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Wound Rotor Induction Generator on the Efficiency of the Wind Turbine

Mohini
Department of Electrical Engineering, University of Delhi
Corresponding Author: mohinieeedelhi@gmail.com

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Abstract*: Variations in wind speed cause the wind turbine's produced torque to fluctuate, increasing turbine blade fatigue and electric machine overloads. This study examines how changing the rotor resistance affects the rotor current control of a wind turbine-powered wound rotor induction generator in various operating modes. The machine's turbine produces a steady thrust by measuring and regulating the rotor current. Wind speed changes, particularly at high wind speeds, are the modes under study. Additionally, the impact of the suggested control on critical fault clearing time and short circuit is examined. Pitch regulator chores will be relieved, the machine will start softly, and torque and power variations will be decreased with this strategy.*

Keywords*: Generator, Wind energy conversion, Wound rotor induction, Rotor resistance control*

I. Introduction

One of the most significant renewable energy sources today is wind energy, which contributes significantly to global power generation and is environmentally benign. Wind turbines come in a variety of forms, primarily the following:

Effect of fixed speed wind turbine stalling Pitch regulation for wind turbines with fixed speeds. Adjustable pitch speed control (Optimal Pitch-Optimal Slip). Direct Drive Synchronous Generator with Doubly Fed Induction Generator (DFIG) In recent years, the optimal pitch optimal slip has been examined from several angles since it is one of the most alluring features from an economic and technical standpoint. Numerous research that may be appropriate for specific applications have been proposed in the literature. A synopsis of the well-known studies is provided below:

Research in [1] begins by creating models for various control methods of variable speed induction generators when responding to small disturbances such as wind speed fluctuations. The paper investigated constant rotor current control methods next to a constant torque, constant equivalent circuit output response. The hardware implementation of constant equivalent circuit method has verified the obtained results.

This approach from [2] employs transfer functions of fifth then third and finally second order to account for different wound rotor induction machine linearization methods. The method enables developers to create appropriate rotor current controllers which can be evaluated against proportional, proportional plus integral, and double integral variations when wind speed changes dramatically especially during wind gust conditions. The implementation of the pitch controller that determines complex control parameters including filter cutoff frequency has been omitted from the system.

An evaluation of the best slip rotor current control wound rotor induction generator and stall effect squirrel cage induction generator appeared in [3]. The research team conducted tests both in short-circuited conditions and when wind gusts occurred. Research results failed to display any stability effects concerning both critical fault clearance time enhancement and the optimal value of additional rotor resistance estimation methods.

The model described in [4] provides coverage for all elements of wind power generation systems that span from mechanical wind turbines to electrical generators, transformers, transmission lines, cables and the electrical grid. The models serve to analyze operating conditions for double feed induction generator wind turbines alongside optimal slip ideal pitch. The method failed to suggest both the control system sampling frequency and a proper approach to determine the elevated rotor resistance value. The research analyzes the performance between squirrel cage pitch-controlled and variable speed slip-and-pitch-control wind turbines. Changes in wind speed.

The operational speed decreases beyond rated wind speeds because of peak wind gusts becoming excessive.

Short circuits affected the generator terminals through a three-phase grounded short circuit. This study enhances rotor current control modules through calculations involving proper added rotor resistance values and control parameters and fault critical times. A winding rotor induction machine powered by a squirrel cage operates at the ZAFARANA Site wind farm in Egypt through this particular method. A new soft starting method is used in this study which connects resistance to the rotor externally.

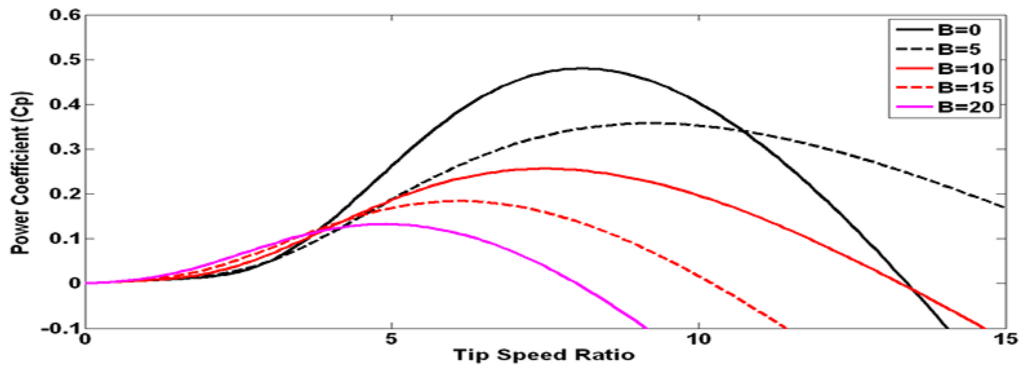


Fig 1: Wind Turbine characteristics

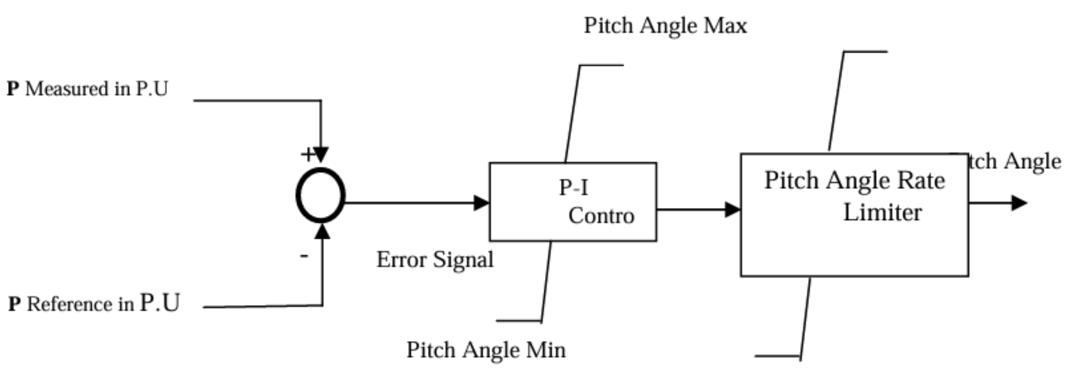


Fig 2: Pitch angle controller

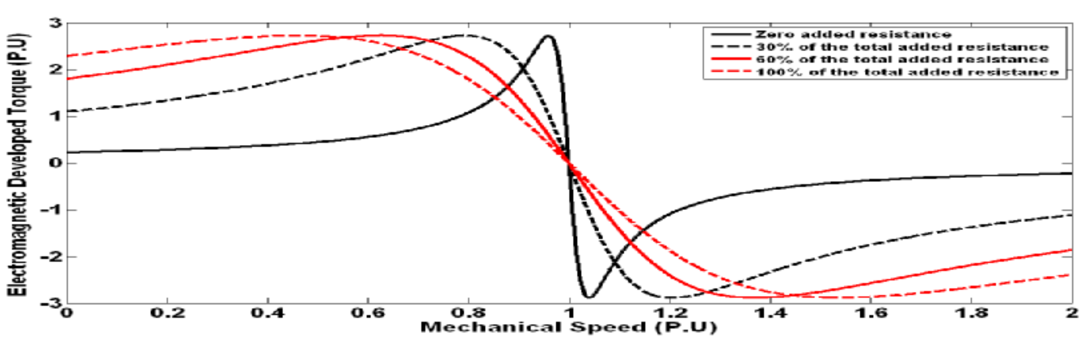


Fig 3: Induction machine Speed-Torque characteristics

II. Rotor Current Control Module

The power electronics equipment connects three-phase star-connected resistances in parallel arrangement with the induction generator rotor windings. At least two current sensing components should be integrated in the switch as depicted in Fig. (4) because modifying the duty ratio changes the additional rotor resistance which affects the rotor current consistency. VESTAS company employs this approach in their actual wind turbine product known as V47-660.

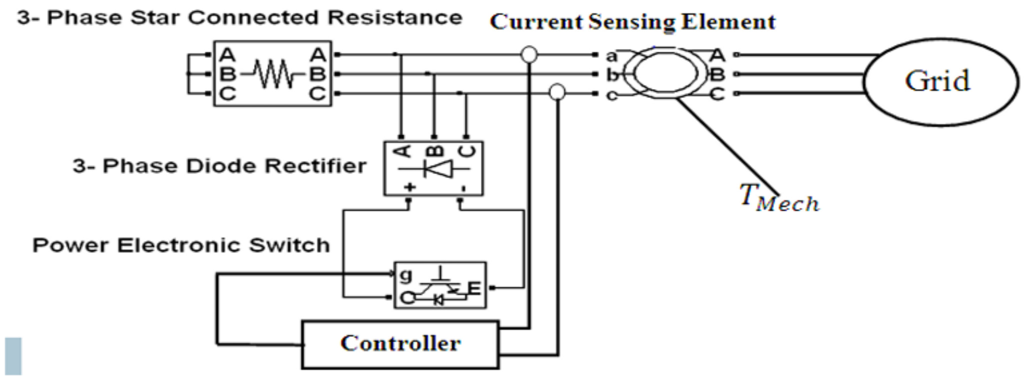


Fig 4: Induction generator with RCC

A torque speed characteristic of the induction machine of equation enables researchers to determine the additional resistance value. The machine operates at 10% slip or 1.1 times the synchronous speed to develop its nominal torque according to equation (18). The generator speed range corresponds to 110% of the synchronous speed when rotor resistance controls the minimal converter losses. The combination of controller, power electronic circuit and resistance allows this module to be connected directly to the machine shaft without slip rings. This control approach stands superior to stator-based methods due to its easy application abilities together with inexpensive cost structure and minimal upkeep needs.

The module uses a PI controller according to Fig. (5) results. The module uses this functionality when rotor current reaches a different value than the reference point to modify the switch duty cycle. A Ziegler and Nichols procedure applies to parameter adjustment of the controller device [1]. The approach can benefit from modern optimization techniques including swarm and genetic which can be implemented to modify this control method. The controller design can be modified to incorporate fuzzy control systems instead of its current scheme. The following section explains both the responsibilities of the module and its effects on system performance.

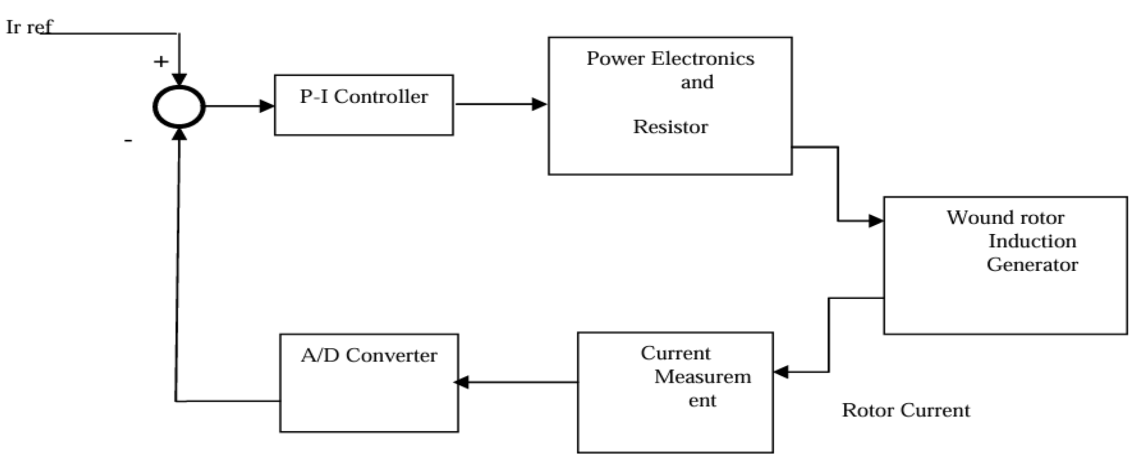


Fig 5: Rotor current controller

III. Result and Analysis

This section discusses how perfect slip or rotor current regulation affects wind turbines. The research establishes a comparison between rotor current controls of wound rotor induction generators and squirrel cage inductors when regulating wind turbine speed. The scientific community supports wind speed variation waveforms in the examined circumstances according to [9]. Several conditions from this research serve as the basis for analysis.

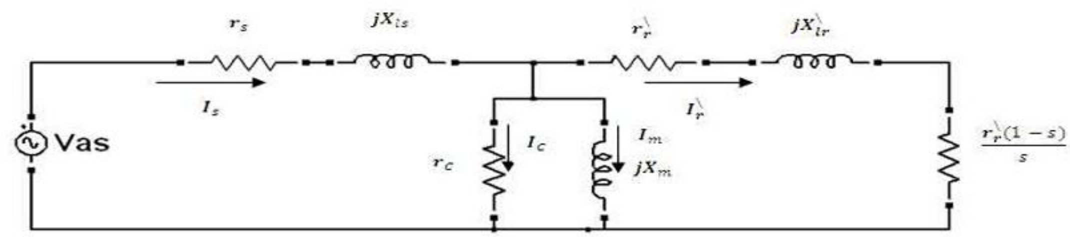
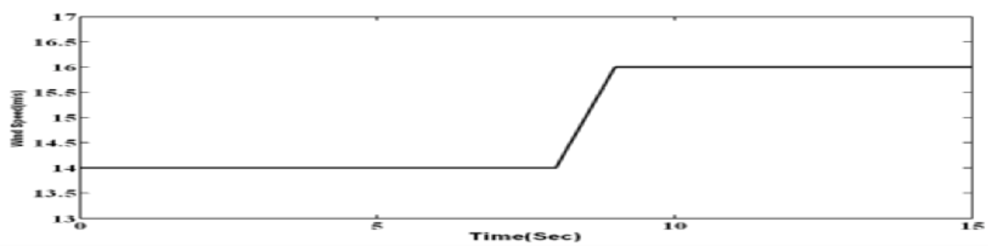
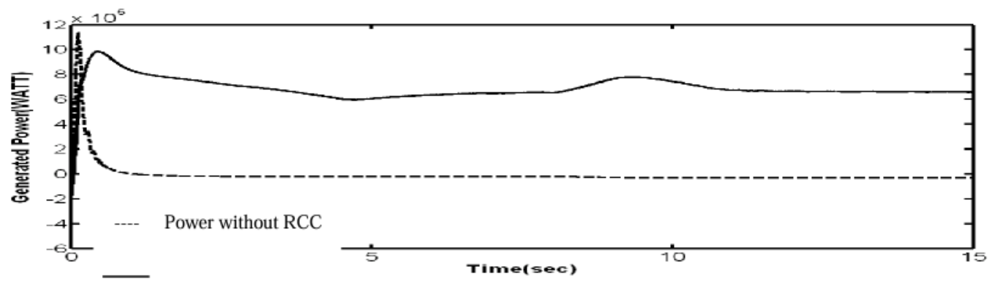


Fig 6: Induction Generator Single Phase Equivalent Circuit

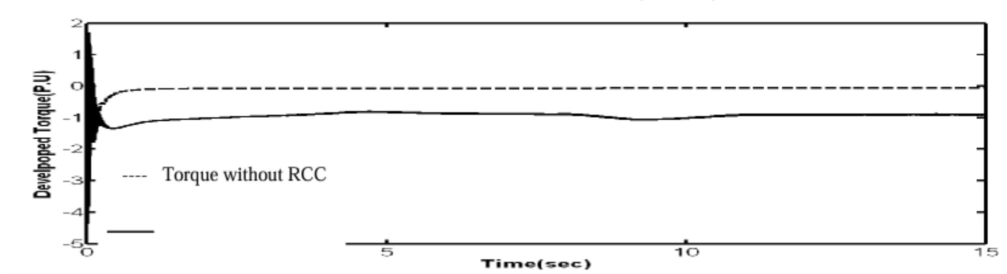
The addition of rotor resistance creates system damping that upholds generator rotational speed within the required range and enables magnetic field growth according to Figs. 7a, 7b, 7c, 7d, and 7e [3]. The purpose of the rotor current control module is to minimize torque and power fluctuations at the wind speed variation point because the generated torque remains steady throughout the 9-second period.



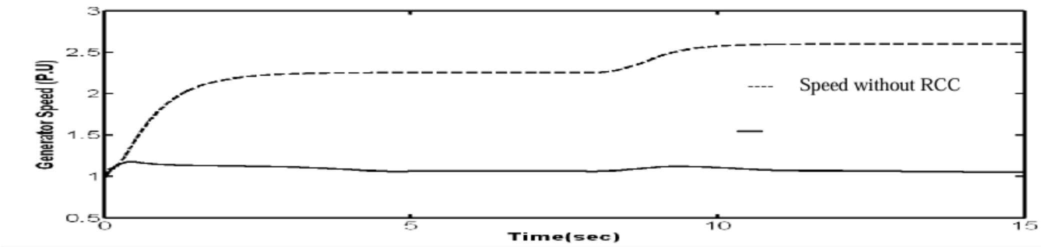
a. Wind Speed Variation



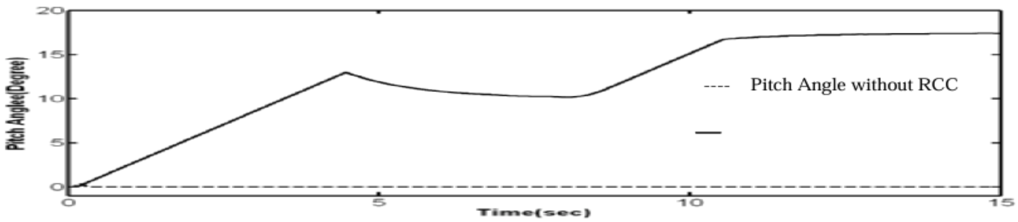
b. Generated Powers (WATT)



c. Electro Magnetic Torque in P.U



d. Generator Speed in P.U

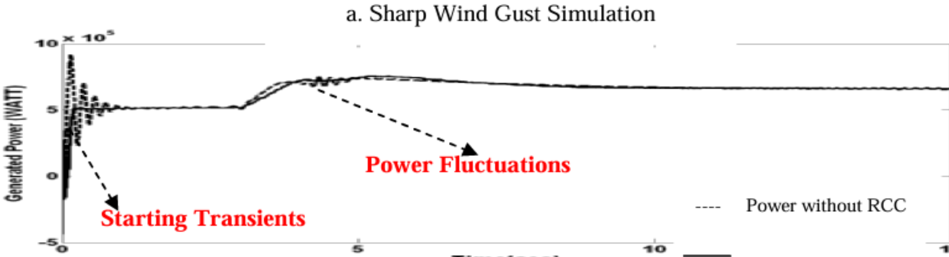


e. Pitch Angle in Degree

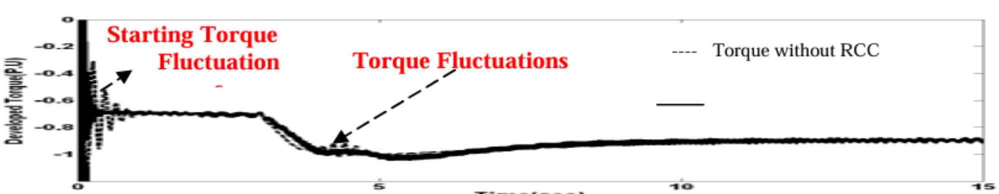
Fig 7: Rotating speed of the generator within the range and permitting the accumulation of the magnetic field

Addition of rotor resistance coupled with rotor current controller in Figures 8a, 8b, 8c reduces the intensity of sudden wind gusts. Grid utilities reject increased power distortions caused by wind turbine flickers that also place additional fatigue on turbine blades and increase blade wear.

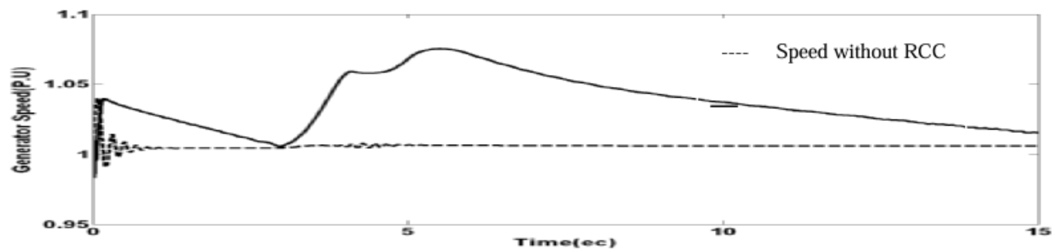
a. Sharp Wind Gust Simulation



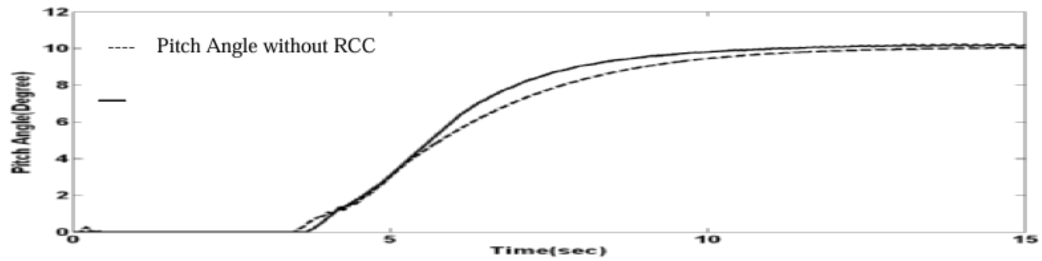
b. Generated Powers (WATT)



c. Electro Magnetic Torque in P.U



d. Generator Speed in P.U



e. Pitch Angle in Degree

Fig 8: Effect of Rotor current with resistance

The critical fault clearance time for the three-phase to ground generator terminals in the squirrel cage wind power generation system calculated to 0.19 seconds as per Fig. (9). The generator terminals received a 0.19-second three-phase grounded short-circuit at 11 seconds that caused power interruption until the fault clearance succeeded in strengthening transient stability and reducing protection systems responsibilities.

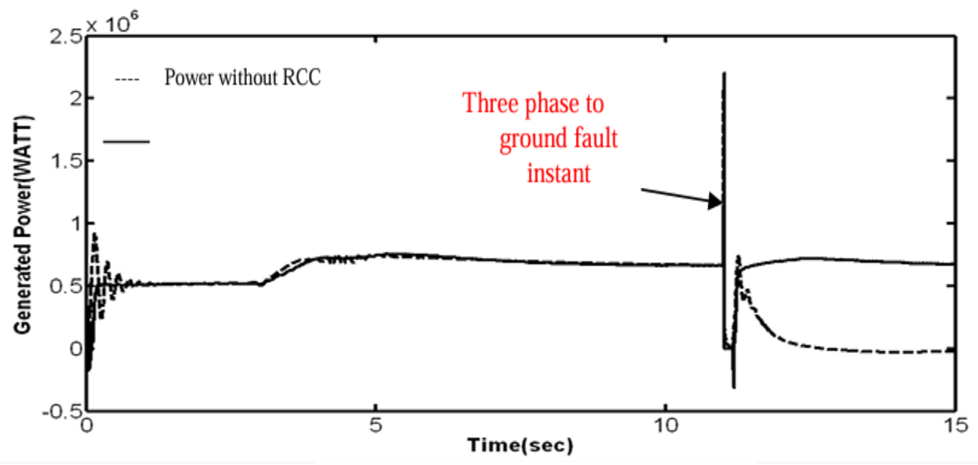


Fig 9: Generated power in watts

IV. Conclusion

This review confirms that the rotor current control or rotor resistance control system represents an affordable and simple method for managing low power wind turbines. The system's transient responsiveness during startup improves as well as power and torque fluctuations decrease during wind gusts due to this control method increasing turbine lifetime. Short circuits decrease in magnitude while the critical clearing fault time extends to the point where protection systems require minimal braking and longest clearing period.

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