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Simulation of Isolated Hybrid Micro grid with Fuzzy Controller

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Abstract:

Microgrids are turning to be one of the most important factors for future power systems. Renewable energy is an alternative solution for power generation in the day today life. Power generation from conventional energy is having a drastic effect to the environment and the ecological life of humans. The energy from renewable sources is abundantly available over the universe. Energy from renewable sources is clean, ecofriendly, efficient and reliable. Solar and wind are gaining much importance in the present world. In this paper, a standalone micro-grid system consisting of a Photovoltaic (PV) and Wind Energy Conversion System (WECS) based Permanent Magnet Synchronous Generator (PMSG) is being designed and controlled. Additionally, an intelligent control technique has been proposed using fuzzy logic control to the MPPT control for effective operation under non-linear parameter variations for a micro grid system. The developed system was built and simulated in MATLAB/Simulink under conditions of constant load, and step load changes. The controllers enabled the BESS to charge even during conditions of varying load and other environmental factors such as change of irradiance and wind speed.

Key Words: Micro-grid, Hybrid systems, PV systems, Wind energy systems, Control strategy

I. INTRODUCTION:

The stand-alone hybrid solar-wind power generation system is recognized as a viable alternative to grid supply or to conventional fossil fuel based remote area power supplies all over the world. The main purpose of this project is to study the potential applications and operation of the stand-alone hybrid energy system. . This project is aimed to fill the gap by providing a smart controller of a specific Hybrid renewable energy micro-grid system. The main contribution of this work can be summarized as follows: the research study in this manuscript focuses on the off-grid hybrid wind-PV system which can be applied in remote areas, where the grid does not exist. A smart controller is applied to achieve a specific behavior for this off-Microgrid. The control system is intended to achieve the load in all cases as follows: when the energy generated by the PV panel exceeds the energy consumed by the load, the excess energy is used to charge the batteries. When the electricity provided by the PV panel is insufficient to meet the load's needs, the extra power is extracted from the charged batteries. Moreover, the smart controller is used to protect the batteries banks in all conditions; normal, overcharging, and over discharging conditions. The controller should handle each scenario appropriately. Under normal operating conditions (20% < SOC < 80%), the controller performs as expected, regardless of the battery's state of charge. When the SOC reaches 80%, a special command is issued that turns off the PV panel and the wind turbine. The PV panel and wind turbine cannot be linked until the SOC reduces to a safe margin, which is 75% in this controller. When SOC falls below 20%, other commands are sent out to turn off the inverter and disconnect the loads. The inverter's electricity is turned off until the batteries are charged to 25% of their full value.

II. System Modeling

The system under study consists of three main parts: PV system, Wind Energy Conversion System based Permanent Magnet Synchronous Generator (WECS-PMSG), and power electronic devices that connect AC and DC sides of the micro-grid system. Several controllers are required for each power electronic device.

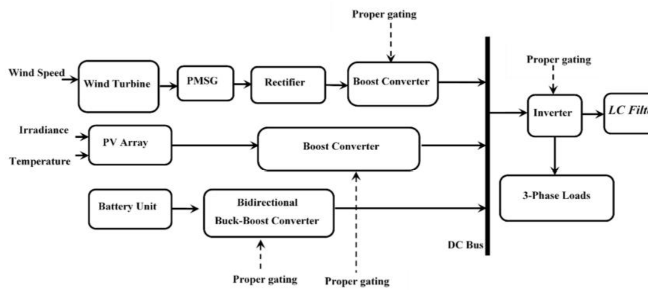

Figure 1. System configuration of the suggested micro grid.

III. Control System

The new control system of this Microgrid is divided into four subsystems: fuzzy logic-based MPPT for controlling the PV system, WECS controllers, battery unit controllers, and inverter controllers.

Fuzzification

Fuzzy logic is a basic control system which relies on the degrees of state of the input and the output depends on the state of the input and rate of change of this state.

Fuzzy logic-based MPPT for controlling the PV System.

The operation point on the P–I curve of the PV array to maintain MPP and control the change in the duty cycle. The output of fuzzy logic control has been controlled through PWM which generated pulses to control the MOSFET switch in a DC–DC converter.

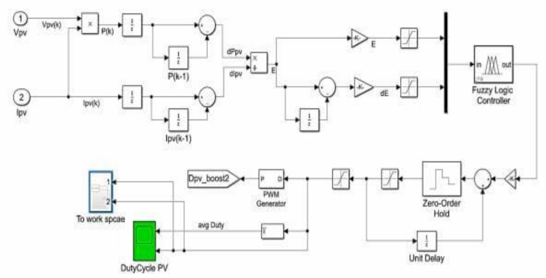

Figure 2. Fuzzy controller circuit diagram, with the use of a microcontroller to turn ON/OFF the boost converter.

WECS Controllers

The PMSG is connected to a three-phase bridge rectifier to convert the variable AC voltage into a DC voltage. Then, a boost converter is used to increase the DC bus voltage and fix it at 700 V. The gating of the boost converter is generated through a basic PI controller which generates the duty cycle to provide the boost converter with a proper gating signal.

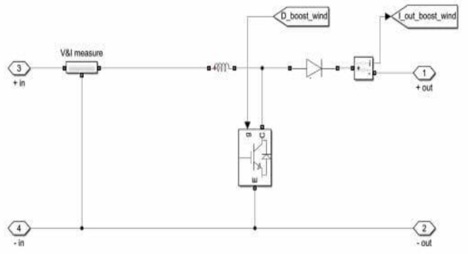

Figure 3. Boost converter used to step up PMSG's terminal voltage

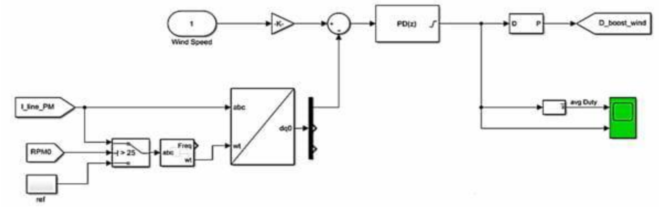

Figure 4. Control circuit for the wind system.

Bidirectional DC–DC Converter with a Battery Storage System

The bidirectional converter is operated as a buck converter with the gate signal applied to the switch S1. This mode of operation occurs to charge the battery system when PV output is high. When the PV system's power is low or the grid is down, the bidirectional converter acts as a boost converter, sending a gate signal to switch S2. As a result, the battery is discharged, and energy is supplied to the load.

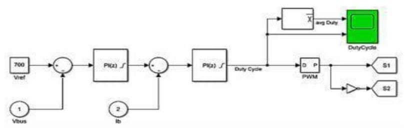

Figure 5. The bidirectional buck–boost converter controller, consisting of two closed loops of PI controllers.

Inverter Unit Control

A three-level inverter with the levels (−VDC, 0, +VDC) is being used. An SPWM method is used to get a proper gating signal for the inverter.

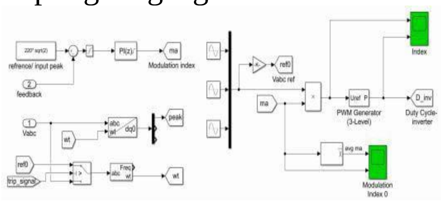

Figure 6. Control circuit for the inverter—SPWM.

Battery Protection Controller

Batteries can get overcharged or over-discharged, which usually leads to damaging the batteries.

(1) Normal condition where the batteries SOC is running between 20% and 80%.

(2) Overcharging condition, where the batteries' SOC is exceeding 80%.

(3) Over-discharging condition, where the batteries' SOC is running below 20%.

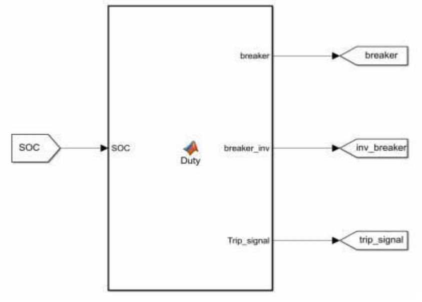

Figure7.MATLAB function block which represents the microcontroller.

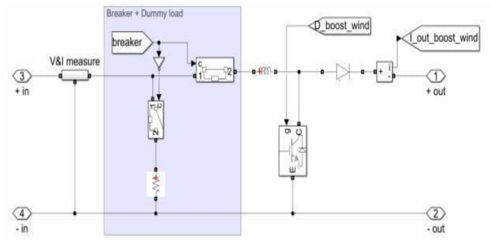

Figure 8. Wind boost converter with the circuit breaker and the dummy load are presented.

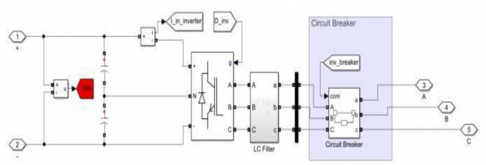

Figure9. Circuit breaker used with the inverter.

IV. Simulation and Results

Normal Condition

(1) In the period between t = (0 to 4 s), the effect of the PV system is examined under variable irradiance and fixed wind speed. The irradiance is changed between (0–1200) W/m2 with a constant wind speed of 16 m/s.

(2) The effect of the wind system is examined under variable wind speed and fixed irradiance in the period between t = (4 s to 8 s). The irradiance has been fixed at 1000 W/m^2, so the effect of the wind controller is simply observed.

(3) In the remaining simulation time, the system is examined under variable irradiance and variable wind speed for (t > 8 s).

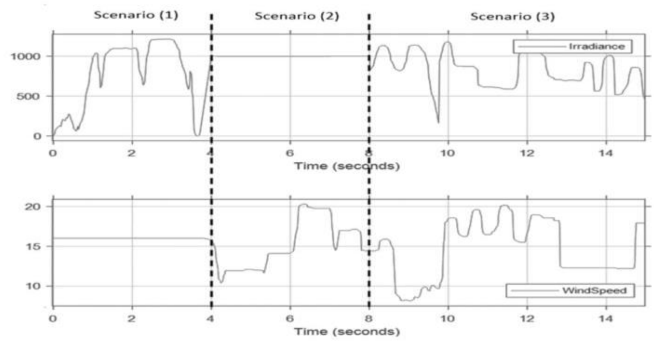

Figure 10. Irradiance (W/m^2), wind speed (m/s).

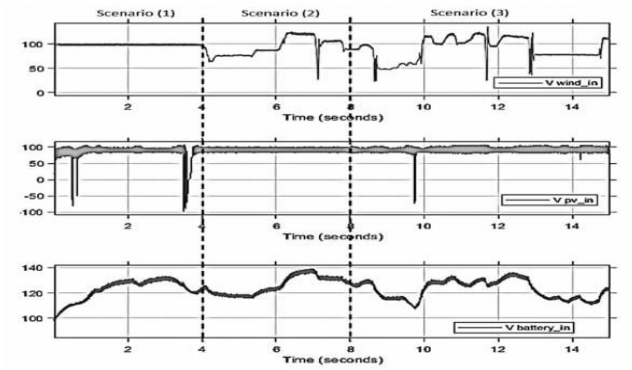

Figure 11. PMSG rectified voltage, PV voltage, and battery voltage, respectively.

As seen in this figure, the MPPT is working well, since the PV voltage, always reaches V_{max} for irradiance greater than 0.

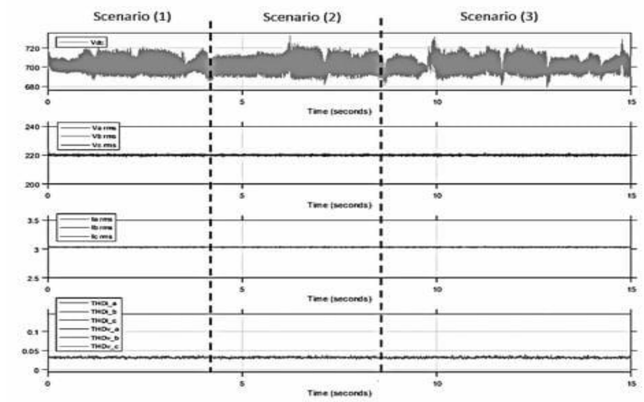

Figure 12. DC output voltage, RMS values of the voltage and current, and THD of the voltage and current.

The three-phase voltages and currents driven through the inverter are shown in this figure. THD for both voltages and currents are 3% and 5%, respectively.

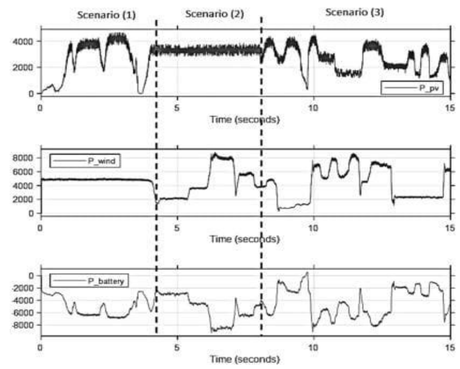

Figure13. Power Flow in the system at a load power of 2k:

(1) Power output of the PV panel, (2) wind power, (3) power storage in the batteries unit.

The power flow in the system, where the power fed to the inverter is constant at around 2080 W. The load is only consuming 2 kW, and the remaining are losses in the LC filter and power electronic devices as well.

Overcharging Condition

The behavior of the controller during overcharging process. SOC follows the sequence (80–79.93–80–79.93%) until the power coming from the sources is dropped to lower values.

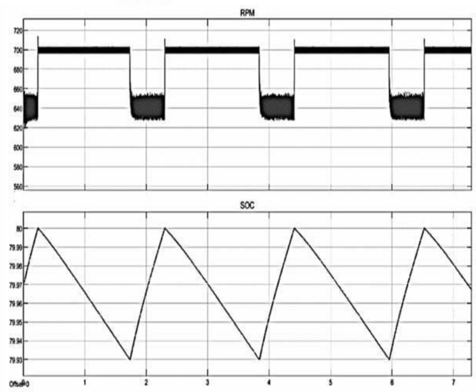

Figure 14. PMSG rotational speed in rpm and Batteries SOC in % for the overcharging condition.

Over discharging Condition

The batteries are being discharged due to low power fed from the PV system and WECS. Therefore, batteries' SOC hits 20%, and the circuit breaker is opened.

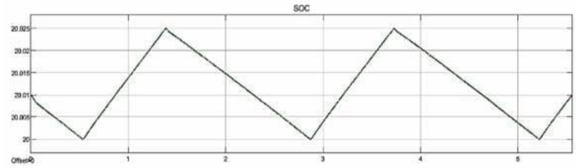

Figure 15. Batteries SOC in % for the over discharging condition.

V. Conclusion

Design and control of a standalone micro-grid system with a PV system and WECS were proposed in this work. To control and harvest the most power possible from the PV system, fuzzy logic-based MPPT was used for a boost converter. The PV system's output provided a constant DC bus voltage to a battery storage system that was regulated by two PI voltage and current control loops. The control system is intended to achieve the load in all cases. When the energy generated by the PV panel exceeds the energy required by the load, the excess energy is used to charge the batteries. When the PV panel's electricity is inadequate to fulfill the load's demands, the extra power is drawn from the charged batteries. Furthermore, the controller is employed to protect the battery banks in all scenarios, including normal, overcharging, and over discharging scenarios. Each case should be handled appropriately by the controller. Regardless of the battery's state of charge, the controller performs as expected under normal operating conditions (20% < SOC < 80%). A specific order is delivered when the SOC hits 80%, which turns off the PV panel and the wind turbine. The PV panel and wind turbine cannot be connected until the SOC drops to a safe margin of 75% in this controller. Other commands are sent out to turn off the inverter and disconnect the loads when SOC falls below 20%. The inverter's power is switched off until the batteries are charged again to a suitable value. The designed stand-alone microgrid system and their controllers solved the problem of supplying the electric energy to remote areas where the electrical grid does not exist.

REFERENCES

1. *Bendary, A.F.; Ismail, M.M. Battery charge management for hybrid PV/wind/fuel cell with storage battery. Energy Procedia 2019, 162, 107–116.*

2. *Muriithi, G.; Chowdhury, S. Optimal energy management of a grid-tied solar PV-battery microgrid: A Reinforcement learning approach. Energies 2021, 14, 2700.*

3. *Shan, Y.; Hu, J.; Chan, K.W.; Fu, Q.; Guerrero, J.M. Model predictive control of bidirectional DC-DC converters and AC/DC interlinking converters—A new control method for PV-wind-battery microgrids. IEEE Trans. Sustain. Energy 2019, 10, 1823–1833.*

4. *Berardi, U.; Tomassoni, E.; Khaled, K. A smart hybrid energy system grid for energy efficiency in remote areas for the army. Energies 2020, 13, 2279.*

5. *Mahesh, A.; Sandhu, K.S. Hybrid wind/photovoltaic energy system developments: Critical review and findings. Renew. Sustain. Energy Rev. 2015, 52, 1135–1147.*

6. *Murty, V.V.S.N.; Kumar, A. Multi-objective energy management in microgrids with hybrid energy sources and battery energy storage systems. Prot. Control Mod. Power Syst. 2020, 5, 1–20.*

7. *Alhasnawi, B.N.; Jasim, B.H.; Esteban, M.D. A new robust energy management and control strategy for a hybrid microgrid system based on green energy. Sustainability 2020, 12, 5724.*

8. *Kumar, G.R.P.; Sattianadan, D.; Vijayakumar, K. A survey on power management strategies of hybrid energy systems in microgrid. Int. J. Electr. Comput. Eng. IJECE 2020, 10, 1667–1673.*

9. *Al-Quraan, A.; Stathopoulos, T.; Pillay, P. Comparison of wind tunnel and on site measurements for urban wind energy estimation of potential yield. J. Wind. Eng. Ind. Aerodyn. 2016, 158, 1–10.*

10. *Rathore, A.; Patidar, N. Reliability assessment using probabilistic modelling of pumped storage hydro plant with PV-wind based standalone microgrid. Int. J. Electr. Power Energy Syst. 2019, 106, 17–32.*

11. *17) Al-Mahmodi, M.; Al-Quraan, A. On-grid solar energy system—A study case in Irbid. In Proceedings of the 6th Global Conference on Renewable Energy and Energy Efficiency for Desert Regions (GCREEDER 2018), Amman, Jordan, 3–5 April 2018.*

12. *Lamichhane, A.; Zhou, L.; Yao, G.; Luqman, M. LCL Filter based grid-connected photovoltaic system with battery energy storage. In Proceedings of the 2019 14th IEEE Conference on Industrial Electronics and Applications (ICIEA), Xi'an, China, 19–21 June 2019; Institute of Electrical and Electronics Engineers (IEEE): New York, NY, USA, 2019; pp. 1569–1574.*

13. *Yahaya, A.A.; Al-Muhaini, M.; Heydt, G.T. Optimal design of hybrid DG systems for microgrid reliability enhancement. IET Gener. Transm. Distrib. 2020, 14, 816–823.*

14. *Samy, M.; Mosaad, M.I.; Barakat, S. Optimal economic study of hybrid PV-wind-fuel cell system integrated to unreliable electric utility using hybrid search optimization technique. Int. J. Hydrog. Energy 2021, 46, 11217–11231.*

15. *Luo, Y.; Yang, D.; Yin, Z.; Zhou, B.; Sun, Q. Optimal configuration of hybrid-energy microgrid considering the correlation and randomness of the wind power and photovoltaic power. IET Renew. Power Gener. 2020, 14, 616–627.*