Design and Analysis of Micro-grid Stability with Various DGs

B. Devulal[1](✉), M. Siva[2], D. Ravi Kumar[1], and V. Rajashekar[1]

[1] Department of EEE, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad 500090, Telangana, India
{devulal_b,ravikumar_d}@vnrvjiet.in

[2] Department of EEE, Annamalai University, Chidambaram 608002, Tamil Nadu, India

Abstract. A Micro Grid (MG) is an isolated electric grid that comprises several elements which are the same as that of the distributed electric grid. The paper presents a total model for optimization of the hybrid solar and wind energy in isolated Micro Grid (MG) by implementing the MPP tracking, including a spare rechargeable battery. MG typically works in ordinary interfacing mode. At the point where an extreme shortcoming happens in the essential conveyance system, then, at that point, the MicroGrid will tend to island mode. In this paper, the model exhibits a solitary shaft miniature Wind turbine, photovoltaic system and a battery. This load of miniature sources is associated with the Micro Grid through inverters with the exception of the breeze age framework. with two control techniques of inverters are illustrated. Specific dynamic and responsive powers are infused into the system which is of PQ control by the inverter. This type of inverter is utilized to interface miniature turbine, power module, and photovoltaic boards to the Micro Grid. Vf control is a consequent technique. The first case considers the effect of islanding which measures on the frequency, voltage, and dynamic force of all tiny sources when the Micro Grid imports dynamic and responsive force from the key conveyance system. The impact of islanding on previous quantities is also demonstrated in the second analyzed instance, particularly when the MG sends out dynamic and respective capacity to the vital dissemination system. Power simulations are designed on the MATLAB platform and power converter efficiencies, power quality performance variables are demonstrated.

Keywords: MG · Dynamic performance · Islanding · Inverter and distributed generators · Power quality

1 Introduction

The electric power being the central spine for on ongoing modernization around the world suffers from aging and weak infrastructures, to be more specific the power system even in the today's generation is prone to more outages and failures. To deal with these events a paradigm shift is necessary in the power sector. In the up coming decades the renewable sources play a key role in generating the green power [1] in contrast to the

S. Mekhilef et al. (Eds.): ICEEE 2022, LNEE 893, pp. 406–414, 2022.
https://doi.org/10.1007/978-981-19-1742-4_34

fossil fuels. So many concepts are being introduced into the power engineering to adapt to the upgrading advancements in electric power.

Since electric grid is complex distributed system of various interfacing elements that act to drives the various linear and nonlinear loads. This has led to the introduction of the isolated grids by implementing the various renewable sources and smart controllers that can regulate the voltage, current and power quality for loads which are simply coined as microgrids.

In this paper, show the recreation of the PV and wind fuel cell fly wheel based microgrid to show the new properties of the interconnected framework with the implementation of various smart controllers which are discussed in the following sections of paper.

2 Literature Survey

The non-renewable power generations inject flue gases polluting the atmosphere. By using Renewable energy Sources, One can prevail over these problems to a large extent such as solar, wind, geothermal, etc. [1] that are greener and ecofriendly. The enhanced performance of hybrid power generation is presented in literature.

Power quality enhancements in the PV-wind integrated grid are discussed in [2–4], the nonlinearities, harmonics that are occurring are primarily related to the network's existence of nonlinear loads. Maximum Power extracts from solar and wind by employing P & O and PSO Algorithms [5–8] and with the following controllers.

- AC/AC converter with electrical component rectifier.
- Several DC/DC Vehicle battery charger converters.
- Supercapacitor battery.
- Distinctive DC/DC capacitor interface converter.

3 Proposed System Configuration

The hybrid system includes two additional power sources connected in parallel. The energy assets of this device are photovoltaic solar cells and wind energy.

The nonlinear loads in the system are powered by the hybrid energy of solar PV system and wind-powered system [2] as depicted in Fig. 1. The power generated from the PV system is routed through a boost converter. The pulses to the boost converter are applied through the fuzzy logic control system. On the other hand, the wind generation system is synchronized to the alternator for additional power or as backup power to the system.

The power from boost converter passes on to the VSC through battery storage system connected across the Dclink capacitor. The various elements of the system design areas follows:

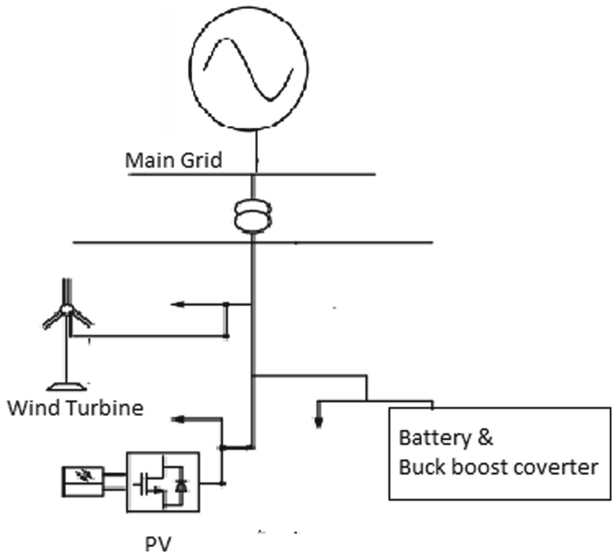

Fig. 1. Proposed system configuration

3.1 Source

To power the nonlinear load of 500kW and an SG of 900 kVA, 20 kV, 50Hz coupled to a wind turbine system. By MPPT strategies One can achieve maximum power and the PV array is designed in such a way.

3.2 Buck Boost Converter

The boostBuck Boost converter is modelled with the fuzzy logic controller for the effective generation of pulses for the MOSFET switching in operating at the peak efficiency. The inductor value in the converter topology is designed from:

$$\mathrm{L} = \frac{(\mathrm{Vo} - \mathrm{Vin}) * \mathrm{Vin}}{\Delta Ipv * frequency * Vo}\ \mathrm{henry}$$

3.3 Dc Link Capacitor and Battery System

Capacitor value is calculated from

$$\mathrm{Cdc} = \frac{(\mathrm{Vo} - \mathrm{Vin}) * \mathrm{Vin}}{2\mathrm{w} * Vdc^2}\ \mathrm{farad}$$

A battery of higher power rating is chosen to withstand the power generated from the boost converter and to mitigate the disturbances and harmonics by incorporating the required filters.

3.4 VSC Designing

For minimize the conduction and switching losses, VSC's are designed to extract the maximum power from system Control is predictable in conventional converters because of its simple structuring. The modern VSC are complex to evaluate duty cycle ratios and PWM methods are too difficult to implement which are unpredictable. So these VSC's are costly both in maintenance and operation. Such converters when incorporated with cost optimized functions and predictive control strategy it evades the limitations detailed. The voltage in each power converters leg is calculated from

$$V_{xn} = S_x S_x S_x V_{xn} \tag{1}$$

$$V_0 = V_{xn} \mathrm{R}_{eq} I_0 - \mathrm{L} \tag{2}$$

For detailing the behavior of the circuit model in Fig. 2 the voltage and current quantities in vector form are

$$V_{pul} = [\, V_R \; V_Y \;\; V_B \,]^T \tag{3}$$

VPwm = 3 ph inv o/p to neutral line voltages

$$I_i = [I_R \; I_Y \; I_B\,] \tag{4}$$

$$V_l = [\, V_R \; V_Y \;\; V_B \,]^T \tag{5}$$

Equation from load view:

$$V_L = R_f + I_{inv} + L_f + V_{pwm} - R_n I_n - L_n \tag{6}$$

$$I_{inv} = I_L + C_r \tag{7}$$

4 Modeling of Wind Turbine Based Synchronous Generator

The wind turbine converts the wind power into the electrical power through an arrangement of mechanical gear settings. The wind power is given as

$$Pw = \frac{pAv^3 w}{2}$$

The power generated from wind depends on the turbine efficiency and given as

$$\mathrm{Pm} = \mathrm{Pw} * \mathrm{Cp} = 0.5\rho \mathrm{L2v3\ Cp}$$

The parks transformation equations for the alternator are as follows:
Stator side equations:

$$ed = p\Psi_{\mathrm{d}} - \Psi_{q}\omega_{\mathrm{r}} - \mathrm{R_a id} \tag{8}$$

$$ed = p\Psi_{q} + \Psi_{d}\omega_{\mathrm{r}} - \mathrm{R_a iq} \tag{9}$$

$$ed = p\Psi_{\mathrm{q}} + \Psi_{d}\omega_{\mathrm{r}} - \mathrm{R_a iq} \tag{10}$$

$$\Psi_{\mathrm{d}} = -\mathrm{L_d i_d} + \mathrm{L_a f_d i_f} + \mathrm{L_a k_d i k_q} \tag{11}$$

$$\Psi_{\mathrm{o}} = -\mathrm{L_o i_o} \tag{12}$$

Rotor side equations:

$$efd = p\Psi_{\mathbf{f}\mathrm{d}} + \mathrm{R}_{\mathbf{f}}\mathrm{d i}_{\mathbf{f}\mathrm{d}} \tag{13}$$

$$0 = p\Psi_{\mathrm{kd}} + \mathrm{R}_{kd}\mathrm{i_{kd}} \tag{14}$$

$$0 = p\Psi_{\mathrm{kq}} + R_{\mathrm{kd}} i_{\mathrm{kd}} \tag{15}$$

$$\Psi_{\mathrm{kd}} = \mathrm{L_{fkd} i_{fd}} + \mathrm{L_{kkd} i_{kd}} - 1.5\mathrm{L_{afd} i_d} \tag{16}$$

$$\Psi_{\mathrm{kd}} = \mathrm{L_{fkd} i_{fd}} + \mathrm{L_{kkd} i_{kd}} - 1.5\mathrm{L_{akd} i_d} \tag{17}$$

$$\Psi_{\mathrm{fq}} = \mathrm{L_{ffq} i_{fq}} + \mathrm{L_{fkq} i_{kq}} - 1.5\mathrm{L_{afq} i_q} \tag{18}$$

$$\Psi_{\mathrm{kq}} = \mathrm{L_{kkq} i_{fq}} + \mathrm{L_{fkq} i_{kq}} - 1.5\mathrm{L_{akq} i_q} \tag{19}$$

Power output is

$$\mathrm{P_e} = 0.67(\mathrm{e_d i_d} + \mathrm{e_q i_q}) \tag{20}$$

Depending on above equation the simulation model is designed for the system to analyze the performance of the variables.

5 Simulation Results

The proposed simulations are verified in MATLAB/Simulink under various loads, it output performance is depicted in various figures as follows:

Waveforms with LLLG Fault in Micro Grid
Output Voltage of Synchronous Generator is shown in Fig. 3.

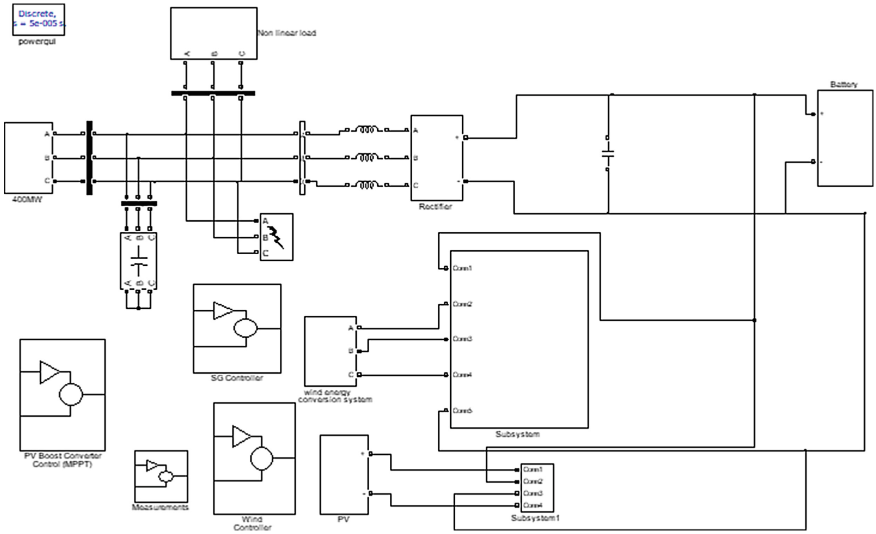

Fig. 2. Simulation diagram for proposed system.

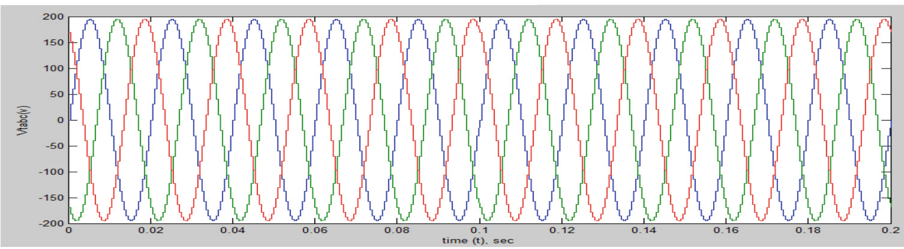

Fig. 3. Synchronous generator output voltage

Wave form of line current is shown in Fig. 4.

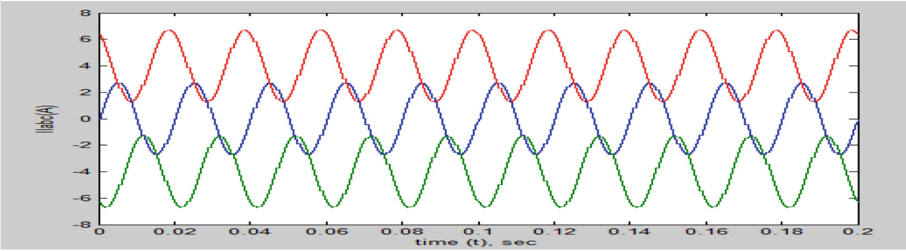

Fig. 4. Line current

Wave form of load current is shown in Fig. 5.

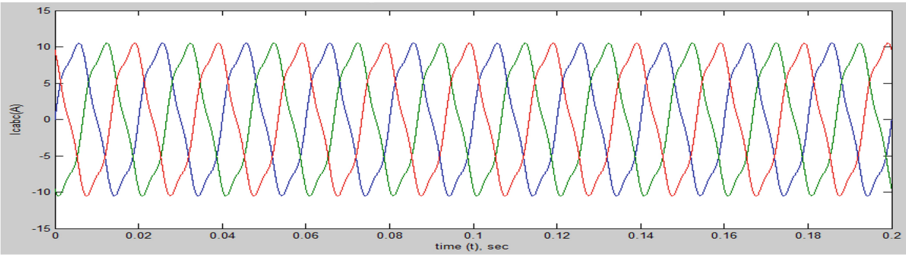

Fig. 5. Load current

Wave form of battery current is shown in Fig. 6.

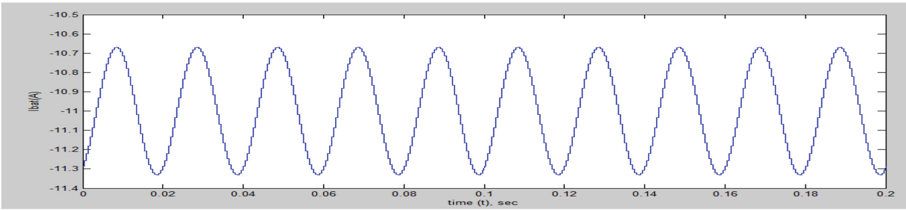

Fig. 6. Battery output current

Wave form of battery voltage is shown in Fig. 7.

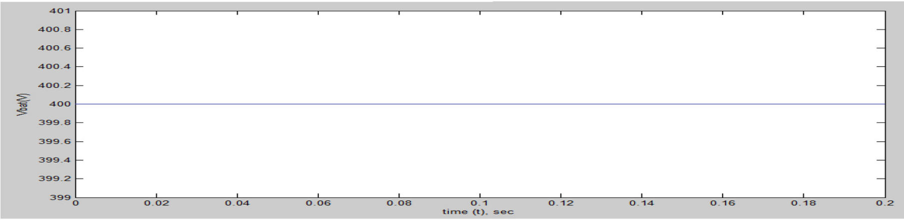

Fig. 7. Battery voltage

6 Conclusion

This paper considered a comprehensive modeling of micro grid behavior. Each one of MG's components is meticulously displayed. The first case investigates the MG's operation following islanding, when the MG imports dynamic and receptive forces from the principal matrix. The subsequent case shows the unique exhibition when the miniature lattice sends out a lot of dynamic and receptive forces to the fundamental matrix. It was demonstrated that the capacity gadgets are significant to execute sufficient control techniques for MG activity in islanded mode. The need of capacity devices is due to the fact that the MG's micro sources have exceptionally low inactivity and sluggish slam up rates. A combination of hang control mode (applied to Vf inverter) and a fundamental control circle (applied to controlled tiny sources) is effective in reducing recurrence during islanded activity. In any case, MG should include at least one controllable small source (PV power device or miniature turbine) to aid in rebuilding when islanding occurs. Even if there are no controllable tiny sources in the MG, the capacity devices will continue to pump power into the MG until their energy is depleted and dark out occurs. Creator's subsequent stage research means to consider the dynamic execution of the MG under various aggravating conditions like disturbances in one of miniature sources, faults in MG feeders etc.

References

1. Hongkai, L., Chenghong, X., Jinghui, S., Yuexi, Y.: Green power generation technology for distributed power supply. In: 2008 China International Conference on Electricity Distribution, Guangzhou, pp. 1–4 (2008)
2. Kamel, R.M., Chaouachi, A., Nagasaka, K.: Detailed analysis of micro-grid stability during islanding mode under different load conditions. Engineering **3**, 508–516 (2011)
3. Pilawa-Podgurski, R.C., Perreault, D.J.: Submodule integrated distributed MPPT for solar photovoltaic applications. IEEE Trans. Power Electron. **28**(6), 2957–2967 (2013)
4. Woei-Luen, C., Tsai, C.: Optimal balancing control for tracking theoretical global MPP of series PV modules subject to partial shading. IEEE Trans. Ind. Electron. **62**(8), 4837–4848 (2015)

5. Shaw, R.N., et. al.: A new model to enhance the power and performances of 4 × 4 PV arrays with puzzle shade dispersion. Int. J. Innov. Technol. Explor. Eng. **8**(12), 456–465 (2019)
6. Mohanty, S., Subudhi, B., Ray, P.K.: A new MPPT design using grey wolf optimization technique for photovoltaic system under partial shading conditions. IEEE Trans. Sustain. Energy **7**(1), 181–188 (2016)
7. Belkhier, Y., Achour, A., Shaw, R.N., Sahraoui, W., Ghosh, A.: Adaptive linear feedback energy-based backstepping and PID control strategy for PMSG driven by a grid-connected wind turbine. In: Mekhilef, S., Favorskaya, M., Pandey, R.K., Shaw, R.N. (eds.) Innovations in Electrical and Electronic Engineering. LNEE, vol. 756, pp. 177–189. Springer, Singapore (2021). https://doi.org/10.1007/978-981-16-0749-3_13
8. Karatepe, E., Hiyama, T.: Performance enhancement of photovoltaic array through string and central based MPPT system under non-uniform irradiance conditions. Energy Convers. Manage. **62**, 131–140 (2012)