Design and Analysis of Hybrid Distributed Generator using MPPT and Hystersis Controller

A.ANN RUFUS
Assistant professor
Department of EEE
SCAD College Of Engineering and Techonolgy,cheranmahadevi
annrufus@gmail.com

Dr.L KALAIVANI
Associate professor
Department of EEE
National Engineering College
Kovilpatti, Tamil Nadu
anuprakad@gmail.com

S.SYEDHALI FATHIMA JAMIN
PG Student
SCAD College Of Engineering and Techonolgy, Cheranmahadevi
Fathimahameed94@gmail.com

Abstract: A hybrid distributed generator based on photovoltaic and wind-driven permanent magnet synchronous generator is proposed. In this generator, the sources are connected together 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. A model of the proposed scheme in the d q-axis 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 sources. The integrated operations of both proposed controllers for different conditions are demonstrated through a simulation model.

Keywords- *Grid-connected hybrid system, hybrid distributed generators (DGs), smart grid, wind-driven (PMSG), photo voltaic (PV)*

1. INTRODUCTION

A grid connected PMSG–PV hybrid system with a battery backup was described in where the dc-link voltage was fixed to the battery voltage, but the maximum power extraction from the wind-driven PMSG was not performed. A grid-connected hybrid system where the PV array and wind-driven PMSG were connected to a common dc link through a multi-input dc–dc converter was proposed earlier. A PMSG–PV hybrid system with multi-input dc–dc converter and multi-input inverter was also brought out in. In all of the aforementioned hybrid DG systems with PMSG–PV attempted so far, the system had either individual power converters for each of the sources or a battery backup. Furthermore, each converter was controlled using complex algorithms for peak power tracking. In order to minimize the conduction and switching losses of the devices, it is necessary to have the minimum number of power converters (power conversion stages), and this has been attempted in this paper. In addition, it is desirable that power supplies in consumer sites employ fewer power electronic conversion stages in order to improve the overall efficiency. It should be noted that losses in conversion stages have to be compensated by increasing the sizes of the generators. This, in turn, increases the cost of the hybrid generator. Generally, the efficiency of a dc–dc converter is maximum around 95% when it is operated in full load condition. Since source powers are varying, it is not always possible to operate the dc–dc converter at its maximum efficiency. In the aforementioned context, the proposed new topology avoids 5% loss in efficiency by eliminating an additional conversion stage.

.

2. HYBRID POWER GENERATION

The hybrid generator has a PV array being directly connected to the dc link of dc–dc converter. The dc-link voltage is varied by a dc–dc converter interposed between the rectifier fed by the PMSG and the grid-connected inverter. The output voltage of the dc–dc converter forms the load line for the PV array now the inverter current is varied to extract the maximum current from both sources using current control strategy. The proposed topology could thus dispense with a dc–dc converter, which, in earlier schemes, was connected after the PV array for maximum power extraction. Two new controllers are attempted for the hybrid scheme proposed in order to achieve the maximum power extraction from both sources. A d q-axis model of the scheme has been developed and validated.

The successful operation of this scheme in extracting maximum power from both sources or from each of the sources has been established through simulation investigations

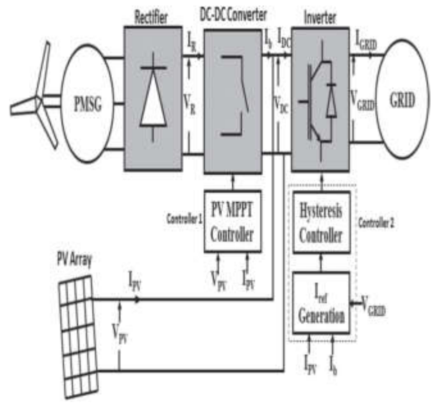

Figure 2.1 Structure of a Hybrid distributed generators

Furthermore, the proposed scheme is also for employment by domestic consumers in a smart grid scenario and hence maintenance-free simple operation is envisaged. The proposed scheme is for a grid-connected operation and hence battery storage is not necessary is main advantage of the paper where the capital cost of the generator is very low because of the absence of battery.

2.1 PROPOSED SYSTEM

OPERATION OF THE CONTROLLERS

PV and PMSG energy generators

The wind and solar sources are generating power together in this case, and the variation of the duty cycle of the dc–dc converter will eventually disturb the PV array's terminal voltage (since $V_{DC} = V_{PV}$).

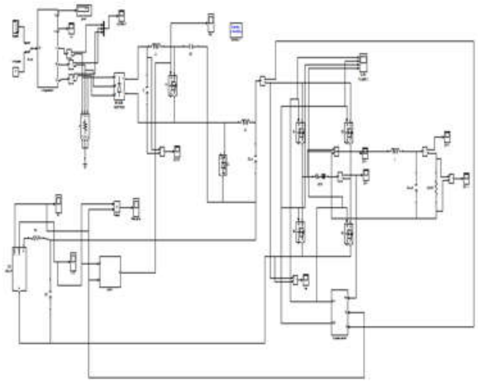

Figure 2.2 PV and PMSG generator simulation circuit

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.

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

$$\delta new = \delta old + sgn(\Delta P)sgn(\Delta VPV)\Delta\delta$$

where

$\Delta\delta$ is the perturbation in duty cycle

ΔP is the difference in PV array power

ΔVPV is the difference in PV array voltage before and after perturbation.

If both ΔP and ΔVPV are 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 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 both 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. The current drawn from the boost converter (I_b) and PV (I_{PV}) together is maximized by changing I_{ref} as

$$Iref(new) = Iref(old) + sgn\,[\Delta(I_{PV} + I_b)]\,K$$

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 ifthe current to be drawn from the 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

$$Iref = \frac{\sqrt{2}(\,VpvIpv + IrVr)}{V_{Grid}}$$

2.2 METHOD OF WORKING

2.2.1Maximum Power Point Tracking (controller 1)

Investigations on MPPT Operation In order to ascertain the successful operation of the hybrid generator for different irradiation and PMSG shaft speed conditions, the following investigations were carried out in the laboratory prototype. The experimentation was conducted when the irradiation has been constant without major variations. The variations of these parameters with respect to the Generator power variations with PMSG shaft speed and irradiation.

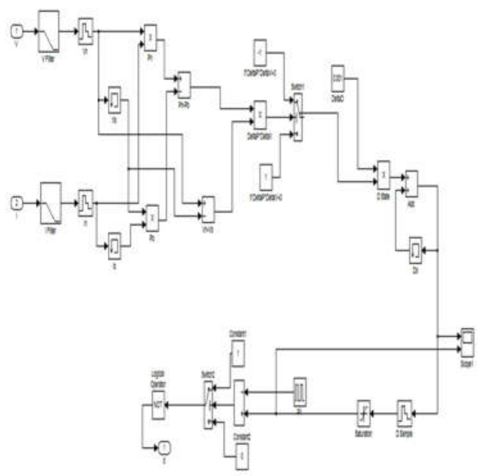

Figure 2.3 Simulation circuit of MPPT

(a) PMSG power, boost converter duty cycle, and reference current variation with PMSG shaft speed. (b) PV power, boost converter duty cycle, and reference current variation with ISC of the PV array.DC motor speed (PMSG speed) are depicted. It is clear that, when the PMSG shaft speed had increased, the PMSG output power also had correspondingly increased and the current reference generated by controller 2 also had increased proportionally in order to extract the available maximum power. As the dc motor speed increases the input voltage to the dc–dc converter also increases, and hence, the duty cycle of the boost converter automatically decreases to maintain the dc-link voltage to the PV's maximum power point voltage. The ISC of the PV array is directly proportional to irradiation. Hence, the variations of the PV power, duty cycle of the boost converter, and reference current with the variation of ISC (instead of irradiation) are given. It can be found that, when ISC (irradiation) increases, the voltage corresponding to its maximum power point also increases and the duty cycle of the boost converter correspondingly increases to match the maximum power point voltage of the PV array. At the same time, the reference current value also proportionally increases to extract the available maximum power from both sources as expected

2.2.2 Hysteresis Current Controller (Controller 2)

The complete schematic of controller 2 is given in Figure.2.4High-frequency op-amps (LM-318) are used to construct the hysteresis current controller. I_{PV} and I_b are sensed by the current transducers and digitized by the internal ADC module of the microcontroller. Based on I_{ref} is determined and available as a digital output from the microcontroller. This digital value is subsequently processed by a digital-to-analog conversion IC to obtain a dc value which corresponds to the peak value of I_{ref}.

Current Controlling System

This dc value is multiplied with the sine wave reference extracted from the grid voltage by a multiplier IC and fed to the hysteresis current controller as the reference current signal. When the PV array (or PMSG) alone generates power, I_b(or I_{PV}) will be zero, and $I_{ref}$is perturbed and adjustedautomatically to extract the maximum power from the PV array (or PMSG). When both sources are generating, I_{ref} will be perturbed based on and adjusted to maximize the dc-link current I_{DC} for the corresponding irradiation and wind speed conditions. As the sine wave reference is taken from the grid

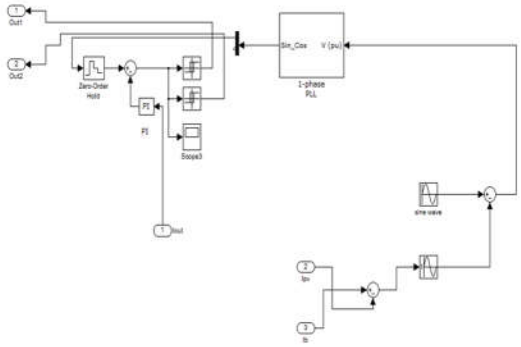

Figure 2.4 simulation circuit of hysteresis current controller

3. SIMULATION RESULTS

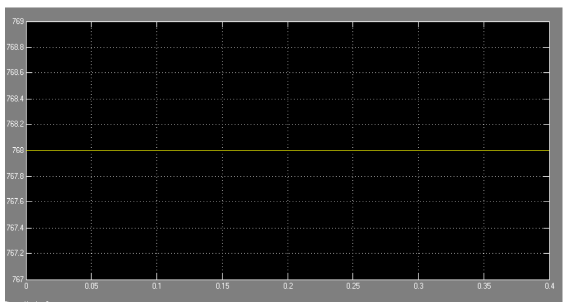

Figure 3.1 waveform of photovoltaic energy

By giving the constant 5v it has been observed that the PV array is producing power

Figure 3.2 current waveform of wind energy

The above simulation waveform for current flow of wind energy system

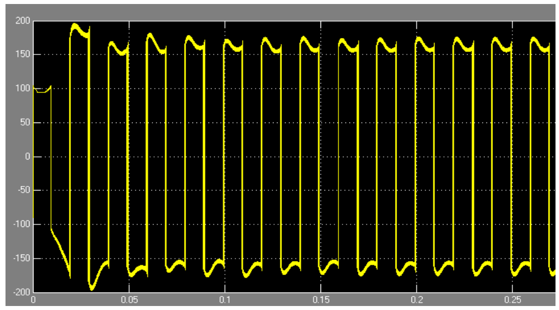

Figure 3.3 Inverted voltage waveform

By combining the both PV and PMSG the converter produces the output voltage waveform by hysteresis controller the observed waveform is taken before followed by the inverter.

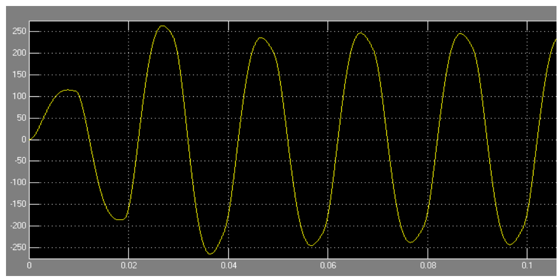

Figure 3.4 output voltage waveform

The observed clear output voltage waveform that obtained from the inverter.

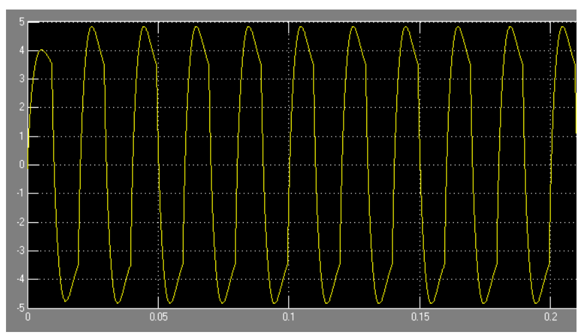

Figure 3.5 inverted current waveform

Inverted current waveform that produced by hysteresis current controller before feeding into the inverter.

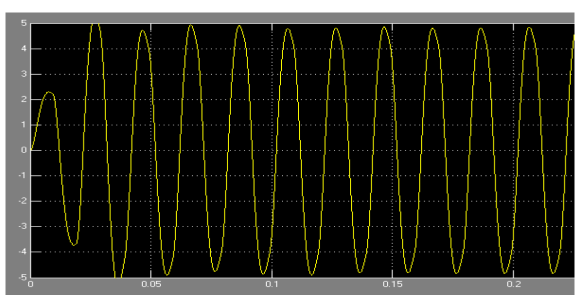

Figure 3.6 output current waveform

Current waveform generated by the inverter is observed.

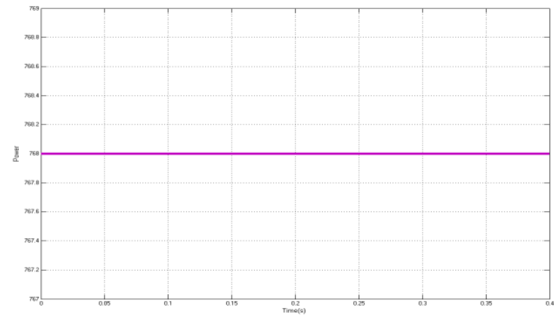

Figure 3.7 Output power generated

By combining the both PV and PMSG the output power waveform is produced

4. APPLICATIONS

The hybrid power system may includes various types of application some of the main applications are listed below

- MOBILE POWER
- BUILDING
- WATER PUMPING
- VENTILATION
- REMOTE LIGHTING
- SECURITY

5. CONCLUSION

A new reliable hybrid DC system based on PV and wind driven PMSG as sources, with only a boost converter followed by an inverter stage, has been successfully verified using MATLAB. In addition, it has been established through 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 sources. Maintenance-free operation, reliability, and low cost are the features required for the DG employed in secondary distribution systems. Steady state waveforms captured at the grid side show that the power generated by the DC system is fed to the grid at unity power factor. Perturb and absorb algorithm can be replaced by current sweep and constant voltage algorithm in future scope for the better improvement of power and efficiency factors

REFERENCES

[1]. J. Byun , S. Park, B. Kang, I. Hong, and S. Park, "Design and implementation of an intelligent energy saving system based on standby power reduction for a future zero-energy home environment," IEEE Trans. Consum. Electron., vol. 59, no. 3, pp. 507–514, Oct. 2013.

[2]. J.He, Y.W.Li, and F. Blaabjerg, "Flexible micro grid power quality enhancement using adaptive hybrid voltage and current controller," IEEE Trans. Ind. Electron., vol. 61, no. 6, pp. 2784–2794, Jun. 2014.

[3]. W. Li, X. Ruan, C. Bao, D. Pan, and X. Wang, "Grid synchronization systems of three-phase grid-connected power converters: A complex-vector-filter perspective," IEEE Trans. Ind. Electron., vol. 61, no. 4,1855–1870, Apr. 2014.

[4]. C. Liu, K. T. Chau, and X. Zhang, "An efficient wind-photovoltaic hybrid generation system using doubly excited permanent-magnet brush-less machine," IEEE Trans. Ind. Electron, vol. 57, no. 3, pp. 831–839, Mar. 2010.

[5]. S. A. Daniel and N. A. Gounden, "A novel hybrid isolated generating system based on PV fed inverter-assisted wind-driven induction generators," IEEE Trans. Energy Convers., vol. 19, no. 2, pp. 416–422, Jun. 2004.
[6]. H. Polinder, F. F. A. van der Pijl, G. J. de Vilder, and P. J. Tavner, "Com-parison of direct-drive and geared generator concepts for wind turbines," IEEE Trans. Energy Converters., vol. 21, no. 3, pp. 725–733, Sep. 2006.

[7]. C. N. Bhende, S. Mishra, and S. G. Malla, "Permanent magnet synchronous generator-based standalone wind energy supply system," IEEE Trans. Sustain. Energy, vol. 2, no. 4, pp. 361–373, Oct. 2011.

[8]. H. C. Chiang, T. T. Ma, Y. H. Cheng, J. M. Chang, and W. N. Chang, "Design and implementation of a hybrid regenerative power system combining grid-tie and uninterruptible power supply functions," IET Renew. Power Gen., vol. 4, no. 1, pp. 85–99, 2010.

[9]. S.-K. Kim, J.-H. Jeon, C.-H. Cho, J.-B. Ahn, and S.-H. Kwon, "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer," IEEE Trans. Ind. Electron., vol. 55, no. 4,1677–1688, Apr. 2008.

[10]. F. Giraud and Z. M. Salameh, "Steady-state performance of a grid-connected rooftop hybrid wind-photovoltaic power system with battery storage," IEEE Trans. Energy Converters., vol. 16, no. 1, pp. 1–7, Mar. 2001.

[11]. S. Bae and A. Kwasinski, "Dynamic modeling and operation strategy for a microgrid with wind and photovoltaic resources," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1867–1876, Dec. 2012

[12]. Y.-M. Chen, Y.-C. Liu, S.-C. Hung, and C.-S. Cheng, "Multi-input inverter for grid connected hybrid PV/wind power systems," IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1070–1077, May 2004

Dr.L.Kalaivani received the B.E degree in Electrical and Electronics Engineering from MS University in Government College of Engineering, Tirunelveli in 1999. Received the M.E degree in Computer Science Engineering from Anna University Chennai in National Engineering College on 2008. Received the Ph.D. degree in Electrical Drives under Anna University, Chennai. Since 2001, she has been working with the National Engineering College in Department of EEE under Anna University Chennai. Her main areas of research interest include Soft Computing Techniques, Electrical Drives, High Voltage Engineering and Renewable Energy.

A. Ann Rufus received the B.E degree in Electrical and Electronics Engineering from Anna University Chennai in St.Joseph College of Engineering, Chennai in 2009. Received the M.Tech degree in Energy Conservation and Management from Anna University Tiruchirappalli in 2011 and is currently working toward the Ph.D. degree in Anna University Chennai. Since 2011, he has been an Assistant Professor with the SCAD College of Engineering and Technology under Anna University Chennai. His main areas of research interest include Soft Computing Techniques, Power Electronics and power systems using Renewable Energy Sources.

Ms. S.Syedhali Fathima Jamin received the B.Tech degree in Electrical and Electronics Engineering from Kalasalingam University, srivilliputtor in 2014. Currently pursuing my M.E in SCAD College of Engineering and Technology under Anna University Chennai