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CONTROL OF A SMALL WIND TURBINE USING MAXIMUM POWER POINT TRAJECTORY

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Abstract-**The wind energy conversion system proposes a soft-stalling control strategy for small wind turbines operating in the high and very high wind speed region. The wind turbine extracts energy from the wind and transmits it to the PMSG. Small wind turbine systems can inject the energy directly into the grid and generating power even in the event of high speed wind conditions. The proposed strategy moves the operating point of the machine from the maximum power point trajectory (MPPT) to a decreased efficiency operating point whenever the wind speed excesses the machine torque or the power converter current capability by stalling the wind turbine. The proposed method uses only the minimum reference generator and over current detector which typically exist in small wind turbines. This method is applied to a wind turbine using a permanent magnet generator connected to an uncontrolled rectifier, which is controlled using a MPPT strategy. This system allows the wind turbine to operate safely with high wind speed and the protection is integrated along with the MPPT control. The rectifier voltage will be used indirectly to control the turbine speed. As the size of the turbine is reduced, cost of generation is reduced.**

I. INTRODUCTION

Recently, there has been a growing interest in generating electricity from renewable energy sources. Among all renewable sources, wind power has the largest market share and is expected to maintain rapid growth in the coming years. Profit maximization and cost minimization is an essential aspect of economic analysis. In the wind power industries, Wind Energy Conversion System (WECS) are expected to maximize the electric power generated from the wind and minimize the overall operational cost.

Wind energy conversion systems have been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day.A high torsional torque in the turbine shaft and large currents in the generator windings can eventually damage the system.The wind turbine during strong wind conditions implies that all the wind power is lost.The rectifier voltage ramp generator starts once the rectifier voltage reaches 100 V, to overcome friction, dead-time, and other sources of error when the machine operates at low speeds.There are two aspects related to electrical braking in small wind turbines that need to be considered. First, stopping the wind turbine during strong wind conditions implies that all the wind power is lost. Second, once the turbine is stopped, a strategy for its restart is needed. This is not obvious, as low cost systems do not include wind speed sensors. Commercial micro-turbines often wait a short period of time before restarting whenever the electrical braking is activated. If the wind speed remains too high, the wind turbine starts and stops repeatedly, which stresses and can eventually damage the system in the long term on the contrary, disconnecting the wind turbine longer than needed obviously has a negative economic impact.

MPPT is a technique that charge controllers use for wind turbines, PV solar systems and Hydro electric power plants to employ and maximize power output. The maximum power point tracking (MPPT) algorithms for wind energy systems are reviewed. As the amounts of power produced in wind power plants is changing due to the instantaneous changing nature of the wind, it is desirable to determine the one optimal generator speed that ensures maximum energy yield. Thus, it is important to include a controller that can track the maximum peak regardless of wind speed. Categorizing the MPPT algorithms can be done regarding whether it has used sensors or not, as well as according to the techniques used to locate the peak value. The performance of different MPPT algorithms is compared on the basis of ability to achieve the maximum energy yield and various speed responses. According to available simulation results in the literature, in cases through which the flexibility and simplicity in implementations is considered, the perturbation and observation (P&O) method is preferred, Due to its simplicity, the best MPPT method for wind energy systems has found to be the controlling the small wind turbine. In general, regardless of wind speed, the optimal TSR for a typical wind turbine is constant. Therefore, to guarantee maximized energy extraction, the TSR should remain

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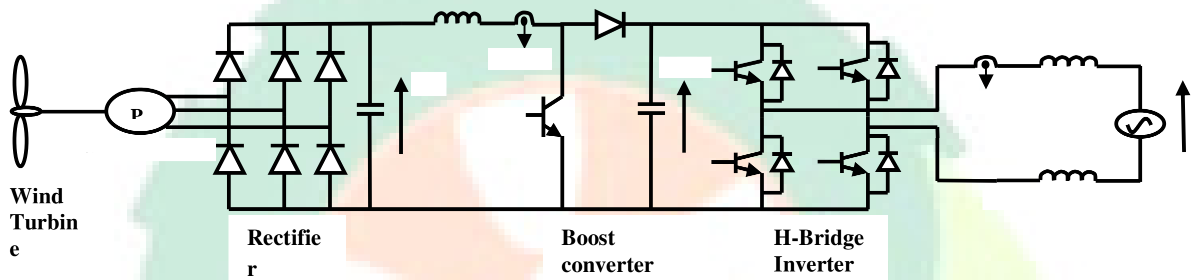
constant at the optimal value. Hence, this method tries to force the energy conversion system to remain at this point by comparing it with the actual value and feeding this difference to the controller. Then the controller changes the speed of the generator to reduce the error and in this way this difference will decrease. Although this method seems simple as wind speed is directly and continuously measured.Synchronous generators are excited by an externally applied or by permanent magnets. There is a considerable interest in the application of the multiple-pole synchronous generators driven by a wind-turbine rotor without a gearbox or with a low ratio gearbox. Synchronous machines powered by wind turbines may not be directly connected to the ac grid.

Fig 1:PMSG Based Wind Energy Conversion System



I MPPT STRATEGY

The typical PMSG based WECS is shown in Fig. 1.The Maximum Power Point Tracking (MPPT) is of the paramount important in renewable energy conversion systems for not only to maximize the return period of the installation cost. In wind energy conversion system, MPPT is to optimize the generator speed relative to the wind velocity intercepted by the wind turbine such that the power is maximized. Every year numerous research efforts are attempted to achieve better and faster techniques on MPPT in WECS. One of the commercially employed loop table MPPT is the TSR control which additionally requires an anemometer for the wind speed measurement and also pre-known value of the optimal tip speed ratio to convert the wind velocity measurement into its corresponding reference for optimal generator speed. The TSR control technique can provide the fastest control action as it directly measures the wind speed and sets the control reference instantaneously; hence it is expected to yield more energy. However the accurate wind measurement is not a trivial task especially in case of large size wind turbines. As anemometer provides limited measurements of wind speed only at the hub height and cannot cover for the whole span of large blades. Moreover, due to the interaction between the rotor and the wind, this usual placement of anemometers on nacelles leads to inaccurate wind speed measurements in both upwind and downwind turbines. In other words the wind speed measured by the anemometer may not be the one intercepted by the wind turbine.

Wind turbines capture the power from wind by means of turbine blades and convert it to mechanical power. It is important to be able to control and limit the converted mechanical power during higher wind speeds. The power limitation may be done either by stall control, active stall, or pitch control. The common way to convert the low speed, high-torque mechanical power to electrical power is using a gearbox and a generator with standard speed. The gearbox adapts the low speed of the turbine rotor to the high speed of the generator, through the gearbox may not be necessary for multi pole generator systems. The generator converts the mechanical power into electrical power, which being fed into a grid possibly through power electronic converters, and a transformer with circuit breakers and electricity meter. The two most common types of electrical machines used in wind turbines are induction generators and synchronous generator.

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III SPEEDCONTROL OF WIND TURBINE

Wind speed is proposed in the wind turbine control. The protection is integrated along with the MPPT control. It is assumed that neither wind speed sensor nor shaft speed sensor are available. The rectifier voltage will be used to indirectly control the turbine speed. Speed control systems work with control unit control unit consist a microcontroller. Microcontroller is a device to control hardware devices, microcontroller control gear motors and stepper motor and many devices.

High rotational speed in the wind turbine can be harmful, as both the turbine and the electronic components can be damaged or destroyed due to mechanical failure or to excessive high back-emf voltages respectively. Too high wind speed would produce a torque that cannot be matched by the generator, eventually resulting in an excessive rotational speed. Some type of protection against high wind speeds is therefore mandatory.

The block diagram of the proposed wind turbine protection scheme can be seen in Fig. 2. This system will ultimately provide a rectifier voltage reference , for the rectifier voltage PI controller. The rectifier voltage reference consists of a constant voltage reference min and a variable voltage reference , tracking the maximum power point. Those two commands will be generated by the blocks labeled as " generator" and "MPPT Tracker".

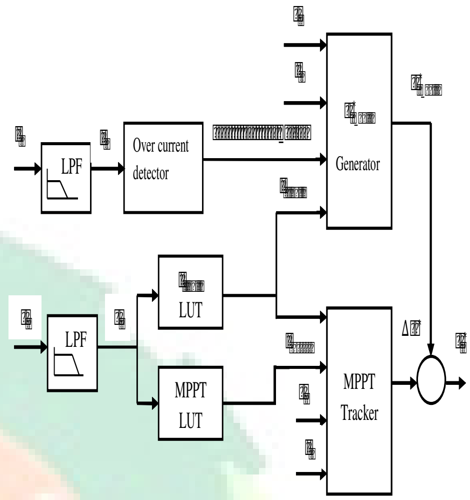

Fig 2:Voltage reference generator for MPPT and over-speed protection

A. Minimum Reference Generator

The flow chart of this generator block shown in Fig. 3. It will provide a rectifier voltage command which follows a ramp from zero to the cut-in voltage .

This reference generator is to have control over the turbine voltage/speed as soon as it starts to rotate, not leaving therefore any dead or uncontrolled zone up to the cut-in voltage. The ramp will be selected not have no effect for wind speeds that can be fully serviced with the rated torque of the generator (i.e. 14.8 m/s) but to provide an increasing braking torque for higher wind speeds. The voltage reference increase is driven by detection of an increasing rectifier voltage.

The generator will increase the rectifier voltage reference following a ramp up to a value of . At this point, the reference is maintained constant whenever the current exceeds the current limit . This prevents that high speed winds could develop high torque at high rotational speeds.

Above the cut-in voltage, the current limit is set as the current required to hold the turbine in the full speed/voltage range when the wind speed is the maximum that can be serviced without exceeding the rated current (i.e. 14.8 m/s). Below the cut-in voltage, the current limit is increased to allow the voltage

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reaching the cut-in value for wind speeds that can be controlled with a limited-time over current. The minimum wind speed at which the turbine operates with reduced rotor speed will depend on the selection of limit for the voltage . In the studied case, this mechanism will prevent from increasing the rectifier voltage when the wind speed is above 30 m/s.

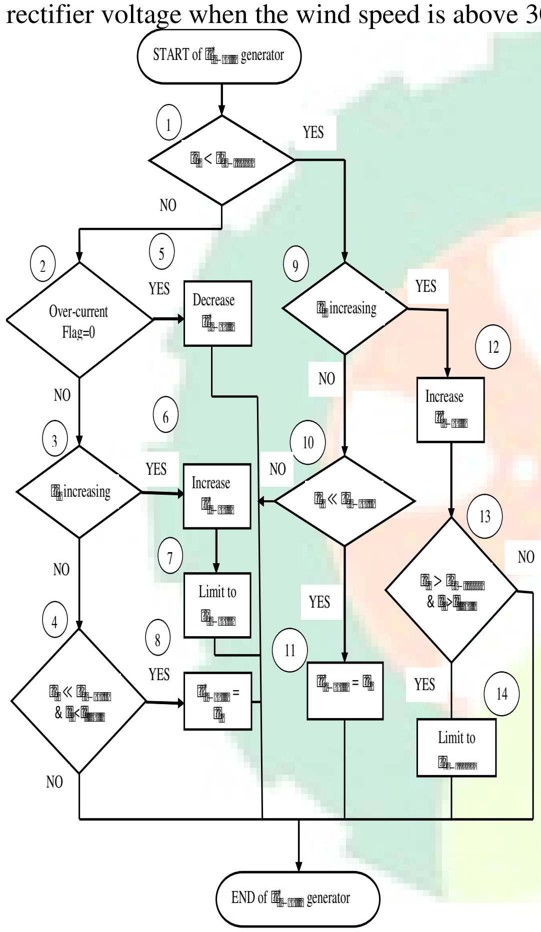

Fig 3:Flow chart of the minimum voltage reference generator

If the current limit is not exceeded of , the voltage command will increase as the actual rectifier voltage increases until it reaches . At this point, this reference is maintained equal to until an over-current situation is detected by the "over-current detector". When this occurs, the rectifier voltage command is decreased following a ramp to , eventually decreasing the current in steady state. If the rectifier voltage drops far below (25 V) due to the absence of wind, then the reference is made equal to the actual voltage to restart the ramp in the minimum reference generator.

B.MPPT Controller

Once the rectifier voltage exceeds the cut-in voltage , the MPPT block starts producing an additional reference needed to track the maximum power point shown in Fig. 4. This reference will be increased or decreased depending on whether the boost current is higher or smaller than the provided by a look-up table. The voltage step must be selected not to delay the voltage increase or to speed up the voltage decrease (i.e. not to draw a current much higher than) in the wind speed range never producing a torque over the rated value.

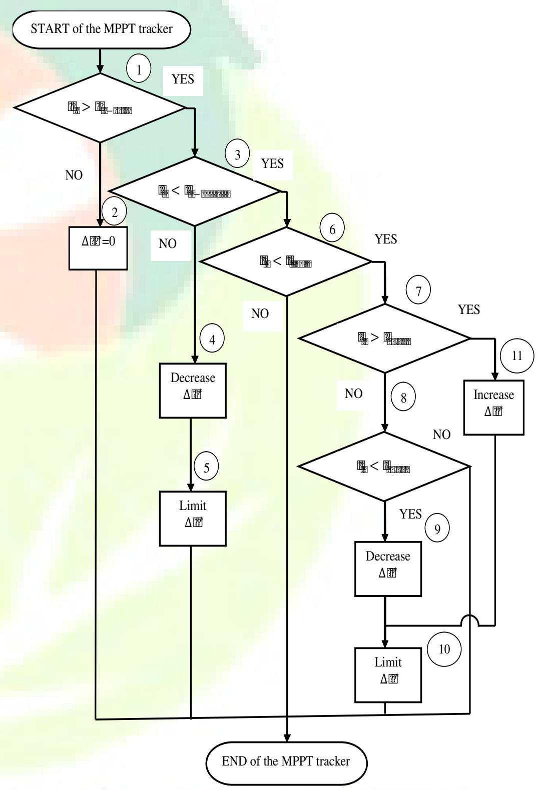

Fig 4:MPPT control flow chart

If the boost current is larger than , the voltage reference held constant. This prevents the turbine speed from increasing, what might lead to a higher torque/current, and avoids breaking the turbine in excess, what might cause the boost current to exceed its rated value.

In the event the current exceeds the rated value due to high wind speed, the voltage must be decreased. This will result in a transitory increase of the current

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level to achieve a higher torque, reducing the voltage reference and thus, the actual voltage, to . The voltage slope must be selected to trade-off the maximum peak transient current and the total time needed to reduce the voltage, considering the dynamic limitations imposed by the rectifier voltage controller. A solution, in which the voltage is not required to reduce to while maintaining the rated current, is currently being developed. This is accomplished in power based stalling methods by adding a delaying filter in the feedback loop.

C. Over-Current Detector

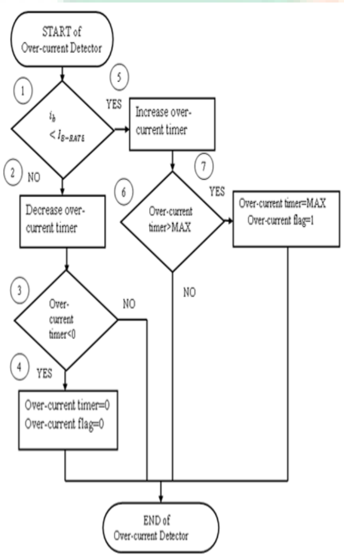

Fig 5:Over-current detector flow chart

If the current in steady-state for is larger than its rated value, the minimum rectifier voltage reference must be decreased to to reduce it. The "over-current detector" block is shown in Fig. 5. It is an up/down counters that increases whenever the current is larger than its rated value, and decreases if it is smaller. If the counter reaches a pre-established threshold, an over-current flag is set and it will only be reset when the counter returns back to zero. If the over-current flag is set, the minimum voltage reference generator will decrease to following a ramp.

The count up and countdown steps can be unevenly selected in the implemented algorithm the countdown was set to be four times faster than the count up. The threshold at which the flag is set on can be selected by measuring the transient time to bring down the voltage to when the turbine is driven by a wind speed producing the rated torque at . Trying to stop a higher wind speeds will produce larger transients, making the minimum voltage reference to change to .

In case of very high wind speeds, the required current can excess the ultimate limits of the machine and/or power converter. In this case, a crowbar must be activated to stop the wind turbine. Since no wind speed information is available, deciding when the wind turbine must be restarted is not trivial, as the wind turbine would start and stop repeatedly if the high wind condition remains. The proposed method overcomes this situation. Once the crowbar has been activated, the turbine can be restarted and the minimum reference generator will prevent the turbine from accelerating while the high wind situation.

IV CONTROL STRATEGIES

The control strategies for small wind turbines can significantly different from those used with high power turbines, due both to the differences in the power converter topology as well as to the number of sensors which are normally available in the hardware model is shown in Fig. 4.1. One of the challenges in small wind turbines is the control and protection under high wind speeds. Whenever the wind power exceeds the turbine power rating, the turbine must be operated below its maximum efficiency point to prevent damage. Eventually, some braking mechanism must be enabled if the wind power excess is too high; pitch or stall control, mechanical brakes and electric brakes can be used to control the wind turbine. The electric brake using a crowbar to shortcut the generator windings to produce a high braking torque is the preferred option for small wind turbines, due to its simplicity and reduced cost. However, this method has some drawbacks, including a high torsional torque in the turbine shaft and large currents in the generator windings, which can eventually damage the system.

The control strategy includes following methods.

A. Wind Turbine Control

A control parameter is available in the wind turbine control system indicative of foreseeable fluctuations in a rotational speed of a rotor due to wind turbulence may be obtained. The first control

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parameter may be calculated based on wind power and wind turbulence intensity. Then, the control parameter may be compared with a threshold value. Next, a maximum power to be generated by the wind turbine may be reduced if the control parameter exceeds said threshold.

Pitch control is used primarily to limit power in high winds, but it also has an important effect on structural loads. Particularly as turbines become larger, there is increasing interest in designing controllers to mitigate loads as far as possible. Torque control in variable-speed turbines is used primarily to maximize energy capture below rated wind speed, and to limit the torque above rated, but it can also be used to reduce certain loads. The design of the control algorithms is clearly of prime importance.Additional sensors such as accelerometers and load sensors can also help the controller to achieve its objectives more effectively. By controlling the pitch of each blade independently, it is also possible to achieve important further reductions in loading. It is important to be able to quantify the benefits of any new controller.

B. High Speed Turbine Rotation

High rotational speed in the wind turbine can be harmful, as both the turbine and the electronic components can be damaged or destroyed due to mechanical failure or to excessive high back-emf voltages respectively. Too high wind speed would produce a torque that cannot be matched by the generator, eventually resulting in an excessive rotational speed. Some type of protection against high wind speeds is therefore mandatory. The control strategy method is allowing the wind turbine to operate safely with high wind speed. The protection is integrated along with the MPPT control. It is assumed that that neither wind speed sensor nor shaft speed sensor are available. A wind turbine would ideally operate at its maximum efficiency for below rated power. Once rated power has been hit, the power is limited.Below rated power, the wind turbine will operate ideally. Once the wind speed has reached a certain level, called rated wind speed, the turbine should not be able to produce any greater levels of power for higher wind speeds. A stall-regulated variable speed wind turbine has no pitching mechanism. However, the rotor speed is variable. The rotor speed can either be increased or decreased by an appropriately designed controller. In reference to the figure illustrated in the blade forces section, it is evident that the angle between the apparent wind speed and the plane of rotation is dependent upon the rotor speed. This angle is termed the angle of attack. The lift and drag co-efficient for an airfoil are related to the angle of attack. Specifically, for high angles of attack, an airfoil stalls. That is, the drag substantially increases. The lift and drag forces influence the power production of a wind turbine. This can be seen from an analysis of the forces acting on a blade as air interacts with the blade (see the following link). Thus, forcing the airfoil to stall can result in power limiting. So it can be established that if the angle of attack needs to be increased to limit the power production of the wind turbine, the rotor speed must be reduced.

Pitch regulation allows the wind turbine to actively change the angle of attack of the air on the blades. This is preferred over a stall-regulated wind turbine as it enables far greater control of the power output. However, due to constraints such as noise levels, this is not possible for the full range of sub rated wind speeds. Below the rated wind speed, the following operating strategy is employed. Above the rated wind speed, the pitching mechanism is employed. This allows a good level of control over the angle of attack, thus control over the torque.

C. Over Current Detected

An over current detection circuit protects a system against currents above rated current that persist for certain exposure times. The allowable exposure times are inversely related to the degree of overload current. Over current detection is a method of establishing that the value of current in a circuit exceeds a particular value for a particular length of time.Over current detection must be able to sense and open the circuit when its rating is exceeded for a specified amount of time. A time compensated over current detection circuit shuts off a DC motor during large over current conditions caused by actual constraints on the motor.

D. Gear System Removed

Connects the low-speed shaft to the high-speed shaft and increases the rotational speeds from about 30-60 rotations per minute (rpm), to about 1,000-1,800 rpm; this is the rotational speed required by most generators to produce electricity. If the wind speed remains too high, the wind turbine starts and stops repeatedly, this develops stresses and can eventually

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damage the system in the long term.The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes. With agearbox the speed is convert between slowly rotating, high torque powerwhich get from the wind turbine rotor and high speed, low torque power, which use for the generator. The gearbox in a wind turbine does not "change gears". The power from the rotation of the wind turbine rotor is transferred to the generator through the power train, i.e. through the main shaft, the gearbox and the high speed shaft, as available with the Components of a wind turbine.

If the ordinary generator is used, directly connected to a 50 Hz AC three phase grid with two, four, or six poles, it will have to have an extremely high speed turbine with between 1000 and 3000 revolutions per minute (rpm). Another possibility is to build a slow-moving AC generator with many poles. But if it is wanted to connect the generator directly to the grid, you would end up with a 200 pole generator (i.e. 300 magnets) to arrive at a reasonable rotational speed of 30 rpm.Another problem is that the mass of the rotor of the generator has to be roughly proportional to the amount of torque (moment, or turning force) it has to handle. So a directly driven generator will be very heavy (and expensive) in any case.

V RESULTS AND DISCUSSION

The comparison table represents the difference between existing system and proposed system shown in Table 1. The protection is integrated along with the MPPT control. It is assumed that neither wind speed sensor nor shaft speed sensor are available. The rectifier voltage will be used to indirectly control the turbine speed. Speed control systems work with control unit control unit consist a microcontroller. Microcontroller is a device to control hardware devices, microcontroller control gear motors and stepper motor and many devices.

Table 1: Comparison between Existing System and Proposed System

Parameter (unit)	Existing system	Proposed system
Voltage (V)	26.4	35.6
Current (A)	0.2	0.5
Wind speed (m/s)	15	21
Rated rotor speed (rpm)	350	750
Efficiency	89.3	95.4

VI CONCLUSION

Small wind turbines respond to the same basic principles as high power units. However, the importance of reducing their cost to make them affordable to the general public, dictates a reduction in the number of sensors resulting in additional control challenges that need to be addressed. Especially important is the turbine operation and protection under high wind speed. A method to control small wind turbines under these conditions has been proposed. The method is able to early detect a high wind condition by supervising the current drawn from the rectifier, allowing the wind turbine to remain connected to the grid and generating power even in the event of high speed wind conditions.

VI REFERENCES

[1] Ahmed A. (2010) 'New constant electrical power soft-stalling control for small-scale VAWTs', IEEE Transactions on Energy Conversion, vol. 25, no. 4, pp. 1152–1161.

[2] Arifujjaman M. (2010) 'Modeling, simulation and control of grid connected permanent magnet generator (PMG)-based small wind energy con-version system', IEEE, pp. 1 –6.

[3] Benjanarasut J. and Neammanee B. (2010) 'The d-, q- axis control technique of single phase grid connected converter for wind turbines with MPPT and anti-islanding protection', IEEE, pp. 649–652.

[4] Castillo O. (2009) 'Average current mode control of three-phase boost rectifiers with low harmonic distortion applied to small wind turbines', pp. 446 –451.

[5] Chen J. (2013) 'New overall power control strategy for variable-speed fixed-pitch wind turbines within the whole wind velocity range', IEEE Transactions on Industrial Electronics, vol. 60, no. 7, pp. 2652–2660.

[6] Dalala Z. (2013) 'New overall control strategy for wind energy conversion systems in MPPT and stall regions', in IEEE Energy Conversion Congress and Exposition (ECCE), pp. 2412–2419.

[7] Hai N. T. (2008) 'Sensorless control of PM synchronous generators for micro wind turbines', IEEE 2nd International, pp. 936–941.

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ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

IJARMATE International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 3, Special Issue 10, March 2017

[8] Heier S. (2006) ‘Grid Integration of Wind Energy Conversion Systems’, 2nd ed. Wiley, pp. 446-451.
[9] Heier S. (2006) ‘Grid Integration of Wind Energy Conversion Systems’, 2nd ed. Wiley, pp. 483-487.
[10] Hua C.-C. and He C.-Z. (2011) ‘Design and implementation of a digital power converter for wind energy conversion’, IEEE, pp. 1398–1402.
[11] Jiao S. (2001) ‘Control system design for a 20 kW wind turbine generator with a boost converter and battery bank load’, IEEE 32nd Annual, vol. 4, pp. 2203–2206 vol. 4.
[12] Matsui Y. (2007) ‘Braking circuit of small wind turbine using NTC thermistor under natural wind condition’, in Power Electronics and Drive Systems, PEDS ’07, pp. 910 –915.
[13] Muljadi E. (1998) ‘Soft-stall control versus furling control for small wind turbine power regulation’, National Renewable Energy Lab., Golden, CO (United States), Tech. Rep, pp. 661-575.
[14] Park H.-G. (2007) ‘Low-cost converters for micro wind turbine systems using PMSG’, in Power Electronics, ICPE ’07. 7th Internatonal Conf. on, pp. 483–487.
[15] Reznik A. (2014) ‘Filter Design and Performance Analysis for Grid- Interconnected Systems’, vol. 50, no. 2, ch. Filter Design and Performance Analysis for Grid-Interconnected Systems, pp. 12.
[16] Reznik A. (2014) ‘Filter Design and Performance Analysis for Grid- Interconnected Systems’, vol. 50, no. 2, ch. Filter Design and Performance Analysis for Grid-Interconnected Systems, pp. 1225– 1232.
[17] Song S.-H. (2003) ‘Implementation and control of grid connected AC- DC-AC power converter for variable speed wind energy conversion system’, Eighteenth Annual IEEE, vol. 1, pp. 154–158 vol.1.
[18] Sugawara A. (2006) ‘Research for electric brake using NTC thermis- tors on micro wind turbine’, pp. 1597 –1601.

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