Starting Transients in a MPPT-Battery Controlled DC Motor – Water Pumping System

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***Abstract*: To address the problems of non-continuous power generation and fluctuations in a solar PV driven DC irrigation water pump systems, leading to low performance, we propose three different schemes. The main components of the system involve a solar PV panel, a Maximum Power Point Tracker (MPPT) circuit, a suitable sized battery storage (and controller) and a DC drive operated water pump. The three operating modes are :1) With only PV and MPPT feeding the motor-pump, 2) With only battery (pre-charged) feeding the motor-pump system and 3) All the three - PV, MPPT and battery feeding the motor pump system. The starting transients of each of these operating modes have been simulated and analyzed in MATLAB-SIMULINK. The battery is controlled using a PI controller. The starting performance has been investigated for a scenario involving a varying solar irradiance (due to shading effects) spread over a period of 10 seconds and the transient curves for the three cases are discussed.**

***Keywords*:** Solar PV Irrigation, DC drive based agricultural water pump, MPPT, Battery control, Starting transients

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I. INTRODUCTION

The agriculture business is seen as a key income source for the rural population living in developing countries [1]. Due to the low availability of grid extensions in rural areas; many rural farmers lack electrical based irrigation facilities and depend largely on the rains. Several schemes have been introduced by the government to provide electricity at every rural house mainly by using renewable energy. Solar power is considered as an abundant form of available energy which can be harnessed usefully for generating electricity. Implementing the solar system for irrigation has been adopted in several villages. However, the irregular and varying nature of solar radiation and the consequent fluctuating power output leads to several operating challenges. One of these challenges is to operate solar PV at maximum power point (MPP) at which the solar PV generates maximum power from the available irradiance input. Basically, the solar array is operated as a current source in relation to the maximum possible power obtained.

To operate at desired MPP several publications have reported in terms of the Maximum Power Point Tracker (MPPT) which is to be implemented in the PV system. MPPT adjusts operation at the desired operating point through the help of converter switching. Some of the popular MPPT algorithms include: Perturb and observation (P&O) MPPT technique [2], Incremental conductance (INC) method, [3] Hill climbing algorithm [4]. Several other techniques such as constant voltage method, short circuit model [5], and utilizing fuzzy [6] have also been reported. Literature on the application of solar PV water pumps is available in [7] – [12]. In all these publications, the authors discuss the issues relating to operation of the solar PV water pump. In [13] the authors have implemented a brushless DC motor (BLDC) in the water pumping system which requires inverter to be interconnected leading to increase in cost and complexity due to involved advanced power electronics circuitry. Thus, the use of MPPT schemes with power electronics based controllers is the accepted mode of operation of solar PV water pumps despite some cost and complexity issues in certain types of systems.

In this paper, we investigate three schemes involving a minimum of power electronics based hardware that can be tried for solar water pumping. The study of the starting transients for these three schemes is the object of the paper. The starting transients of each of these operating modes have been simulated and analyzed in MATLAB-SIMULINK. The battery is controlled using a PI controller. The starting performance has been investigated for a scenario involving a varying solar irradiance (due to shading effects) spread over a period of 10 seconds and the transient curves for the three cases are discussed to understand the degree of transient behavior associated with each type of scheme.

II. METHODOLOGY

In rural areas in developing countries, the use of simple strategies is much preferred for solar PV water pumps. Using the minimum of power electronics based hardware; the simplest schemes will involve the solar PV panel, a MPPT controller, storage battery, battery controller and the DC motor-water pump setup. This hardware can be connected in the following ways to realize solar water – pumping:

[A] With only PV and MPPT feeding the motor-pump,
[B] With only battery (pre – charged) feeding the motor pump system and
[C] All the three – PV, MPPT and battery feeding the motor pump system

In relation to case [B], the battery is charged during the day by the solar – MPPT system and then discharged at night by operating the DC drive –pump set. The charged battery is expected to provide a better and more reasonable constant voltage to the drive, which otherwise may be difficult to obtain during the day due to solar radiance variations. Fig. 1 shows the operating modes of various cases listed above.

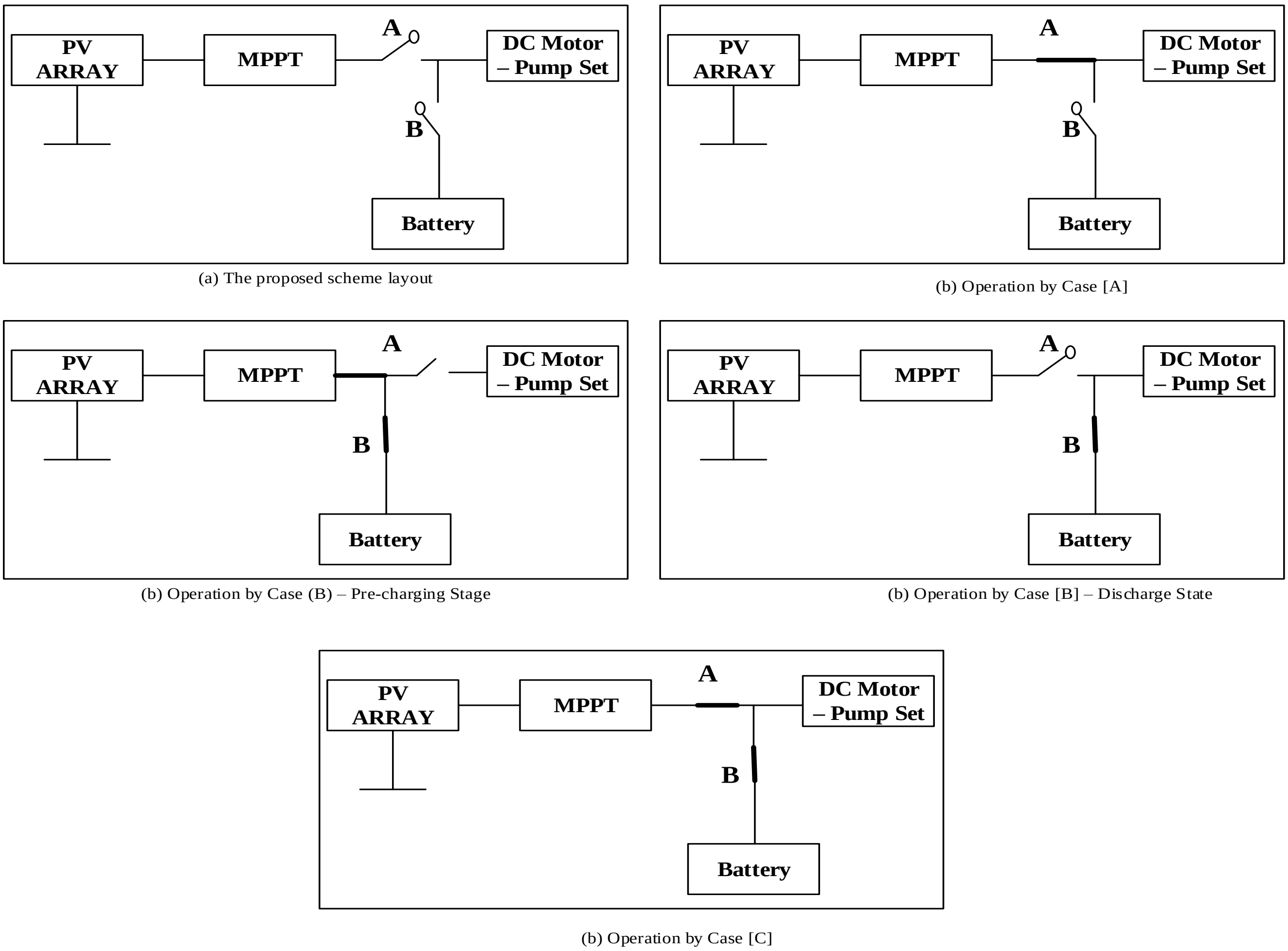

Fig 1. Various operating modes (Cases)

III. RESULT

The transient performance of the isolated PV based water pumping system is simulated for 10 seconds considering a scenario of shading that involves four discrete irradiance values at a constant temperature of 25° Celsius. The considered irradiance at different time intervals are: 1000 W/m^2 for 0 to 3 seconds, 900 W/m^2 for 3 to 5 seconds, 600 W/m^2 for 5 to 8 seconds and 850 W/m^2 till 10 seconds. The simulation was carried out using MATLAB-SIMULINK. Figures 3-6 show the obtained transient performance curves for the three operational cases proposed.

It can be observed that with the implementation of battery in the system, voltage can be maintained almost constant whereas in the case when PV and MPPT alone [Case A] is in operation leads to large voltage variation due to irradiance changes. In the battery alone mode of operation [Case B], voltage is constant. However, it is less than the rated value considering the current limit of battery and hence the limited power is supplied to the motor. In regard to the output power to the motor, larger power turbulence can be seen in the case of PV system operating with MPPT, whereas in the case of battery operating alone power output is reduced. This variation is due to the

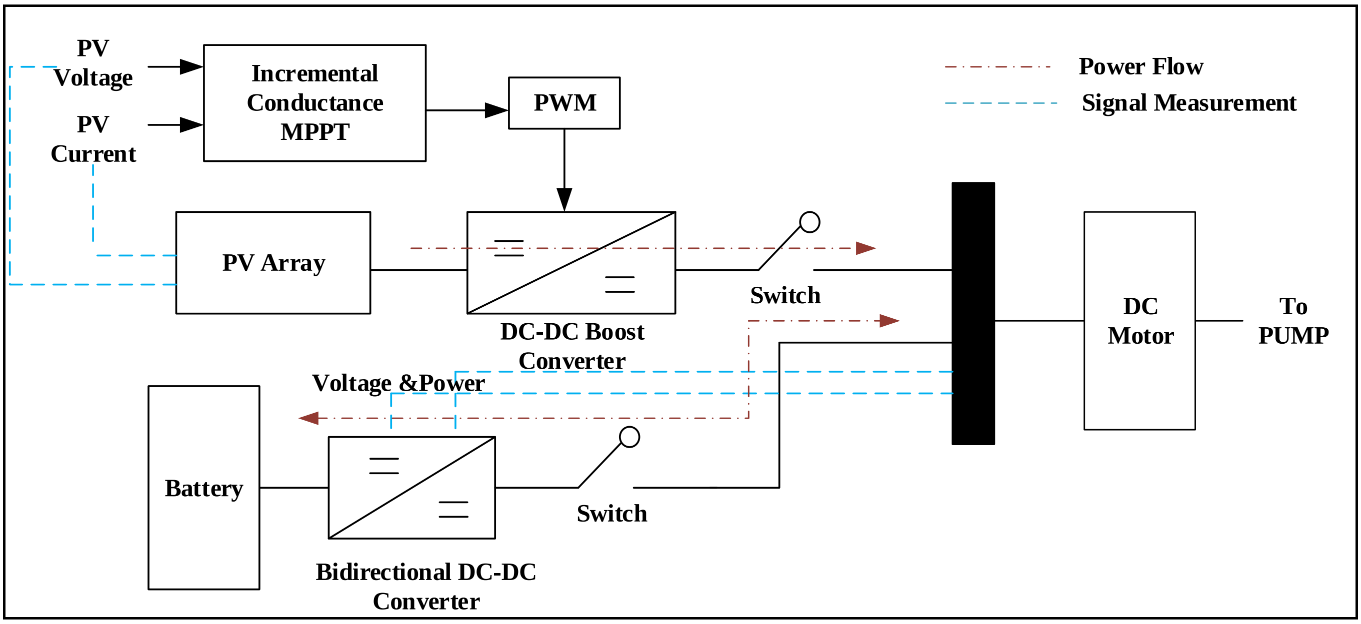

Fig 2. The simulated system

variation in bus voltage at the input side of motor. However, when PV, MPPT and battery together are in operation, [Case C] rated power is supplied. When the irradiance decreases, the deficit power is supplied by the battery to maintain the bus voltage at the input terminals of the motor. The battery operation is analyzed considering the two conditions: (a) When battery operates alone and (b) when PV and MPPT operate along with the battery. Initially SOC of the battery is assumed at 80 % for both the conditions. When the battery is operating alone, its SOC reaches to 79.75 %. However, when operated with PV and MPPT, battery discharge rate is lower leading to improved SOC.

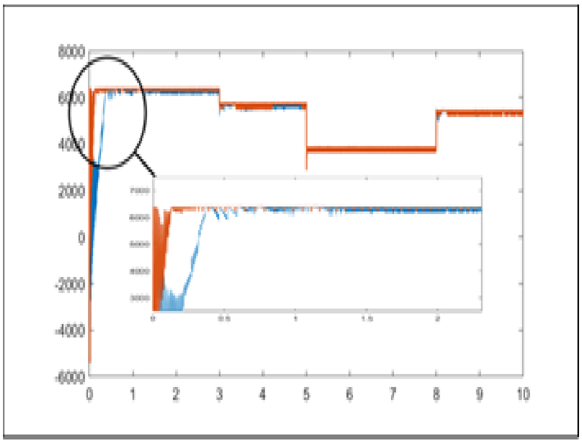

Fig 3. Variation of Solar Radiation for the transient performance evaluation

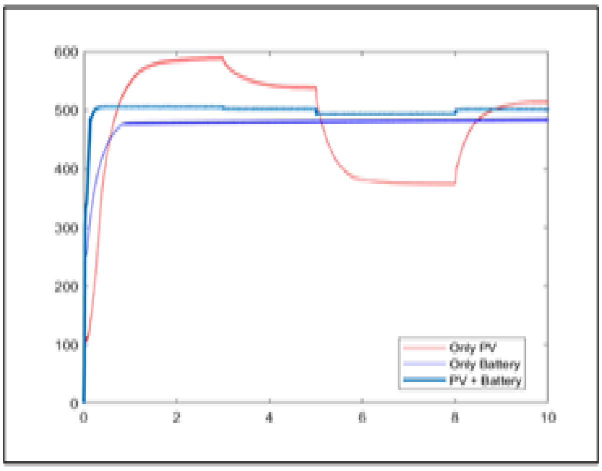

Fig 4. Voltage variation at terminals of Motor-pump

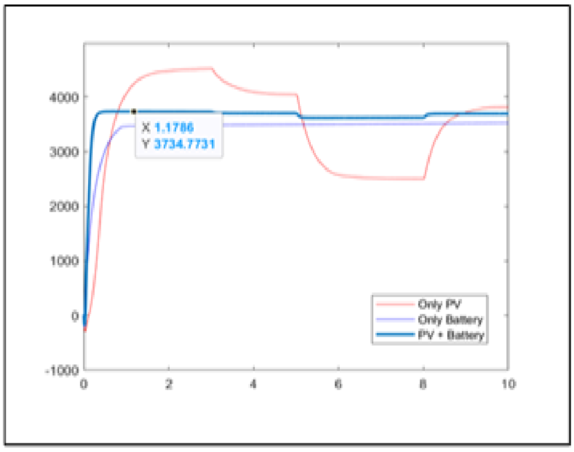

Fig 5. Power variation at output of Motor-pump

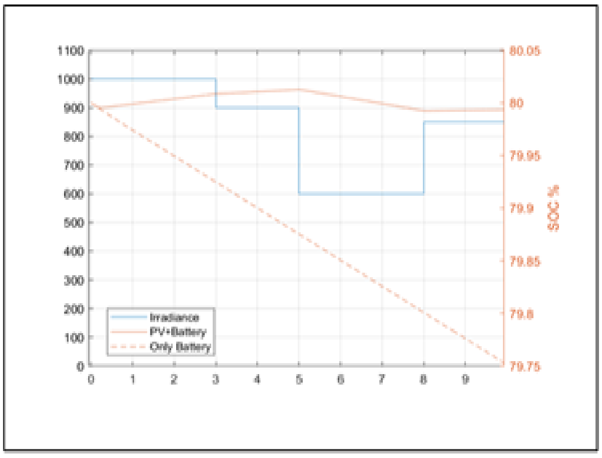

Fig 6. SOC variations in battery

IV. Conclusion

The main focus of the paper is on improvement on the transients of the motor with the present of MPPT and battery. The transient behavior of a solar PV – DC motor driven agricultural water pump is analyzed. The system includes MPPT and battery storage. Three operating modes were investigated and the transient behavior for each case was analyzed. It is seen that the overall best transient behaviors are observed when battery backup is included in the scheme.

At this point cost consideration has not been taken into account. The paper focuses on the performance with or without battery. The implementation of battery is totally depending upon the choice of operator in relation to the kind of performance that is shown in this paper.

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VI. Author's Profile

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