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Design a Half Bridge Inverter and a Full Bridge Inverter with Overload Protection Circuit Using IC555

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Abstract: Inverter is a power electronic circuit that converts the direct voltage (DC) to an alternating voltage (AC). Inverters are used in a range of applications from consumer electronics and industrial to renewable energy. The flexible capability to create an AC signal from a DC voltage, frequency and speed control are all accomplished from the use of Inverter. Inverter takes the voltage and passes it through switching elements which turn the DC signal into an AC square wave signal. This wave is then passes through filter which turns it into a sine wave signal of the required voltage. This paper presents design an inverter with overcurrent protection circuit without microcontroller, where the MOSFET gate driver is controlled by pulses generated from 555 timer, and with using a low pass filter and setup transformer, a low cost sine wave inverter has been obtained. The heart of the design is 555 timer. The design is achieved in Proteus 8. Simulation results demonstrated that a single phase sine wave (50 Hz) has been generated by a half bridge inverter and a full bridge inverter and protection circuit from current higher than 4.5A has been built. The reliability and accuracy of the system are verified through an experiment.

Keywords: Single Phase Sin Wave Inverter, Half Bridge Inverter, Full Bridge Inverter, Overload Protection Circuit

1. Introduction

Pure sine wave inverter is demand of modern era, it not only increases the efficiency of the power system but also prevent the electrical components from damaging [1]. In practice loads operate with an alternating voltage, because generation and transmission cost of the alternating voltage is much less than in the case of the direct voltage [2]. The alternating voltage cannot be stored, so it is converted to direct voltage to store in batteries and then reconverted to an alternating voltage using an inverter to be used in operating loads when the main grid power outage [3]. The electrical power is not continuous in Iraq especially in summer season because, the amount of generation is insufficient for the increasing loads, increasing the voltage drop in wires, and absence power quality requirements such as, harmonics filter, dynamic voltage restorer (DVR), DSTATCOM etc, this lead to frequent interruptions of electrical energy per day, so consumers using inverter to run lights, charger, fans and other small appliances that need a little current. Commercial inverters generate a square wave or a semi-square wave which are contain high harmonics that cause overheating, noise, and reduce the service life of the devices [4], so a sinusoidal inverter with overcurrent protection circuits at a cost roughly equal to the cost of the square wave inverter is introduced in this search.

2. The Main Parts of the Design

2.1. Astable 555 Timer 50% Duty Cycle

An astable 555 timer is an integrated circuit used in a variety applications as, timer, pulses generator, and oscillator [5].

The block diagram of the 555 timer is shown in figure 1

From the voltage divider rule, the reference voltage of the first comparator is(2Vcc/3) and the threshold voltage of the second comparator is (Vcc/3)

The factor of the Ton and Toff is

$$\text{Ln}\left[(2Vcc/3)/\ (Vcc/3\ )\right]=\text{Ln}(2) \quad (1)$$

So, Ton and Toff are determined from the following relations [6]

Ton=Ln(2)*(Ra+Rb)*C (2)

Toff=Ln(2)*Rb*C (3)

Since the factor Ln(2) is the same for both the Ton and Toff, and (Ra+Rb)> Rb, so Ton>Toff, and the duty cycle> 50%

Figure 2 shows the outer circuit connection for the traditional astable 555 timer

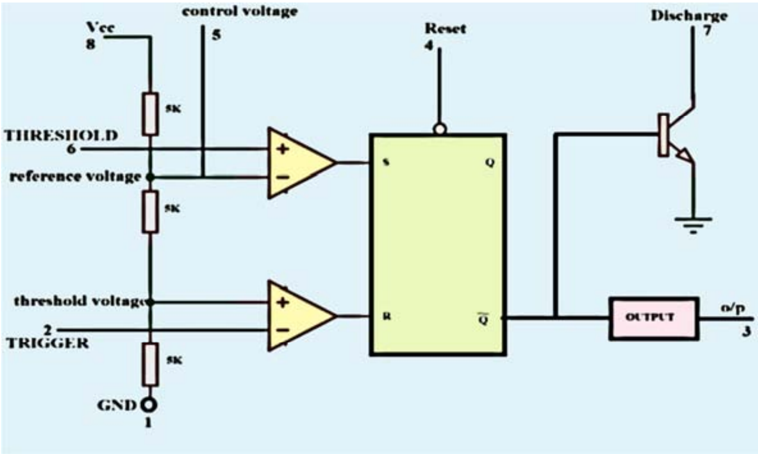

Figure 1. *The block diagram of the 555 timer.*

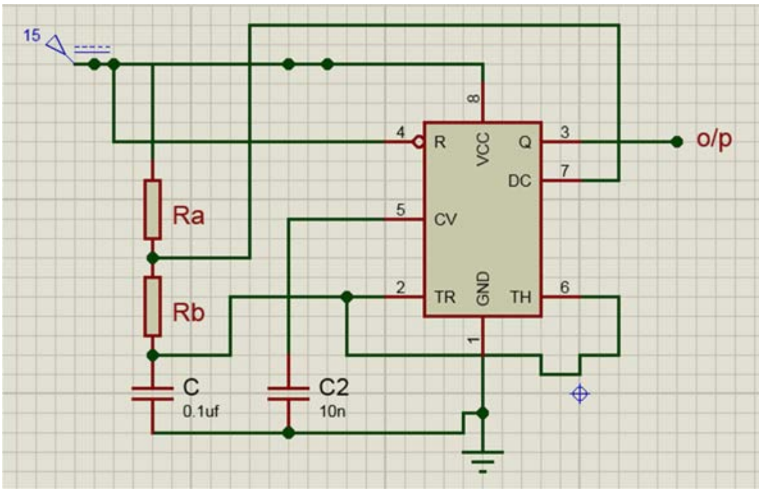

Figure 2. *The outer circuit of the traditional 555 timer.*

50% duty cycle can be obtained by connecting 10kΩ resistor from control pin(CV) to the ground as shown in figure 3.

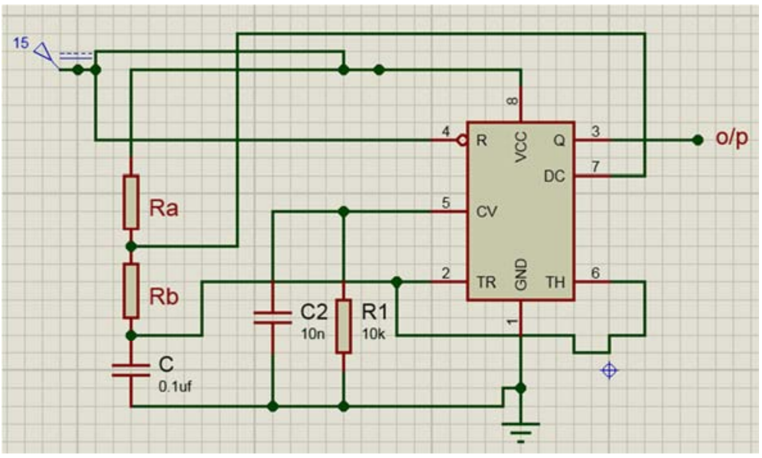

Figure 3. *The outer circuit connection of the modify 555 timer.*

From the voltage divider rule,

The refrence voltage of the first comparator becomes (Vcc/2), and the threshold voltage of the second comparator remains (Vcc/3)

The factor of the Ton becomes,

$$Ln\ [(Vcc/2)/\ (Vcc/3)]=Ln(3/2) \tag{4}$$

Toff is not affected by the resistor connected between (CV)pin and ground, so the factor of the Toff remains Ln(2)

The equations of the Ton and Toff become as follows [1],

$$Ton=Ln(3/2)(Ra+Rb)*C \tag{5}$$

$$Toff=Ln(2)(Rb)*C \tag{6}$$

Now, we can make Ton=Toff, (duty cycle=50%):

For f= 50Hz, $T=\frac{1}{f}$=20ms, Ton=Toff=10ms

From equation 6 calculate Rb

$$10ms=Ln(2)(Rb)*0.1uf$$

$$Rb=\frac{10ms}{Ln(2)*0.1uf}$$

$$Rb=144269.5041$$

From equation 5 calculate Ra

$$10ms=Ln(3/2)(Ra+144269.5041)*0.1uf$$

$$Ra=102360.8421$$

The waveform after connected the 10kΩ resistor is demonstrated in figure 4, where each square is equal to 10ms.

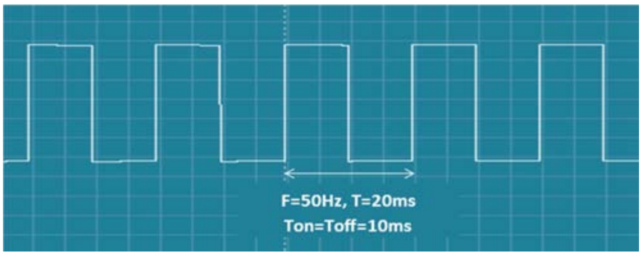

Figure 4. *The output of the modify 555 timer.*

2.2. Low Pass Filter

Filter is designed to pass the fundemental frequency and reject the high order harmonics [7]. Sine wave can be obtained from pulses or square wave after its passage through a low pass filter as shown in the simulation result of the electronic circuit which introduced in figure 5. The electronic circuit consists of astable 555 timer and a low pass filter. First the values of the inductor and capacitor were calculated from the following equation

$$f=\frac{1}{2\pi\sqrt{LC}} \tag{7}$$

For f=50Hz, C=330uf, the value of the inductor is =307mH, then the inductor has been tunned to give a sinewave, the value of 50mH gives a smooth sinewave as shown in figure 6.

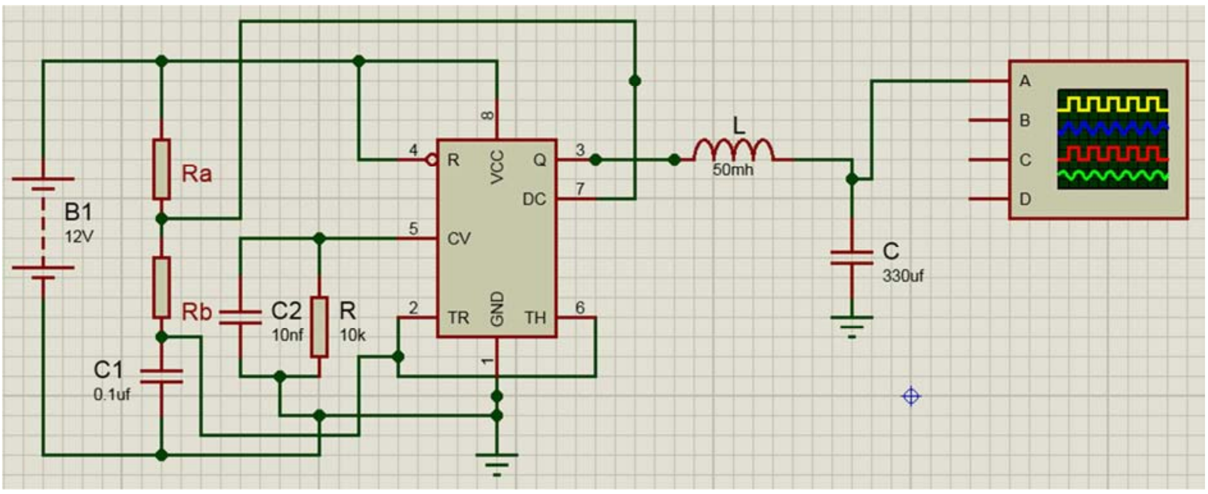

Figure 5. *The electrical circuit that generates the sine wave.*

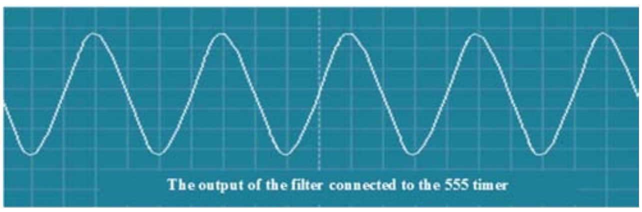

Figure 6. *The output of the low pass filter connected to the 555 timer.*

2.3. MOSFET Gate Driver

MOSFET gate driver is a power electronic device that is used to drive the gate of a power MOSFET efficiently and effectively in high-speed switching applications [8]. The MOSFET gate driver works under the same principle as the MOSFET transistor [9]. In this search IR2101 has been used to drive the MOSFET gate in a half bridge inverter as depicted in figure 7. The IR2101 driver is a powerful and robust in triggering the MOSFET gate, since its output voltage is 12v and the threshold voltage of the MOSFET is 4.5v.

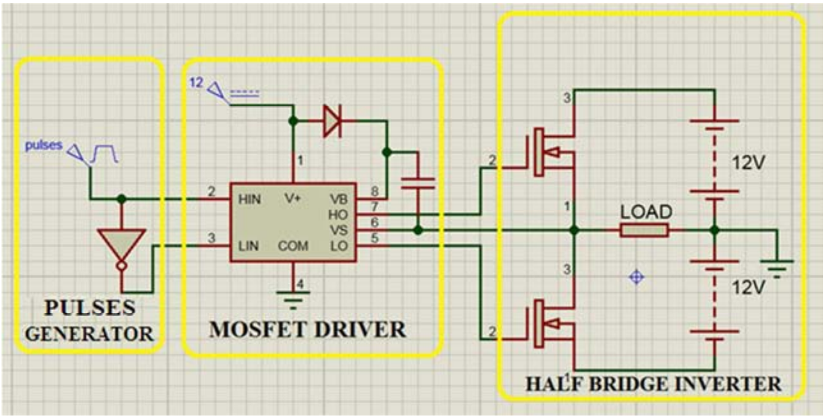

Figure 7. *The IR2101 drive the half bridge inverter.*

IR2101 also has been used in design the full bridge inverter as introduced in figure 8

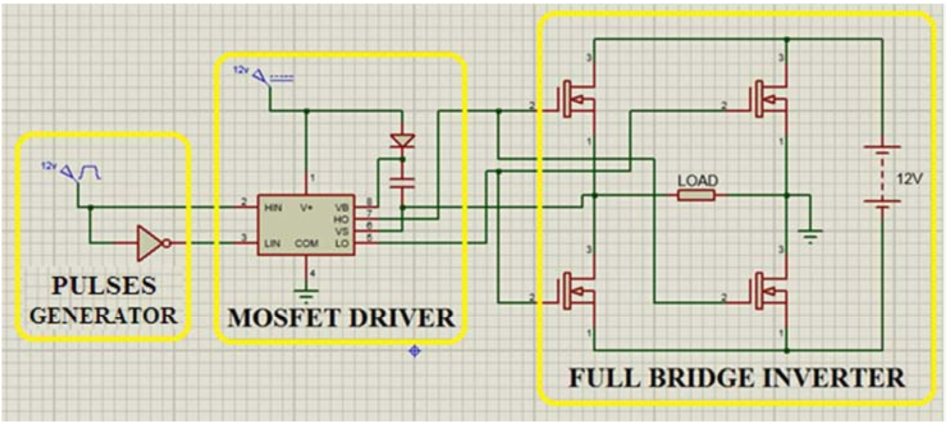

Figure 8. *The IR2101 drive the full bridge inverter.*

3. Design and Simulation

3.1. Half Bridge Inverter

Figure 9 demonstrated the electrical circuit of the half bridge inverter where two capacitors are used instead of two batteries to divide the voltage of the battery on the two mosfet$_S$. The inductor of 50mh and capacitor of 220uf have been used to eliminate the high order harmonics at inverter output, and 12/220 setup voltage transformer to get the desired voltage.

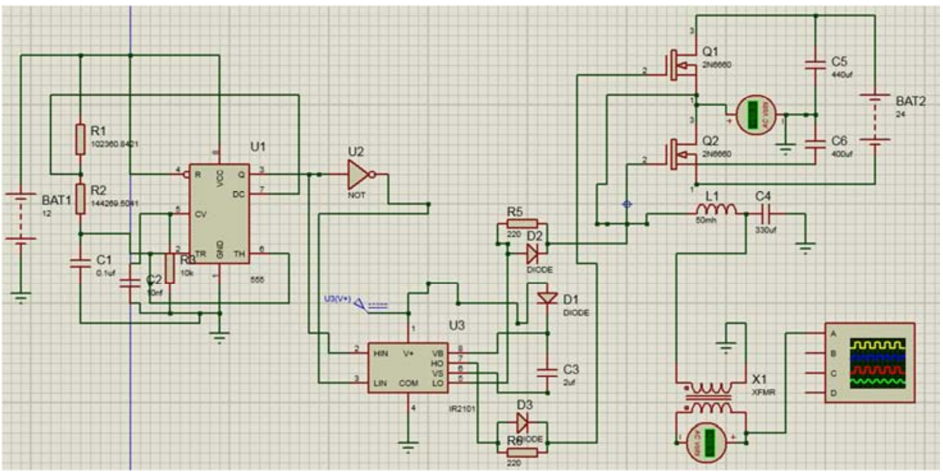

Figure 9. *The design of the half bridge inverter.*

Figure 10 shows the inverter output without low pass filter, and figure 11 introduced the inverter output with low pass filter.

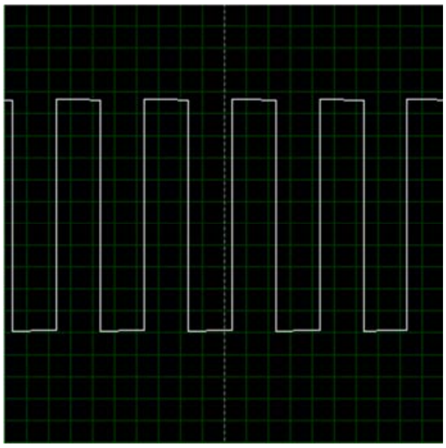

Figure 10. *The output voltage of the half bridge inverter without filter.*

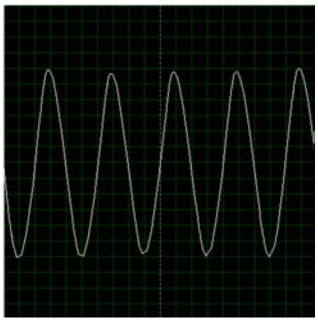

Figure 11. *The output of the half bridge inverter with filter.*

3.2. Full Bridge Inverter

Figure 12 introduced the design of the full bridge inverter with the following values, (24v) battery, (50mh, 330uf) low pass filter, (24/220)v transformer. The sine wave is gotten as shown in figure 14. The inverter output voltage was about 215v and frequency 50Hz. The output of the full bridge inverter was more smooth and stability than the half bridge inverter.

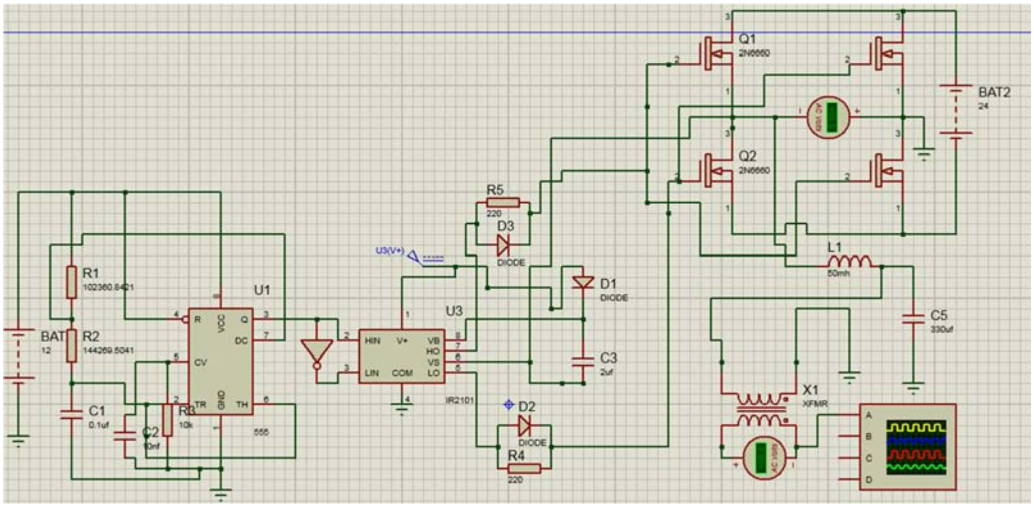

Figure 12. *The design of the full bridge inverter.*

Figures 13, 14 show the output voltage of the full bridge inverter with and without filter.

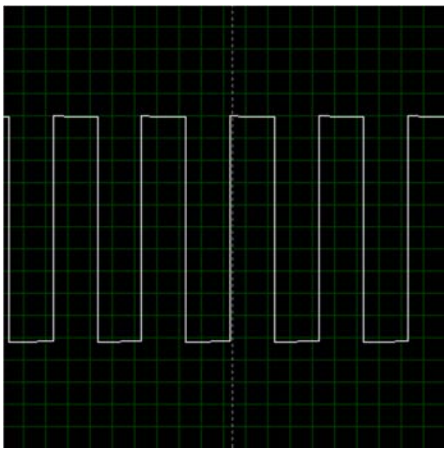

Figure 13. *The output of the full bridge inverter without filter.*

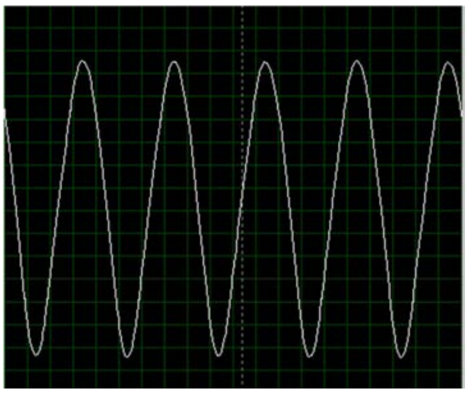

Figure 14. *The output of the full bridge inverter.*

3.3. Over Current Protection Circuit

Overcurrent protection circuit is often used in inverter to cut off the load from the inverter when the load draws a large current than the specified capabilities of the inverter. In this search, a simple over current protection circuit using 555 oscillator has been built. Figure 15 and figure 16 depicted design and simulation the overload protection circuit with the load of 1kw and 1.1kw.

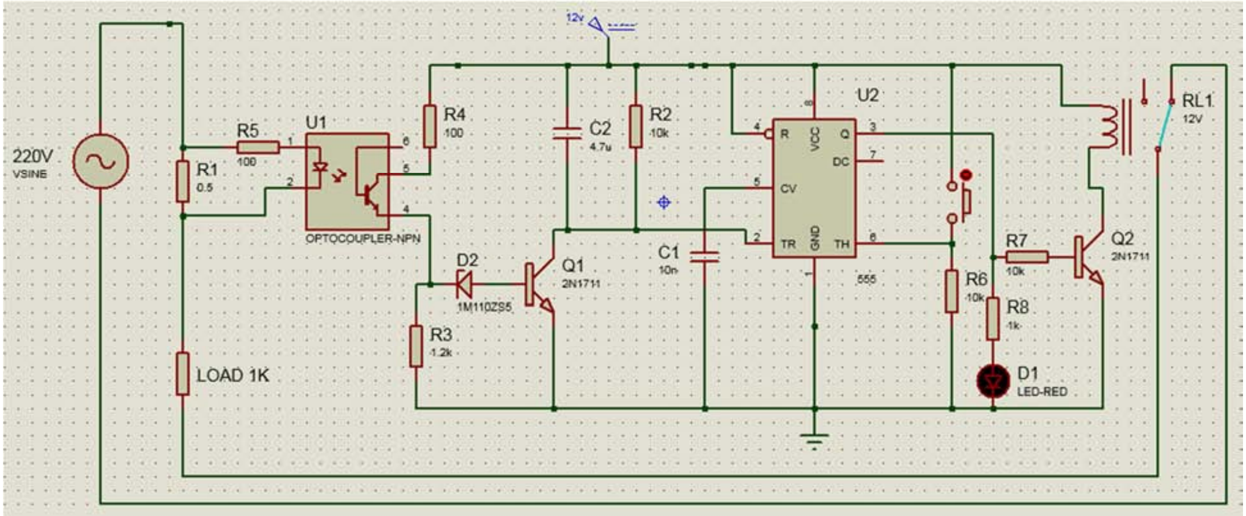

Figure 15. *Design and simulation of the overcurrent protection circuit with the load of 1kw.*

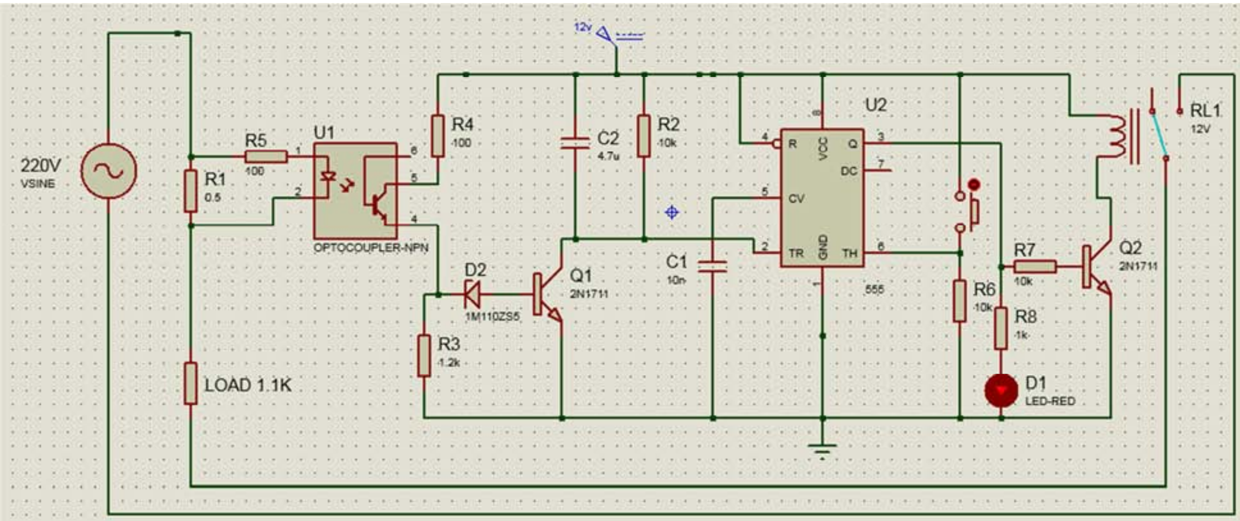

Figure 16. *Design and simulation of the overcurrent protection circuit with the load of 1.1kw.*

Resistor R1 is used as the overload sensing element, it is selected as 0.5 ohm for 220v, 1kw (max). When the load just exceeds 1kw, the current through R1 is higher than 4.5A, producing a potential difference across R1. An optocoupler is used to sense this voltage drop and to isolate the AC mains part from the rest of the circuit. The inbuilt transistor inside the optocoupler senses this voltage and its collector current increases proportionally. Voltage drop across R3 also increases and when this voltage drop becomes greater than breakdown voltage of zener diode (4.7v) and V_{BE} (0.7v) for the first transistor (Q1), it causes forward biasing of the transistor (Q1). This results in the collector of the transistor (Q1) to be pulled down to ground and trigger IC555, which is connected in bistable mode. The output of the IC555 causes overload indicating LDE to glow as shown in figure 16 and forward biasing of the second transistor (Q2) to energize relay. Once the output of bistable goes high, it continuous to remain high, until reset push button S1 or the circuit can be reset after removing unwanted loads

4. Conclusions

With the development of technology, inverter is considered one of the most important parts in electrical and electronic applications [10]. It cannot be dispensed with in all mobile electrical applications and in renewable energy to convert the generated direct voltage to an alternating voltage [11]. In this paper a single-phase half bridge inverter and full bridge inverter without microcontroller are designed. Sine wave was obtained by using a low pass filter that prevents the passage of high-frequency noise. The wave generated by the full bridge inverter contains less distortion than half bridge inverter, due to use capacitors to divide the battery voltage instead of two batteries. Overload protection circuit has been introduced that disconnected the load from the inverter when exceeds 1kw. The simulation results showed acquisition a single phase sine wave inverter with desired voltage and frequency and overload protection circuit using power electronic devices only.

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