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Design & Implementation of Hybrid Wind-Solar Energy Conversion Systems

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Abstract: ***The renewable energy sources like wind and solar energies are combined to increase the total power generation and thereby increase the efficiency of the system. The combination also provides a means to overcome the intermittent nature of the solar and wind renewable energy sources, since one source can be used for power generation when other is not available. AC-DC converters are used convert the Alternating voltage of the wind generator to a constant DC value which can be used to charge the batteries or later converted to AC voltage to drive AC loads. A Maximum Power Point Tracking (MPPT) system using boost converter is designed to extract maximum possible power from the sun when it is available. An inverter stage is implemented using Sinusoidal Pulse width Modulation (SPWM).This method provides better harmonic reduction since Harmonic content is detrimental for the generator lifespan, heating issues, and efficiency. Simulations are carried out in matlab software and results in the form of graphs are provided to highlight the merits of the system under consideration.***

Keywords: Hybrid system, low wind resource, solar isolation, load demand

1. Introduction

With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at sustainable energy solutions to preserve the earth for the future generations. Other than hydro power, wind and photovoltaic energy holds the most potential to meet our energy demands. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. The common inherent drawback of wind and photovoltaic systems are their intermittent natures that make them unreliable. However, by combining these two intermittent sources and by incorporating maximum power point tracking (MPPT) algorithms, the system's power transfer efficiency and reliability can be improved significantly.

Wind- solar Energy Conversion Systems: When a source is unavailable or insufficient in meeting the load demands, the energy source can compensate for the difference. Several hybrid wind/PV power systems with MPPT control have been proposed and discussed in works . Most of the systems in literature use a separate DC/DC boost converter connected in parallel in the rectifier stage as shown in Figure 1 to perform the MPPT control for each of the renewable energy power sources. A simpler multiinput structure has been suggested by that combine the sources from the DC-end while still achieving MPPT for each renewable source. The structure proposed by is a fusion of the buck and buck-boost converter. The systems in literature require passive input filters to remove the high frequency current harmonics injected into wind turbine generators. The harmonic content in the generator current decreases its lifespan and increases the power loss due to heating. In this paper, an alternative multi-input rectifier structure is proposed for hybrid wind/ solar energy systems. The proposed design is a fusion of the Cuk and converters. The features of the proposed topology are: 1) the inherent nature of these two converters eliminates the need for separate input filters 2) it can support step up/down operations for each renewable source (can support wide ranges of PV and wind input 3) MPPT can be realized for each source 4) individual and simultaneous operation is supported. The circuit operating principles will be discussed in this paper. Simulation results are provided to verify with the feasibility of the proposed system..

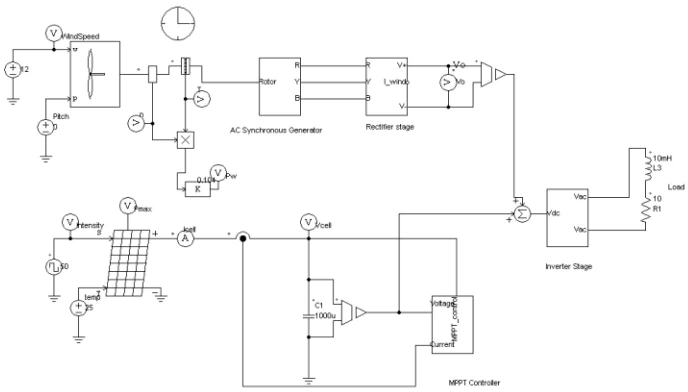

Figure 1: Block diagram of Wind solar hybrid system

1.1 Various Components Used in Hybrid Systems

1) Solar Module Block:
In this paper we have used the Physical model of the Solar Module as can simulate the behavior of the solar module more accurately, and can take into account the light intensity and temperature variation. The various attributes for this block are as follows. For the purpose of simulation the MSX-60 photovoltaic module was taken as reference.

Solar Module (Physical Model)
Number of cells: 36
Standard Light Intensity : 1000lux
Ref. Temperature Tref: 25 degree centigrade
Series Resistance Rs: 0.008 ohm
Shunt Resistance Rsh : 1000 ohm
Short Circuit Current Isc0: 3.8 A
Saturation Current Is0: 2.16e-8 A
Band Energy Eg: 1.12 eV

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Ideality Factor A: 1.2
Temperature Coefficient Ct: 0.0024 A/degree C
Coefficient Ks: 0

2) Wind Turbine Block:
The Wind turbine block gives the power of the turbine shaft as a function of wind speed and pitch angle. The power generated by a wind turbine can be expressed as:

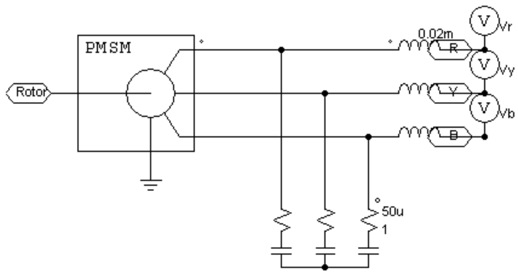
$$P = \frac{1}{2} \cdot A \cdot v_{wind}^{3} \cdot \rho \cdot C_p$$

Where, A = area of the rotor blade (m2)
v = wind speed (m/s)
ρ = air density (kg/m3)
Cp = power coefficient.

The power coefficient Cp is a function of the tip speed ratio λ and the blade pitch angle β. The various attributes for this block are as follows. For the purpose of simulation the Aeolus Wind Turbine 5kw model was taken as reference.

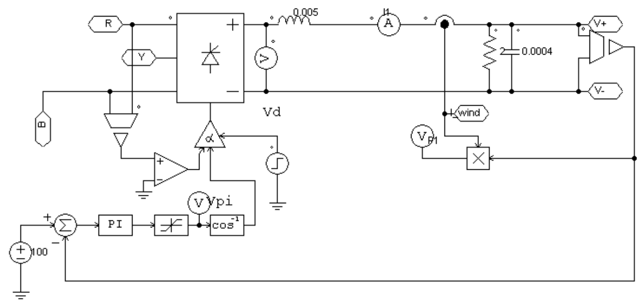
Wind Turbine
Nominal Output Power: 5kW
Base Wind Speed: 12 m/s
Base Rotational Speed : 10m/s
Initial Rotational Speed : 0.8 rpm
Moment of Inertia: 1m kg.m^2
Torque Flag: 0
Master/Slave Flag :1

3) AC Synchronous Generator:
The Generator Used in the wind turbine generator is Permanent Magnet Synchronous Generator. A 3-phase permanent magnet synchronous machine has 3-phase windings on the stator, and permanent magnet on the rotor.



Permanent Magnet Synchronous Machine
Rs (stator resistance) 1m ohm
Ld (d-axis ind.) 1m H
Lq (q-axis ind.) 1mH.
The d-q coordinate is defined such that the d-axis passes through the center of the magnet, and the q-axis is the middle between two magnets. The q-axis is leading the d-axis. Vpk / krpm (Peak line-to-line back emf constant, in V/krpm (mechanical speed)) : 7112
No. of Poles *P :* 30
Moment of Inertia: 100m kg.m^2
Master/slave Flag: 0

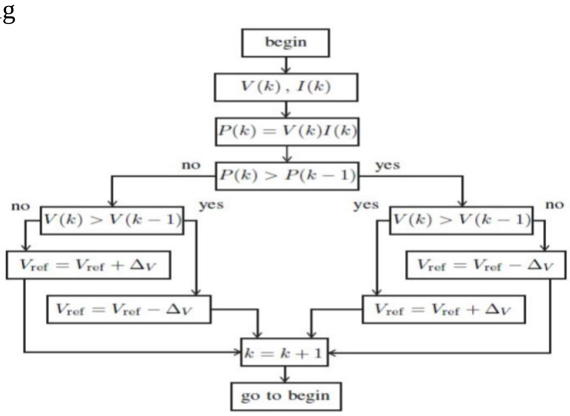
4) Rectifier Stage
The rectifier stage consists of a Three –phase fully controlled bridge with voltage feedback. The output voltage is compared with the reference voltage and feedback is given to the firing angle controller of the SCR's.



5) MPPT Controller
MPPT devices are used in the electric power systems so it will give sufficient voltage and current, its regulation and filtering for driving various loads like motor, including power grids, batteries, or home appliances. The controller consists of boost converter. There are total 4 types of methods by which we can implement maximum power point tracking:

- Perturb and observe method
- Incremental conductance method
- Current sweep method
- Constant voltage method

Out of which we are using perturb and observe (P&O) method. In this method, the voltage is adjusted in steps by small amounts using a controller and power is calculated; if the power increases, voltage is increased in the same direction. If power decreases the direction of voltage increment is reversed. The tracker oscillates about the MPP which may lead to oscillations in power output. It is also referred to as a *hill climbing* method. The algorithm of this method is as follows:
Fig



As the flowchart shows, first of all voltage and current of the system are measured. Thereby power is calculated. The instantaneous calculated power is compared with the power calculated at (k-1)st instant. If the instantaneous power p(k) > p(k-1) then the corresponding voltages are compared. If v(k)>v(k-1) the Δv is subtracted from the corresponding voltage so as to make the maximum power point stable. Similarly there are other 3 cases according to comparison. At the same time there is trade of between the value of Δv and the time required to get the stable output. The lesser the value of Δv, more time we require to get the stable output. These ultimately reduce the perturbations around the maximum power point

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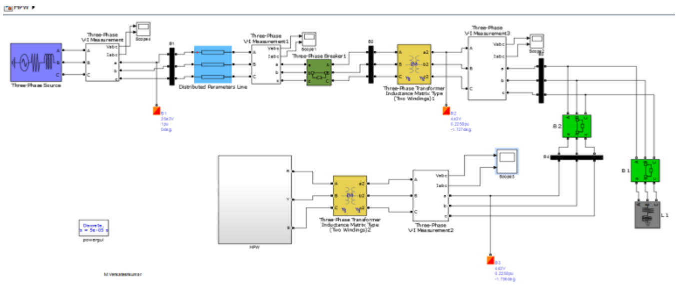
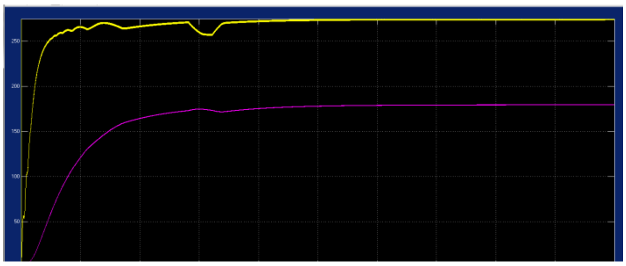
6) Simlink circuit of grid connected hybrid system:





Result of MPPT controller

2. Conclusion

In systems, sizing is extremely important since an adequate design lead to an efficient operation of the components with a minimum investment. So, the objective of this process is to achieve a system with the best compromise between the reliability and cost. However this is not easy because the resources and the load behave in a very random way. For this purpose, continuous effort to develop more attractive systems with lower-cost, higher-performance and multi-functions.

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