

Optimization of Generated Power for a Grid Connected 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.

Keywords: Photovoltaics, Fuel cell, Hybrid systems, modelling.

I. INTRODUCTION

a) 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.
- illage hybrid power systems can range in size from small household systems (100 Wh/day) to ones supplying a whole area (10's MWh/day).
- 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.

A. Configuration of hybrid system

Figure shows the basic configuration of hybrid system discussed in this study. The hybrid system was consisted of reduction gear, main-motor (EM1), sub- motor (EM2), engine, power controller

and battery. It was supposed that a double-motor system was prepared for the driving system discussed in this study. At first, acceleration was assisted by was applied only by main motor when the driving speed was low, while the corporation by two motors was often achieved to drive the system.

If the SOC (state of charge) of battery was decreased below the specific threshold, the battery was charged by sub-motor. This operation was priority to over other actions. Figure 2 shows the modified configuration of hybrid system proposed in this study.

In the modified system, CVT was utilized to keep constant revolution numbers of the sub-motor when the sub-motor contributed to assist the system.

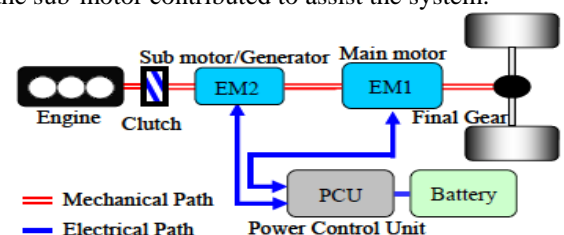
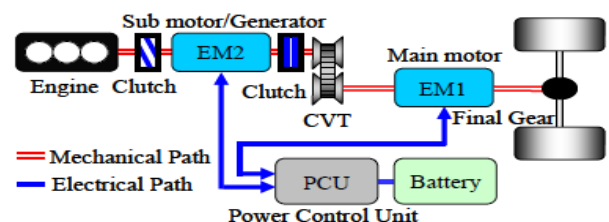


Figure 1 Schematic view of double motor hybrid system



Schematic view of double motor hybrid system with CVT
 Fig:1

b) Petroleum-fuel edenginegenerators (Gensets)

Petroleum-fueled gensets (operating continuously in many cases) are presently the most common method of supplying power at sites remote from the utility grid such as villages, lodges, resorts, cottages and a variety of industrial sites including telecommunications, mining and logging camps, and military and other government operated locations. Although gensets are relatively inexpensive in initial cost, they are not inexpensive to operate. Costs for fuel and maintenance can increase exponentially when these needs must be met in a remote location. Environmental factors such as noise, carbon oxide emissions, transport and storage of fuel must also be considered.



Fig:2

Figure Hybrid PV/Generator System Example; Courtesy Photron Canada Inc., Location: Sheep Mountain Interpretive Centre, Parks Canada Kluone National Park, Yukon Territories, Canada, 63° North Latitude; Components shown include: generator (120/240 V), battery (deep cycle industrial rated @ ± 10 kWh capacity), DC to AC stand-alone inverter (2500 W @ 120 V output), miscellaneous safety + control equipment including PV array disconnect, PV control/regulator, automatic generator start/-stop control, DC/AC system metering etc.; - Components not shown: PV array (800 W peak).

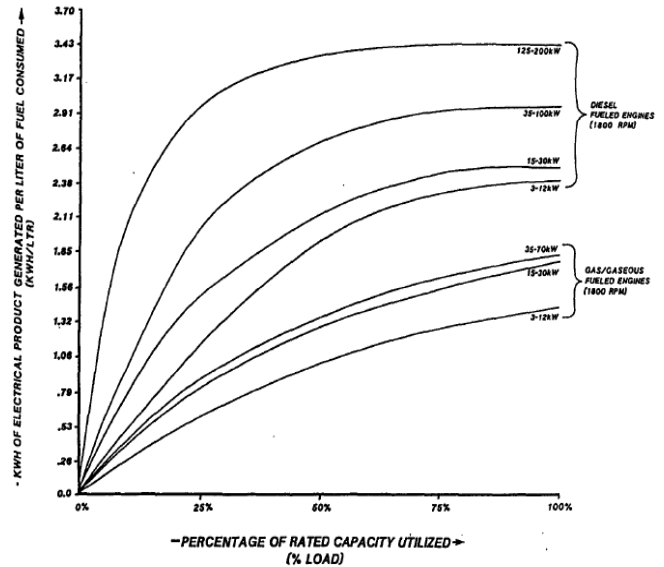


Figure : 3Genset fuel efficiency vs. capacity utilized.

to power conversion efficiencies may be as high as 25% (for a diesel fueled unit operating at rated capacity). Under part load conditions, however, efficiencies may decline to a few percent. Considerable waste heat is therefore available and may be utilized for other requirements such as space and/or water heating.

II. MODELING AND CONTROL OF INVERTER INTERFACED DG UNITS

Basically each DG unit may have DC type or rectified generation unit (Fuel cell, solar cell, wind turbine, micro turbine...), storage devices, DC-DC converter, DC-AC inverter, filter, and transformer for connecting to loads or utility in order to exchange power. Model and dynamic of each of this part may have influence in system operation. But here for simplification it is considered that DC side of the units has sufficient storage and considered as a constant DC source. Hence only DC-AC inverter modeling and control investigated in this paper.

A circuit model of a three-phase DC to AC inverter with LC output filter is further described in Figure As shown in the figure, the system consists of a DC voltage source (Vdc), a three- phase PWM inverter, an output filter (Lf and C with considering parasitic resistance of filter- Rf). Sometimes a transformer may be used for stepping up the output voltage and hence Lf can be transformer inductance.

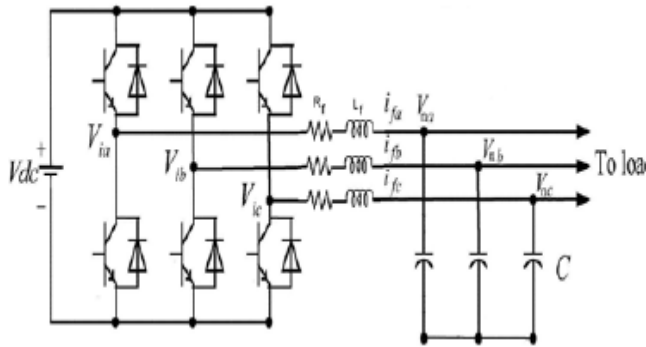


Figure: 4 PWM inverter diagram

There are two ways for controlling an inverter in a distributed generation system

A. PQ Inverter Control

This type of control is adopted when the DG unit system is connected to an external grid or to an island of loads and more generators. In this situation, the variables controlled by the inverter are the active and reactive power injected into the grid, which have to follow the set points P_{ref} and Q_{ref} , respectively. These set points can be chosen by the customer or by a central controller.

The PQ control of an inverter can be performed using a current control technique in qd reference frame which the inverter current is controlled in amplitude and phase to meet the desired set-points of active and reactive power.

With the aim of Park transform and equations between inverter input and output, the inverter controller block diagram for supplying reference value of P_{ref} and Q_{ref} is as figures. For the current controller, two Proportional-Integral (PI) regulators have been chosen in order to meet the requirements of stability of the system and to make the steady state error be zero. With this control scheme, it is possible to control the inverter in such way that injects reference value of P_{ref} , Q_{ref} into other part of stand-alone network.

When the output voltage is needed to be regulated, the PV control scheme that is similar to PQ mode with feedback of voltage used to adjust Q_{ref} .

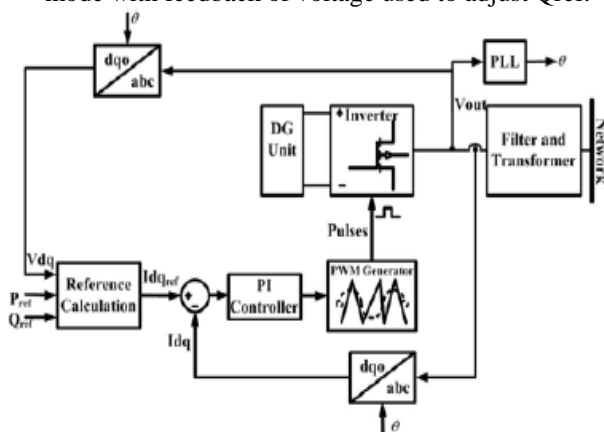


Figure :5 PQ control scheme of inverter

B. Vf Inverter Control

This controller has to act on the inverter whenever the system is in stand-alone mode of operation. In fact in this case it must regulate the voltage value at a reference bus bar and the frequency of the whole grid. A regulators work in order to keep the measured voltages upon the set points. Moreover the frequency is imposed through the modulating signals of the inverter PWM control by mean of an oscillator. A simple PI controller can regulate bus voltage in reference value with getting feedback of real bus voltage.

Figure outlines this control strategy. In this case it is obvious that the DG unit should have storage device in order to regulate the power and voltage.

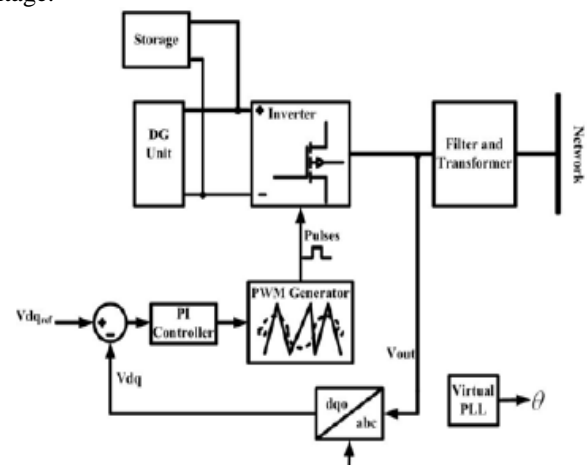


FIG:6

III. 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. Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system.

A. DESIGN FEATURES IN A FUEL CELL ARE:

- The electrolyte substance. The electrolyte substance usually defines the type of fuel cell.
- The fuel that is used. The most common fuel is hydrogen.
- The anode catalyst, which breaks down the fuel into electrons and ions. The anode catalyst

is usually made up of very fine platinum powder.

- The cathode catalyst, which turns the ions into the waste chemicals like water or carbon dioxide. The cathode catalyst is often made up of nickel.

A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnects)
- Mass transport loss (depletion of reactants at catalyst sites under high loads, causing rapid loss of voltage).

To deliver the desired amount of energy, the fuel cells can be combined in series and parallel circuits, where series yields higher voltage, and parallel allows a higher current to be supplied. Such a design is called a fuel cell stack. The cell surface area can be increased, to allow stronger current from each cell.

B. 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. (Depending on the fuel cell system design, some fuel might leave the system unreacted, constituting an additional loss.)

IV. OPTIMIZATION OF POWER

Power optimization 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.

Motivation:

PC power management for computer systems is desired for many reasons, particularly:

- Reduce overall energy consumption
- Prolong battery life for portable and embedded systems
- 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.

i. Power Management System helps to:

• Avoid Black-outs

In case of a lack of power, Load Shedding secures the electrical power to critical loads by switching off non-critical loads according to dynamic priority tables.

• Reduce Energy Costs / Peak Shaving

When all on-site power generation is maximized and the power demand still tends to exceed the contracted maximum electricity import, the system will automatically shed some of the low priority loads.

• Enhanced Operator Support

At sites where electricity is produced by several generators, the demands with respect to control activities by operators are much higher. Advanced functions such as intelligent alarm filtering, consistency analysis, operator guidance, and a well organized single-window interface support the operator and prevent incorrect interventions.

• Achieve Stable Operation

The Power Control function shares the active and reactive power between the different generators and tie-lines in such a way that the working points of the machines are as far as possible away from the border of the individual PQ-capability diagrams so that the plant can withstand bigger disturbances.

• Optimize Network Design

Because the set points for the generators, turbines and transformers are calculated in such a way that no component will be overloaded and the electrical network can be used up to its limits, over-dimensioning of the network is no longer needed.

• Minimize Cabling and Engineering

V. MODELLING OF CASE STUDY: SYSTEM DESCRIPTION

A. Structure of Grid-Connected Hybrid Power System

The system consists of a PV-FC hybrid source with the main grid connecting to loads at the PCC as shown in Fig. 1. The photovoltaic and the PEMFC are modeled as nonlinear voltage sources. These sources are connected to dc-dc converters which are coupled at the dc side of a dc/ac inverter. The dc/dc connected to the PV array works as an MPPT controller. Many MPPT algorithms have been proposed in the literature, such as incremental

conductance (INC), constant voltage (CV), and perturbation and observation (P&O). The P&O method has been widely used because of its simple feedback structure and fewer measured parameters. The P&O algorithm with power feedback control is shown in Fig. 2. As PV voltage and current are determined, the power is calculated. At the maximum power point, the derivative

(dP/dV) is equal to zero. The maximum power point can be achieved by changing the reference voltage by the amount of ΔV_{ref} .

B. Overall Operating Strategy for the Grid-Connected Hybrid System

It is well known that in the microgrid, each DG as well as the hybrid source has two control modes: 1) the UPC mode and 2) the FFC mode.

In the aforementioned subsection, a method to determine in the UPC mode is proposed. In this

subsection, an operating strategy is presented to coordinate the two control modes.

The purpose of the algorithm is to decide when each control mode is applied and to determine the reference value of the feeder flow when the FFC mode is used. This operating strategy must enable the PV to work at its maximum power point, FC output, and feeder flow to satisfy their constraints. If the hybrid source works in the UPC mode, the hybrid output is regulated to a reference value and the variations in load are matched by feeder power. With the reference power proposed in Subsection A, the constraints of FC and PV are always satisfied. Therefore, only the constraint of feeder flow is considered. On the other hand, when the hybrid works in the FFC mode, the feeder flow is controlled to a reference value

VI. MATLAB DESIGN OF CASE STUDY AND RESULTS

Grid connected PV-FC hybrid system

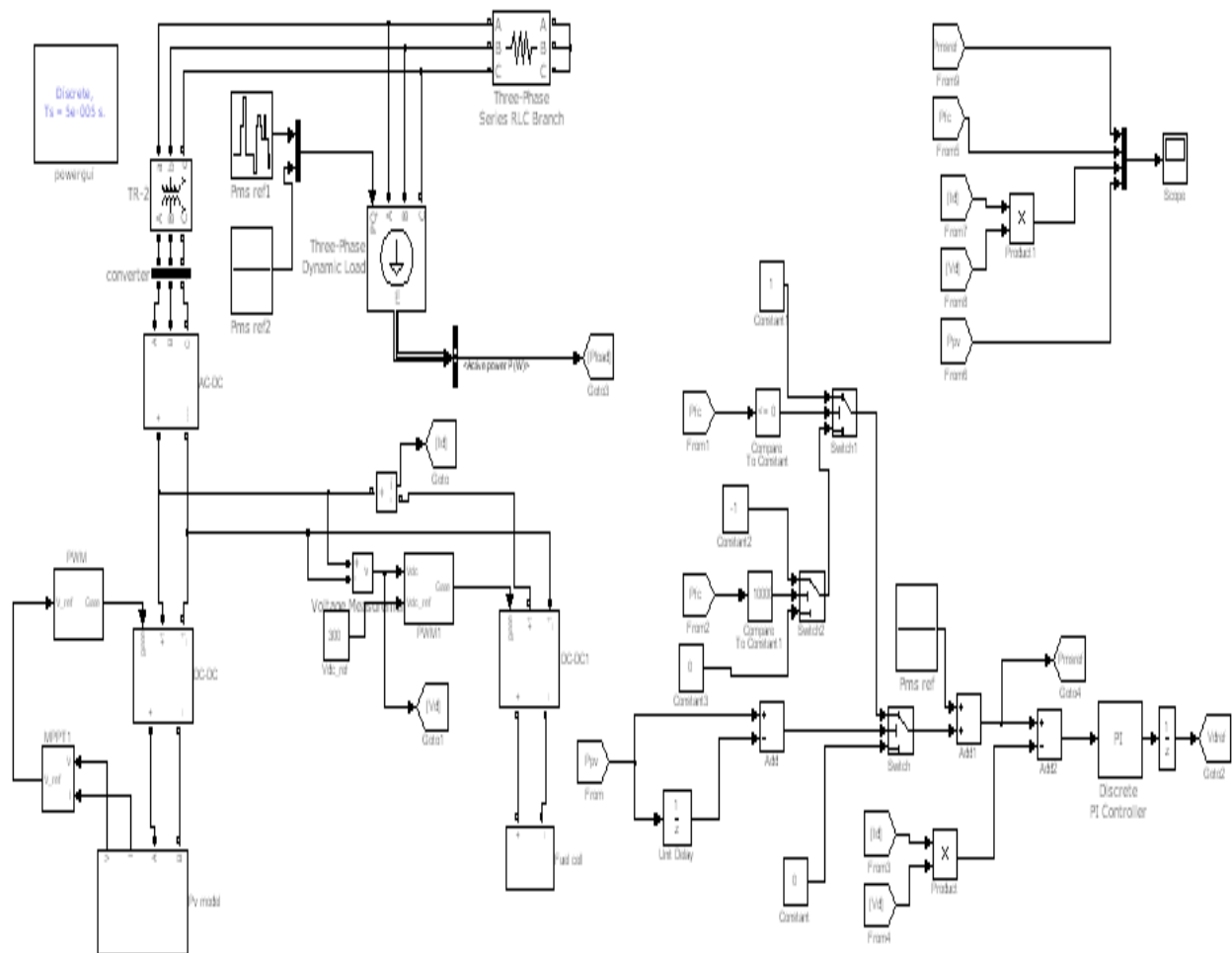


Fig. 11:Grid connected PV-FC hybrid system

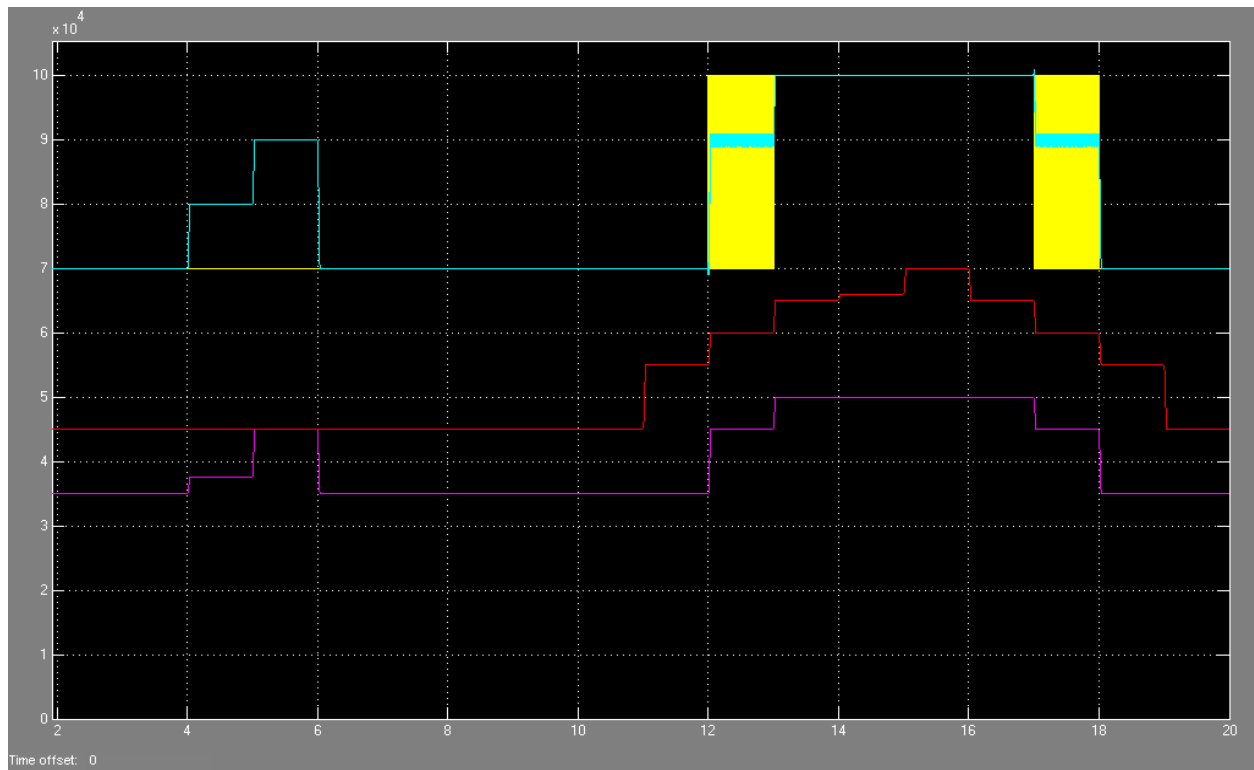


Fig. 12:Operating strategy of the hybrid source.

VII. CONCLUSION

This paper 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 paper 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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