APPLICATION OF 7-LEVEL NPC CONVERTER FOR LOW VOLTAGE WIND ENERGY CONVERSION SYSTEM

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Abstract.

There are many types of converters that can be utilized in low voltage applications. Unfortunately, most of them are not suitable for this type of operation. Choosing the correct converter topology is very important in order to ensure that the system performs efficiently and effectively. In this paper, we present a 7-level multilevel power converter that was utilized to manage the performance of a wind energy conversion system. The power converter was designed using maximum clamping diodes. In addition, the performance of a neutral point-clamp converter is also examined. The goal of this paper is to provide an overview of the various facets of wind energy conversion. It also explores the different techniques that are utilized in the development of such systems.

Keywords. Wind Energy System, WECS, DC-DC Converter, NPC, Switching devices, Grid system etc.

1. INTRODUCTION

This paper aims to discuss the various aspects of wind energy conversion in the world. In the next section, we will talk about the various works that are being carried out in the field of WECS. Also, we will talk about the need of application in this field. A large-scale VSC and a transformer are required to convert AC to DC voltage. An offshore platform is also required to be installed in place of these components. The working of these components will increase the installation and maintenance costs. There are two types of switches used in this process: the isolated switch and the bypass switch. If a fault occurs in the generator, the first step is to block the converter. Then, the insulation switch should be opened and the bypass switch should be closed. This will prevent the faulty converter from working. The rest of the system will operate normally. The proposed configuration of the WECS and the gear box will increase the wind generator's speed. This will result in the output voltage and frequency of the generator being equal to 50 hertz. A PMSG is used as the Wind Generator [1]. A 7-level inverter is also used as the wind power converter. The constant current and the magnitude of the PMSG's output voltage are the main factors that make this component a reliable and high-quality component. As the technology used in the oil and gas industry continues to develop, more sophisticated components and systems are being developed. These are ideal for various applications, such as renewable energy. The desire to have offshore wind energy installations is not just motivated by global warming. It also takes a certain amount of commitment to make this possible.

2. MULTILEVEL CONVERTER (7L-NPC)

A multilevel converter can provide output voltages at higher levels than two. This type of device can be used in combination with a rectifier or inverter to produce a higher voltage output. The lowest type is the three-stage converter, which has a output frequency that's similar to that of a bridge converter. The three-level converter is referred to as a 5-level converter, and its basic topology consists of a frequency converter, a neutral point compensated, and a modular multilevel converter. To achieve high output voltage, switching devices have to be regulated properly. A simple step-through-a-scunder is used to create multiple Direct Current supplies using various DC sources, such as solar photovoltaic arrays and wind turbines. These components need a single supply to operate properly[3][7].The other type of converter is a modular multilevel converter, which requires multiple separated and balanced supplies. A magnetic link can be used to create multiple DC supplies for this device.

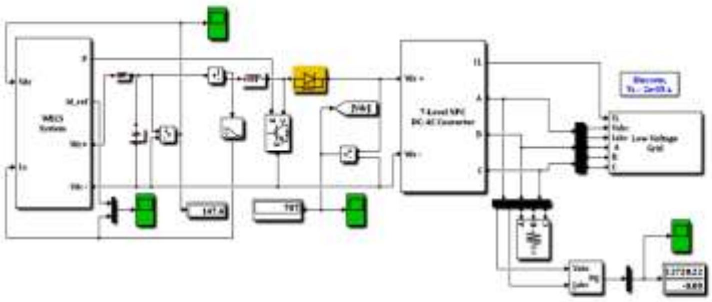

Fig.1.SIMULINK Model of 7-Level NPC Fed Low Voltage Grid Interface WECS

Due to the increasing number of renewable energy sources such as wind turbines and solar photovoltaics, the need for additional diodes is increasing. Six diodes are required for a three-phase converter. Wind turbine mechanical strength can be derived by determining the wind speed, air density, and swept region. The kinetic energy is converted into mechanical energy by the wind turbine [4][5].
The mechanical power output of the wind turbine is,

$$P_m = \frac{1}{2}\rho v_b^2 - \frac{1}{2}\rho v_b v_d^2 = \frac{1}{2}\rho A\left(\frac{v+v_d}{2}\right)\left(v^2 - v_d^2\right) \quad 2.1$$

Where, P_m is mechanical power by wind turbine, v_d is the downwind speed in ms^{-1} and v is the upwind speed. From the aforementioned equation, it can be shown that the mechanical strength of the wind turbine is directly proportional to the cube of wind speed. Any wind turbine has its limit (approximately 59%) which ensures how much energy can be extracted from the wind. Turbine will never extract any of the kinetic energy present in the atmosphere, because if it will then there will be little downwind behind the turbine. Fig 2 shows that the upwind and downwind regions are distinct [8][9]. As a result, upwind speed would be greater than downwind speed.

3. SYSTEM OF WECS

The key component of the simulation is wind energy conversion. This technology is based on electromechanical conversion. Wind energy conversion systems are made up of a mechanical turbine and an electrical generator. So, for the simulation, two components are used: one for the drive train portion and the other for the electrical generator portion. The wind turbines drive train (mechanical components) is made up of a blade-pitching mechanism, a blade hub, and a rotor shaft (for wind turbine converters, relative long). The turbine and generator are used in the design of the drive train in this study. The moment of inertia of the wind wheel (blade-fed hub) is approximately 90% of the overall train moment, whereas the inertia rotor generator time is around 10%. In addition, the generator has the maximum torsion rigidity. To represent the WTGS driver train system, a three-mass model, a two-mass model, a one-luminous mass model, or even a six-mass model can be employed. For correct transient analyses of WTGSs, a six-mass drive train model is necessary. Despite this, a six-mass driver-train system increases simulation time in modest stages because to the complicated and extensive numerical measurement.

a) MPPT

The basic aim of MPPT is to operate at that point where maximum power is generated at the wind speed. MPPT generate the pulses for the operation of boost converter which is connected to the output of the WECS.

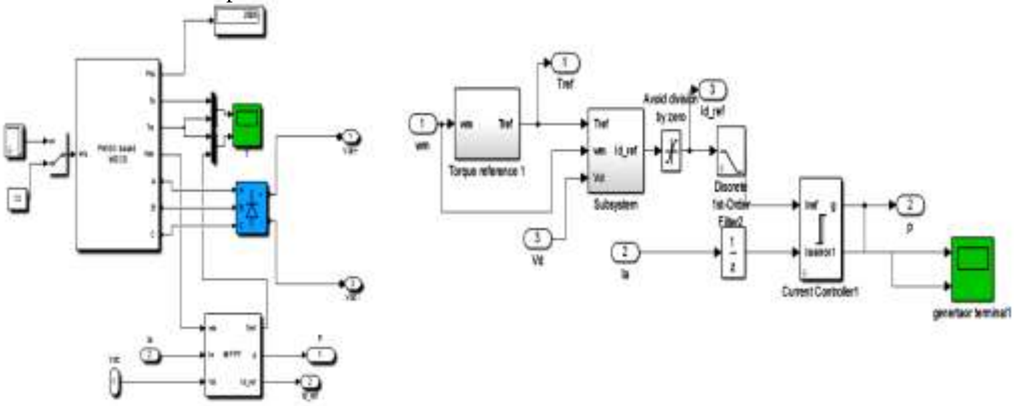

Fig. 2. SIMULINK Model of WECS with MPPT & MPPT used in WECS

4. GRID INTEGRATION OF PMSG WITH WIND TURBINE SYSTEM

Power electronic devices are used to incorporate the grid into WECS that are capable of transforming the power into a useful form. To synchronise WECS with a grid with a constant frequency, a constant voltage and a high-power factor. The voltage level of the MLI can be generated by a staircase. It depends on the number of DC sources used. The harmonic material in the generated voltage decreases with increasing DC sources. The upcoming MLI topologies must have the following things:

- Less switching devices as much as possible.
- Lower switching frequency.
- Capable to stand with very high power and voltage application

a) Model of IGBT Switches in 7-Level NPC

Here in this each leg of three phases supply is connected with diode clamped converter for the converting DC voltage to the AC voltage. Each leg has two different type of connections. Upper part is used for producing positive part of AC cycle and lower part is used for negative part of AC cycle. Figure 6 shows the switching connection of upper and lower part of each leg. Here IGBT switch is used for switching action of the power converter.

i) Switching Schemes for 7-Level NPC Converter

A switching pattern between the carrier signals of a certain cell can be created by adding a phase level shift between the two adjacent cells. This process can be used to create a multilevel multi-channel converter. The converter can be equipped with either a line-shifted or phase-shifted conveyor. If the reference signal is the frequency of fm, the converter's frequency modulation index can be determined:

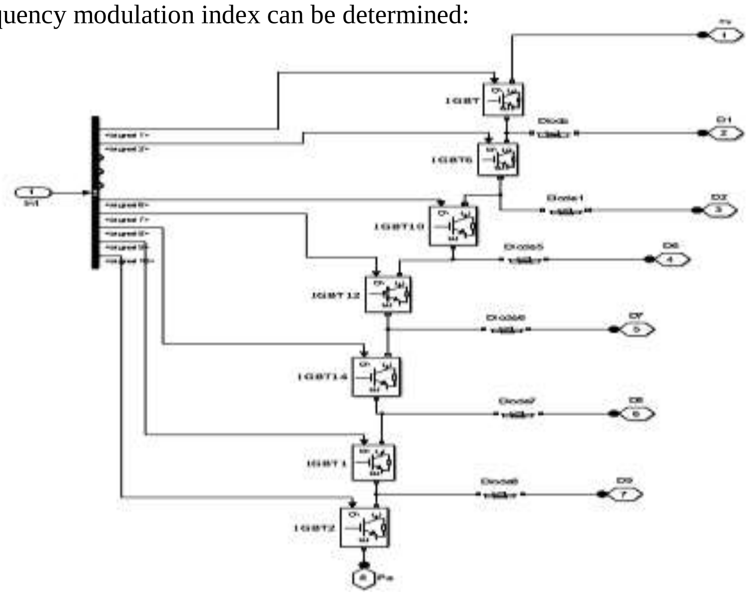

Fig. 3 SIMULINK Model of IGBT Switches in 7-Level NPC

The phase-shifted conveyor is ideal for converting FC and MMC signals. The index of the amplitude modulation can be calculated by comparing the Am and Ac peak-to-peak signals. The block diagram for the 7-level converter of the phase-shifted switching scheme. Three signals are required on this modulation scheme. 120 ^{0} moved by each other. The number of carrier signal depends on the number of conversion levels; in total are $\frac{m-1}{2}$ in multilevel converter. The carrier phase shifted towards the particular pair of cell can be determined as:

$$\theta_{ps} = \frac{360^0}{m-1}$$

the phase shifted signal generated in PWM scheme for 7-level NPC converter system. Each signal is used for upper-level switch for producing pulses for on/off strategy of the NPC.

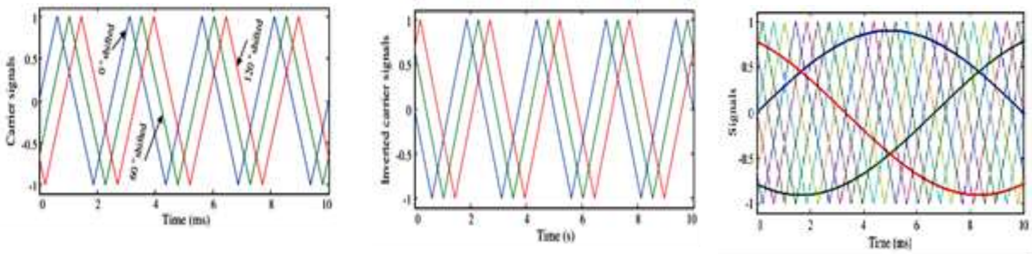

Fig. 4. Three phase carrier signal for phase shifted PWM for 7-Level NPC

5. RESULT ANALYSIS

The whole model of the proposed system is designed in MATLAB. MATLAB is the powerful SIMULINK tool which is used for design a prototype of the working model for testing and validation. The data which is used in the simulation in MATLAB is always standardizing with the IEEE society. Table-1 Shows the parameter used in the simulation work.

TABLE I. SIMULINK PARAMETER

Parameter	Value
Wind Turbine Data	
Mechanical Power	8.5 kW
Base Wind Speed	12 m/s
Pitch Angle	0
Max Power at base speed	0.8
Generator Data	
Type of Generator	PMSG
Generator Specification	10 Nm, 300 Vdc, 2300 RPM
Load Data	
3 Phase Star Connected load	400 V, 50 Hz, 15 kW
Grid Side Converter Data	
Switch Used	IGBT
DC Link Capacitor	2200*5 µF
Carrier Signal Frequency	5 kHz

Filter inductor	2 mH
Filter Capacitor	5µF

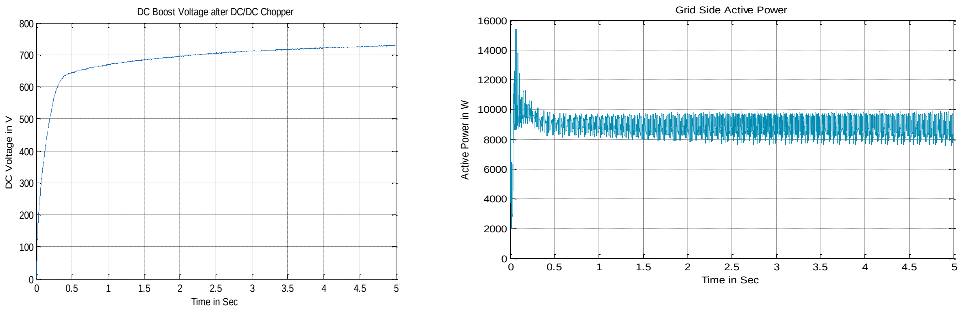

Fig. 5. DC Boost Voltage Generation by Wind Generator & Grid Side Active Power

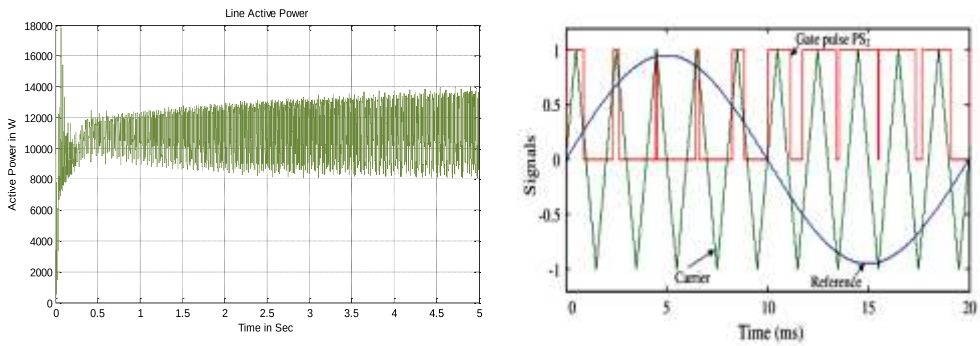

Fig. 6. Line side Power & Inverter Output Line Voltage

6. CONCLUSION

The multilevel inverter holds attractive features, usage of more switches in the conventional configuration poses a limitation to its wide range application. In this paper, the 7-level NPC is proposed on generator and grid-side converters. The 7-level NPC multilevel inverter using 5 switches is successfully introduced in simulation the circuit using MATLAB/Simulink and observed that it decreases the R_{DC} by which switching losses reduced. Therefore, a renewed 7-level NPC multilevel inverter topology is introduced incorporating the least number of unidirectional switches and MPPT used, thereby ensuring the minimum switching losses and reducing size and installation cost.

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