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Performance Analysis and Power Quality Improvement for Hybrid Renewable Energy Source using Multilevel Inverter

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Abstract

Nowadays the usage of electrical system is upgraded. Similarly, all the processing units consume electrical power. In recent days, more number of converters is available for processing the energy. During this energy conversion process, various levels of harmonics are produced. Hence, analysis of the system is essential to identify the problem in traditional methods. The parameter comparison is noticed with respect to the conventional DC-DC Boost converter module. The identification of the problem in the distribution static compensator (DSTATCOM) module is very much essential. The harmonics level and its supply power have been identified and analysed. In order to minimise the harmonics, there is a possibility of reshaping the firing mechanism and the control unit of Multi level inverter. Hence, the proposed hybrid method (solar and wind) is implemented with Developed H-bridge inverter and it can be simulated with the help of MATLAB Simulink. Based on the simulation results, it can be concluded that the Total Harmonic Distortion by the proposed method is reduced compared with the traditional method and performance also improved.

***Key Words: DC –** DC Converter, Harmonics, DSTATCOM, H – bridge inverter, THD*

I. Introduction

Solar energy is the abundant and constant source of energy. It is directly available to people (in the form of solar insolation). Radiant energy such as solar energy is vital in countries like India, where the government is facing problems like oil crises. Tapping of photovoltaic (PV) energy is the need of the our as it is available (in abundance)throughout the year. In accordance with solar power, another form of energy resource is wind energy. This form of energy also is significant in the generation of power in many countries including India.

A Voltage is generated when solar radiation falls on PN junction. This is the principle of solar panel. The striking photons from the radiant energy generate power. There is a great demand for electricity generated via solar insolation and the demand keeps increasing constantly in the recent scenario. Power planners are fond of using photovoltaic system as it attracts in meeting out the world's increasing demand of electricity. PV modules and power electronic interface are cost effective [9]. Hence they can contribute in the power supply of future electricity demands for the industries. Wind energy also being another source of power supply, conversion of wind energy is economic compared to fossil fuels. However solar energy is copious when compared to wind energy.

In order to generate efficient energy from renewable energy sources, combination of two or more energy sources gives better results than a single energy source. In rural and remote areas, Hybrid Energy System (HES) have more scope, because these areas do not benefit from the grid supply and because of increased demand, global warming, depletion of non-renewable energy sources are compel to go for renewable energy sources. There are so many hybrid systems are there among them Solar and wind energy provides good results rather than other energy sources. The drawback of solar and wind are intermittent and also unreliable but combining the solar and wind energy sources, reliability of the system can be improved. Often solar and wind energies are complimentary in nature when there is no sun there is plenty of wind vice/versa. MPPT is very much essential for maximum power generation to track maximum power point it is very much essential for solar array. For large scale industries or power production DFIG based wind turbines are preferred [1]. Different methods of MPPT's are discussed [5] and some of the techniques are implemented. The advantageous features of induction generators are less maintenance, operational simplicity, self-protection against faults, brush

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less and rugged construction. The induction generators, can be operated in two different modes; namely grid connected mode and isolated mode. In grid connected mode of operation, the terminal voltage and frequency are fixed by the grid. But, in isolated mode of operation, the operation depends upon load, speed and excitation capacitance.

In the current scenario, high power applications have found its way to expand its role in leading the digitalized world. Numerous strategies, topologies, methods, techniques and drive applications have been experimented and reviewed [3]. In recent days, industrial converters employ such high power devices. In spite of using such high power devices in industries, power quality also is in need to be monitored [4]. Modern technology emphasizes the use of flexible speed engine drives and shunt capacitors which confers control factor remedy and assures expanding consonant levels on control frameworks.

The application of electrical energy depends on power generation and transmission at nominally consistent levels with controllable recurrence and voltages. Electronic hardware that distorts voltage and current waveforms will be effective in controlling or conditioning the power supply. Significant voltage distortion can be influenced by introducing the neighbouring delicate loads with harmonic delivering load. Such voltage distortion is effected by the introduction of harmonic load which is a component of framework impedance and harmonic current infused. The proposed hybrid model of multilevel inverter is described in figure 1. The harmonics produced in the power converters are due to many issues in the system such as nonlinear load. There are plenty of nonlinear loads are available, some of the nonlinear load devices are arc-furnaces, converters and gas light devices. Apart from this process, the source harmonics are mainly generated by power supply with non-sinusoidal voltage waveform. In this work, the harmonics are also considered as second process. The main objective of improving the power quality is carried out by a closed loop PID controller with a modified CUK converter. The developed H bridge topology is used with the sinusoidal PWM generation triggering scheme for both 7 and 31 levels of MLI with RL Load filter strategy. Finally, the THD levels are noticed whether voltage level is sag or swell. The description of voltage sag or swell is as follows: Voltage sag is a reduction in rms voltage for short duration due to short circuit, overload, or starting of electric motors. It happens when the rms voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute. A voltage swell is an surge in the RMS voltage in the range of 1.1 to 1.8 p.u. for a duration greater than half a main cycle. It happens due to system faults, load switching and capacitor switching.

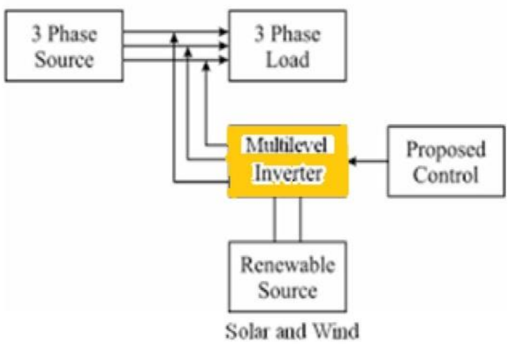

Figure 1. Proposed Hybrid System with MLI

This work focused on implementing the modified version of the SPWM inverter which is connected to convert the DC source into AC for nonlinear AC load. The FACTS devices are connected in parallel between the inverter and load. The Modelling and simulation of the system was developed using MATLAB Simulink.

II. Materials and Methods

Normally, AC load requires constant voltages at their input terminals. Sometimes, such loads are sustained by inverters; to control the output voltage of the inverters, there are number of techniques available [7]. The most efficient way to control the output voltage of the inverter is by varying the gate pulse of the inverter switching device. Here, the Pulse Width Modulation technique is used for triggering pulse generation. Table 1 shows the detail about proposed technology used.

Table 1. Details of the Proposed design model

S.No	Description	Proposed Topology
1	Controller	Closed Loop System with PID Controller
2	Converter	Modified CUK converter
3	Inverter	Developed H bridge topology
4	Triggering Method	PWM generation
5	Level of inverter	7 & 31 level
6	Type of Load	MLI
7	Evaluation Process	Total Harmonic Distortion(THD)

Seven level inverter

The seven level inverter configurations MLI is shown in the Figure 2; this is an improved version of five-level pulse-width modulation switched voltage source inverter topology and uses capacitors, switches [2, 6].

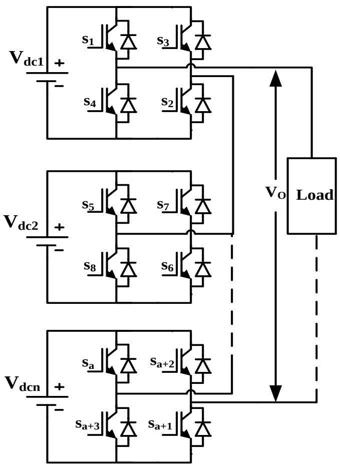

Figure 2. Seven level Inverter Circuit Configuration

It requires only less number of components in each level. The combination of capacitors and switches pair are called as H-bridge and it provides the separate input DC voltage in each H-bridge. This circuit consists of H-bridge cells and each H – bridge cell can provide the three different voltages like zero, positive and negative voltages. The main advantage of this inverter configuration is that it requires less number of components compared with diode clamped and flying capacitor inverters. Economically this configuration is best when compared with the other two configurations (Diode Clamped and Flying Capacitor inverters).

The proposed method uses the hybrid topology with both wind and solar PV panel. The input signal is converted into the required output signal with the use of hybrid converter module. Then, it can be

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processed with the inverter stage; here the output of the inverter is varied with respect to the given input received from the hybrid system.

At the beginning, the wind and solar panel is coupled as hybrid model to act as a source. The signal developed by the hybrid model is applied to the Converter circuit to manage the input signal. Likewise, the solar panel output is given to another converter in order to get the controlled output voltage. The controlled voltage source is applied as input to the Voltage Source Inverter .This inverter converts the controlled DC into AC based on the triggering pulse applied to the devices. Finally, it is transferred to the grid system and tested. Figure 3 shows the Simulink model of proposed hybrid system.

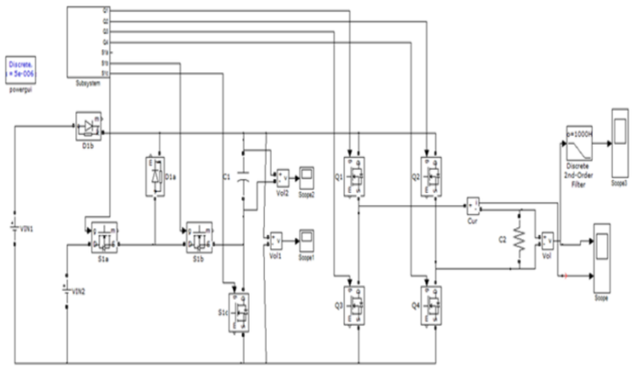

Figure 3. Simulink Model for hybrid proposed system

Alternating current produced by the inverter at positive side voltage is obtained from the following equations (1), (2) and (3)

$$IV_{01} = v_{oaa1} \qquad (1)$$

$$C_{02} = voaa_2 \qquad (2)$$

$$v_o = IV_{01} + C_{02} = v_{oaa1} + v_{oaa2} \qquad (3)$$

Alternating current produced by the inverter at negative side voltage is obtained from the following equations (4), (5) and (6)

$$IV_{01} = -V_{oa1} \quad (4)$$

$$C_{02} = -V_{0a2} \qquad (5)$$

$$V_0 = IV_{01} + C_{02} = [V_{01} + V_{02}] = -[V_{oa1} + V_{oa2}] \qquad (6)$$

The obtained output form inverter topology with a non-linear load having fluctuation [10]. To minimize such fluctuation, the topologies are constructed with developed H-bridge. Figure 4 and 5 shows the output voltage and current waveform of 7 level H-Bridge Inverter. The majority of the designs are framed to manage the voltage stability.

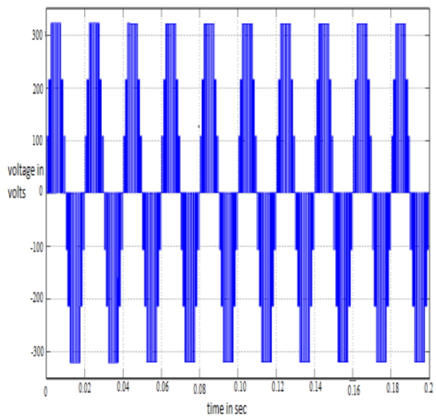

Figure 4. Output voltage waveform of 7-level H-Bridge Inverter

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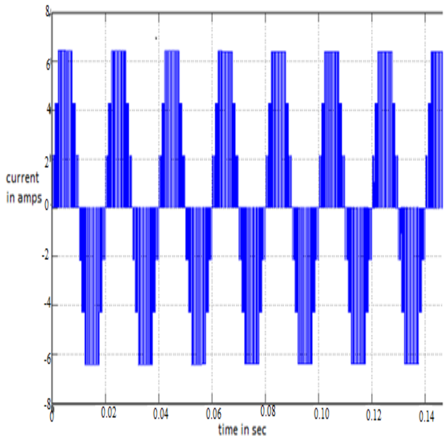

Figure 5. Output current waveform of 7-level H-Bridge Inverter

PV Module and Wind Energy topology

The photovoltaic system or module converts the radiation from the sun in the form of light, into electric power. It consists of solar array and the required system components. The PV Array is a five parameter model. The diode current can be calculated by using the equations (7), (8) and are given as,

$$Diode\ Current, I_d = I_o[\exp\left(\frac{V_d}{V_T}\right) - 1] \quad (7)$$

$$V_T = \frac{kT}{q} * nl * Ncell \quad (8)$$

From the above two equations, the current and voltage characteristics are noticed with the help of diode saturation current (I_d). Where, *nl* is the diode identity factor, k is the boltzman constant, q is the Charge of an electron and T is the temperature of the cell.

Generation of wind module depends on the type of turbine used and their control qualities. The output developed by the turbine can be calculated by the following equations (9), (10) and are given as,

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2} v_{wind}^3 \quad (9)$$

$$p_{m_{pu}} = k_p c_{p\_pu_{wind\_pu}^{v^3}} \quad (10)$$

From the above equation (10), $p_{m_{pu}}$ is the input power for the given value. The performance coefficient value depends upon the maximum value of cp. The total power factor depends upon the three phase input signal, pitch angle and other coefficient. The figure 6 shows the output power produced by wind system based on the wind speed. From this figure we can conclude that minimum speed required to produce the output power is 3.5m/s.

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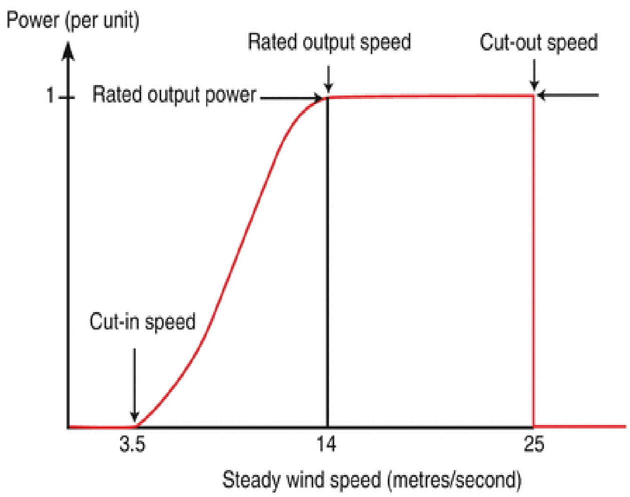

Figure 6. Wind Speed Vs Power Characteristics

Triggering mechanism

In order to obtain the desired or required output from the inverter, the gate pulse produced from the pulse generation circuit can be varied. There are number of triggering circuit or gating circuits are available. Out of which the most efficient method to produce the gate pulse is PWM triggering mechanism. PWM based inverters can able to control both the magnitude and frequency of the voltage and current. Different PWM techniques are available, that are Single Pulse Width Modulation, Multiple Pulse Width Modulation, Sinusoidal PWM and Space-Vector PWM. These techniques are commonly used to produce the controlled voltage from the inverter, after receiving the controlled voltage that is applied as input to the load. The load may be used as induction motor, Brushless Direct Current (BLDC) and Switched Reluctance motor (SRM). Compared with other triggering mechanism this PWM technique provides better efficiency and higher performance. The PWM pulse generation circuit as shown in figure 7.

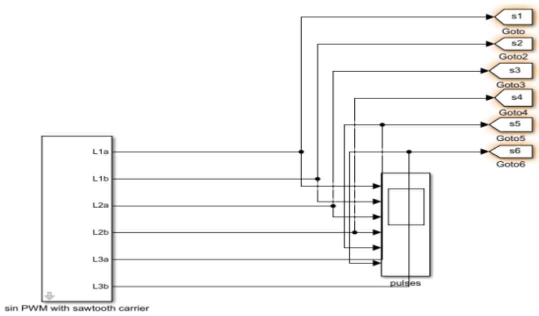

Figure 7. Pulse Generation Circuit

31 level inverter

The hybrid 31 level multi-level inverter was simulated with MATLAB Simulink and is shown in figure 8. If the number of output levels is increased the harmonic content will get reduced and performance also improved.

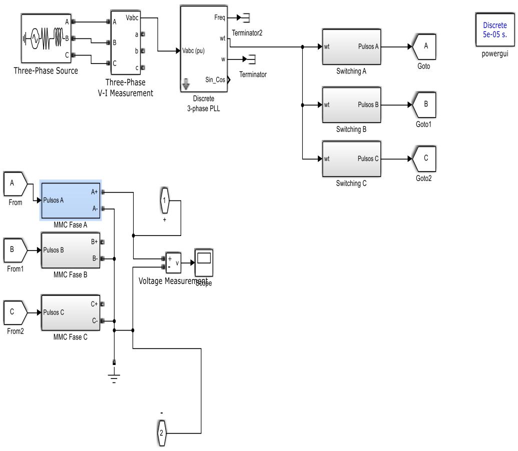

Figure 8. Simulink Model of 31 Level Inverter topology

III. Performance Evaluation

In order to find the equation for THD, the average power for single harmonic is represented by the equation (11)

$$P_a = 2|C_a|^2 \quad (11)$$

Where a=1 represents the fundamental harmonic and a ≥2 are the higher order harmonics. The total average power in the signal is given by the sum of the average powers at each harmonic and is given in equation (12).

$$P = |C_0|^2 + \sum_{a=1}^{\infty} P_a = |C_0|^2 + \sum_{a=1}^{\infty} 2|C_a|^2 \quad (12)$$

THD can be calculated by the sum of power in all harmonics divided by the fundamental power and is given by the equation (13).

$$THD = \frac{P_2+P_3+P_4+\cdots}{P_1} = \frac{2|C_2|^2+2|C_3|^2+2|C_4|^2+\cdots}{2|C_1|^2} \quad (13)$$

THD can be expressed in dB and is given by the equation (14)

$$THD = 10\log_{10}\left(\frac{P_2+P_3+P_4+\cdots}{P_1}\right) \quad (14)$$

The proposed control topology is simulated with MATLAB Simulink, FFT analysis and the corresponding output voltage waveform for the 31 level inverter topology is shown in the figure 9 and 10.

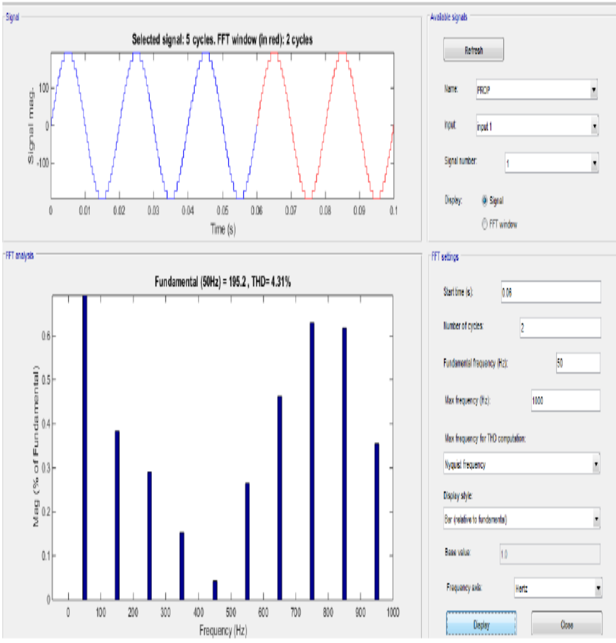

Figure 9. FFT Analysis of 31 Level inverter Topology

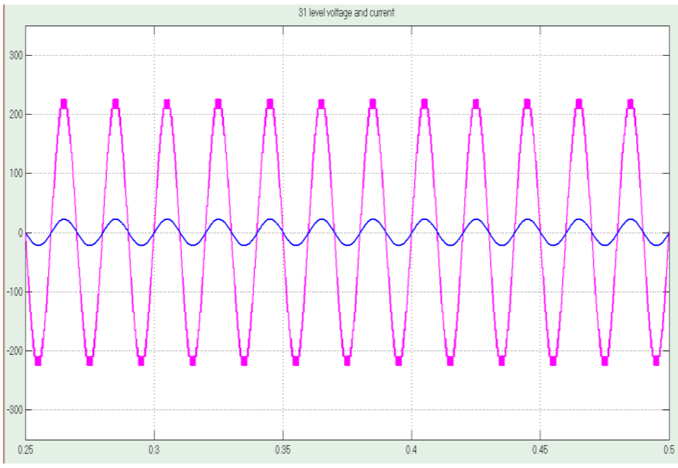

Figure 10. Multilevel inverter with 31-level output voltage waveform

The performance of seven level and 31 level was compared and tabulated in table 2.

Table 2. THD Comparison of 7 level and 31 level MLI Topology

Parameter	**Proposed**	
Type	Diode clamped	Developed H bridge
THD for level 31 (%)	11.8	4.31

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THD for level 7(%)	35.11	29.12

IV. Conclusion

The proposed system includes the hybrid converters with two sources namely solar and wind energy. This network has the ability to increase the voltage level from both wind energy and solar photovoltaic system. Whereas the conventional network has some more limitations to step up the voltages and has discontinuity of input current and voltage and current stresses. In order to avoid the previous disadvantages a new H-bridge Multilevel Inverter has constructed with improved efficiency and reduced Total Harmonic Distortion and also designed with two different Multilevel Inverter operations (7 level and 31 level) with MATLAB/Simulink. Finally, its operation is tested and concluded based on the Total Harmonic Distortion. From the simulation results, it is concluded that the newly introduced H bridge converter produces the low Total harmonic distortion as 4.31% and 29.12 % for 31 level and 7 level Multilevel Inverter circuit.

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