A Project Report

On

Development and validation of a real time flow control integrated MPPT charger for solar PV applications of vanadium redox flow battery

GROUP NUMBER: 3

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ABSTRACT

In this study, a real-time flow control integrated solar PV Maximum Power Point Tracking (MPPT) charge controller for Vanadium Redox Flow battery (VRFB) is developed and shown under practical dynamic insolation profiles.

Unlike traditional lead acid and lithium-ion batteries, the key to developing a solar MPPT charger for a VRFB is to adjust the charging current and flow rate at the same time in order to maintain the VRFB's overall system efficiency while also attaining maximum charging efficiency. In this study, the standard Perturb & Observe (P&O) algorithm for building MPPT chargers for conventional batteries has been extensively updated in the case of VRFB charge controller by integrating real-time flow rate control in addition to charging current.

A practical 1 kW 6 h VRFB system operation validated the proposed charging algorithm. The three stage constant current constant voltage (CC-CV) charging architecture based on modified MPPT is determined to be the most efficient for VRFB charging from solar PV. MPPT for solar energyCharging of VRFB with a constant flow rate causes the charge controller to prematurely shut down, resulting in incomplete charging of the VRFB, which is avoided by using dynamic flow control integrated solar PV MPPT charging. For the validation of the integrated MPPT charge controller, two practical case studies of sunny and overcast weather situations were used.

CONTENTS

1. INTRODUCTION

Battery energy storage systems (BESS) are gaining popularity in renewable energy applications such as solar PV and wind.

Vanadium Redox Flow is ideal for large-scale renewable energy systems.

Battery (VRFB) is being considered as one of the most promising BESS due to its numerous advantages, including independent scalability of its power and energy capacity, deep discharge capacity, lack of crosscontamination, and, most importantly, a very long life cycle that closely matches that of a solar PV power plant. Efforts to improve the efficiency of VRFB technology have led to numerous paths of research, including stack design, electrode, membrane, and electrolyte material improvements. Over the recent years there have been breakthroughs that improved the VRFB overall system efficiency. In this model a hybrid micro-grid system was used to demonstrate it's performance. The dynamic internal parameters of the VRFB were retrieved, and the flow rate was optimised while taking stack loss and pump loss into account.

Concurrently in the article, the need of dynamic impedance matching between a solar PV source and a VRFB while constructing an efficient battery management system (BMS) was discussed. Nguyen investigated the performance of VRFB in photovoltaic microgrids. Qiu presented a field proven VRFB model for microgrid applications. Turkar and co.presented a VRFB model suitable for large-scale applications. Hosseina explored an effective distribution network scheduling with redox flow battery storage to meet peak shaving, load levelling, and other requirements. Turkar described the use of VRFB in an electricity market to reduce wind power fluctuation fines. Given these practical uses, BMS for VRFB is critical for efficient interface with renewable energy sources. Given the intermittent nature and low efficiency of solar PV sources, the maximum power point tracking

(MPPT) technique must be used to optimise power conversion when charging solar PV battery source. discussed the design and performance of a solar MPPT-based battery charge controller. electricity converters play an important part in the effective conversion of solar PV electricity to batteries and loads/grids. Fathabadi demonstrated the performance of a high efficiency DC-DC boost converter-based solar PV battery charge controller. López discussed the operation and control of a dc-dc buck converter for a stand-alone solar battery charge controller. With a focus on solar PV charge controllers, it is worth noting that the voltage excursion/cell in VRFB is around 38% lower than that of a similar capacity lead acid battery.

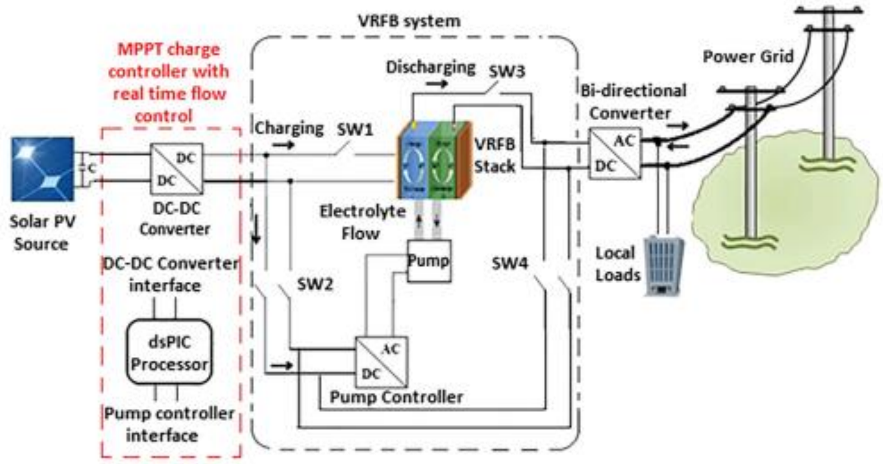
This is approximately 20%. As a result, the role of MPPT in VRFB charging is more crucial than that of lead acid or other battery storage systems. Because VRFB batteries have a broader cell voltage range (1-1.6 V/cell) than lead acid batteries (1.95-2.4 V/cell), it is more appealing to use MPPT while charging VRFB from a solar PV source. The voltage range for a 48 V lead acid battery is 46.8-54.4 V, which is equivalent to a 34 cell VRFB stack. A real-time flow control-based solar PV MPPT charge controller for VRFB systems is developed in this study, and its performance is proved using dynamic solar irradiance profiles.

The power conditioning unit is a DC-DC buck converter developed for integrating the VRFB with a solar PV source. Three distinct charging methods are built and compared on the developed charging system using the dsPIC (dsPIC33FJ32MC204) controller platform. In addition to the MPPT-based CC-CV charging architecture for maximising charging efficiency, the charging algorithm incorporates real-time flow rate management to ensure maximum VRFB overall system efficiency and regulated temperature rise inside the VRFB stack. The redesigned charging topology also eliminates the likelihood of the charge controller shutting down prematurely owing to temperature rises above 40 °C, ensuring complete VRFB charging. A 1 kW 6 h VRFB system validates the charge control algorithm's performance. The suggested controller is generic, making it ideal for large-scale VRFB systems in solar PV applications.

2. METHODOLOGY

2.1Schematic diagram

Block Diagram Of MPPT charger



Schematic of Controller sub system:

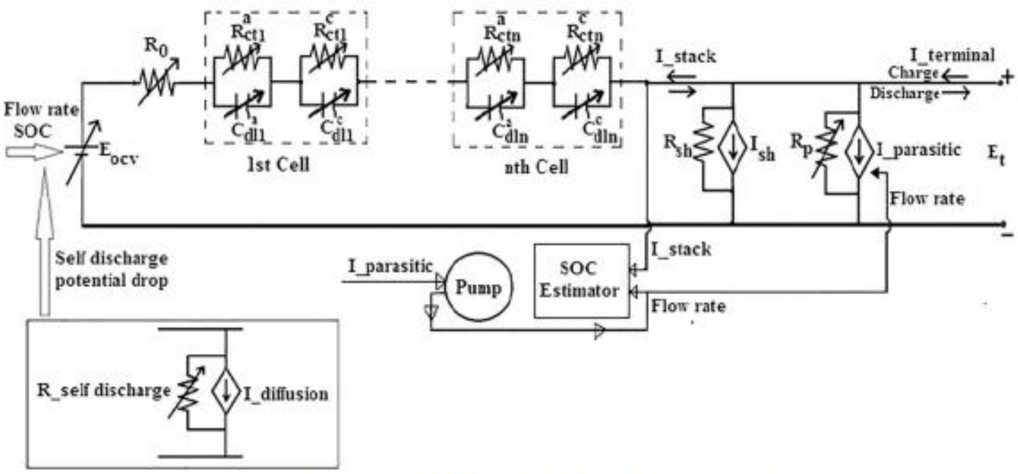


Fig. 2a. Schematic of VRFB system electrical equivalent circuit [20].

2.2. Description

The development of an efficient VRFB charge controller necessitates precise estimate of its stack terminal voltage under dynamic charging and discharging current with real-time flow rate regulation.

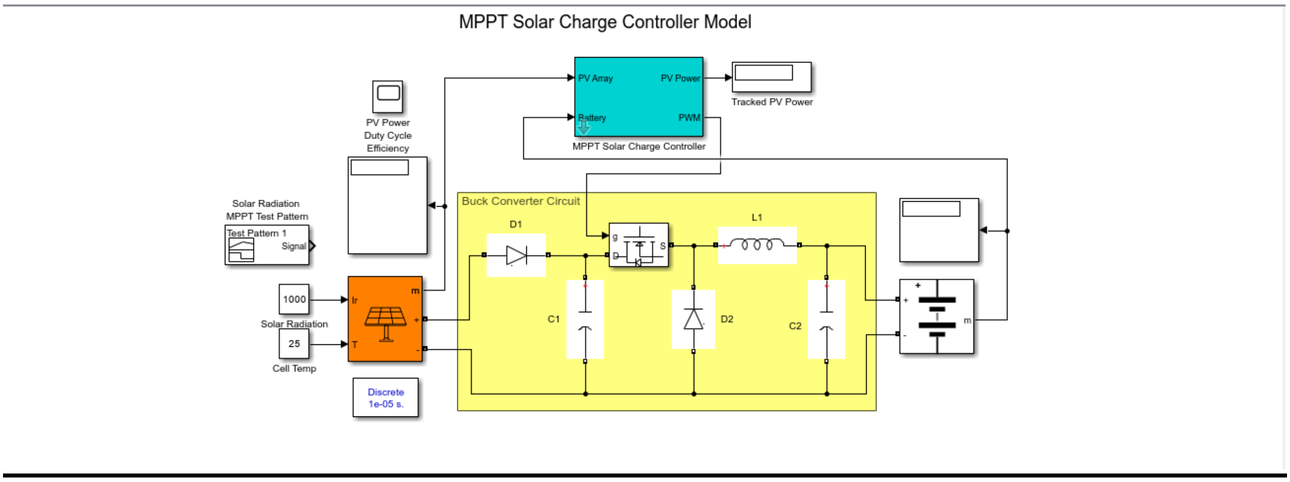
Another important aspect of this electrical equivalent circuit model of VRFB is the impedance matching between the solar PV source, VRFB, and the grid/load for transmitting maximum power in the charge controller application network as depicted

This model is used to calculate the precise stack terminal voltage of a VRFB during charging and discharging operations while taking into account realistic aspects such as flow rate, SOC, and self discharge drop, among others. The effect of shunt current (Ish) owing to the guide and

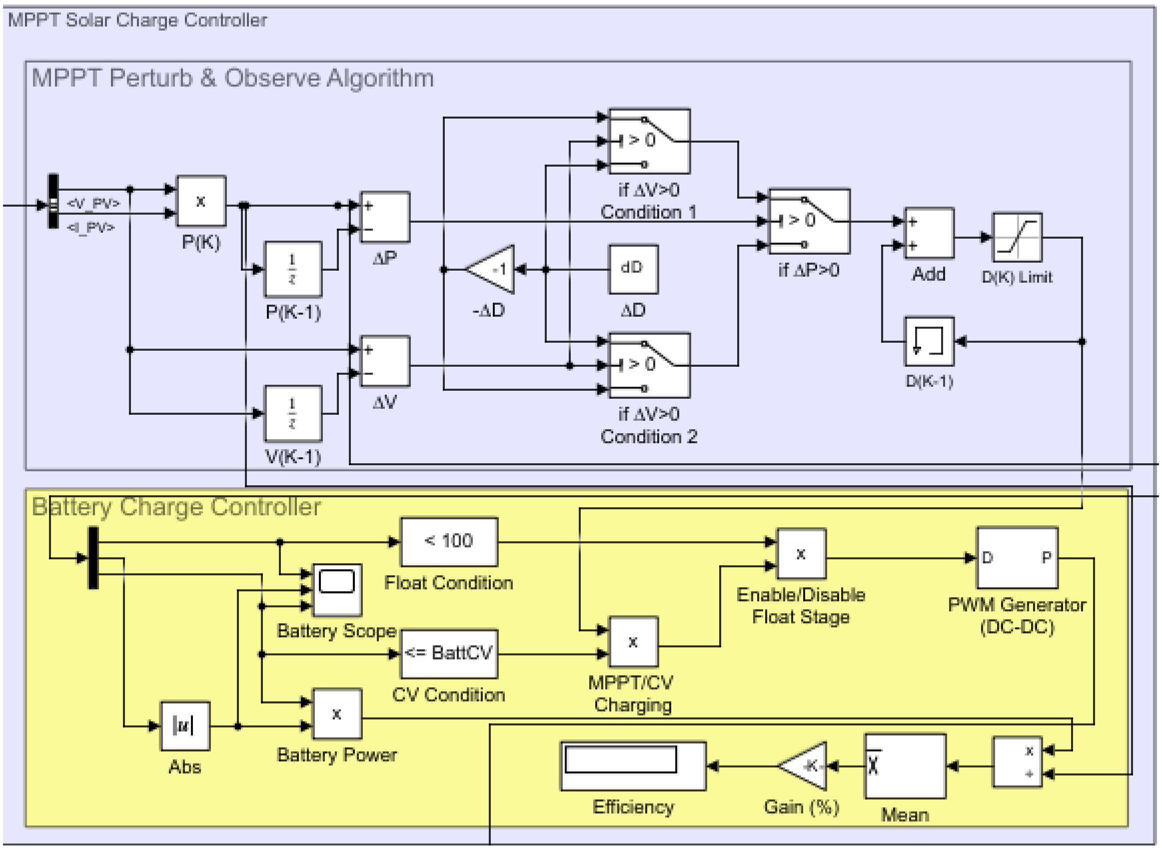
As revealed by Zhang et al., manifold channels in the VRFB stack are ignored due to their negligibly tiny magnitude within 1% of the terminal current.

3. SIMULATION

Model of MPPT charger:



MPPT charge control subsystem:



4. RESULTS

Plots of Electrical power consumption and Optimal flow rate:

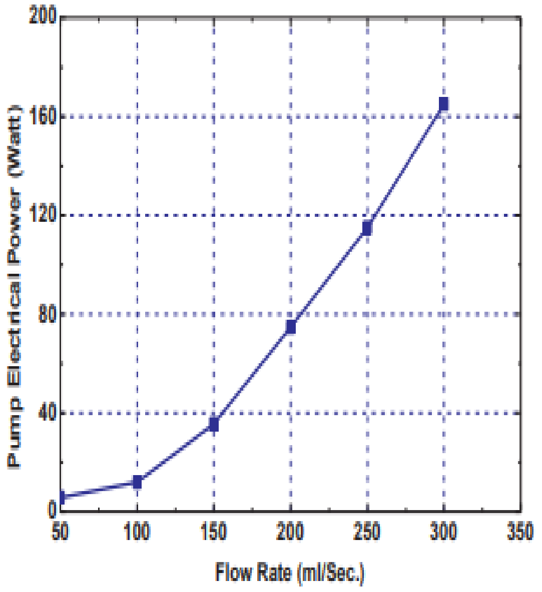


Fig. 6. Pump electrical power consumption under different flow rates [18].

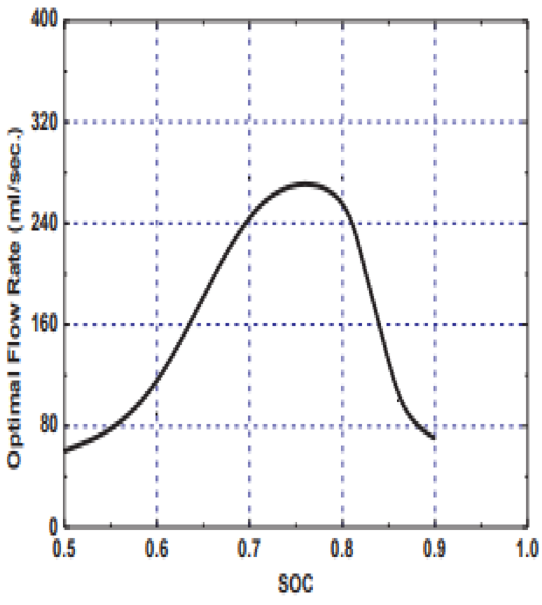
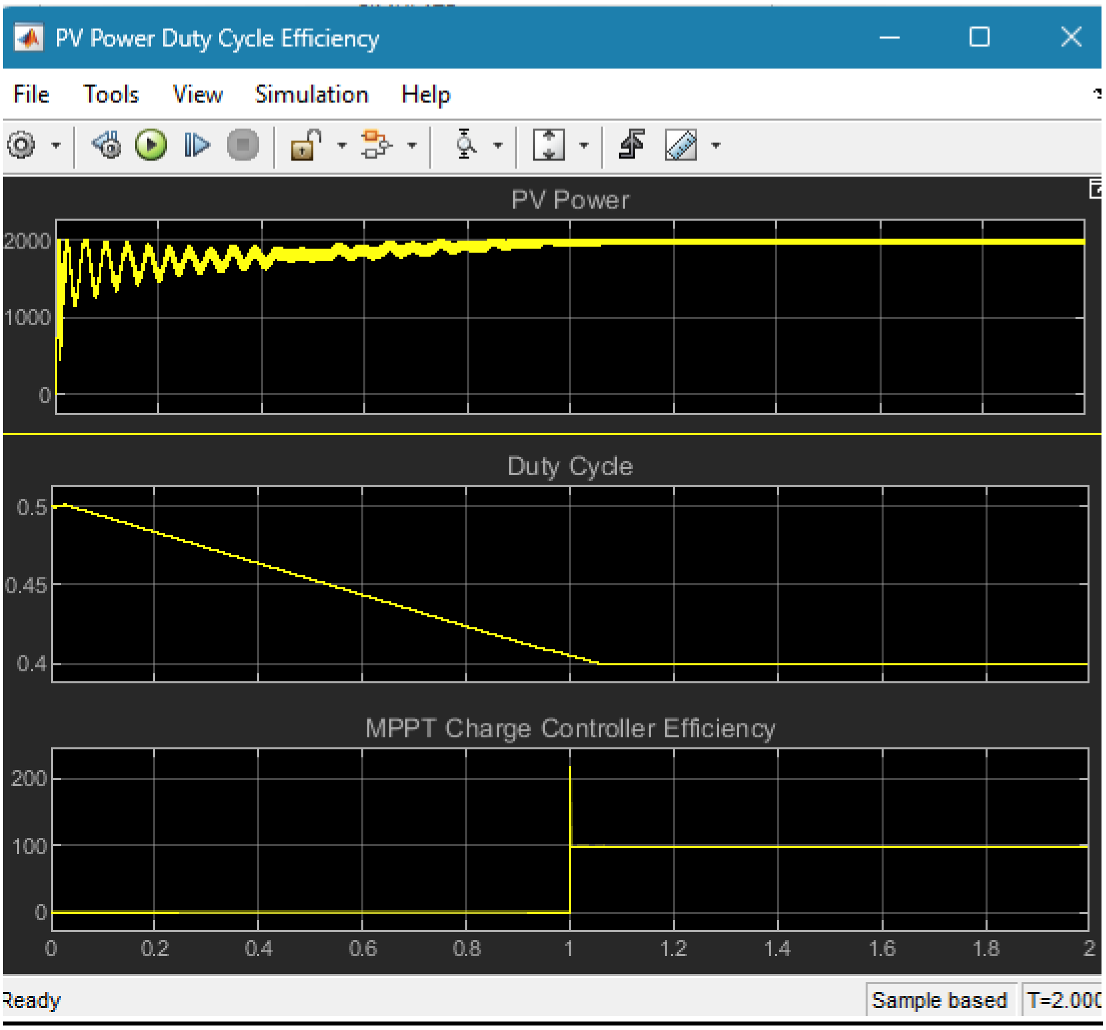


Fig. 7. Dynamic optimal flow rate for the three stage CC-CV solar MPPT charging for 1 kW 6 h VRFB.

Graphs of PV power, duty cycle and efficiency



<u>Duty cycle</u>: Duty cycle is the ratio of time a load or circuit is ON compared to the time the load or the circuit is off .

5. CONCLUSION

For the first time, this study proposes a real time flow control integrated solar PV MPPT based charge controller for Vanadium Redox Flow Battery (VRFB), and its performance is proved under dynamic insolation profiles that are practical. The standard algorithm for building MPPT chargers for conventional batteries such as lead acid, lithium-ion, and others has been extensively enhanced by integrating real-time flow rate management for maximising VRFB total system efficiency in addition to charging efficiency. A practical 1 kW 6 h VRFB system was used to validate the suggested charging method. Three distinct solar PV charging topologies were constructed and their performances were compared for the VRFB system. It is observed that the modified MPPT based three stage CCC charging topology becomes the most efficient for VRFB charging from solar PV source. The charging efficiency is improved from 83% (Conventional three stage CC-CV charging) to 94.5% (Modified three stage CC-CV charging with MPPT in bulk charging phase) by applying suitable MPPT algorithm in the bulk charging stage of VRFB.

6. REFERENCES

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3) Current and future prospective for battery controllers of solar PV integrated battery energy storage systems by Mustafa Hasan and H.Serra Altinoluk