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A novel of grid connected hybrid system with single DC-DC converter

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ABSTRACT

The proposed system has a hybrid wind driven PMSG-PV system with grid connected, along with a hysteresis current controller. Here the two renewable resources are connected through a single DC-DC converter. Hence compared to earlier system the proposed system has low power consume converters are used. The proposed system is developed by a model of MPPT with fuzzy controller along d-q axes reference frame. Through simulation the proposed module is performed.

1. INTRODUCTION

An overview through the most important literature on rural electrification will prove that renewable energies (RES) are one of the most suitable and environmentally friendly solutions to provide electricity within rural areas. A combination of different but complementary energy generation systems based on renewable energies or mixed is known as a hybrid power system. Hybrid systems capture the best features of each energy resource and can provide "gridquality" electricity, with a power range between 1 kilowatt (kW) to several hundred kilowatts. They can be developed as new integrated designs within small electricity distribution systems. In such hybrid schemes, permanent magnet synchronous generators (PMSG).

Hence a combinations of hybrid PMSG-PV systems are proposed in this paper. Wind-PV system along with battery was explained, in which both the sources were connected to a common DC bus link through dc-dc boost converters, then to the utility grid through an inverter. Further, each converter was controlled using complex algorithms for peak power tracking. The successful operation of this scheme in extracting maximum power from both the sources or from each of the sources has been established through simulation and experimental investigations. The proposed scheme is for a grid connected operation and hence battery storage is used.

Description of the scheme: The block diagram of proposed DG scheme is given in Fig.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 (VPV) is fixed to the output voltage of the DC-DC converter (VDC) 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 Fuzzy logic control algorithm is employed with an inverted duty-cycle adjustment in controller 1. 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 (IGRID) follows the reference current signal (Iref), which is automatically varied by controller 2 for drawing the maximum current from both PMSG & PV array.

Model of the proposed system: A model of the proposed DG system is developed to investigate the system performance. The rectifier DC output voltage (VR) and current (IR) in terms of stator phase voltage VS (rms) and stator current IS (rms) are given as

$V_R = 3\sqrt{6}/\pi\, V_S$ (1)

$I_R = \pi/\sqrt{6}\, I_S$ (2)

The output voltage of the DC-DC converter is given as

$V_b = V_{DC} = V_R 1/(1-\delta)$ (3)

The DC link current is

$I_{DC} = I_b + I_{pv}$ (4)

The PV array current (IPV) is given by

$I_{PV} = I_{SC} - I_d$ (5)

The *d*-axis and *q*-axis voltage of the inverter are related with the DC link voltage as

$V_d = V_{DC}\, g_d$ (6)

$v_q = V_{DC}\, g_q$ (7)

Considering zero power loss in the inverter,

$I_{DC} = 1/2\,(i_d g_d + i_q g_q)$ (8)

Assuming zero power loss in DC-DC converter,

$V_R I_R = V_b I_b$ (9)

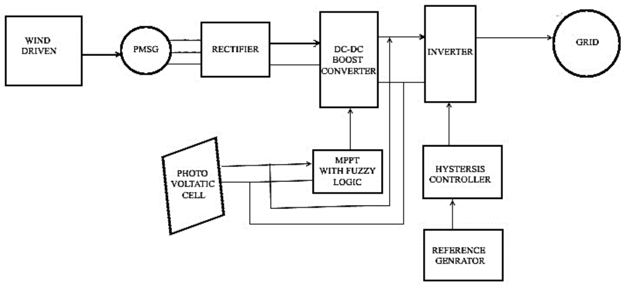

Figure.1.Proposed DG system based on PMSG-PV sources

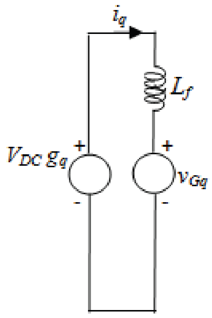

Figure.2.q-axis equivalent

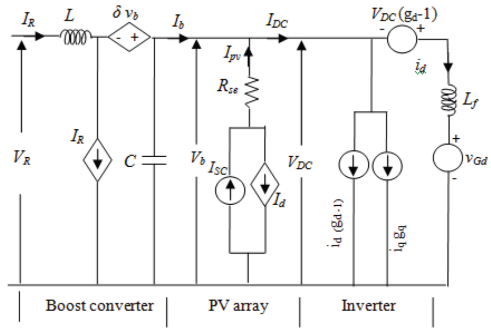

Figure.3.d-axis equivalent

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 VDC = VPV). The rectifier voltage varies with the wind-speed and the duty-cycle of the boost converter needs to be automatically adjusted such that VDC is equal to the peak power point voltage (Vm) of the PV array. At this point the PV array delivers the maximum current (Im) which is concurrently drawn by the current .To operate the PV array at its maximum power point (A), the DC-DC converter output (DC link voltage) is adjusted to Vm by varying the duty-cycle of the DC-DC converter by controller 1 is given by

$$\delta_{new}=\delta_{old} + sgn_{(\Delta P)} sgn_{\Delta VPV}\, \Delta\delta \qquad (10)$$

where $\Delta\delta$ is the perturbation in duty-cycle, sgn is Signum function. The main objective of controller 2 (Fig. 1) is to vary the inverter output current fed to the grid. The reference current (Iref) 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).At steady-state, the reference current value for a particular condition of irradiation and wind speed is

$$I_{ref} = 2(V_{PV}\, I_{PV} + V_R\, I_R) / V_{GRID} \qquad (11)$$

B. Case2 (PMSG alone generating power): During night time the current transducer which is connected with the PV system will not produce any output current. At that time the controller 1 will not operate the MPPT algorithm of the PV system and its starts working in a voltage control mode. Now the output voltage from the voltage transducer act as a feedback signal the ratio of the duty cycle is varied by the controller 1 of the boost converter to get the corresponding dc output voltage in a rated rms voltage value of the grid through the dc link voltage. As the current transducer value is said to be zero the controller2 will starts adjusting the

$$i(ref)\ I_{ref}(new) = I_{ref}(old) + sgn[\Delta(I_b)]K \qquad (12)$$

C. Case 3 (PV alone generating power): When PV array alone working no power is generated through PMSG and hence there is no input is fed to the DC-DC boost converter and there is no triggering pulse is generated. Since current in the boost converter Ib is zero the controller 2 varies the I(ref) values.

$$I_{ref}(new) = I_{ref}(old) + sgn[\Delta(I_{PV})]K \qquad (13)$$

D. Composite operation of controllers: It is clearly seen from the above cases ,when PV system alone generate power the controller 1 is idle and by adjusting Iref value controller 2 always get maximum power from either from both the source or any one of the sources to the grid. Functions of controllers under different conditions is shown below in the table.

Table.1 Comparison of controllers

Source	Controller 1	Controller 2
Both PV and PMSG operate	Generates duty-cycle for PV array MPPT voltage	Generate maximum current from both the sources
PV array is operate alone	Triggering pulse not Generated (duty-cycle is zero)	Generate maximum power from the PV system
PMSG is operate alone	Duty-cycle is generated and Maintain constant DClink	Generate maximum power from PMSG alone

Implementation of the controllers:

A. Controller for DC-DC Converter (Controller 1): DC-DC converter which used here is boost converters formed by a very low cost 16bit microcontroller along with inbuilt pulse width modulation module to produce signals. This controller get the feedback signal from both the current and voltage transducers. These signals are further processed by a signal conditioning circuits and fed to analog to digital conversion module. The 16 bit microcontroller is programmed with fuzzy logic algorithm for PV array.

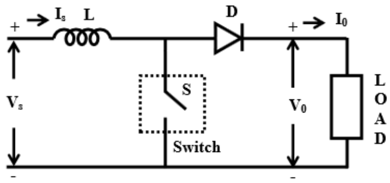

Figure.5.Boost dc-dc converter

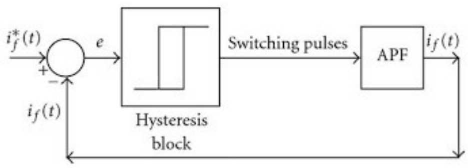

Figure.6.Schematic of current reference generation with hysteresis controller

B. Hysteresis Current Controller (Controller 2): The schematicc diagram of hysteresis current controller is shown above in the fig. The base current Ib and pv current Ipv are flow through the ADC module from current transducer. Based on Iref from ADC is converted into analog form by DAC. This DAC will produce a DC value corresponding to Iref.to get current to the controller 2 the DC value is multiplied with Iref and current from grid. Hence the hysteresis controller work with grid current as input. Thus the output from the controller 2 is fed to the inverter for the working of PV array alone or PMSG alone. When both the sources working together DC link will get maximum value of power .The sine wave references is taken from the grid so the output of the inverter will also have the phase frequency value.

Simulation and experimental results: For the proposed hybrid generator a single phase inverter was concoct with available IGBT. The input pulses are given from the hysteresis controller. A DC-DC boost converter was also concoct with IGBT and also has a hyper fast diode. The simulation block diagram for the proposed system.

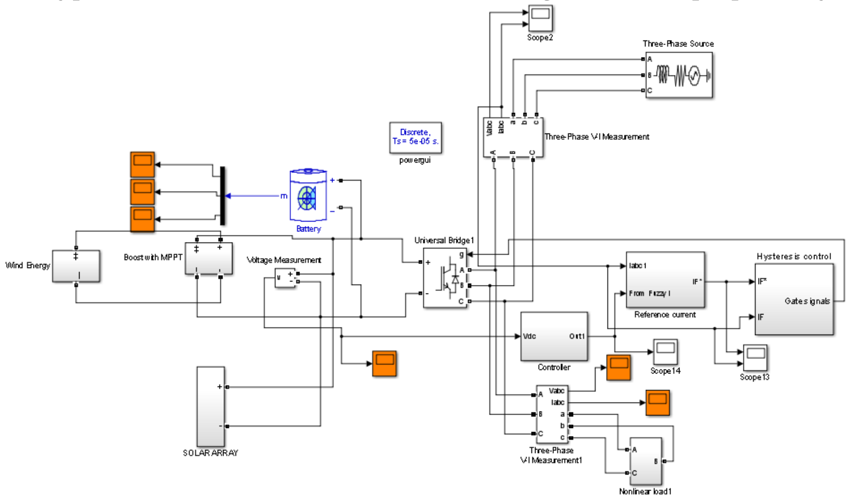

Figure.7.Proposed Simulation Diagram

(a) Output of grid connected current and voltage: The proposed system has grid connection with output from the two hybrid sources PV and wind driven. The output of the inverter is fed to the grid connection. Hence the output from the grid is given as an input for the iref generator this act as a reference current from the grid .the fig shows the output voltage and current.

(b) Load current and voltage: The load connected across the inverter through the hysteresis controller gives the three load voltage and load current. RLC circuit branch is connected as a load the fig shows the waveform of load current and voltage.

(c) Actual current and reference: The input for the hysteresis controller is uses dc voltage from the PV system as well as from the grid which is said to be the iref. Even though the current is fed from PV, iref is used during the night time or no current is from pv system.

(d) Battery output: In the proposed system battery is used for storage of voltage from PV system before it goes through the DC link to the converter.

(e) Hystersis current limit: Controller output of hysteresis used in the proposed system in both forward and reverse direction.

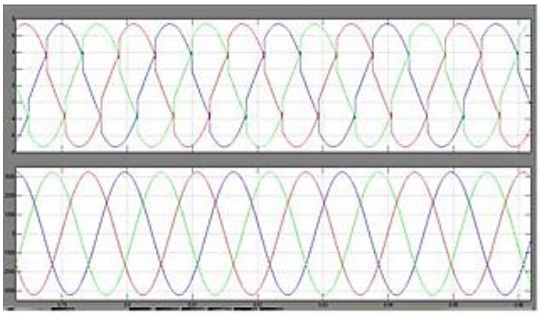

Figure.8.Grid voltage and current

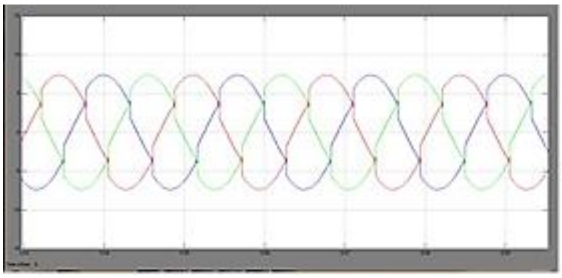

Figure.9.Wave form of load and voltage

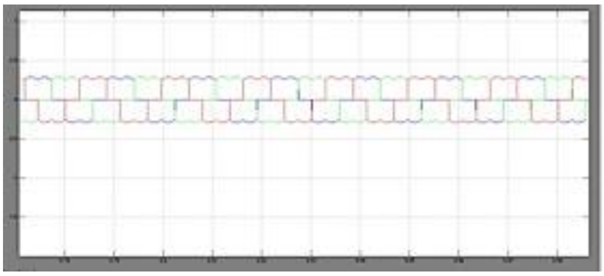

Figure.10.Wave form of load current

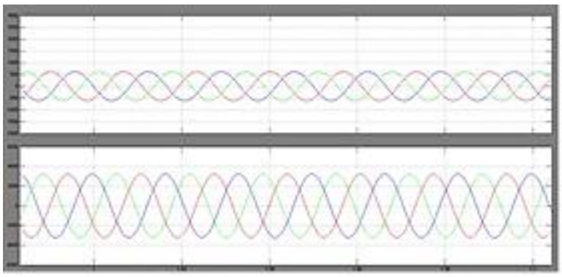

Figure.11.The output current of iref waveform

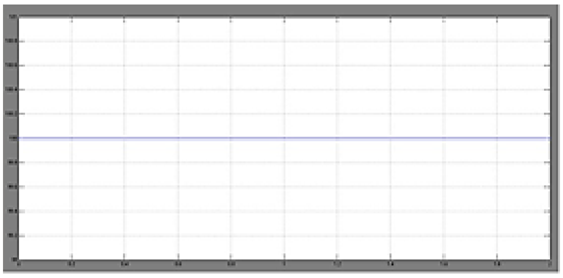

Figure.12.Wave form of battery input

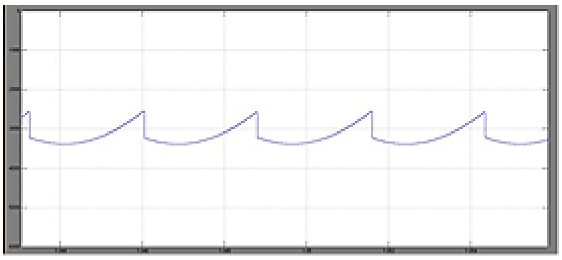

Figure.13.Wave form of Hysteresis current limit in reverse direction

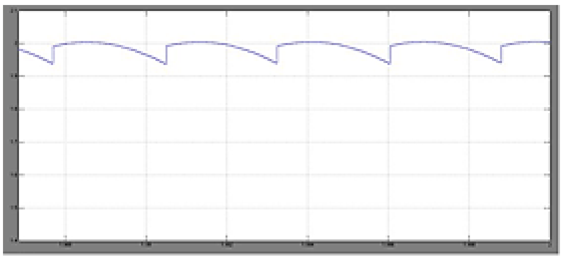

Figure.14.Wave form of Hysteresis current limit in forward direction

2. CONCLUSION

The new topology of hybrid dg system based on wind-driven and PV system with a boost converter followed by an inverter has been successfully implemented. The mathematical model for this system is used to study the system performance in MATLAB. It has been established through experimental and simulation with the help of two controllers' digital MPPT controller and hysteresis controller which tracks the maximum power from both sources. This proposed system has an advantages of maintained free operation, reliability and low-cost circuits. Also the experimental and simulated output matches closely. The steady state waveform of the grid system shows the system fed to the grid at unity power factor. The proposed system can be applied for the application of erection and smart grid in domestic consumer's sites.

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