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Simulation of a Novel Renewable Energy Based Hybrid Power System

A.V.Ravi Kumar[1], K.Nagalinga Chary[2], Y.Murali Krishna[3]

Assistant Professor, Dept. of EEE, Lakireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh, India[1]

Assistant Professor, Dept. of EEE, Lakireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh, India[2]

Assistant Professor, Dept. of EEE, Lakireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh, India[3]

ABSTRACT: A combination of different energy generation systems based on renewable energies or mixed is known as Hybrid power system .Hybrid systems capture the best features of each energy resource and can provide “grid-quality”. Renewable energy sources are suitable option to supply electricity in fragmented areas or at certain distances from the grid. By choosing renewable energy the reduction of greenhouse gases and other pollutants can stabilize their CO2 emissions. This project describes dynamic modelling and simulation of a renewable energy based on hybrid power system. Modelling and simulations are carried out using Matlab/Simulink to verify the effectiveness of the proposed system. The results show that the proposed hybrid power system can tolerate the rapid changes in natural conditions and suppress the effects of these fluctuations on the voltage within acceptable range.

I. INTRODUCTION

In wind turbines, the variable wind speed causes voltage and power fluctuation problems at the load side. This problem can be solved by using appropriate power converters and control strategies. Another significant problem is to store the energy generated by wind turbines for future usage when no wind is available but the user demand exists**.**

The solar cell depends on the weather factors, mainly the irradiation and the cell temperature. Therefore, the weather factors such as the irradiation and the temperature are utilized for the estimation of the maximum power in this paper. After many technological advances, proton exchange membrane fuel cell technology has now reached the test and demonstration phase.

Electrical energy requirements for many remote applications are too large to allow the cost-effective use of stand-alone or autonomous PV systems. In these cases, it may prove more feasible to combine several different types of power sources to form a "hybrid" system. To date, PV has been effectively combined with other types of power generators such as wind, hydro, thermoelectric, petroleum-fuelled and even hydrogen. The selection process for hybrid power source types at a given site can include a combination of many factors including site topography, seasonal availability of energy sources, cost of source implementation, cost of energy storage and delivery, total site energy requirements, etc.

II. WIND TURBINE

This project presents a modelling method to aid in the design and evaluation of multi-source power systems. For site-specific weather data and load requirements, it visualizes the relative proportions of wind and solar. In this manner, given the particular needs, a designer can arrive at the most suitable balance for preferred system architecture. As an example to illustrate the method developed, an autonomous site powered from several renewable sources has been analyzed. This offers the ideal semantics through which it is possible to illustrate the principles, scales and limitations to which we must work if we are to achieve sustainable energy solutions.

The main components of a wind turbine for electricity generation are the rotor, the transmission system, the generator, and control system.

2.1 Tower:

It is the most expensive element of the wind turbine system. The lattice or tubular types of towers are constructed with steel or concrete. Cheaper and smaller towers may be supported by guy wires. The major components such as rotor brake, gearbox, electrical switch boxes, controller, and generator are fixed on to or inside nacelle, which can rotate or yaw according to wind direction, are mounted on the tower.

The tower should be designed to withstand gravity and wind loads. The tower has to be supported on a strong foundation in the ground. The design should consider the resonant frequencies of the tower do not coincide with induced frequencies from the rotor and methods to damp out if any. If the natural frequency of the tower lies above the blade passing frequency, it is called stiff tower and if below is called soft tower.

2.2 Rotor :

The aerodynamic forces acting on a wind turbine rotor is explained by aerofoil theory. When the aerofoil moves in a flow, a pressure distribution is established around the symmetric aerofoil. The characteristics of an aerofoil, the angle of attack, the magnitude of the relative wind speed are the prime parameters responsible for the lift and drag forces. These forces acting on the blades of a wind turbine rotor are transformed into a rotational torque and axial thrust force. The useful work is produced by the torque where as the thrust will overturn the turbine. This axial thrust should be resisted by the tower and foundations.

2.3 Rotor speed :

Low speed and high-speed propeller are the two types of rotors. A large design tip speed ratio would require a long, slender blade having high aspect ratio. A low design tip speed would require a short, flat blade. The low speed rotor runs with high torque and the high-speed rotor runs with low torque. The wind energy converters of the same size have essentially the same power output, as the power output depends on rotor area.

The low speed rotor has curved metal plates. The number of blades, weight, and difficulty of balancing the blades makes the rotors to be typically small. They get self-started because of their aerodynamic characteristics. The propeller type rotor comprises of a few narrow blades with more sophisticated aerofoil section. When not working, the blades are completely stalled and the rotor cannot be self-started.

Therefore, propeller type rotors should be started either by changing the blade pitch or by turning the rotor with the aid of an external power source (such as generator used as a motor to turn the rotor). Rotor is allowed to run at variable speed or constrained to operate at a constant speed. When operated at variable speed, the tip speed ratio remains constant and aerodynamic efficiency is increased.

III. SOLAR CELL

The electrical output of a single cell is dependent on the design of the device and the Semi-conductor material(s) chosen, but is usually insufficient for most applications. In order to provide the appropriate quantity of electrical power, a number of cells must be electrically connected. There are two basic connection methods: series connection, in which the top contact of each cell is connected to the back contact of the next cell in the sequence, and parallel connection, in which all the top contacts are connected together, as are all the bottom contacts. In both cases, this results in just two electrical connection points for the group of cells.

3.1 Series connection:

Figure shows the series connection of three individual cells as an example and the resultant group of connected cells is commonly referred to as a series string. The current output of the string is equivalent to the current of a single cell, but the voltage output is increased, being an addition of the voltages from all the cells in the string (the voltage output is equal to 3Vcell).

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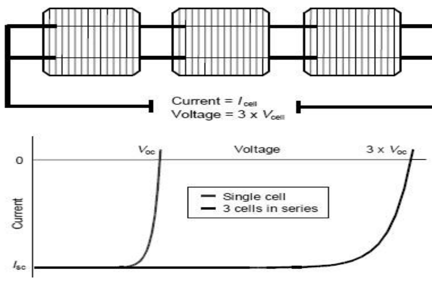
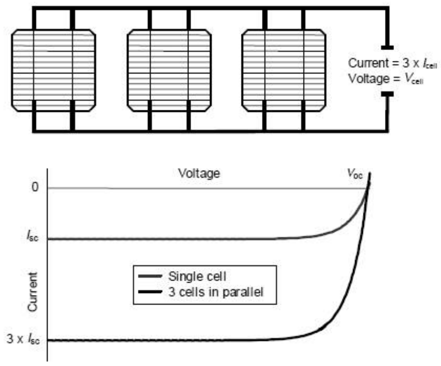


3.2 Parallel connection:

Figure shows the parallel connection of three individual cells as an example. In this case, the current from the cell group is equivalent to the addition of the current from each cell (in this case, 3 Icell), but the voltage remains equivalent to that of a single cell.



IV. FUEL CELL & ULTRA CAPACITOR

A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained.

Molten-carbonate fuel cells (MCFCs) are high-temperature cells, that operate at temperatures of 600°C and above.

Molten carbonate fuel cells (MCFCs) are currently being developed for natural gas and coal-based power plants for electrical utility, industrial, and military applications. MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic matrix of beta-alumina solid electrolyte (BASE). Since they operate at extremely high temperatures of 650°C (roughly 1,200°F) and above, non-precious metals can be used as catalysts at the anode and cathode, reducing costs.

Unlike alkaline, phosphoric acid, and polymer electrolyte membrane fuel cells, MCFCs don't require an external reformer to convert more
energy-dense fuels to hydrogen. Due to the high temperatures at which MCFCs operate, these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.

The efficiency of a fuel cell is dependent on the amount of power drawn from it. Drawing more power means drawing more current, which increases the losses in the fuel cell? As a general rule, the more power (current) drew, the lower the efficiency. Most losses manifest themselves as a voltage drop in the cell, so the efficiency of a cell is almost proportional to its voltage. For this reason, it is common to show graphs of voltage versus current (so-called polarization curves) for fuel cells.

4.1 ULTRA CAPACITOR

The reason the ultra capacitor has the potential to change the world is because it has a few properties that conventional batteries don't. The two most important are its rapid charge and discharge capabilities and the fact that

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they last more than 4 times longer than the best lithium ion batteries. Under the same stresses. Add to this the absence of toxic chemicals in their manufacture and disposal and you are very close to having the perfect energy storage solution. An ultra capacitor with such capabilities could, combined with other current technologies, literally change the face of the planet. Capacitors of any type have been unable to sustain a charge for more than a few hours. This means that if we replace your car battery with an Ultra capacitor you find the battery dead every morning.

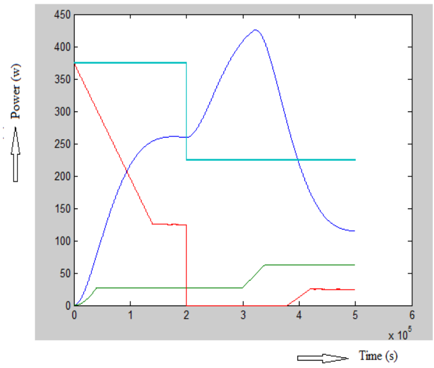
An electric double-layer capacitor (EDLC), also known as super capacitor, super condenser, electrochemical double layer capacitor, or ultra capacitor, is an electrochemical capacitor with relatively high energy density. Their energy density is typically hundreds of times greater than conventional electrolytic capacitors. EDLCs are used for energy storage rather than as general-purpose circuit components. They have a variety of commercial applications, notably in "energy smoothing" and momentary-load devices. They have applications as energy-storage and KERS devices used in vehicles, and for smaller applications like home solar energy systems where extremely fast charging is a valuable feature.

V. SIMULINK RESULTS

The system consists of a 75W solar cell, a 400W wind turbine, a 500W proton exchange membrane fuel cell, ultra-capacitors, an electrolyzer, and a power conditioner. The power conditioner includes a boost circuit and a SPWM inverter. It is used to step up ultra capacitor voltage to DC 200V and invert to 120Vrms, 60Hz AC. The wind turbine adopted is Southwest Wind power Air 403. When wind speed is 12.5m/s, the wind turbine produces the maximum power 400W. Solar cell adopted is SIEMENS SP75 and its maximum power is 75W. Wind turbine and solar cell are the main sources to supply load demand.

Fuel cell model includes a fuel cell module and a fuel controller. The fuel controller consists of two PID controllers to limit the flows of hydrogen and oxygen. The fuel cell is a accessory generator in this system and supplies insufficient power. In order to keep the supply and demand is balanced. When the supply is bigger than the load need, the electrolyzer model electrolyzes water to produce hydrogen and store it for further usage. Thus, the system can circulate supply load demand and energy will not be wasted.

Simulation results with step changes in load demand, wind speed, radiation, and ambient temperature are analyzed and shown in Figs. The initial wind speed is 10 m/s. Wind speed increases, at t=10s, from 10 to 12 m/s and decreases to 8 m/s at t=16s. The solar cell initially supplies power at the radiation 400W/m^2 and temperature 25°. At 15s, the radiation increases to 600W/m^2 and temperature also increases to 28°. The load demand changes from 375W to 225W at 10s. These step inputs cause changes in available power and load consumption. The power tracking performance of the hybrid topology with respect to load demand change and environmental variations is shown in Fig.



Associated parameter variations in solar cell, wind turbine, fuel cell, ultra capacitor, power converter output, and system performance are analyzed. With variation in load, the power demand changes from 375W to 225W at 10s as shown in Fig. The fuel cell provides power for load requirement because of the output powers of the wind turbine and solar cell are not sufficient enough to supply load demand at t=0s to 10s. However, as the wind speed increases, the captured power increases and the contribution of the fuel cell decrease. Any excess power is diverted to the electrolyzer during this period. Similarly, with sudden decrease in wind speed, the contribution of the fuel cell starts at t=19.1s. With changes in load and environmental conditions, the solar cell current and fuel cell current vary as shown in Fig.

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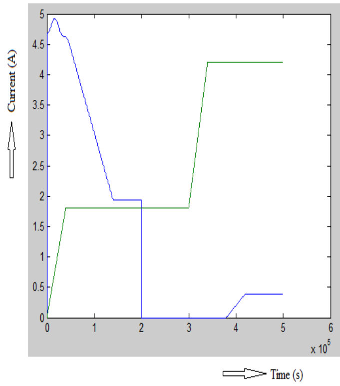
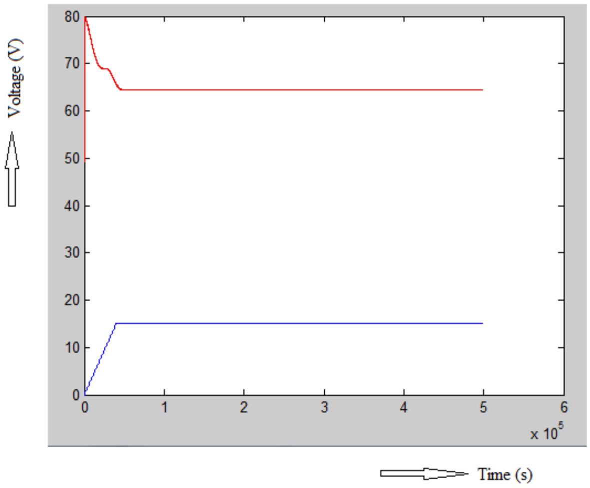


These changes are reflected in the performance of the fuel cell system. The stack current variation at t=0s to t=10s is due to start-up transients and load demand, as the solar cell's and wind turbines contributions are limited and fixed. During t=10s to t=16s, the fuel cell current decreases to zero because load demand is reduced and the wind turbine increases output power. After t=16s, variation in fuel cell current is due to changes in power demand from the fuel cell with varying availability of wind energy. Such changes in fuel cell current cause the stack voltage to vary significantly. Generally, a lower level of current implies higher stack voltage and vice versa. The use of an ultra capacitor in parallel with the fuel cell reduces the stack's output variation as shown in Fig.



With variations of the ultra-capacitor voltage between 49 and 62 V, the power converter unit regulates the load voltage. The controller in the boost converter adjusts the duty ratio so as to attain a fixed 200V DC in the inverter's input. The inverter, on the other hand, delivers a 120 Vrms, 60 Hz AC to the load. The hydrogen is a fuel of fuel cell.
The electrolyzer electrolyzes water to produce hydrogen by the excess power of the system and store it from t=10s to t=19.1s. The variation of hydrogen in storage tank is shown in Fig.

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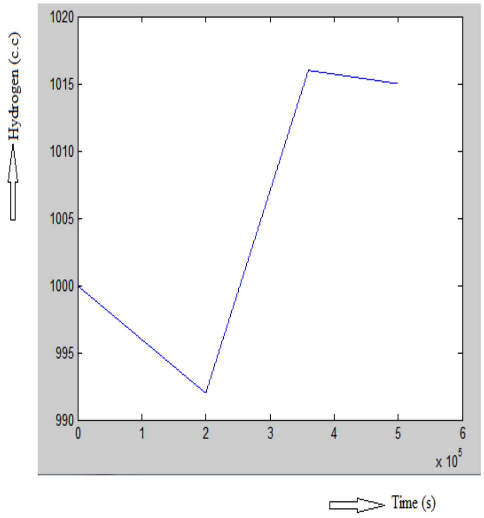

VI. CONCLUSION

In this project, a novel renewable energy based hybrid power system is developed and modelled for a stand-alone user with appropriate power conventional controllers. The available power from the renewable energy sources is highly dependent on environmental conditions such as wind speed, radiation, and ambient temperature. To overcome this deficiency of the solar cell and wind system, an integrated system with FC/UC is used. The voltage variation at the output is found to be within the acceptable range. The output fluctuations of the wind turbine varying with wind speed and the solar cell varying with both environmental temperature and sun radiation are reduced using a fuel cell. Hence, this system can withstand the rapid changes in load and environmental conditions, and suppress the effects of these fluctuations on the equipment side voltage. The proposed system can be used for off-grid power generation in non interconnected areas or remote isolated communities.

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