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Application of Multilevel Inverters in Solar, Battery and Wind hybrid System for Domestic Load Application

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Abstract *- In this paper, a control strategy for the power flow from a pv, battery and wind hybrid system coupled with a multilevel inverter for a domestic load application is presented. The proposed system aims to control the power flow from different sources to charge battery, supply the load demand and inject surplus power into the grid. The power from the pv and battery unit is harnessed using a buck boost converter and the power from wind is harnessed using a transformer coupled boost half bridge converter. The ac loads and power grid are connected through a single phase full bridge converter. The proposed converter architecture improves voltage gain, reduces the total harmonic distortion at the inverter level reducing the dependency on filters. This improvement in voltage gain helps to improve efficiency, lower the rating of circuitry components which in turn reduces the overall cost of the equipment used in the system. Simulation results show the improvement of the proposed system in various modes of operation.*

Keywords- Maximum power point tracker, Multi input transformer, Multilevel inverter, Solar energy, Wind energy.

I. INTRODUCTION

With the depletion of fossil reserves and the ever increasing energy demand, the modern world is shifting towards a period of energy crisis. The increasing carbon footprint from these conventional sources has compelled to look for an alternative energy sources which are both cost effective and eco friendly. Solar energy and wind energy comes under this category but their intermittent nature makes it difficult to supply stable and continuous power. However a hybrid system which includes a storage system such as battery helps to overcome this problem. Modern techniques are developed to increase the efficiency of storage system and converters ensuring maximum power generation with minimum requirement of equipment. This new multilevel inverter system for the hybrid renewable energy system increases the voltage gain and improves the voltage profile by reducing the harmonic content resulting in the improved power quality compared to the existing system.

II. MULTILEVEL INVERTER

Some of the industrial loads require low and medium power requirement. Using a high power source to all the loads may be beneficial for higher power applications but will damage other low and medium power equipment. Sources like batteries, super capacitors, solar panel are medium voltage sources. The multilevel inverter consists of several switches and consists of various levels to increase the power as per the requirement.

Multilevel inverters are the preferred choice in industry for the applications in high voltage and high power application. Some of the advantages of multilevel inverter are

- Higher voltage can be generated using devices of lower rating.
- Increased number of voltage levels produces better voltage waveform and reduced total harmonic distortion.
- The switching frequency can be reduced for PMW operation.

Owing to these advantages multilevel inverters are preferred to normal inverters. There are essentially three types of multilevel inverters. They are

- Cascaded H-Bridge multilevel inverter
- Diode Clamped multilevel inverter
- Flying Capacitor multilevel inverter

The number of levels in the multilevel inverter is selected based on the application requirement. Here we consider a five level and seven level multilevel inverters for study.

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A) FIVE LEVELS MULTILEVEL INVERETER

The circuit of a five levels inverter is shown in Fig. 1 which consists of a full bridge inverter, an auxiliary circuit and two voltage dividing capacitors. The auxiliary circuit mainly generates half level DC voltage. The switching conditions for five output voltage levels were tabulated in Table I. The switching in the auxiliary circuit is determined by the direction of load current.

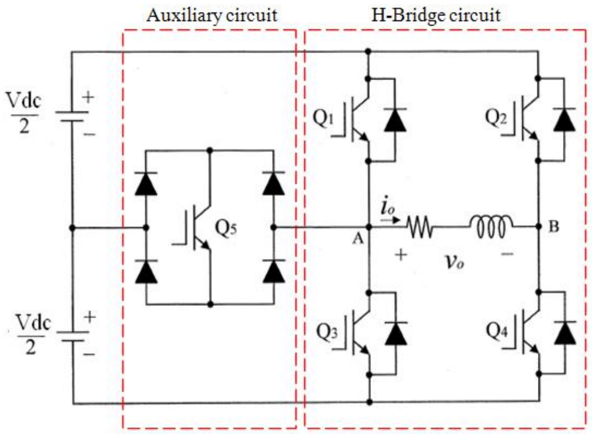

Fig. 1: Circuit of a five level multilevel inverter

Output Voltage	Q1	Q2	Q3	Q4	Q5
+Vdc	1	0	0	0	1
+Vdc/2	0	0	0	1	1
0	0	0	1	1	0
-Vdc	0	1	0	0	1
-Vdc/2	1	0	0	1	0

TABLE .I: *FIVE LEVELS MULTILEVEL INVERTER SWITCHING TABLE*

B) SEVEN LEVELS MULTILEVEL INVERETER

The circuit of a seven levels multilevel inverter is quite similar to that of a five level multilevel inverter with an addition of an auxiliary circuit. The seven levels multilevel inverter consists of a full bridge inverter, two auxiliary circuits and three voltage dividing capacitors. LCL filter is used to filter the current to be injected into the utility grid. Seven output voltage level can be achieved when the switching signal for the IGBTs in the topology were done properly. The circuit is shown in Fig. 2 and switching combinations for seven output

voltage levels were tabulated in Table II.

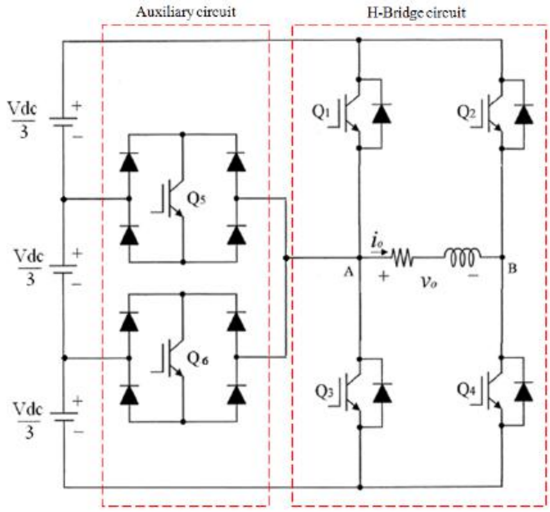

Fig. 2: Circuit of a seven level multilevel inverter

Output Voltage	Q1	Q2	Q3	Q4	Q5	Q6
+Vdc	1	0	0	1	0	0
+2Vdc/3	0	0	0	1	1	0
+Vdc/3	0	0	0	1	0	1
0	0	0	1	1	0	0
0*	1	1	0	0	0	0
-Vdc/3	0	1	0	0	1	0
-2Vdc/3	0	1	0	0	0	1
-Vdc	0	1	1	0	0	0

TABLE .II: *SEVEN LEVELS MULTILEVELINVERTER SWITCHING TABLE*

Compared to a 5 level multilevel inverter the seven levels multilevel inverter has a higher output voltage and reduced total harmonic distortion. These results will be shown in the simulation.

III. MAXIMUM POWER POINT TRACKING

Maximum power point tracking finds its application in interconnected renewable energy systems such as solar and wind. This technique controls the load characteristics of solar and wind energy system as the intensity of sunlight and velocity of wind is varying in nature. To attain maximum energy from these energy sources the specified load characteristic is altered and this point is called maximum power point and the process is called maximum power point tracking. Electrical circuits are designed based on the loads and the power generated from the solar panels and then converted to the rated voltage, current and frequency. MPPT computes the best amount of load to be connected to produce maximum

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energy. Hence MPPT improve the overall efficiency of the entire hybrid system.

IV. BLOCK DIAGRAM

The block diagram shown in Fig.3 shows the arrangement for a pv, battery and wind hybrid system. The photo voltaic system is connected in series with the battery so that power from pv is used to charge the battery and supply the load. Energy from wind is harnessed using a wind turbine which is connected to a generator to supply alternating current. In the absence of power from the pv, the power is supplied from the battery to the domestic load. A multi input transformer sums up the power generated from these sources and the power is further stepped up using a multilevel inverter where the voltage is boosted. The power output is connected to the domestic load and the surplus power is injected into the grid. With the use of multilevel inverter higher power and voltage is attained. Various level multilevel inverter are used and their simulations are presented to determine their advantages.

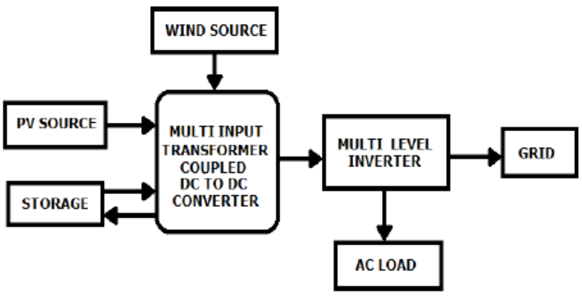

Fig. 3: Block diagram of multilevel inverter connected hybrid system

V. CIRCUIT DIAGRAM

The voltage and power generated from the solar panels are low. So a number of panels are connected in series to increase the voltage. Modern domestic loads require higher power and higher voltage. Hence the power from the solar panels is increased to meet the load requirements and inject surplus power if any, into the power grid. The circuit diagram for a 5 level multilevel inverter connected solar and wind hybrid system is shown in Fig. 4.The pv array and battery are connected in series to the half bridge converter which acts as a boost converter. This voltages is stepped up using a step up transformer. This transformer is a multi input transformer which also receives input from the generator connected to the wind turbine. This cumulative power generated from these sources is stepped up using the step up transformer. The transformer secondary is coupled to a boost half bridge converter and its output is connected to a multilevel inverter which further amplifies the voltage.

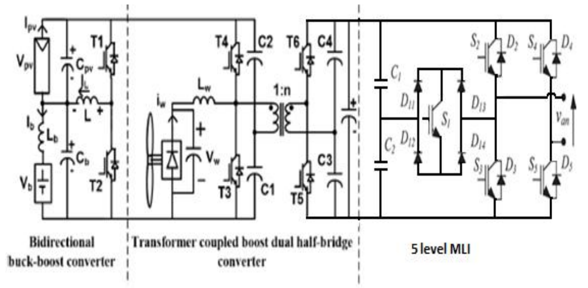

Fig. 4: Circuit diagram of five levels multilevel inverter connected hybrid system

Because of its advantage of increasing the power and voltage level, the multilevel inverter enhances the flexibility of reducing the number of panel connected together or reducing the turns ratio of the transformer and even using a lower rating components which reduces the cost of equipment and the level of insulation to be provided. The simulation results shows the increased voltage level in case of a multilevel inverter application compared to conventional inverter. Also multilevel inverters produces lower total harmonic distortion compared to conventional inverters and the total harmonic distortion in case of a multilevel inverters can be further reduced by increasing the number of levels. By increasing the levels from five to seven in the multilevel inverter hybrid system, the voltage gain is increased by 9% and the total harmonic distortion has been reduced from 29.09% to 20.50% which are reflected from the simulation results.

VI. SIMULATION RESULTS

The simulation results of voltage in a conventional inverter connected solar, battery and wind hybrid system is shown in Fig.5.

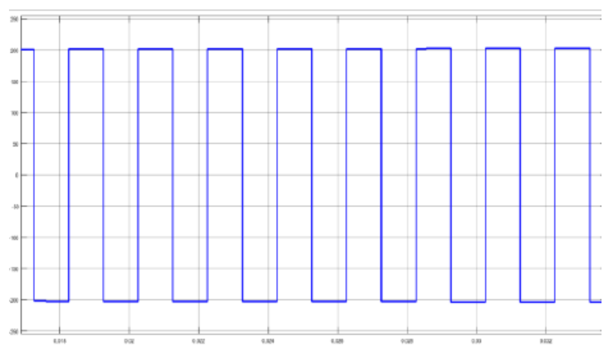

Fig. 5: Output voltage of conventional inverter connected in the hybrid system

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The output voltage in the conventional inverter connected hybrid system is 200 volts. Also from the waveform we can deduct that the voltage is not exactly sinusoidal and hence there is a greater dependency on filters.

The simulation results of voltages in a five level inverter connected solar, battery and wind hybrid system is shown in Fig.6. The proposed system which uses a five levels multilevel inverter produces a voltage around 240 volts which is 20% more than the conventional inverter system. The multilevel inverter has an added advantage of reduced total harmonic distortion. Also from the voltage waveform we can see the improvement in sinusoidal nature of the signal and this translates into better voltage profile and reduced dependency on filter. Attaining higher voltage at the output gives a flexibility to use lower rating circuit components such as solar panels, switching devices (igbt, thyristors and diodes), transformers etc and lower rating insulation which reduces the overall cost of equipment.

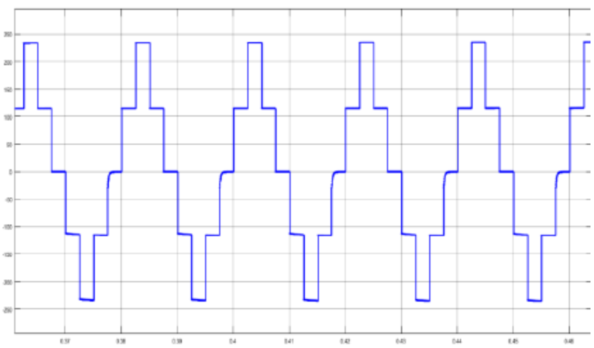

Fig. 6: Output voltage of 5-level multilevel inverter connected in the hybrid system

By increasing the number of levels from five to seven the output voltage can be increased further and the total harmonic distortion can be reduced. The simulation results of voltages in a seven level inverter connected solar, battery and wind hybrid system is shown in Fig.7. The output voltage in a seven level multilevel inverter is around 260 volts which is 30% more than the conventional inverter and around 9% more than the a five level multilevel inverter. Attaining higher voltage at the output gives a flexibility to use lower rating circuit components such as solar panels, switching devices (igbt, thyristors and diodes), transformers etc and lower rating insulation which reduces the overall cost of equipment. Also from the waveforms we can clearly see that the sinusoidal nature of the waveform improves further by increasing the levels in the multilevel inverter system. This translates into a better voltage profile and reduced dependency on the filters.

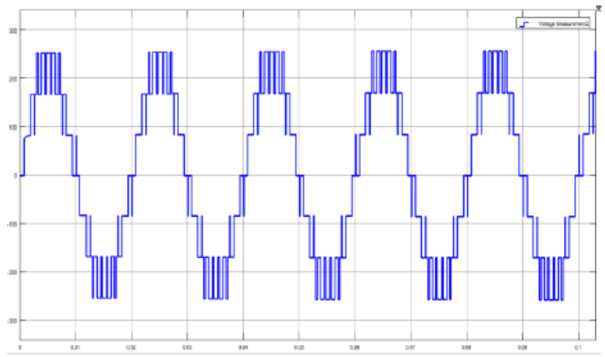

Fig. 7: Output voltage of 7-level multilevel inverter connected in the hybrid system

Total harmonic distortion gives an account of harmonic content present in a waveform. It is desired to keep the harmonic distortion as low as possible. The total harmonic distortion produced from a multilevel inverter is lower compared to a conventional inverter. The simulation result for total harmonic distortion in a five level multilevel inventor is 29.09% and is shown in the Fig. 8.

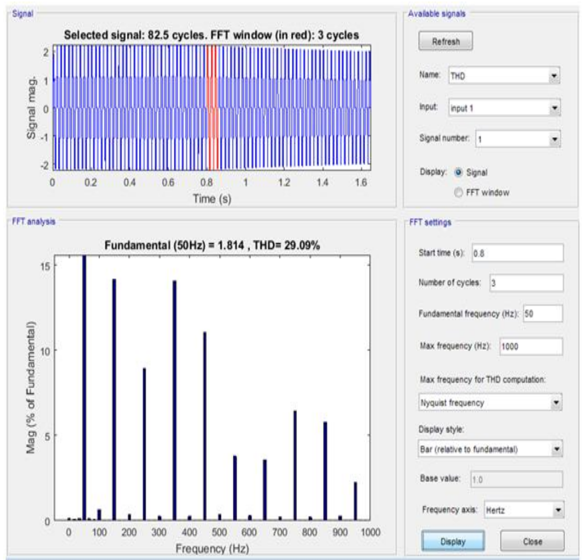

Fig. 8: THD of a 5-level inverter connected in the hybrid system

This total harmonic distortion can be further reduced by increasing the levels in multilevel inverter. Simulation results show a decrease from 29.09% to 20.50% by increasing the number of levels as shown in Fig. 9 and hence the application of multilevel inverter in the hybrid

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system generates higher voltage and reduced total harmonic distortion.

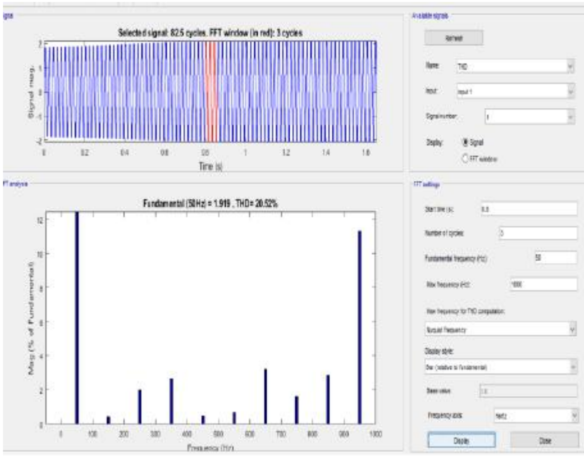

Fig. 9: THD of a 7-level inverter connected in the hybrid system

This is how the voltage gain and profile from the existing conventional inverter system can be improved using proposed system with the help of multilevel inverters and also the total harmonic distortion is reduced by increasing the number of levels in the multilevel inverter system.

VII. CONCLUSIONS

A pv, battery and wind hybrid system with a multilevel inverter is proposed. The proposed system extracts maximum energy from the system with higher voltage and reduced total harmonic distortion. Simulation results show the improvements of various level multilevel inverters over conventional inverters in the system. This hybrid system provides a wider range and so gives flexibility with the equipment used in the system. This system is capable of providing stable and continuous power to domestic loads and injects surplus power into the power grid.

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