5].

Advanced Control and Modulation Techniques: Researchers have proposed advanced control and modulation techniques to address various challenges in single-phase inverters. These include adaptive

control, predictive control, artificial intelligence-based control, sliding mode control algorithms. Modulation techniques, such as selective harmonic elimination (SHE), space vector modulation (SVM) and have been investigated to minimize harmonic distortion and improve output waveform quality [6].

Reliability and Fault Diagnosis: Reliability and fault diagnosis of single-phase inverters are critical for their long-term operation. Studies have focused on fault detection, fault-tolerant control, model-based fault diagnosis. Robustness, reliability, and fault handling capability are essential aspects of single-phase inverter research [7].

The main contribution of this paper is to create AI based inverter and also to compare it with traditional methods like fuzzy logic based inverter as well as conventional method.

2. Two stage grid connected PV system

In this method, from the solar panels the voltage is boosted by the boost converter and then given to single phase bridge inverter and to remove the ripple content present in the inverter output a filter is used and from there a smooth supply of power is connected across the grid circuit [8]. The block diagram representation presented in Fig.1 gives the reference blocks that are to be used in the simulation model. The conventional method which is mainly a single-phase utility integrated system is shown in Fig.2.

2.1 Fuzzy controller based single phase inverter

FLC is employed in this circuit to provide switching signals for the proposed boost inverter, which injects power into the traditional grid without breaching grid standards. Table.1 depicts the membership functions and fuzzy rules for the suggested system. In this fuzzy logic system, two input variables are used: error (e) and change of error (de). The suggested boost inverter's solitary output variable (u) is the duty cycle. The Fuzzy Logic Controller's inputs are the error and change in error of a boost inverter's output voltage. These two inputs are divided into five categories: ZO (Zero Area), PS (Positive Small), NB (Negative Big), PB (Positive Big), NS (Negative Small) and their parameters. Fig.6 depicts the fuzzy rules for the proposed converter.

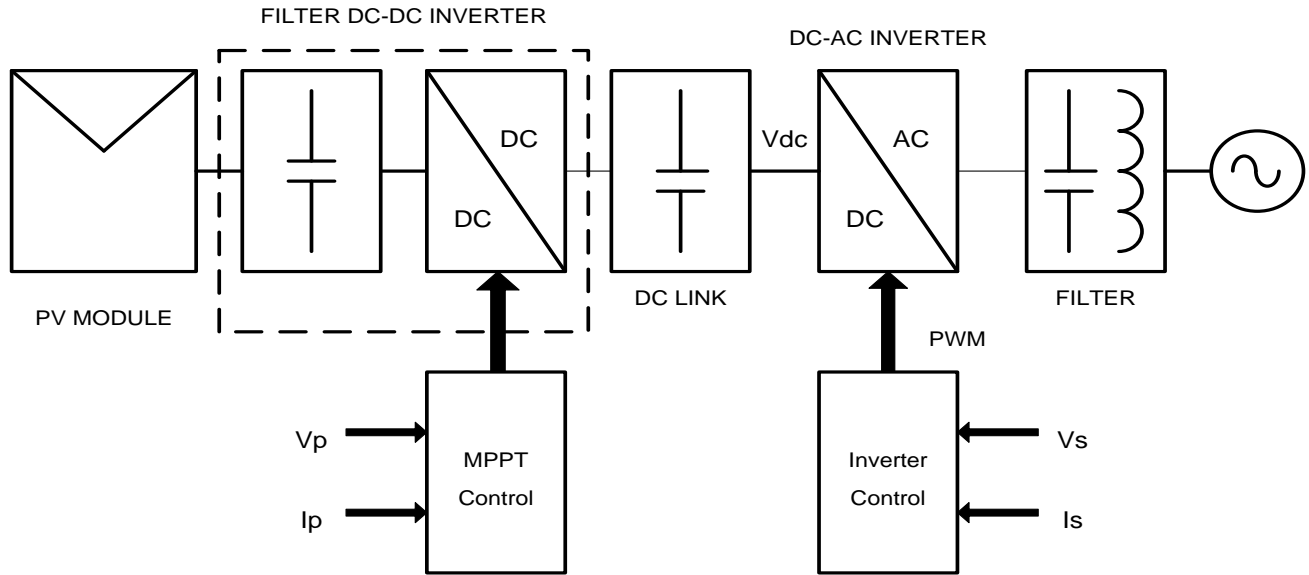


Fig.1: Block diagram of conventional method

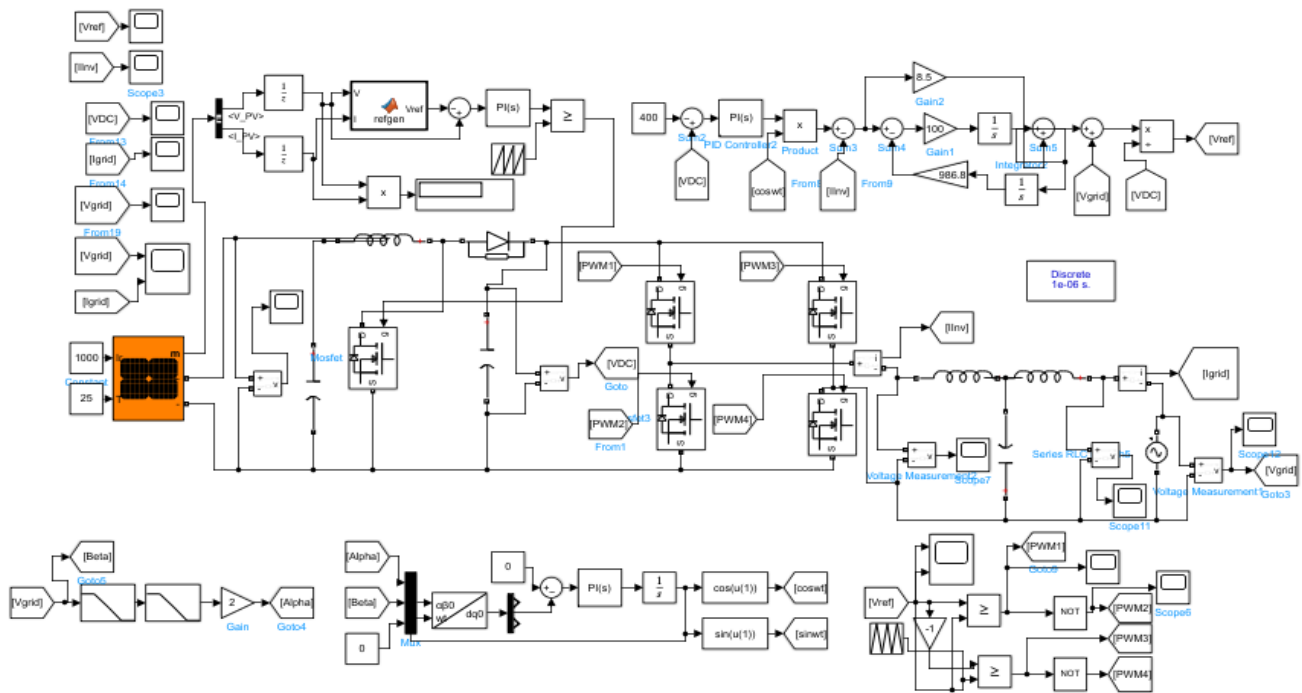


Fig.2: Simulation model for the proposed system

The basic Block diagram to understand this method using fuzzy logic is shown in Fig. 3. In this entire model, the voltage source is taken as a solar panel output and then boost inverter is the combination of boost converter and inverter and the inverter works on receiving PWM gate signals from the fuzzy logic controller. The simulation model for fuzzy logic based single phase grid connected inverter is shown in Fig.4 and Fig.5.

Table.1: Fuzzy rule base

(de)/(e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

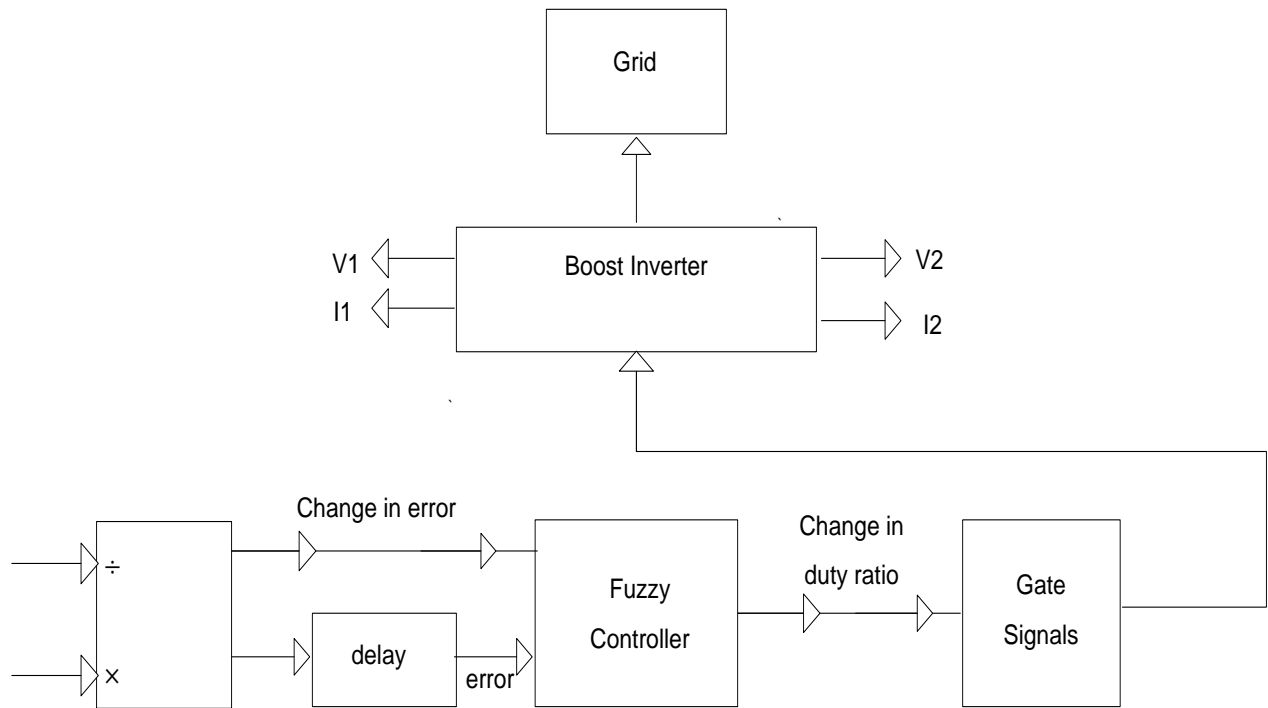


Fig.3: Block diagram of Fuzzy logic based inverter circuit.

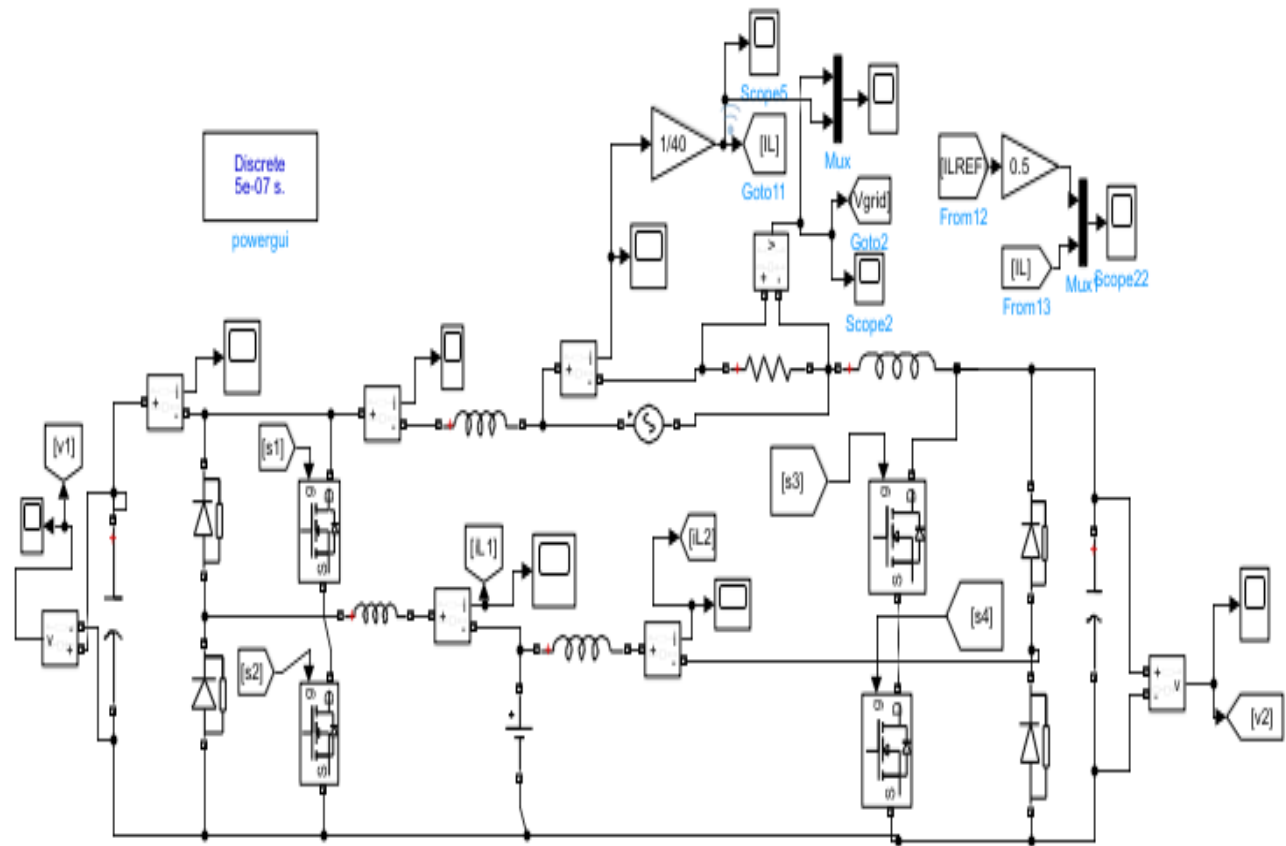


Fig.4: Simulink model of proposed inverter circuit.

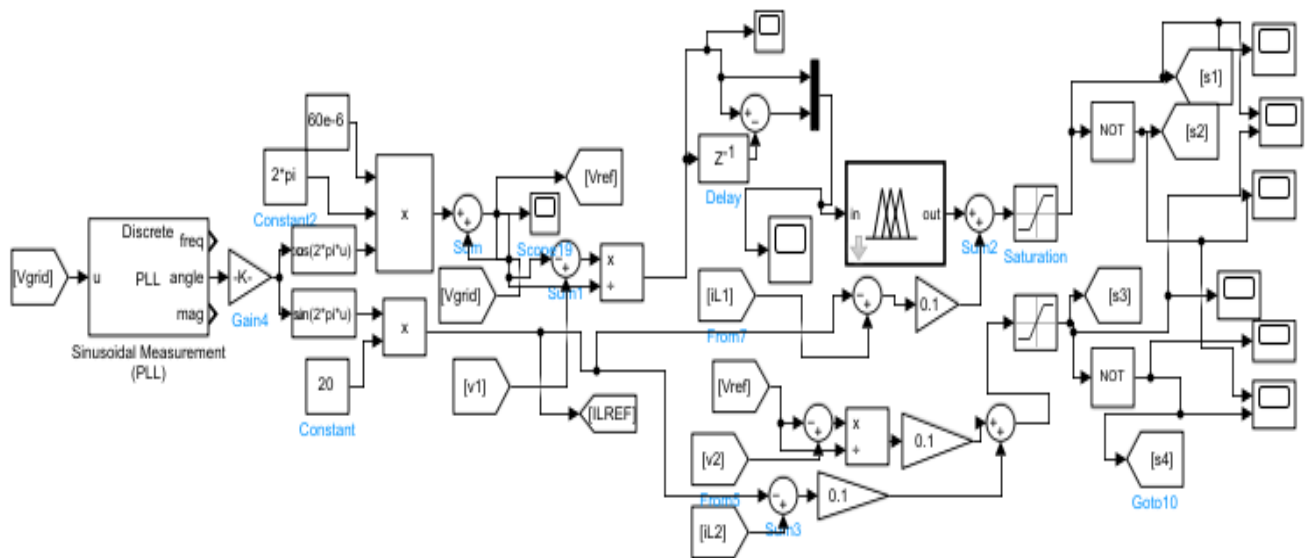


Fig.5: Model showing the generation of PWM pulses using fuzzy logic controller.

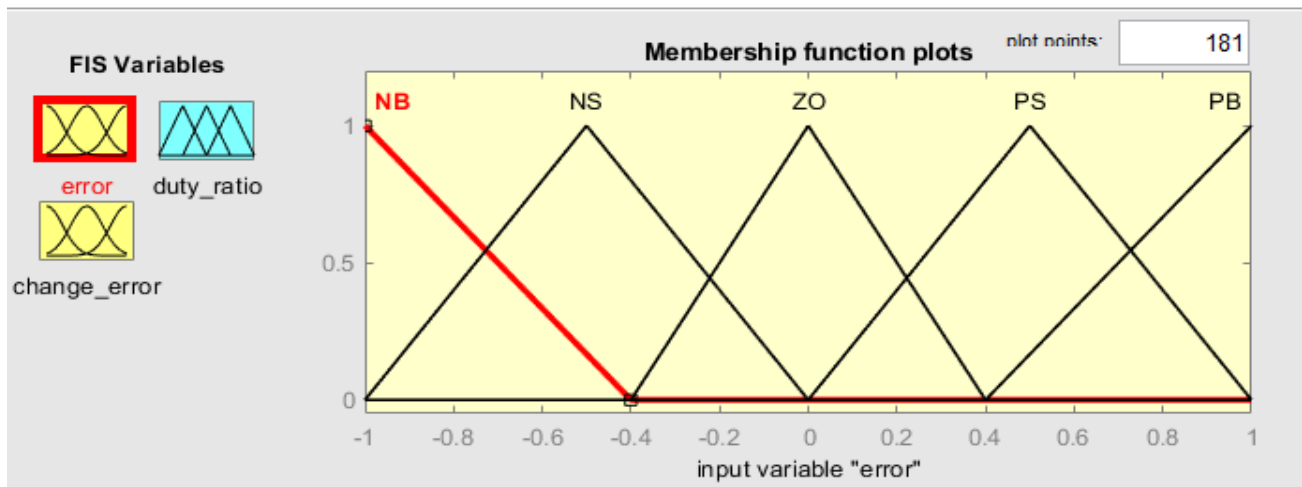


Fig.6: Membership function for input variable error.

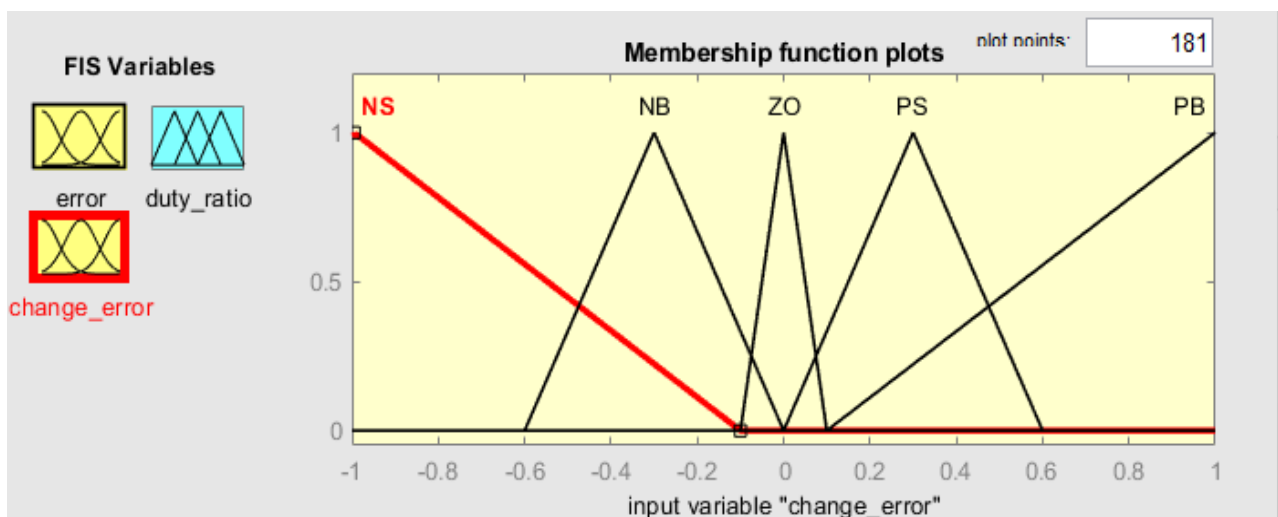


Fig.7: Membership function for input variable change in error.

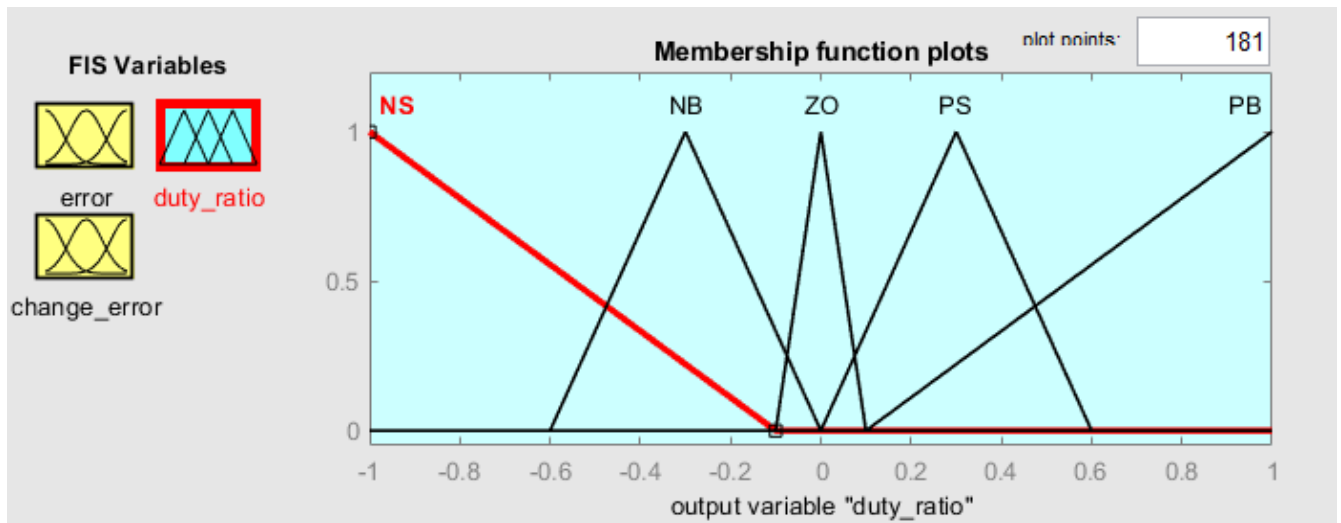


Fig.8: Membership function for input output variable change in duty ratio.

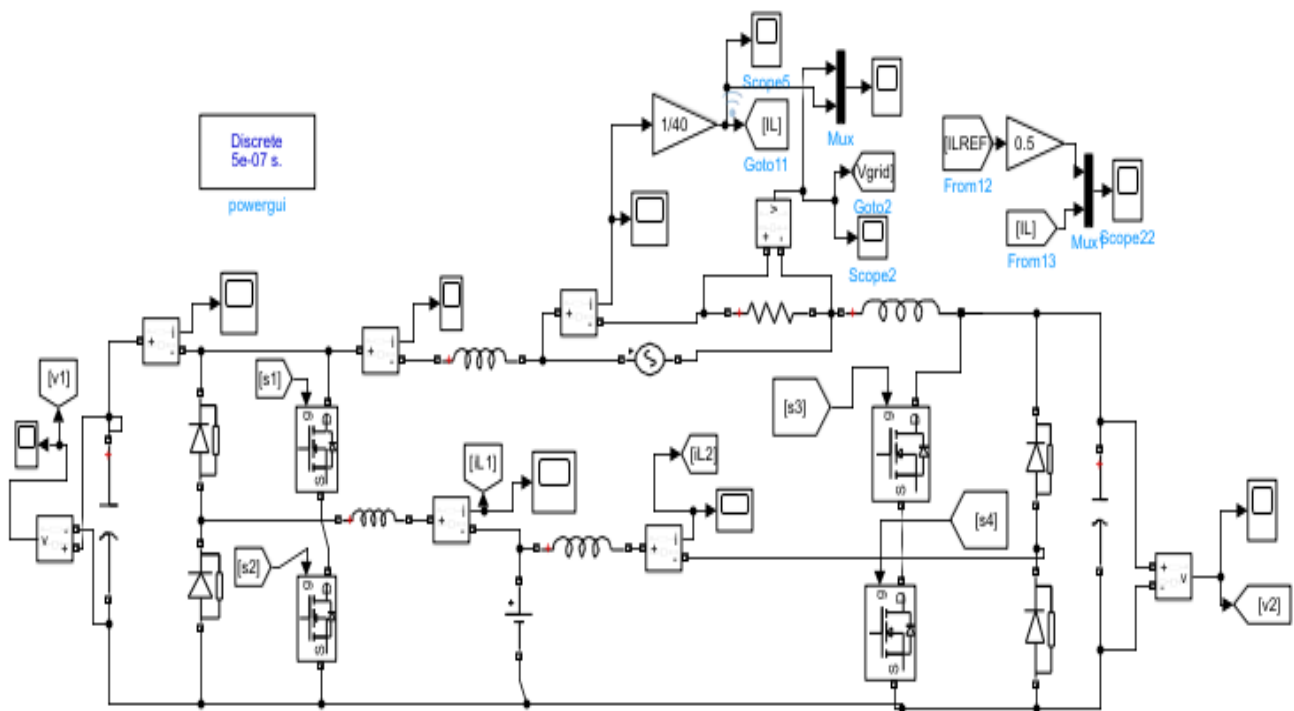


Fig.9: Simulink model of proposed inverter circuit.

The Table.1 shows the rules are created in fuzzy logic controller. Inputs for the controller are error and change in error and output of the controller is change in duty ratio. The Fig.6 shows the membership function of the input variable that is NS error which gives the difference between the measured value and the reference value. The Fig.7 shows another input variable that is change in error and Fig.8 presents the membership function for input output variable change in duty ratio.

2.2 Artificial intelligence controller based inverter

The basic block diagram for this method is same as previous method except fuzzy logic controller is replaced by artificial neural network. The proposed inverter circuit is same as the fuzzy logic only change comes in the circuit of generating pulse signals. The model is similar to the fuzzy logic based single phase grid connected inverter except the replacement of fuzzy logic controller with the artificial neural network as shown in Fig.9.

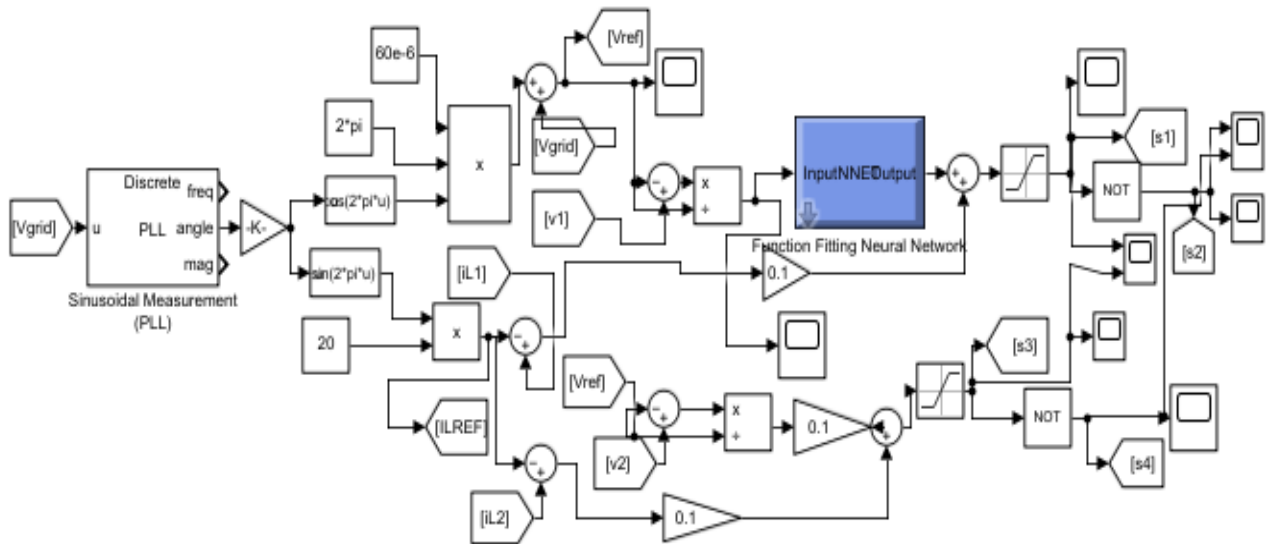


Fig.10: Model showing the generation of PWM pulses using artificial neural network.

3. Results and Discussion

In this section, we will look into the outputs of all the three methods.

3.1 Conventional method

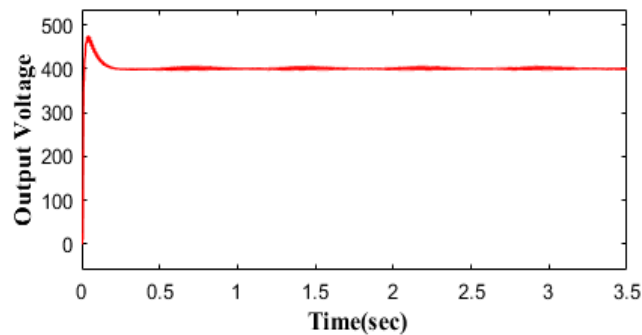


Fig.11: Output voltage of boost converter.

The output voltage of boost converter is settled to 400 volts after getting boosted from 240 volts to 400 volts as shown in Fig.11.

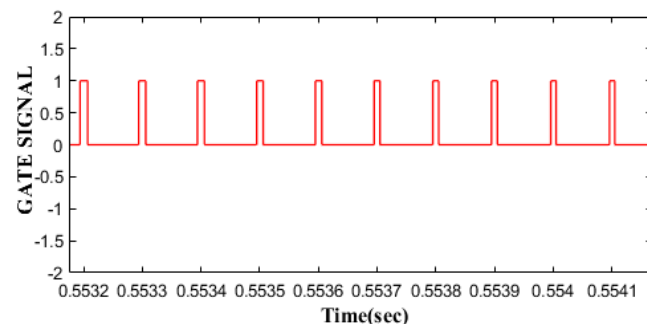


Fig.12: PWM gate signal for the inverter.

These are the PWM signals designed for the inverter which are of continuous pulses as shown in Fig. 12.

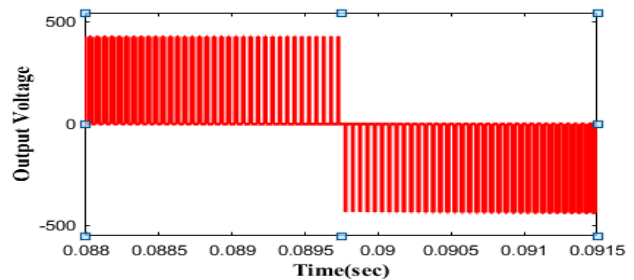


Fig.13: Output voltage of the inverter.

The filtered output voltage of inverter is 400 volts as shown in Fig.13.

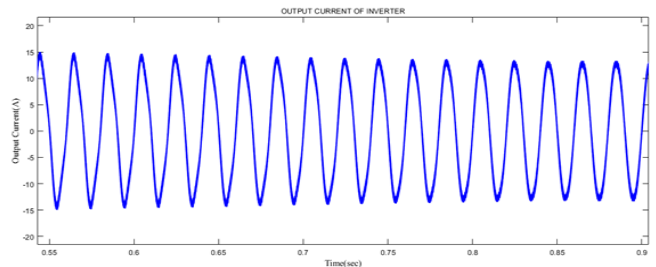


Fig.14: Output current of the inverter.

Inverter produced 15 Amperes of current as output it is of sinusoidal in nature as in Fig.14. The peak to peak current of this output is 30 Amperes. Further, the inverter's filtered output voltage and current are fed to the grid as shown in Fig.15.

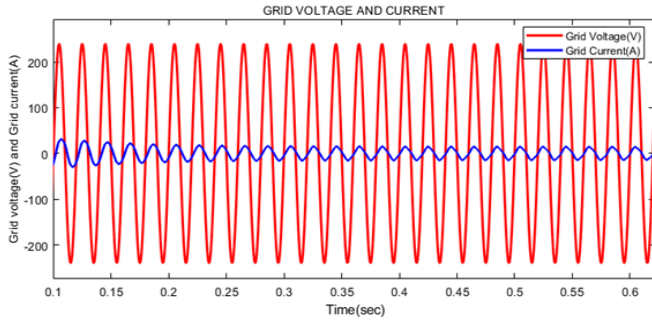


Fig.15: Grid voltage and current.

Here, without grid the output of filter is experienced some transient of over voltage and when the grid is connected the Grid itself resolved the inverter from experiencing those transients. Finally, the active power is sent to the grid and the indication of voltage and current to be in phase with each other reveals that active power is being supplied to the grid.

3.2 Fuzzy logic based grid connected inverter

The various scope output results of the fuzzy logic based inverter circuit for synchronization is shown below in Fig.16.

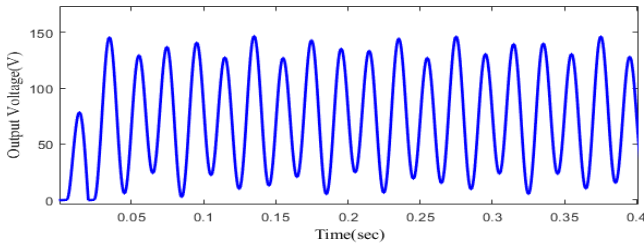


Fig.16: Output voltage of boost inverter

The output voltage of boost inverter is 240 volts and the solar panels gave input. Further, this voltage is given as a reference to fuzzy controller to estimate the error and change in error as shown in Fig. 17.

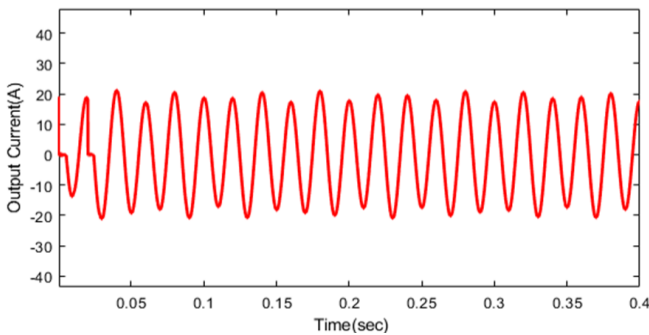


Fig.17: Output current of boost inverter

The output current of the boost inverter is 20 amperes. The peak to peak current value is 40 amperes. This is also taken as reference to the fuzzy controller as shown in Fig. 17.

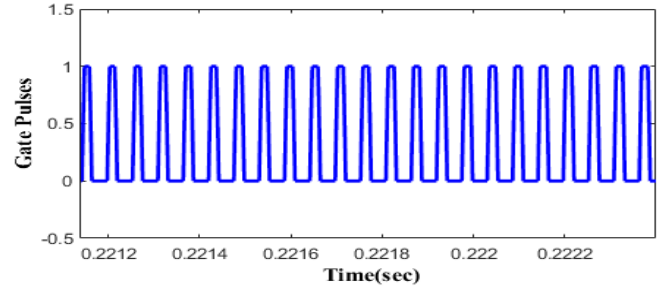


Fig.18: Gate pulses of switches

Fuzzy logic controller generated corresponding signals for duty ratio and the saturation limiter made the signals to be within the limits of 0 and 1 as in Fig.18.

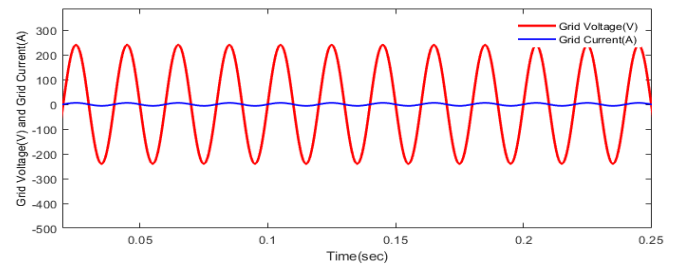


Fig. 19: Grid voltage and current.

Finally, the active power is sent to the grid and the indication of voltage and current as shown in Fig.19 to be in phase with each other reveals that active power is being supplied to the grid.

3.3 ANN based inverter

The various scope outputs are shown in below.

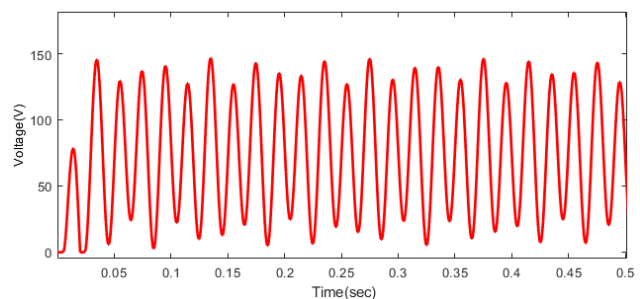


Fig. 20: Output voltage of boost inverter

The output voltage of boost inverter got boosted to 140 volts from the input of volts from the solar panels. Further, this voltage is given as a reference to fuzzy controller to estimate the error and change in error as shown in Fig.20.

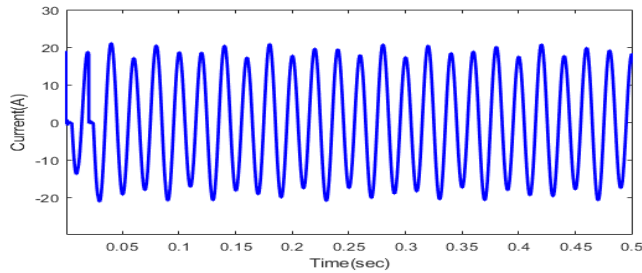


Fig. 21: Output current of boost inverter

The output current of the boost inverter got stepped up to 20 amperes. The peak-to-peak current value is 40 amperes. This is also taken as reference to the fuzzy controller as shown in Fig.21.

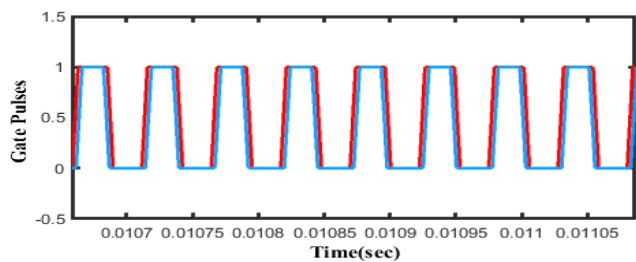


Fig. 22: Gate pulses of S1 and S3

The above figure shows the combined gate signals that are supplied to the switches S1 and S3. Artificial neural network generated corresponding signals for the duty ratio and the saturation limiter made the signals to be within the limits of 0 and 1 as shown in Fig. 22.

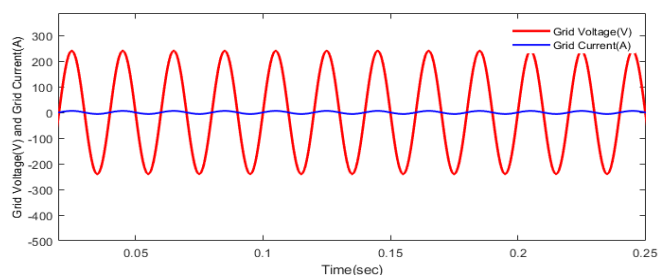


Fig.23: Grid voltage and current.

Finally, the active power is sent to the grid and the indication of voltage and current to be in phase with each other reveals that active power is being supplied

to the grid as shown in Fig. 23. Comparison of all three techniques based on total harmonic distortion can be shown in below Table. 2.

Table.2: Comparison of all three techniques based on total harmonic distortion

Ref No.	PWM	FUZZY	ANN
[5]	-	-	15%
[6]	20%	-	-
[7]	-	-	-
[8]	-	16%	-
Proposed one	14%	10%	10%

4. Conclusion

From the simulation till now for all different techniques and their comparison with already existing techniques reveals that fuzzy and ANN have total harmonic distortion as very less and best suitable for today’s smart city world for our residential application purpose. Perfect creation of dataset values is necessary to train a dataset for better results in all the cases to eliminate any distortion if it’s about to occur.

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Conflict of Interest

The authors declare “no conflict of interest”

References

- [1] P. Aurobinda, M. K. Pathak, and S. P. Srivastava “A single phase photovoltaic inverter control for grid connected system”, *Sadhana*, Vol. 41, No. 1, pp. 15-30, 2016.
- [2] A. Nasim, and Z. R. Khan “A Single-Phase Grid-Connected Inverter using Phase Control Method”, *In 2021 IEEE International Conference in Power Engineering Application*, pp. 183-187, 2021.
- [3] P. R. Kumar, S. Saxena, B. Singh, T. Sharma and J. Srikakolapu “Introduction to various controlling techniques for inverters as a part of undergraduate course in power electronics”, *In 2014 IEEE International Conference on MOOC, Innovation and Technology in Education*, pp. 89-95, 2014.

- [4] G. Pragma and Amit Ojha "Recent advances in synchronization techniques for grid-tied PV system: A review", *Energy Reports*, Vol. 7, pp. 6581-6599, 2021.
- [5] Y. Swathi, R. Kiranmay, and K. V. G. Reddy "ANN Based Model Predictive Control of Single Phase Grid Connected Photovoltaic System Using Mppt Technique", *International Journal of Engineering Sciences & Research Technology*, Vol. 6, No. 4, pp. 407-419, 2017.
- [6] D. P. Argo and E. Taryana "A new voltage control method for single-phase PWM inverters", *Journal of Engineering and Technological Sciences*, Vol. 43, No. 2, pp. 139-152, 2011.
- [7] H. N. F. Abdul, M. A. A. Jalil and N. S. S. Mohamed "Design and simulation of single phase inverter using SPWM unipolar technique", In *Journal of Physics: Conference Series*, Vol. 1432, No. 1, art.no. 012021, 2020.
- [8] R. Balasubramaniam, K. P. Kathirvelu, K. Sathishkumar, R. Amirtharaj and S. Palani "Fuzzy Based Single Phase Double-Tuned Current Source Inverter with Reduced Harmonics for Microgrid", *Journal of Applied Sciences*, Vol 14, No. 18, pp. 2098-2108, 2014.



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