Single Phase SPWM Inverter using Arduino Uno

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Abstract: This project deals with the hardware implementation of single-phase SPWM using Arduino with the help H Bridge. The circuit is divided into five parts i.e. DC voltage supply circuit (rectifier), Gate Driver Circuit, Inverter Circuit (Power Circuit), Control Circuit (Arduino Uno) and RC filter circuit. DC voltage supply circuit also know as rectifier circuit consists of a step down transformer, rectifier circuit using diodes, voltage regulator IC and capacitors to remove the ripples in the DC output. Inverter circuit consists of 4 MOSFETs connected in H bridge fashion, the control circuit consists of Arduino Uno and gate driver circuit consists of an optocoupler and a pull-down resistor. The filter circuit consists of a RC circuit of variable resistor and a capacitor. The whole of the inverting process works on 12V received from the DC supply and finally the 12V AC is stepped up to 230V using the step-up transformer.

Index Terms – SPWM, ARDUINO, INVERTER, MOSFET, H BRIDGE

1. INTRODUCTION

Majority of the electric devices operate on AC power. It's available at our home at 230 Volts at a frequency of 50 Hz, which is easily accessible from the electric plug points on our walls. But in the case of loss of power we get AC supply from the UPS (Uninterruptable Power Supply) unit installed at our home, of which main component is inverter.

So, basically an inverter is essentially a gadget that changes over electricity of DC power into that of AC power. The intend of a DC to AC inverter is to take DC supply from a battery and change over it into an AC supply. For instance, the UPS unit, which is used at our home, has an inverter in it which gets DC supply from a 12 volt battery, and afterward inverter changes it to 12 volt AC and then with the help of a step up transformer 12 volt is stepped over to 230V AC with a frequency of 50 Hz .

2. APPLICATIONS OF INVERTER

There are a lot of applications of Inverters like

- Uninterruptable Power Supply (UPS): As stated above UPS are used in domestic application is case of loss of power. A battery is connected to the inverter which supplies DC power to the inverter.
- HVDC Power Transmission: In high voltage DC transmission, inverters are used to invert DC power transmission to the AC power distribution network.
- Variable Frequency Drives (VFDs): Inverters are used in variable frequency drives, as the fixed frequency is fed to the rectifier which converts it into DC. The inverter is connected to the DC link which hence converts DC into variable frequency AC depending upon the requirement.
- Electric Vehicles: Many of the modern days electric vehicles use induction motor, so to vary there speed variable frequency is required which is fed from the inverter connected to the batteries.

3. SPWM INVERTER

SPWM stands for sine wave pulse width modulation. This method is used to invert DC power to AC power. We are employing this methodology because, it's easy to remove harmonic content from SPWM and hence the overall losses decreases. In this methodology, DC supply is chopped into a pulse train, in which the pulse in the middle has the maximum width and as we move away from the centre the width decreases.

There are basically 2 types of SPWM strategies

- Bipolar SPWM
- Unipolar SPWM

In this project, we would be dealing with Unipolar SPWM.

For generating SPWM a high frequency carrier wave (triangular wave) is compared to the reference wave (sine wave). The output of comparison results in a pulse train which determines the switching of the inverter components and hence be varying the frequency of the reference wave output frequency of the inverter can be varied and by changing the frequency of the carrier wave, the output voltage can be varied.

Let, the amplitude of the carrier wave be Ac and the amplitude of the reference wave be Ar, so the term modulation index (m) is defined as , the ratio of amplitude of reference wave Ar and amplitude of carrier wave Ac i.e. Ar/Ac. When m<1, it's defined as under modulation and when, m>1 it's defines as over modulation. Generally value of m is kept less than 1.In this project SPWM pulse train is produced by Arduino Uno microcontroller, the program utilizes a simple logic of delaying. The pin number 10 and 11 produces the positive half and negative half of the waveform respectively, which is fed to the mutually opposite MOSFET's
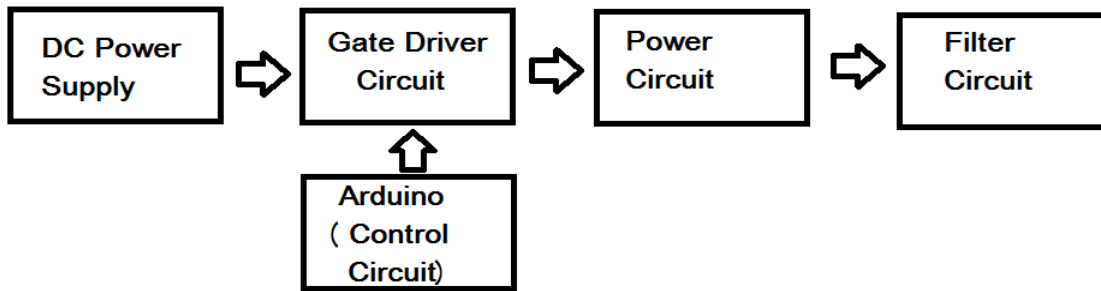
4. BLOCK DIAGRAM OF THE INVERTER

Figure 1

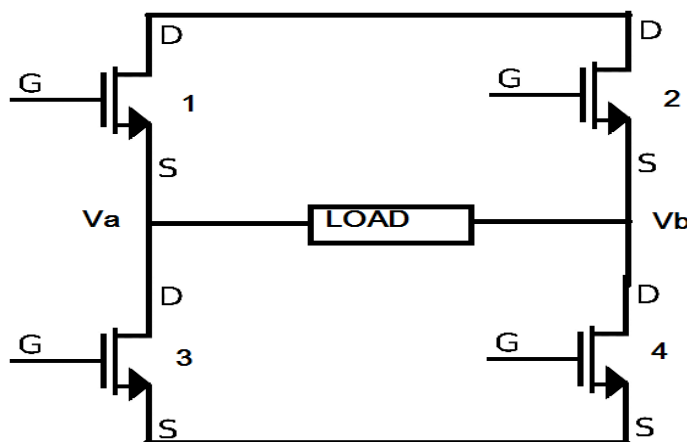## 5. UNDERSTANDING H BRIDGE

Figure 2

SPWM pulse train generated from the Arduino pin number 10 is fed to the MOSFETs (1&4) for the positive half cycle and for the negative half cycle, MOSFETs (2&3) are fed from the pin number 11.

6. COMPARISON BETWEEN MOSFET AND IGBT

Sr. No.	MOSFET	IGBT
1	MOSFET stands for METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR	IGBT stands for INSULATED GATE BIPLOAR TRANSISTOR.
2	Terminals of MOSFET are Drain, Source and Gate.	Terminals of IGBT are Collector, Emitter and Gate.
3	MOSFET has higher switching frequencies.	IGBT has lower switching frequencies as compared to MOSFET.
4	For low voltage and low power applications MOSFET is preferred.	For high voltage and high power applications IGBT is preferred.
5	MOSFET is a unipolar device.	IGBT is a bipolar device.
6	Higher conduction losses.	Lower conduction losses

Table 1

From the above it can be concluded that, for higher switching frequency applications, MOSFET would be more suitable.

7.   SIMULATION OF THE CIRCUIT IN MATLAB

Simulation of the single phase SPWM inverter was done in MATLAB Simulink R2016a. The following circuit diagram was used and the following output waveform was obtained. Comparison between sine wave and triangular repeating sequence was done, and the pulse train was fed to the MOSFETs. For the negative half cycle, phase shift of 180 degrees was given to the sine wave of the negative half cycle and afterwards comparison was done.

7.1 Circuit Diagram of the Simulation
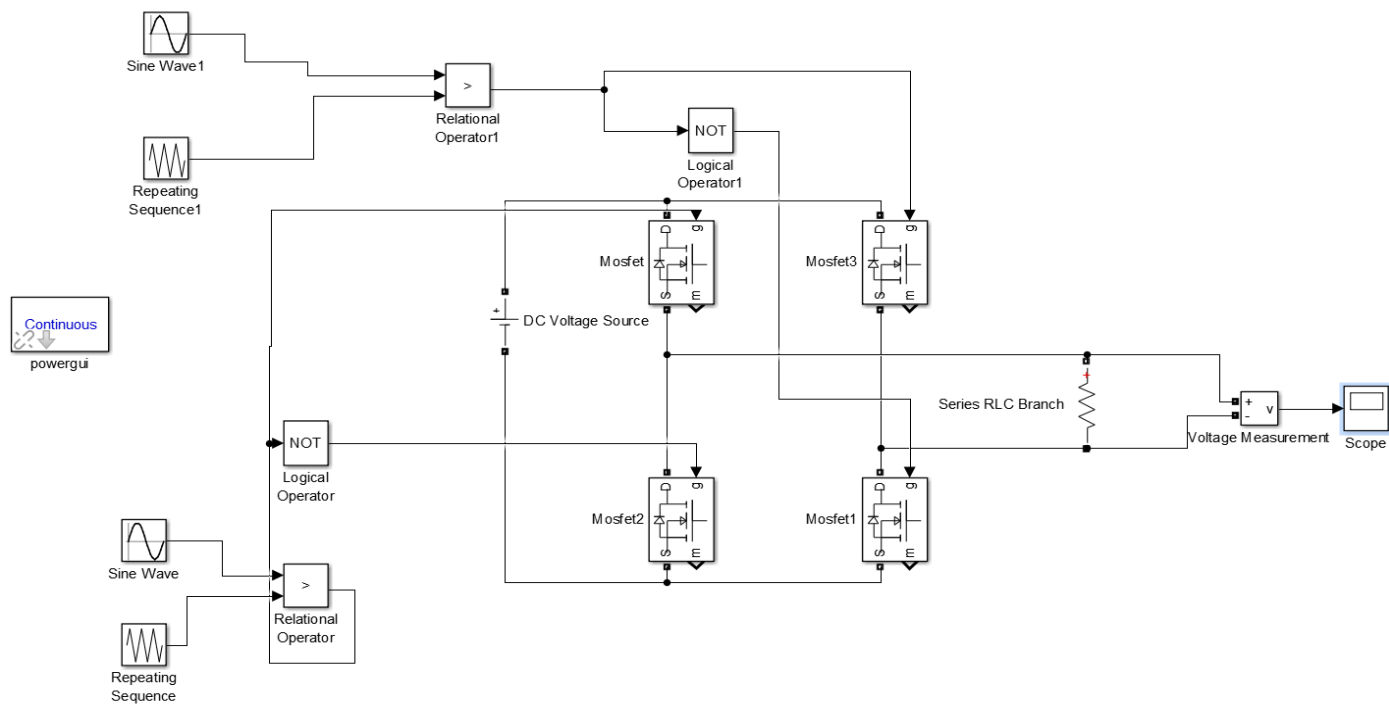
Figure 3
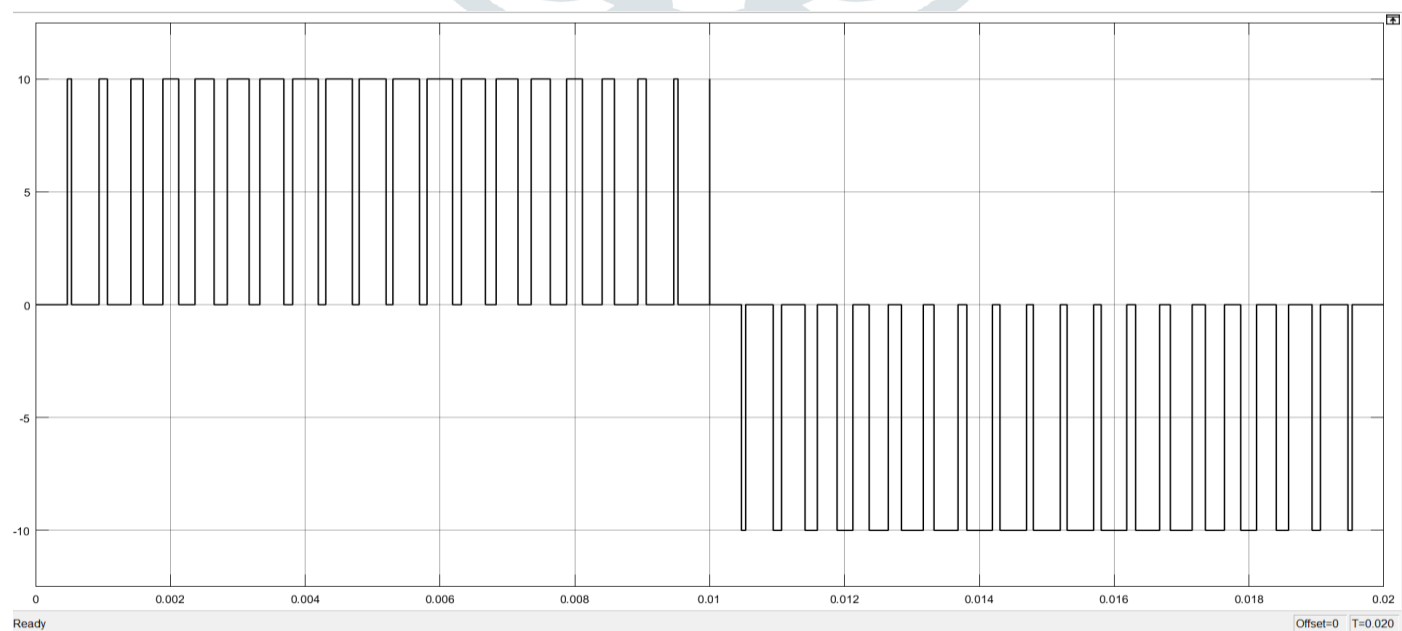
7.2 Waveform obtained from the Simulation

Figure 4

8. Sections of Inverter and the circuit diagram

Following are the sections used in our project

- **Power Circuit:** Four IRZ44N MOSFETs were used for the power circuit. They are connected in an H bridge fashion.

- **Gate Driver Circuit:** Two PC817 optocouplers, and 2 pull down resistors of 1k Ω each were used for the gate driver circuit. Pull down resistors are connected to the emitter (pin number 3) of the optocoupler.

- **Filter Circuit:** Filter Circuit consists of RC filter. For the capacitor, a 1μF capacitor is used and for the resistor a variable resistor of 220k Ω is used.

- **Power Supply:** A Power supply circuit is used to convert 230V of the mains to 12 V DC with the help of step down transformer, bridge rectifier and for the removal of pulses a capacitor of 1m F is used. A voltage regulator IC7812 is also used.

- **Step up Transformer:** A step up transformer is used to step up 12 V AC to 230 V AC for driving to loads.

- **Control Circuit:** Control circuit of the inverter involves the use of arduino uno.
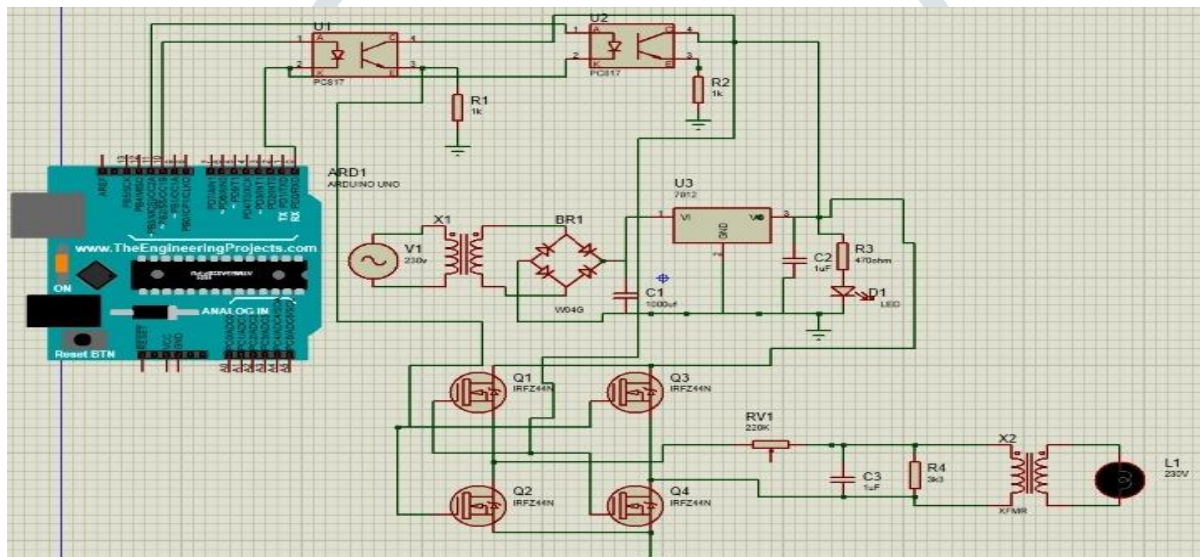

Figure 5: Circuit Diagram

9. Hardware of the Circuit
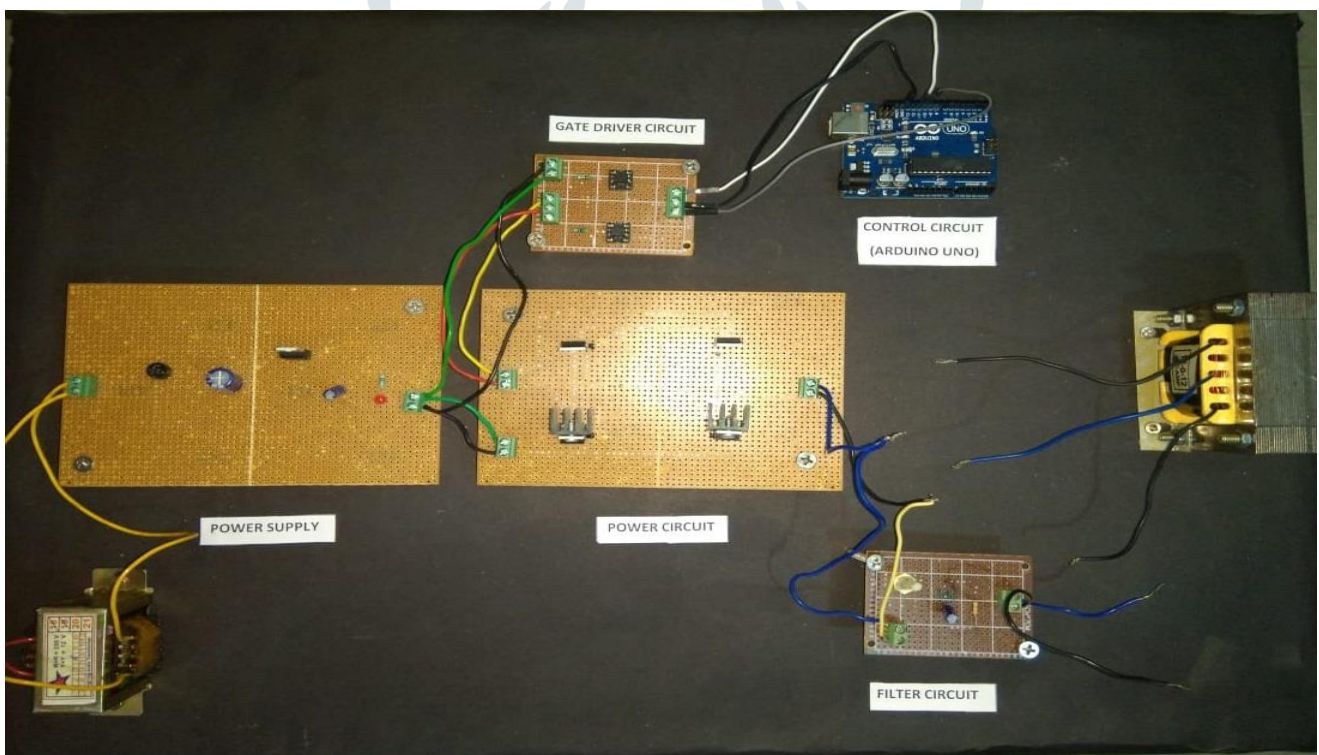
Figure 6(Side View)

Figure 7(Top View)

10. Output of the Circuit

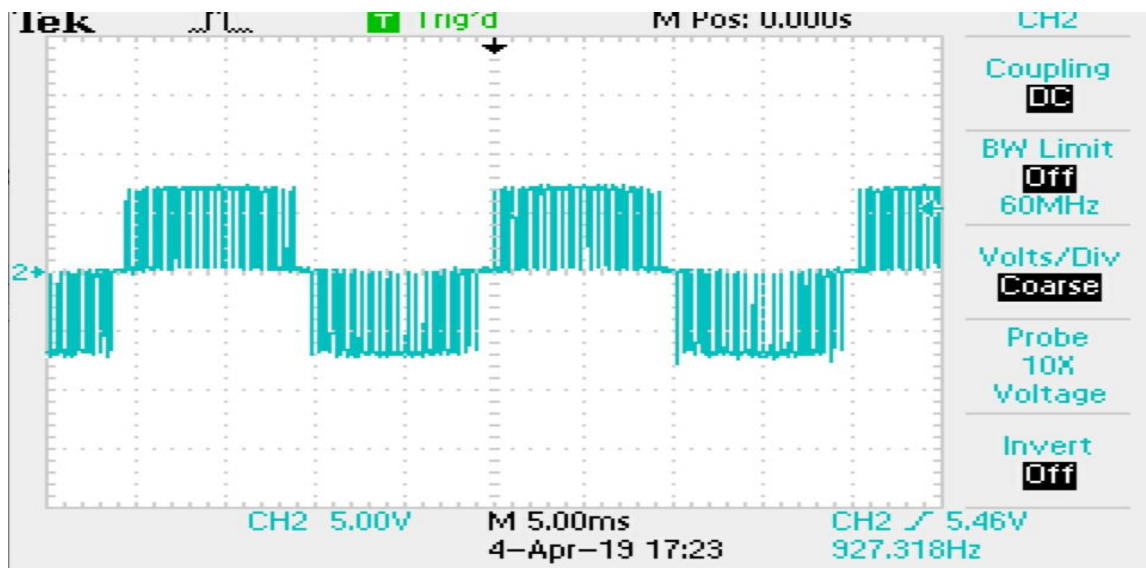Following waveforms were obtained from the circuit with the help of DSO:

Figure 8: SPWM output of the inverter (V vs. t)

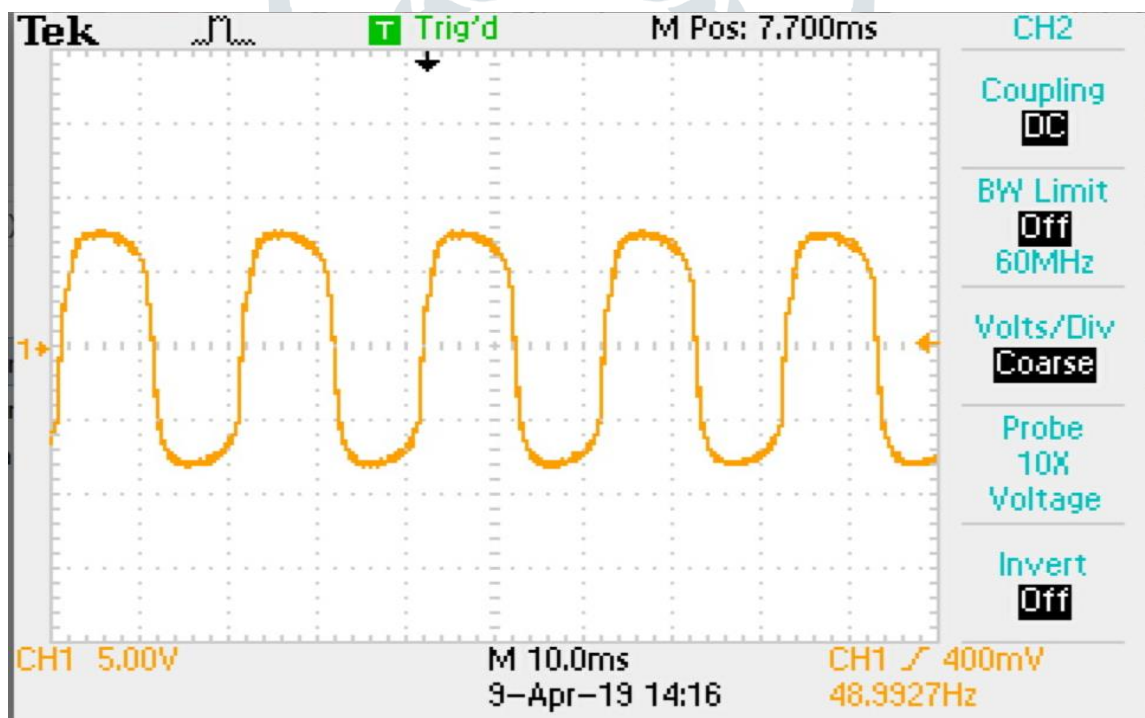After filtering with the RC filter the following waveform was obtained

Figure 9: Output of the inverter after filtering (V vs. t)

11. Result and Discussion:

Following results were obtained from the above experiment:

- Output pulse train is obtained, with varying pulse width. The width of the middle pulse is maximum, and keeps on decreasing.

- After the filter circuit, sine wave is obtained.

- Output frequency of the inverter is 48.9 Hz which is nearly equal to the grid frequency.

The above inverter works on DC power supply, which draws AC power from the mains. But, in real time scenario batteries are used to store the DC power, or the inverters draw the DC power from them or the solar panels installed at the solar power stations.

For obtaining, pure sine wave multilevel inverters can be used, with the help of cascaded H Bridge or by externally changing the DC voltage.

If a feedback loop is developed, output voltage regulation can be improved.

12. Conclusion:

Following conclusions can be drawn from the above experiment:

- Filtering of the SPWM inverter results in a sine wave output.

- After filtering Total Harmonic Distortion of the inverter decreases.

- As the harmonics are reduced, hence losses of the overall system reduce.

- Variable frequency drives can be made from the SPWM inverter easily, just by varying the frequency of the reference wave.

13. REFERENCES

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