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Control of Hybrid Diesel-Wind-PV based Energy Generation System with Brushless Generators by GSM

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Abstract:
This paper presents an experimental implementation of automation by using GSM technology in a standalone microgrid topology based on a single voltage source converter (VSC) and brushless generators. The microgrid system is energized with different renewable energy sources namely wind and solar PV array from the commands given by GSM to a remote location. However, a diesel generator (DG) set and a battery energy storage system (BESS) are also used to maintain the reliability of the system. The proposed topology has the advantage of reduced switching devices and simple control. The implemented topology has DG set as an AC source. The wind generator and the solar PV array are DC sources which are connected to the DC link of the VSC. The BESS is also used at the DC link to facilitate the instantaneous power balance under dynamic conditions. Along with the system integration, the VSC also has the capability to mitigate the power quality problems such as harmonic currents, load balancing and voltage regulation. A wide variety of test results are presented to demonstrate all the features of the proposed system. The application of GSM technology will reduce the man power, saves time, most dynamic and reliable.

Index Terms: Brushless Generator, Composite Observer, Power Quality, and Standalone Micro grid, Voltage Regulation, Voltage Source Converter, Block Diagram and GSM.

I. INTRODUCTION

There are many locations in the world where the small localities are developed far away from the well-developed societies. It is technically and economically difficult to setup a transmission system to make electricity available there due to the cost incurred, the problems related to grounding of the transmission tower at hilly areas and ROW (Right of Way) problems due to forests in between. However on the other hand, these areas have abundance of natural resources like solar energy, wind, hydro etc. Due to uncertain nature of all these renewable energy sources, a small self-sustaining supply system cannot be established which can supply the loads continuously. To make the system self-sustaining, some reliable sources are required. Therefore, generally a diesel generator is used at these sites. To account for randomness of the natural resources, a full rating diesel generator is a costly option. Some energy storage device can be employed there, which reduces the diesel generator rating and considerable fuel consumption. As described earlier, since the system is setup at a remote area, the brushless generators [1] are used to avoid the maintenance as much as possible. The proposed topology in this paper includes solar PV array and wind energy as natural resources. A substantial literature is available for different topologies, control, operational aspects, power electronics of the wind and solar PV systems [2-5]. Authors have proposed many topologies, control algorithms and operation strategies for the micro grid system with many energy sources. Like DFIGs (Doubly Fed Induction Generators) are used for wind and diesel based system [6], where the controller is optimizing the fuel consumption and regulating the voltage and frequency of the system with maximum available power extraction from wind. Different operating strategies to include wind power in a diesel based system to save fuel and to reduce the overall cost of the system is proposed in [7,8]. A time frame based control algorithm is proposed in [9] for a wind-diesel system with an energy storage. In this paper, authors have proposed an ESS (Energy Storage System) to account for wind randomness and fuel cost. A standalone hybrid wind-solar system with engine generator and a battery is proposed in [10], where the operational aspects and topology are described. The proposed topology has six VSCs to integrate the complete system. Lin *et. al.* [11] have proposed a solar and diesel–wind hybrid generation system with BESS, in which synchronous generator is used for a diesel generator which requires AVR (Automatic Voltage Regulator) and speed governor for voltage and frequency regulation. Yogianto *et. al.* [12] have proposed different configurations of a hybrid system using solar PV array, wind and diesel systems. An optimal operation of solar PV/diesel hybrid system without storage is described in [13]. With the given load profile of an area for whole day, size and scheduling of the generator are performed to maximize the generator efficiency. Similarly to reduce the battery size and to increase efficiency of the system, an ultra-capacitor is used with the battery to exchange power during dynamics and the battery is used to supply under sustained load generator power mismatch [14]. Along with these different topologies and control strategies, other studies are also reported in the literature. Simulation studies are carried out for a microgrid system with many sources and energy storage devices with different controllers to regulate frequency of the system [15]. Different generators are used with the diesel engine and the studies are performed with diesel, PV and diesel-PV mixed generation. Moreover, the short circuit studies are performed on the system by Bonanno *et. al*[16]. Reliability evaluation of a wind-diesel-battery based system is reported by Liu et.al. [17], where wind energy conversion system reliability is obtained taking into consideration the wind fluctuations and component failure. Moreover, the reliability analysis of the complete system is also performed by taking diesel, wind and battery. The control of a PMSG (Permanent Magnet Synchronous Generator) based WECS (Wind Energy Conversion System) connected to an inverter with battery acting as grid is presented in [18]. The power generated by WECS is used to control the SOC of battery. In most of the systems, described in the literature, variable speed wind energy conversion system operates to extract the maximum power from the wind. Wind energy is free energy at the operation stage, so it is beneficial to extract the maximum power and to increase the efficiency and the utilization of WECS. It needs initial capital cost, but the fuel is free. There are many topologies and algorithms reported for MPPT in WECS and solar PV system. As in [19-21] different methods for MPPT in WECS are proposed like algorithm similar to hill climbing, the mechanical sensor less MPPT algorithm with the current controlled inverter and the mechanical sensor less MPPT algorithm with a boost converter. Basic MPPT algorithms for solar PV system are described in [22, 23]. These are perturb and observe algorithm and incremental conductance based algorithm. Moreover, a control algorithm is required to control the VSC connected for its operation as voltage and frequency controller, mitigating power quality problems and integrating the DC sources with AC sources. Many basic control algorithms are reported in the literature. Singh *et. al.* [24] has reported SRF, IRPT and ADALINE based control algorithms and Icos phi based algorithm for DSTATCOM [25]. An advanced control algorithm based on composite observer is reported in [26]. Composite observers are used to extract harmonic components from any signal and then the extracted fundamental is further used in this control algorithm [27, 28]. This paper deals with an implementation of a reduced converter topology of a diesel-wind-solar PV based standalone microgrid system with the battery energy storage system (BESS). These generators are synchronous reluctance generator (SyRG) and permanent magnet brushless DC generator (PMBLDCG). Both these generators are brushless in construction. The wind and solar PV systems are always operated at their maximum power point using boost converters and the diesel generator is operated within a specified power range to optimize the efficiency of the diesel generator. A VSC is used to integrate the DC sources with the AC sources with the bidirectional power flow capability and the power quality improvement capability. A mechanical sensor less MPPT algorithm is used for WECS and an incremental conductance based MPPT algorithm is used for solar PV system.

II. STANDALONE MICROGRID TOPOLOGY

The proposed system is a diesel-wind-solar PV based standalone microgrid with the battery energy storage to feed the local loads. The complete system topology is shown in Fig. 1. A synchronous reluctance generator (SyRG) is used as a diesel generator and a permanent magnet brushless DC generator as a wind generator. These generators are selected purposefully due to the following reasons. Both these generators are brushless generators that reduces the maintenance cost relative to the brushed ones. For a diesel generator, Synchronous Generator is used rather than a conventional synchronous generator, so the need of a speed governor and AVR is eliminated yet the voltage and frequency of the system are regulated using VSC. The PMBLDC generator is driven by a wind turbine. As shown in Fig. 1, the WECS is connected at the DC link of the VSC through a diode rectifier and a boost converter. PMBLDCG is best suited for an uncontrolled rectification due to trapezoidal back emf. If the winding currents are also made quasi-square wave, then a low ripple torque is produced and the machine operates smoothly. This feature is not there with PMSG as the EMF generated is sinusoidal, so the quasi square wave currents produce a fluctuating torque. Moreover, the energy density of the PMBLDC machine is high which makes it small in size, hence good option for pole mounting application. The proposed topology also includes solar PV system which is also connected to the DC link of the VSC for power transfer to the AC side where loads are present. As discussed earlier, to maintain the power balance and reliability of the supply, the battery energy storage device is required. Hence, a battery bank is also installed at the DC link of the VSC.

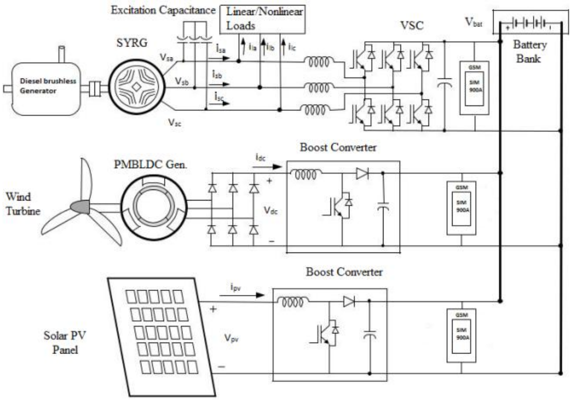


Figure.1. Proposed single VSC and brushless generation based standalone microgrid system with GSM

CONTROL STRATEGY FOR PROPOSED STANDALONE MICROGRID SYSTEM

The proposed system topology has many sources, so an operational strategy is developed to optimize the fuel efficiency and to maximize the extraction of free energy available. The diesel generator is the only AC source in the system, so the system and the load end frequency is related to the operation of the diesel generator only. A constant frequency of the system means the constant speed of the generator (as the generator is synchronous reluctance generator). It is stated in [29] that with fixed speed operation of the diesel engine, the fuel consumption doesn't vary much from its value at full load, thus making the diesel engine fuel efficiency poor at lighter loads. The diesel engines operate at reasonable good efficiency between 80%-100% loading.

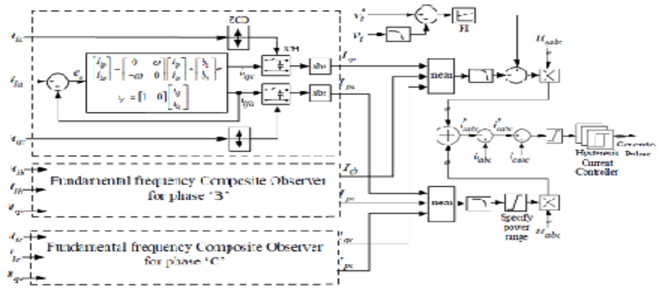


Figure.2. Control Stratedy

EQUATION

A.Mechanical Sensorless Based MPPT Algorithm for WECS

The wind energy is free energy as there is no fuel cost, so WECS is operated to extract the maximum available power from the wind. An MPPT algorithm is used to perform this task. To simplify the control and to make it cost effective, an MPPT algorithm is used which doesn't require measurement of any of wind speed, rotor speed or turbine speed [21]. Hence, mechanical speed sensor is eliminated by virtue of proposed system configuration and control algorithm. A perturb and observe based MPPT algorithm is used to control the boost converter which extracts the maximum power from the wind generator. The mathematical formulation for MPPT algorithm is described as,

$$(\Delta i_{dc} > 0 \; \& \; \Delta p_{dc} > 0) \; OR \; (\Delta i_{dc} < 0 \; \& \; \Delta p_{dc} < 0); \; i_{ref} = i_{dc} + \delta$$

$$(\Delta i_{dc} > 0 \; \& \; \Delta p_{dc} < 0) \; OR \; (\Delta i_{dc} < 0 \; \& \; \Delta p_{dc} > 0); \; i_{ref} = i_{dc} - \delta$$

Block Diagram for Hybrid Diesel-Wind-PV System

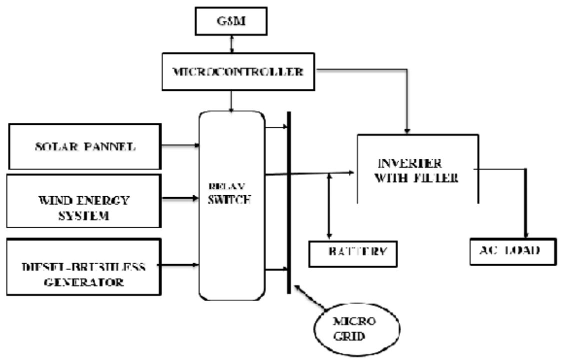
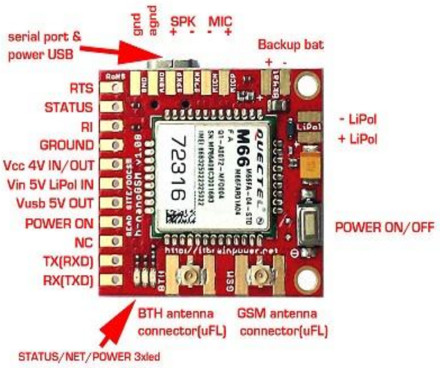


Figure.3. Block Diagram for Hybrid Diesel-Wind –PV System by using GSM Based Switch

The output of the three power plant or input sources are directly connected to the microgrid topology system from the output of microgrid is directly connected to the battery energy storage system (BESS). If we need to operate any AC load means with the help of inverter easily convert from DC to AC source then harmonics or any power quality issues are reduced by using of filter. Due to bad weather or atmospheric condition wind and solar systems are does not operate simultaneously on that time diesel brushless generator is operate with the help of GSM-based relay switch. There is no back up charge in battery by using brushless diesel generator to continuously charging the battery and also given to the appropriate loads.

GSM: GSM (Global System for Mobile Communications, originally Groupe Special Mobile) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation digital cellular networks used by mobile devices such as tablets, first deployed in Finland in December 1991.[2] As of 2014, it has become the global standard for mobile communications – with over 90% market share, operating in over 193 countries and territories.[3] 2G networks developed as a replacement for first generation (1G) analog cellular networks, and the GSM standard originally described as a digital, circuit-switched network optimized for full duplex voice telephony. This expanded over time to include data communications, first by circuit- switched transport, then by packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution,orEGPRS).Subsequently, the 3GPP developed third-generation (3G) UMTS standards, followed by fourth-generation (4G) LTE Advanced standards, which do not form part of the ETSI GSM standard.



III. XPERIMENTAL RESULTS AND DISCUSSION

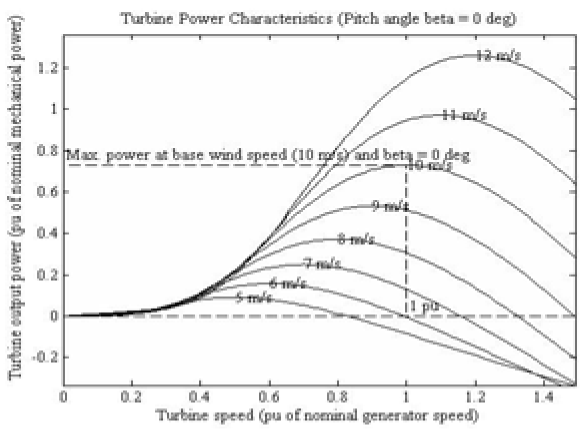
An experimental prototype of the proposed microgrid system described above is developed in the laboratory and the control algorithm and the operation strategy are verified on this system. The system information is provided in Appendix. The diesel generator is operated under specified power range. The wind and solar systems are operated always at MPP. The MPPT algorithm for the wind has not been tested on the experimental system due to unavailability of the wind turbine emulation facility. The MPPT algorithm is verified using simulation and the experimentation is performed for verifying the control considering that the reference current *idc* to be tracked is available.

A. Steady State and Dynamic Performance of Simulation Based Verification of MPPT Algorithm for WECS

As described earlier, the complete system is simulated using MATLAB/SIMULINK and from simulation results the MPPT of WECS is verified. A basic wind turbine model is considered for this purpose [30]. The power characteristic of the simulated wind turbine is shown in Fig. 8. The pitch angle is taken as fixed and the base wind speed as 10 m/s. The corresponding performance of the MPPT algorithm under variable wind operation is shown in Fig. 11. The results with constant wind speed is sown in Fig. 11 until t=4 s. The wind speed is changed from 10 m/s to 12 m/s at t=4 s. The dynamic behavior of the system is demonstrated during such variation in wind speed. From these results it is seen that with an increased in the wind speed, the power output of the WECS increases and also it can be seen that the PMBLDCG current as also increased.

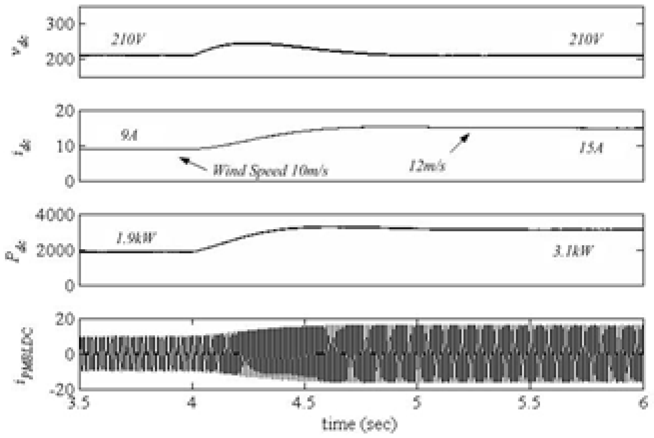
B. Steady State Performance of Standalone System

The proposed system is operated under various loading conditions to verify the control algorithm. The loading conditions are defined according to the state of the battery whether charging or discharging. Steady state results of the system in both the conditions are shown in Figs. 10, 12. Figs. 10(a-c) show the three phase source currents (*isabc*) and Figs. 10(d-f) show the load currents (*ilabc*). From here it can be seen that in addition to voltage and frequency control, the VSC is also performing the task of harmonics elimination, load balancing and reactive power compensation. All three source currents are almost balanced and sinusoidal. The VSC currents (*icabc*) shown in Figs. 8(g-i) verify this compensation. Figs. 8(j, show the PMBLDC generator current (*iPMBLDCG*) and DC side current of DBR (*idc*). The PMBLDCG current (*iPMBLDCG*) is approximately a quasi-square wave current and the *idc* confirms that the WECS system is working well and the power is extracted from the PMBLDCG.

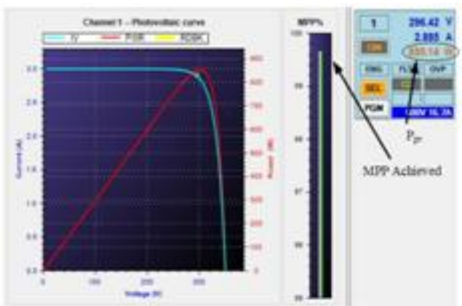


The power quality improvement capability of the VSC along with the voltage and frequency control is demonstrated. The THD of source current is only 4.9%, thereby negligible harmonic currents are entering the machine windings, hence no extra losses and thus no de-rating of the machine is required. The voltage THD is shown in Fig. 10 (r).

This shows the quality of supply given to the customer loads.



The performance of microgrid system under heavily loaded condition is shown in Fig. 12. Fig. 10(a) show the source current (*isa*) and Fig. 12(b) show the load current (*ila*) which are significantly more than the source currents. Even the system is heavily loaded, the DG is still supplying the load within the specified power range. Fig. 12(c) show the VSC current (*ica*).PMBLDC generator current (*iPMBLDCG*) is shown in Fig 12(d). The power output from the WECS is kept same for the comparison purpose. With the same power from the wind turbine and solar PV array, if the system loading is increased, the DG hits its upper power limit and the load is then fed from the battery. This is seen from Fig. 12(e) where the battery current is negative and hence the battery is discharging. This confirms the functioning of the control strategy for the complete system. Figs. 12(f) show the battery voltage and the output current of boost converter after solar array, *ipvo.* In this case also, the solar PV current and voltage which are same as previous case of light load. It can be seen from Fig 12(f), *ipvo,* that the power obtained from solar PV array is kept same as in previous case.



IV. CONCLUSION

The proposed microgrid topology with a single voltage source converter and brushless generators has been implemented under various operating conditions. An integrated operation of control algorithms is also tested for system's voltage and frequency control, mitigation of power quality issues, power balance in the whole system under various disturbances ranging from large load variation to renewable energy supply uncertainty. Some idea of battery charge discharge control and fault analysis is also discussed. Test results have confirmed the suitability of this topology for rural/isolated areas as the topology is simple and cost effective.

V. REFERENCES

[1]. Loi Lei Lai and Tze Fun Chan, Distributed Generation - Induction and Permanent Magnet Generators, John Wiley & Sons, 2007.

[2]. Bin Wu, Yongqiang Lang, Navid Zargari and Samir Kouro, Power Conversion and Control of Wind Energy Systems, John Wiley & Sons, 2011.

[3]. S. C. W. Krauter, Solar Electric Power Generation - Photovoltaic Energy Systems: Modeling of Optical and Thermal Performance, Electrical Yield, Energy Balance, Effect on Reduction of Greenhouse Gas Emissions, Springer, 2007.

[4]. Pragya Nema, R.K. Nema and Saroj Rangnekar, "A current and future state of art development of hybrid energy system using wind and PV-solar: A review", Journal of Renewable and Sustainable Energy Reviews, vol. 13, no. 8, pp. 2096-2103, October 2009.

[5]. J.M. Carrasco, L.G. Franquelo, J.T. Bialasiewicz, E. Galvan, R.C.P. Guisado, Ma. A. M. Prats, J.I. Leon and N. Moreno-Alfonso, "Power-Electronic Systems for the Grid Integration of Renewable Energy
a.Sources: A Survey," IEEE Trans. on Industrial Electronics, vol.53, no.4, pp.1002-1016, June 2006.

[6]. R. Pena, R. Cardenas, J. Proboste, J. Clare and G. Asher, "Wind–Diesel Generation Using Doubly Fed Induction Machines", IEEE Trans. on Energy Conversion, vol.23, no.1, pp.202,214, March 2008.

[7]. D.G. Infield, G.W. Slack, N.H. Lipman and P.J. Musgrove, "Review of wind/diesel strategies", Proc. of IEE Physical Science, Measurement and Instrumentation, Management and Education - Reviews, vol.130, no.9, pp.613-619, Dec. 1983.

[8]. R. Sebastian and R. Pena-Alzola, "Study and simulation of a battery based energy storage system for wind diesel hybrid systems," in Proc. of IEEE Inter. Energy Conf. and Exh. (ENERGYCON), pp.563-568, Sept. 2012.

[9].C. Abbey, Li Wei and G. Joos, "An Online Control Algorithm for a. Application of a Hybrid ESS to a Wind–Diesel System," IEEE Trans. on Industrial Electronics, vol.57, no.12, pp.3896-3904, Dec. 2010.

[10]. T. Hirose and H. Matsuo, "Standalone Hybrid Wind-Solar Power Generation System Applying Dump Power Control Without Dump Load," IEEE Trans. Ind. Elect., vol.59, no.2, pp.988,997, Feb. 2012.

[11]. Lin Whei-Min, Hong Chih-Ming and Chen Chiung-Hsing, "Neural-Network-Based MPPT Control of a Stand-Alone Hybrid Power a. Generation System," , IEEE Trans. on Power Electronics, vol.26, no.12, pp.3571-3581, Dec. 2011.
A. Yogianto, H. Budiono and I.A. Aditya, "Configuration hybrid solar system (PV), wind turbine, and diesel," in Proc. of Inter. Conf. on Power Engg. & Renewable Energy (ICPERE), pp.1, 5, July 2012

[12]. D. Yamegueu, Y. Azoumah, X. Py and N. Zongo, "Experimental study of electricity generation by Solar PV/diesel hybrid systems without battery storage for off-grid

areas”, Journal of Renewable Energy, vol. 36, no. 6, pp. 1780-1787, June 2011.

[13]. M.A. Tankari, M.B. Camara, B. Dakyo and G. Lefebvre, “Use of Ultracapacitors and Batteries for Efficient Energy Management in Wind–Diesel Hybrid System,” IEEE Trans. on Sustainable Energy, vol.4, no.2, pp.414-424, April 2013.

[14]. Dulal Ch. Das, A.K. Roy and N. Sinha, “GA based frequency controller for solar thermal– diesel–wind hybrid energy generation/ energy storage system”, International Journal of Electrical Power & Energy Systems, vol. 43, no. 1, pp. 262-279, Dec. 2012.

[15]. F. Bonanno, A. Consoli, A. Raciti, B. Morgana and U. Nocera, “Transient analysis of integrated diesel-wind-photovoltaic generation systems,” IEEE Trans. Ener. Con., vol.14, no.2, pp.232-238, Jun 1999.

[16]. Liu Xu, S. Islam, A.A. Chowdhury and D.O. Koval, “Reliability evaluation of a wind-diesel-battery hybrid power system,” in Proc. of IEEE/IAS Industrial and Commercial Power Systems Technical Conference (ICPS), May 2008.

[17]. J. de Matos, F. e Silva, L. Ribeiro, “Power Control in AC Isolated a.Microgrids with Renewable Energy Sources and Energy Storage b. Systems,” IEEE Transactions on Industrial Electronics, vol. no.99, pp.1,1, Nov. 2014.

[18]. R-J Wai, C.Y. Lin and Y.R. Chang, “Novel maximum-power-extraction algorithm for PMSG wind generation system,” IET Electric Power Applications, vol.1, no.2, pp.275-283, March 2007.

[19]. K. Tan and S. Islam, “Optimum control strategies in energy conversion of PMSG wind turbine system without mechanical sensors,” IEEE Trans. Ener. Con., vol.19, no.2, pp.392-399, June 2004.

[20]. Z.M. Dalala, Z.U. Zahid, Yu Wensong, Cho Younghoon and Lai Jih-a.Sheng, “Design and Analysis of an MPPT Technique for Small-Scale b.Wind Energy Conversion Systems,” IEEE Trans. on Energy Conversion, vol.28, no.3, pp.756-767, Sept. 2013.

[21]. D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, R. Teodorescu, “On the a.Perturb-and-Observe and Incremental Conductance MPPT Methods for PV Systems,” IEEE Journal of Photovoltaics, vol.3, no.3, pp.1070,1078, July 2013.

[22]. M. A. Elgendy, B. Zahawi and D. J. Atkinson, "Assessment of the Incremental Conductance Maximum Power Point Tracking Algorithm," IEEE Trans. on Sustainable Energy, vol.4, no.1, pp.108-117, Jan. 2013.