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MPPT Based Grid Connected WECS Using DC-DC Converter

Poojn Sen
NRI Institute of Information Science and Technology Bhopal, India poojasen.93@gmail.com
Shashank Shukla
Assistant Professor NIIST Bhopal, MP, India, ssshashankshukla84@gmail.com
Amar Shukla
Government Polytechnic Talbehat Lalitpur, UP, India amarshukla95@gmail.com

Abstract— *This research deals with grid connected WECS. Now renewable energy sources have become a popular alternative electrical energy source where power generation in conventional ways is not practical. Wind is the fastest growing renewable energy resources due to their free availability and environmental benefits. The common disadvantages of wind power plants are as it generates unreliable power. In order to overcome this problem, this paper proposes MPPT technique (IC) and new topology of MLI which reduces more THD content from output waveform than conventional one. Simulation of Wind plant is done by the use of MATLAB 2016a. Boost converter is used to boost up the output voltage of Wind plant and the controlling of switch of boost converter is done by the use of MPPT technique (IC). The THD content present in the voltage and current at the AC side of inverter is reduces using five levels inverter. Enhancement of power quality is the main aim of this work.*

Keywords—PMSG, GSC, MLI, MPPT.

I. INTRODUCTION

Generally, electric power sector has three sectors which are: generation, transmission and distribution. In generation sector, different kind of energies is converted into electrical energy. Transmission activity is dedicated for transporting electrical energy from sending end to end centers. In distribution activity energy is transferred from utility grid to consumers. This paper concludes generation sector with transmission in which wind energy conversion system is connected with main power transmission system which are supplied by conventional power station. Wind energy is a large renewable energy source. Global wind power potential is of the order of 11,000 GW [1]. It is about 5 times the global installed power generation capacity. This excludes offshore potential as it is yet to be properly estimated. About 25,000 MW is the global installed wind power capacity. It is about 1% of global installed power generation capacity [3]. Wind produces about 50 billion kWh per year globally with the average utilization factor of 2000 hours per year. The Wind Turbine Generator is designed for optimal operation at a wind speed of 10-14 m/s. The Turbine Generator starts at a cut-in speed of 3-3.5 m/sand generate power at speeds 4.5 m/s and above. In India, the best wind speed is available during monsoon from May to September and low wind speed during November to March. The annual national average wind speed considered is 5-6 m/s. Wherever average wind speed of 4.5 m/s. and above is available it is also an attractive option to supplement the energy supply. Wind turbines can be used to harness the energy available in airflows [2]. Current day turbines range from around 600 kW to 5 MW of rated power. Since the power output is a function of the cube of the wind speed, it increases rapidly with an increase in available wind velocity. Recent advancements have led to aero foil wind turbines, which are more efficient due to a better aerodynamic structure.

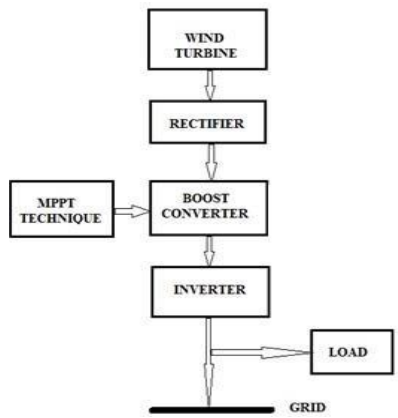

Figure 1: Flow chart of proposed model.

This system comprises of a wind turbine which transforms wind's kinetic energy into rotating motion, a gear box to match the turbine speed to generator speed, a generator which converts mechanical energy into electrical energy, a rectifier which converts ac voltage to dc, a controllable dc-dc converter to track the maximum power point and an inverter which converts dc voltage to ac [1]. The schematic diagram of the wind energy system is manifested in the figure below.

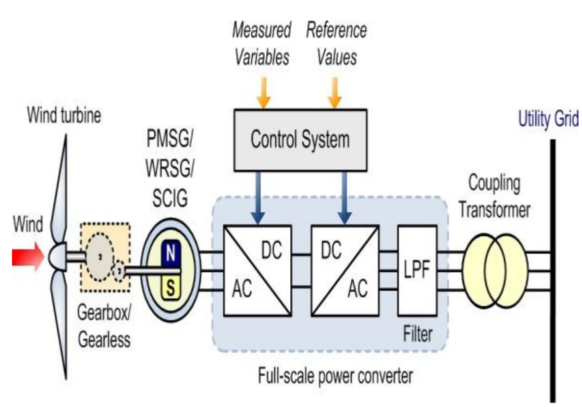

Figure 2: Schematic diagram of grid connected WECS.

The turbine should be developed with two blades or three blades which have the higher efficiency to collect more wind power [2]. Higher speed and more efficient turbines were necessary electricity generation with the help of wind power, wind turbine generator electricity by driving an electrical generator. By using the power of the wind, wind turbines produce electricity by drive an electrical generator. The Wind produces a driving force to the blades while passing over it which drive the generator. A shaft connected to blades and shaft will rotate when blades are rotating and gear box is connected to the shaft. The gearbox helps to adjust the rotational speed which is favorable or suitable for the generator at the speed where the appropriate output is obtained [1]. The obtained power from the wind generator is transferred to the transformer which steps up generated voltage. Wind energy can be defined as the kinetic energy of the air mass flowing per unit time.

$$P0 = \tfrac{1}{2}(\text{air mass per unit time}) * (\text{Wind Velocity})^2$$

$$P0 = \tfrac{1}{2}(\rho A V w) * (Vw)^2$$

Where,
ρ = air density (Kg/m3),
A =Swept area of the wind turbine
V_W =Wind Speed (m/s),
C_P= Coefficient of Power

MPPT of wind power: Wind power versus wind speed characteristics of wind power system is shown in fig below:

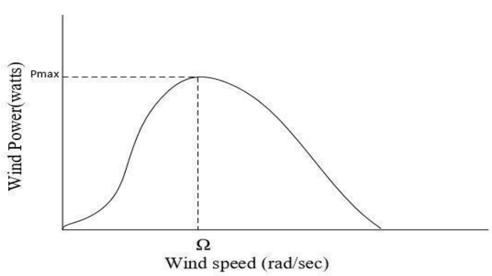

Figure 3: Power vs. speed characteristics of the wind turbine.

At maximum power point

$$\frac{dP}{d\Omega} = 0$$

From chain rule

$$\frac{dP}{d\Omega} = \frac{dP}{dD} * \frac{dD}{dVw} * \frac{dVw}{d\Omega e} * \frac{d\Omega e}{d\Omega}$$

Where, P = Wind power, Ω = Rotor Speed, Ω_e = Generator phase voltage angular speed, V_W = Rectifier output voltage, D = Duty cycle of converter.

II. CONVERTERS & CONTROLLING

AC-DC Converters (RECTIFIERS): In the previous years, according to particle physician point of view, the output of the ideal power converter should be the best direct current supplied to the load. The best direct current means that it should have very low ripple content in it and very high stability. So the main aim of the researchers has become to get the best direct current. They are doing it by increasing the number of pulses of a rectifier which reduces the dc ripple content from dc current. In previous years, the rectifier was uncontrolled because they were using a diode for making the DC to AC and diode is an uncontrolled device. The basic principle of the diode is that it works when the forward bias voltage is applied to it. It doesn't require any control signal to on or off. By the invention of the thyristor, a new area of research has made. The thyristor is a controlled device means it requires some signal to turn on and turn off. When thyristors are used instead of diode the rectifier is known as a controlled rectifier. Thyristors require commutation circuit also. In a diode bridge rectifier, pulses present in output waveform is equal to the twice of a number of phases, i.e., p=2m, where p is the number of pulses and m is a number of phases. Diodes are always rated by their peak inverse voltage (PIV). The equivalent circuit diagram of the three-phase six-pulse diode rectifier is shown. The average DC output voltage of this circuit is given by the following:

$$V_{DC} = 3\left(\frac{3\sqrt{2}}{\pi}\right) * VL * \cos\alpha$$

Where, VL= line-to-line voltage on three-phase AC side of the rectifier, **α**= angle of firing delay in the switching.

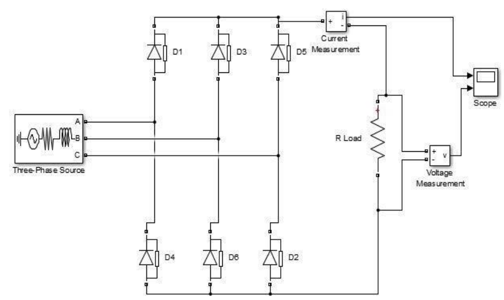

Figure 4: Diagram of three-phase six pulse rectifier.

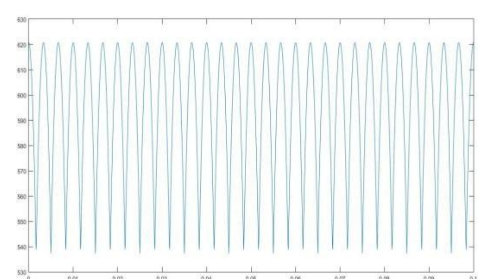

Figure 5: Output voltage of three-phase six pulse rectifier.

INVERTER (MLI):

MLI have attracted many utilities and power industries because of their use and advantages. It is well suited for reactive power compensation. It can work with high voltage and high power application with the use of IGBTs. It produces voltage waveform in shape of staircase.

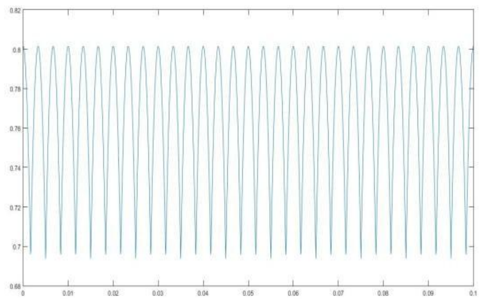

Figure 6: Output current of three-phase six pulse rectifier.

The level of voltage is dependent on the number of DC voltage sources are used. Harmonic content present in the voltage waveform decreases with the increase in DC voltage sources [12]. The upcoming topologies of MLI must have these things which are given below:

a) Less switching devices as much as possible.
b) Lower switching frequency.
c) Capable of withstanding with very high power and voltage application.

Types of MLI

1) Diode-clamped MLI (DCMLI)
2) Flying-capacitor MLI (FCMLI)
3) Cascade MLI (CMLI)

DC-DC Converter: The dc-dc converter is an electrical circuit whose main application is to transform a dc voltage from one level to another level. It is similar to a transformer in AC source, it can able to step the voltage level up or down. The variable dc voltage level can be regulated by controlling the duty ratio (on-off time of a switch) of the converter. [12] There are various types of dc-dc converters that can be used to transform the level of the voltage as per the supply availability and load requirement. Some of them are discussed below.

1. Buck converter
2. Boost converter
3. Buck-Boost converter.

Boost converter- The functionality of boost converter is to increase the voltage level. The circuit configuration of the boost converter is manifested in figure (7). The current carried by the inductor starts rising and it stores energy during ON time of the switching element. The circuit is said to be in charging state. During OFF condition, the reserve energy of the inductor starts dissipating into the load along with the supply. The output voltage level exceeds that of the input voltage and is dependent on the inductor time constant. The load side voltage is the ratio of source side voltage and the duty ratio of the switching device. [12]

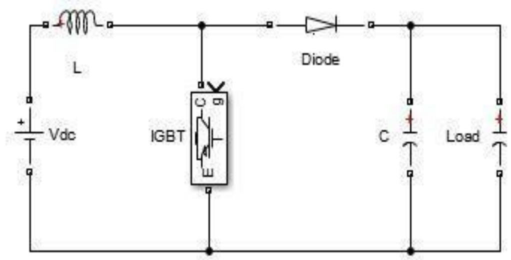

Figure 7: Circuit diagram of boost converter.

Maximum Power Point Tracking (MPPT): Maximum Power Point Tracking frequently referred to as MPPT, is an electronic system that operates the Wind turbine in a manner that allows the turbine to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves". MPPT is a fully electronic system that varies the electrical operating point. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different [10]. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the venin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem.

The equation has defined the efficiency of the algorithms, where Pact is the product of current and voltage at the output of the wind turbine when the simulation is carried out under desired operating conditions. The power obtain is maximum obtained from wind turbine theoretically which is Pmax.

$$\eta = (P_{act}/\ P_{max})*100$$

Different MPPT techniques- There are different techniques used to track the maximum power point. Few of the most popular techniques are: [10]

I. Perturb and Observe (hill climbing method)
II. Incremental Conductance method
III. Fractional short circuit current
IV. Fractional open circuit voltage
V. Neural networks
VI. Fuzzy logic

Incremental conductance- Incremental conductance method uses two voltage and current sensors to sense the output voltage and current. The P&O method has limitation to track the peak power under fast varying wind speed condition. This problem is overcome by Incremental Conductance (IC) technique. The IC method stops perturbation at the operating point when MPPT has reached the Maximum Power Point. Perturbation can be calculated using dI/dV and –I/V when above condition is not fulfilled. This relationship comes from the fact that, when MPPT will be right to the MPP then dP/dV will be negative conversely it will be positive when MPPT will be left to the MPP. The IC technique has benefits over P&O because it has disadvantaged that, it oscillates across MPP. Also, the variation in wind speed can be tracked quickly by IC with higher accuracy than P&O but it increases the complexity as compare to P&O.

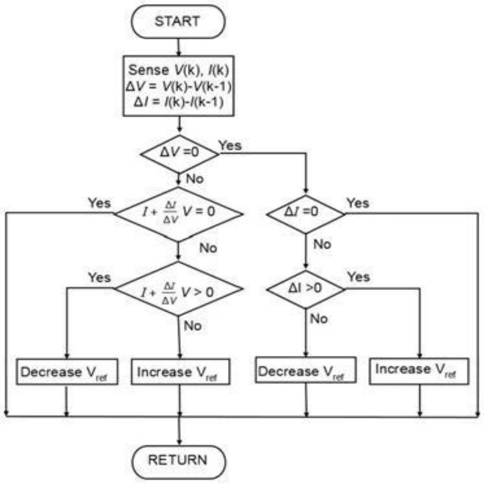

Figure 8: Flow Chart of Incremental Conductance.

III. SIMULATION & RESULTS

Complete simulation model of wind turbine system: The wind system has been interfaced with the rectifier, boost converter, MPPT controller and DC-AC inverter as shown in figure (9).

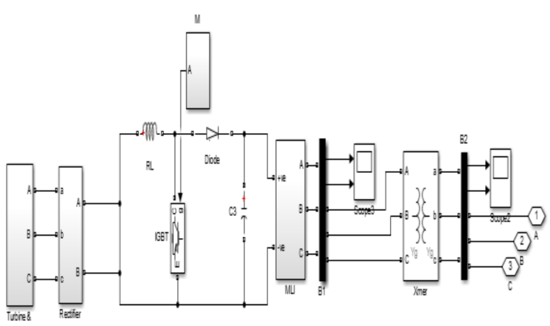

Figure 9: Simulation model of Wind turbine.

Output of the wind system-

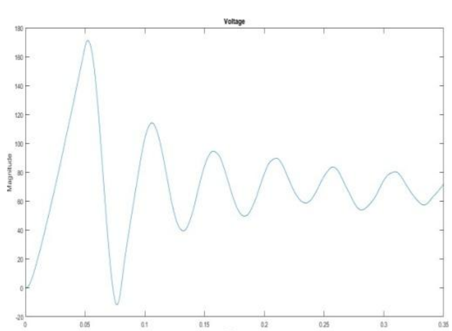

Figure 10: Input voltage of boost converter.

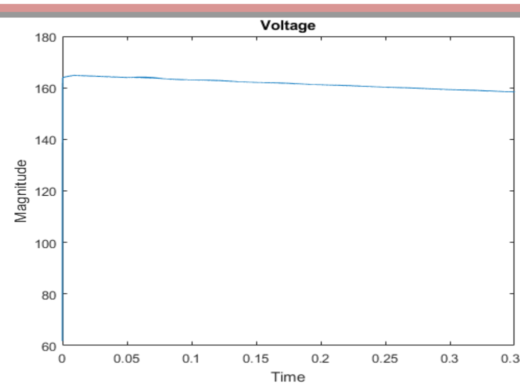

Figure 11: Output voltage of boost converter.

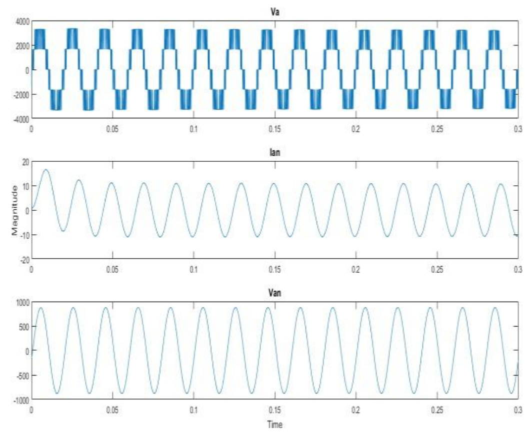

Figure 12: Output voltage and current of inverter.

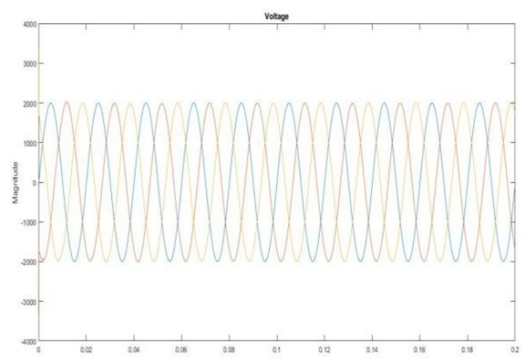

Figure 13: Output voltage of wind system.

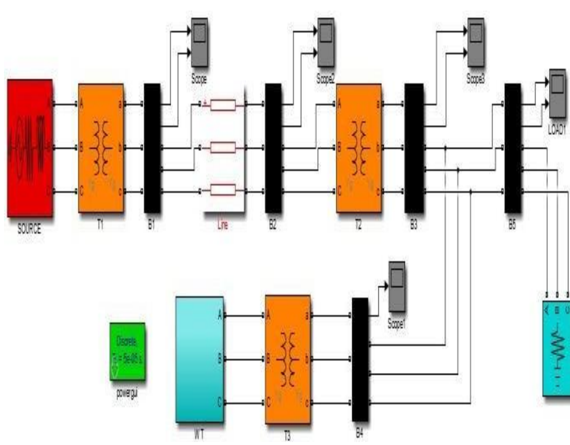

Figure 14: Simulation model of WECS with the micro grid.

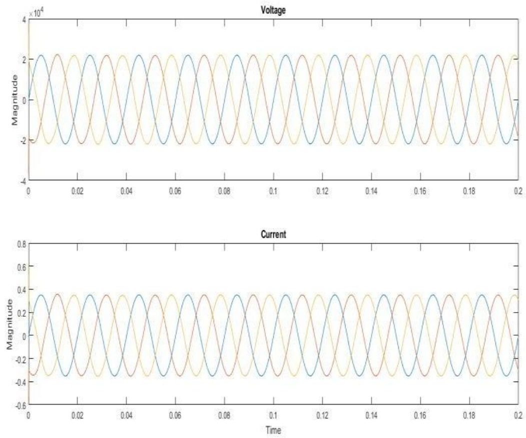

Figure 15: Output voltage & current WECS grid connected at load.

IV. CONCLUSION

Wind Farm: In this thesis work, Electric power has been generated from the wind by wind turbo-generator set. The produced voltage is given to the rectifier where rectifier converts it into smooth DC voltage by using a bridge rectifier. This work proposed a reduction of THD at load side.

Topology	THD in voltage	THD in current
5-levels	29.35	28.21
Improved 5-levels	0.11	5.98

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