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# Advanced Cascaded H-Bridge & Modular Multilevel Converter Applied to a Wind Energy Generation

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Abstract: As the number of renewable energy sources increases worldwide, wind energy is one of themwho stand out from the crowd. With the development of technology, wind turbine projects have had a significant impact increased their capacity, reaching a higher capacity mainly for offshore installations. One of the most important challenges are power Converter, specifically semiconductor components that have limited voltage and current characteristics. This gave birth to the concept of multilevel Converter , which increased the voltage level and thus carried a higher power level. Apart from the application In multilevel converter , it is possible to increase the voltage and power level by using an generator. This context was investigated in this work the use of a multi-level converter (three-level cascaded H-bridge in series), which controlsan open coil of Generator Analysis of the proposed system was developed dynamicallySimulation of 1.71 MW WECS using PLECS software including basic system modeling components: generator, power converters, system control, filter and grid connection. The score show that the goal of achieving 5-level behavior of the output voltage is achieved by using OEW connection. In addition, a low harmonic concentration is achieved in the machine flow as such current supplied to the grid. In addition, it is possible to control the distribution of power between converter, indicating that lower power converter can be connected in a higher direction Wind power
Keywords: Multilevel Converter, Induction Generator,

## I.INTRODUCTION

In recent years, the expansion of renewable energy sources has increased by approx world; in particular, the significant growth of solar electric and wind systems appeared. As for wind generation, new factories are expected to be built around the world will remain high for years to come, as Figure 1 of the Global study shows Wind Energy Council (GWEC) and International Energy Agency (IEA). Reflecting that, the expected annual growth of new installations is 6.7 %. Offshore installations every year became a way to expand wind generation. In the years 2018-2023 (Figure 1), there were approx more than 30 GW of total offshore capacity growth, which is approx 7% of the total capacity of the wind energy conversion system. It was a highlight By 2023, what was best for new offshore facilities. Because the capacity of wind turbines is increasing, especially when it comes to the offshore area in the installation, the power converters work in the border areas of voltage and current.

Developed to allow transformers to operate at higher voltages special attention is given to multilevel converters Multilevel converters are topologies consisting of combinations of interconnected power semiconductors and controlled to produce a voltage waveform at the output, Another way to get multi-level stress behavior and the electrical machine has an open winding (OEW) .in OEW configuration, the machine terminals are not connected in delta or star, so six machines connectors (for a three-phase system) are available for connection to power transformers.

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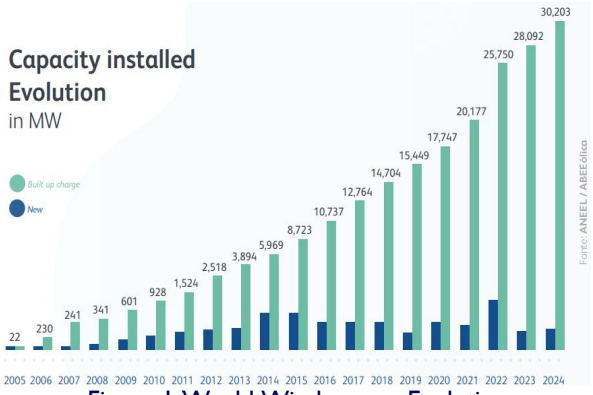


Figure-1 World Wind energy Evolution

Several applications have been proposed to use this open coil topology: electric vehicles [16], photovoltaic water pump drive systems , nine-level engine motors inverters using traditional three-phase two-level voltage source inverters (2L-VSC) and CHB [18], six-level inverter motor motors using two 2L VSCs and one cascade 2L-VSC and wind systems [20]. Considering the use of multilevel transformers and open winding in wind energy conversion systems (WECS), several works have proposed different topologies: three-phase. Two-level series transformers, zero-point fixed transformers, Diode full bridge rectifiers with NPC inverter and flying capacitor transformers. Studies evaluating the use of wind energy conversion systems are still lacking CHB in multilevel converter open ended coil drives.

## 2. SYSTEM OF WIND ENERGY CONVERSION

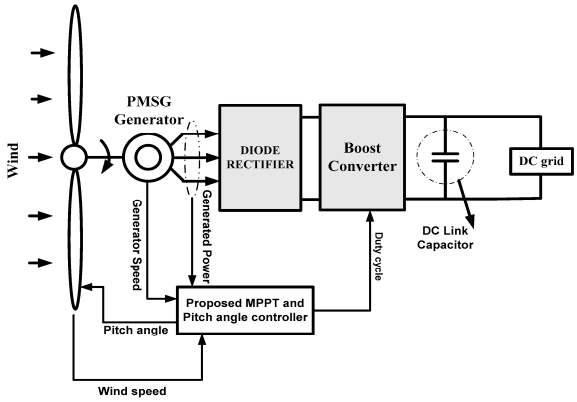


Fig. 1 Wind Energy Conversion System Block Diagram

Using a wind turbine, wind energy may be converted into mechanical energy and utilised. A mechanical drive train connects the turbine to the power producing system. A gearbox is typically used because of the disparity in turbine and generator speeds. Multiple, low-speed generators with synchronous or permanent magnet excitation are used in new wind turbine designs to remove the gearbox. It is possible to regulate how much electricity a turbine converts by adjusting its blade pitch angle. Turbines with stall control do not permit this level of control. An anemometer is used to measure wind speed. Figure 1 depicts a typical Wind energy conversion system. The generator converts the wind turbine's mechanical energy into electrical energy. If the application requires it, the generator might be either synchronous or asynchronous. Permanent magnets or an excitation mechanism are utilised in the first scenario. A power electronic interface must be present in order for variable speed systems to work. Filters and active or passive power factor correction devices might be included in the compensating unit.

$$\text{Power} = 1/2\ C\rho AV^3$$

$\rho$ = Air density
C = Coefficient of performance
A = Frontal area
V = Velocity of the wind

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## 3. MULTILEVEL CONVERTER AND ELECTRIC MACHINES

With Open-End Windings As previously mentioned, by increasing the power of wind turbines, conventional converters operate at their electrical limits. Multilevel converters and machine drives with OEW are employed to reduce the individual power of the converters, also increasing the voltage level of the arrangement. In a CHB multilevel converter, the number of resulting levels, per phase, at the output of this arrangement are given by 2n + 1, where n is the number of full bridge converter (cells). Thus, a five-level converter, as employed in this work, needs two cells per phase to reach this number of levels

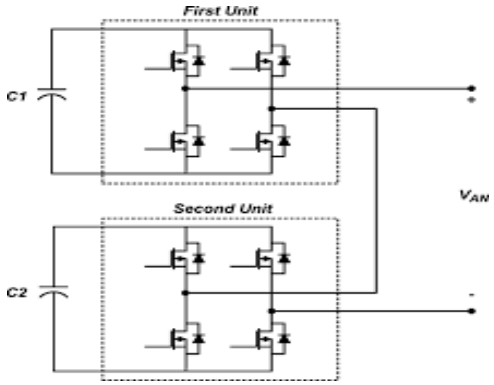


Figure 3. Multilevel converter

## 4. COMPARISON OF MULTILEVEL CONVERTER TOPOLOGIES.

In order to support the choice of the CHB multilevel converter used in this work, Table 2 presents a summary of the advantages and disadvantages of the most used multilevel converters in the industry

| | Basic topologies of Multi-level inverter | | | |
|---|---|---|---|---|
| **Topology** | **FC** | **NPC** | **CHB** | **Proposed topology** |
| No. of switches per phase | 12 | 12 | 12 | 4 |
| Antiparallel diode per phase | 12 | 12 | 12 | 4 |
| The DC bus Capacitor | 6 | 6 | 3 | 2 |
| DC voltage sources | 1 | 1 | 3 | 2 |
| Close phase diode | 0 | 30 | 0 | 0 |
| Capacitor balance | 15 | 0 | 0 | 0 |

Table.I

## 5. MODULAR MULTILEVEL CONVERTER

For effective conversion of renewable energy, power converters are employed. One section of converters employs midway DC link and another category directly converts fixed AC to variable AC without any midway DC link. Voltage source converters utilizes midway DC link. Depending on the output voltage, voltage source converters have been classified as two-level inverters and multilevel inverters. As multilevel inverters have better efficiency when compared to two level inverters they are preferred. The various topologies in multilevel converters are H bridge, flying capacitor and neutral point clamped converter. The disadvantage associated with these topologies is presence of circulating current, requirement of isolation transformer. These two features reduce its importance in medium and high-power applications. Hence an advanced version of multilevel converters came into picture known as modular multilevel inverters (MMI) [6,11-15]. Power converters are employed to enhance the efficiency of the conversion. In order to convert DC to AC inverters are proposed. Literature survey suggests to employ multilevel inverter but due to circulating current they were disregarded and modular multilevel inverter have been proposed. The system employed MMI to convert the extracted wind energy to AC. Cascaded Converter topologies feature is being employed in MMI which eliminates the need for isolated DC sources and phase shifting transformer. MMI consists of submodules which are connected in series. The various submodule configurations are i) Half bridge ii) Full bridge iii) Flying capacitor iv) Cascaded half bridge v) Doublclamp Fig 4 represents three phase MMI consisting of three legs. Fig 5 shows one leg of proposed MMI which has half bridge inverter as the submodule.

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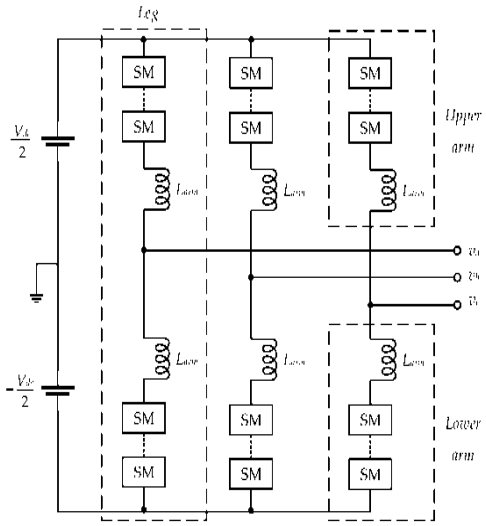


Figure .4 Circuit diagram of three phase MMC

The sub module consists of two switches which are to be operated in complementary manner. The switches have the freewheeling diode connected in parallel. When one switch is ON either the switch or the freewheeling diode will conduct. To estimate the dynamic behavior the mathematical description of any system is required. Each arm is represented with the electromotive force and voltage drop across series connected impedance.

## 6. SIMULATION RESULTS

The system has been designed in MATLAB with wind turbine, generator, PWM rectifier, converter and MMI. The simulation parameters of wind turbine together with MMI are displayed in Table 1-2. Both converters are operated on PWM switch in strategies

Table1.MMI Simulation Parameters

| Quantity | Value |
|---|---|
| Sub module capacitance | 20 F |
| Switch resistance | 0.1Ω |
| No of sub modules in each arm | 5 |
| PWM Carrier frequency | 1KHz |

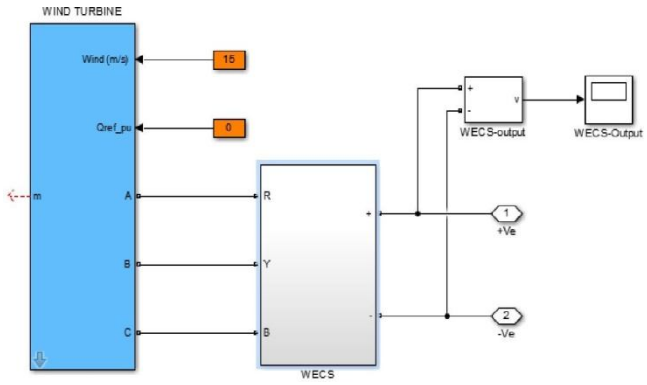


Figure.5 Represents the MATLAB model of the wind turbine along with WECS

## 7. RESULT VERIFICATION

The proposed system has been implemented in hardware by using a wind energy training system along with a DC-DC Converter and MMI. The DC-DC Converter and MMI is realized by IRPF 150N MOSFET devices. The realization of converter and inverter along with its pulses is shown in Fig

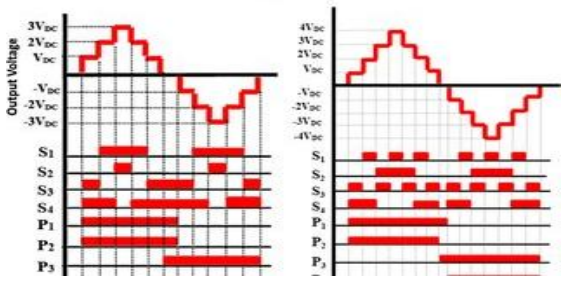


Figure 6 .Voltage output of 11level MMI

The system proposed provides modularity and has increased the efficiency of the wind conversion system rather than conventional already existing systems. The lower the THD the efficient the system is. THD depends on the number of levels which depends on number of sub modules

## 8. CONCLUSIONS

The implemented control also demonstrated a good performance. The machine speed was controlled without overshoots and following the references even during abrupt turbine torque variations. During such variations, the DC-link voltage was also well controlled, permitting the delivery of power to the grid. This can be seen in the low value of the oscillation present in the measured DC-link voltage, which in a steady state is approximately equal to 3% of its nominal value. Future work will include obtaining experimental results on a prototype of a low-power WECS, under development. Furthermore, strategies to operate the system under converter fails will be investigated, in order to take advantage of the multi converter structure, Due to converter features such as modularity and scalability it is being favored for high and medium power applications. Performance of the overall conversion system has been evaluated under MATLAB environment and prototype implemented in hardware.

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