ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Operation and Control of Wind/Fuel Cell Based Hybrid Micro Grid in Grid Connected Mode

Boosharaju Ravikumar
Research Scholar,
Department of Power Systems,
SRTIST Engineering College,
Nalgonda, India.

Dr.Y.R.Manjunath
Professor,
Department of Power Systems,
SRTIST Engineering College,
Nalgonda, India.

ABSTRACT

A micro grid is a collection of loads and micro sources that operate as a single controllable system to provide both heat and power to a small area. A hybrid grid consists of both AC and DC grid. AC power sources and loads are connected to the AC grid whereas DC power sources and loads are connected to the DC grid and both the grids are connected together by a bidirectional converter. In this paper, a hybrid microgrid consisting a wind turbine and fuel cell stack is proposed to reduce the process of multiple AC-DC-AC and DC-AC-DC conversions which are commonly seen in an individual AC grid or DC grid. The proposed hybrid grid is operating in grid connected mode. The various control mechanisms are implemented for the power electronic converters for smooth power exchange between AC and DC grids and for stable operation of the proposed hybrid microgrid under various resource conditions. A small hybrid grid is considered and simulated using the Matlab/Simulink environment.

INTRODUCTION

For the past hundred years, the electrical power system is dominated mainly by the three phase AC power system due to various reasons such as efficient transformation of AC power at various voltage levels, for long distance transmission and for inherent characteristic from fossil fuel driven rotating machines for electric power generation.

The basic structure of the present day power system is the integration of generation, transmission and distribution system. In conventional power plants, electricity is produced from fossil fuels such as coal, oil and natural gas and these generating stations will be located far away from the load centers due to safety concern and due to the availability of energy sources.

Power generated from these stations are then transmitted over long distance at high voltage levels to the load centers and then delivered to the customer load points with the help of sub-transmission networks and distribution networks. This leads to the higher transmission losses and also the complexity of the system increases. Also, the environmental effects caused by these fossil fuels are high due to their high carbon emission. As a result, renewable energy resources such as wind, tidal, solar, small hydropower and biomass are becoming the best option for generating electric power due to their low environmental effects.

The current power system is undergoing considerable amount of changes, because more renewable energy based power conversion systems are connected to the low voltage distribution systems as distributed generators due to their environment friendliness and reliability. On the other hand, dc loads such as LED lights, refrigerators and electric vehicles are increasing to save electric energy and to reduce emissions. In the present system, these loads are supplied by means of AC power sources along with the help of power electronics converters. This further increases the cost of the system and appliances as it requires additional converters.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

When power can be supplied by renewable energy based distributed generators, there is no need for high voltage transmission and also transmission losses can be reduced. AC microgrids have been developed to enable the connection of renewable energy based power generating sources to the present AC system. As stated earlier, due to increasing amount of DC loads in residential, industrial and commercial buildings the power system loads are becoming DC dominated. In many industries DC power is required for the speed control purpose. If these loads are supplied by means of AC grid, then it requires embedded AC/DC converters and DC/DC converters to supply different DC voltages. As a result, DC grids are resurging due to the various advantages of renewable energy sources and their inherent advantage of supplying DC loads.

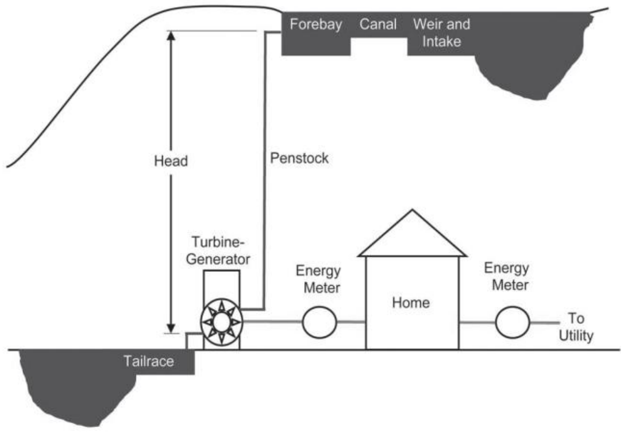
The multiple reverse conversions associated with an individual ac or dc grid leads to additional costs and losses and hence reduces the overall efficiency of the system. A hybrid AC/DC microgrid helps to minimize these multiple reverse conversion problem which normally associated with individual AC grids or DC grids. In this hybrid system AC loads are connected to the AC grid and DC loads are connected to the DC grid and the AC and DC grids are connected through a bidirectional converter. The proposed architecture, operation and control of the hybrid microgrid are more complicated than those of individual DC grid or AC grid. The various control mechanisms for controlling the converters and to maintain the stable system operation in grid connected mode is explained in the following sections.

Types of Renewable and Alternative Energy

There are several renewable energy sources that are in use today. Listed below are brief descriptions of these resources; later we will discuss how some of these can be used in residential applications.

Hydropower:

Hydropower represents one of the oldest and largest renewable power sources and accounts for close to 10% of our nation's electricity. Existing hydropower capacity is about 80,000 megawatts (MW – one million watts or one thousand kilowatts). Hydropower plants convert the energy of flowing water into electricity. This is primarily done by damming rivers to create large reservoirs and then releasing water through turbines to produce electricity. Hydropower results in no emissions into the atmosphere but the process of damming a river can create significant ecological problems for water quality and for fish and wildlife habitat.



Biomass

Biomass is second to hydropower as a leader in renewable energy production. Biomass has an existing capacity of over 7,000 MW. Biomass as a fuel consists of organic matter such as industrial waste, agricultural waste, wood, and bark. Biomass can be burned directly in specially designed power plants, or used to replace up to15% of coal as a fuel in ordinary power plants. Biomass burns cleaner than coal because it has less sulfur, which means less sulfur dioxide will be emitted into the atmosphere. Biomass can also be used indirectly, since it produces methane gas as it decays or through a modern process called gasification. Methane can produce power by burning in a boiler to create steam to drive steam turbines or through internal combustion in gas turbines and reciprocating engines.

The largest use of biomass energy in Virginia is the forest products industry. Furniture plants, sawmills, and paper mills usually burn their wood waste to produce heat and electricity. Many homeowners use firewood or pellets for winter heat.

Geothermal

Geothermal electric capacity in the United States is over 3,000 MW. Geothermal power plants use high temperatures deep underground to produce steam, which then powers turbines that produce electricity.

Geothermal power plants can draw from underground reservoirs of hot water or can heat water by pumping it into hot, dry rock. High underground high temperatures are accessed by drilling wells, sometimes more than a mile deep. In one sense, this geothermal energy is not renewable, since sometime in the future the core of the earth will cool. That time is so far off (hundreds of millions of years) that that we think of it as renewable. Most geothermal power plants are located in the western United States, but some costal regions of Virginia (near Wallops Island) have geothermal power potential.

Geothermal heat pumps use compressors to pump heat out of the earth (for winter heating) or into the earth (when running as air conditioners in summer). The energy they pump into and out of the earth is renewable, since it is replaced by the cycle of the seasons. The energy that runs the compressor can either be renewable or conventional.

Solar Energy

Solar energy comes directly from the power of the sun and is used to produce electricity, to produce heat, and for light. Solar represents a small share of the electric market in the United States – about ½ of one percent of electrical capacity. Solar's contribution to heating and lighting is much larger.

Solar-electric power can be produced either by power plants using the sun’s heat or by photovoltaic (PV) technology, which converts sunlight directly to electricity using solar cells. PV technology is more practical for residential use.

Systems to use the heat of the sun directly can be either active or passive. In active systems, air or liquid circulate through solar collectors and bring heat to where it is used. In passive systems, buildings are built with windows and heat-absorbing surfaces set up to maximize solar heating in winter. Either technology is suitable for residential use.

Systems to directly use the light of the sun are most common. The most usual device for using sunlight is the window, but skylights and skylight tubes are also used.

Wind Power

Wind energy represents 4,700 megawatts (MW) of installed electric capacity in the United States. Wind has been the fastest growing energy source in the U.S. over the last decade mainly due to very significant improvements in wind energy technology. The American Wind Energy Association predicts that 6,000 MW of windpower will be installed by the end of 2004. This is enough to power 1.5 million homes.

Wind power is produced by the energy of the wind turning aerodynamic blades mounted to a hub. The hub is connected to a shaft that turns a generator.

Large utility-scale wind turbines range in size from 50 kilowatts to over four megawatts. Smaller wind towers (under 50 kW) are suitable for residential and agricultural use.

Fuel Cells

A fuel cell is an alternative energy device, but it is not necessarily a renewable energy device. It is only renewable if the source of the fuel used is renewable.

A fuel cell is an electrochemical device, like a battery in that it converts the energy from a chemical reaction directly into electricity and heat. But unlike a battery, which is limited to the stored chemicals within, a fuel cell has the capability of generating energy as long as fuel is supplied.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Currently produced fuel cells combine hydrogen and oxygen without combustion to produce electricity. The oxygen comes from the air, while the hydrogen can either be produced from water (using electricity) or extracted from fossil fuels. New fuel cells are being developed that can use fossil fuels directly. Fuel cell technology has been around for over 150 years and it shows great promise in powering vehicles and in providing energy for residential applications.

Wind hybrid power systems

Wind hybrid power systems combines wind turbines with other storage and/or generation sources.

One of the key issues with wind energy is its intermittent nature. This has led to numerous methods of storing energy.

VOLTAGE SOURCE INVERTER

When the power requirement is high, three phase inverters are used. When three single phase inverters are connected in parallel, we can get the three phase inverter. The gating signals for the three phase inverters have a phase difference of 120o. These inverters take their dc supply from a battery or from a rectifier and can be called as six-step bridge inverter.

Fig.1.1 shows the three phase inverter using six MOSFET's and with diodes.

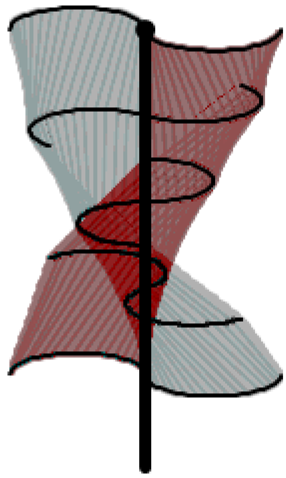
A large capacitor is connected at the input terminals tends to make the input dc voltage constant. This capacitor also suppresses the harmonics fed back to the source.

The Voltage Source Inverter is widely used. However, it has the some conceptual and theoretical barriers and limitations. The AC output voltage is limited and cannot exceed the AC input voltage. Therefore the Voltage Source Inverter is only buck (step down) inverter operation for DC to AC power conversion or boost (step-up) operation for AC to DC power conversion.

CURRENT SOURCE INVERTER

A Current Source Inverter is fed from a constant current source. Therefore load current remains constant irrespective of the load on the inverter. The load voltage changes as per the magnitude of load impedance. When a voltage source has a large inductance in series with it, it behaves as a Current Source .The large inductance maintains the current constant.

Vertical axis design



Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable, for example when the turbine is integrated into a building. Also, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance.

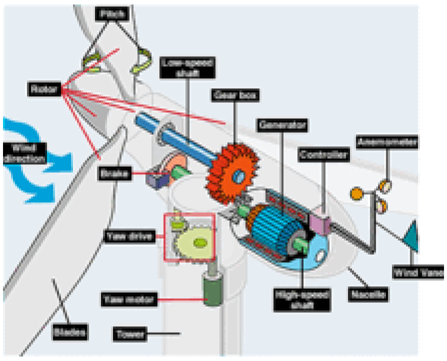
The key disadvantages include the relatively low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower power coefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

modelling the wind flow accurately and hence the challenges of analysing and designing the rotor prior to fabricating a prototype.

When a turbine is mounted on a rooftop the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of a rooftop mounted turbine tower is approximately 50% of the building height it is near the optimum for maximum wind energy and minimum wind turbulence. Wind speeds within the built environment are generally much lower than at exposed rural sites, noise may be a concern and an existing structure may not adequately resist the additional stress.

DESIGN AND CONSTRUCTION:



Components of a horizontal-axis wind turbine

Inside view of a wind turbine tower, showing the tendon cables

Wind turbines are designed to exploit the wind energy that exists at a location. Aerodynamic modelling is used to determine the optimum tower height, control systems, number of blades and blade shape.

Wind turbines convert wind energy to electricity for distribution. Conventional horizontal axis turbines can be divided into three components:

- The rotor component, which is approximately 20% of the wind turbine cost, includes the blades for converting wind energy to low speed rotational energy.
- The generator component, which is approximately 34% of the wind turbine cost, includes theelectrical generator, the control electronics, and most likely a gearbox (e.g. planetary gearbox), adjustable-speed drive or continuously variable transmission component for converting the low speed incoming rotation to high speed rotation suitable for generating electricity.
- The structural support component, which is approximately 15% of the wind turbine cost, includes the tower and rotor yaw mechanism.

A 1.5 MW wind turbine of a type frequently seen in the United States has a tower 80 meters (260 ft) high. The rotor assembly (blades and hub) weighs 22,000 kilograms (48,000 lb). The nacelle, which contains the generator component, weighs 52,000 kilograms (115,000 lb). The concrete base for the tower is constructed using 26,000 kilograms (58,000 lb) of reinforcing steel and contains 190 cubic meters (250 cu yd) of concrete. The base is 15 meters (50 ft) in diameter and 2.4 meters (8 ft) thick near the center.

Among all renewable energy systems wind turbines have the highest effective intensity of power-harvesting surface because turbine blades not only harvest wind power, but also concentrate it.

CONCLUSION:

The proposed architecture, operation and control of the hybrid microgrid consisting of fuel cell stack and DFIG wind turbine generator is studied and simulated using Matlab/Simulink environment. Converters are coordinately controlled for smooth power exchange between AC and DC grids. Although the hybrid grid can reduce the process of multiple reverse conversions in an AC or DC grid, there are so many technical challenges lies for the implementation of the hybrid grid. As power rating of the SOFC is high, it can be effectively used along with WTG to supply the loads without any interruption. The hybrid microgrid is one of the best options for small isolated industrial plants as the major power supply.

REFERENCES

[1] Xiong Liu, Peng Wang, and Poh Chiang Loh, “A hybrid AC/DC microgrid and its coordination control,” IEEE Trans. Smart Grid, vol. 2, pp. 278-286 June. 2011.

[2] F. D. Kanellos, A. I. Tsouchnikas, N. D. Hatziargyriou, "Micro-Grid simulation during grid-connected and islanded modes of operation", International Conference on Power Systems Transients (IPST 05) in Montreal, Canada on June 19-23, 2005.

[3] Ramon Zamora, Anurag K. Srivastava, "Controls for microgrids with storage: Review, challenges, and research needs", Renewable and Sustainable Energy Reviews, Volume 14, Issue 7, pp. 2009–2018 September 2010.

[4] A. Arulampalam, N. Mithulananthan, R.C. Bansal, and T.K. Saba, “Micro-grid control of PV-Wind-Diesel hybrid system with islanded and grid connected operations,” in Proc. IEEE Int. Conf. Sustainable Energy Technologies, pp. 1-5, Dec. 2010.

[5] M. Barnes, J. Kondoh, H. Asano, and J. Oyarzabal, “Real-World microGrids- An overview,” in IEEE Int. Conf. Systems of Systems Engineering, pp.1-8, April 2007.

[6] J.Lee, B.Han, Y.Seo, “Operational analysis of DC Micro-grid using detailed model of distributed generation,” Energy Conversion Congress and Exposition (ECCE), pp.3153-3160, 12-16 Sept. 2010

[7] Guiting Xue, Yan Zhang, Dakang Zhu, “A distributed control strategy for an isolated residential DC microgrid,” Research Journal of Applied Sciences, Engineering and Technology vol.4, Issue 20 pp. 4138-4144, Oct. 2012.

[8] Yinjiao Xing, Eden W.M.Ma, Kwok L.Tsui and Michael Pecht, “Battery management systems in electric and hybrid vehicles,” Energies, vol. 4, Issue 11, pp. 1840-1857, Oct. 2011.

[9] Tremblay O, Dessaint L.A, Dekkiche A.I, "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles," Vehicle Power and Propulsion Conference, pp.284-289, Sept. 2007.