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A Multiple Input Single Output DC-DC Converter for a Microgrid

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ABSTRACT: A new topology of a hybrid distributed generator based on photovoltaic and wind-driven permanent magnet synchronous generator is proposed. In this generator, the sources are together connected to the grid with the help of only a single boost converter followed by an inverter. Thus, compared to earlier schemes, the proposed scheme has fewer power converters. Model of the proposed scheme in *d*-*q* axes reference frame is developed. Two low cost controllers are also proposed for the new hybrid scheme to separately trigger the DC-DC converter and the inverter for tracking the maximum power from both the sources. The integrated operations of both the proposed controllers for different conditions are demonstrated through simulation and experimentation. Steady-state performance of the system and transient response of the controllers are also presented to demonstrate the successful operation of the new hybrid system. Comparison of experimental and simulation results are given to validate the simulation model.

I. INTRODUCTION

With the rise of concerns regarding traditional power systems' vulnerability to physical attacks, cyber-attacks, or failures due to natural disasters or aging, trends in power systems research have turned toward the development of distributed micro-grids. Micro-grids are small-scale power grids that integrate clean and/or conventional generation systems into a unified power system for robust, reliable, resilient, and sustainable load support. They provide an attractive ability to sense critical changes in the utility grid to facilitate an autonomous control action to disconnect from the utility grid into the island mode. The ability of these microgrids to disconnect and reconnect to the utility grid creates transient properties that must be controlled in order to maintain stable and sustainable power. When the micro-grid is grid-tied, it is common to have synchronous connection where all micro-grid voltages must be synchronized with the utility grid, and later operate at desired voltage and frequency in the island mode. Harmonics, synchronization, voltage sags, failure of rotating machinery, and many other anomalies could arise when voltage and frequency conditions are not met. Asynchronous interconnection and DC micro-grids are expected to be viable alternatives to mitigate the frequency and synchronization requirements. For existing and near-future micro-grids, the detailed simulation models, including high levels of clean energy penetration, must be established.

Throughout literature, modeling approaches to micro-grids have been very limited. One approach was through the development of inverter-based models. These assume that distributed generators output a DC voltage that gets synchronized to the utility grid through inverters even though some conventional sources with diesel and natural gas are AC. Others have modeled micro-grids with off-the-shelf libraries, e.g. Simulink in islanded mode but did not analyze various system integration and time scale requirements, e.g. several hours of simulation time that can take several days or weeks to process. Other literature has focused on microgrid control methods based on small signal models in state-space format where eigenvalues are utilized for control. Other approaches to modeling have tried studying the behavior of a micro-grid with electrical energy storage devices under utility grid disturbances and for lifetime analysis of the micro-grid in island mode.

Recently renewable energy sources are attractive options for providing power in places where a connection to the utility network is either impossible or unduly expensive. As electric distribution technology steps into next century, many trends are becoming noticeable that will change the requirements of energy delivery. The ever increasing energy consumption, soaring cost and exhaustible nature of fossil fuels, and the worsening global environment have created increased interest in green power generation systems. Renewable sources have gained worldwide attention due to fast depletion of fossil fuels along with growing energy demand. DC power from photovoltaic panels (PV) or fuel cells has to be converted into ac using dc/dc boosters and dc/ac inverters in order to connect to an ac grid. Recently, DC micro grids are resurging due to the development and deployment of renewable dc power sources and their inherent advantage for dc loads in commercial, industrial and residential applications.

Most literature focuses on modeling one or two aspects of the micro-grid, but no model exists that integrates the electrical energy infrastructure as loads, distributed generation, energy conversion (power electronics), control at component levels, system integration, and real-time simulation. The power system simulators, meanwhile, the investigation of gridtied power electronics usually ignores generator models and their transient impact, but both levels of systems and their transients are considered and analyzed in the existing work to provide a more realistic model of a micro-grid. Note that the model presented here and which is formed by integrated several other models can be used as an example to apply a similar approach to this presented here for other micro-grids.

This existing work aims to develop detailed models of a real micro-grid's electrical energy infrastructure. This includes clean and conventional generation systems: two PV arrays, a fuel cell, a diesel generator, inverters and their interconnections. Each generation system has voltage control with inverter voltages synchronized using phase lock loops (PLLs). Once all models are implemented into a larger micro-grid model, case studies are simulated on a Simulink Real Time platform.

A microgrid installed with distributed generations (DGs) is a new type of power system. DGs, which include micro turbines, photovoltaics, wind cells, and fuel cells, are small generation units of less than 100 kW. At present, power systems are experiencing a rapid growth in the connection of DG units. Integrating DGs in a distribution system offers technical, environmental, and economic benefits. Moreover, such integration allows distribution utilities to improve system performance by reducing power losses.Electric energy market reforms and developments in electronics and communication technology enable the advanced control of DGs.

The DC micro grid has been proposed to incorporate various distributed generators and ac sources have to be converted into dc before connected to a dc grid and dc/ac inverters are required for conventional ac loads. DC micro grid cannot completely eliminate losses occurring in multiple stage conversions, though losses occurring in dc/dc conversions are lesser than those occurring in dc/ac or ac/dc conversions. Multiple reverse conversions are required in an individual ac or dc grids may add additional loss to the system operation and will make current home and office appliances more complicated. Thus, a hybrid micro grid is more beneficial to reduce the processes of multiple reverse conversions in an individual ac or dc micro grid to facilitate the connection of variable renewable ac and dc sources and loads with the power system in order to minimize the conversion losses. Since the operational issues of hybrid grid is more complicated than those of an individual ac and dc micro grids. A micro grid comprises of low voltage distributed systems with distributed generations, storage devices, loads and interconnecting switches. The operation of micro grids provide advantages of higher flexibility, better power quality, controllability, efficiency of operation, and bidirectional power flow between the utility grid and the micro grid in the grid connected mode of operation.

DG units can be integrated and efficiently operated as a microgrid in grid-connected and islanded modes. A microgrid system can strategically be placed on any site in a power system for grid reinforcement, thereby deferring or eliminating the need for system upgrades and improving system integrity, reliability, and efficiency of the existing power system. Therefore, many efforts have been exerted to control power electronic converters and thus allow the grid connection of microgrids in a distribution system. This technique is necessary to maximize the potential of DGs to enhance power quality and reliability and provide auxiliary services, such as active reserve, load following, interruptible loads, reactive reserve, and restoration. A microgrid operated in islanded mode is controlled by several inverters connected in parallel and sharing load to maintain voltage and frequency. Among the various techniques applicable to parallel inverter control in islanded mode operation, voltage and frequency droop based methods are appropriate to fulfill the requirements for communications control. Active power acts on voltage, and reactive power acts on frequency. That is, the active power output is dependent on local voltage. PI controllers have simple control structures and maintenance. However, the performance of these controllers degrades as the system operating conditions change. Fuzzy logic controllers are superior to conventional controllers because they can be easily adapted to different system structures, parameters, and operation points. In addition, they can be implemented in large-scale nonlinear systems. Thus, many researchers have attempted to combine conventional PI with fuzzy logic controllers to improve performance.

II. LITERATURE SURVEY

In [1] As the scale of power systems gradually expands, large-scale blackouts occasionally happen, exposing the reliability and security issues of the power system. The construction and production mode of the power system produce a serious energy crisis and environmental problems. In this context, the microgrid has received much attention because of its reliability and high efficiency.

Microgrids provide an effective technical means for the application of renewable energy. Since the access of many distributed generators (DGs) depends on inverters, the sources in microgrids are more flexible and controlled compared with conventional generators. Therefore, microgrids can operate in parallel to a grid and can work as an autonomous island by the rapid and robust control of power electronic devices. This allows microgrids to be used based on the operation condition of the distribution network or the economic requirements [2, 3].

The features of the microgrid can improve the security and reliability of the power supply, but it also produces many problems. The problem of transient dynamics is fundamentally important because it concerns the protection configuration, control strategy formulation, and transient stability assessment of the whole power system. However, studies on microgrids have mainly concentrated on the system structure and control mode because the attention has been mainly on the realization of the microgrid. Studies on the transient dynamics of microgrids are few, and most of them are directed at macroscopic simulation analyses [4-8].

The standard way to analyze the dynamics of a power system is to model the physical system mathematically. Various features of power system models have been established based on decades of experience. Thus, standard models of synchronous generator of various orders that capture particular classes of problems exist. However, related studies on microgrids are still few. The use of a recently proposed dynamic model needs considerations on certain prerequisites, including inverter type, switching frequency, and bandwidth, because it assumes that the DGs are ideal voltage sources. Another proposed microgrid model captures the detail of the control loops of the inverter and contains a full dynamic model of the network. However, its emphasis is on the problem of state stability and small-signal dynamics of microgrid to assess the influence of controller. The dynamic equivalent method used to adopt port-based network modeling decomposes the overall system into subsystems interconnected with each other through pairs of variables. Network-reduction models represented by a set of ordinary differential equations are major methods. In these models, all loads are converted to constant admittance, and the network is reduced to generator internal buses. These equivalents have caused many problems [9-15].

Microgrids can provide a more reliable power supply and can enable the interconnection of renewable energy. The microgrid has been recognized as one of the most important directions of power systems. The transient characteristics of the microgrid are very important for the planning and operation of the whole power system. However, its mechanism still needs further exploration because the circuit structure, control feature, and even the operation mode of the microgrid are quite different from those of the traditional power system. In this article, a dynamic model is proposed for a microgrid according to the difference in transient processes between the microgrid and the traditional grid. The model is expressed as a differential-algebraic equation system, so the structure of the microgrid and the physical meaning of original variables are preserved. The focal point in is the fast control function of the inverter and the strong coupling between inverter and grid. [16-18]

In [19] presents a simulation platform for the modeling and study of microgrid (MG) power systems. Using MathWorks Simulink modeling software, the platform provides a library of tools for designing and simulating the behavior of an MG on time scales from seconds to days. The library includes a collection of power system and power electronics components (sources, loads, switches, etc.) that may be arbitrarily configured.

III. EXISTING METHOD

This work aims to develop detailed models of a real micro-grid's electrical energy infrastructure. This includes clean and conventional generation systems: two PV arrays, a fuel cell, a diesel generator, inverters and their interconnections. Each generation system has voltage control with inverter voltages synchronized using phase lock loops (PLLs). Once all models are implemented into a larger micro-grid model, case studies are simulated on a Simulink Real Time platform where the simulated system is shown in Fig. 3.1. Fig. 3.2 shows a higher-level block diagram of the same system. Note that R-L loads shown in orange in Fig. 3.1 were extracted as average values from real dynamic building loads.

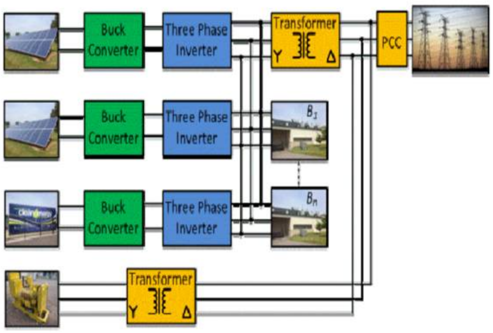

Fig. 3.1 High-level block-diagram of the micro-grid

3.1 Models of distributed generation

Each distributed generator is grid-tied through power electronics where a DC/DC stage regulates individual DC busses and a DC/AC stage inverts to synchronize with the grid or other sources, except for diesel generators. The PV arrays' voltage levels allow for the use of a buck converter to regulate higher voltage from the PV model to lower voltage at the DC bus. Local sources support building loads in grid-tied and island modes. Fig.s3.2-3.4 show generation model block diagrams. Note that PCC is the point of common coupling.

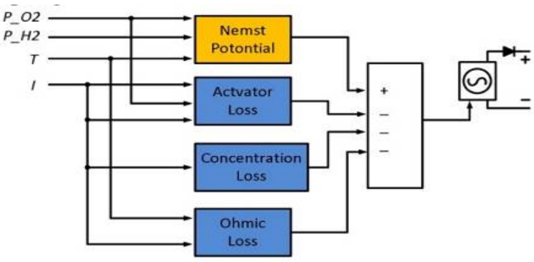

Fig. 3.2 Non - ideal fuel cell model as a controlled voltage source taking into account various losses

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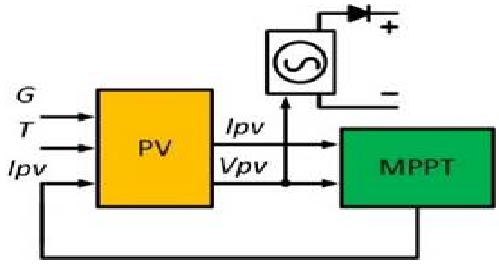


Fig.3.3 Non-ideal PV array model as a controlled voltage source

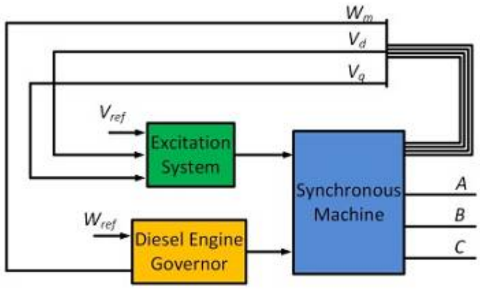


Fig. 3.4 Diesel generator model

For the fuel cell in Fig. 3, a polymer electrolyte membrane (PEM) fuel cell is used. PEM fuel cells have the advantages of operating at a low temperature, high power density, fast response and low emissions. They convert chemical energy of hydrogen and oxygen reactions into electrical energy. This paper models the fuel cell by assuming the hydrogen, oxygen, initial current and temperature are constant values , and losses are modeled as steady/dynamic state activation loss, ohmic loss and concentration loss as shown in Fig. 3.3 The model of a fuel cell can be represented by open circuit voltage E. The output voltage of the fuel cell is thus,

$$V_{fc} = E - V_{act} - V_{ohm} - V_{con} \quad (1)$$

The diesel generator shown in Fig. 3.1 and elaborated upon in Fig.3.4 consists of three parts: diesel engine governor, excitation system and synchronous machine. The excitation system provides the initial magnetic field to startup the synchronous machine, while the diesel engine governor utilizes a feedback mechanism to regulate and maintain the speed as needed to maintain electrical frequency by setting the reference speed w_f . The on and off state of the diesel engine can be controlled. The diesel generator model contains two main parts: Diesel engine governor and synchronous generator. The structure of the diesel engine governor is shown in Fig. 3.5. The PI controller and actuator are modeled by transfer functions with time constant τ1, τ2, τ3, τ4and PI parameters Ki and K_p.

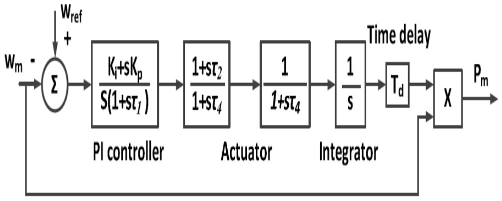


Fig. 3.5Diesel engine governor model

Closed-loop control is also applied to three phase inverter, different from classic PI control where the inverter output and balanced three-phase reference signals are synchronized as shown in Fig. 3.6. To maintain this reference when the grid is lost, a synchronized source shown in Fig. 3.7 is generated from the grid and synchronizes all necessary parameters, especially phase information, for all inverters on the micro-grid. After one cycle from the simulation start time, selection switches shown in Fig. 3.7 switch to replace the utility grid generated ω_t to create stand-alone sinusoidal control waveforms.

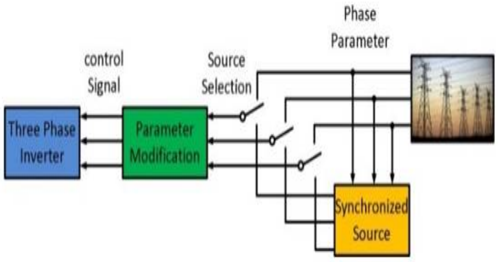


Fig. 3.6Closed-loop control for three phase inverter

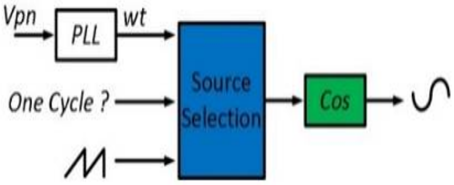


Fig. 3.7 Synchronized source

Note that the models developed in the paper address a specific implemented micro-grid but other models can be integrated to the micro-grid simulation for more generation and load options. The main purpose of the models presented here is to achieve a robust and flexible real-time simulation platform for further research and development while capturing fast and slow dynamics in addition to control effects.

IV. PROPOSED SCHEME

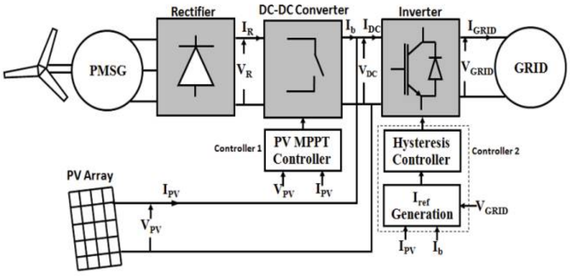


Fig. 4.1 Proposed DG system based on PMSG-PV sources

The block diagram of proposed DG scheme is given in Fig. 4.1, where a direct driven PMSG and a PV array are the sources. The PMSG output is rectified and fed into a DC-DC boost converter. The rectifier output voltage varies with the wind-speed. The PV array terminals are connected to the output of the DC-DC converter to form a common DC link for the proposed system. The inverter input terminals are tied to this common DC link. The PV array voltage (V_{PV}) is fixed to the output voltage of the DC-DC converter (V_{DC}) since the output terminals of both the PV array and the DC-DC converter are tied together. The output voltage of the DC-DC converter is automatically varied by a PV MPPT controller (Controller 1) to PV array's maximum power point voltage. Under this condition, the maximum current for the given irradiation is drawn from the PV array by the action of current controller (controller 2) of the inverter. The basic Perturb & Observe (P&O) algorithm is employed with an inverted duty-cycle adjustment in controller 1. This revised adjustment in the proposed scheme is because of the DC-DC boost converter being fed by a stiff DC source (rectifier output) instead of the PV array. The output voltage of the current controlled inverter is tied to the grid voltage and the frequency and the phase requirement for synchronization are automatically met. The current fed to the grid by the inverter (I_{GRID}) follows the reference current signal (I_{ref}), which is automatically varied by controller 2 for drawing the maximum current from both PMSG & PV array. In the proposed scheme, the setting of DC voltage reference of the DC-DC converter to the peak power point voltage of the PV array and the reference current setting of current controlled inverter corresponding to the maximum current extractable from both the sources, results in peak power extraction from both the sources.

4.1. Hill Climb Search (HCS) method

HCS method of MPPT makes use of the inverted U shaped graph between power and rotor speed. As there is a definite peak power corresponding to a particular rotor speed, the algorithm compares the present power at an instant to the power obtained at the previous step. If the power is found to be increasing, then the duty cycle of the gating pulse applied to the converter switches are increased to drive the operating point more towards the peak power. If the power is found to be decreasing, then the duty cycle is reduced. The primary advantage of this method is its simplicity and independence from wind turbine characteristics. A severe limitation of the HCS method is its inability to track the maximum power point in cases of abruptly varying wind conditions. In normal HCS methods the increments/decrements given to the duty cycle are fixed.

4.2 Operation of the Controllers

A. Case 1 (PV and PMSG generating power)

The wind and solar sources are generating power together in this case and the variation of duty-cycle of the DC-DC converter will eventually disturb the PV array's terminal voltage (since $V_{DC}= V_{PV}$). The rectifier voltage varies with the wind-speed and the duty-cycle of the boost converter needs to be automatically adjusted such that V_{DC} is equal to the peak power point voltage (V_m) of the PV array. At this point ($V_{PV}= V_{DC}= V_m$), the PV array delivers the maximum current (I_m) which is concurrently drawn by the current controlled inverter. The DC link voltage may be, say V_1(B) or V_2(C) depending upon the present duty-cycle of the DC–DC converter. To operate the PV array at its maximum power point (A), the DC-DC converter output (DC link voltage) is adjusted to V_m by varying the duty-cycle of the DC-DC converter by controller 1. The duty-cycle variation of controller 1 is given by

$$\delta_{new} = \delta_{old} + \text{sgn}\,(\Delta P)\,\text{sgn}(\Delta V_{PV})\,\Delta\delta \quad (2)$$

Where $\Delta\delta$ is the perturbation in duty-cycle, sgn is Signum function. ΔP is the difference in PV array power and ΔV_{PV} is difference in PV array voltage before and after perturbation. If ΔP and ΔV_{PV} are both either positive or negative then the duty-cycle increases and vice-versa if different. The duty cycle variation in this scheme is hence exactly opposite to the duty-cycle variation of a P&O controller used in existing schemes, where a PV array precedes a boost converter.

The main objective of controller 2 shown in Fig. 4.1 is to vary the inverter output current fed to the grid. The reference current (I_{ref}) for this hysteresis current controller is derived based on the available maximum power from the both the sources for a particular condition (i.e. irradiation and PMSG shaft torque). V_{PV}, is at maximum power point value by the action of controller 1. Current drawn from the boost converter (I_b) and P_V (I_{PV}) together is maximized by changing I_{ref}as

$$I_{ref(new)}=I_{ref(old)}+\text{sgn}[\Delta(I_{PV}+I_b)]\,K \qquad (3)$$

Where $\Delta(I_{PV}+I_b)$ is the change in the sum of I_{PV} and $I_b$and K is the step in perturbation of I_{ref}. It is clear from (3), if current to be drawn from boost converter increases, I_{ref}also increases correspondingly.
At steady-state, the reference current value for a particular condition of irradiation and wind speed is
Iref =

$$I_{ref} = \sqrt{2}(V_{PV}I_{PV} + V_R I_R)\,/\,V_{GRID} \qquad (4)$$

B. Case 2 (PMSG alone generating power)

It is obvious that during night time, the current transducer connected to the PV terminal will not give any response. In such a case, the controller 1 will skip the PV-MPPT algorithm and work in a voltage control mode. By taking the voltage transducer output (VDC) as feedback signal, the controller 1varies the duty-cycle of the boost converter to maintain the DC link voltage to a DC value corresponding to the rated RMS voltage of the grid. As IPV is zero in this case, the controller 2 will keep adjusting the (Iref) such that [by substituting IPV= 0 in (3)]

$$Iref(new) = Iref(old) + \mathrm{sgn}[\Delta(Ib)]K \qquad \text{Eq.5}$$

to extract the maximum power from the PMSG alone.

C. Case 3 (PV alone generating power)

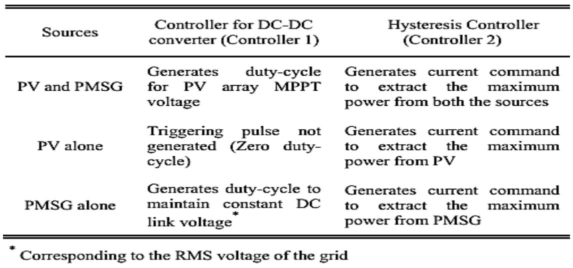
When PMSG is not generating power, there is no input to the DC-DC converter and hence no triggering pulse is generated by controller 1. The controller 2 varies Irefsuch that [by substituting Ib= 0 in (3)] to feed the maximum power from PV array alone.

$$Iref(new) = Iref(old) + \mathrm{sgn}[\Delta(IPV)]K \qquad (5)$$

D. Composite operation of controllers

It is evident from all the three cases explained above, that controller 2 functions always to feed the maximum power either from both the sources or from any one of the sources to the grid by adjusting Iref. On the other hand, controller 1 is idle when power is generated by PV alone. Different status of sources and the corresponding functions of two controllers are summarized in Table. 4.1.

Table 4.1 Functions of controllers under different conditions



Sources	Controller for DC-DC converter (Controller 1)	Hysteresis Controller (Controller 2)
PV and PMSG	Generates duty-cycle for PV array MPPT voltage	Generates current command to extract the maximum power from both the sources
PV alone	Triggering pulse not generated (Zero duty-cycle)	Generates current command to extract the maximum power from PV
PMSG alone	Generates duty-cycle to maintain constant DC link voltage*	Generates current command to extract the maximum power from PMSG

* Corresponding to the RMS voltage of the grid

V. RESULTS AND DISCUSSION

In order to validate the performance of the proposed converter and the gird connected system, this project is designed with a wind generator system and voltage controller along with the gird connected control system that maintains the dc link voltage based on the PQ transform, the grid voltage and current are synchronized through the inverter which stabilizes the link dc voltage. In order to verify the performance of the proposed single converter system a model based on MATLAB /Simulink is designed and the experimental waveforms are obtained.

5.1 Existing method

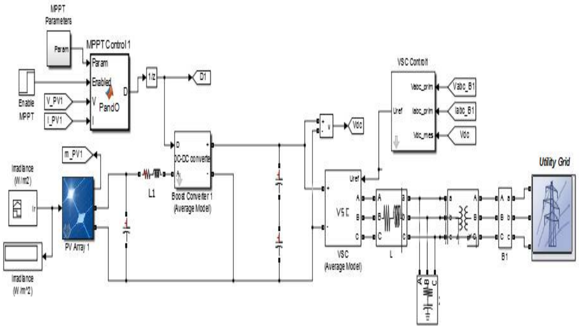


Fig. 5.1Simulation model contain PV, dc-dc converter and utility grid

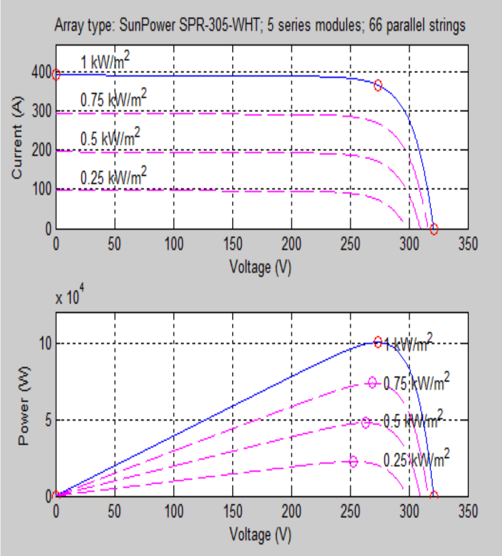


Fig. 5.2 PV panel response towards various irradiation levels of solar with series connected configurations

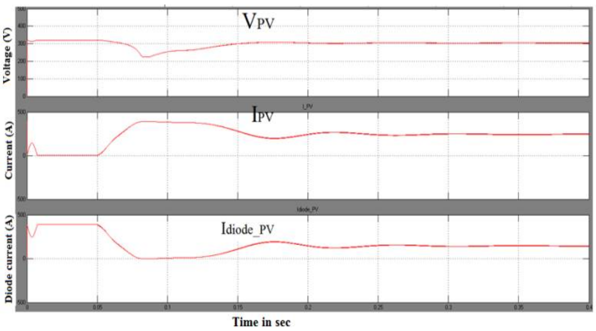


Fig5.3 PV voltage and current characteristics along with a diode voltages for PV module -1

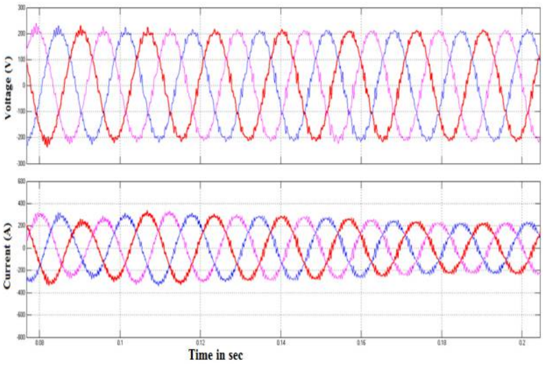


Fig. 5.4 Generate and filtered PV-1 voltage and current output to grid

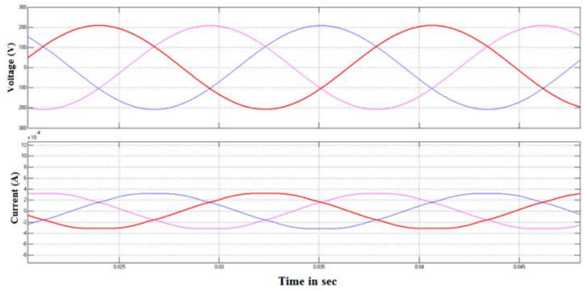


Fig. 5.5Generate and filtered PV-2 voltage and current output to grid

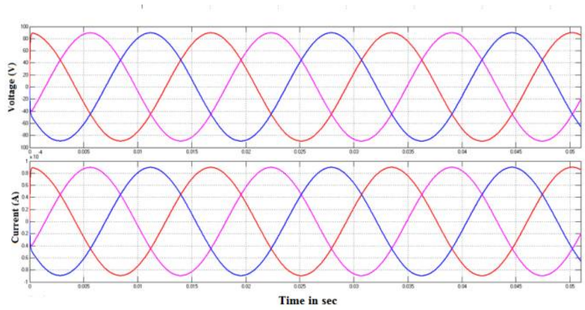


Fig. 5.6 Diesel generator voltage and currents under islanding mode

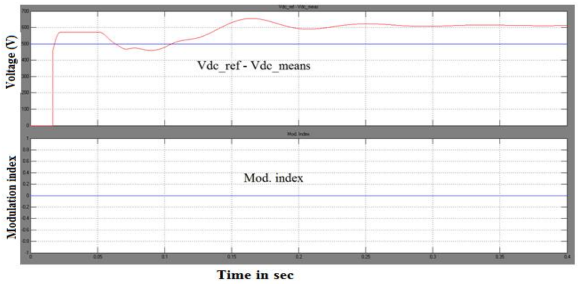


Fig. 5.7 Modulation index and v regulation maintenance for a voltage regulation under grid connected mode

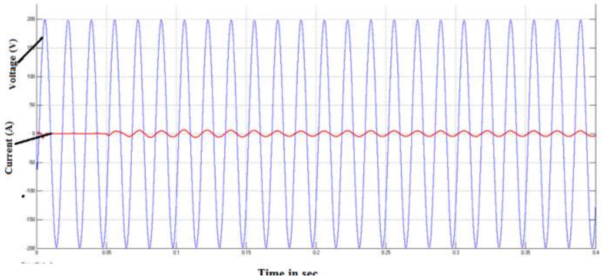


Fig. 5.8 voltage of the grid and generated current are in phase

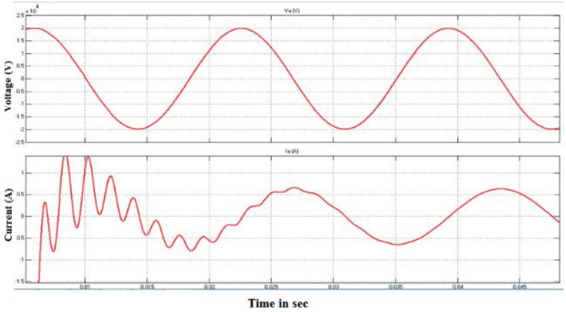


Fig. 5.9 Grid synchronization starts at 0.02.

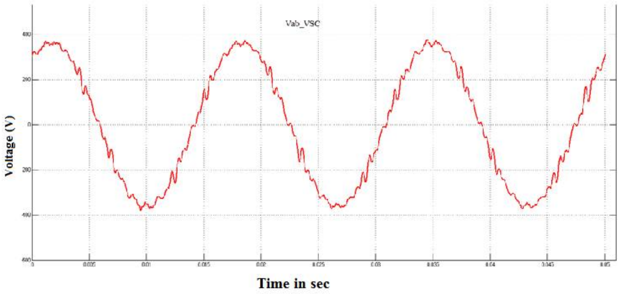


Fig. 5.10 Filtered output voltage at terminal Vab of VSC

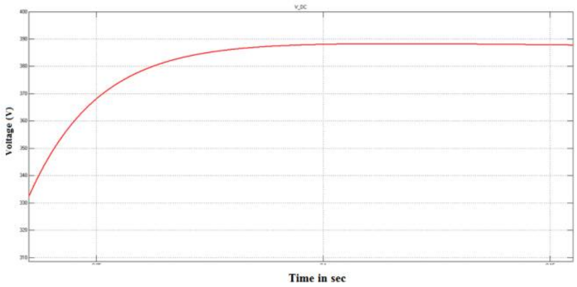


Fig. 5.11 Fuel cell dc output voltage

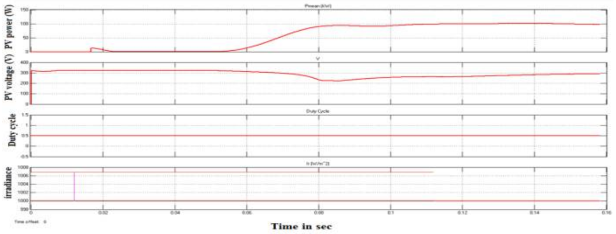


Fig.5.12 PV power regulation

5.2 Proposed method

The proposed simulation model of the grid connected wind and PV generations consists a solar and the wind power generators, in that, wind generator is connected to the dc-dc converter followed by a solar which is connected to the dc link capacitor, the speed of the wind turbine and energy generated from the solar panel are taken in account and analyzed and this is shown in Fig. 5.2.1.

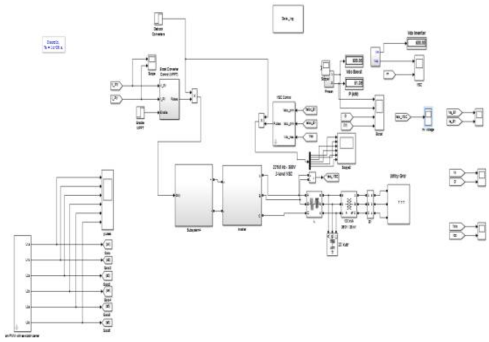


Fig. 5.2.1 MATLAB simulation of the Grid Connected Hybrid Wind-Driven PMSG-PV System

Simulation of wind model which was analyzed in MATLAB is shown in Fig. 5.2.2where the output of wind generator (AC) is converted into DC. Simulation of PV model which was analyzed in MATLAB is shown in Fig5.2.2.where the output of PV panel (DC) is directly given to the DC bus.

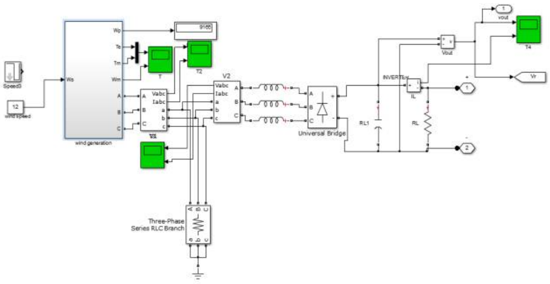


Fig. 5.2.2 MATLAB simulation of wind Model

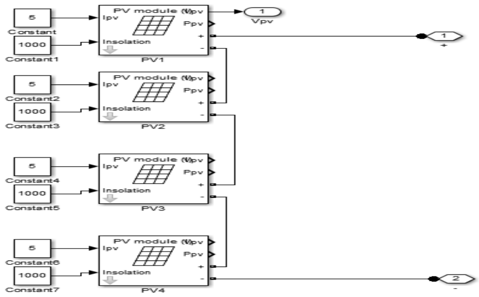


Fig. 5.2.3 MATLAB simulation of PV Model

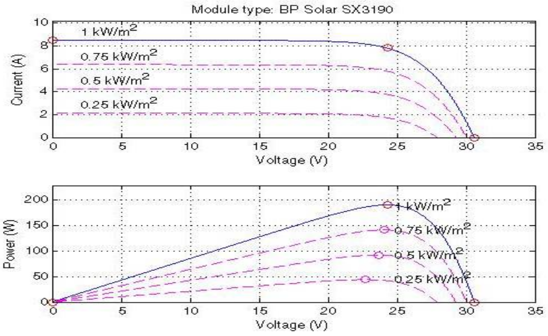


Fig. 5.2.4 PV panel properties used to simulate the proposed solar panel model

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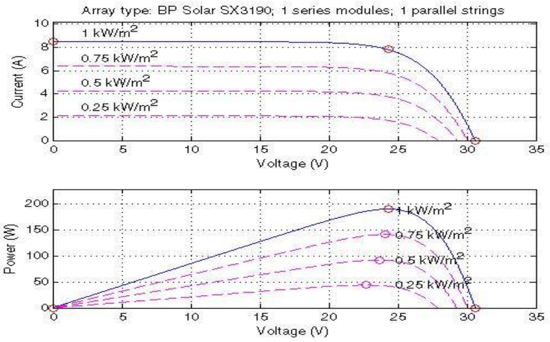

Fig. 5.2.5 Characteristics of a single module of the simulated panel

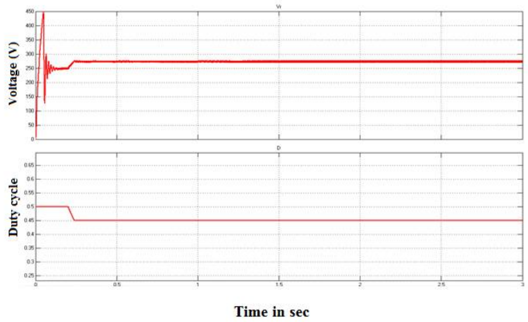

Fig. 5.2.6 Changes in rectifier output voltage and duty cycle of boost converter

For a step increase, the rectifier voltage level and duty-cycle of boost converter changes and is shown in Fig. 5.2.6.

The proposed controller efficiently tracks the set point voltage by varying the modulation index of the inverter which shown in the figure below to the voltage control graph. As the voltage changes the dc tracking voltage variation of the system, it also changes the index which is fluctuating between 0.85 to 0.84 due to the variation of the boost converter the dc link voltage would tend to change, as the composite controller is linked with the dc link voltage it generates the required control signal to adjust the grid voltage and maintains the dc link to ref, by varying the inverter triggering signals through the variation of the modulation index. Fig 5.2.7 shows the dc link voltage control by the controller 2 which is responsible to maintain the dc link voltage.

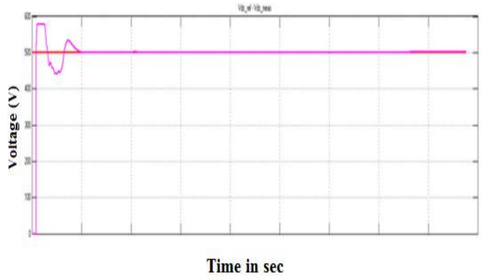

Fig. 5.2.7 DC link voltage control

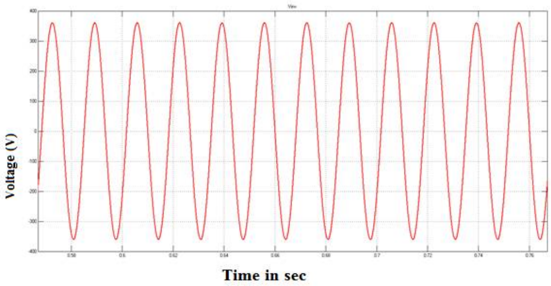

Fig. 5.2.8 Inverter output voltage

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Fig. 5.2.8depicts the inverter voltage which is the output of inverter converted from DC to AC. The converted AC voltage is filtered for harmonics reduction and then it is synchronized into the grid.

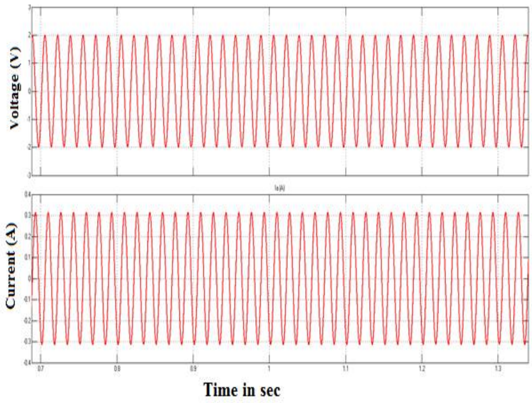
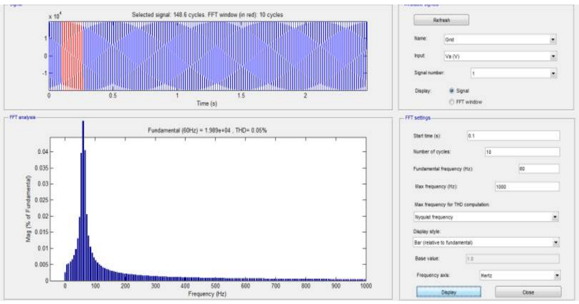


Fig. 5.2.9 Steady-state grid voltage and current waveforms

The current was delivered to the grid by the inverter at unity power factor. Grid voltage and current of the proposed grid connected system represents the voltage and current are maintained as inline by the controller 2 and this shown in Fig. 5.2.8 From the simulated results, we can able to analyze the THD for grid voltage and current and are shown in fig 5.2.9 and 5.2.10.



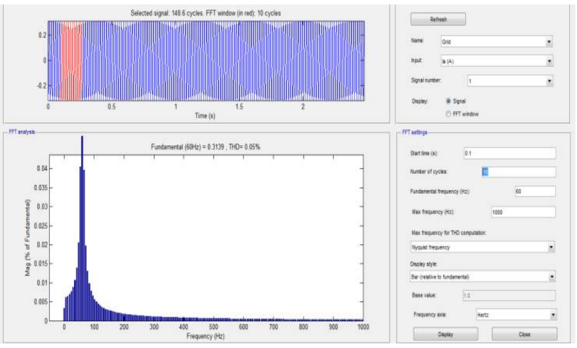
Selected signal: 148.6 cycles. FFT window (in red): 10 cycles

Name: Grid
Input: Va (V)
Signal number: 1
Display: ● Signal ○ FFT window

Fundamental (60Hz) = 1.989e+04 , THD= 0.05%

Start time (s): 0.1
Number of cycles: 10
Fundamental frequency (Hz): 60
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig. 5.2.10 Harmonic analysis of grid voltage



Name: Grid
Input: Ia (A)
Signal number: 1
Display: ● Signal ○ FFT window

Start time (s): 0.1
Number of cycles: 10
Fundamental frequency (Hz): 60
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig. 5.2.11 Harmonic analysis of grid current

The total harmonic distortion (THD)0.5 of the voltage and the current at grid side were measured by using FFT analyzer and the results are shown in above Fig. 5.2.10 and 5.2.11.

VI. CONCLUSION

A new reliable hybrid DG system based on PV and winddriven PMSG as sources, with only a boost converter followed by an inverter stage, has been successfully implemented. The mathematical model developed for the proposed DG scheme has been used to study the system performance in MATLAB. The investigations carried out in a laboratory prototype for different irradiations and PMSG shaft speeds amply confirm the utility of the proposed hybrid generator in zero net energy buildings. In addition, it has been established through experimentation and simulation that the two controllers, digital MPPT controller and hysteresis-current-controller which are designed specifically for the proposed system have exactly tracked the maximum powers from both the sources.

REFERENCES

[1] Lasseter, R. H., “Microgrids,” Proc. Power Eng. Soc. Winter Mtg., Vol. 1, pp. 305–308, January 2002.

[2] Katiraei, F., and Iravani, M. R., “Micro-grid autonomous operation during and subsequent to islanding process,” IEEE Trans. Power Delivery, Vol. 20, No. 1, pp. 248–257, January 2005.

[3] Hatziargyriou, N., Asano, H., Iravani, R., and Marnay, C., “Microgrids,” IEEE Power Energy Mag., Vol. 5, No. 4, pp. 78–94, July/August 2007.

[4] Chung, I., Park, S., Kim, H., Moon, S., Han, B., Kim, J., and Hoi, J., “Operating strategy and control scheme of premium power supply interconnected with electric power systems,” IEEE Trans. Power Delivery, Vol. 20, No. 3, pp. 2281–2288, July 2005.

[5] Katiraei, F., and Iravani, M. R., “Power management strategies for a microgrid with multiple distributed generation units,” IEEE Trans. Power Syst., Vol. 21, No. 4, pp. 1821–1831, November 2006.

[6] Lopez, J. A. P., Moreira, C. L., and Madureira, A. G., “Defining control strategies for microgrid islanded operation,” IEEE Trans. Power Syst., Vol. 21, No. 2, pp. 916–924, May 2006.

[7] Guerrero, J. M., Hang, L., and Uceda, J., “Control of distributed uninterruptible power supply systems,” IEEE Trans. Indust. Electron., Vol. 55, No. 8, pp. 2845–2859, August 2008.

[8] Sortomme, E., Mapes, G. J., Foster, B. A., and Venkata, S. S., “Fault analysis and protection of a microgrid,” IEEE North American Power Symposium (NAPS), pp. 1–6, Calgary, AB, Canada, 1–6 Septebmer 2008.

[9] Bollen, M., Zhong, J., Samuelsson, O., and Bjoernstedt, J., “Performance indicators for microgrids during grid-connected and island operation,” IEEE Bucharest Powertech, Vol. 1–5, pp. 866–871, 2009.

[10] van der Schaft, A. J., and Polyuga, R. V., “Structure-preserving model reduction of complex physical systems,” 48th IEEE Conference on Decision and Control (CDC) and 28th Chinese Control Conference (CCC 2009), pp. 4322–4327, Shanghai, China, December 2009.

[11] Sao, C. K., and Lehn, P. W., “Intentional islanded operation of converter fed microgrids,” IEEE Power Engineering Society General Meeting, pp. 1–6, Montreal, Quebec, Canada, December 2006.

[12] Barklund, E., Pogaku, N., Prodanovic, M., Hernandez-Aramburo, C., and Green, T. C., “Energy management in autonomous micro-grid using stability-constrained droop control of inverters,” IEEE Trans. Power Electron., Vol. 23, p. 2346, 2008.

[13] Mohamed, Y., and El-Saadany, E. F., “Adaptive decentralized droop controller to preserve power sharing stability of paralleled inverters in distributed generation micro-grids,” IEEE Trans. Power Electron., Vol. 23, pp. 2806–2816, 2008.

[14] Pogaku, N., Prodanovic, M., and Green, T., “Modeling, analysis and testing of autonomous operation of an inverter-based microgrid,” IEEE Trans. Power Electron., Vol. 22, No. 2, pp. 613–625, March 2007.

[15] Hao, J., Chen, C., Libao, S., and Jie, W., “Nonlinear decentralized disturbance attenuation excitation control for power systems with nonlinear loads based on the Hamiltonian theory,” IEEE Trans. Energy Conversion, Vol. 22, No. 2, pp. 316–324, 2007.

[16] Chen, Weiqiang, Ali M. Bazzi, James Hare, and Shalabh Gupta. "Real-time integrated model of a micro-grid with distributed clean energy generators and their power electronics." In *2016 IEEE Applied Power Electronics Conference and Exposition (APEC)*, pp. 2666-2672. IEEE, 2016.

[17] Theubou, T.; Wamkeue, R.; Kamwa, I, "Dynamic model of diesel generator set for hybrid wind-diesel small grids applications," , In *Proc. 2012 25th IEEE Canadian Conference on Electrical & Computer Engineering (CCECE), pp.1,4, April 29 2012-May 2 2012.*

[18] Xiong, Xiaofu, and Jinxin Ouyang. "Modeling and transient behavior analysis of an inverter-based microgrid." In *Proc. Electric Power Components and Systems 40.1 (2011): 112-130.*

[19] Brissette, Alexander, et al. "A micro-grid modeling and simulation platform for system evaluation on a range of time scales." In *Proc. Energy Conversion Congress and Exposition (ECCE), 2011 IEEE. IEEE, 2011.*