

# A MULTILEVEL MATRIX CONVERTER FOR GRID-CONNECTED BASED WIND ENERGY CONVERSION SYSTEMS

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**Abstract-** Wind energy is one of the most affordable renewable energy sources. The usage of a matrix converter for grid-connected wind turbine systems powered by permanent magnet synchronous generators (PMSG) is discussed in this research. The MATLAB/Simulink environment has been used to create a simulation model. The system is made up of a wind turbine, a PMSG, and a 3-phase matrix converter that serves as a connection point between the wind turbine system and the electrical grid. Small-scale wind turbine systems that can be installed in eco-friendly homes can also use the proposed system.

**Keywords:** Wind energy conversion system (WECS), Power converters (PC), Matrix converter (MC), Permanent magnet synchronous generator (PMSG).

## 1. INTRODUCTION

The power industry has long struggled with the use of fossil fuels. Although they are scarce, emit dangerous gases, and significantly contribute to global warming, mankind is forced to rely on them. The use of renewable energy has increased, yet dealing with nature's unpredictable behaviour has always been difficult. The usage of renewable energy sources in the production of electricity is on the rise today and in the future. This is because they are widely available, emit no greenhouse gases, and come from clean, environmentally favourable sources.

A further advantage of wind energy is that it can generate electricity both on land and at sea. When these renewable energy sources are integrated into the grid, the increased use of them presents a variety of problems for the electrical power system. The techniques utilised to control the aerodynamic efficiency over the rated power set wind energy conversion systems (WECS) classes apart based on the power control capacity. Therefore, WECS is divided into three groups [1] based on the input wind power control ability: stall controlled, pitch controlled, and active pitch controlled. WECS are classified as either fixed speed or variable speed, depending on the speed control measure [2–4].

For the WECS, the Permanent Magnet Synchronous Generator (PMSG) will be more appropriate. This is so that power loss can be reduced compared to the direct drive generator, which also does not require a gear box, as it is possible to bypass the gearbox. But because of its size and weight, it loses power as well [5].

The voltage source rectifier (VSR)/voltage source inverter (VSI) and the current source rectifier/current source inverter are the two types of typical back-to-back converters. A voltage source inverter and a common DC-link connect a diode bridge rectifier, which is essentially what the BB-VSI is. Since a diode rectifier's current cannot reverse, some systems cannot use it, giving rise to the creation of BB-VSI. A DC-link connects the converter's VSR and VSI components, allowing for independent operation of each. The converter's source filter inductor is the source of the issue since, in low and medium power operations, they are often larger and heavier than the DC-link capacitor.

Instead of dealing with that issue, BB-CSI can be applied. Similar to BB-VSI, the CSI generates sinusoidal supply current waveforms, and its DC-link inductor is often bigger and heavier than its BB-VSI counterpart's DC-link capacitor. Being a low-pass LC-type filter, the source filter for BB-CSI is substantially smaller than the one used in BB-VSI.

Another distinction is that in BB-CSI, the diode and IGBT are always coupled in series, increasing semiconductor conduction losses. A 3x3 direct matrix converter serves as a general-purpose direct matrix converter. For simplicity, a direct matrix converter is referred to as a "m-n" matrix converter, where "m" stands for the number of input phases, which theoretically must be at least three, and "n" stands for the number of output phases (which can be one to infinity).

Bi-directional switches are used to construct the circuit for the three-phase matrix converter. These switches have a four-quadrant operating range, the ability to conduct current, and the ability to block voltages of both polarities. The majority of power converter specifications in wind energy systems [6–11] aim to minimise cost, increase reliability, and reduce size and weight. Thus, a type of converter that converts AC to AC in a single step is the matrix converter [12].

A distinctive topology is the MC. This is so that the intermediary DC conversion is removed by the MC. It functions as a simple AC-AC converter. The centre of the input and output phases of the converter contain bi-directional switches.

Select opening and closing switches are linked to the output. A filter on the input side aids in filtering and stops switching-related harmonics from affecting the power input. Large energy storage components, like DC-link capacitors, are not necessary for MC [13] [14]. It can reduce its size and weight significantly as a result. The variable speed wind turbine interfaced to the grid through the MC and coupled to the PMSG is shown in Fig.1.1.

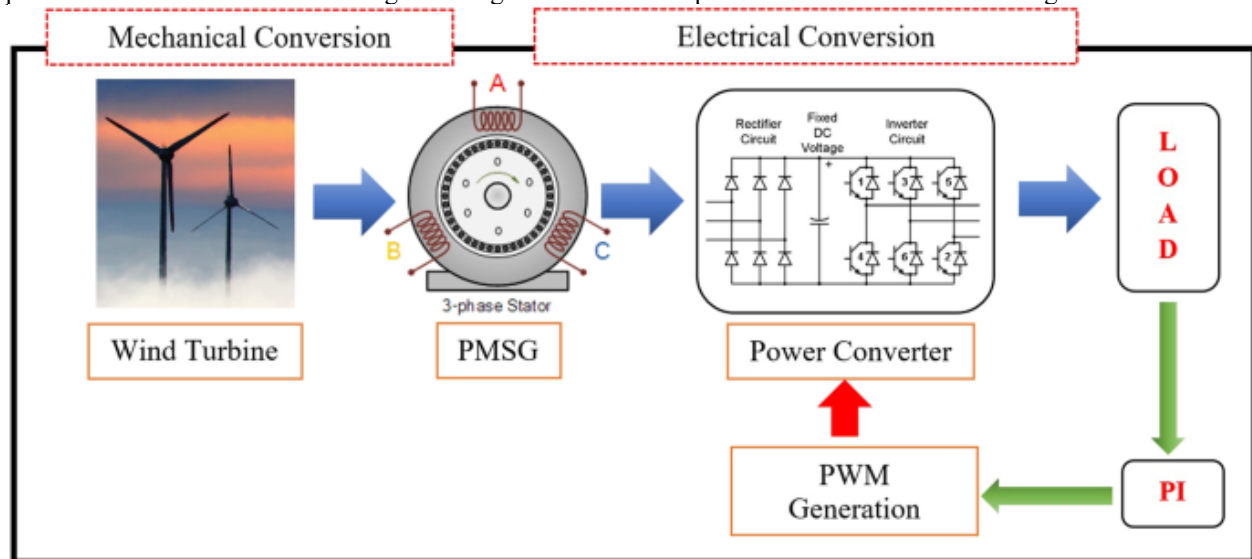


Fig. 1.1 Schematic of Wind Energy Conversion System Using Matrix Converter

## 2. MATRIX CONVERTER

A one-stage converter called the Matrix Converter is made up of 9 bi-directional switches that are designed to connect each input phase to its appropriate output phase. The switches are manipulated in a way to regulate the output voltage's magnitude, phase angle, and frequency. A matrix converter's improved input, output voltage and current waveforms enable bidirectional power flow.

### 2.1 MC Classification

AC to AC converters are normally categorized as:

#### 2.1.1 Indirect Converter

The indirect matrix converters do the conversion in two stages, namely, rectification and inversion stages. The rectifier stage provides a fictitious DC link voltage with a variable average. The inverter stage synthesizes three-phase output voltages. The switching pattern can be constructed using different methods such as space vector, and saw-tooth wave modulations. Fig. 2.1 illustrates the DC link that connects two AC systems. A wind turbine generator may serve as the source, and grid demand or client load may serve as the load.

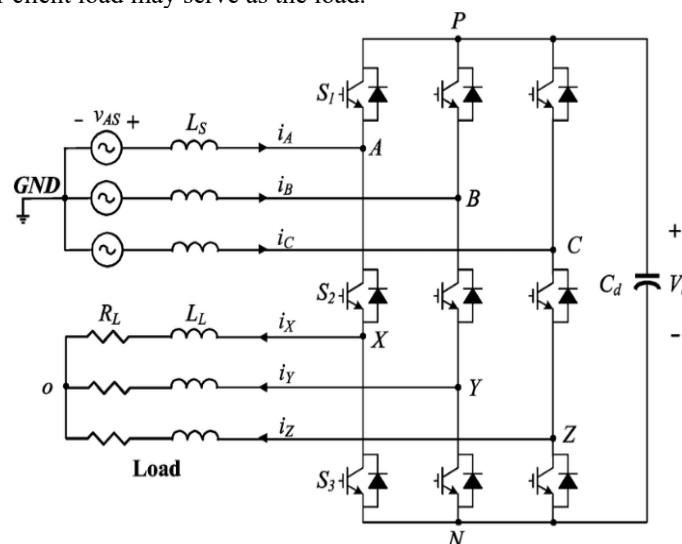


Fig. 2.1 AC-AC Converter with DC link

### 2.1.2 Direct Converter

The Direct Matrix Converter is a single-stage topology composed by a set of  $m \times n$  bidirectional power switches to connect a  $m$ -phase voltage source to a  $n$ -phase load. The  $3\Phi-3\Phi$  MC is the preeminent topology as it connects a three-phase voltage source (e.g., electric grid) with a three-phase load (e.g., motor) as shown in Figure 3.

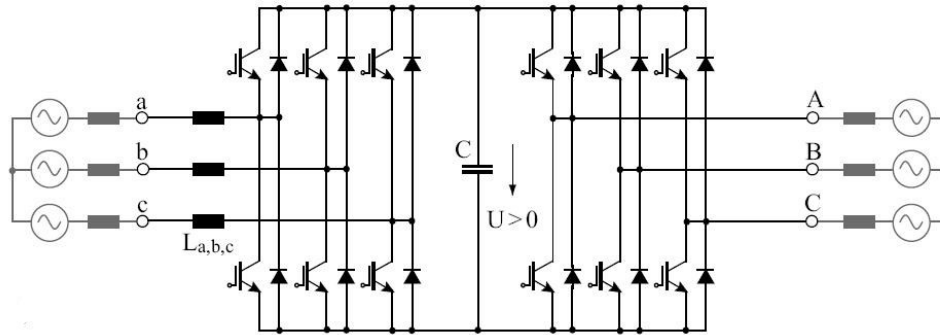


Fig. 2.2 Direct AC-AC Conversion

### 2.2 MC Modulation Techniques

Various modulation techniques are available for the MC which is discussed below:

- One of the important techniques that employ a direct transfer function approach is the Venturini modulation method. The result of the converter transfer matrix utilized to produce the output voltage and the input voltage [16].
- This modulation technique aids in producing sinusoidal output voltages with variable frequency and variable amplitude from constant frequency and constant amplitude input voltages.
- Due to the input voltage waveforms and the converter's operating principle, it is significant to highlight that the voltage gain of the matrix converter employing this method cannot exceed 0.5 [14,17].
- The voltage ratio is increased by reallocating the converter's null output states, which is comparable to the method used in traditional DC-link PWM converters and connects all of the output lines to the same input line.
- In order to fit the reference output voltage within the input voltage system envelope, injection of the third harmonic of the input and output voltages was recommended in [18] [19]; the voltage transfer ratio should approach the maximum value of 0.86.
- The instantaneous voltage ratio of the input phase voltages is used to generate the converters ON and OFF states for the switches. The scalar method is another name for this.
- The input voltage, output voltage, and output current are represented by an instantaneous space vector in the space vector modulation (SVM) approach. Indirect space vector modulation, or ISVM, is a technique that offers 27 potential switching configurations for a three-phase matrix converter [21] [22] [23].
- The primary concept underlying indirect modulation is to think of the matrix converter as a two-stage transformation converter with an inversion stage that generates three output voltages and a rectification stage that maintains a constant virtual DC-link voltage during the switching period.
- Sinusoidal PWM is a straightforward and often applied pulse width modulation (PWM) technique. This method compares a sinusoidal reference waveform to a high frequency triangular carrier wave. This technique, which is also known as indirect modulation, lowers switching losses. Due to its simplicity, the fundamental modulation strategy is utilized in this paper. Direct modulation is another name for the fundamental modulation scheme.

## 3. SIMULATION MODEL AND RESULTS

Fig. 3.1 depicts simulink model of grid connected WECS with PMSG and a matrix converter. The simulation has been performed using ideal switches. Use of the MATLAB/Simulink environment was used to model the entire system. The simulation model's rated power is 8.5 kW, which can be applied to wind turbines of a lesser size. However, the matrix converter-based system can also be used in massive power systems. The MC's switching frequency is set to 6 kHz, and the model is discretized at a tiny time step of 2 s. This model is capable of tracking the dynamics and harmonics of the control system over a brief period of time. A variable speed wind turbine, a PMSG, and an MC with a line filter connected to the grid make up the system. The MC will manage the PMSG's output power and deliver a steady output

power to the grid. The LC filter is used to reduce harmonics caused by the MC switching.

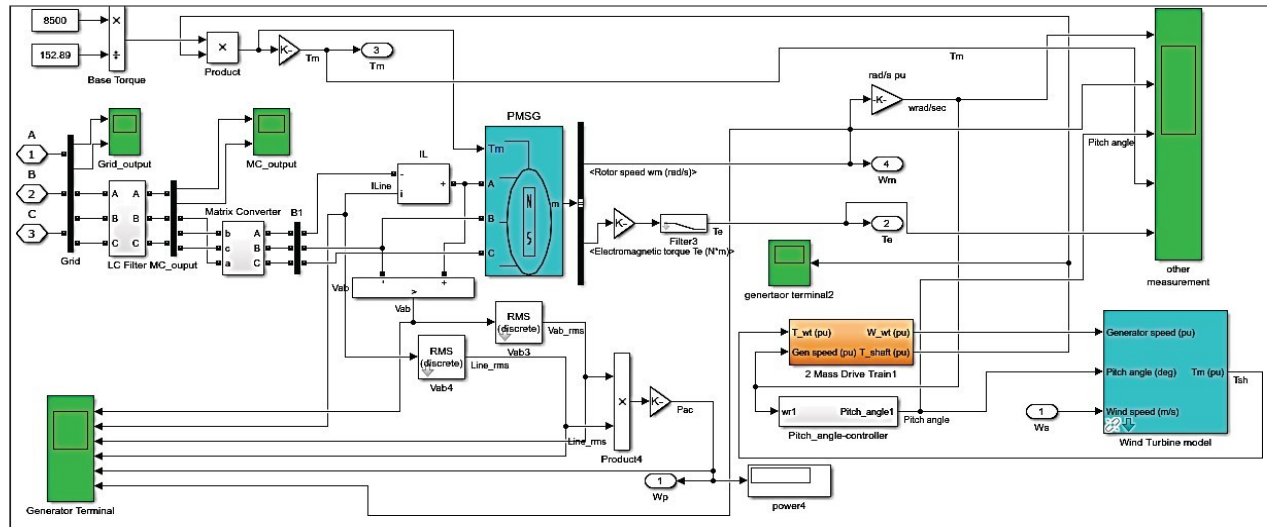


Fig. 3.1 Simulink model of Grid Connected WECS with PMSG and a Matrix Converter

#### 4. SIMULATION RESULT

The system is subjected to a step change in wind velocity in order to assess the WECS simulation model at various wind speeds. Models predict that the wind turbine will run at speeds as low as 3 m/s and as high as 12 m/s. The model has a cut-off speed of 18 m/s. The system starts out with a 3 m/s wind speed. At  $t = 0.7s$ , the wind speed increases to 6 m/s, and at  $t = 1.4s$ , it increases again to 12 m/s. In Figure 7, this is displayed. The dynamic response of the MC-based WECS, the MC output voltage, and the corresponding current waveforms are shown in Figure 7. Fig. 7 shows that the transients in the WECS are clearly within bounds, validating the simulation model's performance for a changeable wind speed.

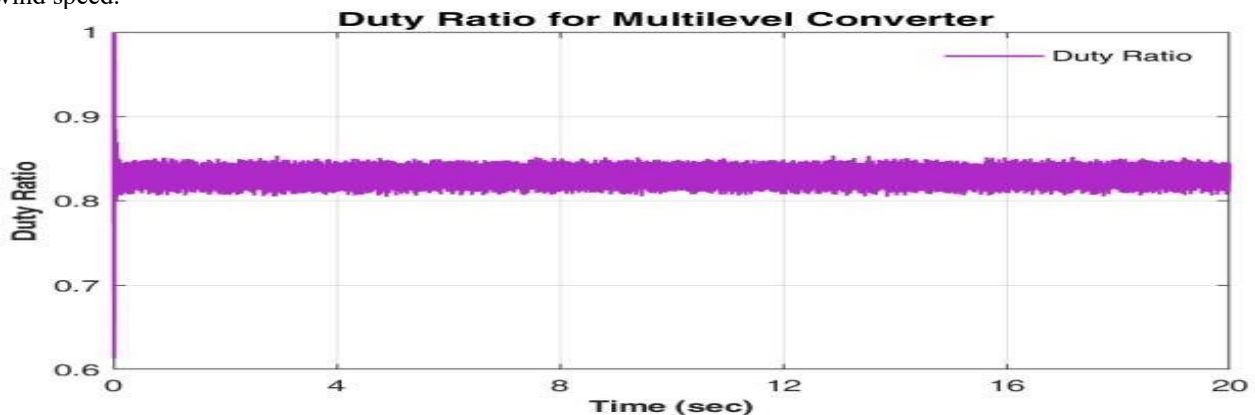


Fig. 4.1 Simulation Waveform of MMC Duty Ratio

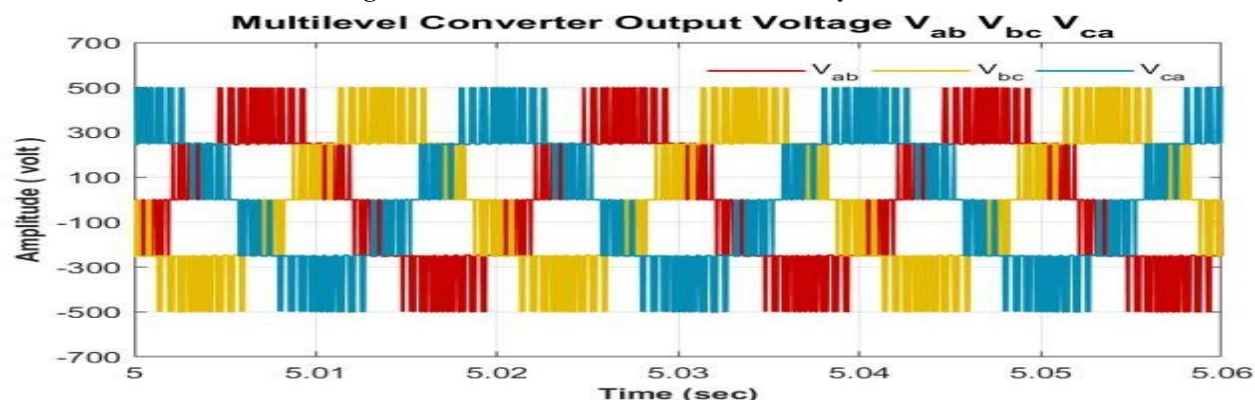


Fig. 4.2 Simulation Waveform of MMC Output Voltage

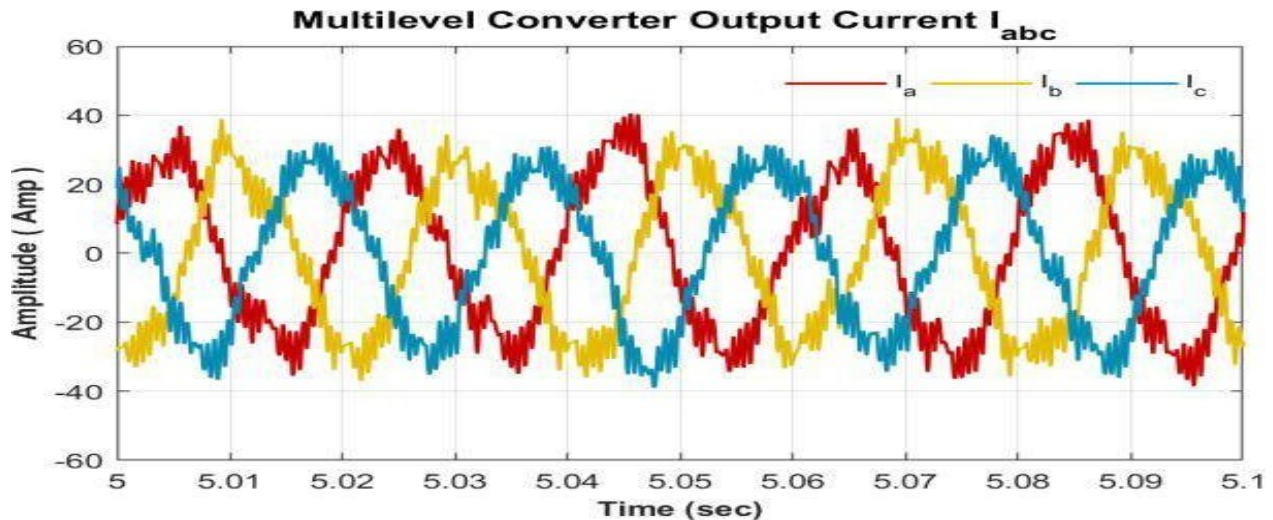


Fig. 4.3 Simulation waveform of MMC Output Voltage

## CONCLUSION

In this study, a WECS with an MC interface and a PMSG foundation for grid integration is given. The MATLAB/Simulink modelling environment is used to model the system. Without using DC link components, the MC offers a regulated output voltage for fluctuating wind speed. For the wind turbine to produce its maximum power at all wind speeds, MC regulates the synchronous generator's terminal voltage and frequency. Results from simulations of dynamic wind speeds show that the MC can function effectively during transients, proving its effectiveness and suitability for a grid connected.

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