AI Based Single Phase Grid Connected Inverter

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Abstract---Solar-grid integration is a method for incorporating large amounts of photovoltaic (PV) power into the utility grid. Advanced inverter technology, anti-islanding technology, grid-plant protection technology, solar-grid forecasting technology, and smart grids technology are all part of solar-grid synchronization technology. Many methods are used to control inverters, including sinusoidal pulse width modulation, space vector width modulation, and selective harmonic suppression pulse width modulation. Among control methods, pulse width modulation (PWM) 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 --- Grid connected inverter ,conventional model, fuzzy logic and Artificial neural network.

I. INTRODUCTION

Renewable energy sources (RESs) are increasingly being used to generate power due to their versatility and capacity to support utility systems. The integration of renewable energy sources (RESs) into the electric grid has created challenges for administration, maintenance, operation, and planning, notwithstanding their benefits. The main goal 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. Grid-connected inverters are an important component of resource management because they allow RES and DG to integrate with utility networks. Furthermore, although inverters connect the complete power plant to the grid, DC-DC converters are required to manage the DC power generated by PV or fuel cell sources (Kabalci, 2015; Kabalci and Kabalci, 2018, 2017).

Microgrid applications have raised the demand for efficient power conversion, particularly in the low-voltage range (Schweizer and Kolar, 2013), with numerous power converter research on cascaded multilevel inverters and DC-DC converters proposed in the literature. The highest share is held by PV power plants, which are predicted to reach 1000 GWp capacity by 2022 after increasing installed capacity to 400 GWp by the end of 2017 (JaegerWaldau, 2017; Masson et al., 2018; Schmela, 2018). The governments of the United States and Europe provide subsidies to support the major contribution. The decreased generating and installation costs of PV technology suggest that more PV power plants will be able to handle other renewable energy sources. Even as PV power plants' installed capacity increases, overall efficiency—which is based on the performance of PV modules, power converters, and control techniques—remains critical. Several studies have examined the main components of a power converter, including DC-DC converters, inverter stages, and control strategies (Çelik et al., 2018; Meneses et al., 2013; Romero-Cadaval et al., 2013).

The basic purpose of a PV power converter is to capture and transfer as much power as possible from a PV beam to the utility grid. Thus, maximum power point tracking (MPPT) management techniques are critical for optimizing the output power of a solar array. The overall structure of the PV arrays determines how the power converters and control systems are arranged. There are various definitions for power converter types used in grid connection of PV power plants, but three main categories are widely used (Díez-Mediavilla et al., 2014; Romero-Cadaval et al., 2013; Shayestegan et al., 2018; Sridhar and Umashankar, 2017; Zeb et al., 2018). An inverter's output stage consists of a line frequency (LF) three-phase transformer that boosts the low voltage (LV) output while lowering losses. building a link to medium-voltage distribution lines. The most typical central inverter topologies have an efficiency of 85-90%, however they are built in huge, heavy constructions due to transformers and cooling. Furthermore, as compared to 3L topologies, 2L inverter topologies have a lower power factor and higher total harmonic distortion

(THD) ratio (Jana et al., 2017; Kouro et al., 2015). Originally based on thyristors as switching devices, central inverters have developed into power converters that use insulated gate bipolar transistors (IGBT) and MOSFETs. While some of the previously described issues, such poor power quality and higher THD, have been addressed by the higher switching frequency, the intended total efficiency has not yet been achieved (Ankit et al., 2018; Goroohi Sardou et al., 2018; Jana et al., 2017). The 3L-NPC or 3L T-type inverter topologies, which are seen in Figs. 3a and b, respectively, make up the most recent centralized inverter designs (Kouro et al., 2015). In contrast to traditional inverter topologies, the 3L-NPC offers a low THD ratio and a stable common mode voltage (CMV).

Conergy created the T-type architecture, which uses two-way switching semiconductors to clamp

II. DOUBLE STAGE SINGLE PHASE GRID CONNECTED PV INVERTER

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.

The block diagram shown below gives the reference blocks that are to be used in the simulation model.

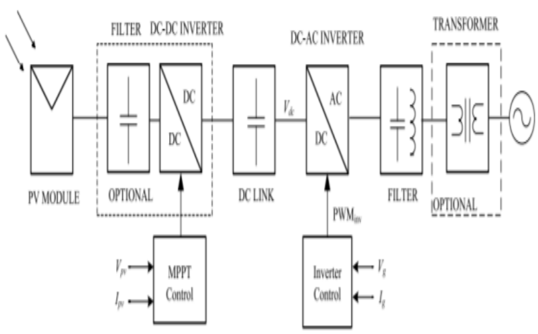

Fig.1. Block diagramof conventional method

The conventional method which ismainly a single phase grid connected inverter is shown in figure as follows.

the utility grid's phase voltage to create a zero-voltage level. Thus, like the 3L-NPC topology, the 3L T-type inverter can function without a transformer at the output (Ahmad and Singh, 2018; Faraji et al., 2017; Kouro et al., 2015). The primary disadvantage of centralized type inverters is their reliance on a single MPPT algorithm, which restricts their overall efficiency with respect to the solar array that receives the greatest shade. Since each string is directly connected to an inverter and coupled inverter arrays improve total power capacity, the string inverter is a smaller version of a centralized inverter. If the string voltage in the string inverter design is insufficient, a second boost transformer or DC-DC boost converter is needed. Since they combine the benefits of centralized and string inverters because of their adaptable design features, multi-string PV inverters based on boost DC-DC converters that are less expensive and smaller are designed to address these shortcomings (Kabalci et al., 2015c, 2015b, 2015a; Romero-Cadaval et al., 2013).

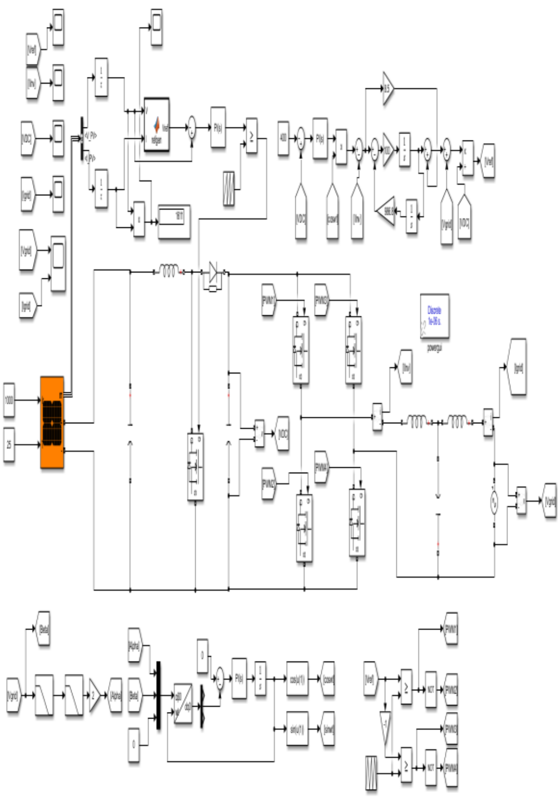

Fig.2.Simulation model for Double stage single phase grid connected solar PV inverter.

III. FUZZY LOGIC BASED SINGLE PHASE GRID CONNECTED INVERTER

In this circuit FLC is used to generate the switching signals for the proposed boost inverter which injects the power into conventional grid without violating the grid rules. The following

Figure6 shows the membership functions and fuzzy rules for the proposed converter. Twoinput variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of the proposed boost inverter.

The error and change in error of the output voltage of a boost inverter are the inputs of Fuzzy Logic Controller. These two inputs can be classified into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive Small and PB: Positive Big and its parameter8–10. The following figure 6 shows the fuzzy rules for the proposed converter.

The basic flow diagram to understand this method using fuzzy logic is shown in figure 3.

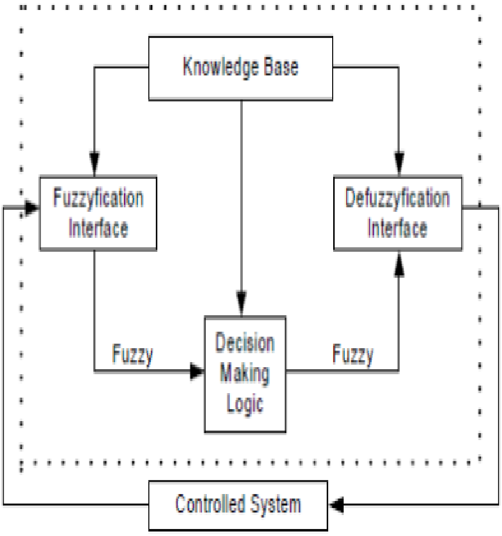

Fig.3. flow chart for the fuzzy logic controller

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 figure 4 and 5.

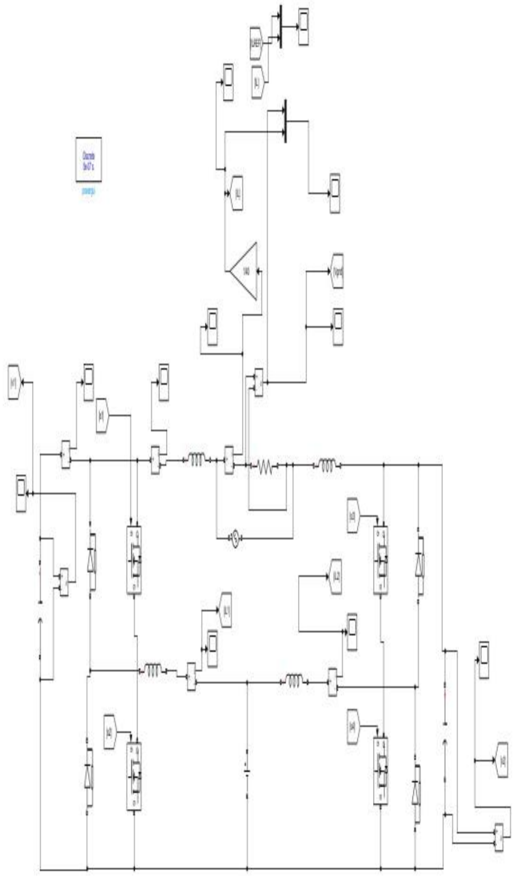

Fig.4. Simulink model of proposed inverter circuit.

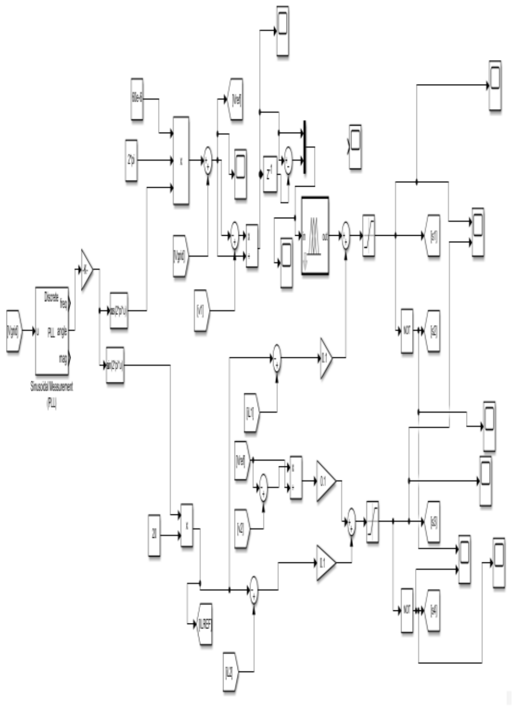

Fig.5.Model showing the generation of PWM pulses using fuzzy logic controller.

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(e) / (de)	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.6.Fuzzy rules for the proposed inverter.

The above 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.

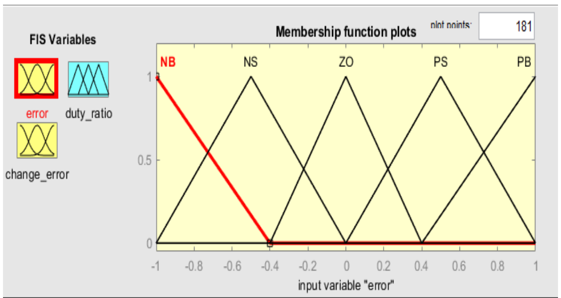

Fig.7.Membership function for input variable Error.

The above figure shows the membership function of the input variable that is error which gives the difference between the measured value and the reference value.

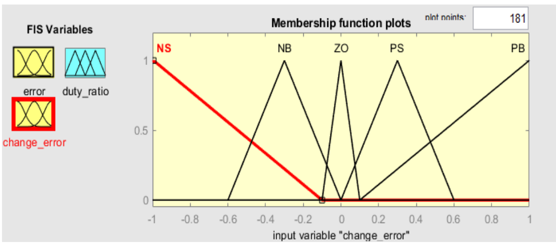

Fig.8.Membership function for input variable Change in error.

The above figure shows the another input variable that is change in error.

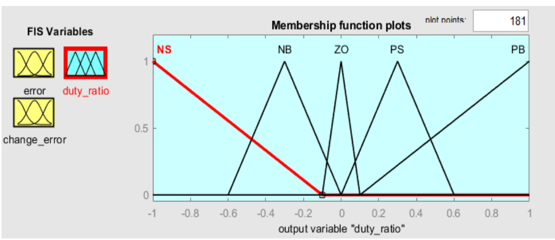

Fig.9.Membership function for input output

Variable change in duty ratio.

III.ARTIFICIAL NEURAL NETWORK BASED SINGLE PHASE GRID CONNECTED INVERTER

The proposed inverter circuit is same as the fuzzy logic only change comes in the circuit of generating pulse signals.

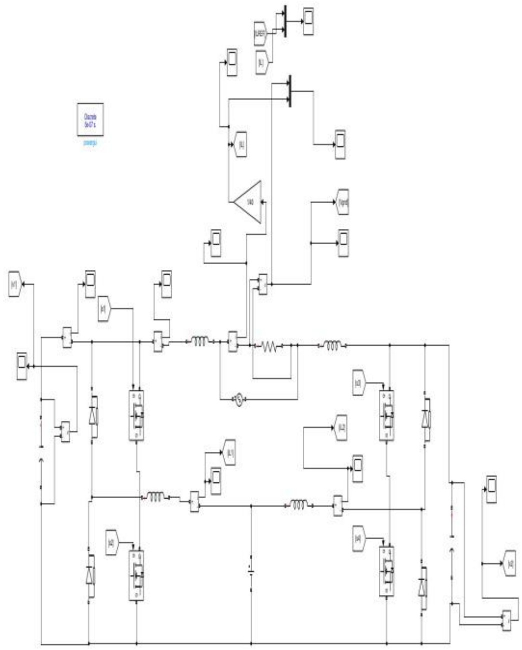

Fig.10.Simulink model of proposed inverter circuit.

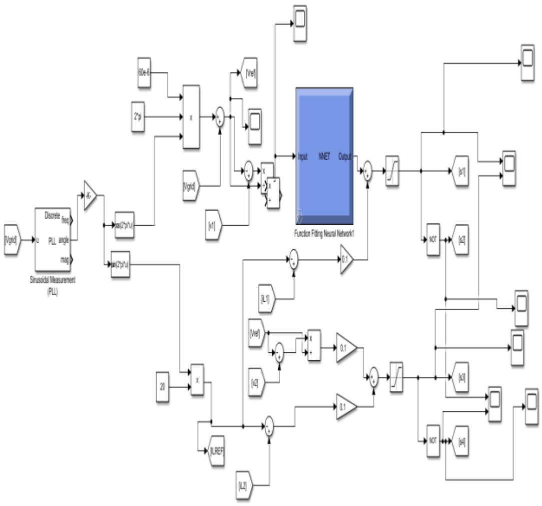

Fig.11. Model showing the generation of PWM pulses using artificial neural network.

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.

IV. SIMULATION RESULTS

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

a) Conventional method

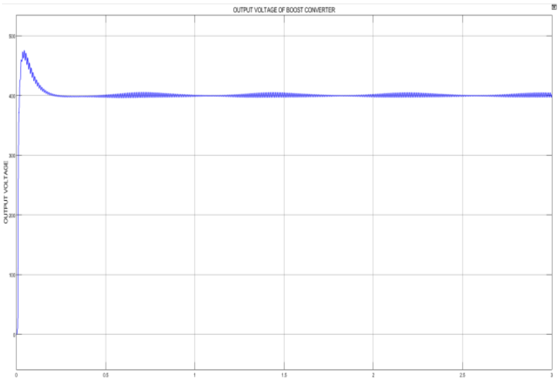

Fig.12.output voltage of boost converter.

The output voltage of boost converter is settled to 400volts after getting boosted from 240volts to 400 volts.

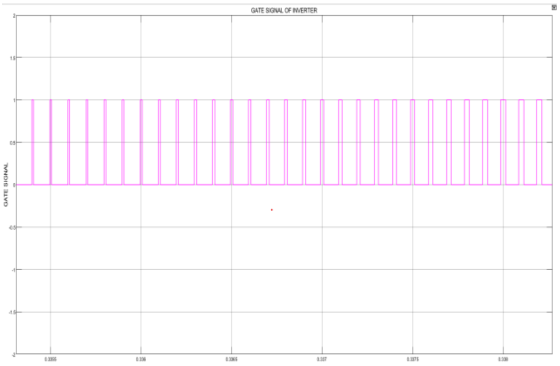

Fig.13.PWM gate signal for the inverter.

These are the PWM signals designed for the inverter which are of continuous pulses.

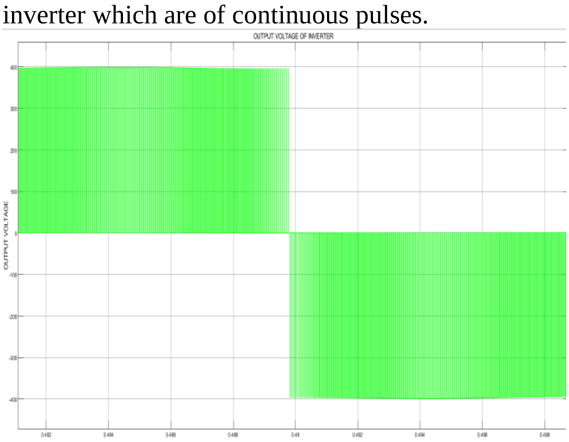

Fig.14.Output voltage of the inverter.

The filteredouput voltage of inverter is 400 volts.

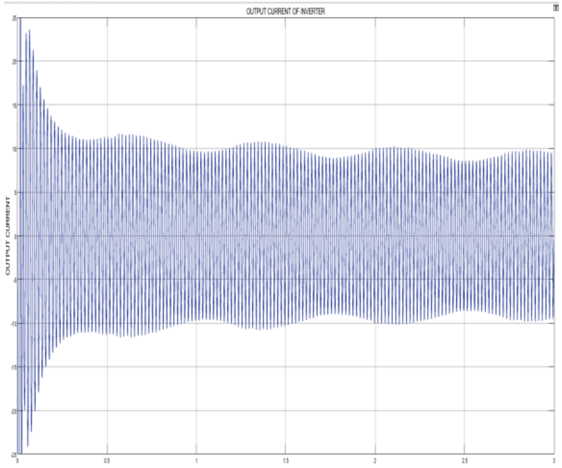

Fig.15.Output current of the inverter.

The output current of inverter is 10 Amperes.

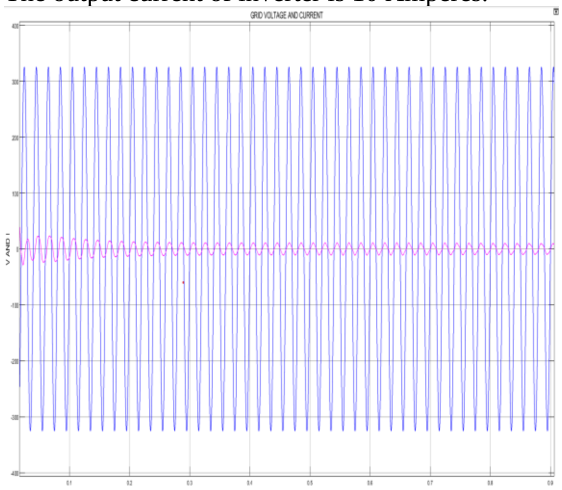

Fig.16.Grid voltage and current.

In the above figure , it shows V and I are in phase with each other which means we are supplying active power to the grid.

B) Fuzzy logic based grid connected inverter

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

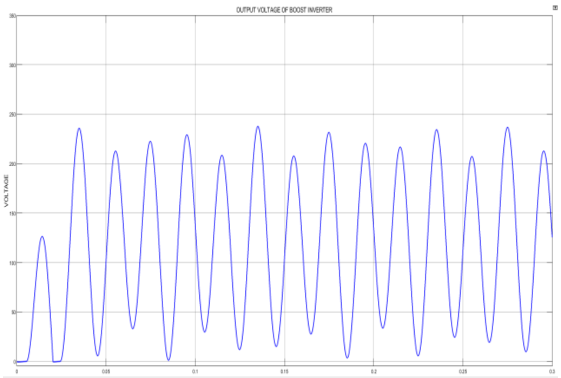

Fig.17.Output voltage of boost inverter

The output voltage of the boost inverter is 240 volts.

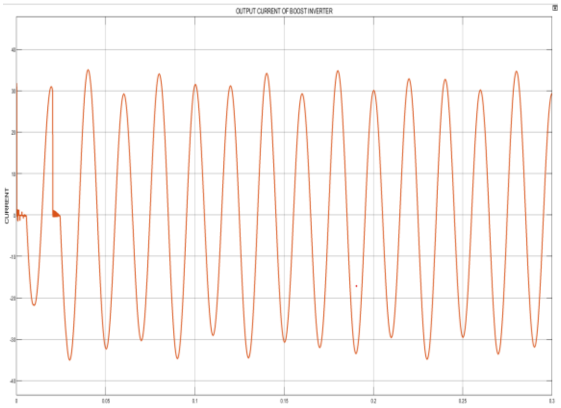

Fig.18.Output current of boost inverter

The output current of the boost inverter is a around 30 amperes.

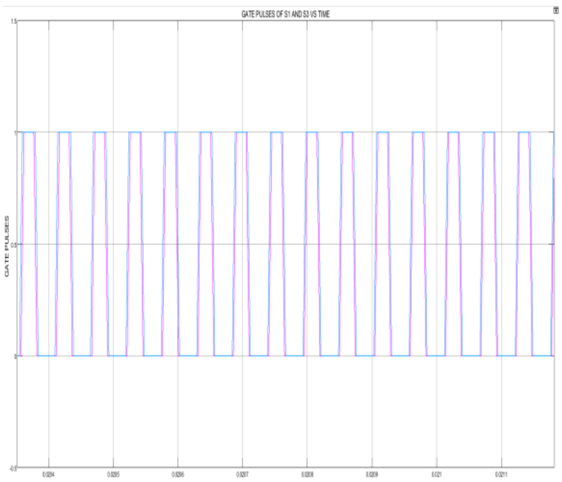

Fig.19. Gate pulses of S1 and S3

The above figure shows the combined gate signals that are supplied to the switches S1 and S3.

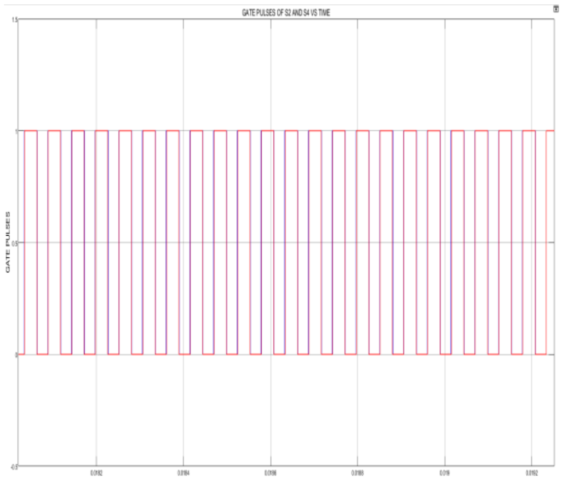

Fig.20. Gate pulses of S2 and S4

The above figure shows the combined gate signals of both the switches S2 and S4.

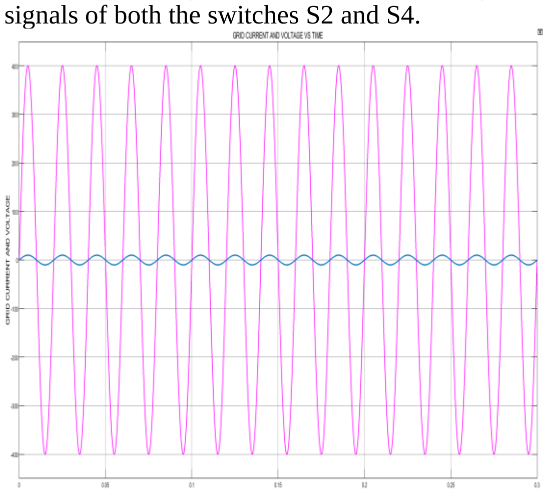

Fig.21. Grid voltage and current.

In the above figure , it shows V and I are in phase with each other which means we are supplying active power to the grid.

C)ANN based inverter

The various scope outputs are shown in below figures.

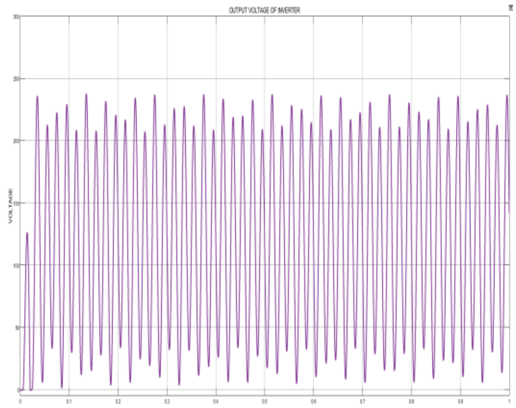

Fig.22.Output voltage of boost inverter

The output voltage of the boost inverter is 240 volts.

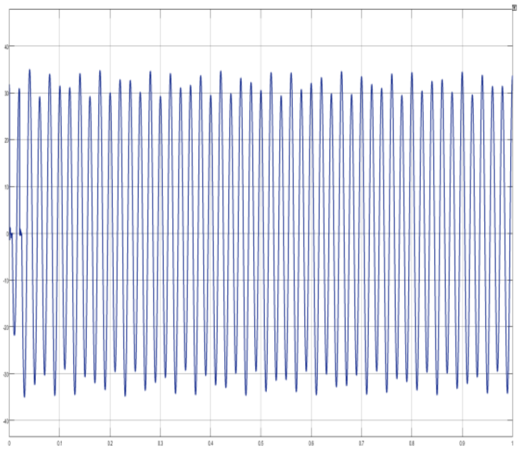

Fig.23.Output current of boost inverter

The output current of boost inverter is 30 amperes.

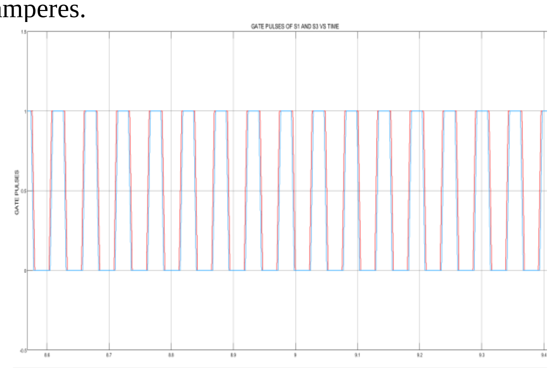

Fig.24. Gate pulses of S1 and S3

The above figure shows the combined gate signals that are supplied to the switches S1 and S3.

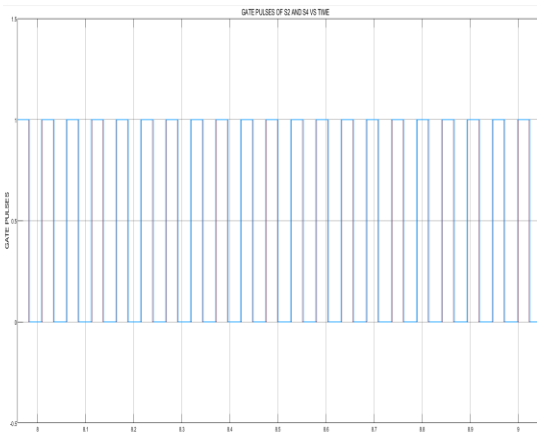

Fig.25. Gate pulses of S2 and S4

The above figure shows the combined gate signals of both the switches S2 and S4.

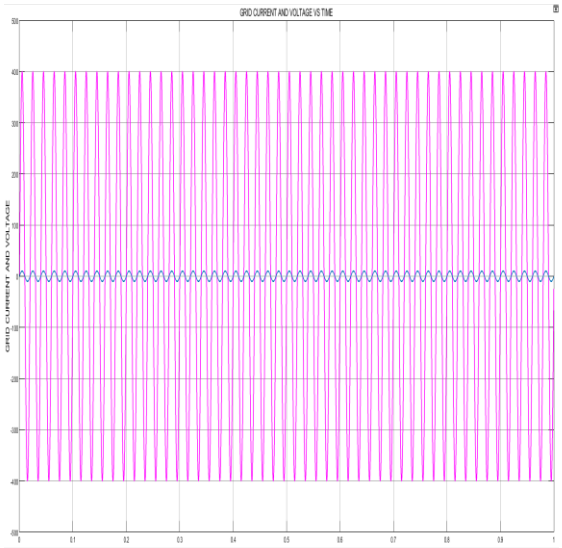

Fig.26. Grid voltage and current.

In the above figure , it shows V and I are in phase with each other which means we are supplying active power to the grid.

V. COMPARISION

In conventional method the inverter has given direct pulses of PWM where the ripple content is some what high in its output and THD is 14.17% whereas in fuzzy the controller is able to use its membership rules to absorb the quick change in voltage i,e error and continuously producing the required pulses with some distorted shape of pulse and THD for this is 10 %. In artificial neural network based method the inverter is getting exact shape of the signal with out distortion and its improving the overall output characteristics with the help of the training dataset used in the model and the THD is 10%.

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