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POWER MANAGEMENT STRATEGIES FOR A GRID OF PV-FC HYBRID SYSTEM

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Abstract

This paper presents a method to operate a grid connected hybrid system. The hybrid system composed of a Photovoltaic (PV) array and a Proton exchange membrane fuel cell (PEMFC) is considered. Two operation modes, the unit -power control (UPC) mode and the feeder-flow control (FFC) mode, can be applied to the hybrid system. In the UPC mode, variations of load demand are compensated by the main grid because the hybrid source output is regulated to reference power. Renewable energy is currently widely used. One of these resources is solar energy. The photovoltaic (PV) array normally uses a maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load when there are variations in irradiation and temperature. The disadvantage of PV energy is that the PV output power depends on weather conditions and cell temperature, making it an uncontrollable source. Furthermore, it is not available during the night. In order to overcome these inherent drawbacks, alternative sources, such as PEMFC, should be installed in the hybrid system. By changing the FC output power, the hybrid source output becomes controllable. Therefore, the reference value of the hybrid source output must be determined. In the FFC mode, the feeder flow is regulated to a constant, the extra load demand is picked up by the hybrid source, and, hence, the feeder reference power m ust be known. system can maximize the generated power when load is heavy and minimizes the load shedding area. When load is light, the UPC mode is selected and, thus, the hybrid source works more stably.

The proposed operating strategy with a flexible operation mode change always operates the PV array at maximum output power and the PEMFC in its high efficiency performance band, thus improving the performance of system operation, enhancing system stability, and decreasing the number of operating mode change.

Index Terms: *Distributed generation, fuel cell, hybrid system, photovoltaic, power management.*

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1. INTRODUCTION

Renewable energy is currently widely used. One of these resources is solar energy. The photovoltaic (PV) array normally uses a maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load when there are variations in irradiation and temperature. The disadvantage of PV energy is that the PV output power depends on weather conditions and cell temperature, making it an uncontrollable source. Furthermore, it is not available during the night. In order to overcome these inherent drawbacks, alternative sources, such as PEMFC, should be installed in the hybrid system. By changing the FC output power, the hybrid source output becomes controllable. However, PEMFC, in its turn, works only at a high efficiency within a specific power range.

The hybrid system can either be connected to the main grid or work autonomously with respect to the grid-connected mode or islanded mode, respectively. In the grid-connected mode, the hybrid source is connected to the main grid at the point of common coupling (PCC) to deliver power to the load. When load demand changes, the power supplied by the main grid and hybrid system must be properly changed.

2. DISTRIBUTED GENERATION

Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers and large complex plants to reduce pollution. However, modern embedded systems can provide these traits with automated operation and renewables, such as sunlight, wind and geothermal. This reduces the size of power plant that can show a profit.

3. PROBLEM STATEMENTS

DES technologies have very different issues compared with traditional centralized power sources. For example, they are applied to the mains or the loads with voltage of 480 volts or less; and require power converters and different strategies of control and dispatch. All of these energy technologies provide a DC output which requires power electronic interfaces with the distribution power networks and its loads. In most cases the conversion is performed by using a voltage source inverter (VSI) with a possibility of pulse width modulation (PWM) that provides fast regulation for voltage magnitude.

4. FUEL CELL

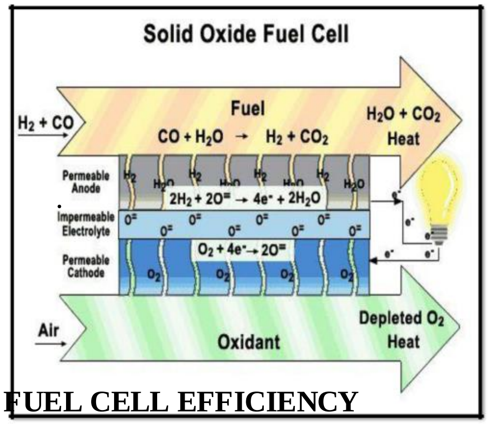
A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it,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

4.2 SOLID OXIDE FUEL CELL

A solid oxide fuel cell (SOFC) is extremely advantageous ,because of a possibility of using a wide variety of fuel' [Unlike most other fuel cells which only use hydrogen, SOFCs can run on hydrogen, butane, methanol, and other petroleum products. The different fuels each have their own chemistry.

For methanol fuel cells, on the anode side, a catalyst breaks methanol and water down to form carbon dioxide, hydrogen ions, and free electrons. The hydrogen ions move across the electrolyte to the cathode side, where they react with oxygen to create water. A load connected externally between the anode and cathode completes the electrical circuit. Below are the chemical equations for the reaction:

Anode Reaction: $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$
Cathode Reaction: $3/2\ O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$
Overall Reaction: $CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O$ + electrical energy.



4.3 FUEL CELL EFFICIENCY

The efficiency of a fuel cell is dependent on the amount of power drawn from it. Drawing more power means drawing more current, this increases the losses in the fuel cell. As a general rule, the more power (current) drawn, 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. A typical cell running at 0.7 V has an efficiency of about 50%, meaning that 50% of the energy content of the hydrogen is converted into electrical energy; the remaining 50% will be converted into heat.

5. HYBRID POWER SYSTEMS

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 what is known as a "hybrid" system. To date, PV has been effectively combined with other types of power generators such as wind, hydro, thermoelectric, petroleum-fueled 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.

- Hybrid power systems use local renewable resource to provide power.
- Village hybrid power systems can range in size from small household systems (100
- They combine many technologies to provide reliable power that is tailored to the local resources and community

- Potential components include: PV, wind, micro-hydro, river-run hydro, biomass, batteries and conventional generators .
- Potential components include: PV, wind, micro-hydro, river-run hydro, biomass, batteries.

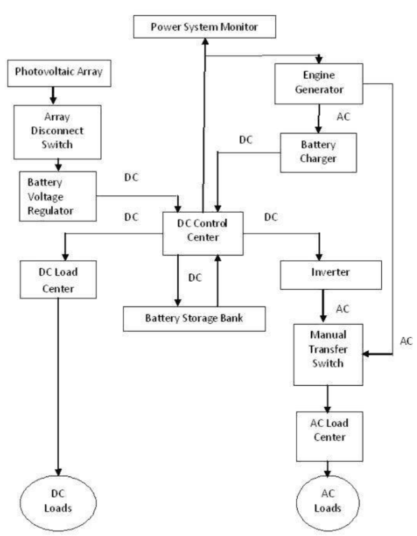
5.1 WHY A PV/ GENSET HYBRID?

When a genset is added, additional battery charging and direct AC load supply capabilities are They are a proven and reliable method for efficient and cost effective power supply at remote sites.

5.2 PV/ GENSET HYBRID SYSTEM

The PV/genset hybrid utilizes two diverse energy sources to power a site's loads. The PV array is employed to generate DC energy that is consumed by any existing DC loads, with the balance (if any) being used to charge the system's DC energy storage battery.

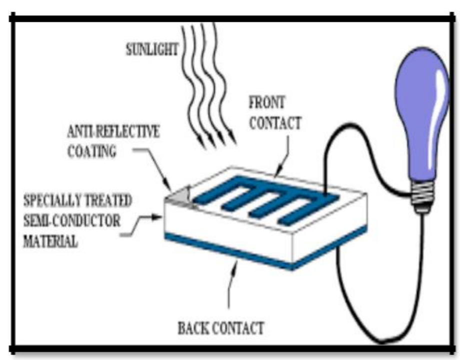
The PV array is automatically on line and feeding power into the system whenever solar insolation is available and continues to produce system power during daylight hours until its rate of production exceeds what all existing DC loads and the storage battery can absorb. Should this occur, the array is inhibited by the system controller from feeding any further energy into the loads or battery. A genset is employed to generate AC energy that is consumed by any existing AC loads, with the balance (if any) being used by the battery charger to generate DC energy that is used in the identical fashion to that described for the PV array above.



6. PHOTOVOLTAIC TECHNOLOGY

provided. The need to build in system autonomy is therefore greatly reduced. When energy demands cannot be met by the PV portion of the system for any reason, the genset is brought on line to provide the required backup power. Substantial cost savings can be achieved and overall system reliability is enhanced. PV/ genset hybrid systems have been utilized at sites with daily energy requirements ranging from as low as 1 kWh per day to as high as 1 MWh per day, which illustrates their extreme flexibility.

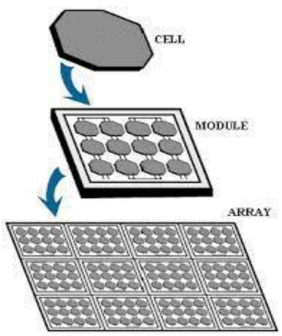
Photovoltaic's is the field of technology and research related to the devices which directly convert sunlight into electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic effect involves the creation of voltage in a material upon exposure to electromagnetic radiation. The photovoltaic effect was first noted by a French physicist, Edmund Becquerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use.



7. SOLAR CELL

Naturally n type silicon wafers developed a p type skin when exposed to the gas boron trichloride. Part of the skin could be etched away to give access to the n type layer beneath. These p{n junction structures produced much better rectifying action than Schottky barriers, and better photovoltaic behaviour. The rust silicon solar cell was reported by Chapin, Fuller and Pearson in 1954 and converted sunlight with an efficiency of 6%, six times higher than the best previous attempt. That figure was to rise significantly over the following years and decades but, at an estimated production cost of some $200 per Watt, these cells were not seriously considered for power generation for several decades.

Nevertheless, the early silicon solar cell did introduce the possibility of power generation in remote locations where fuel could not easily be delivered. The obvious application was to satellites where the requirement of reliability and low weight made the cost of the cells unimportant and during the 1950s and 60s, silicon solar cells were widely developed for applications in space. Also in 1954, a cadmium sulphide p{n junction was produced with an efficiency of 6%, and in the following years studies of p{n junction photovoltaic devices in gallium arsenide, indium phosphide and cadmium telluride were stimulated by theoretical work indicating that these materials would over a higher efficiency. However, silicon remained and remains the foremost photovoltaic material, beneting from the advances of



variations in design according to the purpose of the system, system sizing and aspects of system operation and maintenance.. The design of the system depends on the task it must perform and the location and other site conditions under which it must operate. This section will consider the components of a PV system, variations in design according to the purpose of the system, system sizing and aspects of system operation and maintenance.

9.3 SYSTEM DESIGN

There are two main system configurations – stand-alone and grid-connected. As its name implies, the stand-alone PV system operates independently of any other power supply and it usually supplies electricity to a dedicated load or loads. It may include a storage facility (e.g. battery bank) to allow electricity to be provided during the night or at times of poor sunlight levels. Stand-alone systems are also often referred to as autonomous systems since their operation is independent of other power sources. By contrast, the grid-connected PV system operates in parallel with the conventional electricity distribution system. It can be used to feed electricity into the grid distribution system or to power loads which can also be fed from the grid. It is also possible to add one or more alternative power supplies (e.g. diesel generator, wind turbine) to the system to meet some of the load requirements. These systems are the n known as 'hybrid' systems. Hybrid

silicon technology for the microelectronics industry. Short histories of the solar cell are given elsewhere.

9.2. THE PHOTOVOLTAIC SYSTEM

A PV system consists of a number of interconnected components designed to accomplish a desired task, which may be to feed electricity into the main distribution grid, to pump water from a well, to power a small calculator or one of many more possible uses of solar-generated electricity. The design of the system depends on the task it must perform and the location and other site conditions under which it must operate. This section will consider the components of a PVsystem.

systems can be used in both stand-alone and grid-connected applications but are more common in the former because, provided the power supplies have been chosen to be complementary, they allow reduction of the storage requirement without increased loss of load probability. Figures below illustrate the schematic diagrams of the three main system types.

10. POWER MANAGEMENT

Power management is a feature of some electrical appliances, especially copiers, computers and computer peripherals such as monitors and printers, that turns off the power or switches the system to a low-power state when inactive. In computing this is known as PC power management and is built around a standard called ACPI. This supersedes APM. All recent (consumer) computers have ACPI support.

10.1 MOTIVATION:

- PC power management for computer systems is desired for many reasons, particularly:
- Reduce overall energy consumption
- Reduce cooling requirements
- Reduce noise.
- Reduce operating costs for energy and cooling.
- Lower power consumption also means lower heat dissipation, which increases system stability, and less energy use, which saves money and reduces the impact on the environment.

10.2 PROCESSOR LEVEL TECHNIQUES:

The power management for microprocessors can be done over the whole processor, or in specific areas.
With dynamic voltage scaling and dynamic frequency scaling, the CPU core voltage , clock rate, or both, can be altered to decrease power consumption at the price of potentially lower performance. This is sometimes

done in real time to optimize the power-performance trade off.

10.3 MINIMIZE CABLING

All the signals and information which are available in protection/control relays, governor/excitation controllers and other microprocessor based equipment can be easily transmitted to the Industrial PMS via serial communication links. This avoids marshalling cubicles, interposing relays, cable ducts, spaghetti wiring, cabling engineering and provides extra functionality such as parameter setting/reading, stored events, disturbance data analysis and a single window to all electrical related data.

11. CONCLUSION

This seminar has presented an available method to operate a hybrid grid-connected system. The hybrid system, composed of a PV array and PEMFC, was considered. The operating strategy of the system is based on the UPC mode and FFC mode. The purposes of the proposed operating strategy presented in this seminar are to determine the control mode, to minimize the number of mode changes, to operate PV at the maximum power point, and to operate the FC output in its high-efficiency performance band.

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