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Solar Power Inverters

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***Abstract*- An inverter converts the DC generated by the solar panels to AC which is used by the electrical grids. Inverters are the example of a class of devices called power electronics that regulate the flow of electrical power.**

***Keywords*- DC** , AC, **Electrical grids** etc.

I. INTRODUCTION

An inverter accomplishes the DC-to-AC conversion by switching the direction of a DC input back and forth very rapidly. As a result, a DC input becomes an AC output. In DC, electricity is maintained at constant voltage in one direction. In AC, electricity flows in both directions in the circuit as the voltage changes from positive to negative.

II. FUNCTIONS OF POWER ELECTRONICS FOR INVERTERS

Solar panels produce DC voltage, and if we connect to an electric circuit we get DC. But most of the devices and machines don't use DC as they are designed to work with AC. The power grids work with AC. Therefore, we use inverters to convert DC to AC used by grids.

They have the following functions:

- Converting the higher voltages from solar strings to AC voltage used by grids. 220V and 400V are used by Europe countries and 110V is used by US, Japan.
- A medium voltage grid, based on the size of solar generator, is fed by inverter. If the value of grid voltage is large, the AC voltage which is being adjusted by inverter is also large.
- Frequency of AC that is converted to grid. 50hz in Europe, 60hz in US and Japan.
- Maximum Power Point Tracking (MPPT) means making the best use of solar energy received. This is taken care by maintaining the VI characteristics of solar voltage and current at maximum power.
- If there is a lack of stability in the grid, solar generators are controlled.
- If there is any type of mechanical failure, inverters will act as switches.
- Inverters along with storage batteries make the best use of consumed solar energy for supplying required electricity to the grid.
- Smart inverters use direct current to charge electric vehicles and batteries.

III. DESIGN OF SOLAR POWER INVERTER

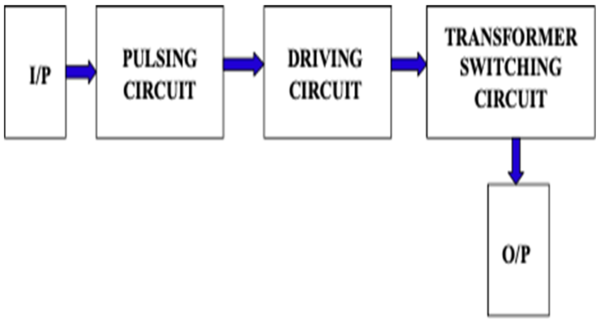

Fig 1. Schematic Diagram of Inverter Circuit. [1]

The inverter circuit has 3 different sections:

- Pulsing circuit
- Driving circuit
- Transformer switching circuit

1. Pulsing Circuit:
The IC 555 is used as timer, pulse generation and oscillator applications.

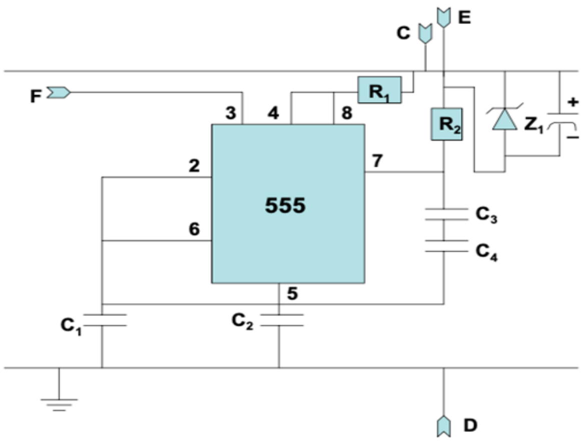

Fig 2. Pulsing Circuit of Inverter Pulsing Circuit. [1]

Here we use IC 555 as a monostable multivibrator. Capacitor C2 is used to supply the control voltage and capacitor C1 is used to set the triggering voltage. The 3rd terminal of IC 555 is connected to +Vcc. Transistor Q2 is driven by reset and the 8th terminal of IC 555. The terminal 7 is used by zener diode (Z1) for discharging.

In order to have the same voltage capacitor C5 at terminal 5 is used. Then the pulse which is generated is sent to the driving circuit. The time taken by the pulse is calculated using a resistor-capacitor circuit connected. When no trigger pulse is applied the output will be low. When the trigger pulse is given output will become high and this duration is calculated by the resistor-capacitor circuit. Later, the output by itself becomes low and remains in low state until the next trigger pulse is applied.

The internal diagram for a 555 timer acting as monostable multivibrator:

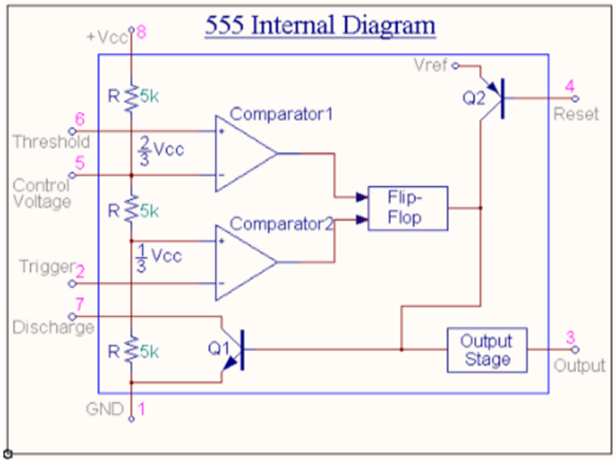

Fig 3. Internal Diagram of Multivibrator. [1]

Table 1. Specifications of 555 Timer. [1]

PIN	NAME	PURPOSE
1	GND	Ground, low level (0 V)
2	TRIG	OUT rises, and interval starts, when this input falls below 1/3 V_{CC}
3	OUT	This output is driven to $+V_{CC}$ or GND.
4	RESET	A timing interval may be interrupted by driving this input to GND
5	CTRL	"Control" access to the internal voltage divider (by default, 2/3 V_{CC})
6	THR	The interval ends when the voltage at THR is greater than at CTRL.
7	DIS	Open collector output; may discharge a capacitor between intervals.
8	V+,VCC	Positive supply voltage is usually between 3 and 15 V.

Supply voltage (V_{CC})	4.5 to 15 V
Supply current (V_{CC} = +5 V)	3 to 6 mA
Supply current (V_{CC} = +15 V)	10 to 15 mA
Output current (maximum)	200 mA
Maximum Power dissipation	600 mW
Power Consumption (minimum operating)	30 mW@5V, 225 mW@15V
Operating Temperature	0 to 70 °C

2. Driving Circuit:

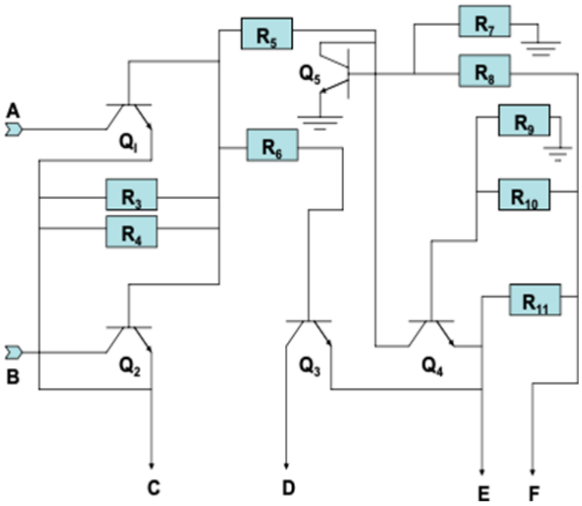

Fig 4. Driving Circuit of Inverter. [1]

The driving circuit is required because the accepted voltage is inadequate to operate and control the transformer. For more efficient dissipation of heat, the power transistors are connected to the heat sink.

Square wave output is obtained using Q1 and Q2. To change the position of half square wave to full square wave Q5 is used. R11 and R7 are used to set voltage sources to Q4 and Q5. To restrict the current flowing through the base of Q4, R9 and R10 are used. Similarly, R8 is used to restrict the current flowing through Q5. R12 and R13 are used to send the square wave to Q6, Q7 and Q8, Q9. To continue to have the same current flow, D1 and D2 are used.

3. Transformer Switching Circuit:

The transformer switching circuit is fed by the output of the driving circuit. The output is sent to Q6-Q7 and Q8-Q9 through R12 and R13. The current flowing through the base is restricted using the resistors.

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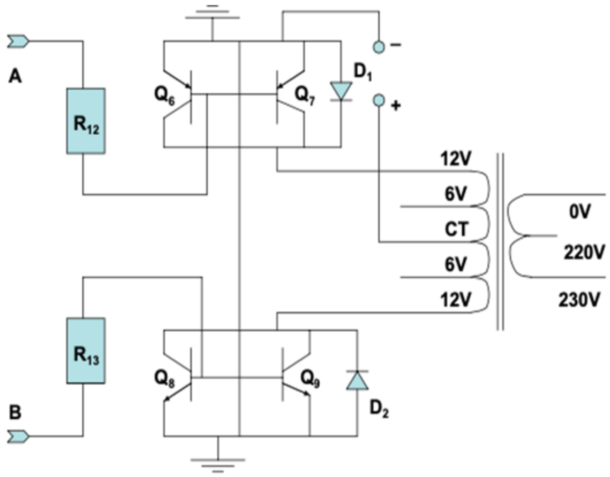

Fig 5. Transformer Switching Circuit of Inverter. [1]

The emitter terminal is connected to ground. To continue to have the same current flow, D1 and D2 are connected to Q6-Q7 and Q8-Q9. For more efficient dissipation of heat, the power transistors are connected to the heat sink.

When signal is sent through A, the upper primary coil of the transformer gives a voltage of 220V at the secondary coil.

Similarly, when signal is sent through B, the lower primary coil of the transformer produces the voltage secondary coil. Here, a 12-0-12 push pull transformer is used to get a voltage of 220V.

IV. CIRCUIT DIAGRAM OF SOLAR INVERTER

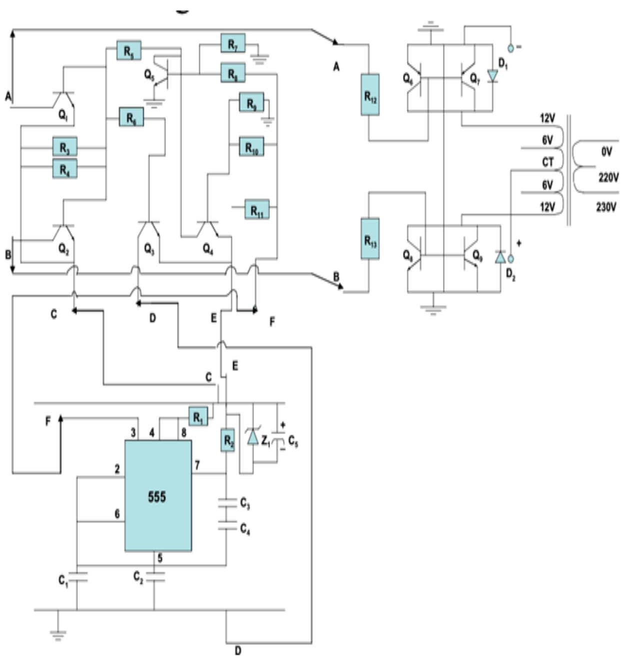

Fig 6. Circuit Diagram of Solar Inverter. [1]

The output of the inverter is square wave and not a sine wave.

V. PROTECTIVE FUNCTIONS OF THE SOLAR INVERTER USED

1. Overloading Protection:
If the power consumed by the appliances exceeds the total power of the solar inverter, it will revert to the protection state within 20 seconds until you reduce the load.

2. Short Circuit Protection:
Until the appliance is removed the solar inverter will revert to the protection state when the appliance gets short circuited.

3. Thermal Protection:
If temperature of the solar inverter gets too high, it will revert to the protection state until it is turned off to cool down.

4. Reverse Polarity Protection:
If connected incorrectly no current will pass through the solar inverter. The diode (IN5408) is connected to the positive terminal of the inverter.

VI. INVERTER EFFICIENCY

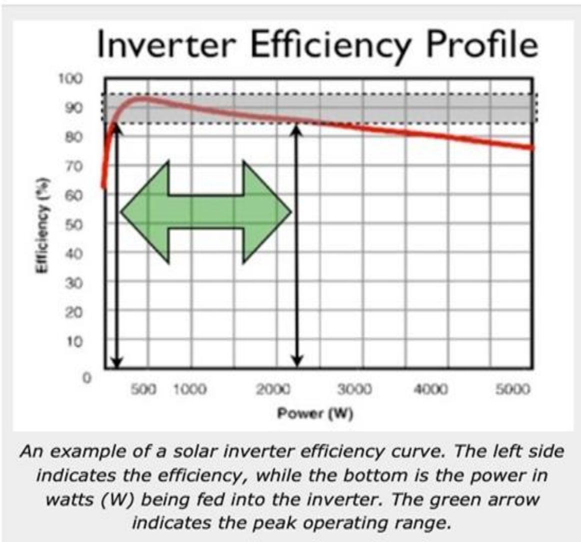

Fig 7. Inverter Efficiency.

1. Peak Efficiency:

- Peak efficiency is the nominal rating of the inverter.
- For example, peak efficiency of a 3kW inverter is reached, when it is receiving 3kVA from the solar panel array.
- When the inverter is operating at its rated capacity, peak efficiency is calculated as DC input to AC output. Peak efficiency for some of the best inverters can get up to 99%.

- The CEC and Euro weighted efficiencies have been developed to overcome the problem of inverters being operated in its peak efficiency range for a very small part of the day or not at all.

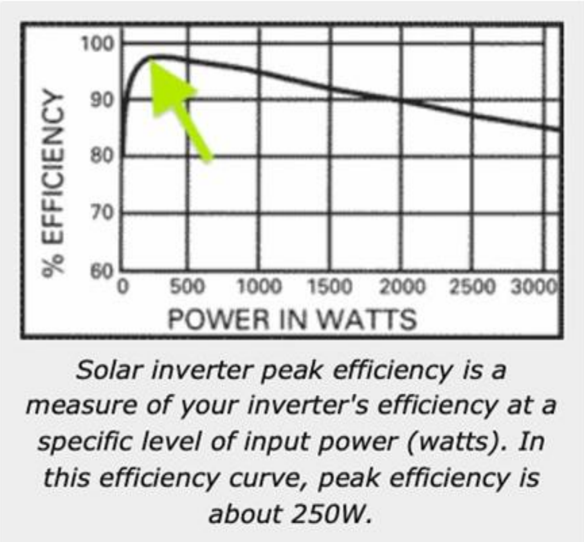

Fig 8. Peak Efficiency.

Euro and CEC Inverter Efficiency:

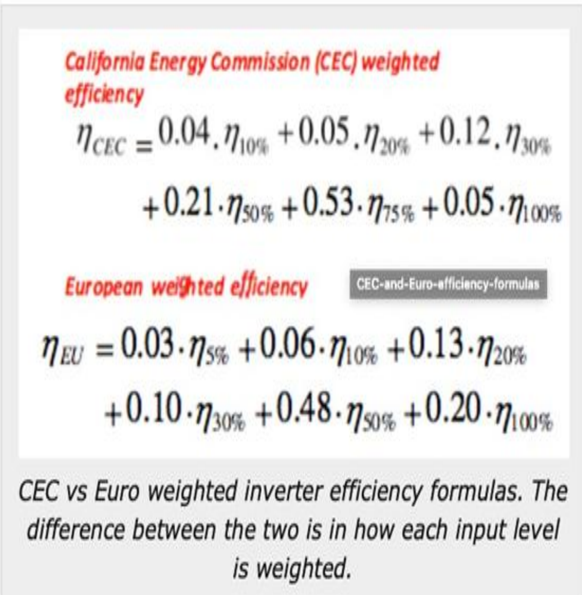

Fig 9. Euro and CEC Inverter Efficiency.

- While calculating the Euro efficiency and CEC efficiency which are the 'weighted' efficiencies of an inverter, depending on the importance, different values of the operating range are considered and balanced. Since, this is used to measure inverter performance across the range of the inverter's capacity; it is more useful than peak efficiency.
- There are 6 efficiency points in the calculation for Euro and CEC.

VII. LITERATURE SURVEY

Table 2. Residential Survey.

City	Houses	E.Inverter	E.I Percent	New/Mod	%
Khairpur	220	62	28%	Modify	53 (85%)
Hyderabad	250	78	31%	Modify	71(91%)
Sukkur	180	34	19%	Modify	30(88%)
Karachi	260	44	(17%)	Modify	37(84%)

In this survey, it is observed that in Khairpur about 220 houses use 62 electrical inverters and in percent it's about 28%. Similarly, in Hyderabad the use of electrical inverters is 31%, in sukkur its 19% and in Karachi its 17%.

Yu-Jen Liu et. al. proposed a Photovoltaic inverter, which is required for electric power conversions. It is a part of sunlight based photovoltaic power works.

Tai-Hung Wang Chen Liu et. al. has exhibited work on the outline and execution of a DSP-based framework tied sun based cascode-miniaturized scale inverter.

VIII. ADVANTAGES

- Solar energy has constantly helped in decreasing the greenhouse effect and global warming.
- The use of solar based devices will help in saving money and also energy. Because many people have started using these devices.
- A solar inverter helps in changing the DC into batteries or AC. This supports people who use a partial amount of electricity.
- As the size is very huge synchronous solar inverter help small homeowners and power companies.
- The multifunction solar inverter converts DC to AC which is the finest among all and works powerfully. It is also suitable for commercial establishments.
- These inverters are low cost than generators.
- Other devices which use solar energy are solar heater and cooker.

IX. DISADVANTAGES

- We have to use lot of many in purchasing the solar inverter.
- It works efficiently and produce DC only during daytime.
- The space occupied by the solar panels is large.

- Solar Inverters work only with the help of battery which is fully charged at night.

X. APPLICATIONS

- String inverters are used for residential, commercial purposes because it covers the small utility installations that are under 1 MW.
- Micro-inverters are used for residential and commercial arrangements.
- Off-grid inverters are most suitable for remote or rural areas. Because the power grid is far from the solar inverter. The connection is also impractical and uneconomical.
- Grid-tied inverters are capable of feeding the converted energy into the main power grid by matching their corresponding phase and frequency.
- Battery-based inverters/Hybrid solar inverters are used by who want to cut costs by utilizing energy produced from sunlight during daytime as well as store the same in batteries to support energy usage after sunset.

XI. CONCLUSION

In this paper, we designed an inverter using an IC 555 timer acting as a monostable multivibrator. The output square wave has an edge over sine wave because for lighting a tube light we don’t require a choke for square wave unlike sine wave which reduces the cost.We also took a look at the important terminology ‘inverter efficiency’. We understood that the value of the inverter's efficiency is not fixed and how it fluctuates with input power or voltage fed into it.

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