International Journal of Multidisciplinary Engineering in Current Research
Volume 6, Issue 2, February 2021, http://ijmec.com/

# DESIGN AND ANALYSIS OF A WIND POWER ENERGY CONVERSION SYSTEMS WITH TWO-PHASE PM MACHINE AND A RECTIFIER WITH REDUCED NUMBER OF CONTROLLED SWITCHES

**Kuldeep K Soni1, Vishal Prajapati**

PG Scholar, 1 Lecturer, Department of Kaumarabhritya, Major SD Singh Alex Hankey1, TM Srinivasan2
*Assistant Professor, 1, 2 Professor, Swami Vivekananda Yoga Anusandhana Samsthana, Eknath Bhavan, 19 Gavipuram Circle, K. G. Nagar, Bengaluru 560 019, Karnataka, India.

**Abstract—** Switching losses and power efficiency are both improved by using multilevel inverters that decrease voltage distortions during switching operations. When it comes to power efficiency, reduced switching harmonics, and a smaller filter inductor than traditional half-bridge and full-bridge inverters, the multilayer inverter is the clear winner. A rectifier with a modest number of controlled switches is connected to a two-phase permanent magnet (PM) synchronous machine in this project. It is possible to utilise them in grid-connected applications, stand-alone applications, or to feed a microgrid.

While certain three-phase generating systems with fewer controlled switches may provide sinusoidally regulated machine currents, the suggested topologies can also lower the dc-link voltage and provide low harmonic distortion for dq currents, making them more efficient. It has a single controlled switch, is easy to construct and manage, and has minimal harmonic distortion and a good power factor throughout the whole system. Extensive MATLAB/Simulink simulation studies are used to assess the power generating system's performance.

Pulsewidth modulated power converters and synchronous generators are included in the index terms for AC machines, power conversion, and power electronics.

## I.INTRODUCTION

Power electronics subsystems coupled with variable speed systems may provide utility-grade AC in the long future for large-scale use of wind energy. Advanced wind energy converters utilising power electronics interface, variable-speed direct-coupled modular PM generators are examined in this thesis as a reaction to the growth of the wind power sector. To be effective, a direct-drive wind generator needs a high number of poles. There is a modular, permanent magnet, synchronous generator that can fit in a wind turbine.

a three-phase, 50 Hz, ac turbine nacelle with standard dimensions and a direct grid connection.

It is not necessary for synchronous or induction generators to provide field current or reactive power correction while using permanent magnet excitation.

The direct-drive modular PM generator has a number of beneficial characteristics for a variable-speed generator that may be built.

variable-speed operating also eliminates the requirement for expensive and difficult-to-implement synchronisation equipment and dampening. Therefore, a direct-coupled, modular PM generator with variable-speed operation should be an appealing equipment for the wind energy sector to consider. The new variable-speed generator will need a high-quality, efficient power electronic interface.

To maximise the amount of wind energy that may be extracted and to decrease total harmonic distortion (THD) of converter output current, a boost rectifier is used in the given design. However, when the wind speed is strong, the dc-link voltage should be restricted to a particular level in order to decrease the stress on power components in the inverter. There are two types of rectifiers often used in WECS generators: three-phase diode and three-phase pulse width modulation (PWM). Using a three-phase PWM rectifier increases system costs and losses due to its usage of six switch-controlled switches, making it an unattractive architecture for low-power wind applications due to the severe harmonic distortion it causes in machine currents.

The use of a grid-connected, two-phase PM synchronous generator is explored in a WECS. To maximise the amount of wind energy that may be extracted and to decrease total harmonic distortion (THD) of converter output current, a boost rectifier is used in the given design. However, when the wind speed is strong, the dc-link voltage should be regulated to minimise the stress on the inverter's power electronics. The generator and the output are combined into a single unit for convenience.

If you have a single-phase grid and a single-phase inverter, you may utilise a 3-phase grid and a three-phase inverter as well. According to these designs, the three-phase semi-controlled rectifier has a number of disadvantages.

**Machine currents regulated by sine waves;**

• Lessening of the DC-link voltage

dq machine currents with reduced low-frequency distortion.

For WECSs, we need power converters

There have been power electronics devices used in WECSs since the 1980s, when a SCIG system linked directly to the grid was fitted with a thyristor-based soft-starter. It was decided to employ a thyristor soft-starter to reduce the first current spike. Variable-speed operation was made feasible in the 1990s by the introduction of the rotor resistance control technique. Progress in wind turbine energy capture efficiency has been made even if the maximum speed of the generator is restricted to 10% over the synchronous speed. The converter-controlled variable resistance has increased this efficiency. Figure 1 shows a DFIG system with back-to-back converters operating at reduced power (30% of the rated power is processed by the power converters) while Figure 2 shows a PMSG/SCIG/WRSG system with full power (the generator's rated output is processed by the power converters). Back-to-back converters are now widely used in

# International Journal of Multidisciplinary Engineering in Current Research

**Volume 6, Issue 2, February 2021, http://ijmec.com/**

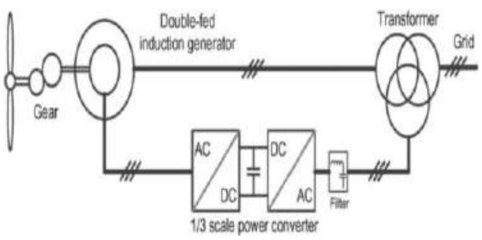




**Figure 1. DFIG with partial-scale power converters [8]**

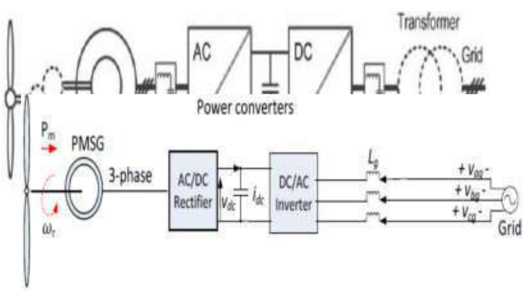



**Figure 2. Wind turbine generators with full-scale power converters.**

With the use of back-to-back power converters that divorce a wind turbine from the grid, it is possible to manage its speed, control its power output, as well as increase its quality. They've been extensively used in the wind power business, and their dependability has been well established. For wind energy generating systems, multilevel converters have been explored and commercialised in recent years as a result of developments in semiconductor devices and digital control technology. The two-level back-to-back voltage source converters are the most extensively used power converters for the best-selling range of 1.5-3.0 MW WECSs (VSCs). Three system variables must be strictly controlled in wind turbine PMSG systems: (1) the optimal power generated by the PMSG at various wind speed levels; (2) the active and reactive power injected into the grid; and (3) the DC bus voltage of the back to back converter........................................................

Direct drive wind turbine PMSG is shown in Figure 3 with a back-to-back converter feeding it. To implement MPPT control, the generator-side converter in this system adjusts the speed of the PMSG. During this time, the grid-connected converter manages the injected active and reactive electricity.

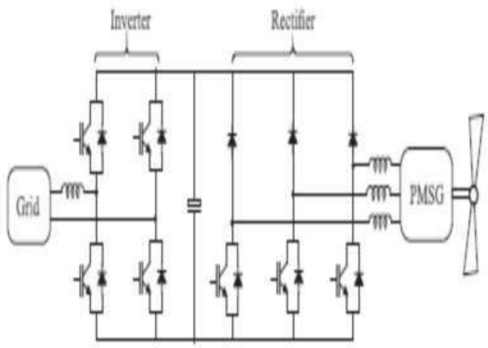
**Figure 3. Direct-drive PMSG system**

This chapter will examine the generator-side converter's control mechanisms. In this chapter, we'll look at how to achieve maximum power point tracking (MPPT) using an appropriate tip speed ratio. Direct torque control (DTC) and field-oriented control (FOC), two significant PMSG control methods, are examined and contrasted. Then, the results of the generator-side converter control simulations are shown to demonstrate the concepts of control algorithms in practise.

**Part II: Modeling of the system**

The cost and efficiency of a converter may be solved by reducing the number of controlled switches, as fewer switches form a cheaper system and it is still possible to produce low-current harmonic distortion and lower semiconductor diode current..

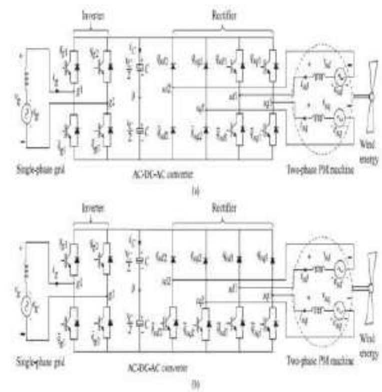
loses. Different topologies, such as the three-phase diode rectifier linked to a boost converter, have been employed in tiny WECS in this context. Since each phase contains three semiconductor devices, this arrangement has a poor efficiency in terms of power losses. Fig. 4 shows a three-phase semi-controlled rectifier with excellent




**efficiency and cheap cost as an alternative to this design.**

**Semi-controlled three-phase rectifier for WECS in Fig. 4.**

A hysteresis current control, although being a robust technique with excellent dynamic, causes the topology to function at varied switching frequencies. In addition, since this topology only permits sinusoidal current in the positive half-cycle, the low-order current harmonic distortion is increased.. "Conventional" or "three-phase semicontrolled rectifier" will be used in this project to describe this design. Figure 5 depicts the topology of a two-phase PM generator and a single-phase grid used in this project's energy conversion systems. Semicontroller rectifiers, as shown in Fig. 5(a), are used in Configuration 1 to control one leg while the other is uncontrolled. IGBTs and diodes are used in Configuration 2 [see Fig. 5(b)], but all legs are formed of an IGBT and a diode (lower semiconductor device).



A two-phase semi-controlled rectifier is used in these low-power WECSs. (a) The first configuration. c) Configuration 2.

Single-phase grid and single-phase inverter are utilised for simplicity, however a three-phase grid and three-phase inverter might be used as well. According to hypothesised topologies, compared to a 3-phase semi-controlled rectifier,

Controlled sinusoidal machine currents

Reduced voltage across the dc-link

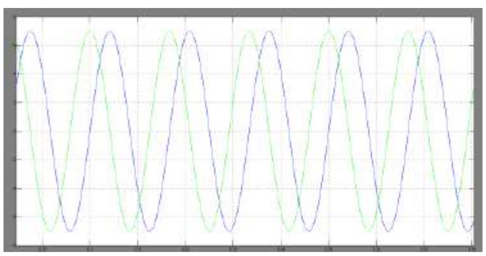
dq machine currents with reduced low-frequency distortion.

This section focuses on the machine side of the converter concept. Configuration 1 has a two-phase machine and a four-leg rectifier as system components. The rectifier has four legs, two of which are regulated and the other two of which are not. As shown in Fig. 5, the machine is linked to the converter using an open-end winding (OEW) arrangement, with one terminal of each phase being attached to a controlled leg and the other terminal being connected to a noncontrolled leg (a). Fig. 5 shows the rectifier's legs made up of diodes and IGBTs in configuration 2. (b).

One of the configurations

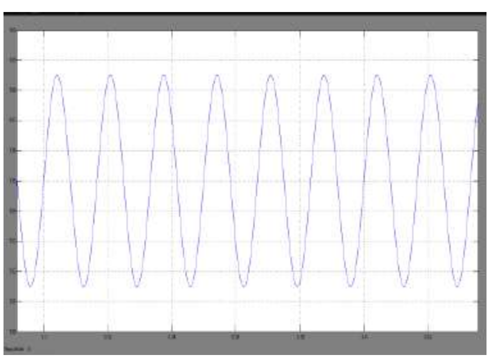
International Journal of Multidisciplinary Engineering in Current Research
Volume 6, Issue 2, February 2021, http://ijmec.com/

A closed switch is represented by a value of qsj1, while an open switch is represented by a value of qsj1. This is shown in Figure 5(a) by the power switches of the controlled legs. Upper and lower switch states are symmetrical for each leg. Both designs operate in different ways because of the existence of diodes, which affects the direction of the machine phase currents (isj).



**INFRASTRUCTURE 2 (B)**

Figure 5(b) shows the working mode of configuration 2, which is similar to configuration 1 in that it relies on the direction of isj. The states of the qsj1 and the value of vC determine voltage vsj10 when isj is positive, while voltage



vsj10 only has a relationship to the value of vC when isj is negative. To counter this, the states of the two quantum jumpers, qsj2 and C, dictate the voltage vsj20 when isj is positive whereas the voltage vC is related when this parameter is negative. By comparing the variable references with triangle carriers in the PWM approach, the pulse pattern of the rectifiers in Fig. 5 may be determined.

**Simulated results from Method-1:**

The WECS with a 3-PHASE SEMICONTROLLED RECTIFIER is the first example.Fig:6. Current waveforms of the three-phase semi controlled rectifier.

It was observed that the three-phase semicontrolled rectifier introduced a high harmonic distortion in the currents of three-phase machine, generating a current waveform that was sinusoidal during the positive half-cycle only, as shown in Fig. 6. These nonsinusoidal currents originate several undesirable effects to the generator, presented such as increased losses and reduced machine torque, reducing generator efficiency as well. On the other hand, the rectifier of the proposed topologies ensured that the two-phase machine had completely sinusoidal phase currents, i.e., producing significantly less harmonics in the generator than the three-phase semicontrolled rectifier, allowing the machine to operate with high efficiency.

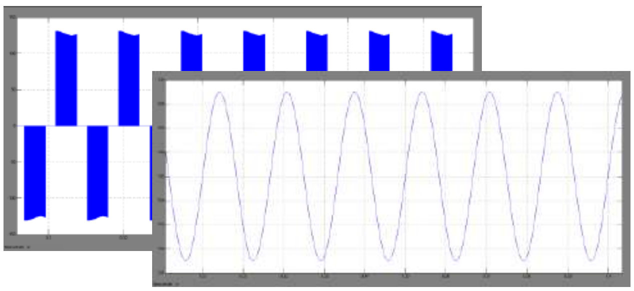
**CASE-2: CONFIGURATION 1**

**Fig:7(a) Currents isj (simulated and reference curves).**

The above figure 7 shows the machine currents of a simulated and references waveforms. In this waveforms switching losses increased due to the presence of one extra controlled switch.

**Fig:7(b) Voltage VC controlled in 132 V.**

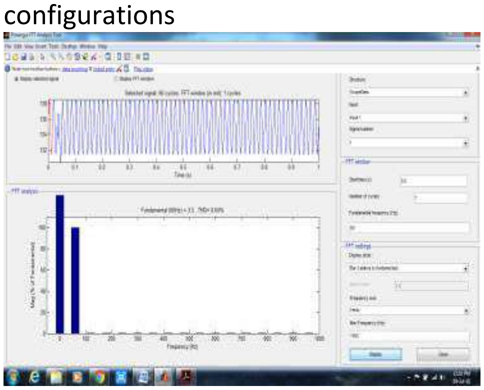
**In Figure 7(c), we can see the voltage vs time**



**graph.**

**Figure 7 shows the simulation results for Configuration 1.**

Figure 7 depicts the waveforms of the estimated and reference currents isj, voltage vC, and voltage vsd at the machine terminals for configuration 1 in the windings, and voltage vC and voltage vsd. There was a minor difference in total losses between the suggested topologies and traditional topologies in example 1. There was an increase in conduction losses in configurations 1 and 2 compared to a three-phase semicontrolled rectifier because configurations 1 and 2 had one additional leg transmitting a current of equal size to that in configurations



3 and 4.

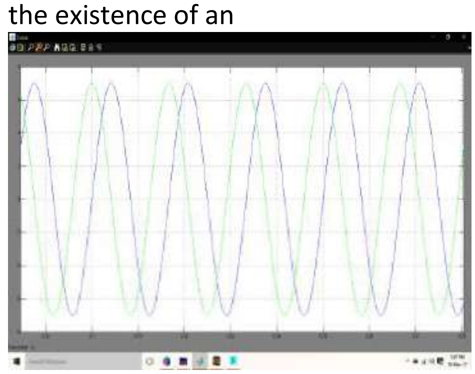
**A machine current's THD is shown in Figure 8.**

Machine currents simulated and reference waveforms have a THD value of 0.04 percent.

Configuration 2 in this case is the third case.

Fig. 9(a) Currents in the isj circuit (simulated and reference curves).

Using a simulated and reference waveform, the machine currents are shown in Figure 9. Due to the existence of an



additional controlled switch in this waveform, switching losses increased.

Fig:9(b) Voltage vC controlled in 132 V.

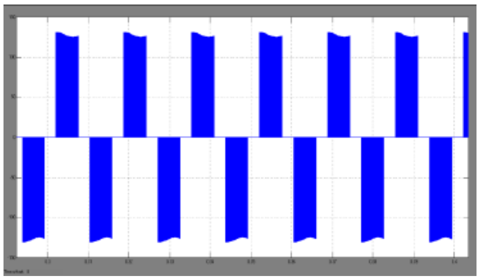
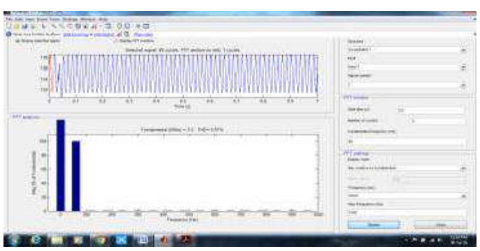


Figure 9(c) shows the voltage as a function of time.

Figure 9 shows the results of the simulation using Configuration 2 as the input.

Figure 9 shows the same curves for arrangement 2. Because of this, sinusoidal phase currents with decreased zero-



crossing distortion and regulated dc link voltage have been constructed for the suggested systems. The power factor was corrected by syncing the phase current with the phase voltage in order to improve efficiency.

Fig:10. THD values of a machine currents.

Machine currents simulated and referenced waveforms have a THD of 0.01 percent.

**II. CONCLUSION**

A two-phase machine was used in this study to demonstrate two low-power WECS conversion technologies. In order to decrease the weight, volume, and cost of the system, the converters are unidirectional and have a reduced number of controlled switches. When operating at half the switching frequency compared to three-phase semi-controlled rectifier, suggested topologies have had reduced losses in semiconductor devices. Although non-controlled semiconductor devices were used, the introduction of PWM and control techniques has resulted in reduced zero-crossing distortion and low harmonic content in machine currents and voltages.

**REFERENCES**


(1) A comparison of the dependability of the power electronics in grid-connected small wind turbine systems, in Proceedings of the Canadian Conference on Electrical and Computer Engineering (CCECE'09), May 2009, pp. 394–399.

[2] "Field weakening control of PM generator utilised for small wind turbine application," in Proc. IET Conf. Renew. Power Gener. (RPG'11), Sep. 2011, pp. 1–8. N. Milivojevic, N. Schofield, I. Stamenkovic, and Y. Gurkaynak,

Three researchers from Istanbul/Turkey examined the financial payback of tiny wind turbines for a smart home application in Proc. International Conference on Renewable Energy Research and Applications (ICRERA), published in October 2013, pp. 686–689.

Micro wind turbines in the built environment: a review, by D. Li, S. Wang, and P. Yuan, published in Proceedings of the 8th Asia-Pacific Conference on Electrical and Electronic Engineering (APPEEC), in March 2010, p. 1–4.

This is a good place to start (2007, Aug.). What You Need to Know About Small Wind Electric Systems.

International Journal of Multidisciplinary Engineering in Current Research
Volume 6, Issue 2, February 2021, http://ijmec.com/

IEEE Ind. Appl. Mag., vol. 10, no. 4, pp. 24–32, July 2004.

induction motors with a single or two phases," in Proceedings of the International Symposium on Power Electronics and Automated Motion (SPEEDAM), 2012, pp. 259–264.

Z. Guo and L. Chang, "New converter topologies for two-phase wind turbine PMSG generating system," in Proceedings of the 22nd Annu.
Power Electron Conf. (APEC'07), Feb. 2007, p. 536–539.
Two-phase converter utilised for wind turbine PMSG generating system, Z. Guo and L. Chang, Proceedings of the 2008 Canadian Conference on Electrical and Computer Engineering (CCECE'08), pp. 001255–001258,
(p4061–4068), in Proceedings of the IEEE Energy Convers. Conference and Expo (ECCE), September 2015, F A da C Bahia, C Jacobina, N Rocha, I da Silva and F Salvadori, "Low power energy generating systems for two-phase PM machine with decreased switch-count controlled switches." (p4061–4068).

"A novel high frequency grid interface system for PMSG-based wind turbine generators in low power applications" was presented at the 38th Annual Conference of IEEE Ind. Electron. Soc. (IECON'12) in October 2012.

An investigation of an open-winding PMSG system with the combination of a full-controllable and an uncontrollable converter was presented at the IEEE Energy Convers. Congr. Exposition (ECCE) in 2013.

[5] "Open-winding power conversion systems supplied by half-controlled converters," IEEE Trans. Power Electron., vol. 28, no. 5, May 2013, pp. 2427–2436, Y. Wang, D. Panda, T. Lipo, and D. Pan.