A High Efficiency Maximum Power Point Tracker for Regenerative Fuel Cells

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Abstract-Photovoltaic (PV) panels have low efficiencies and thus need to be operated at maximum power. There is only one such point where the voltage and current produces maximum output power and is called the Maximum Power Point (MPP). The output power will vary according to solar irradiation and ambient temperature. Further, under partial shading conditions, the output power-voltage curve contains multiple MPPs. To track the MPP it becomes necessary to use a method known as MPP tracking. Normally a Maximum Power Point Tracker (MPPT) is either connected to a battery (any DC storage component) or to an inverter. This work focuses on the design and development of a MPP tracking charge controller to operate at maximum efficiency under all conditions to deliver an optimal voltage to a regenerative fuel cell (RFC).

Index Terms—Photovoltaic, maximum power point tracking, maximum power point, extremum seeking control, regenerative fuel cell, charge controller.

I. INTRODUCTION

Issues like global warming, power shortages and the depletion of fossil fuels necessitates the use of environmentally friendly renewable energy sources. One such alternative energy source is photovoltaic (PV) energy [1]. PV energy as an alternative energy source is presently considered as the most useful source of energy as it is inexhaustible, abundant, free and clean [2].

This work combines PV energy with a RFC through the use of a MPPT to create a hybrid system as presented in Figure 1.

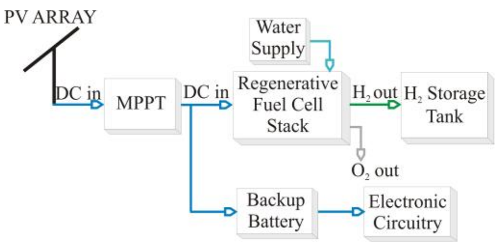

Figure 1 Hybrid system

A RFC is in fact a fuel cell (FC) operating in reverse mode. A FC uses hydrogen and oxygen to produce electrical energy and water. A RFC uses electrical energy and water to produce oxygen and hydrogen [3]. The dedicated RFC used in this work should not be confused with a unitized regenerative fuel cell (URFC). The RFC only works in the reverse mode (electrolyser), whereas a URFC works in both reverse and forward modes [3, 4]. This work concentrates on the RFC.

Despite all the advantages that PV energy offers, the initial implementation costs are still high and the energy conversion efficiency is still very low. It therefore becomes necessary to use methods that extract the maximum power from the PV panels in order to operate at maximum efficiency during all atmospheric conditions. As illustrated in Figure 2 [5], there is only one point where the current and voltage produces maximum power and that is called the MPP. This point varies according to different parameters, namely: array temperature, solar irradiation and panel shadowing [1].

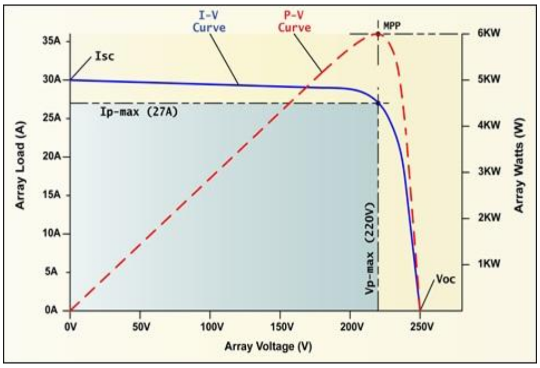

Figure 2 PV array characteristic curve

MPP tracking is a technique used in charge controllers to extract the maximum available power, by measuring the output of the PV panels, comparing it to the battery voltage and then setting the highest power that the PV panel can deliver to charge the battery. It then converts the power to the optimum voltage to transfer maximum current into the battery [6]. Some of the more commonly used techniques are: Hill climbing, Perturb & Observe, Incremental Conductance, Fractional V_{OC} and Fractional I_{SC}. The latest algorithms can be categorized as follows: 1) Real-time identification method. 2) Extremum seeking control. 3) Particle swarm optimization. 4) DIRECT search algorithm. 5) Adaptive step-size method [1, 7].

II. MPPT ALGORITHM

The algorithm that is to be improved in this research is the extremum seeking control (ESC) algorithm. The ESC algorithm has one major advantage over other algorithms: It does not rely on the PV panel characteristics; in other words it is not a model-based algorithm! A typical system block diagram of a ESC is illustrated in Figure 3 and it comprises an integrator, differentiator, a logic circuit and an amplifier [8].

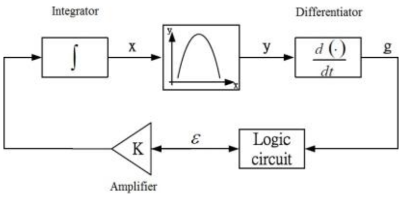

Figure 3 System block diagram of an ESC

A comparison of different ESC techniques done by Yau and Wu [8] shows that the ESC method has a high efficiency and fast response to changes in the system.

III. Hybrid System

Most RFC systems are dependent on grid electricity as illustrated in Figure 4.

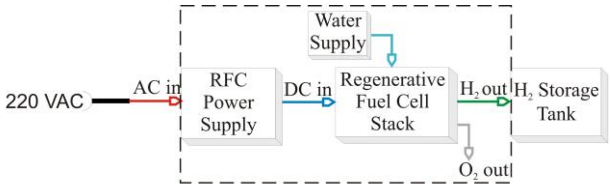

Figure 4 Common RFC system

This has two negative effects on the efficiency. First, AC power is fed to the RFC power supply which does not necessarily provide an optimum DC voltage to the RFC. Second, if the AC power is down the RFC will not produce hydrogen. It should be noted that a RFC only needs DC power to operate.

The RFC system in Figure 4 will be configured to operate as a hybrid system, as shown in Figure 1. The system will consist of a PV array, MPPT, backup battery, optional electronic circuitry and the RFC. The MPPT will provide an optimum voltage to the RFC in order to achieve the highest possible efficiency. The reason for that is if the voltage supplied to the RFC is greater or less than a certain value, the efficiency will decrease. Also if the supply voltage is below the minimum; the water will not decompose [3]. During operation of the PV array (daytime), hydrogen will be produced.

IV. Conclusion

A previous research study on the optimization of the voltage for a RFC indicated that there exists only one voltage value where the efficiency will be at a maximum (see Figure 5) [3]. The optimum voltage is unique to each RFC and thus the output voltage of the MPPT charge controller must be controllable in order to operate with any type of RFC. Figure 5 clearly shows that a single voltage value of 5.05 V gives a maximum efficiency of 56.85%. On either side of the optimum voltage the efficiency drops.

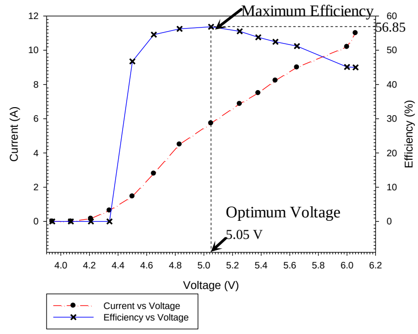

Figure 5 Efficiency and current vs. voltage of the RFC

Work so far concentrated on the analysis of the power requirements of the Hogen GC 300 RFC. The data obtained will be used to design a MPPT for the commercial H_2 generator. Later work will focus on a MPPT for the VUT RFC.

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Neil Jansen van Rensburg received his undergraduate degree in 2011 from the Vaal University of Technology, South Africa. He is presently studying towards his Master degree in electrical engineering at the same institution. His research interest is photovoltaic MPPT control for regenerative fuel cells.