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Designing of Hybrid System Based on Predictive Controller of An Off-Grid Renewable Source

Boopathi Raja. S, Dr.V.Gopalakrishnan

Power System Engineering
Department of Electrical and Electronics Engineering, Government College of Technology, Coimbatore, Tamil Nadu, India

ABSTRACT

Due to the decade of fossil fuels, renewable energy plays an important role to supply the power to meet our load requirements. The main drawback of renewable energy system is its installation cost is very high and renewable energy sources are mainly unpredictable. To eliminate the drawbacks in renewable energy, hybrid system plays a major role. The hybrid system is an interconnection of two or more sources. In this project solar energy and wind are used as a different sources. Power from the solar energy is boosted by boost converter and boost converter act as an impedance matching network. When the internal impedance of solar is matched with the boost converter impedance power will be transferred from source to load. Energy from wind is converted into DC by using rectifier and the output of the rectifier is fed as input to boost converter. The output power of both wind and solar are boosted by boost converter and output of boost converter is used to run the DC load. During excess power battery gets charged and during deficit power battery energy is used to run the load. The proposed work is implemented using mat lab software.

Keywords : Boost Converter; Photovoltaic System; Hybrid system, Renewable Energy

I. INTRODUCTION

The Renewable energy sources are mainly larger than the traditional fossil fuels and in theory can easily supply the world's energy needs. The present situation of the energy sector with a continuous increase in the energy demand, together with the exhaustion of the fossil fuel reserves and the Greenhouse gas emissions have enhanced the combination of renewable energy sources for distributed generation. This combination is denominated simply Hybrid Systems (HS) or Hybrid Renewable Energy Systems (HRES) which are composed by one or more renewable energy sources and energy storage systems. ESS allows adapting the unregulated power generated by the renewable sources to a specific demanded power. This hybrid system can work in stand-alone [1,2] or grid-connected mode.

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services. Based on REN21's 2014 report, renewables contributed 19 percent to our global energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively. This energy consumption is divided as 9% coming from traditional biomass, 4.2% as heat energy (non-biomass), 3.8% hydroelectricity and 2% is electricity from wind, solar, geothermal, and biomass. Worldwide investments in renewable technologies amounted to more than US$214 billion in 2013, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels.

The exact design of the energy dispatching for Hybrid systems is essential for their operation. The Energy dispatching strategies are designed to track the load power by satisfying the secondary objectives such as keeping the charge level of the energy storage devices by satisfying the operational limits and operating the system at high efficiency, reducing the fuel consumption, etc. The tasks related to energy dispatching can be classified according to the objectives [3]. Depending on the given objectives to meet by the energy dispatching there are two kinds of simulations that can be carried out such as short term and long-term simulations. The Short-term simulations are focused on the basis of dynamics of the sources which compose the system and consider it into account to face the net power variations due to the changes in load power or disturbances in the renewable energy sources.

Wind power plants require the presence of fast and flexible control of other generators in the power system so as to balance power generation with demand. The impacts of wind power integration that need to be considered include reactive power generation/voltage support, fault ride through capability, frequency control, and dispatch of conventional generating units [4]. A hybrid wind-PV microgrid with storage has a great potential to provide higher quality and more reliable power than a system based on a single resource [5].

Traditional circuits use critical path delay as the overall circuit clock cycle in order to perform correctly. However, the probability that the critical paths are activated is low. In most cases, the path delay is shorter than the critical path. For these noncritical paths, using the critical path delay as the overall cycle period will result in significant timing waste. Hence, the variable-latency design was proposed to reduce the timing waste of traditional circuits. The variable-latency design divides the circuit into two parts: 1) shorter paths and 2) longer paths, shorter paths.

In the recent past there has been an increased use of the Doubly Fed Induction Generator (DFIG) in wind beenenergy conversion systems due to its special features. The unique capabilities of DFIG are: (1) it can supply power at constant voltage and frequency; (2) the rotor can operate in both sub-synchronous or super-synchronous speeds; (3) the rating of the power converter is approximately 30% of the rated wind turbine power; (4) the generated active and reactive power can be independently controlled; and (5) high efficiency and reduced mechanical stress on the wind turbine.

The design integration of two sets of rechargeable batteries on the DFIG back-to-back converter DC-bus in a wind power generation scheme. One battery set is used to supply rotor currents while the other is used to smooth out wind turbine power output. Integration of PV array and battery storage on the DFIG DC-bus is presented in [6]. The battery in [6] is directly connected to DC-bus and is used to control the DC-bus voltage.

II. METHODS AND MATERIAL

1. Literature Survey

A. Dynamic performance analysis of an integrated wind photovoltaic microgrid with storage

This paper presents a power and energy management strategy for a wind-photovoltaic (PV) microgrid with an energy storage system (ESS) and PV array current injection on the DC-link. The ESS consists of a battery and a supercapacitor interfaced to the DC-link through bi-directional DC-DC converters. Cascade PI control is used to regulate the current supplied by the ESS to the DC-link. A fuzzy logic controller is proposed for efficient power sharing between the battery and the supercapacitor. A discrete-time simulation model is used to study the microgrid operation. The PV array model is implemented as an s-function. Using the proposed system, the power supplied to the grid is maintained at the desired reference value during changes in wind speed, solar radiation, and grid power demand. Results also show that the ESS improves the DC-link voltage stability during three phase to ground faults. The PV array, battery, and the supercapacitor models are implemented and interfaced to the 1.5MW DFIG wind power system in MATLAB SimPowerSystems.

B. Power management of a standalone wind /Fuel cell energy system

This paper proposes an AC-linked hybrid wind/ photovoltaic (PV) /fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and an FC electrolyzer combination is used as a backup and a long-term storage system. An overall power management strategy is designed for the proposed system to manage power flow among the different energy sources and the storage unit in the system.

C. A Frequency-Control Approach by Photovoltaic Generator in a PV–Diesel Hybrid Power System

In this paper, a simple fuzzy-based frequency control method is proposed for the PV generator in a PV–diesel hybrid system without the smoothing of PV output power fluctuation. A photovoltaic (PV) system's output power fluctuates according to the weather conditions. Fluctuating PV power causes frequency deviations in the power utilities when the penetration is large. Usually, an energy storage system (ESS) is used to smooth the PV output power fluctuations and then the smoothed power is supplied to the utility. By means of the proposed method, output power control of a PV generator considering the conditions of power utilities and the maximizing of energy capture is achieved. Here, fuzzy control is used to generate the PV output power command. This fuzzy control has average insolation, change of insulation, and frequency deviation as inputs. The proposed method is compared with a maximum power point tracking control-based method and with an ESS-based conventional control method.

2. System Design

The objective of the strategy was to meet the load demand taking into account the dynamic limitations of the energy sources but it was not shown if the strategy is able to maintain the hydrogen level in the tank. The fuel cell was assisted by an ultra-capacitor which was directly connected to the DC bus. A MPC generated the reference current of the fuel cell in order to ensure an optimal distribution of current demand between the two power sources and maintain the oxygen excess ratio of the fuel cell and the ultra-capacitor SOC within their operational limits.

The power management scheme of the microgrid is implemented as shown in Fig. 5. The control scheme is based on the power balance equation expressed as:

$$P_{sto,ref} = P_d - P_{gen} - P_{pv} + P_{L,Filter} + P_{dc,ref}$$

Where,

Psto, ref is the extra power that needs to be generated,

Pd is the requested power demand,

Pgen is the total power generated by DFIG stator and rotor,

Ppv is the power generated by PV array,

PL,filter is the grid filter power loss, and

Pdc,ref is the power needed to charge the DC-bus capacitor.

Model Predictive Control (MPC) has been widely used in the energy dispatching design because of its ability to deal with constraints in a systematic and straightforward manner. The load power consumption profiles were collected hourly during four different days [7] .Fig 1 shows the general block diagram of proposed design

Wind : The wind generated power by calculate pitch angle and rotating speed of turbine. The output of AC source will connected to the rectifier.

Rectifier : It converts ac source to dc source will connected to dc-dc converter .

Photovoltic Panel : It function is produced the dc voltage connected to the dc-dc converter.

Converter : Here we use dc – dc converter to step up(boost) the input voltage of battery.

PWM : pulse width modulation is generate the pulses through the gate of switches used by converter.

Battery: It input will be consumed by dc – dc converter, the output will connected through the ESS.

ESS : Energy storage system will get the input power from battery, the output will connected to the load to get the sufficient power of dc source

Load : we get the input of dc source, so we use the dc load.

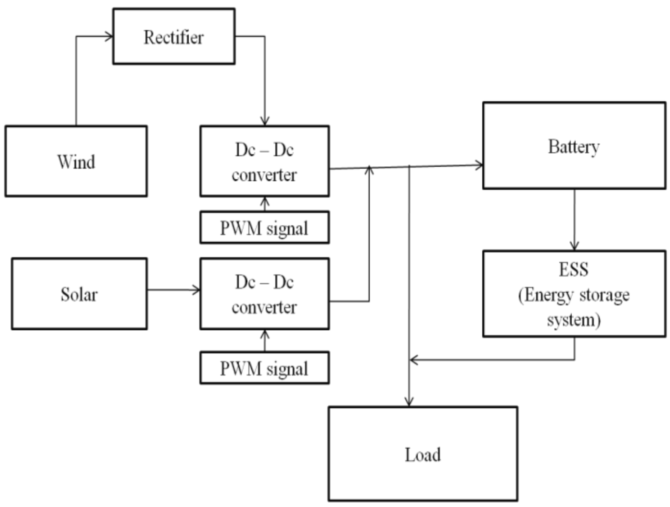

Figure 1. Block Diagram of Proposed Design

Fig 2 shows the boost converter, when the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.

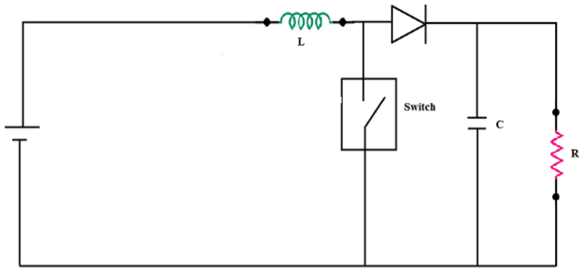

Figure 2. Boost Converter

A. DC to DC Converter

A DC-to-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. It is a class of power converter. DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Additionally, the battery voltage declines as its stored energy is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

Most DC to DC converters also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the output voltage. DC to DC converters developed to maximize the energy harvest for photovoltaic systems and for wind turbines are called power optimizers.

B. Wind Turbine

A wind turbine is a device that converts kinetic energy from the wind into electrical power. The term appears to have migrated from parallel hydroelectric technology (rotary propeller). The technical description for this type of machine is an aerofoil-powered generator.

The result of over a millennium of windmill development and modern engineering, today's wind turbines is manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

C. Maximum power point tracking (MPPT)

Maximum power point tracking (MPPT) is a technique that charge controllers use for wind turbines and PV solar systems to maximize power output. PV solar systems exist in several different configurations. The most basic version sends power from collector panels directly to the DC-AC inverter, and from there directly to the electrical grid. A second version, called a hybrid inverter, might split the power at the inverter, where a percentage of the power goes to the grid and the remainder goes to a battery bank. The third version is not connected at all to the grid but employs a dedicated PV inverter that features the MPPT. In this configuration, power flows directly to a battery bank. A variation on these configurations is that instead of only one single inverter, micro inverters are deployed, one for each PV panel. New MPPT equipped specialty inverters now exist that serve three functions: grid-connecting wind power as well as PV solar power, and branching off power for battery charging.

D. Photovoltaic Cell

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current[8]. However a photovoltaic cell is different from a photo diode. In a photodiode light falls on n-channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased. Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W).

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n top junction and parallel resistance is due to the leakage current.

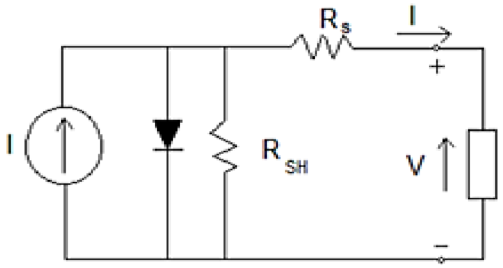

Figure 3. Single diode module of a PV Cell

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (RSH) in parallel is very high, has a negligible effect and can be neglected.

The output current from the photovoltaic array is

$$I = Isc - Id \qquad (2)$$

$$Id = Io\,(eqVd/kT - 1) \qquad (3)$$

Where,
Io is the reverse saturation current of the diode, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K) from Equ (2) and Equ (3)

$$I = Isc - Io\,(eqVd/kT - 1)\ \text{Equ} \qquad (4)$$

Using suitable approximations,

$$I = Isc - Io\,(eq((V+IRs)/nkT) - 1)\ \text{Equ} \qquad (5)$$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin and n is the diode ideality factor.

III. RESULTS AND DISCUSSION

Simulink Model

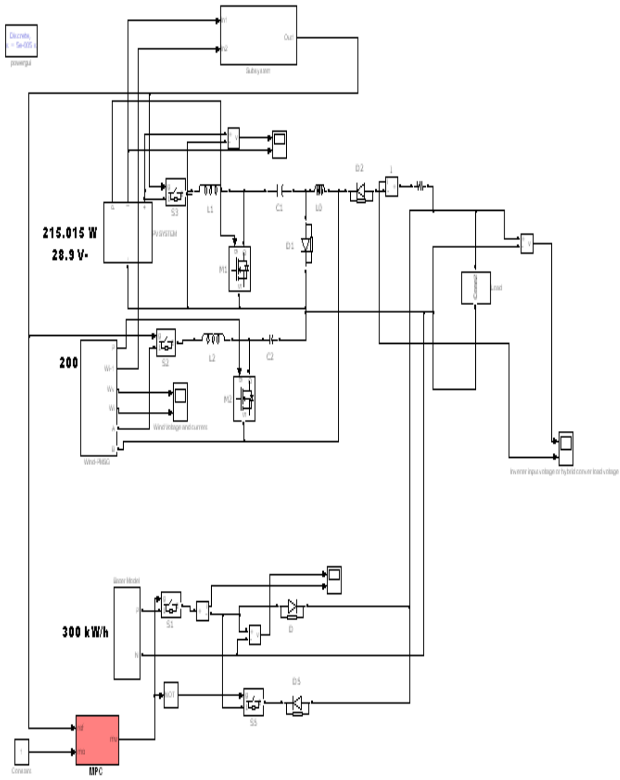

Figure 4. Proposed Design

Fig 4 shows the MATLAB simulink model for proposed design. To simulate the model the solver used is discrete. The power generated by solar and wind is used to run the load.The power generated by wind power is and the power generated by solar is . The type of the battery used is lead acid battery. minimizing the generation costs, operating the system at high efficiency, reducing the fuel consumption and etc.

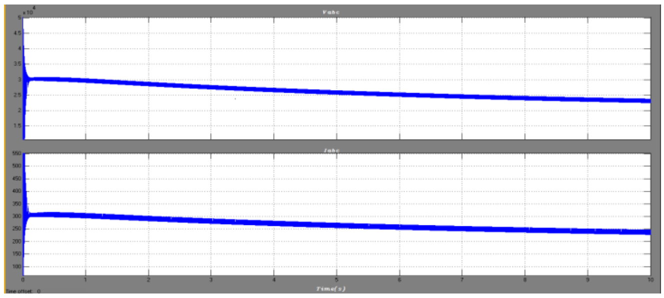

Figure 5. DC ouput load waveform

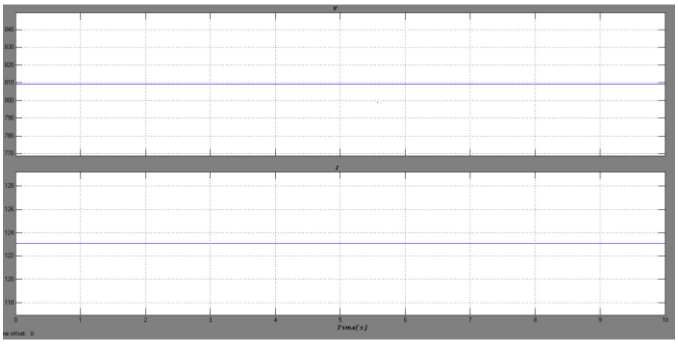

Figure 6. Solar input voltage and current waveform

Figure 7. Wind input voltage and current waveform

IV. CONCLUSION

The main contribution of this work has been to present and evaluate an energy dispatching based on MPC for an off-grid HS integrating wind turbine, PV panels and battery. In this HS, the renewable energy sources generate the maximum available power, whereas the energy dispatching is responsible for controlling the operation of battery .In this energy dispatching, the predictive controller mainly determines the power of the hydrogen system. The battery power is obtained from the difference between the net power. From the simulated waveform it is clear that by using MPC control technique the power supplied to the load is continuous even there is deficit power during poor weather conditions.

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