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A NOVEL APPROACH TO OPTIMAL DESIGN OF PI CONTROLLER OF DOUBLY FED INDUCTION GENERATOR USING PARTICLE SWARM OPTIMIZATION

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ABSTRACT

Due to continuous increase in power demand and environment pollution we cannot depend on limited conventional sources so we go for the non-conventional energy sources in which wind energy has proven technology. Among the different available wind turbines of variable speed, doubly fed induction generator (DFIG) is the commonly used wind turbine in growing wind market. DFIG is usually used to fulfill standard grid requirements like power quality improvement, stability of the grid, grid synchronization, power control and fault ride through in grid tied wind energy system. To fulfill these requirements DFIG needs a control strategy for both stator and rotor side along with variable frequency power electronic converters (VFC).

In general VFC control is done by using set of proportional integral (PI) controllers but tuning of these controller gains is a difficult task due to non-linearity and complexity of the system. In ordered to apply proper voltages to the rotor windings to maintain constant terminal voltage & control both active and reactive powers of DFIG and to find out PI controllers parameters optimally an effective PSO algorithm is used in this paper.

Key words: Particle Swarm Optimization, Tuning of PI controllers. Controlling of DFIG, Doubly fed induction generator.

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1. INTRODUCTION

Due to continuous mismatch between load demands, depleting fossil fuels, environmental concerns forced the power sector to move towards alternative power generation sources apart from the conventional

Sources. Because of this situation renewable energy sources became the hot research spot in the recent past. Among the available non-conventional energy sources wind is one of the mostly available source and has many prominent advantages compared with others.

Among the available wind turbine configurations, horizontal axis, three-bladed, up wind turbine are most commonly used. Variable speed wind turbines (VSWT) are used for larger machines, whereas fixed speed wind turbines for smaller machines. For constant speed wind turbines the change in wind speed effects the power quality of the grid. In variable speed wind turbines the generator output power at variable wind speed is controlled by using power electronic equipment. Hence compared to fixed speed wind turbine variable speed wind turbine is better in effecting power quality. Over the past decade the usage of wind turbine with variable speed in combination with DFIG is more popular because of its advantageous in comparison with other topologies. In DFIG, windings of stator connect grid directly and windings rotor connected to grid through partial-load (25-30%) variable frequency converter (VFC) and transformer. VSWT along with the synchronous generator (SG) uses full-scale rated (100%) AC/DC/AC converters (VFC) placed in between stator and grid therefore compare to SG, VFC of DFIG is smaller and cheaper

Various modern control techniques have been developed since from the last ten years Such as adaptive control, intelligent control, and variable modern control for the controlling the nonlinearities of the power system(8). But being simple in structure and its easy tuning process PI controllers are most widely and commonly employed for the controlling. The tuning of PI controller for a obtaining a optimal set of gain values for the desired objective is a complex problem because of nonlinearities in the system. The various authors have solved the optimal designing of these controllers for different objectives. For this different heuristic search based algorithms has been presented such as Genetic algorithm (GA), Particle Swarm Optimization (PSO), Tabu Search Algorithm, simulated annealing. Z.L. Gang reported about conventional turbo generator with automatic voltage regulator (AVR) system by using PID controller. And there is no investigation on transient performance of controller and the design is only based on the response of step. Wei Qiao et.al. Described[4] about the PSO technique for obtaining optimal perimeters of various proportional integral controllers for the RSC of VFC by using fitness function in time domain in ordered to improve transient performance of wind turbine system. Joao P.A. Vieira used [3] GA to obtain the gain optimal value for the PI controller in RSC of DFIG to minimize over current in the rotor and compares transient performances with traditional methodology to design PI controller using placement of poles. B. hamane, m. l. doumbia, A. M. bouhamida, m. benghanem [14] comparison for performance of the controllers using conventional PI and Sliding mode of the WECS DFIG Heri Suryoatmojo Arif Musthofa A. M. B. Zakariya Imam Robandi [13] the performance of optimized is obtained by the integral absolute error. And comparison of results in normal and abnormal conditions of DFIG.In this paper gives the design of DFIG from induction machine and simulation results of active and reactive power of DFIG, the tuning of PI controllers is obtained from the particle swarm optimization and also shows the decoupled control of active and reactive power

2. WORKING PRINCIPLE OF DOUBLY FED INDUCTION GENERATOR

In DFIG the mechanical power at is rotor shaft converted into electrical energy and then fed to the grid through both windings of stator and rotor. DFIG operates similar to the synchronous generator but synchronous speed of DFIG can be changed by varying the frequency of AC currents given to the rotor. The frequency of ac currents (f_{rotor}) that need to be fed into the DFIG rotor windings in order to match frequency of stator voltage and grid (f_{grid}) is given by the equation (1).

$$f_{rotor} = f_{grid} - \frac{n_{rotor} * N_{poles}}{120} \quad \ldots..(1)$$

Where, n_{rotor}= speed of rotor in rotations/min

N_{poles} = Number of poles in DFIG per phase.

3. CONTROLLING OF DFIG

In DFIG configuration, wound rotor induction machine is used but both stator and rotor windings are connected to grid where stator winding is directly connected to the grid whereas rotor winding is connected through variable frequency converter (VFC) to the grid. By controlling VFC we can generate power at a constant frequency of voltage over a wide range of speed from sub to super synchronous speed.

The converter placed near to rotor circuit is called as rotor side converter (RSC), whereas near to grid is called as grid side converter (GSC). VFC contains two four –quadrant switches are connected by DC-link capacitor which controls the power flow direction, magnitude in between grid and rotor. During steady state condition we know that

$P_m = P_s + P_r$ …….. (2)

Where, P_m is mechanical power, P_s is power of stator, P_r (-S*P_S) is power of rotor and S is slip of the machine.

In sub synchronous mode (S is positive) only stator produces active power, rotor takes the power from the grid. But in super synchronous mode (S is negative) both stator and rotor can develop active power. Whereas reactive power can be generated or absorbed based on control techniques being used and amount of reactive power is controlled by applying proper voltage magnitude to the rotor circuit.

VFC control incorporates control strategies of RSC and GSC converter control, the decoupled control of grid side active power (by control of speed) and by using rotor current regulation control the reactive power is done by RSC. For this the instantaneous three phase rotor current and its regulation is sampled and changed into d-q components Id and Iq in the stator – flux oriented reference frame. The reference values of i_{dr} and i_{qr}can are obtained directly from the Q_s and $P_s$commands (these are functions of individual current components). The error signals are obtained by comparing actual current signals with reference current signals by passed through PI controllers which are used to generate gate control signal for controlling IGBT converter module by using pulse width modulation.

Irrespective of rotor power magnitude and direction the dc link voltage is maintained constant by GSC, at any instant the power taken from GSC is determined by the state of DC link voltage, if the inflow and outflow power to the dc-link capacitor do not match then the dc-link voltage tend to change. GSC should maintain the voltage within the desired range when DFIG is in the weak power system and there is no reactive power compensation whereas in strong power system the reactive power needs to be set to zero by GSC.

4. PROPOSED METHODOLOGY

This paper the parameters of PI controller are tuned using Particle swarm optimization with a objective to improve the transient response of active and reactive power of DFIG to get a constant terminal voltage.

4.1. Objective Function

In order to improve the transient response of active power the output waveform obtained from the simulation is modeled into a statistical data points at different times. The variance of these data points has been calculated which gives the measure of variations in these data points.

Objective function = min (variance (Ps))

Where Ps is the active power values of DFIG at each point instant of time.

4.2. Particle Swarm Optimization

Particle swarm optimization is a biologically inspired a search algorithm which Particles search the search space for a optimal solution. This particle imitates the social behavior of birds and fish schooling in search of food. Each particle fly with a velocity and changes its position and update its velocity based on personal best and global best positions. In this paper particle swarm optimization has been used to tune The PI controller parameters.

4.3. Algorithm for Particle Swarm Optimization

- Initialize a random particles of Kp KI values for Ps and Qs controllers within their range. Particle (i, j) = [Kp1 Ki1 Kp2 Ki2]
- Initialize random velocities for each particle.
- Set and run simulation for each particle obtain the Ps output.
- For reducing the oscillations in the Ps waveform obtain the Ps values at each point of time
- Store the objective function value as personal best (pbest) of that particle and store this particle as pbest particle.
- Obtain the global best particle (gbest particle) which minimum of objective function.
- Update each particle velocity by the formula.
- V(i,j)= K*[w*V(i,j) + (c2*(pbest particle (i,j) – particle (i,j)) + (c1*(gbest particle (i)-particle (i,j)))]
- Obtain the new particle position by Particle (i,j) = particle(i,j) + V(i,j)
- Run the simulations for new particle positions and obtain the value of objective function for each particle
- If the objective function value is less than the pbest then update the pbest with the current objective function value.
- Obtain the gbest and gbest particle which gives minimum of objective function value among all particle.
- Repeat the step 9 to 12 until the convergence criteria is reached

4.4. Simulink Implementation of DFIG

Fig. 1 shows the Simulink diagram of DFIGPI. In this model rotor is excited by slip frequency of voltage derived from PI controller. These PI controllers are tuned using Particle swarm optimization technique. To improve transient response of active power and reactive power of DFIG

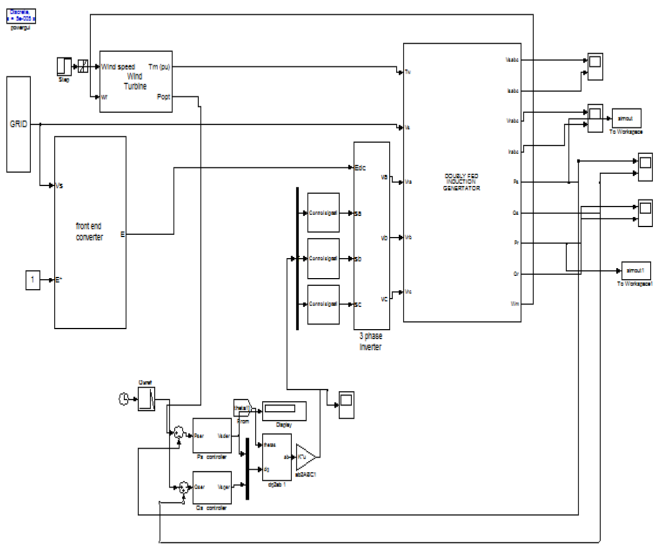

Figure 1 Simulation block diagram of DFIG

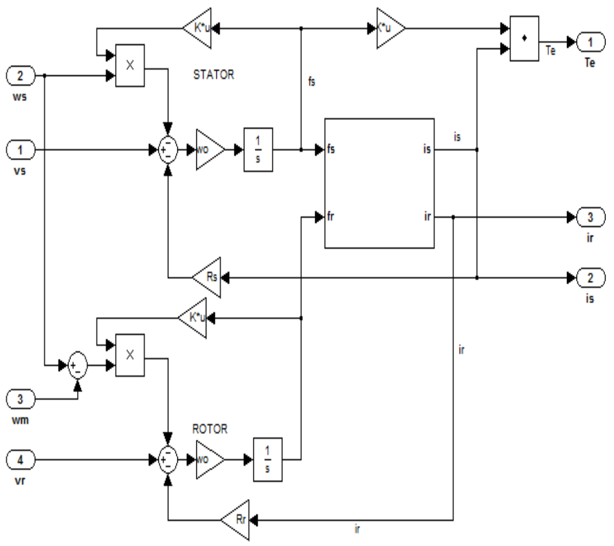

Figure 2 Dynamic model of induction machine in arbitrary reference frame

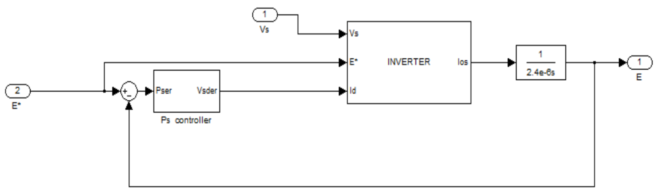

Figure 3 Simulink diagram for Grid side converter

The grid side converter is modelled through the mathematical functions in ordered to get the actual function of inverter

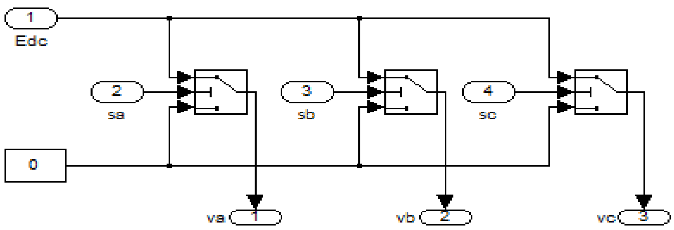

Figure 4 Simulink diagram for rotor side converter

Wind turbine output power is controlled by RSC. The power is controlled in order to follow a pre-defined power tracking characteristics.

4.5. Simulation Results

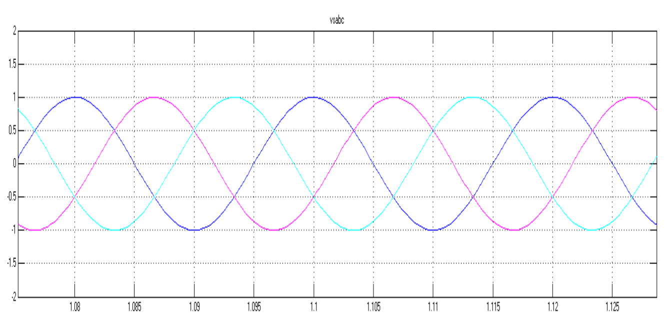

Figure 5 Three phase stator voltage.

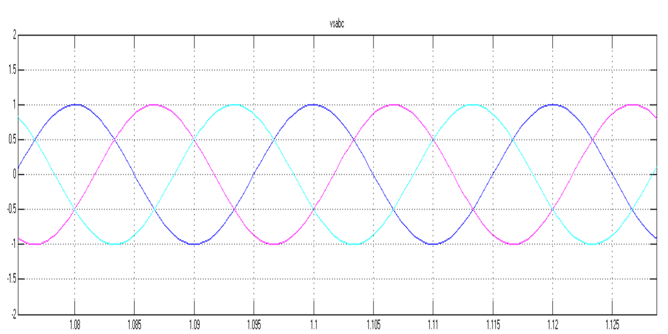

Figure 6 Three phase rotor voltage.

The above figure shows three phase open circuit voltages which are displaced by 120 electrical degrees apart. Hence from this we can say that power is generated from doubly fed induction generator.

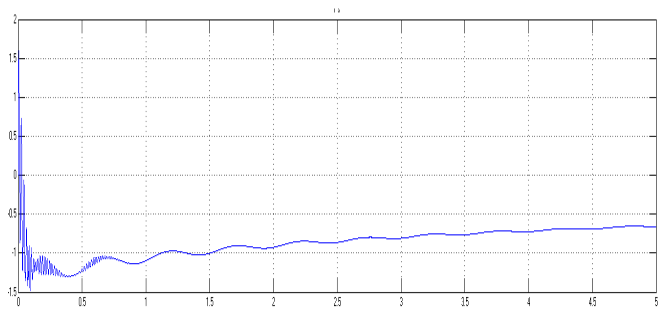

Figure 7 Stator active power.

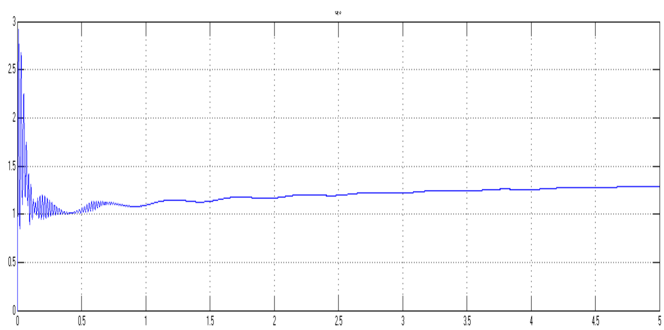

Figure 8 Stator reactive power

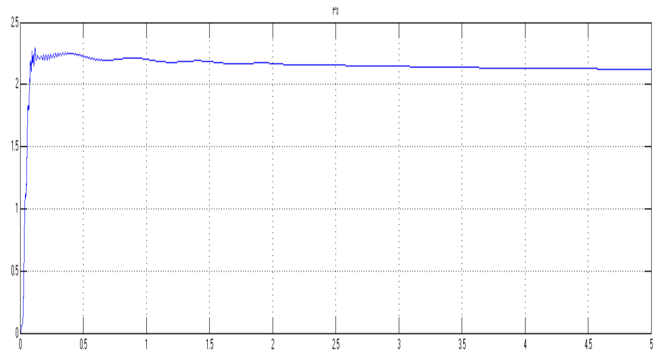

Figure 9 Rotor active power

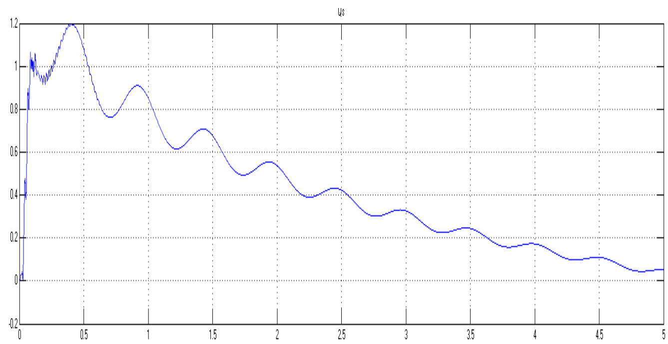

Figure 10 Rotor reactive power.

The above figures represent simulation results for one active power and other reactive power set values. These figures shows that even though there is any change in Reactive power set value the Active power is not changed and change in active power set value no change in reactive power i.e., we can achieve independent control of Active and Reactive power.

5. CONCLUSION

In this paper the active and reactive power and stator voltage of DFIG is controlled by PI controller, the tuning of these PI controllers is obtained from Particle Swarm Optimization (PSO) technique. The results obtained by the proposed method shows its effectiveness in improving the transient response of active power and reactive power of DFIG i.e., less oscillations in the powers of DFIG. Consequently leads to get a constant terminal voltage of DFIG. Proposed method also ensures an independent control of active and reactive power of DFIG

REFERENCES

[1] R.G. Almeida, E.D. Castronuovo, J.A. Peças Lopes, "Optimum Generation Control in Wind Parks When Carrying Out System Operator Requests,"IEEE Transactions Power System. Vol. 19. Pp1942-1950. 2006

[2] M.V.A. Nunes, H.H. Zurn, U.H. Bezerra, J.A. Peças Lopes, R.G.Almeida, "Influence of the Variable Speed Wind Generators in Transient Stability Margin of the Conventional Generators Integrated in Electrical Grids," IEEE Transactions on Energy Conversion. vol.19 (4), pp.692-701. 2004.

[3] João P. A. Vieira, Marcus N. A. Nunes, and Ubiratan H. Bezerra, “Design of Optimal PI Controllers for Doubly Fed Induction Generators in Wind Turbines Using Genetic Algorithm” IEEE 2008.

[4] W. Qiao, G.K. Venayagamoorthy, R.G. Harley, "Design of Optimal Control PI Controllers for Doubly Fed Induction Generators Driven by Wind Turbines Using Particle Swarm Optimization," Int. Joint Conf. on Neural Network, Vancouver, BC, Canada, pp. 1982-1987, July, 2006

[5] Y. Lei, A. mullane, G. Lightbody, R. Yacamini, "Modeling of the Wind Turbine with a Doubly Fed Induction Generator for Grid Integration Studies," IEEE Transactions on Energy Conversion. vol. 21, pp.257-264

[6] R. Datta and V. T. Ranganathan, “Variable-speed wind power generation using doubly fed wound rotor induction – a comparison with alternative schemes,’ IEEE Trans. Energy Conversion, vol. 17, no. 3, Sept. 2002, pp. 414-421.

[7] J. Morren and S. W. H. de Haan, “Ride through of wind turbines with doubly-fed induction generator during voltage dip,” IEEE Trans. Energy Conversion, vol. 20, no. 2, Jun. 2005, pp. 435-441.

[8] M. Lown, E. Swiden bank, B. W. Hogg, “Adaptive fuzzy logic control of a turbine generator system,” IEEE Trans. Energy Conversion, vol.12, no. 4, Dec. 1997, pp. 394-399.

[9] R. Pena, J. C. Clare, and G. M. Asher, “Doubly fed induction generator using back-to-back PWM converters and its application to variable-speed wind-energy generation,” IEE Proceedings – Electric Power Applications, vol. 143, no. 3, May 1996, pp. 231-241.

[10] Tapia, G. Tapia, J. X. Ostolaza, and J. R. Saenz, “Modeling and control of a wind turbine driven doubly fed induction generator,” IEEE Trans. Energy Conversion, vol. 18, no. 2, Jun. 2003, pp. 194-204.

[11] M. A. Abido, “A novel approach to conventional power system stabilizer design using tabu search,” Int. Journal Electrical Power and Energy Systems, vol. 21, no. 6, Aug. 1999, pp. 443-454.

[12] Nalinitela, k.veerasham, Rohini“Design, Simulation and control of A Doubly fed induction generator”. International Journal of Engineering Research of applications (IJERA), vol.2, Issue3,may-2012,pp.634-639

[13] Herisuryoatmojo,Arifmusthofa, A.M.B Zakariya,Iman Robandi,Sjamsjul Anam “optimal controller for doubly fed induction generator using differential evolutionary algorithm”.978-1-4799-7711-6/15/2015IEEE

[14] B.Haman,M.L.Doumbia,A.M.Bouhamida,M.Benghamem “Direct active and reactive power control of DFIG based WECS using PI and Sliding mode controllers”.978-1-4799-4032-5/14/201

[15] Swapnil Shende, Sankalp Pund, Pratik Suryawanshi, Shubhankar Potdar, Analysis of PI Controller’s Manual Tuning Technique for Residential Loads Powered by Solar Photovoltaic Arrays. *International Journal of Electrical Engineering & Technology (IJEET)* , 7(6), 2016, pp. 75–80

[16] P. Sobha Rani and Dr. A. Lakshmi Devi, Performance Improvement of Distribution System With Multi Distributed Generation Using Particle Swarm Optimization. *International Journal of Electrical Engineering & Technology (IJEET)* , 5(2), 2014, pp. 44–50