Qatar University First Solar Car to Compete in the World Solar Challenge: Design of Energy Management System

Mariam ElMenshawy and Mena ElMenshawy
Supervised by: Dr. Ahmed Massoud and Prof. Adel Gastli
Department of Electrical Engineering, Qatar University

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Abstract —Solar vehicles still have limitations in terms of energy management technology, including photovoltaic and energy storage system. Energy efficiency and light weight are important factors for a successful vehicle. In order to achieve that in this work, a 5 kWh Lithium ion battery, 2 kW in-wheel axial flux permanent magnet brushless DC motor with a rated voltage of 48 V, and 1035 W monocrystalline PV modules are selected to attain such constraints. In addition, ultra-capacitors are used as a second energy storage device to take the advantages of the fast charging and discharging. Buck-Boost converters are designed to regulate the output voltage of the three sources which are PV panel, battery, and ultra-capacitors. To draw the maximum power from the PV modules, PV module I-V and P-V characteristics are studied under the effect of solar insolation and temperature by developing the PV model using Matlab/Simulink. In addition, the maximum power point tracker model is developed and implemented using perturb and observe technique to select the optimum point. Moreover, different energy management cases are considered under different operating conditions using the three sources mentioned earlier that supply the load according to its power requirements.

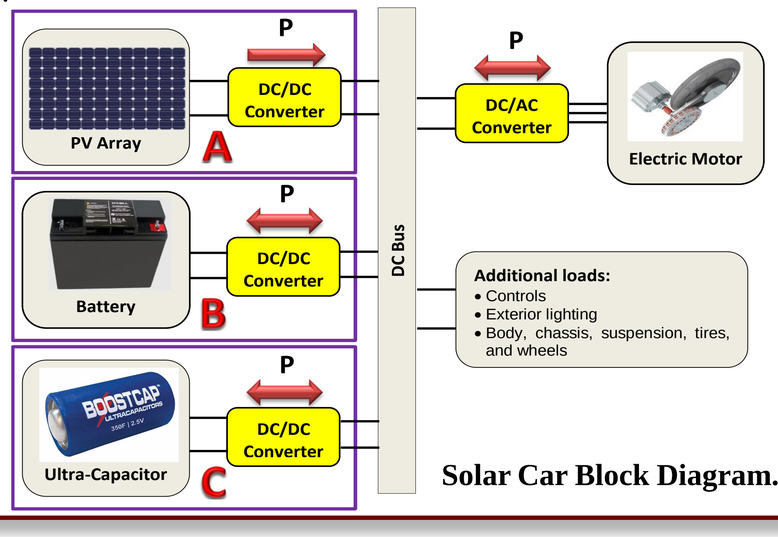
Introduction

Research and development in the area of renewable energy are expanding significantly, owing to increasing sustainability and environmental awareness. Among the renewable energy resources, solar energy through PV panels has been the most attractive, due to its low installation costs, ease of maintenance and the fact that, the generation of electricity in that way is rather clean. Solar energy is a convenient energy supply with great long-term benefits relative to oil prices. To further improve energy efficiency, several electric power applications have recently used PV array systems, where the idea of installing PVs on EVs has been emerged resulting in solar powered electric vehicles.

Solar cars, like many student engineering projects, showcase innovation, technology development, applicable solutions, and carry on an engineering legacy. The building of solar vehicles is now referred to as "brain sport". Designing, developing and testing solar powered vehicles introduce new methods to improve and integrate systems from experimental solar cars to marketable cars. Solar vehicle competition is an environment in which technology has been built for research. The World Solar Challenge held in Australia is one of the events that have been organizing the world solar car competition every two years. The race aims to promote solar energy usage, to encourage energy sufficient technology development, such as PV cells, batteries, electric motors and lightweight vehicles, and to show the need of good energy management strategies.

System Structure

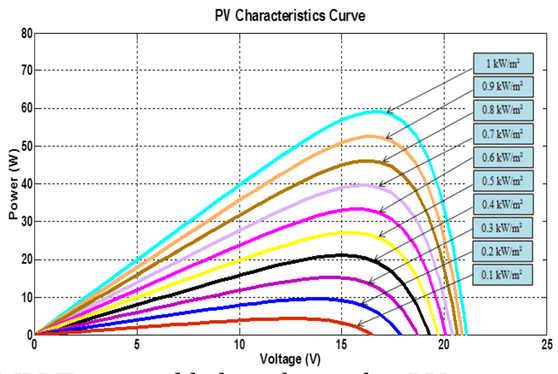
DC/DC converters are the main building blocks. Since the PV cells are energy converters and not energy storage devices, thus a unidirectional converter for maximum power point tracking should be designed for maximum power point operation of the PV. On the other hand, batteries and ultra-capacitors are energy storage devices that are charged and discharged according to the energy management system, thus bidirectional converters should be designed to manage the energy and regulate the voltage of both batteries and ultra capacitors so that they match the load voltage requirements.

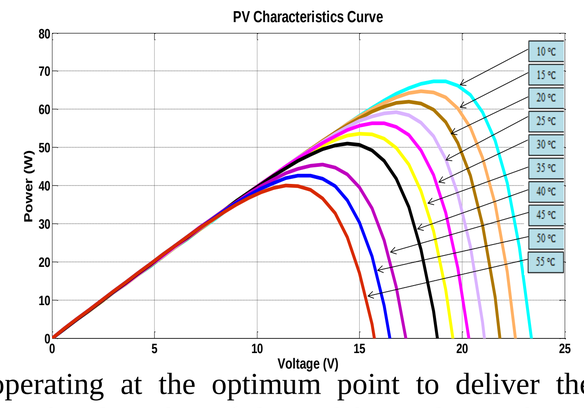


Solar Car Block Diagram.

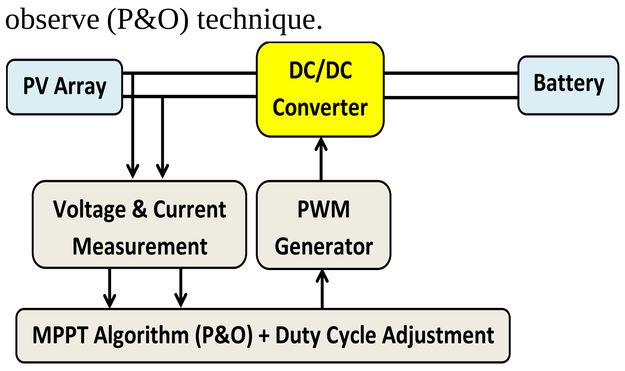
PV & MPPT Model

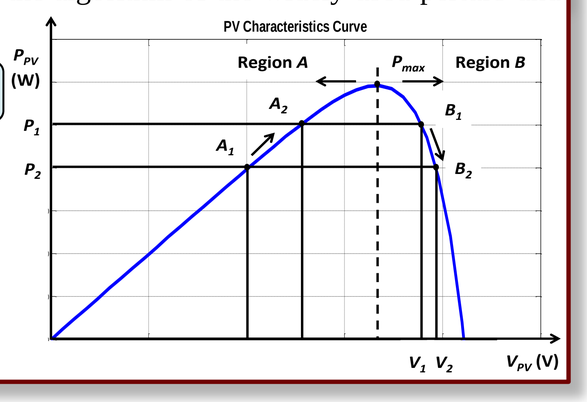
The simplified PV model has been developed and used as Simulink subsystems where the simulated P-V output characteristics shows the solar insolation and PV array temperature effect respectively on commercial PV modules.





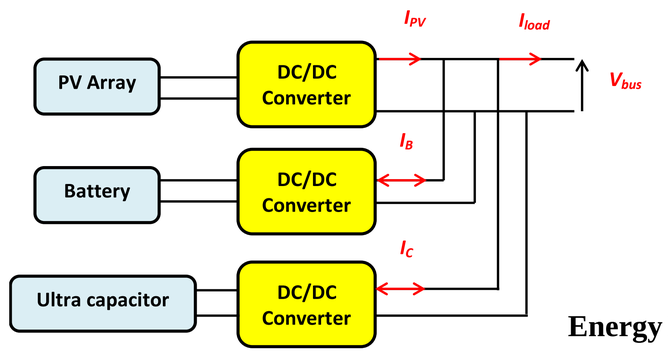
MPPTs are added to keep the PV system operating at the optimum point to deliver the maximum power. The following figures illustrate the algorithm of the widely used perturb and observe (P&O) technique.





Energy Management System

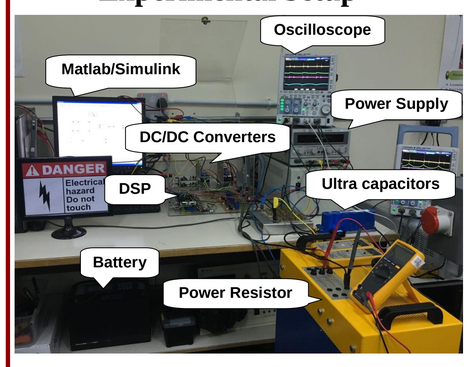
During solar car racing, the car is driven with speed variations in response to the road conditions and the solar power. The following figure describes the flow of energy into the system, and the flow of energy from and to the energy storage devices. The flow of power from the PV array is varying depending on the environmental conditions. The energy drawn from the PV is allocated for the drive system and the battery. When the car accelerates, power flows to the load and the battery discharges. However, in deceleration situations, current flows back from the motor to the battery and the battery charges. The current flowing into or from the ultra-capacitors can flow in both directions depending on the load requirements, it could be negative in regenerative breaking conditions, where it is highly required to charge the ultra capacitor to get use of the energy.



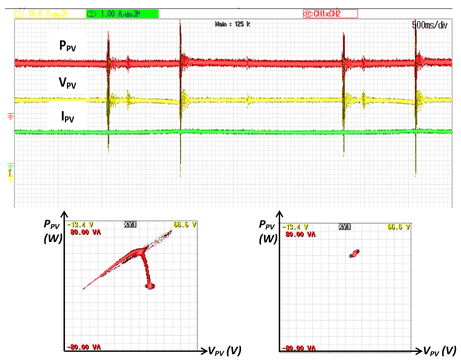
Energy Management.

Practical Results

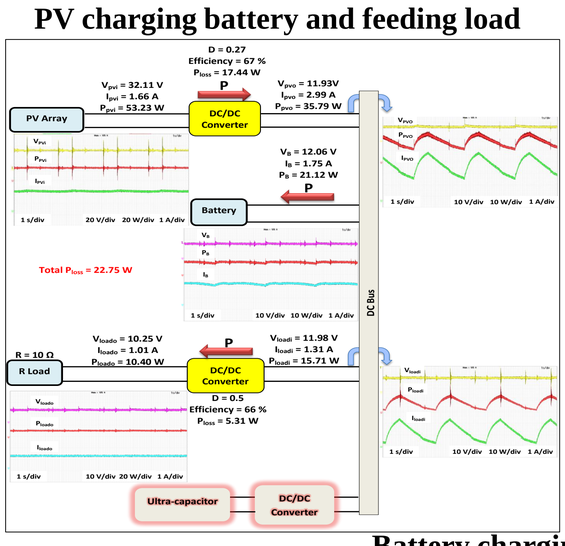
Experimental Setup



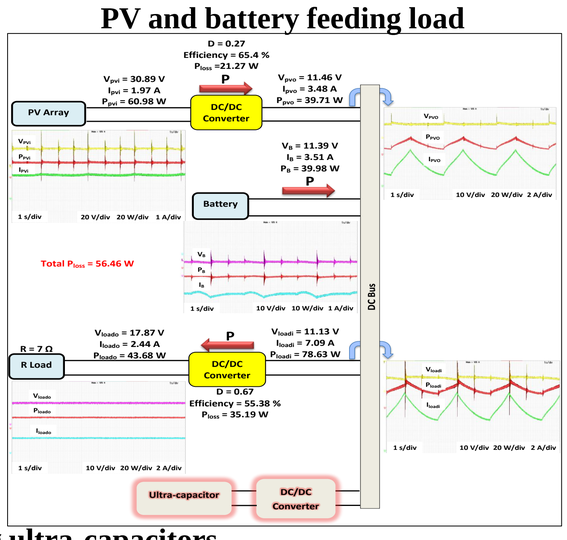
MPPT Results using P&O algorithm with ΔD=0.0000001



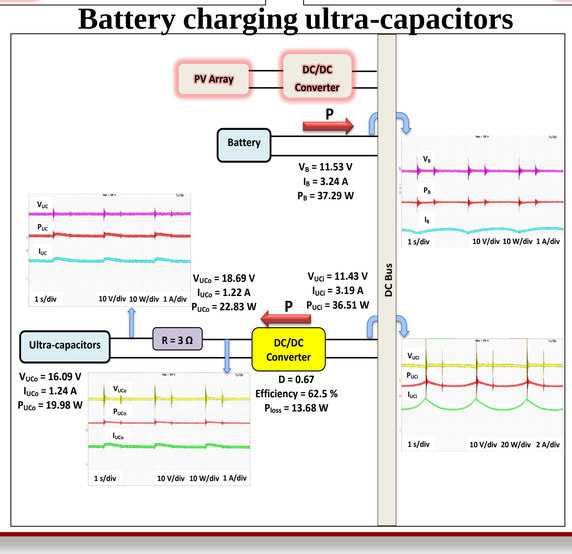
PV charging battery and feeding load



PV and battery feeding load



Battery charging ultra-capacitors



Conclusion & Future Work

Solar car racing has raised the interest of energy issues and research topics in the public domain. The aim of this project is to develop the energy management system of a solar powered car that includes three different sources. Practically, energy management system is accomplished with an open-loop control scheme, where different cases are tested under different conditions. For further improvements, a closed-loop control scheme should be designed to control the current flow between the storage devices and the DC bus.

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