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CASCADED H-BRIDGE 15-LEVEL INVERTER USING RENEWABLE ENERGY SOURCES

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Abstract – This paper aims at reducing the THD (Total Harmonic Distortion) in the sine wave of the transmission system. These harmonics occurs in the power wave due to external disturbances and noise which affect the system. In order to reduce these harmonics a component called asymmetric cascaded H-bridge multilevel inverter is introduced in place of a normal inverter which converts DC power to AC power in high voltage long transmission system. This paper deals with a MATLAB simulation to calculate the overall percentage of THD obtained when a 15 level DC source cascaded MLI is used. Also a comparison between the THD of DC sourced cascaded 7 level inverter and a DC sourced 15 level is done to prove that 15 level inverter is better in reducing harmonics than a seven level inverter. A new method of using asymmetric hybrid sources instead of asymmetric DC sources is also proposed. So, a MATLAM simulation is also done for a 15 level Hybrid Cascaded H-bridge multilevel inverter to calculate the THD and a comparison is made between the THD of a hybrid cascaded 15 level multilevel inverter and a DC sourced cascaded 15 level multilevel inverters to see if there are any changes in the THD using hybrid sources. Since, the overall aim is to totally eliminate the THD in the power system, these are some measures proposed to eliminate them. Though complete elimination of harmonics in the power system is not possible now, in future as technology and awareness increases THD could be possibly reduced to zero.

Keywords – ***Cascaded H-Bridge(CHB), Multilevel Inverter (MLI), Pulse Width Modulation (PWM), Total Harmonic Distortion(THD), Peripheral Interface Controller (PIC), Renewable Energy Sources (RES)***

I.INTRODUCTION

In recent years, the energy demand is rapidly rising. In order to meet the rising demands, generating units have been set up. The power generated is transmitted through power systems. The quality of power transmitted is characterized by THD (Total Harmonic Distortion). The THD is the ratio of sum of the powers of all harmonic components to the power of the fundamental frequency. Lower THD means reduction in peek currents, heating and core loss in motors. THD is represented in percentage. The power generated is stored in batteries in the form of DC power and converted to AC power using inverters. Cascaded H-bridge multilevel inverters are medium or high voltage inverters used in high voltage applications, industrial drives, static VAR compensators etc. A DC source is connected to a H bridge inverter. In order to reduce the THD the levels are increased. This project is aimed at achieving the minimum THD of the staircase modulated output voltage of single-phase cascaded H-bridge multilevel inverter with elimination of the lower order harmonics. The THD value obtained, accounting for the device voltage drops when the load is resistive or moderately inductive, is less than 5%. Hybrid energy source which includes renewable energy is used as the input to the multilevel inverter, instead of a DC power source to make use of energy available around us efficiently.

In this paper [1] the different topologies used in the case of multilevel inverter are discussed. The important topologies are Diode-clamped inverter (neutral-point clamped), Capacitor clamped (flying capacitor) and cascaded multilevel with separate DC sources. This paper also presents the most relevant control and modulation methods developed like multilevel sinusoidal pulse width modulation, multilevel sinusoidal pulse width modulation, multilevel selective harmonic elimination and space vector modulation. The **drawback** in the case of these topologies is that when more number of diodes and capacitors are used more reactive power is injected in the system, hence more losses occur. In the paper [2] Multilevel inverters have some disadvantages compared to a conventional two level inverter, the number of components increases and causes more harmonic distortion, complex pulse width modulation control method and voltage balancing problem. In this paper a new topology with a reversing-voltage component is proposed to improve the multilevel performance.

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In the paper [3] cascaded H-bridge multilevel power electronic converter requires several DC sources. This paper introduces a new concept to replace all the separate DC Sources feeding the H-bridge cells with capacitors, leaving only one H-bridge cell with a real DC voltage source. The **drawback** in this method is that more reactive power is induced in the Circuit and the required capacitor voltage balancing is challenging. This paper [4] considers achieving the minimum total harmonic distortion (THD) of the staircase-modulated output voltage of single-phase multilevel inverters with or without the elimination of the lowest order harmonics. It is proposed that as the number of levels increases the harmonic distortion will be lower. The **drawback** in increasing the number of levels is that it requires more number of D.C sources and the circuit complexity increases.

II. EXISTING SYSTEM

The general concept involves the use of an isolated DC source of equal values as an input to cascaded H-bridge inverters. Greater the output voltage levels, greater is the number of input sources. It is given by the formula m=2n+1, where m is the voltage levels, n is the number of input sources. For example, a 7-level cascaded H-bridge inverter would require 3 input sources. These multilevel inverters are popular due to their advantages of higher voltage capability, higher power quality, lower switching losses and improved electromagnetic compatibility. The THD in case of a 7 level inverter is 10.27. Higher the number of levels lower is the total harmonic distortion. The number of sources would increase in case of a higher voltage level output. Fewer numbers of switches would increase resulting in greater switching losses. The circuit becomes complex, hence there is an overall drop in efficiency and use of capacitors increases due to drop in voltage.

Cascaded H-Bridge for a 7-level output voltage

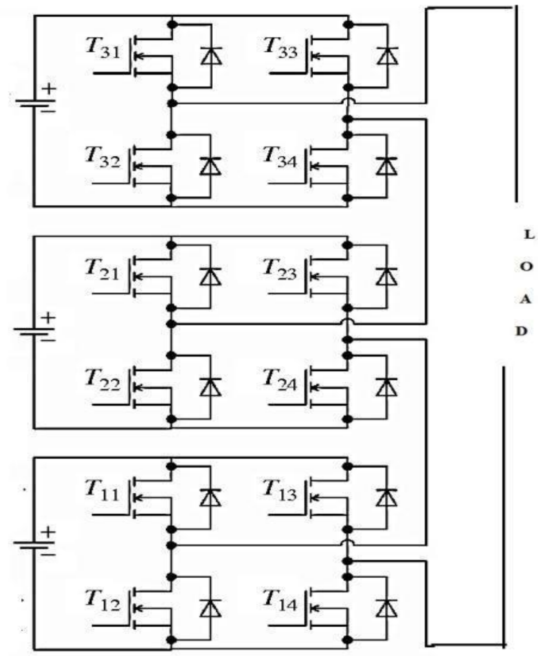

Fig 1

Cascaded H-Bridge for a 7-level output voltage

B) PROPOSED SYSTEM

This paper aims at producing 15-level voltage output with reduced THD using a cascaded H-bridge multilevel inverter. The number of input sources is reduced as compared to the existing system. This is achieved by using unequal DC voltage sources as input. Also, instead of using isolated DC sources hybrid sources are used which includes renewable energy sources (solar and wind).

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C) Block Diagram of Proposed System

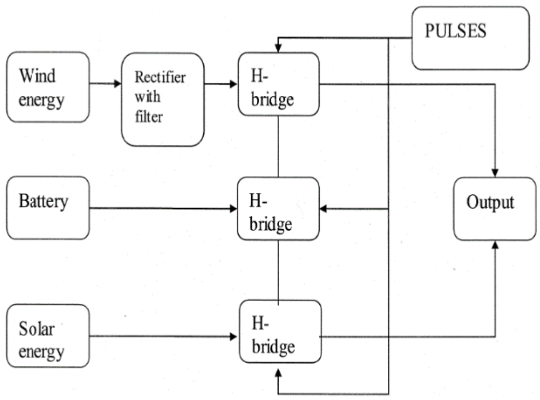

Fig 2

Block Diagram of Proposed System

D) Simulink Model with Hybrid Sources

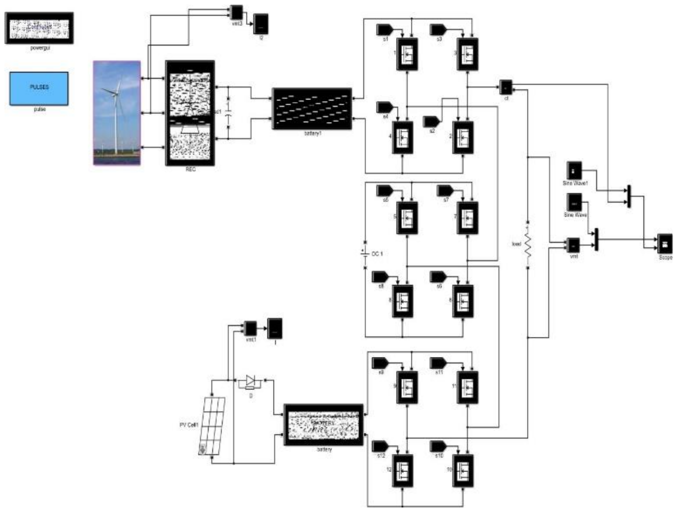

Fig 3 **Simulink Model with Hybrid Sources**

III.WIND TURBINE

Wind turbines are used to capture wind power. The standard wind power turbine of today consists of a turbine, which has three blades and the wind upwards, so the tubular steel or concrete tower is behind the turbine (also known as the Danish concept). Figure shows an example of the design elements of a wind turbine generator (WTG). The rotor captures the wind energy at the low-speed shaft. Since most generators are designed for high speed, a gear box is used and the energy is the transferred to the 6 high-speed shaft and then to the generator. The generator is connected to a transformer to increase the voltage level to a suitable transmission level.

This block implements a variable pitch wind turbine model. The performance coefficient Cp of the turbine is the mechanical output power of the turbine divided by wind power and a function of wind speed, rotational speed, and pitch angle (beta). Cp reaches its maximum value at zero beta. Select the wind-turbine power characteristics display to plot the turbine characteristics at the specified pitch

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angle. The first input is the generator speed in per unit of the generator base speed. For a synchronous or asynchronous generator, the base speed is the synchronous speed. For a permanent-magnet generator, the base speed is defined as the speed producing nominal voltage at no load. The second input is the blade pitch angle (beta) in degrees. The third input is the wind speed in m/s.

B) CONTROLLED VOLTAGE SOURCE

The Controlled Voltage Source block converts the Simulink input signal into an equivalent voltage source. The generated voltage is driven by the input signal of the block. You can initialize the Controlled Voltage Source block with a specific AC or DC voltage. If you want to start the simulation in steady state, the Simulink input must be connected to a signal starting as a sinusoidal or DC waveform corresponding to the initial values.

WIND OUTPUT WAVEFORM

Fig 4 Wind output waveform

C) SOLAR CELL

A solar cell, or photovoltaic cell, is a semiconductor device consisting of a large-area p-n junction diode, which, in the presence of sunlight is capable of generating usable electrical energy. . When the sunlight or any other light is incident upon a material surface, the electrons present in the valence band absorb energy and, being excited, jump to the conduction band and become free. These highly excited, non-thermal electrons diffuse, and some reach a junction where they are accelerated into a different material by a built-in potential (Galvani potential). This generates an electromotive force, and thus some of the light energy is converted into electric energy. The photovoltaic effect can also occur when two photons are absorbed simultaneously in a process called the photovoltaic effect. The field of research related to solar cells is known as photovoltaic.

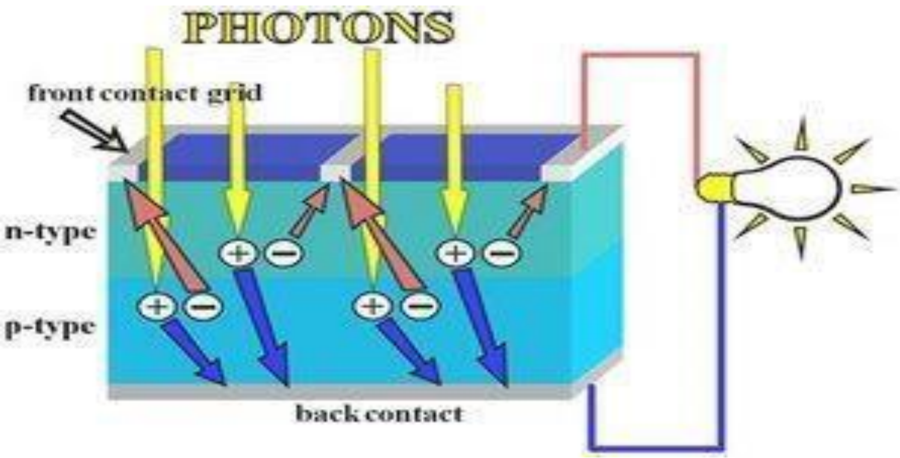

Fig 5 Photovoltaic Cell

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Solar cells have many applications. They are particularly well suited to, and historically used in situations where electrical power from the grid is unavailable, such as in remote area power systems, Earth orbiting satellites, handheld calculators, remote radiotelephones, water pumping applications, etc. Solar cells (in the form of modules or solar panels) are appearing on building roofs where they are connected through an inverter to the electricity grid in a net metering arrangement.

SOLAR PANEL

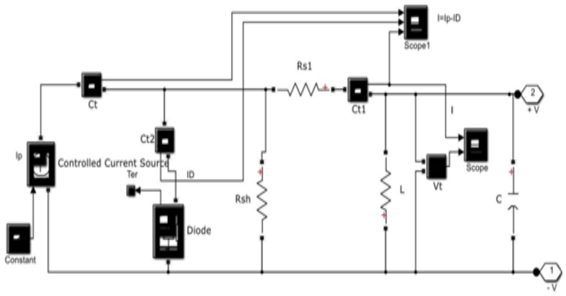

Fig 6 Simulink model of Solar Panel

SOLAR OUTPUT WAVEFORM

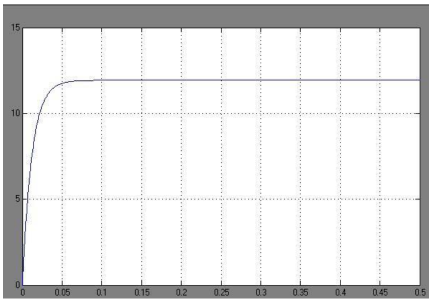

Fig 7 Solar output voltage

IV) SIMULINK MODEL WHEN ISOLATED DC SOURCES ARE USED

The entire model remains the same as mentioned in the above mentioned model. Only the input sources have been changed. Hybrid sources are replaced with isolated DC sources as in a conventional system for the sake of comparison. We can now obtain their respective outputs and analyze them.

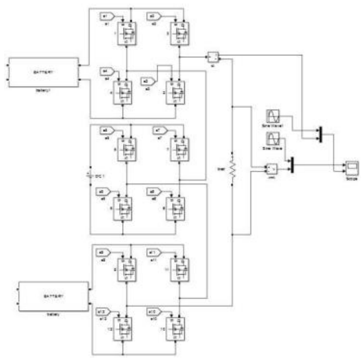

Fig - 8 Simulink model when isolated DC sources are used

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V) SIMULATION OUTPUT AND ANALYSIS

CASE 1: OUTPUT WHEN ISOLATED DC SOURCES ARE USED

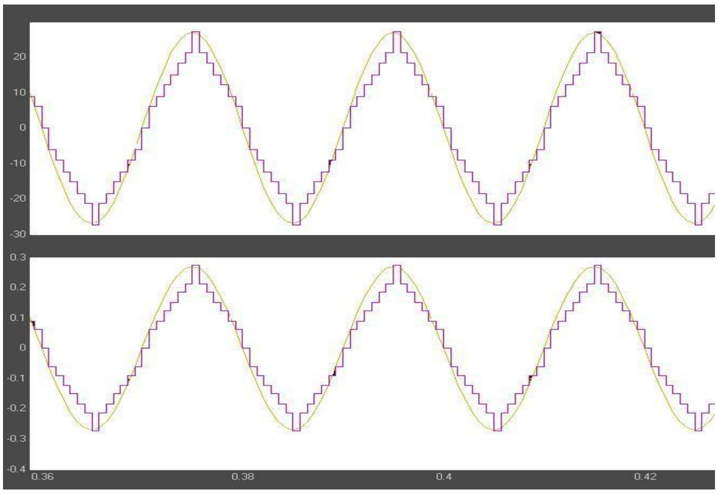

Fig 9 Output when isolated DC Sources are used

CASE 2: OUTPUT WHEN HYBRID SOURCES ARE USED

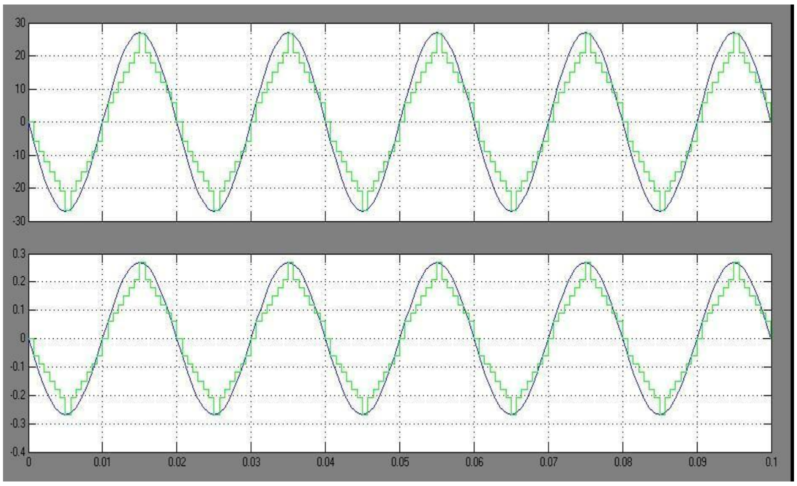

Fig – 10 15-level output when hybrid sources are used

With the use of MATLAB SIMULINK pulses required for each switch to operate has been carefully designed and given. As a result a successful output has been obtained as shown above in both cases. The blue sinusoidal wave denotes the ideal sine wave and the green colour stepped output voltage is the desired output in **case – 1,** the green wave denotes the ideal wave and the pink wave is the stepped output voltage, and in **case – 2,** we can clearly count the number of steps in both the cases. Thus, the desired 15-level output is obtained. On comparing the simulation outputs in both cases we can conclude that use of hybrid sources does not affect both the 15-level stepped output voltage .In both cases the THD levels are found to be less than 5%.

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VI) HARDWARE CIRCUIT DIAGRAM

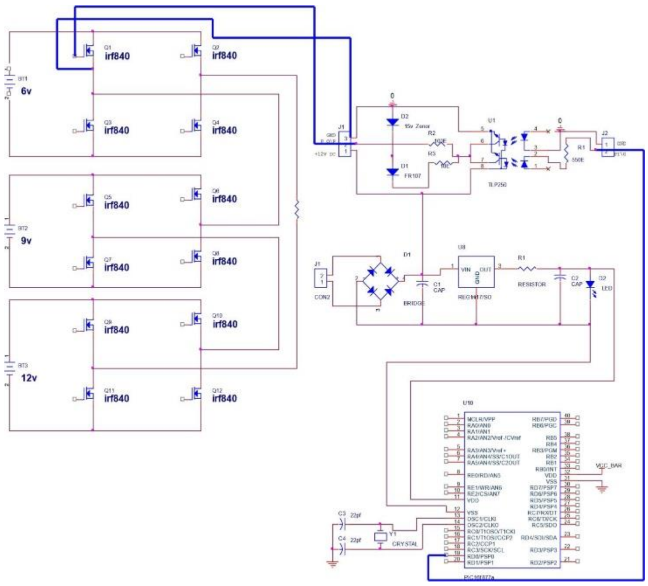

Fig - 11

HARDWARE CIRCUIT DIAGRAM

The operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an AC voltage, a steady DC voltage is obtained by rectifying the AC voltage, Then filtering to a DC level, and finally, regulating to obtain a desired fixed DC voltage. The regulation is usually obtained from an IC voltage regulator Unit, which takes a DC voltage and provides a somewhat lower DC voltage, Which remains the same even if the input DC voltage varies, or the output Load connected to the DC voltage changes

B) GENERATION OF PULSES

In this paper the PIC16F877A is used to generate PWM(Pulse Width Modulation) which is a powerful technique for controlling analog circuits with a processor's digital outputs. PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion.

C) INTERFACING PWM

The Fig(12) shows four different **PWM signals**. One is **PWM** output at a 25% duty cycle. That is, the signal is on for 25% of the period and off the other 75%. Next shows **PWM** output at 50%, 75% and 100% duty cycles, respectively. These three PWM outputs encode three different analog signal values, at 10%, 50%, and 90% of the full strength.

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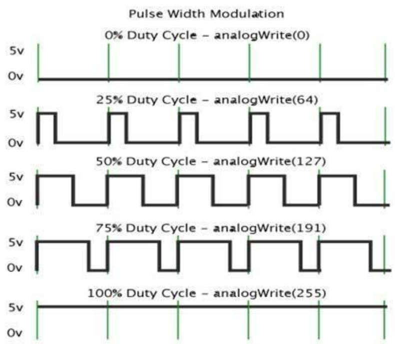

Fig 4.3 PWM outputs

D) HARDWARE SET-UP

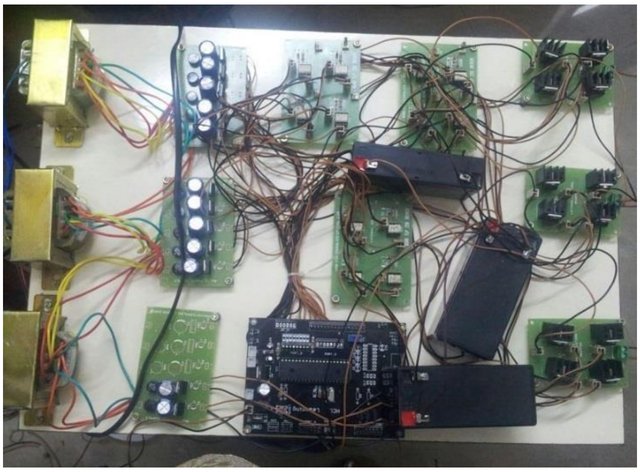

Fig – 13 Hardware Set-up

The circuit consists of cascaded H-bridge multilevel inverter (comprising of power MOSFETS), PIC microcontroller and gate driver circuit. The power required to switch on the PIC microcontrollers and gate driver circuit is supplied by isolated transformers through bridge rectifiers and regulator circuit. PIC requires 5Vsupply whereas gate driver requires 15V. The cascaded H-Bridge inverters are supplied with 3 unequal DC voltages i.e 6V, 9V, 12V respectively using hybrid sources. Once the PIC microcontroller is switched on it is programmed to produce PWM pulses with certain delay. These pulses are then sent to the driver circuit which amplifies each pulse. One pulse requires one gate driver. Totally 12 pulses are to be amplified and hence 12 gate divers are installed. The amplified signals are fed to the power MOSFET. Thus the MOSFETS get triggered and the switches are turns ON and OFF accordingly. Then the final output is viewed on the CRO. A 15-level stepped voltage waveform is obtained.

VII. HARDWARE RESULT

From the hardware result we can conclude that use of hybrid sources does not affect both the 15-level stepped output voltage as well as the THD levels. In both cases the THD levels are found to be less than 5%.

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CONCLUSION

A 7- level Cascaded H- Bridge inverter requires 3 DC input sources. When the levels are increased, the complexity of the circuit and the number of sources required increases. For a 15-level Cascaded H-Bridge inverter the number of sources required is 6. Using unequal DC sources we have reduced the number of sources to just 3 DC sources. Therefore the complexity reduces and also the number of switches used is reduced. Hence switching losses are reduced. Also the DC input sources have been obtained from the renewable energy (wind and solar) sources. The Total Harmonic Distortion for a 15 level is less as compared to that of a 7level. For a 7-level the THD is 10.27% whereas for a 15-level we have obtained a THD less than 5%. The use of renewable energy sources does not affect the 15-level output also there is no effect on THD. Our project can be used in the area of high power medium voltage energy control. Also, it can be used in Power Systems and industrial drives. It can also be used as FACTS devices to obtain pure AC waveform.

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