INDIAN INSTITUTE OF TECHNOLOGY HYDERABAD

DISSERTATION OF SEGMENT (3-4)

DEPARTMENT OF ELECTRICAL ENGINEERING

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Household Solar Ups (Uninterrupted Power Supply)

Supervised By:

Prof. Kapil Jainwal

Submitted By:

Aditi Rajesh Dure EE23BTech11016

13th October 2023

ABSTRACT:

In an era characterized by a growing emphasis on sustainability, energy efficiency, and power reliability, Household Solar Uninterrupted Power Supply (UPS) Inverters have emerged as a transformative solution for modern residential energy needs. This report presents an in-depth exploration of the intricate world of these hybrid devices, which seamlessly integrate solar energy generation, energy storage, and uninterrupted power supply functionalities within the confines of households.

The report commences with an elucidation of the core principles and technological components that underpin Household Solar UPS Inverters. It dissects the intricate synergy between photovoltaic solar panels, advanced energy storage systems, and high-performance inverters, culminating in an eco-conscious, reliable, and uninterrupted power supply solution.

A focal point of this report is the state-of-the-art features and innovations in Household Solar UPS Inverters. Topics such as intelligent charge controllers, grid-tie capabilities, hybrid inverter designs, and remote monitoring and control are discussed in detail. These technological advancements not only enhance energy efficiency but also empower households to become more self-sufficient and resilient in the face of grid instability or power outages.

In summary, this report serves as a valuable resource for homeowners, renewable energy enthusiasts, and policymakers seeking to harness the full potential of Household Solar UPS Inverters. It emphasizes their pivotal role in augmenting energy resilience, minimizing carbon footprints, and delivering uninterrupted and sustainable power to homes.

ACKNOWLEDGEMENT:

The completion of this study could not have been possible without the expertise of Prof. Kapil Jainwal, our respected ITE professor.

I express my deepest gratitude towards my Professor Kapil Jainwal**,** our ITE professor, who gave me all the motivation, encouragement and guidance for the dissertation work. His guidance and encouragement helped. It is my pleasure to complete my work under such a dedicated and optimistic person.

A heartfelt and sincere gratitude to my beloved parents and my sister for their tremendous motivation and moral support that helped me complete my Dissertation work.

ADITI RAJESH DURE

Roll. No : EE23BTech11016

TABLE OF CONTENT:

HOUSEHOLD SOLAR UPS

INTRODUCTION:

A household UPS, also referred to as an inverter, converts a DC voltage source to an AC voltage source. Energy is stored in batteries and rectifiers in the form of direct current. An inverter converts this energy to AC voltage because home appliances operate on alternating voltage. When there is a power cut, the energy stored in the battery of inverter is used.

FIG 1: INVERTER

IMPORTANCE:

Inverters are essential devices in the household. Things would have been different if there were no inverters. Their role comes into play once there is a power cut. The DC voltage sources from the battery would be of no use unless they are converted to AC voltage which is used for household electricity. That is why household UPS (inverters) are important.

FIG 2: DC TO AC CONVERTER

CHALLENGES:

Challenge issues of household UPS are:

We need to check the specific power requirements of the household devices, based on the power ratings i.e., we need to keep in mind the most less power-rated device and go with the minimum inverter capacity which we need to avoid any overloading of power.

1. Some devices that take in huge power, like air conditioners, refrigerators, etc., need higher surge power*. The inverter should be able to provide it with it.

2. When it comes to challenges, we must also think of safety challenges like overload protection, over-temperature protection, and short circuit protection.

Mains voltage 240 V			
Appliance	**Power rating / W**	**Time / h**	**Energy consumption / J ($E = Pt$)**
DVD player	20	1	7.2×10^4
Lamp	60	1	2.2×10^5
Air conditioner	2000	1	7.2×10^6
Electric oven	2000	$\frac{1}{2}$	3.6×10^6
Electric heater	2000	$\frac{1}{4}$	1.8×10^6

FIG 3: POWER RATINGS

- Overload Protection: There are two circuits involved, the first circuit deals with the detection of overload, and the second one deals with the control to shut off the power circuit whenever overload is detected.
- Over temperature protection: In this, a system gets activated when the temperature exceeds the safe level.
- Short circuit problem: When such a problem occurs, the load is removed from the inverter, changed, and loaded back.

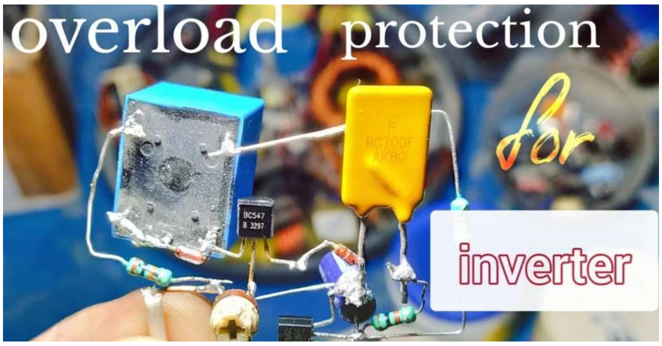

FIG 4: OVERLOAD PROTECTION

APPLICATIONS:

The applications of this system are as follows:

1. The term UPS itself indicates the first application i.e., it provides an uninterrupted power supply.
2. It converts a DC voltage source to an AC voltage source.

3. In some appliances like air conditioners, fridges, etc. it controls the speed of the compressor and regulates the power requirements.

HISTORY OF EVOLUTION:

It was in the late 19th century till the middle 20th century were rotary converter or motor generator (m-g) sets were being used to convert DC to AC. Gas-filled tubes as well as vacuum tubes were used as switches in inverters during the early 20th century.
In the time around 1957, SCR* was introduced, which were the first solid-state inverter circuits. Before that, transistors could not provide sufficient current ratings for most of the applications of inverter.
Another similar type included CSI**, in which the power supply was a current source. It's commutation method*** was different than SCR.
Now a days, modern technology uses components like H-bridges****.

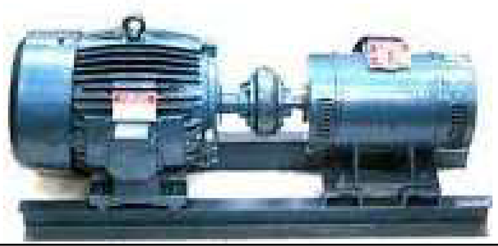

FIG 5: M-G SET

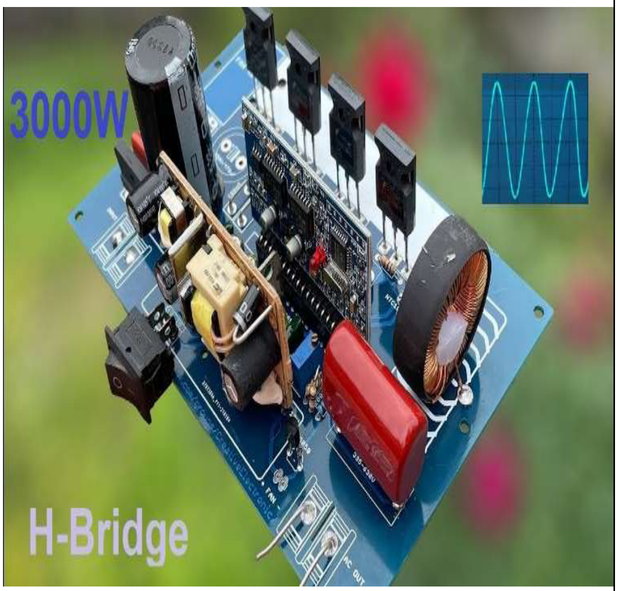

FIG 6: H-BRIDGE

STATE OF ART:

State of the art for UPS inverters:

- Efficiency: State-of-the-art UPS inverters aim for very high efficiency levels, often exceeding 95%. Efficiency is critical to minimize energy losses during power conversion, which not only saves energy but also reduces heat generation.
- Advanced Battery Management: Modern UPS systems incorporate advanced battery management technologies, such as lithium-ion batteries. These batteries offer a longer lifespan, faster recharge times, and better energy density compared to traditional lead-acid batteries.

- Smart Features: The latest UPS systems often come with smart features, including remote monitoring and management capabilities through network connectivity. This allows for real-time monitoring of UPS performance and status.
- Scalability: State-of-the-art UPS systems are designed to be scalable, enabling businesses to easily expand their backup power capacity as their needs grow.
- Power Factor Correction (PFC): Power factor correction is an important feature in modern UPS inverters. It ensures that the UPS draws power efficiently from the main supply and corrects any power factor issues.
- Sine Wave Output: High-quality UPS systems generate a pure sine wave output, which is essential for sensitive electronic equipment. This provides a clean and stable power source.
- Redundancy: State-of-the-art UPS solutions often incorporate N+1 or N+X redundancy to ensure that backup power is always available, even if one module fails.

EXPLANATION OF THE SYSTEM:

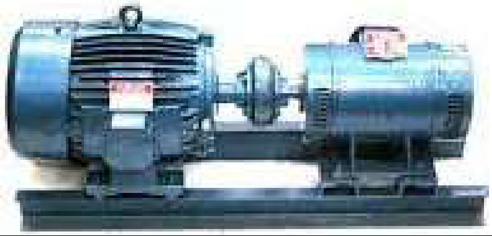

FIG 7: M-G SETS

In this section we will be discussing about how a household UPS functions. We will be specifically dealing with a solar inverter which works without a battery. Since battery is an energy storage, it cannot store energy without a battery, whence it works only in daytime. During the period of day, intensity of sunlight is not constant, so, we are able to capture a fluctuating DC. This fluctuating DC used to be converted to constant dc using a battery, but now this must be included in the inverter itself. In this project, it will be done using buck-booster* and PID controller**.
Whenever we deal with such a system, we also need to keep a track of how much harmonic distortion*** is there. Typically, harmonic distortion should be minimum in order to get best outputs. It can be minimised using Fourier transformation in which 3rd harmonic**** is removed. It is more important to have low THD***** in medical devices (they are more sensitive towards these distortions).

BLOCKS:

In this system, we will use a variety of electrical components viz a viz Arduino*, transistor, MOSFET, resistor, capacitor, transformer.

So, the overview of how this system works is described below:
All these electrical devices are first placed in a virtual simulator called Proteus ISIS. It checks whether required specifications of the particulars are met. As soon as they are, they are converted to real time products.

Next, Arduino generates PMW** signals based on its input (which is not a part of this system, hence not discussed). These signals have less strength to turn on H-bridge configuration*. To strengthen/amplify these signals, switching circuit is used, where transistors are used as switches. The detailed analysis of how it works will be discussed in upcoming part of the project, the functionality.

The signals provided by Arduino are taken as input by the inverter, which then produces sine wave outputs. This sine wave output contains some harmonic distortions, which are removed by OTT filters*** using Fourier transformations. Fourier transformations will be discussed in the later part of this project wherein we will be discussing about the functionality. The OTT filters convert the modified sine wave forms to pure sine wave form at a very cheap cost.
The sine wave form is now taken in by DC AC H-bridge inverter, which converts DC to AC. The mechanism of this will also be discussed in functionality. The AC is then given to transformer and then through OTT filter, it is amplified.

At last, the most important topic of discussion that the source voltage is provided through voltage regulator to all the powered devices like Arduino, transistor switch and MOSFET, and a DC load used in this system.

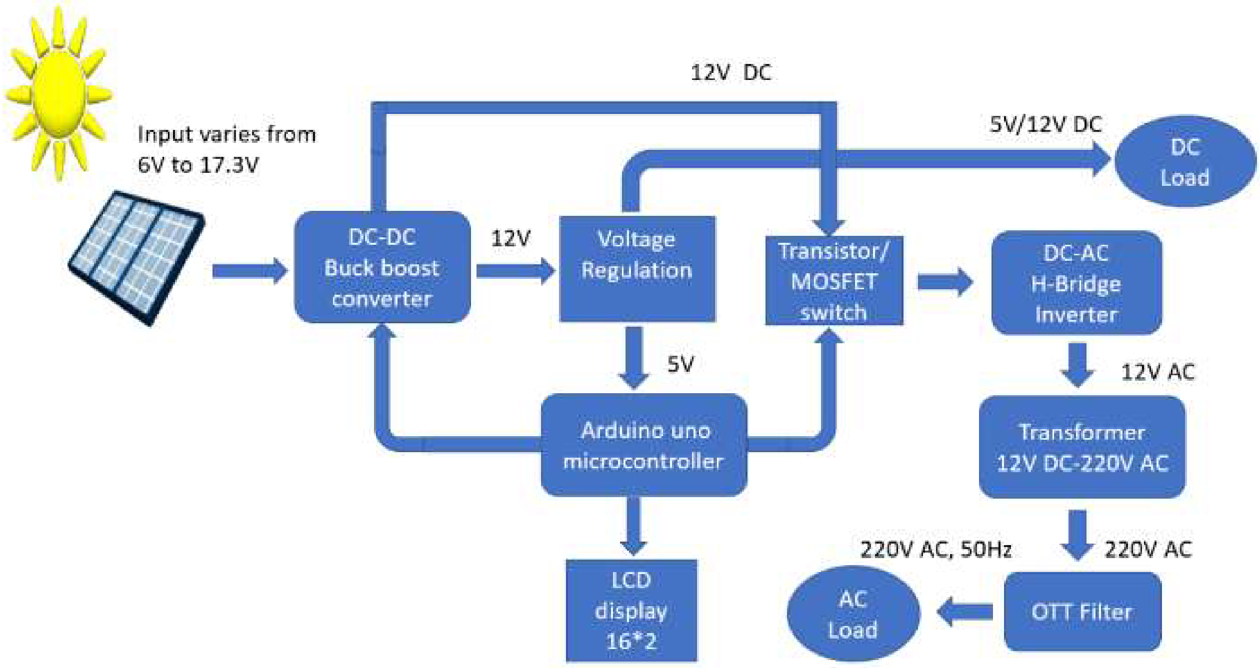

FIG 8: BLOCK

FUNCTIONALITY:

In this section we will discuss

1. Switching circuit (transistor)
2. Fourier transformations
3. H-bridge inverter

Switching circuit (transistor)

As we know switch operates between cases/conditions, here there are two conditions viz a viz cut off – switch off case and saturation – switch on case.

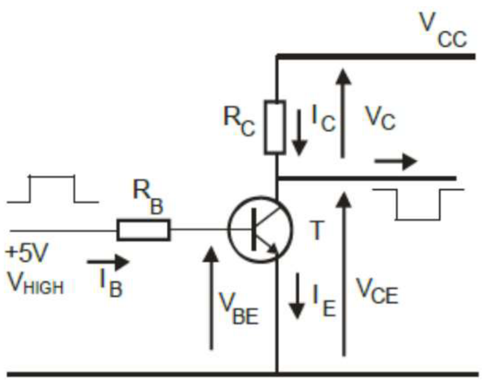

FIG 9: KHILOU8OUHYL

Saturation condition:

Collector emitter voltage: $V_{CE} = 0$

Collector current: $I_C = V_{CC} / R_C$

Cutoff condition:

Collector emitter voltage: $V_{CE} = V_{CC}$

Collector Current: $I_C = 0$

Fourier Transformation

It includes higher mathematics. in this Fourier series are first converted to Fourier transform. Fourier series is an infinite sum of sines and cos function. They are periodic functions. This Fourier transform is taken to be odd.
$f(x) = a_0 + \sum_{n=1}^{\infty}(\text{an}\cos n\pi + \text{bn}\sin n\pi)$

converting this to time domain

$f(x) = a_0 + \sum_{n=1}^{\infty}(\text{an}\cos nwt + \text{bn}\sin nwt)$

modified one is odd function

$f(t) = -f(-t)$
from maths, we finally get

$f(t) = (4V/\pi)\cos\beta\sin\omega t + (4V/3\pi)\cos 3\beta\sin 3\omega t + (4V/5\pi)\cos 5\beta\sin\omega t$
where $V = f(t)$ and β is the angle on which the amplitude now depends.

On varying the values of β, we get the value of amplitude which we need.

H-Bridge inverter

The input voltage to the gate controls the current flow from the source to flow. The gate does not draw a continuous current though; the gate draws current peaks to fill the gate capacitance. They are used as a switch which works in cutoff as well as saturation region.
At cutoff condition, $VGS - VTh < 0$ $VGS = VTh$.

$ID = 0$

Switch is open in this condition.

At saturation Condition, $VGS - VTh >> 0$.

$ID = \text{max}$.

Switch is Closed in this condition.

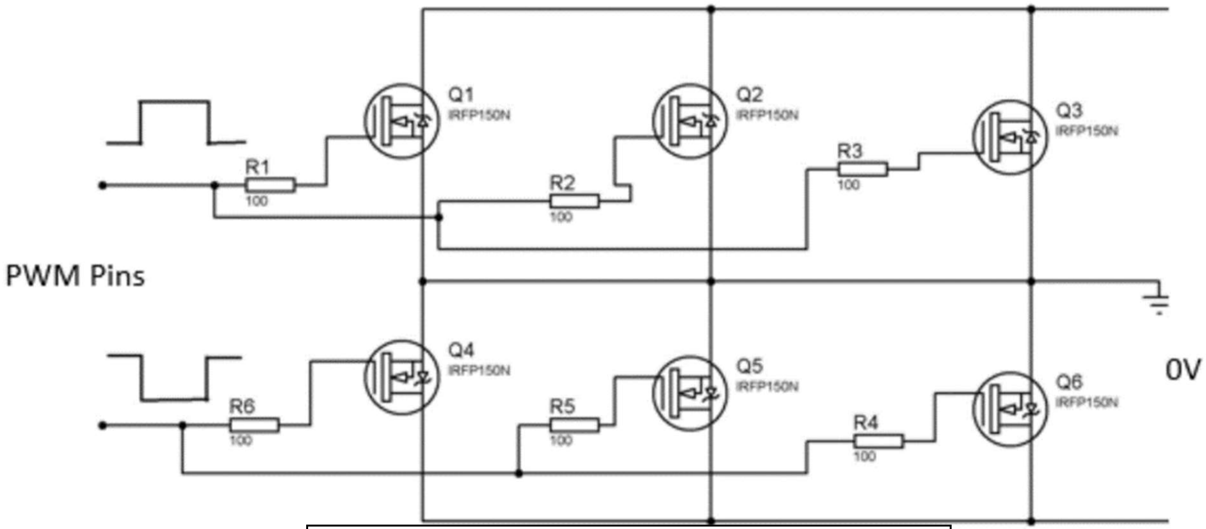

FIG 10: CIRCUIT

ANALYSIS:

In this project, we dealt several challenges to get an outcome which can be used in various applications.
First, we dealt with the problem of getting a continuous voltage which was the business of battery, but since this project was solar inverter without battery, we had to include it in our project.
Next, we had to decrease harmonic distortions.
And finally convert dc to ac using some core mathematics.

DESIGN OF SYSTEM:

The design of a household UPS should include the factors mentioned below:

POWER CAPACITY (WATTAGE):

The most critical factor is the power capacity of the inverter, which is typically measured in watts (W) or kilowatts (kW). To determine your power requirements, make a list of all the appliances and devices you want to run on the inverter simultaneously. Add up their power ratings in watts to calculate the minimum inverter capacity you need. It is a good idea to choose an inverter with some additional capacity to handle occasional power surges.

Appliance	Power rating(in Watts) Standard	Current consumption in 1 Hour (in Amps)
Compact Fluorescent Lamp CFL	8,11,18,35	0.03,0.040,0.078,0.15
Bulb	25,40,60,100	0.11,0.17,0.26,0.43
Fluorescent Lamp	20,40	0.01,0.2
Fan	25-80	0.1-0.4
TV	80-400	0.4--2
Fridge	200-300	1-1.4
Heater	1000-3000	4.5-15
Vacuum cleaner	150-400	0.7-2
Mixi	300-600	1.4-2.8
Washing Machine	800-1000	4-4.5
Microwave Oven	600-1500	2.6-6.5
Table Fan	10-25	0.04-0.11
Computer	80-150	1-1.3
Laptop	20-50	0.09-0.22
Laser Printer	1000-1500	4.3-6.5
Ink Jet Printer	25-50	0.11-0.22
Electric Iron	450-1000	2-3
DVD	20-50	0.09-0.22
A/C 1HP	1000-1500	4.3-6.5
Water Pump ½ HP	500-1000	2.17-4.3
Hair Dryer	1200-1500	5.2-6.5
Music system	20-40	0.09-0.17

FIG 11: POWER RATING

TYPE OF APPLIANCES:

Some appliances, such as refrigerators, air conditioners, and power tools, may require a higher surge power (starting power) when they first turn on. Ensure that your inverter can handle these surges comfortably. You may need an inverter with a higher peak or surge power rating to accommodate such appliances.

BATTERY VOLTAGE:

Inverters come in various voltage configurations, such as 12V, 24V, or 48V DC. Your choice of battery voltage should be compatible with the inverter. The choice of voltage may depend on the size and capacity of your battery bank.

FIG 12: BATTERY VOLTAGE

BATTERY CAPACITY:

The capacity of your battery bank is crucial because it determines how long your inverter can provide power when the grid is down. Calculate your battery capacity based on the desired runtime during a power outage and the power consumption of your appliances. It's important to choose high-quality deep-cycle batteries designed for renewable energy applications.

OUTPUT WAVEFORM:

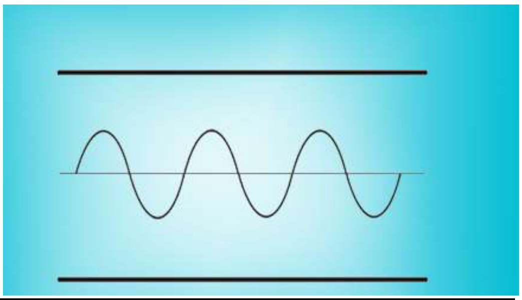

FIG 13: PURE SINUSOIDAL WAVE

Inverters produce two types of wave functions.

They are:

1. Modified sine wave function: It is inexpensive but is not efficient and cannot be used for sensitive applications.

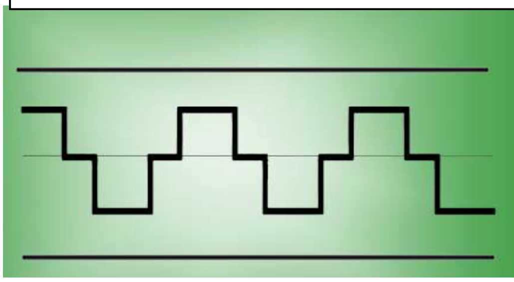

FIG 14: MODIFIED SINUSOIDAL WAVE

2. Pure sine wave function: It is more expensive but provides efficiency and low harmonic distortions. It is used in medical application where efficiency matters a lot.

AUTOMATIC TRANSFER SWITCH (ATS):

If you want your inverter to seamlessly switch between grid power and battery power during power outages, consider an inverter with an automatic transfer switch. This feature ensures that your essential appliances continue to operate without interruption.

SOLAR COMPATIBILITY:

If you plan to integrate solar panels with your inverter system, ensure that the inverter is compatible with solar input and has the necessary charge controller functionality.

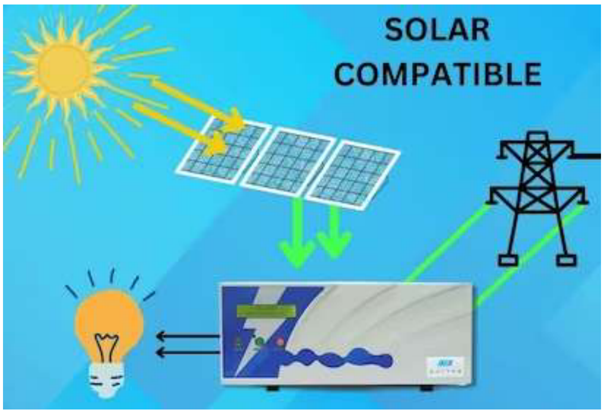

FIG 15: SOLAR COMPATIBILITY

MONITORING AND CONTROL:

Some inverters come with monitoring and control features, allowing you to track your system's performance, set parameters, and control it remotely. Consider whether these features are essential for your setup.

SAFETY FEATURES:

Look for safety features like overload protection, short-circuit protection, and over-temperature protection to protect your inverter and connected appliances.

BUDGET:

It is obvious that for high quality inverters are expensive. We find any different costs for different types of inverters which are used for different applications.

MY INPUT/UNDERSTANDING/IDEAS TO IMPROVE THE SYSTEM:

In this system, we got to know about the working of a solar inverter without a battery.

If we do not go deep into the maths of inverter, my input or understanding about it is:

1. It takes in DC voltage which is not constant.
2. Converts the non-constant DC voltage to constant DC voltage. Here we can find some improvement i.e., instead of converting non-constant input to constant and working on it, we should make a system in which we can directly work on the non-constant input, which is voltage here.
3. This constant voltage is then amplified to some extent which can enable h-bridge configuration in the inverter.
   Here too, we can bring in some changes for improvement…we can somehow manage to be able to activate the H-bridge configuration at low voltage. This will decrease the number of devices used and the cost of the system.
4. The H-bridge inverter then converts this DC voltage to AC and gives it as output.
5. Somewhere during this process, we also focus on minimizing total harmonic distortions.
   It indirectly converts the modified sine wave function almost to pure sine wave function.
   By doing this, this system can have applications in areas like medical appliances.

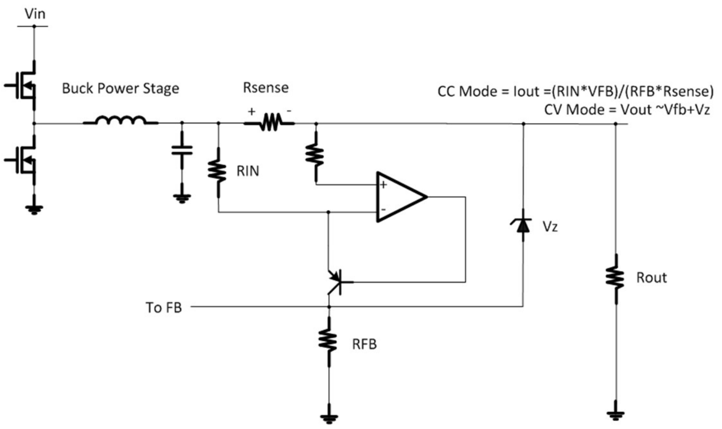

FIG 16: CIRCUIT

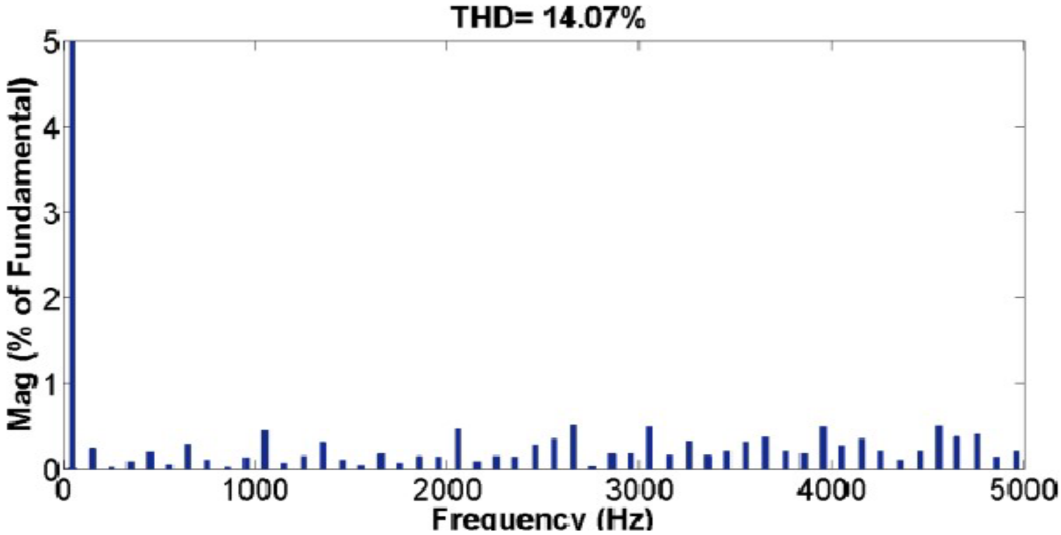

FIG 17: THD

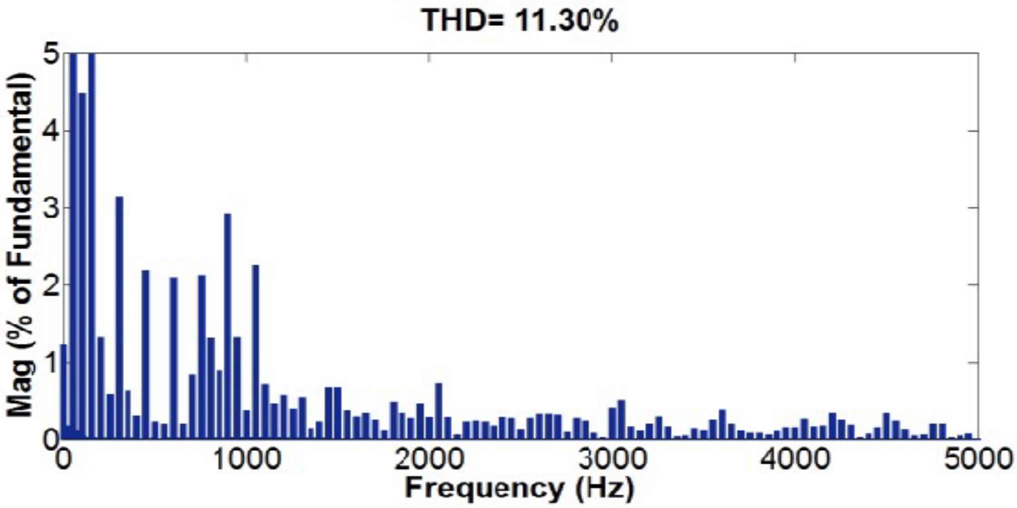

FIG 18: THD

CONCLUSION

The conclusion for this project is the input DC voltage, which is before non-constant is converted to constant and then fixed to a certain value.

The sinusoidal pulse generated by Arduino contains harmonics, which are to be removed.

After this, the main function of inverter i.e., converting DC to AC is done using H-bridge configuration.

This project is suitable for some designing UPS but not all.

Because however different purposes need different UPS.

REFERENCES:

1. P Sai Santosh and Nikhil Deep Gupta; "Design and Implementation of a Solar Inverter without Batteries for IoT Node's and Household Application".
2. Kaushik Kushalappa Naik and Dr.Venugopal N; "1kW Home Inverter using cascaded Current Fed Push Pull Converter and SPWM Inverter".
3. https://housing.com/news/how-inverter-works-a-complete-guide/
4. Bin Wu, 'High-Power Converters and AC Drives', A John Wiley & Sons, Inc., Publication