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Enhancing Power Quality with a Grid-Connected Wind Turbine PID Controller

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Abstract: This project discusses the comprehensive control of a wind turbine system integrated with a mechanical plant using a Proportional-Integral-Derivative (PID) controller. The project presents an algorithm that enables a control structure utilizing a four-leg inverter connected to the grid side. This control structure serves the purpose of injecting the available energy and functioning as an active power filter, mitigating load current disturbances and enhancing power quality. In this study, we examine a four-wire structure that incorporates three stages and includes both single-stage straight and nonlinear loads. In the context of wind turbines, the utility side controller serves the purpose of mitigating disturbances that arise due to the presence of reactive, non-linear, and unbalanced single- and multi-phase loads. Additionally, it is responsible for delivering dynamic and responsive electricity in accordance with the system's requirements. In situations when wind power is unavailable, it is recommended to utilise a controller that enhances power quality by employing a DC-link capacitor in conjunction with a power converter connected to the grid. The primary distinction of the suggested methodology, in comparison to existing approaches in the field, lies in its reliance on the deteriorations of the Conservative Power Theory as the basis for its control structure. This choice provides separate power and current references for the inverter control, hence giving very versatile, specific, and powerful features. Continuous benchmarking of programming has been conducted in order to evaluate the performance of the suggested control algorithm for uninterrupted and continuous operation. The control approach is implemented and validated in hardware-in-the-loop (HIL) systems utilising Opal-RT and a Texas Instruments digital signal processor (DSP). The control system is implemented and validated using MATLAB/SIMULINK. The results validated our ability to enhance quality control and allowed for the exclusion of separate channels, contributing to a more streamlined, adaptive, and reliable implementation of an intelligent system-based control.

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

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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,[2] 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[3]. The primary issue with sustainable power sources is that the power isn't constantly accessible when it is required[4]. With the expansion of intensity creation of inexhaustible assets, utility joining has been produced and actualized and control electronic inverters are utilized to control dynamic/receptive power, recurrence[5], and to help lattice voltage amid issues and voltage droops A few control approaches have been presented in the writing for wind turbine in independent [6]and lattice associated frameworks. The machine side controllers are intended to remove the 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]. To permit the hypothetical structure, distinctive power speculations have been proposed and actualized in electrical power frameworks to break down flow and voltage parts[9], 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 to separate dynamic and receptive parts in an improved way.

With the end goal of this article, [11]we will characterize control quality issues as: Any power issue that outcomes in disappointment or disoperation of client gear, shows itself as a financial weight to the client, or produces negative effects on the earth[12]. 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[13]

1. FRAMEWORK CONFIGURATION AND CONTROL DESIGN

Fig.1 demonstrates an outline of a utility associated with 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 [14]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[15].

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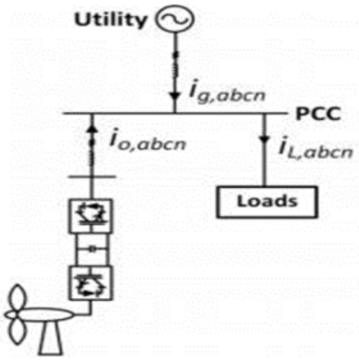

Fig 1: Single line diagram of the addressed industrial system with wind turbine system.

The model of the breeze turbine framework considered in this paper is depicted [16]. The generator of the framework depends on the Permanent Magnet Synchronous Generator (PMSG). The model of the PMSG utilized in this paper is introduced [17].

2. 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 (seen fig 2). 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.

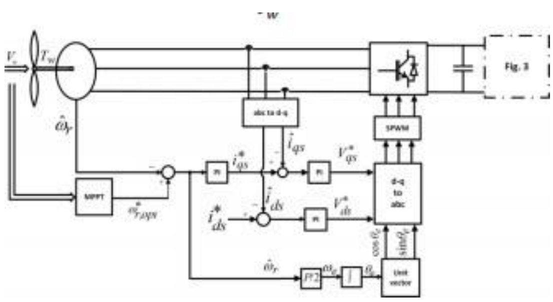

Fig2: Control scheme of machine side control

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: $\omega w,opt = vw\lambda opt\ Rw$. (15) Then, this ideal rotor reference is subtracted from the deliberate rotor speed to deliver the speed blunder[18]. 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 detail of the controller plan strategy is displayed. The parameters and estimations of the lattice side framework and the heap are outlined in Table I.

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TABLE I
PMSG Parameters and Wind Turbine Specifications

Parameters	Values
Stator resistance, R_s	0.672 ohm
d-axis leakage inductance, L_d	13.74 mH
q-axis leakage inductance, L_q	13.74 mH
Flux linkage, ψ_m	2.39Wb
Number of poles of machines, P	24
Voltage	500V
Nominal output power of wind turbine	10 kW
Base wind speed	10 m/s
Base rotor speed	200 rpm

3. Grid Side Controller

In this section the current-controlled voltage source inverter is designed and modelled. The control scheme for the four-leg grid side inverter is shown in Fig. 3.

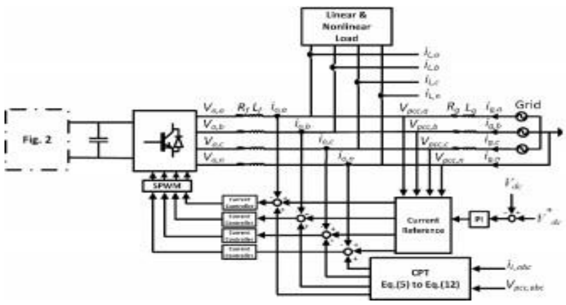

Fig3: control scheme of grid side control

Fig. 3 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 Lf and Rf is the ohmic loss of the inductor. The machine side converter is associated in parallel with the VSC DC- interface capacitor Cdc. It is demonstrated that the matrix side inverter unit is controlled in a abc-reference outline. $vpcc$ 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. 4 demonstrates the circuit, containing both adjusted and uneven direct and non-straight loads.

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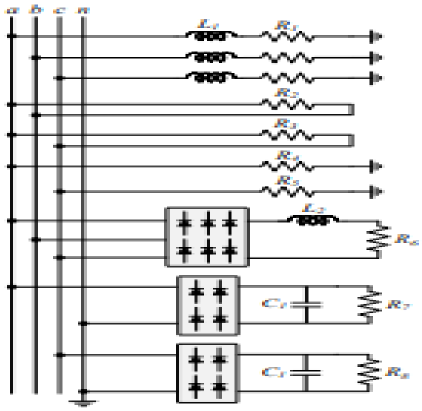

Fig4: Simulation diagram

3.1 SIM LINK BLOCK DIAGRAM WITH PID CONTROLLER

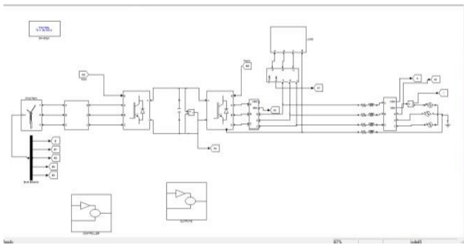

Fig5: Simulation diagram

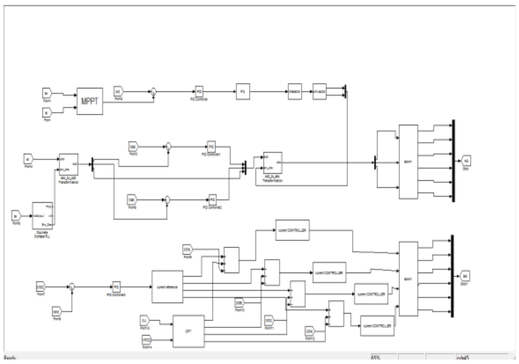

Fig6: Control design

4. SIMLINK RESULTS

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 settling time and top overshoot. The square graph demonstrates that the voltage and current estimations at

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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.

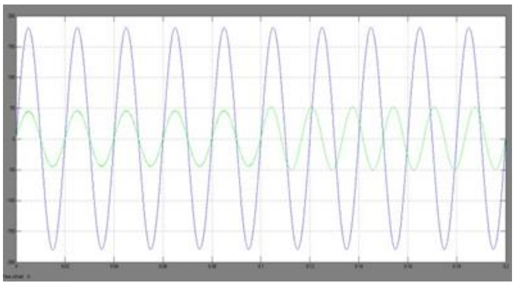

Fig7: Active power reactive power delivery pcc voltage and inverter current

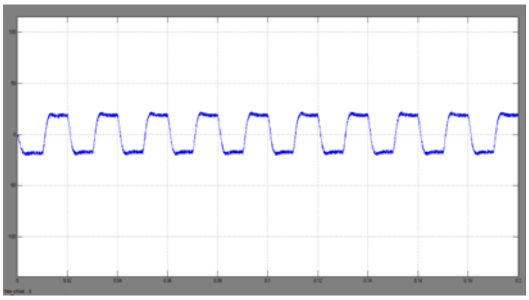

Fig8: Grid neutral current and inverter neutral current

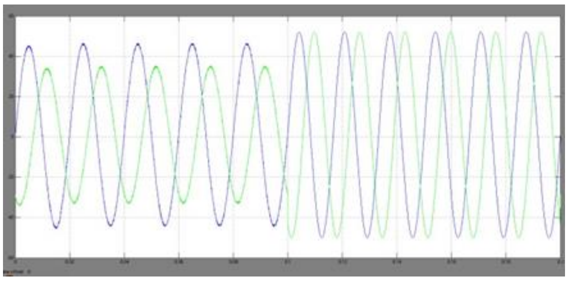

Fig9: Two phases of grid currents

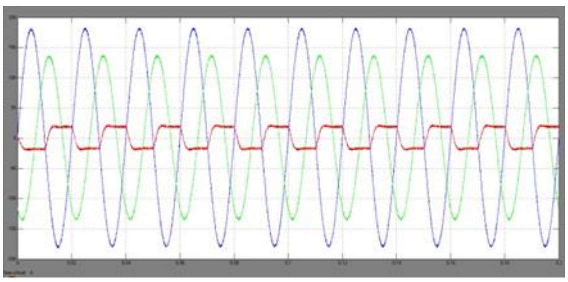

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Fig10: Active power delivery and non-active compensation

5. CONCLUSION

This project focused on a comprehensive control method for a wind turbine framework connected to a mechanical plant using a PID controller. The control makes use of the four-leg inverter on the lattice side to deliver both the full pay of load current augmentations and available dynamic power from the wind turbine system. The primary commitment relies on CPT to motivate the set-point reference and compel the reduction of unsettling impacts, adding vital flexibility to the control structure. A comprehensive real-time benchmarking contextual examination was conducted on top of the control framework. The control computations were put together on our TI DSP and authorized using the "Opal-RT" constant framework. The calculations were adjusted, and they are now ready for testing approval during a breeze turbine refit (future work). The results showed excellent computation performance, and the THD was improved for each special job condition. The results support the architecture presented here, which can prevent the utility or a contemporary buyer from establishing dynamic channel equipment.

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