International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

Control System For PMSG Turbines Against Grid Disturbances

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Abstract:
One of the most common reports for disconnection of wind turbine units in wind farms when they occur in the face of external short circuits, these faults are felt by the wind turbine units as voltage dips and deactivate the units very quickly. This work provides the study of the operation of variable speed synchronous wind turbines connected to the grid and the problems that these control systems present in the face of disturbances, such as voltage dips. Computational tools were used to evaluate the behavior of the control system in the face of disturbances caused by voltage dips; Matlab software was used to study the events that generate the disconnection of the generation units, instead of mitigating the effects. It was determined that the control system confuses the voltage reduction with lack of wind and sends orders to maximize the wind resource, and then the momentary action of the braking units in the presence of a voltage dip is originated. It was concluded that the control system tolerates voltage dips depending on their depth and duration, the highest value being 50% of depth (voltage) and ranges less than 300 milliseconds of duration.
Key Words: *Wind turbines, wind turbine control, permanent magnet synchronous generators, converters, voltage dips.*

INTRODUCTION:

Currently, electricity generation based on wind energy is acquiring a prominent role. Generally speaking, wind turbines are known to convert wind energy into electrical energy, however, this overview does not allow for a comprehensive understanding of the challenges that arise from the interaction of the various technologies that make up such turbines. On the other hand, variable speed turbines with double-fed induction generators (DFIG) are the most common in high-power projects in developed countries [1]. In addition, there are synchronous generators with permanent magnets (PMSG), these generators are used in low-power wind farms, and are the object of study in this work. These technologies face new challenges and requirements in the electrical codes of many countries, all of them aimed at solving the problems produced in the connection of these turbines to the electrical power system [2].
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The wind turbine system, with low power connected to distribution networks, is composed of several subsystems, which have been the subject of studies and modeling, such as: The three-bladed turbine [3][4], The permanent magnet rotor generator (PMSG) [5], [6], The twelve-pulse uncontrolled rectifier converter [7], [8], The three-stage step-up chopper converter [9], [10], the two-stage inverter converter [11], [12], the LC passive filter [13], [14] and the control system [15], [16]. There are techniques to reduce the impact of the wind turbine, in the presence of failures that occur in the electrical power system, these techniques are based on installing external equipment to the wind turbines, such as: SVC, STATCOM and BESS [17], on the other hand, internal changes can also be incorporated in them [18], these changes can be grouped in the use of braking resistors [19], or making changes to the control of the wind turbine [20]. In this work, the control of the wind turbine converter is extensively described as one of the internal technologies applied against voltage dips. The central control integrates the DC/DC converter duty cycle control and the blade pitch angle control [21], [22]. In addition, the control of the DC/AC converter, which is responsible for transferring active power to the grid [23], will be addressed. The control of the wind turbine was analyzed and simulated considering changes in wind speed, changes in the reference power and the presence of voltage dips with different depths and duration times.

METHODOLOGY

There are several control systems in the wind turbine. Pitch control, DC/DC converter control, DC/AC converter control and central control. All these control systems are necessary to achieve the stability of the wind turbine. The Pitch control maintains the angle of inclination of the paddles where requested by the central control. The DC/DC converter control maintains the DC voltage at the DC/AC converter input. The DC/AC control is responsible for synchronisation with the system and allows the transfer of the active power that can be transferred to the grid, depending on the wind speed that exists at that time. The central control system is responsible for maximizing the acquisition of the wind resource.
Two control systems were developed to work independently, the DC/DC converter control and the pitch control. The DC/AC converter control system performs the synchronization and export of the electrical energy used from the wind resource, but this control is not directly dependent on the central control system. In the central control system are the DC/DC converter and pitch control controls. The control of the DC/DC converter has the mission of stabilizing the active power by controlling the DC voltage at its output, based on the rotation speed of the wind turbine. The Pitch control has two actions, the reduction of the speed and the maximization of the wind resource, in figure 1 the generic control scheme of a wind turbine is shown.

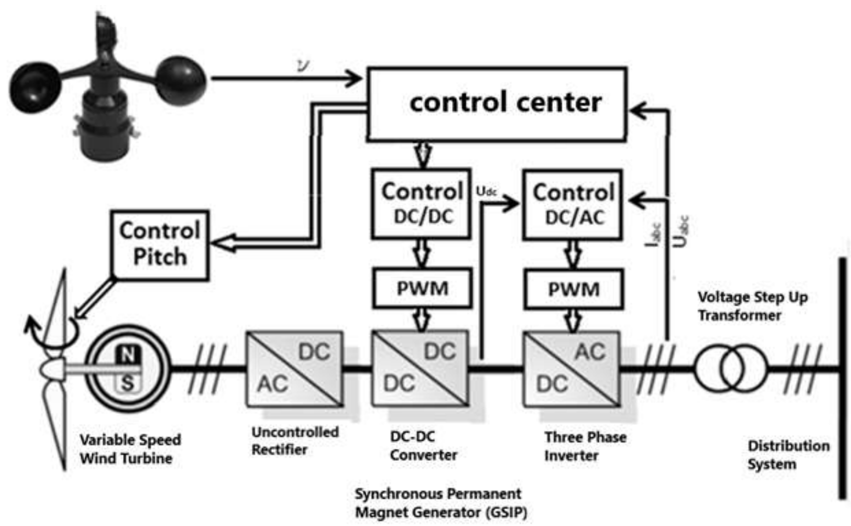

Figure 1. Existing control schemes in a generic wind farm

The central control acts on the control of the angle of the Pitch, in the same way it affects the PWM that controls the DC/DC converter, and this in turn, through the DC voltage, exerts control actions on the DC/AC converter.

The main control actions of the DC/AC converter, which is independent of the central control of the wind turbine, as shown in Figure 2, starts from the comparison of the DC voltage with a calculated nominal voltage value (VDC_nom). This control system prioritizes the export of active power, as well as reactive power. In turn, it depends on the tension control strategy desired.

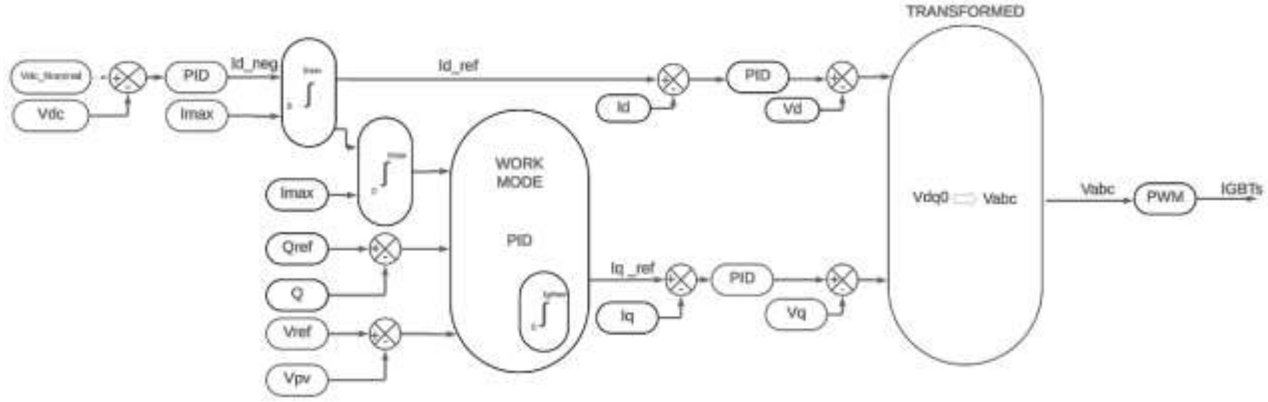

Figure 2. DC/AC Converter Control Diagram

The DC/AC converter control, where the VDC voltage value from the output of the DC/DC converter is inputted, is compared with the reference Vdc voltage, producing the error signal. It also uses the voltage (Vdq) and current (Idq) parameters, obtained from the Park transform of the three-phase voltages and currents of the network. With the control process, the Vabc voltages that enter the PWM are determined, which sends the orders to the IGBTs for the inverter to work, as indicated in Figure 2.

Figure 3 shows the simplified schematic of the DC/DC converter control system or chopper converter. This is the converter that keeps the DC voltage constant at the input of the DC/AC converter, but it is also responsible for establishing the necessary active power through the inductor current (IL).

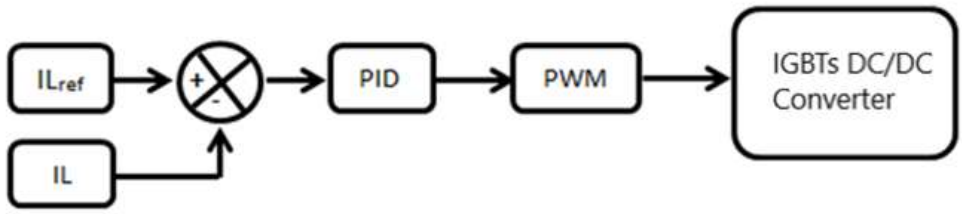

Figure 3. DC/DC Converter Control Subsystem

In DC/DC converter control, the inductor currents are directly related to the magnitude of the active power that is required to be transferred to the grid. After the control process, a resulting signal is obtained that enters the PWM, which will give the orders to the IGBTs for the converter to start working.

Figure 4 shows the simplified block diagram of the Pitch control. This is in charge of maintaining the Pitch according to the reference value established by the speed control scheme or the central control. It is known that the higher the pitch angle rises, the less kinetic energy of the wind is being captured and the lower the pitch angle, the greater its capture.

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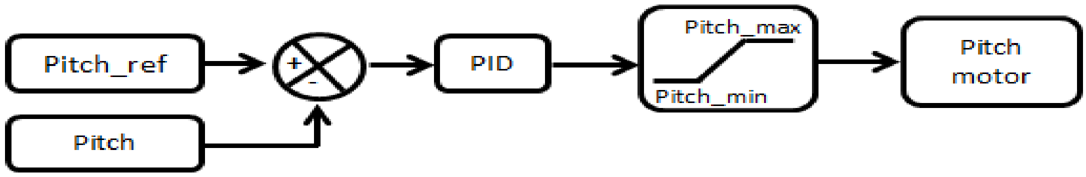


Figure 4. Pitch Control Subsystem

Figure 4 shows the control of the tilt angle of the blades (Pitch). In this control process, a resulting signal is obtained that sends the commands to operate electric motors that rotate the wind turbine blades. This movement of the blades is slow (4 degrees/minutes or 7 degrees/minutes in emergence) due to the physical dimensions of the blades and the force that is being applied to them. This speed is not constant and depends on the manufacturer's technology, but it is variable.

Figure 5 shows the simplified scheme of the central control scheme that is responsible for speed control. From this control, commands are sent to the Pitch control and the DC/DC converter control.

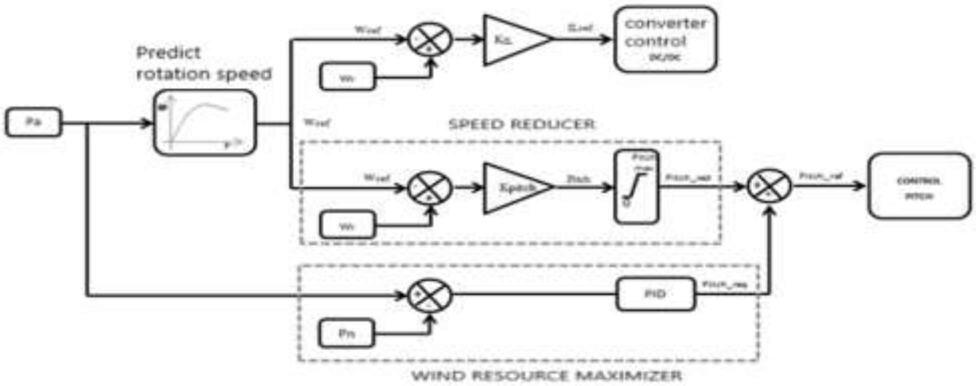


Figure 5. Central Control System

As shown in Figure 5, the reference current is obtained from the comparison between the rotational speed (Wr) and the active power that the wind turbine is exporting at any given moment. The objective of central control is to maximize the wind resource. To increase or decrease the active power transfer, the central control sends command to the chopper control (DC/DC converter) to increase or decrease the inductor current. At the same time, you have to send command to the Pitch control because you'll probably have to change the angle of the Pitch if it's not in bounds.

ANALYSIS AND DISCUSSION OF RESULTS

Simulations were carried out to analyze the operation of the control system. Modifications of wind speed and reference power were established, and voltage dips with different depths and duration were emulated. Figure 6 shows the disturbances caused.

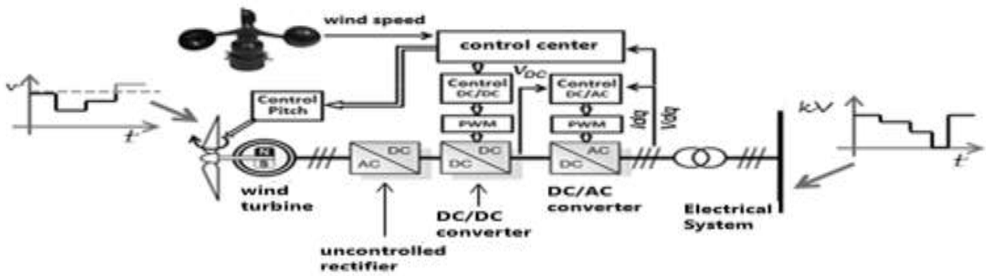
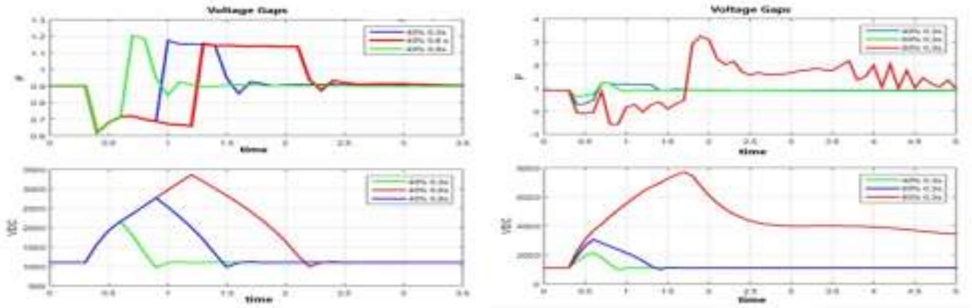


Figure 6. Diagram showing the variations to be simulated

In the same way, it can be seen that the control of the variable speed wind turbine, based on a generator with a permanent magnet rotor, is made up of a central control that is directly connected to the DC/DC converter control. The DC/AC converter control, on the other hand, is indirectly connected to the central control. When the wind speed decreases, the rotation speed on the generator shaft decreases and with this change in speed the central control sends an order to the DC/DC control to lower the current of the inductor, and with it the active power exported by the wind turbine. With the increase in speed, the exact opposite happens. The results obtained during voltage dips were analyzed, considering the behavior of the wind turbine control without the braking resistance and with the inclusion of it. In this case, the need to change the control system for when voltage dips occur was noted.

- Voltage gaps without braking unit

Figure 7 shows some of the variables that demonstrate the behavior of the wind turbine during two types of voltage dips, but without the action of braking resistance. A less severe stress gap of a depth of 40% was produced and the duration time of the gap was varied as shown in Figure 7a, while the result of a more severe gap (60% and 80% depth), but with a constant duration time of 300 ms, is shown in Figure 7b.



(a) (b)

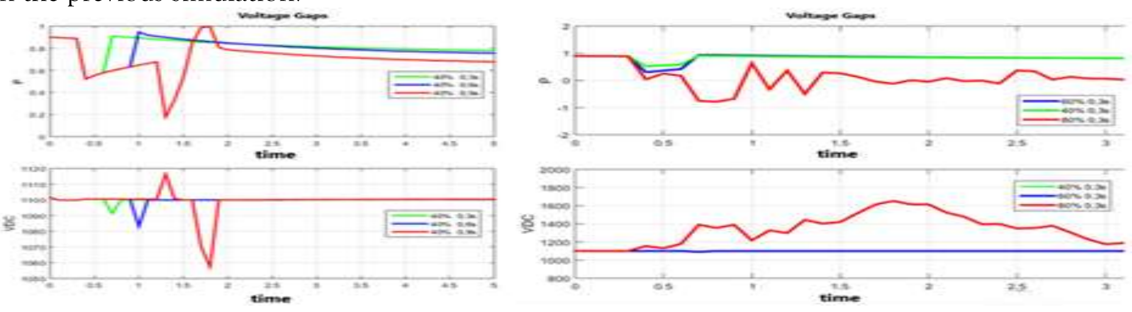
Figure 7. Results of active power and DC voltage during a voltage dip: a) short duration and b) long duration.

As can be seen in Figure 7, when the dip occurs, the active power decreases and the VDC voltage increases, subsequently stabilizing. However, when the voltage dip is not fixed, i.e. the depth of the voltage dip increases, by 40%, 60% and 80% with a fixed duration time of 0.3s, the voltage Vdc fails to stabilize. It is noticeable that even when the voltage dip is not so deep, the VDC voltage grows to high values that can compromise the converters themselves or their parts. It is known that the first components to be damaged are the supercapacitors that accompany IGBTs.

To reduce the hazards caused by high DC voltage during voltage dips, a braking unit is applied. This braking resistance, during the presence of a voltage dip, absorbs all the power that is being transferred to prevent the PMSG generator from accelerating.

- Tension gaps with braking unit

Figure 8 shows some of the variables that demonstrate the behavior of the wind turbine during two types of voltage dips, but with the action of braking resistance. A less severe voltage gap occurred as shown in Figure 8a and a more severe gap is shown in Figure 8b. The depths of the gaps and durations are the same as those used in the previous simulation.



(a) (b)

Figure 8. Results of active power and DC voltage during a voltage dip: a) short duration and b) long duration

As can be seen in Figure 8a, in the presence of a gap of constant depth of 40% but with durations of 0.3s, 0.6s and 0.9s, the VDC voltage of the DC/DC converter rises and falls momentarily, as the converter tries to stabilize the VDC voltage with the presence of the braking resistance. In Figure 8b, when the depth of the voltage dip varies from 40%, 60% and 80% with a duration time of 0.3s, the VDC voltage fails to recover when the voltage dip is deeper. The braking resistance is no longer effective and the VDC voltage reaches values outside the operating range for your electronic components and the rest of the system.

CONCLUSIONS:

Wind turbine units tolerate voltage dips depending on their depth and duration. Units are less tolerant of deeper gaps and those that Last much longer. Wind turbines do not tolerate gaps greater than 50% for more than 300 ms. The central control that governs the controls of the chopper or speed regulator, confuses the reduction in the exported power caused by the voltage dip with an opportunity to take advantage of wind resources and increases the tension DC to values dangerous to one's own control. Activating the braking resistance or braking unit is not always satisfactory to prevent disconnection of the unit. Changes in control actions are necessary to fully solve the problem of loss of stability during voltage dips.

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