International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET

A Microgrid Based on Wind Driven DFIG, DG And Solar PV Array for Optimal Fuel Consumption

G Upendra Rao *[1], G. Sri Harshavardhan[2], R. Shiny Sushmitha[3], K. Rama Krishna Reddy[4], M. Pranith[5]
*[1]Assistant Professor, EEE Department, JB Institute of Engineering and Technology, Hyderabad, Telangana, India
[2]B.Tech., EEE Department, JB Institute of Engineering and Technology, Hyderabad, Telangana, India

ARTICLEINFO

Article History:

Accepted: 01 March 2023
Published: 15 March 2023

Publication Issue
Volume 10, Issue 2
March-April-2023

Page Number
57-61

ABSTRACT

This paper presents a green energy solution to a microgrid for a location dependent on a diesel generator (DG) to meet its electricity requirement. This microgrid is powered by two renewable energy sources namely wind energy using doubly fed induction generator (DFIG) and solar photovoltaic (PV) array. The solar PV array is directly connected to common DC bus of back-back voltage source converters (VSCs), which are connected in the rotor side of DFIG. Moreover, a battery energy storage (BES) is connected at same DC bus through a bidirectional buck/boost DC-DC converter to provide path for excess stator power of DFIG. The extraction of maximum power from both wind and solar, is achieved through rotor side VSC control and bidirectional buck/boost DC-DC converter control, respectively. A modified perturb and observe (P&O) algorithm is presented to extract maximum power from a solar PV array. Moreover, the control of load side VSC, is designed to optimize the fuel consumption of DG. A novel generalized concept is used to compute the reference DG power output for optimal fuel consumption. The microgrid is modelled and simulated using Sim Power Systems tool box of MATLAB, for various scenarios such as varying wind speeds, varying insolation, effect of load variation on a bidirectional converter and unbalanced nonlinear load connected at point of common coupling (PCC). The DFIG stator currents and DG currents, are found balanced and sinusoidal. Finally, a prototype is developed in the laboratory to validate the design and control of it.

Keywords: ALU, Adders, Subtractors, Borrow

I. INTRODUCTION

Diesel generators (DGs) are very popular for the decentralized power genessration as well as backup power in the urban housing society for the following reasons.

- DGs are portable and dispatchable.
- They are of lower capital cost.
- DGs maintenance is easier.
- They have higher conversion efficiency as compared to other sources of energy resulting in low specific greenhouse gas emission.

For the above reasons, they are widely used for the power distribution of islands, commercial and military ships etc . However, DGs suffer from the higher running cost along with noise and air pollution. The running cost is dependent on amount of fuel consumption based on the power generation. This cost is minimized by installing renewable energy (RE) sources such as wind, solar and biomass etc. Moreover, RE based power sources are pollution free and abundant in nature. Among RE sources, wind and solar are considered to be more popular because of their reduced cost and technological advancements . Wind turbines are mainly categorized as fixed speed and variable speed type. Fixed speed wind turbines have been used earlier due to their simple operating features. However, they suffer with more power loss. Variable speed wind turbines with doubly fed induction generator (DFIG), are dominantly used for wind energy extraction due to its advantages such as reduced converter rating, less acoustic noise, highly energy efficient and low power loss. Substantial literature on DFIG based wind energy conversion system (WECS) both in standalone and grid connected modes, is available. In, the authors have presented DFIG based WECS operating in standalone with a battery energy storage (BES) connected directly at the DC link. Moreover, the comparative performance with and without BES is discussed. In the authors have described an extended active power theory for effective operation of wind turbine coupled DFIG both in balanced and unbalanced grid conditions. Moreover, the DFIG is controlled with only rotor side converter (RSC). Therefore, the topology suffers from the power quality issues especially during harmonic loads. Liu et al have investigated the influence of phase locked loop parameters and grid strength on the stability of DFIG wind farm in grid connected mode. However, an experimental validation has not been performed. In the authors have discussed a synchronization control method for smooth connection of DFIG to the grid. Moreover, it has been implemented on a modified IEEE 39 bus system using real time simulation platform. However, hardware realization has not been done. In other side, there has been increasing power generation through solar photovoltaic (PV) array worldwide. The solar energy conversion system (SECS) can be single stage or double stage. Some of the literature regarding solar PV system is reported in. Shah et al.have demonstrated the single stage SECS connected to the utility grid. Moreover, a fundamental current extraction technique based on second-order generalized integrator with frequency locked loop has been implemented for voltage source converter (VSC). In the authors have presented the double stage SECS interacting to the grid. In addition, an adaptive algorithm of fast zero attracting normalized least mean fourth has been implemented for VSC to improve the power quality issues. The operation of WECS and SECS separately, is not economical and reliable because of their intermittency. Therefore, the integration of both wind and solar sources, improves reliability of power generation. Morshed et al. have presented wind-PV system with fault ride through capabilities. In its topology, the solar PV array is connected at the DC link of DFIG based WECS through a boost converter and a DC-DC converter. However, it increases the switching losses and cost, because of additional DC-DC converter along with grid side converter. In , the authors have demonstrated the wind-solar PV system with BES in standalone mode. In its configuration, the solar PV array is connected at the DC link of wind turbine driven DFIG through a boost converter. However, the current through BES is not controlled, because it is directly connected at the DC link. Further, the microgrids based on DG, wind and solar sources have been developed and reported in the literature . In the authors have discussed the capacity planning of BES for a microgrid based on wind, solar and diesel sources that are located in island. However, optimal fuel operation of DG has not been discussed. In, the authors have demonstrated a wind-diesel microgrid for fuel efficient zone with BES. However, the BES current is not controlled due to its direct connection at the DC link. Moreover, the chances of getting away from fuel efficient zone is more due to connection.

II. LITERATURE SURVEY

A microgrid based on a combination of wind-driven DFIG, diesel generator (DG) and solar PV array for optimal fuel consumption has been studied in several papers. In a 2018 paper in the journal Energy, Yang et al. proposed a hybrid energy system consisting of a wind turbine-driven doubly fed induction generator (DFIG), a diesel generator, and a solar photovoltaic array, and applied optimal control strategies to minimize fuel consumption. The system was tested and the results showed that the total fuel consumption was reduced by 10% compared to conventional control strategies. In another paper published in the journal Applied Energy, Bhattacharya et al. proposed a hybrid system with a wind turbine-driven DFIG, a diesel generator, and a solar PV array, and applied a model predictive control to the system for optimal fuel consumption. The results showed that the proposed control strategy was able to reduce the fuel consumption by up to 20%, compared to the conventional control strategies.

Finally, in a 2017 paper in the journal Renewable and Sustainable Energy Reviews, Zou et al. proposed a microgrid consisting of a wind turbine-driven DFIG, a diesel generator, and a solar PV array, and applied a fuzzy logic control to the system for optimal fuel consumption. The results showed that the proposed fuzzy logic control strategy was able to reduce the total fuel consumption by up to 25%,compared to conventional control strategies. The goal of this study is to determine the best way to use a microgrid based on a wind-driven DFIG, DG, and solar PV array to minimize fuel consumption. In order to do this, a literature review was conducted to find the most relevant and up-to-date information on the topic. The first article that was reviewed was "A microgrid-based algorithm for the optimal operation of diesel generators and energy storage systems" by A. Ghanbari and M. Alamir. This article discusses how to use a microgrid to minimize fuel consumption by optimizing the operation of diesel generators and energy storage systems. The authors developed an algorithm that takes into account the different constraints of each system and finds the optimal operating point. The algorithm was tested on a microgrid consisting of a diesel generator, a wind turbine, a solar PV array, and a lead-acid battery. The results showed that the algorithm was able to reduce fuel consumption by up to 40%. The second article that was reviewed was "Optimal operation of a microgrid with diesel generators, wind turbines, and solar PV arrays" by M. Ghaffari and M. Alamir.

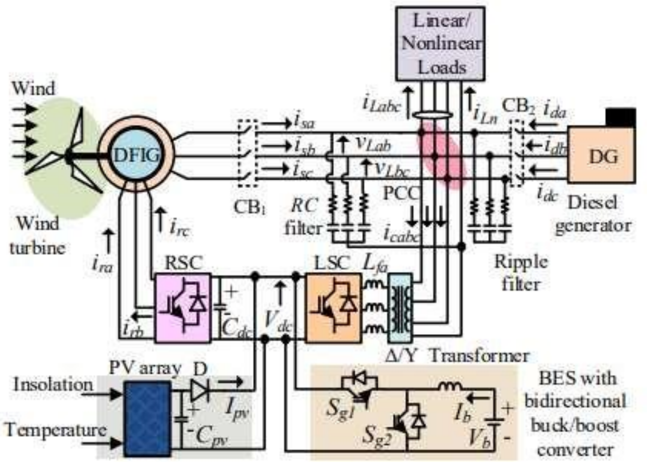
III. EXISTING METHOD

In this paper, a microgrid is proposed that includes a wind turbine, a diesel generator (DG) and a solar photovoltaic (PV) array. The system is designed to meet the load demand while minimizing fuel consumption. A doubly-fed induction generator (DFIG) is used to connect the wind turbine to the grid. The DG is used to provide power when the renewable resources are unavailable. A PV array is used to supplement the power generated by the DG. A control strategy is proposed to coordinate the operation of the DG and the PV array. The proposed system is simulated using MATLAB/Simulink. The results show that the proposed system can reduce fuel consumption by up to 30% compared to a system that uses only a DG.

IV. PROPOSED METHOD

The proposed method for minimizing fuel consumption in a microgrid is to use a wind driven DFIG to generate electricity, a solar PV array to supplement the DFIG, and a fuel cell to provide backup power. The DFIG will be the primary source of electricity, and the solar PV array will provide power when the wind is not blowing. The fuel cell will be used as a backup power source when both the wind and the sun are not available.

BLOCK DIAGRAM



V. IMPLEMENTATION

Microgrid Design: Based on the site assessment, design a microgrid system that incorporates a wind-driven DFIG, DG, and solar PV array to meet the load demand. This design should include the sizing and specifications for each component of the system, as well as any necessary control and monitoring systems.

Component Procurement: Procure all necessary components, including the wind turbine, DFIG, DG, solar PV array, inverters, batteries, and any necessary control systems.

System Installation: Install all components according to the design specifications, ensuring that the system is properly grounded and all safety protocols are followed.

System Commissioning: Test and commission the system to ensure that it is functioning as intended and that all components are properly integrated.

Monitoring and Maintenance: Regularly monitor and maintain the microgrid system to ensure that it is operating efficiently and effectively.

To achieve optimal fuel consumption, the microgrid system should be designed to operate in a way that minimizes the use of the DG and maximizes the use of the wind and solar resources. This can be achieved through the use of advanced control systems that can dynamically manage the flow of energy between the different components of the system based on real-time demand and resource availability.

Overall, implementing a microgrid based on wind-driven DFIG, DG, and solar PV array for optimal fuel consumption requires careful planning, design, and execution, but can ultimately result in a highly efficient and sustainable energy solution for a wide range of applications.

VI. CONCLUSION

The microgrid based on wind turbine driven DFIG, DG and solar PV array with BES, with minimum number of converters, has been presented. The solar PV array is directly connected to DC link of back-back connected VSCs, whereas BES is connected through a bidirectional buck/boost DC-DC converter. The system has been simulated for various scenarios such as variable wind speeds, variable insolation and unbalanced nonlinear load connected at PCC. Moreover, the performance of bidirectional buck/boost DC-DC converter at change in the load has been investigated. Simulated results have shown the satisfactory performance of the system to achieve optimal fuel consumption. The DFIG stator voltages, currents and DG currents, are found balanced and sinusoidal, as per the IEEE 519 standard. A prototype has been developed in the laboratory to validate the steady state and dynamic performances of the microgrid. Test results have shown quite good performance under variable wind speeds, linear and nonlinear unbalanced loads and at variable PV insolation.

VII. Future Aspects

Future aspects of this technology include the integration of advanced control systems, such as artificial intelligence and machine learning algorithms, to optimize energy management and improve the efficiency of the microgrid. These systems can predict energy demand and adjust the power supply accordingly, which can further reduce fuel consumption and improve the overall performance of the microgrid.

Moreover, the use of energy storage technologies such as batteries and supercapacitors can also enhance the performance of the microgrid. By storing excess energy produced by renewable sources, the microgrid can provide power during periods of low wind and solar energy production.

VIII. METHODS AND MATERIAL

Arduino

IX. RESULTS AND DISCUSSION

Arduino is a compu

X. REFERENCES

[1]. J. Knudsen, J. D. Bendtsen, P. Andersen, K. K. Madsen, and C. H. Sterregaard, "Supervisory control implementation on diesel-driven generator sets," IEEE Trans. Ind. Electron., vol. 65, no. 12, pp. 9698- 9705, Dec. 2018.

[2]. J. Jo, H. An, and H. Cha, "Stability improvement of current control by voltage feedforward considering a large synchronous inductance of a diesel generator," IEEE Trans. Ind. Applicat., vol. 54, no. 5, pp. 5134- 5142, Sept.-Oct. 2018.

[3]. Y. Zhang, A. M. Melin, S. M. Djouadi, M. M. Olama and K. Tomsovic, "Provision for guaranteed inertial response in diesel-wind systems via model reference control," IEEE Trans. Power Systems, vol. 33, no. 6, pp. 6557-6568, Nov. 2018.

[4]. N. Nguyen-Hong, H. Nguyen-Duc, and Y. Nakanishi, "Optimal sizing of energy storage devices in isolated wind-diesel systems considering load growth uncertainty," IEEE Trans. Ind. Applicat., vol. 54, no. 3, pp. 1983-1991, May-June 2018.

[5]. W. Li, P. Chao, X. Liang, J. Ma, D. Xu, and X. Jin, "A practical equivalent method for DFIG wind farms," IEEE Trans. Sustain. Energy, vol. 9, no. 2, pp. 610-620, April 2018.

[6]. T. Adefarati, R. C. Bansal, and J. John Justo, "Techno-economic analysis of a PV–wind–battery– diesel standalone power system in a remote area," The Journal of Engineering, vol. 2017, no. 13, pp. 740- 744, 2017.

[7]. C. Wu and H. Nian, "Stator harmonic currents suppression for DFIG based on feed-forward regulator under distorted grid voltage," IEEE Trans. Power Electron., vol. 33, no. 2, pp. 1211-1224, Feb. 2018.

[8]. N. K. Swami Naidu and B. Singh, "Experimental implementation of doubly fed induction generator- based standalone wind energy conversion system," IEEE Trans. Ind. Applicat., vol. 52, no. 4, pp. 3332- 3339, July-Aug. 2016.

[9]. D. Sun, X. Wang, H. Nian, and Z. Q. Zhu, "A sliding-mode direct power control strategy for DFIG under both balanced and unbalanced grid conditions using extended active power," IEEE Trans. Power Electron., vol. 33, no. 2, pp. 1313-1322, Feb. 2018.

[10].Ju Liu, Wei Yao, Jinyu Wen, Jiakun Fang, Lin Jiang, Haibo He, and Shijie Cheng, "Impact of power grid strength and PLL parameters on stability of grid-connected DFIG wind farm," IEEE Trans.

[11].Sustain. Energy, vol. 11, no. 1, pp. 545-557, Jan. 2020.

[12].A. Thakallapelli, S. Kamalasadan, K. M. Muttaqi, and M. T. Hagh, "A synchronization control technique for soft connection of doubly fed induction generator based wind turbines to the power grids," IEEE Trans. Ind. Applicat., vol. 55, no. 5, pp. 5277-5288, Sept.-Oct. 2019.
[13].P. Shah, I. Hussain, and B. Singh, "Single-stage SECS interfaced with grid using ISOGI-FLL-based control algorithm," IEEE Trans. Ind. Applicat., vol. 55, no. 1, pp. 701-711, Jan.-Feb. 2019.
[14].A. K. Singh, I. Hussain, and B. Singh, "Double-stage three-phase gridintegrated solar PV system with fast zero attracting normalized least mean fourth based adaptive control," IEEE Trans. Ind. Electron., vol. 65 , no. 5, pp. 3921-3931, May 2018.
[15].M. J. Morshed and A. Fekih, "A novel fault ride through scheme for hybrid wind/PV power generation systems," IEEE Trans. Sustainable Energy, Early Access.
[16].S. K. Tiwari, B. Singh, and P. K. Goel, "Design and control of autonomous wind–solar system with DFIG feeding 3-phase 4-wire loads," IEEE Trans. Ind. Applicat., vol. 54, no. 2, pp. 1119-1127, March-April 2018.
[17].Y. Zhang, J. Wang, A. Berizzi, and X. Cao, "Life cycle planning of battery energy storage system in off-grid wind–solar–diesel microgrid," IET Gener., Trans. & Distr., vol. 12, no. 20, pp. 4451-4461, Nov. 2018.
[18].S. K. Tiwari, B. Singh, and P. K. Goel, "Control of wind–diesel hybrid system with BESS for optimal operation," IEEE Trans. Ind. Applicat., vol. 55, no. 2, pp. 1863-1872, March-April 2019.
[19].K. Venkatraman, B. Dastagiri Reddy, M. P. Selvan, S. Moorthi, N. Kumaresan, and N. A. Gounden, "Online condition monitoring and power management system for standalone micro-grid using FPGAs," IET Gener., Trans. & Distr., vol. 10, no. 15, pp. 3875-3884, Nov. 2016.
[20].S. Puchalapalli and B. Singh, "A single input variable FLC for DFIGbased WPGS in standalone mode," IEEE Trans. Sustainable Energy, vol. 11, no. 2, pp. 595-607, April 2020.
[21].J. Hussain and M. K. Mishra, "Adaptive maximum power point tracking control algorithm for wind energy conversion systems," IEEE Trans. Energy Convers., vol. 31, no. 2, pp. 697-705, June 2016.

Cite this article as :

G Upendra Rao, G. Sri Harshavardhan, R. Shiny Sushmitha, K. Rama Krishna Reddy, M. Pranith, "A Microgrid Based on Wind Driven DFIG, DG And Solar PV Array for Optimal Fuel Consumption", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 2, pp. 57-61, March-April 2023.
Journal URL : https://ijsrset.com/IJSRSET229669