Improving the Energy Storage of Standalone PV Systems while Enhancing the Charging Efficiency using Supercapacitors

P L A K Piyumal
Department of Physics
University of Kelaniya
Kelaniya 11600, Sri Lanka
peumalkasun@gmail.com

A L A K Ranaweera
Department of Physics
University of Kelaniya
Kelaniya 11600, Sri Lanka
arunaran@kln.ac.lk

S R D Kalingamudali
Department of Physics
University of Kelaniya
Kelaniya 11600, Sri Lanka
kalinga@kln.ac.lk

Nihal Kularatna
School of Engineering
University of Waikato
Hamilton, New Zealand
nihalkul@waikato.ac.nz

***Abstract*—Usually a battery is used as the energy storage device in typical standalone solar photovoltaic (PV) systems. It is charged by a solar charge controller. The charging efficiency of the system depends on the efficiency of the DC-DC converter of solar charge controller. However, a considerable amount of usable energy is wasted during the charging process. In this work, a method is proposed to utilize this wasted energy and thereby to enhance the charging efficiency. In the case of an empty capacitor being charged by an external source, it stores only half of the energy delivered by the source as compared to that of an electrochemical battery. Therefore, it wastes 50% of useful energy. A portion of this wasted energy can be collected and utilized if a useful resistive load is connected in series to this capacitor charging loop. In this study, a DC-DC converter and battery bank is connected as the useful resistive load in the capacitor charging loop. A supercapacitor (SC) bank is used replacing the conventional capacitor. Therefore, total energy loss in capacitor charging loop can be minimized by storing energy in both battery bank and SC bank. This concept is introduced into a typical PV system for reducing its energy losses. Experimental results show an enhancement in charging efficiency when this new method is employed. The energy stored in the SC bank could be used for driving loads with required electronics.**

Keywords—Standalone PV systems, DC-DC converter, Supercapacitor, Charging efficiency

I. Introduction

Nowadays, electric energy is the most important form of energy for humans' survival. Because there aren't any natural sources of electrical energy, various ways of energy conversions methods are used to convert the other forms of energy to electrical energy. By doing so, the living environment of humans and animals is heavily polluted with toxic gases and other unhealthy particles. Therefore, finding a better solution through renewable energy sources to meet the future energy demand is an important task due to the shortage of world energy sources. Among the various types of renewable energy harnessing devices, photovoltaic (PV) cells remain on top of the most popular methods to harness solar energy [1]. Nowadays, many countries and organizations are trying to develop a variety of solar cell technologies to gain higher efficiencies. Currently, conventional solar panels have a maximum efficiency of about 20-25% [2]. When they are used in a PV system, most of the energy is wasted during the power conversion process inside PV converters. Therefore, it is necessary to find a way to utilize this energy in an effective manner.

Houses and other buildings located in remote areas where the national grid is not available, depend mainly on standalone PV systems. Fig. 1 shows a block diagram of a typical standalone PV system with loads. Rechargeable batteries are commonly used in standalone PV systems to store energy in day time and produce power for the loads at night. Each device in power conversion path waste enormous amount of usable energy. Recent advances in solar technologies proposed the use of supercapacitors (SCs) in battery-SC hybrid systems to provide several key advantages that make them better suited for self-sustainable and low-maintenance systems [3-4].

Battery charge controller is the most important device of a standalone PV system. It must have the ability to extract and deliver maximum energy from the PV array and store it into the battery bank in order to maximize the system efficiency. In typical charge controlling systems, DC-DC converters are being used in order to step up or step down the PV array voltage into the battery charging voltage while achieving the maximum power point of the PV array. Modern solar charge controllers can achieve maximum efficiency of around 90% [5].

SC is a short term energy storage device which has a low energy density as compared to electrochemical batteries such as lead acid batteries, Ni-metal batteries and lithium-ion batteries.

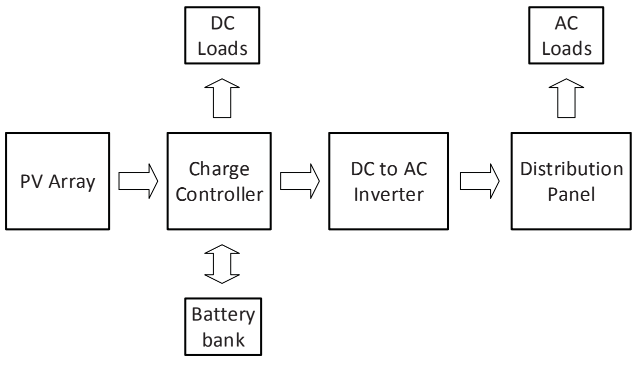

Fig. 1. Typical standalone PV system with DC and AC loads