PID CONTROLLER BASED GRID CONNECTED WIND TURBINE ENERGY SYSTEM FOR POWER QUALITY IMPROVEMENT

Pathan Shabnam1, A K Priyanka2, T Vijay Muni3, S Rajasekhar4

1,2,3,4Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

Received: 13.02.2020 Revised: 17.03.2020 Accepted: 24.04.2020

Abstract
A thorough control of a breeze turbine framework associated with a mechanical plant with pid is talked about in this undertaking where a calculation has been produced permitting a control structure that uses a four-leg inverter associated with the matrix side, to infuse the accessible vitality, just as to fill in as a functioning force channel, alleviating load current aggravations and improving force quality. A four-wire framework is considered with three stage and single-stage straight and nonlinear burdens. Amid the association of the breeze turbine, the utility side controller is intended to repay the unsettling influences caused in nearness of receptive, non-direct as well as lopsided single-and intra-stage loads, notwithstanding giving dynamic and responsive power as required. At the point when there is no wind control accessible, the controller is proposed to enhance the power quality utilizing the DC-connect capacitor with the power converter joined to the lattice. The fundamental contrast of the proposed technique as for others in the writing is that the proposed control structure depends on the Conservative Power Theory deteriorations. This decision gives decoupled power and current references for the inverter control, offering truly adaptable, particular and ground-breaking functionalities. Constant programming benchmarking has been directed so as to assess the execution of the proposed control calculation for full continuous usage. The control technique is actualized and approved in equipment on top of it (HIL) in view of Opal-RT and a TI DSP. The control system is actualized and approved in MATLAB/SIMULINK. The outcomes confirmed our capacity quality improvement control, and permitted to prohibit detached channels, adding to a progressively minimized, adaptable and solid electronic execution of a keen framework based control.

Keywords: Conservative power hypothesis, Four-leg voltage source converter, Hardware-tuned in, Power quality, perpetual magnet synchronous generator.

© 2020 by Advance Scientific Research. This is an open-access article under the CC BY license [http://creativecommons.org/licenses/by/4.0/]
DOI: http://dx.doi.org/10.31838/jcr.07.07.06

INTRODUCTION
The worldwide limit of introduced wind turbines has quickly expanded over the most recent couple of years, by 2013 there were around 300 GW of introduced wind limit [1]. There have been colossal improvements in the breeze turbine industry supporting this vitality source as a standard inexhaustible asset, with aggressive expenses in $/kWh when contrasted with customary petroleum product control plants. This improvement is because of the headway in electrical generators and power gadgets. The primary issue with sustainable power source is that the power isn’t constantly accessible when it is required. With the expansion of intensity creation of inexhaustible assets, utility joining has been produced and utilized and control electronic inverters are utilized to control dynamic/receptive power, recurrence, and to help lattice voltage amidst issues and voltage droops [2]-[4]. A few control approaches have been presented in the writing for wind turbine in independent and lattice associated frameworks [5], [6]. The machine side controllers are intended to remove greatest power point from wind utilizing slope climbing control, fluffy based, and versatile controllers [7], more often than not founded on field-situated or vector control approach. The lattice side controllers are intended to guarantee dynamic and responsive power is conveyed to the network [8], [9]. So as to permit the hypothetical structure, distinctive power speculations have been proposed and actualized in electrical power frameworks to break down flow and voltage parts, for example, the prompt power (PQ) hypothesis for a three-stage framework made by Akagi [10]. In PQ hypothesis, the three-stage is changed into a two-stage reference outline so as to separate dynamic and receptive parts in an improved way.

A three-stage control hypothesis in a more expansive viewpoint has been presented, known as the Conservative Power Theory (CPT), where the current and voltage segments are determined in the three-stage shape, without requiring any reference-outline change. The execution of these hypotheses has been thought about in references . This paper proposes a control structure in three-stage fourwire frameworks that gives greater usefulness to the matrix side converter of a breeze turbine framework utilizing the traditionalist power hypothesis (CPT) as an option in contrast to producing distinctive current references for specific unsettling influences remuneration, where both single-and three-stage loads are sustained. Three-phase, four-wire inverters have been acknowledged utilizing ordinary three-leg converters with "split-capacitor" or four-leg converters . In a three-leg customary converter, the air conditioner unbiased wire is straightforwardly associated with the electrical midpoint of the DC transport. In four-leg converter, the air conditioner impartial wire association is given through the fourth switch leg. The "four-leg" converter topology has preferred controllability over the "split-capacitor" converter topology . The considered framework comprises of single-and three-stage direct and nonlinear (adjusted and unequal) loads. The CPT is utilized to distinguish and to evaluate the measure of resistive, receptive, unequal and nonlinear qualities of a specific load under various supply voltages condition for four-wire framework.

POWER QUALITY
The contemporary holder crane industry, in the same way as other industry sections, is frequently captivated by the extravagant accessories, brilliant symptomatic showcases, rapid execution, and dimensions of robotization that can be accomplished. In spite of the fact that these highlights and their in a roundabout way related PC based upgrades are key issues to a proficient terminal activity, we should not overlook the establishment whereupon we are building. Power quality is the mortar which bonds the establishment squares.

Power quality likewise influences terminal working financial aspects, crane unwavering quality, our condition, and beginning interest in power appropriation frameworks to help new crane establishments. To cite the service organization pamphlet which went with the last month to month issue of my home utility charging: “Utilizing power astutely is a decent ecological and business practice which spares you cash, diminishes emanations from producing plants, and rations our
common assets. As we are generally mindful, compartment crane execution prerequisites keep on expanding at a dumbfounding rate.

Cutting edge holder cranes, as of now in the offering procedure, will require normal power requests of 1500 to 2000 kW – practically twofold the complete normal interest three years prior. The quick increment in power request levels, an expansion in holder crane populace, SCR converter crane drive retrofits and the substantial AC and DC drives expected to power and control these cranes will build familiarity with the power quality issue in the precise not so distant future.

**Power quality issues**

With the end goal of this article, we will characterize control quality issues as: Any power issue that outcomes in disappointment or discontinuation of client gear, shows itself as a financial weight to the client, or produces negative effects on the earth. At the point when connected to the compartment crane industry, the power issues which debase control quality include:

- Power Factor
- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips
- Voltage Swells

The AC and DC variable speed drives used on board holder cranes are huge supporters of all out symphonic current and voltage twisting. Though SCR stage control makes the alternating normal power factor, DC SCR drives work at not as much as this. Also, line indenting happens when SCR’s commutate, making transient pinnacle recuperation voltages that can be 3 to multiple times the ostensible line voltage relying on the framework impedence and the extent of the drives. The recurrence and seriousness of these power framework unsettling influences fluctuates with the speed of the drive. Symphonic current infusion by AC and DC drives will be most noteworthy when the drives are working at moderate rates. Power factor will be least when DC drives are working at moderate velocities or amid introductory quickening and deceleration periods, expanding to its most extreme esteem as the administrator endeavors to spot and land the cranes. Lamentably, holder cranes can invest significant energy at low speeds.

Above base speed, the power factor basically stays consistent. Lamentably, holder cranes can invest significant energy at low speeds as the administrator endeavors to spot and land compartments. Poor power factor puts a more prominent kVA (Pv) and the setpoint (SP).

3.1 How a PID controller works

The P represents relative control, I for fundamental control and D for subordinate control. This is likewise what is known as a three-term controller. The fundamental capacity of a controller is to execute a calculation (electronic controller) in view of the control specialist’s info (tuning constants), the administrators wanted working quality (set point) and the present plant process esteem. As a rule, the necessity is for the controller to act with the goal that the procedure esteem is as near the set point as could reasonably be expected. In an essential procedure control circle, the control design uses the PID calculations to accomplish this.

3.1 How a PID controller works

The PID controller’s job is to maintain the output at a level so that there is no difference (error) between the process variable (Pv) and the setpoint (SP).
Seaward wind control alludes to the development of wind cultivates in waterways to produce power from wind. More grounded breeze speeds are accessible seaward contrasted with ashore, so seaward wind power’s commitment regarding power provided is higher and NIMBY resistance to development is normally a lot flimsier. Notwithstanding, seaward wind ranches are generally costly toward the finish of 2012, 1,662 turbines at 55 seaward wind cultivates crosswise over 10 European nations were producing power enough to control just about five million family units.

FRAMEWORK CONFIGURATION AND CONTROL DESIGN
Fig.5 demonstrates an outline of an utility associated modern framework tended to in this paper. The structure of the power converter utilized in the breeze turbine framework is a consecutive converter with a perpetual magnet synchronous generator (PMSG) associated with a similar transport with the heaps. The heaps are a blend of direct and exceedingly inductive burdens causing sounds at the PCC.

The model of the breeze turbine framework considered in this paper is depicted. The generator of the framework depends on the Permanent Magnet Synchronous Generator (PMSG). The model of the PMSG utilized in this paper is introduced.

CONSERVATIVE POWER THEORY
The Conservative Power Theory, proposed by [11], disintegrates the power and flow in the stationary edge, as indicated by terms specifically identified with electrical qualities, for example, normal power exchange, receptive vitality, lopsided burdens and nonlinearities. Expecting a conventional poly-stage circuit under occasional task (period T), where (v) and (i) are, separately, the voltage and current vectors, and (V̄) is the fair necessary of the voltage vector estimated at a given system port (stage factors are shown with subscript “m”), the CPT creators characterize:

Instantaneous active power:

$$ p(t) = v(t) \cdot i(t) = \sum_{m} v_m(t_m) i_m(t_m). \quad (1) $$

Instantaneous reactive energy:

$$ w(t) = \frac{1}{j} \int v(t) i^*(t) dt = \sum_{m} v_m(t_m) i_m(t_m). \quad (2) $$

The corresponding average values of (1) and (2) are the active power and reactive energy defined in (3) and (4), respectively as follows:

$$ P = \langle p(t) \rangle = \frac{1}{T} \int_0^T p(t) dt = \sum_{m} P_m \quad (3) $$

$$ W = \langle w(t) \rangle = \frac{1}{T} \int_0^T w(t) dt = \sum_{m} W_m \quad (4) $$

The phase currents are decomposed into three current components as follows:

Active phase currents are defined by:

$$ i_{m,a} = \frac{v_{m,a}}{\sum_{m} v_m}, \quad (5) $$

where (G_m) is the equivalent phase conductance.

Reactive phase currents are given by:

$$ i_{m,b} = \frac{1}{j} \frac{v_{m,b}}{\sum_{m} v_m}, \quad (6) $$

WIND POWER
Seaward wind control alludes to the development of wind cultivates in waterways to produce power from wind. Not at all like the ordinary utilization of the expression “seaward” in the marine business, seaward wind control incorporates inshore water territories, for example, lakes, fjords and shielded seaside regions, using customary settled base breeze turbine advances, just as profound water zones using gliding wind turbines. A subcategory inside seaward wind power can be close shore wind control.

Fig.4. Wind turbines and electrical substation of Alpha Ventus in the North Sea
Where they convey neither active power nor reactive energy. The active and reactive phase currents can be further decomposed into balanced and unbalanced terms. The balanced active currents have been defined as: \[ i_{a,b} = \langle v, i \rangle \| v \|^2 v_m = P V, v_m = G b v_m, \] (8) and such currents represent the minimum portion of the phase currents, which could be associated with a balanced equivalent circuit, responsible for conveying the total active power \( P \) in the circuit, under certain voltage conditions.

### CONTROL DESIGN

**Machine Side Controller**

The purpose of the machine side converter is to track the optimum point of the rotor to extract the maximum power existing in the turbine. For a given wind turbine, the maximum power occurs at the maximum power coefficient of the turbine. For a given wind speed there is an optimum rotor speed that gives the optimum tip speed ratio.

By realizing the tip speed proportion of the breeze turbine one can remove the greatest power from the rotor by figuring the ideal rotor speed as:

\[ \omega_{opt} = \frac{v_{opt}}{R_w}. \] (15) Then, this ideal rotor reference is subtracted from the deliberate rotor speed to deliver the speed blunder. As appeared in Fig. 2 a rotor speed controller is intended to create the quadrature current reference to the interior current controller. The immediate current reference in this paper is set to zero. The parameters and estimations of the lattice side framework and the heap are outlined in Table I.

### Grid Side Controller

In this section the current-controlled voltage source inverter is designed and modeled. The control scheme for the four-leg grid side inverter is shown in Fig. 7.

![Fig6: Control scheme of machine side control](image)

![Fig7: control scheme of grid side control](image)

Fig. 7 represents the schematic chart of the lattice tied four-leg inverter unit, comprising of a four-leg voltage source converter (VSC) and the system stack that are associated with the circulation organize at PCC. The inductance of the channel is \( L_f \) and \( R_f \) is the ohmic loss of the inductor. The machine side converter of Fig. 2 is associated in parallel with the VSC DC-interface capacitor \( C_{dc} \). It is demonstrated that the matrix side inverter unit is controlled in a abc-reference outline. \( v_{pcc} \) is managed by the network speaking to the PCC/stack voltage. The control objective is to permit the breeze source to infuse its accessible vitality, just as to fill in as a functioning force channel for enhancing power quality dependent on CPT functionalities. Fig. 8 demonstrates the circuit, containing both adjusted and uneven direct and non-straight loads.

![Fig8: configurable load](image)

### SIM LINK BLOCK DIAGRAM WITH PID CONTROLLER

The figure demonstrates that the PID Controller as utilized in the place of PI Controller. The PI Controller is supplanted with the PID Controller for the better execution in working and progressively productive. By utilizing the PID Controller we can keep up the rising time and settling time and top over shoot. The square graph demonstrates that the voltage and current estimations at the lattice side and wind turbine side and load side. The structure of the power converter utilized in the breeze turbine framework is a consecutive converter with a lasting magnet synchronous generator associated with a similar transport with the heaps. The heaps are a mix of direct and exceedingly inductive burdens.

![Fig9: Simulation diagram](image)

![Fig10: Control design](image)
This undertaking tended to a far reaching control technique for a consecutive wind turbine framework associated with a mechanical plant with PID controller. The control utilizes the four-leg inverter at the lattice side to supply accessible dynamic power from the breeze turbine framework alongside full pay of load current aggravations. The principle commitment depends on CPT to inspire the set-point reference and force unsettling influences alleviation, which adds critical adaptability to the control structure. The control structure was tried with a far reaching realtime benchmarking contextual investigation with equipment on top of it. The control calculations were assembled inside our TI DSP and approved utilizing the constant framework "Opal-RT". The calculations were repaired and are prepared for test approval in a retrofitting of a breeze turbine (future work). The outcomes indicated great execution of the calculation and the THD was enhanced for all unique task conditions. The outcomes bolster the framework displayed here which can maintain a strategic distance from establishment of dynamic channel equipment by the utility or by the modern purchaser.

REFERENCES
1. "Worldwide Wind Report Annual Market Update 2013," 2013. [Online]. Accessible: http://www.gwec.net.
2. S. Li, T. A. Haskew, R. P. Swatloski, and W. Gathings, "Ideal and Direct-Current Vector Control of Direct-Driven PMSG Wind Turbines," IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2325–2337, 2012.
3. N. Angela, M. Lisere, R. A. Mastromauro, and A. D. Aquila, "A Survey of Control Issues in PMSG-Based," IEEE Trans. Ind. Informatics, vol. 9, no. 3, pp. 1211–1221, 2013.
4. J. Lagorse, M. G. Simões, and A. Mirouë, "A Multiagent Fuzzy-Logic-Based Energy Management of Hybrid Systems," IEEE Trans. Ind. Appl., vol. 45, no. 6, pp. 2123–2129, 2009.
5. X. Tan, Q. Li, and H. Wang, "Advances and Trends of Energy Storage Technology in Microgrid," Int. J. Electr. Power Energy Syst., vol. 44, pp. 179–191, Jan. 2013.
6. P. F. Ribeiro, B. K. Johnson, M. L. Crow, A. Arsov, and Y. Liu, "Vitality Storage Systems for Advanced Power Applications," Proc. IEEE, vol. 89, no. 12, pp. 1744–1756, 2001.
7. M. G. Simoes, B. K. Bose, and R. J. Spiegel, "Fluffy Logic Based Intelligent Control of a Variable Speed Cage Machine Wind Generation System," IEEE Trans. Power Electron., vol. 12, no. 1, pp. 87–95, 1997.
8. A. Chaulan and R. P. Saini, "A Review on Integrated Renewable Energy System Based Power Generation for Stand-alone Applications: Configurations, Storage Options, Sizing Methodologies and Control," Renew. Support.Vitality Rev., vol. 38, pp. 99–120, Oct. 2014.
9. C. N. Bhende, S. Mishra, and S. G. Malla, "Lasting Magnet Synchronous Generator-Based Standalone Wind Energy Supply System," IEEE Trans. Continue. Vitality, vol. 2, no. 4, pp. 361–373, 2011.
10. H. Akagi, E. H. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning, 2007.
11. P. Tenti, H. K. M. Paredes, and P. Mattavelli, "Moderate power hypothesis, a structure to approach control and responsibility issues in keen microgrids," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 664–673, 2011.
12. A. Mortezaei, M. G. Simoes, and F. P. Marafao, "Agreeable Operating Based Master-Slave in Islanded Microgrid with CPT Current Decomposition," in Proc. IEEE PES, Denver, Colorado, USA, 2015, pp. 1–5.
13. S. Sai Chandan, T. L. Sai Kiran, G. Swapna, T. Vijay Muni, "Intelligent Control Strategy for Energy Management System with FC/Battery/SC", JCR. 2020; 7(2): 344-348. doi:10.31838/jcr.07.02.66
14. Mounika Muppavarapu, G G Rajasekhar, T Vijay Muni, R R Prakash, ENHANCEMENT OF POWER QUALITY IN A GRID CONNECTED IDE BASED PV INVERTER JCR. 2020; 7(2): 340-343. doi:10.31838/jcr.07.02.65
15. Muni, T. V., & Lalitha, S. V. N. L. (2019). Power management strategy in solar pv system with battery protection scheme in dc microgrid, International Journal of Innovative Technology and Exploring Engineering, 8(6), 960–964.
16. Vijay Muni, T., & Lalitha, S. V. N. L. (2019). Fast acting mppt controller for solar pv with energy management for dc microgrid. International Journal of Engineering and Advanced Technology, 8(5), 1539–1544.
17. Vijay Muni, T., Satya Pranav, A., & Amara Srinivas, A. (2020). IoT based smart battery station using wireless power transfer technology. International Journal of Scientific and Technology Research, 9(1), 2876–2881.
18. Muni, T.V. and Varma, P.S. and Priya, S.K. and Bhavya, J. and Rajasekhar, S., "Energy management in a DC microgrid with energy storage system", Journal of Advanced Research in Dynamical and Control Systems, 2020, 12(2), 130-136, 10.5373/JARDCS/V12I2/S202010015.