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PERFORMANCE ANALYSIS AND CONTROL FOR AN OFF GRID WIND ENERGY CONVERSION SYSTEM

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Abstract: Nowadays energy need depends majorly on conventional resources and since, these resources are limited in supply; and the demand is increasing significantly, the focus is shifted towards the non conventional energy resources. Wind energy is one of the most trusted technologies in terms of cost of electricity generation hence, Wind Energy Conversion System (WECS) is deployed for meeting the needs. In this paper durability and control of hybrid Wind/Battery system has been investigated. The choice of hybridisation increases the efficiency of the system considering the intermittent nature of wind flow. This off grid system is highly needed in areas like coastal regions and isolated areas where transmission lines cannot be installed easily. To ensure controlled charging/discharging of battery, state of charge has been developed and the mechanical safety of the WECS has been assured by means of the pitch control technique. Both of these control strategies have been integrated and the efficacy has been validated by testing the system with various load and wind profiles in MATLAB/SIMULNIK.

Index Terms: MATLAB, Pitch Control, State of Charge (SoC), Wind Energy Conversion System (WECS), Maximum Power Point Tracking (MPPT).

I. INTRODUCTION

Energy is the main input for the development of any nation. Presently, the conventional resources are depleting at a great rate, therefore use of renewable resources have to be implemented to meet the increasing demand of energy, electricity is being produced at low cost [1]. The wind energy is accepted to be a great source of clean energy for upcoming generation [2].

Since, wind flow is probabilistic hence, careful testing is needed to be carried out to obtain an efficient control strategies for Wind Energy Conversion System (WECS). Many off grid loads are being powered by non-conventional source of energy, with this interest a great deal of research has been being carrried out for deciding a right generator for an off grid WECS. A detailed comparison between asynchronous and synchronous generators for wind farm application has been made [3]. Asynchronous machine is used because it provides variable speed operation also reduces torque fluctuation. Induction generator is robust and simple to operate, but at isolated points it needs capacitor banks [4].

In this paper Self Excited Induction Generator (SEIG) is used. The excitation phenomenon of SEIG has been explained in detail [5]. The output developed by SEIG is dependent on wind flow, to avoid varying voltage and flicker the WECS is incorporated with electronic converters to ensure regulated voltage [6] and also to avoid intermittent characteristics of wind battery storage. Hence, a hybrid wind battery system is considered to meet the load demand of an off grid telecom station. It is taken as a dc load which needs a 50V as a nominal regulated voltage. The MPPT and state of charge (SoC) are the parameters when charging of battery bank is considered [7].

The battery bank connected acts as a source when charging and as a load when it is discharging. Figure 1 gives the complete layout of the model used [8].

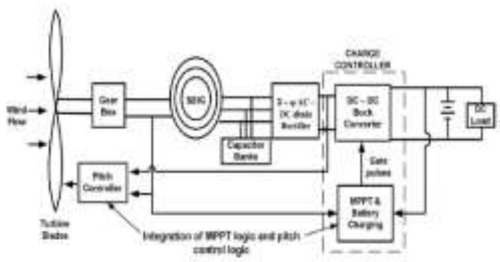

Figure 1: Model Layout

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The control of WECS has been performed in two ways:

i. Pitch Control
ii. Charge Control (Battery Charging)

II. CONTROL STRATEGY OF HYBRID WIND BATTERY SYSTEM

The proposed hybrid system which has WECS and battery storage in hybrid form uses a 400Ah, C/10 Pb (acid) battery. Designed system is for a three Kw off grid dc load, since the load is an off grid load for self excitation the stator of SEIG is connected to capacitor bank. The output which is generated is in ac form, hence, it is made to go through a rectification process by an uncontrolled diode rectifier. When there is no wind power available the role of battery storage comes into play. The control logic is used to link a hybrid system to load, dc to dc buck converter is used as a charge controller, output of rectifier is passed through this which determines the charging and discharging rate of the battery. The MPPT algorithm helps in battery bank charging while mechanical and electrical parameters have been controlled by the pitch control mechanism.

III. PITCH CONTROL MECHANISM

Output power regulation of wind turbine is achieved through the blade pitch control, which has been dominantly used in recent years [9]. The output power of wind turbine is directly proportional to cube of wind velocity**.** Generally, the cut-off wind speed of a modern Wind Turbine (WT) is much higher as compared to the rated wind speed [10]. If the wind turbine is made to function for an entire range of wind speed without any control mechanism,damage to the blades can be done if angular speed of shaft exceeds its rated value[11] this could be achieved by varying the pitch angle. The relation between the tip speed ratio and power coefficient is established as shown in Figure 2[12]. The power coefficient is determined by the Tip Speed Ratio (TSR) λ, which is characterized by the air flow around the blades [13].The pitch control mechanism controls the power output by reducing the power coefficient at higher wind speeds; below the rated wind speed the blade pitch is maintained at zero degree to obtain maximum power. The pitch controller increases the blade pitch as the WT parameters exceeds the rated value. In figure 3 the pitch control mechanism simulation model has been shown.

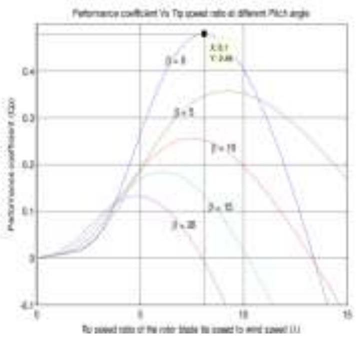

Figure 2: TSR vs Power Coefficient

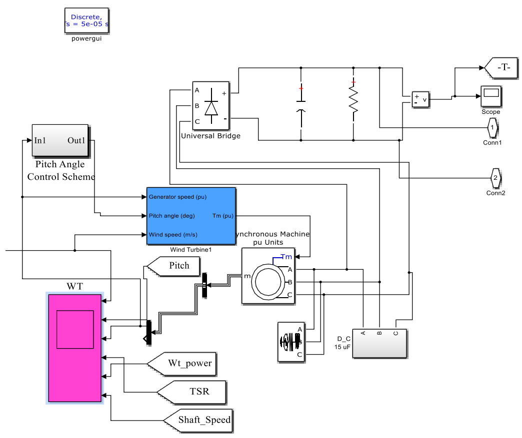

Figure 3: Simulation Model of the Pitch Control Mechanism

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IV. CHARGE CONTROL MECHANISM

This control mechanism involves battery storage charging and discharging technique because no physical parts are controlled[14]. The charge controller with rating of 400 Ampere-Hour (Ah) is charged at C/10 rate where, C denotes Ah. However, the current required for charging the battery bank depends on the battery SoC, A typical battery generally charges at a constant current (CC), i.e., C/10 rate mode till battery SoC reaches a certain level (90%–98%) [8]. The charge control logic is shown in figure 4 control is performed by 3 nested loops, the MPPT logic has been performed by comparing actual TSR to optimum TSR and the error is tuned by a PI controller [8].

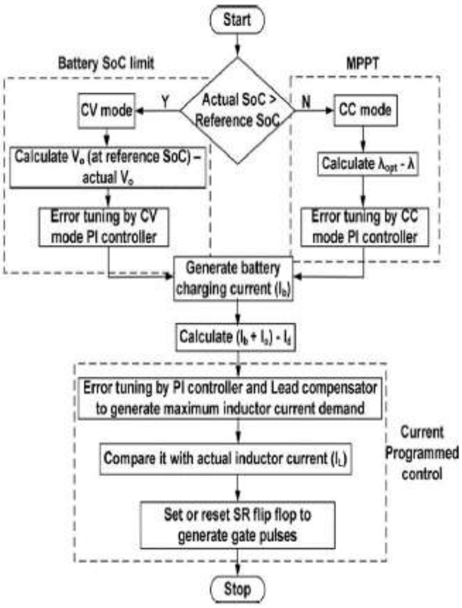

Figure 4: Charge Control Logic

MODES OF BATTERY CHARGING:

A. CONSTANT CURRENT (CC)
B. CONSTANT VOLTAGE(CV)

CONSTANT CURRENT MODE:
Charging mode is decided from MPPT logic. It is taken from converter output all the power is taken and transferred to batteries for charging, current that is obtained is not always same it fluctuates with the speed of wind.
In the CC mode, the battery voltage and SoC rise fast with time, however the charge controller should not overcharge the batteries to avoid gasification of electrolyte[15].

CONSTANT VOLTAGE MODE:
Controller switches from CC mode to CV mode when State of Charge (SoC) becomes same as that of reference SoC. The output of converter is maintained at constant value, in this mode SoC and voltage of battery rise slowly w.r.t time.
Figure 5 shows complete simulation model for hybrid wind-battery system.

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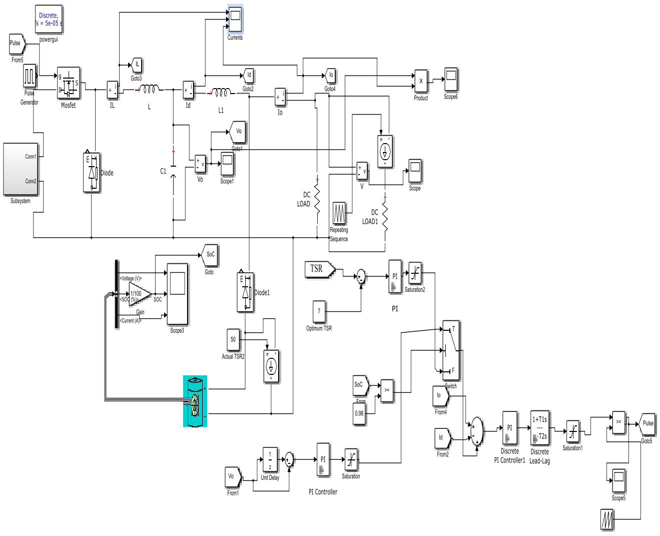

Figure 5: Final Hybrid Wind-Battery Simulation Model

V. SPECIFICATION AND PARAMETERS:

WIND TURBINE SPECIFICATION:

PARAMETERS	VALUES
Rated Power	4000W
Cut in wind speed	4 m/s
Rated wind speed	10 m/s
Optimum TSR	7

BATTERY SPECIFICATION:

PARAMETERS	VALUES
Ampere Hour Rating	400 Ah
Nominal Voltage	48 V
Charging Rate	C/10

VI. SIMULATION RESULTS

WIND PARAMETERS OUPUT WAVEFORM:
Figure 6 represents wind turbine parameters output waveforms which are responsible for pitch control mechanism:
Base wind speed (m/s) = 12 m/s
Max power at base wind speed (p.u of nominal mechanical power) = 0.73
Base rotational speed (p.u. of base generator) = 1

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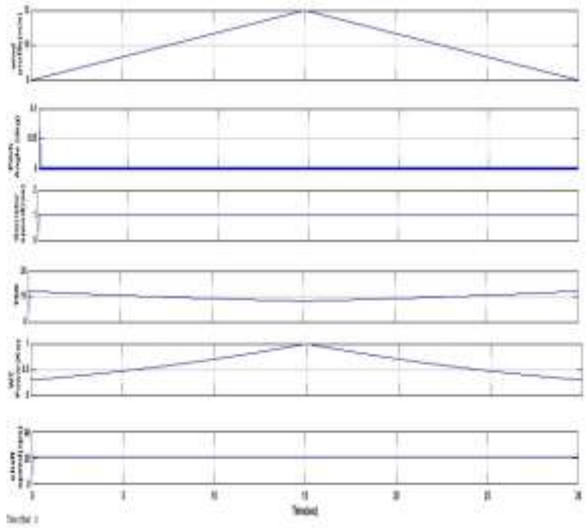

Figure 6: WT Parameters Output

BATTERY PARAMETERS OUTPUT WAVEFORM:

Figure.7 shows battery parameters output:
Nominal Voltage value is set to 48v
Rated capacity = 400Ah
Initial state of charge = 97.95%

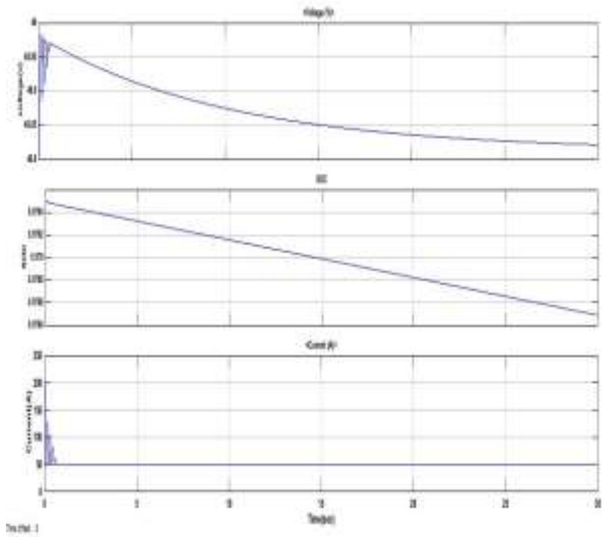

Figure 7: Battery Parameters Output

VII. CONCLUSIONS

The Power obtained by wind turbines is not reliable owing the fact that wind supply is intermittent therefore, to overcome this problem a sustainable battery bank has been introduced. Hence, in this paper a hybrid wind battery system has been incorporated to meet the desired need. The use of controllers eliminate the random characteristic of wind flow. The pitch control mechanism ensures mechanical safety however, charge controllers and battery charging/discharging ensures proper power supply to the load. The obtained results show better efficiency of the system.

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VIII. REFERENCES

[1] R. David Richardson and G. M. McNerney, "Wind Energy Systems," Proc. IEEE, vol. 81, no. 3, pp. 378–389, 1993, doi: 10.1109/5.241490.
[2] R. Saidur, M. R. Islam, N. A. Rahim, and K. H. Solangi, "A review on global wind energy policy," Renew. Sustain. Energy Rev., vol. 14, no. 7, pp. 1744–1762, 2010, doi: 10.1016/j.rser.2010.03.007.
[3] O. Meroz, D. Ben-ayoun, O. Beeri, and Y. Gelbstein, "Generation Applications," J. Alloys Compd., vol. 679, no. 1, pp. 196–201, 2016, [Online]. Available: http://dx.doi.org/10.1016/j.jallcom.2016.04.072.
[4] D. K. Palwalia and S. P. Singh, "Design and implementation of induction generator controller for single phase self excited induction generator," 2008 3rd IEEE Conf. Ind. Electron. Appl. ICIEA 2008, pp. 400–404, 2008, doi: 10.1109/ICIEA.2008.4582547.
[5] R. C. Bansal, "Three-phase self-excited induction generators: An overview," IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 292–299, 2005, doi: 10.1109/TEC.2004.842395.
[6] A. Chakraborty, "Advancements in power electronics and drives in interface with growing renewable energy resources," Renew. Sustain. Energy Rev., vol. 15, no. 4, pp. 1816–1827, 2011, doi: 10.1016/j.rser.2010.12.005.
[7] K. Y. Lo, Y. R. Chang, and Y. M. Chen, "Battery charger with MPPT function for stand-alone wind turbines," 2010 Int. Power Electron. Conf. - ECCE Asia -, IPEC 2010, vol. 2, no. 1, pp. 932–937, 2010, doi: 10.1109/IPEC.2010.5543872.
[8] A. S. Satpathy, N. K. Kishore, D. Kastha, and N. C. Sahoo, "Control scheme for a stand-alone wind energy conversion system," IEEE Trans. Energy Convers., vol. 29, no. 2, pp. 418–425, 2014, doi: 10.1109/TEC.2014.2303203.
[9] M. H. Mughal and L. Guojie, "Review of pitch control for variable speed wind turbine," Proc. - 2015 IEEE 12th Int. Conf. Ubiquitous Intell. Comput. 2015 IEEE 12th Int. Conf. Adv. Trust. Comput. 2015 IEEE 15th Int. Conf. Scalable Comput. Commun. 20, pp. 738–744, 2016, doi: 10.1109/UIC-ATC-ScalCom-CBDCom-IoP.2015.148.
[10] F. Díaz-gonzález, A. Sumper, O. Gomis-bellmunt, and R. Villafáfila-robles, "A review of energy storage technologies for wind power applications," Renew. Sustain. Energy Rev., vol. 16, no. 4, pp. 2154–2171, 2012, doi: 10.1016/j.rser.2012.01.029.
[11] A. I. Generator, "Design of Adjustable Blade Wind Turbine for Constant Generated Power," pp. 1–5.
[12] M. A. Hossain, "Approach to Harmonic Mitigation Study in Wind Turbine Energy Conversion Systems Using Three Phase Boost Rectifiers," IOSR J. Eng., vol. 4, no. 3, pp. 21–26, 2014, doi: 10.9790/3021-04342126.
[13] J. D. M. De Kooning, L. Gevaert, J. Van De Vyver, T. L. Vandoorn, and L. Vandevelde, "Online estimation of the power coefficient versus tip-speed ratio curve of wind turbines," IECON Proc. (Industrial Electron. Conf., pp. 1792–1797, 2013, doi: 10.1109/IECON.2013.6699403.
[14] M. Ramaswamy, "for a Standalone Solar Photovoltaic," pp. 4–10, 2016.
[15] K. Lo, Y. Chen, and Y. Chang, "MPPT Battery Charger for Stand-Alone Wind Power System," vol. 26, no. 6, pp. 1631–1638, 2011.

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