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A Study of H-Bridge Multilevel Inverter Driven Marine Propulsion System

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Abstract: On account of non-availability of non-renewable resources, Greenhouse gas emissions, CO_2 emissions, environmental aspects increased the utilization of alternative energy resources for marine applications. The current research work fills the need of a typical purpose of social event, tending to clarify the most recent updates, past accomplishments and future focuses of the shipping industry. The main goal is to create a multi-level inverter for a diesel/wind/PV/battery hybrid power system with an induction generator (IG) for a wind-energy conversion system and a synchronous generator (SG) for a diesel-generator (DG) installed in onboard ships. The Maximum Power Point Tracking (MPPT) techniques have been used to get the renewable energies such as solar and wind. Multilevel inverter topologies provide lower THD, lower EMI generation, a better output waveform and higher efficiency for a given output waveform quality. Cascaded H-Bridge topology has been chosen in this research work to design a multilevel inverter. The output of the RES is variable in nature, which is regulated by a hybrid buck boost converter. The regulated DC output is fed to the 13 level H bridge inverter to enhance the performance of the hybrid system. This combination can satisfy the voltage to load in the desired level. H-bridge multilevel inverter improves the voltage profile and simulation results are obtained using Mat lab/Simulink. Results obtained have shown that the system is designed well and the load current and voltage of 9.43% THD rate is maintained in the standard limits for multilevel inverter to get a smooth sinusoidal output.

Keywords: PV system, Wind energy conversion system, Hybrid Buck-Boost Converter, cascade H bridge multilevel inverter, Total harmonic distortion.

1. Introduction

The latest generation system must satisfy increasing demands for electrical energy while expanding usage in industrial and residential applications. Nowadays, the conventional resources have created a major environmental pollution and exhaustion. This problem has significantly emulated the alternative source of energy [1]. Non –conventional resources such as hydro, solar and wind can be used for generation of electrical power to meet the above mentioned power demand issue.

Energy produced from renewable sources can also be used to satisfy the power load demand, and surplus power could be sent to the grid using power electronics conversion system [2]. Renewable energy resources (RES) have fluctuating nature of power flow and the solar photo voltaic (SPV) and wind energy are the most popular and widely used power generation because of its tremendous price reduction over the last decade [3]. The power quality of renewable resources depends on the output voltage and current [4]. PV and Wind energy systems require proper maximum power point tracking to get maximum power from the resources [5]. Thus, the design of system requires suitable converters, proper optimization control and cost by considering all environmental factors. [6]

With the help of modern power electronic converters, the output of RES can be regulated.The primary goal of RES is to generate the real power. Active filter functionality, voltage and reactive energy maintenance can be achieved by utilizing a multi-functional inverter on the RES system. The focus is on developing several new inverter topologies, especially medium voltage converters, which have only recently entered into the industry. In order to get good quality of power, multi-level inverters (MLI) are used for DC-AC conversion. MLI integrates the output voltage by chopping the DC voltage into various levels. Because of the modular structure and requirement for distributed DC sources, the CHBMLI is better adapted in renewable energy sources. In comparing to other MLIs, the effectiveness of CHBMLI is superior due to the enhanced harmonic profile of the stepped output wave and need for reduced number of switches. It also has less electromagnetic interference and dv/dt stress [7,8].

In this research work, the output of RES with MPPT control has given as input to DC-DC/ AC-DC converter. The output of the converter is fed as an input to CHBMLI. The output of MLI is fed to the ship propeller which is shown in Figure 1. The performance of the MLI is made for different levels of configuration and the model is simulated in MATLAB/SIMULINK using power system tool box.

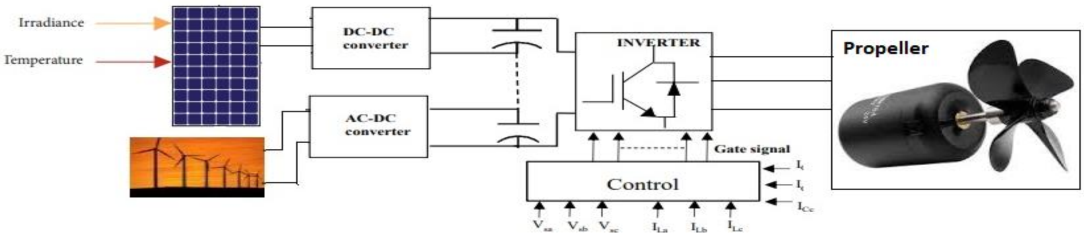

Figure 1 Structure of Hybrid Power System for Marine Applications

2. Hybrid Power Fed H Bridge Inverter Topology

2.*1 PV System:*

Solar PV's primary issue is that its output power varies depending on weather conditions and solar radiation intensity. Due to non-linear PV properties and unexpected panel temperature, research on PV panels and DC-DC converters is progressing. Solar panel arrays equivalent circuit is shown in Figure 2[5].

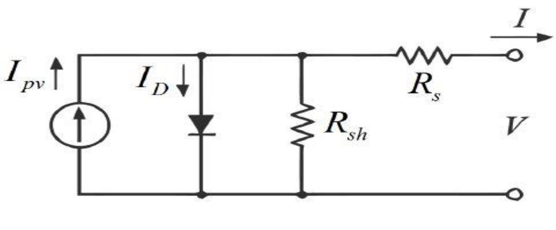

Figure 2 PV Equivalent Circuit

Values of series and parallel resistance and the environmental parameters temperature and irradiation are the deciding factor to get the I-V characteristics. PV cells offers more current, whereas parallel connection of PV cells offers more voltage.

2.2 Wind Energy Conversion System

Wind energy, in particular has a significant benefit in navigation activities since, unlike all the other renewable energies, it is constantly available on the high seas. A wind turbine changes active energy from the wind into mechanical energy.

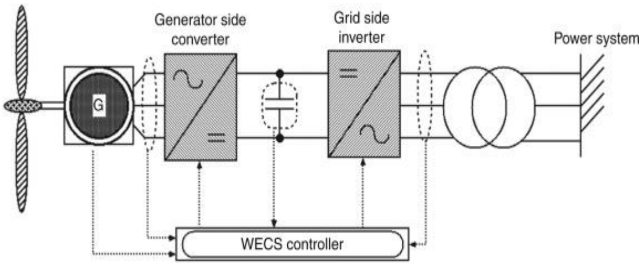

Figure 3 WECS

The structure of wind energy conversion system is shown in Figure 3. The Permanent Magnet DC Generator (PMDCG) is a DC brushed motor with a constant magnetic flux that is separately excited [9,10]. In fact, nearly all permanent magnet direct current (PMDC) brushed motors can be used as a PMDC generator; however, because they were not designed to be generators, they do not make better wind turbine generators so because rotating magnetic field acts as a brake, decelerating the rotor if used as a basic DC generator. The Wind Energy Conversion System (WECS) now has an Optimal Power Control MPPT technique in addition to pitch angle control [11-13].

2.3 Hybrid Buck – Boost Converter:

The structure of buck-boost converter is shown in Figure 4. Variable output of RES is given as an input to Diode Bridge which has an inductor and capacitor across the load. The converter may be used as a step-down or step –up converter and the inductor stores the energy when the switch is ON and discharges when it is OFF. The voltage can be raised or lowered by suitably switching the switching device. Duty cycle determines the output voltage. The rectification process is done by the Diode Bridge circuit; the switching part is carried out by the IGBT switch the finally PWM technique is used for controlling the output voltage [14].

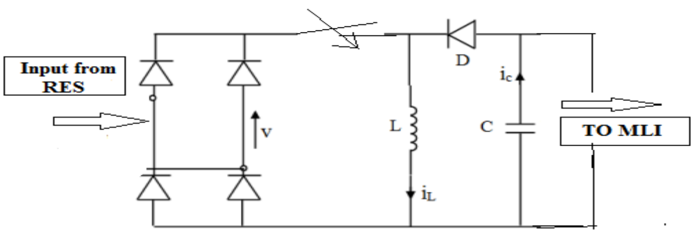

Figure 4 Structure of Buck -Boost Converter

3. **Cascaded H Bridge Multilevel Inverter Topology**

3.1 *Cascaded H Bridge Multilevel Inverter*

The cascaded H bridge inverter is independent of DC sources. For n number of DC source, number of levels must be (2n+1). Depending upon the nature of Dc sources, CHB inverter can be classified as symmetric and asymmetric and the asymmetric topology is considered in this research. Here six unequal DC sources are used to generate thirteen-level output. Number of switches as well as the THD is reduced much in the inverter topology. Figure 5 shows the structure of thirteen level CHB inverter.

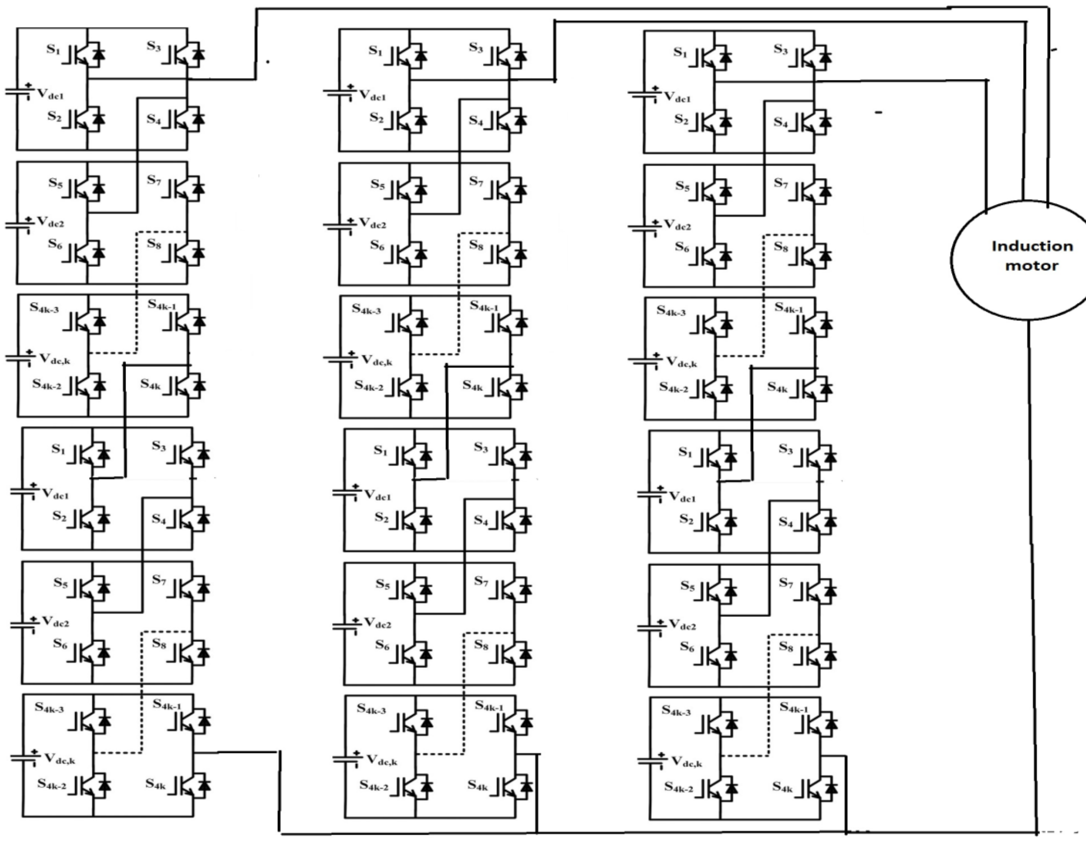

Figure 5 Structure of 13 Level Inverter

3.2 *Modulation Technique*

Pulse width modulation (PWM) is an efficient modulation technique because it has the capacity to minimize harmonics, it does not require additional components. Phase Shift Modulation is used to produce the PWM signals which in reduce the THD also.

4. **Results and Discussion**

The proposed topology of a solar PV and wind energy combination of BUCK BOOST Converter and thirteen level cascaded H-bridge inverter fed induction motor drive propeller was simulated using MATLAB/Simulink R2020a and the simpower system in MATLAB. With the help of a DC/DC Buck Boost converter and an AC/DC Converter, a 1 KW solar and wind energy system is converted to six different 100v outputs. The 600v input to a multilevel inverter with 24 IGBT switches and 6 separate DC sources is converted to 415V, 3 phase with the help of a 13 level inverter using the Level shift modulation technique. A reference wave and a carrier wave are required for the carrier-based Disposition approach. The reference and carrier wave frequencies are 50 Hz and 2500 Hz, respectively is shown in Figure 6. The staircase output voltage and current waveform of 13-level inverter thus obtained is shown in Figure 7 and 8.

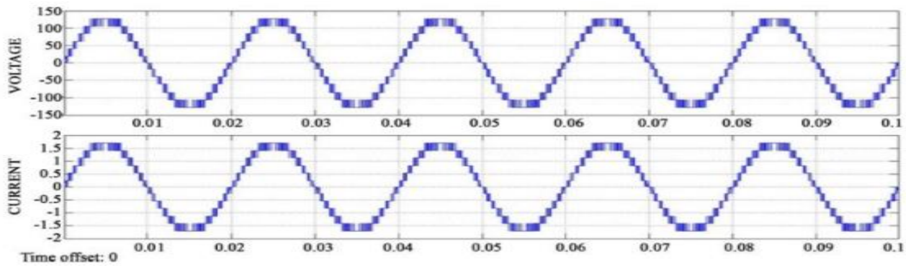

Figure 6 Output Voltage and Current Waveform

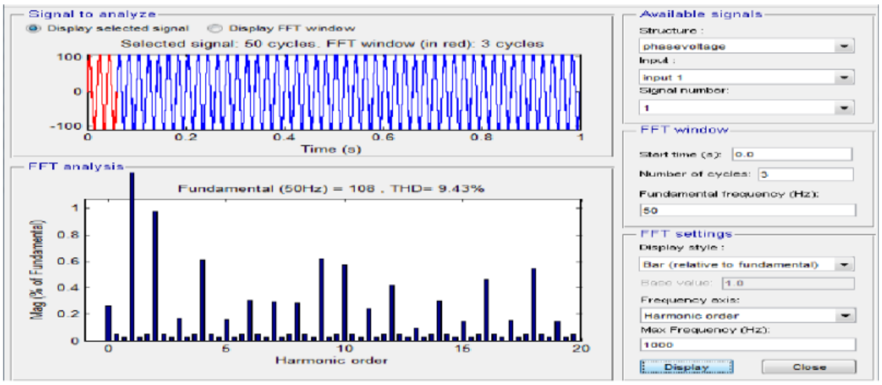

Figure 7 FFT Analysis for 13 Level Inverter (Phase to Neutral Voltage)

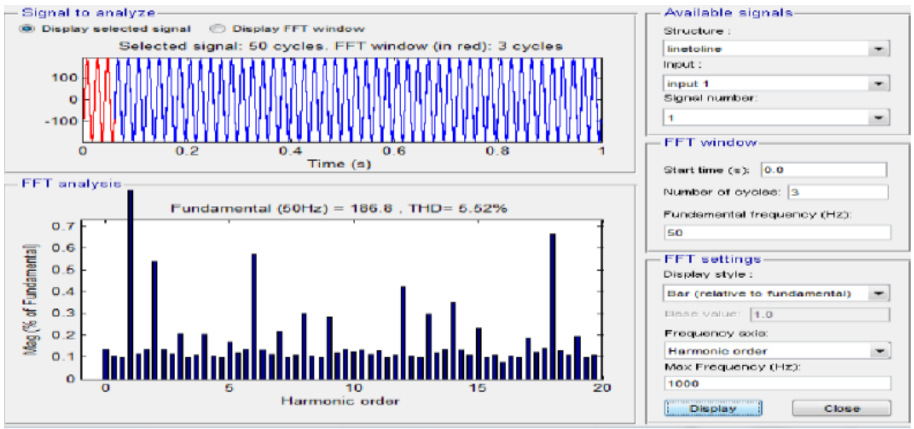

Figure 8 FFT Analysis for 13 Level Inverter (Line to Line Voltage)

The staircase output and the FFT analysis for THD% is shown in Figure 10 and 11 for phase to neutral and line to line. By using PWM technique the odd harmonics are minimized by varying the modulation index (0 to1). For the modulation index value 0.8, the THD obtained is 9.43 for phase to neutral and 5.52 for line to line voltage which is satisfying the IEEE standard for harmonic guidelines. Table 1 shows the comparison of THD of various levels of CHB Inverter, number of H bridges, output levels and number of DC sources.

Table 1 Comparison of THD of various levels of CHB inverter

Sr. No.	Parameters	Three level	Five level	Seven level	Nine level	Eleven level	Thirteen level
1	No. of H bridges	1	2	3	4	5	6
2	No. of switches	4	8	12	16	20	24
3	Output levels	3	5	7	9	11	13
4	No. of DC sources	1	2	3	4	5	6
5	%THD	36.15	26.87	25.66	14.59	11.50	9.43

5. Conclusion

The design and implementation of thirteen level Cascade H bridge inverter with renewable resources (PV and wind) and hybrid buck-boost converter has been discussed in this research work. The proposed system is operated under asymmetric mode with ship propeller/three phase induction motor as the load. The designed system is validated by using MATLAB Simulink tool. Results reveal that this CHBI minimizes the odd harmonics which is very harmful and affects the power quality. The implementation of the modulation index is also visible here when changing the modulation index (varying from 0.3 to 1) to maintain the AC output voltage. It is cost-effective since it uses less number of switches and other components in the design. The proposed model produces lower THD levels, which might fulfill the IEEE 519-1992 standard. This 13 level CHBI inverter enhances the power quality of inverter-based drives by increasing output voltage and lowering THD. The proposed configuration results in a compact and low-cost system with lesser number of switches and switching states which in turn simplifies the inverter control circuitry.

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