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Modeling and Analysis of Sliding Mode MPPT Controller for Solar Photovoltaic System

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ABSTRACT: Analog circuitry based photovoltaic (PV) maximum power point (MPP) tracking (MPPT) method is alluring because of its minimal effort and ability of simple incorporation with ordinary dc-dc switching converters. Be that as it may, acknowledgment of traditional computerized MPPT calculations utilizing simple hardware is a testing errand. It fundamentally requires to store the data of module voltage/current and power with a specific end goal to locate the coveted MPP. While in the meantime, despicable outline of advanced MPPT controllers may cause poor following exhibitions or farthest point cycle motions to show, which are for the most part observed as being bothersome. This paper proposes a quick and strong simple PV MPP tracker without forcing any outside control or bother. The quick powerful exhibitions with supreme heartiness are guaranteed here by incorporating the ideas of Utkin's proportional sliding-mode control (SMC) law and quick scale dependability examination of real exchanged converter frameworks. Additionally, the prevalence of the proposed MPP tracker (as far as high following exhibitions) over established ones, and its effect in arrangement associated converters setup are scientifically shown through the methodology created in this paper. At long last, the systematic outcomes have been approved by methods for reenactments and trials.

KEYWORDS: Photovoltaic systems, maximum power point tracking (MPPT), analog controller, sliding mode control (SMC), and stability analysis.

I. INTRODUCTION

Solar energy is gaining popularity in the field of electricity generation. The solar power by means of photovoltaic (PV) it consists of an arrangement of several components, including solar panels to absorb and convert sun light into electricity a solar inverts to change the electric current from DC/AC. Photovoltaic (PV) system is noiseless, no air pollution, no fuel costs and low maintenance.

A fast and robust method for maximum power point tracking is called as Sliding Mode Controller. In normal dc-dc switching converters the sliding mode controller is low cost and capable of easy integration [2]. The Cuk converters capable of operating in step-up or step-down and the dc-dc converters, localized control of module current and voltage can be achieved, and each module can operate at its independent MPP to improve the energy extraction of the overall system [3]. However, designing a fast and robust PV maximum power point tracking (MPPT) controller with high tracking efficiency. In most of cases, investigations are primarily based on standard Incremental Conductance algorithms, constant-frequency (CF) pulse-width modulated (PWM) operation, and small-signal averaging technique or transfer function based stability analysis. However, averaging is only an approximated procedure to obtain the low frequency behavior of the actual switching model of the dc-dc converter.

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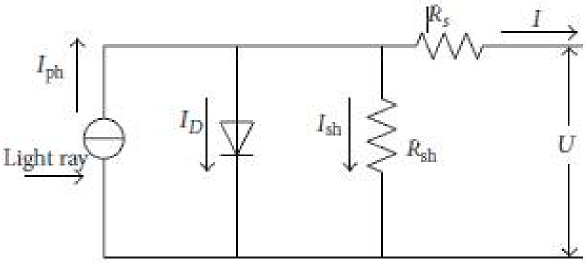
The average model was failed to predict many fast-scale instabilities (e.g., sub harmonic oscillations and chaotic behavior) that may develop in the current and voltage waveform at clock frequency causes high conduction loss and excessive switching stress [4]. In this proposes a fast and robust analog- MPP tracker also called as analog sliding-mode controller (SMC) which is implemented and designed by using the concepts of Utkin's equivalent control theory and fast-scale stability analysis.



Fig,1 PV Cell Equivalent Circuit

The main objectives of applying such concepts are to provide the control support for the MPPT system which are required for 1) guaranteed stability with high robustness against the parameters uncertainties, and 2) fast dynamic responses under rapidly varying environmental conditions. This cannot be met by conventional digital or analog MPPT controllers without continuously tuning the controller parameters and complex controller architecture [5][6]. The proposed analog MPPT technique and its switching dynamics is discussed. Based on this discussion, a modular PV system (MPVS) is analyzed by using the concepts of Utkin's equivalent control law and fast-scale stability analysis in Section III. In particular, this section explores how the method of analysis and design of MPVS can play the strategic role for characterizing the fast and robust dynamic performances. Finally, the performances are experimentally verified and compared numerically with the classical Incremental Conductance algorithm.

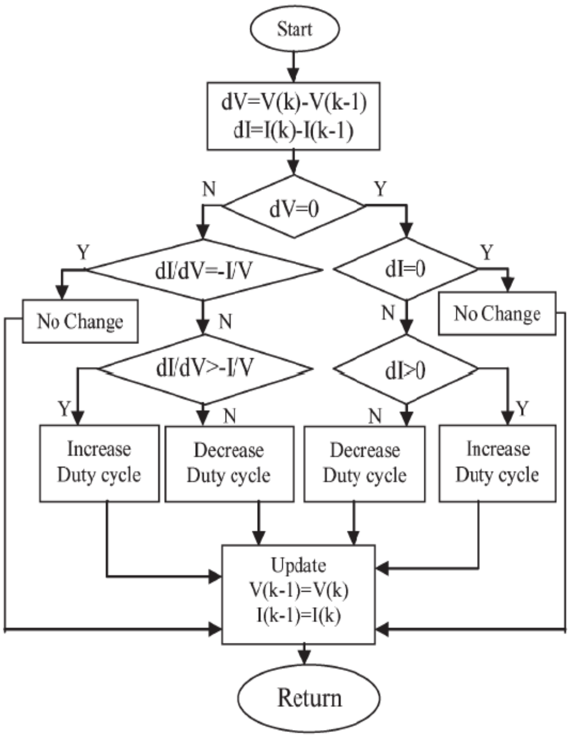


Fig.2. Flow chart for Incremental conductance Algorithm Using MPPT

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II. GENERAL DESIGN OF PV

To model the PV Panel, There are several Models for modeling PV panel. The equivalent circuit (Figure3.1) consists of current Source to model the incident luminous flux, a diode for cell polarization Phenomena, a parallel resistance due to leakage current and a series resistance representing various contacts [6].The general mathematical PV cell equation is given by the following Equation [7]:

$$I=I_{ph}N_p-I_d-I_{sh} \qquad (1)$$

Where, is a photo current, is a diode current and a shunt current .The module photo-current evaluated as:

$$I_{ph}=G_k\,[I_{sc}+K_1(T_{op}-T_{ref})] \qquad (2)$$

III. MPPT TECHNIQUES

Many MPPT algorithms have been introduced to improve the efficiency of the PV system. The most commonly used MPPT are given as follows. Including fractional open circuit voltage, fractional short circuit current, fuzzy logic, neural network, hil climbing (or) P&O and Incremental conductance are most popular algorithm. There are several types Of MPPT Techniques, some of them are listed below:

- Perturbation observation (P&O) MPPT techniques.
- Incremental conductance of MPPT techniques.
- Sliding mode control of MPPT techniques.
- Particle swarm optimization techniques etc.

IV. SLIDING MODE CONTROLLER WITH MPPT

A Sliding mode controller is useful for any kind of DC/DC converter. This overcomes the varying switching frequency which depends on the working point steady state error. The steady state error can affect the controlled variable and the selection of control parameters. There are difficult due to the complexity of the sliding mode control. The advantage of sliding mode controller is given as follows:

- Switching frequency is kept constant in the steady state.
- Steady state error is eliminated.
- Control tuning is easy.
- Circuitry is simple.
- Switch current limitation can easily to be implemented.

The proposed controller has several DC/DC converter topologies. They are buck, boost, buck-boost, cuk, and SEPIC. The advantages of sliding mode controller are stability even for large supply and load variations, robustness, good dynamic response, and simple implementation. The large number of algorithms is able to track Maximum power point. Some of them are simple, it based on voltage and current feedback, and some other are more complicated, such as perturbation and observation (P&O) or the incremental conductance (Inc Cond) method.

V. EXISTING APPROACHES – A SUMMARY

When proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. The efficiency of switch-mode dc–dc converters is widely discussed in [15]. Most switching-mode power supplies are well designed to function with high efficiency. Among all the topologies available, both Cuk and buck–boost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. Although the buck–boost configuration is cheaper than the Cuk one, some disadvantages, such as discontinuous input current, high peak currents in power components, and poor transient response, make it less efficient.

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The Cuk Converter has low switching losses and the highest efficiency among non-isolated dc–dc converters. It can also provide a better output-current characteristic due to the inductor on the output stage. Thus, the Cuk configuration is a proper converter to be employed in designing the MPPT. The power circuit of the existing system consists of a Cuk converter and a gate drive, and the control of the switching is done using the control circuit. The control tasks involve measuring the analog voltage and current of the PV module. The PV panel specifications used for simulations are presented in Table 1.

TABLE.1 PV PANEL SPECIFICATIONS

PARAMETERS	VALUES
Input Maximum power (Pmax)	153.8822 W
Maximum Voltage (Vmax)	17.2 V
Open-circuit voltage (Voc)	21.95 V
Short-circuit current (Isc)	5.45 A
Voltage optimum MPP(Vmpp)	11.92 V
Optimum operating current (Impp)	6.935A
Output Maximum power(Pmax)	82.69 W

VI. PROPOSED SYSTEM SUMMARY

The basic principle of SM control is to employ a certain sliding surface as a reference path such that the controlled state variables' trajectory can be directed toward the desired equilibrium. Theoretically, such ideology of the SM control can be fully achieved only with the absolute compliances of certain conditions, namely, the hitting condition, the existence condition, the stability condition, and the condition that the system operates at an infinite switching frequency. In such respect, what is derived is an idealized controlled system, whereby no external disturbances or system's uncertainties can affect the ideal control performance of having zero regulation error and very fast dynamic response.

TABLE.2 SLIDING MODE CONTROLLER PARAMETERS

PARAMETERS	VALUES
Input Maximum power (Pmax)	153.8822 W
Maximum Voltage (Vmax)	17.2 V
Open-circuit voltage (Voc)	22.2 V
Short-circuit current (Isc)	5.45 A
Voltage optimum MPP(Vmpp)	47.8V
Optimum operating current (Impp)	2.3A
Output Maximum power(Pmax)	109.7 W

VII. LITERATURE SURVEY

"Modeling and Analysis of a Fast and Robust Module-Integrated Analog Photovoltaic MPP Tracker"2015.Analog circuitry based photovoltaic (PV) maximum power point (MPP) tracking (MPPT) technique is attractive due to its low cost and capability of easy integration with normal dc-dc switching converters. However, realization of classical digital MPPT algorithms using analog circuitries is a challenging task. It necessarily requires to store the information of module voltage/current and power in order to find the desired MPP. While at the same time, improper design of digital MPPT controllers may cause poor tracking performances or limit cycle oscillations to manifest, which are generally seen as being undesirable.

This paper proposes a fast and robust analog PV MPP tracker without imposing any external control or perturbation. The fast dynamic performances with absolute robustness are ensured here by integrating the concepts of

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Utkin's equivalent sliding-mode control (SMC) law and fast-scale stability analysis of actual switched converter systems. Moreover, the superiority of the proposed MPP tracker (in terms of high tracking performances) over classical ones, and its impact in series-connected converters configuration are analytically demonstrated through the procedure developed in this paper. Finally, the analytical results have been validated by means of simulations and experiments.

"Simulation and Hardware Implementation of Incremental Conductance MPPT with Direct Control Method Using CUK Converter" 2011. This paper presents simulation and hardware implementation of incremental conductance (IncCond) maximum power point tracking (MPPT) used in solar array power systems with direct control method. The main difference of the proposed system to existing MPPT systems includes elimination of the proportional–integral control loop and investigation of the effect of simplifying the control circuit. Contributions are made in several aspects of the whole system, including converter design, system simulation, controller programming, and experimental setup.

The resultant system is capable of tracking MPPs accurately and rapidly without steady-state oscillation, and also, its dynamic performance is satisfactory. The IncCond algorithm is used to track MPPs because it performs precise control under rapidly changing atmospheric conditions. MATLAB and Simulink were employed for simulation results. The system indicates the feasibility and improved functionality of the system.

"Improved design of sliding mode controllers based on the requirements of MPPT techniques‖ 2015.In many grid-connected applications a dc/dc switching converter is usually connected between the PV modules and the inverter. This paper presents an improved procedure to design a sliding controller for the PV system, which drives the PV voltage to follow a reference provided by an external MPPT algorithm and mitigates the perturbations caused by the irradiance changes and oscillations in the bulk-voltage. By considering that the switching surface is the linear combination of the input capacitor current and the PV voltage error, the proposed design exhibits advantages in comparison with existing solutions that rely in the linearization of inner current loop dynamics.

The proposed integral procedure, by taking also into account the effects in the closed loop system dynamics of a reference filter, ensures a stable sliding regime in all the desired operation range of the system, while the settling time and overshoot of the PV voltage required by an MPPT algorithm are provided. Differently from a previous similar but less rigorous approach, the switching function and reference filter parameters are obtained by numerically solving a set of nonlinear equations. Simulations and experiments were used to demonstrate the efficiency of the proposed solution in presence of environmental and load perturbations.

VIII. EXPERIMENTAL RESULTS

The following figure illustrates the simulation view of the proposed system.

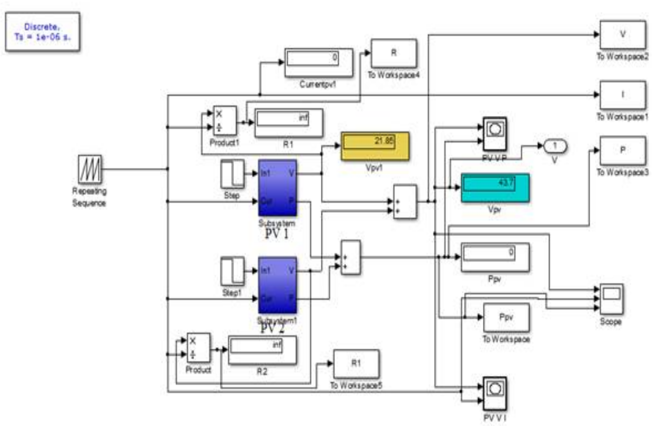

Fig.3 Simulation View for Two PV-Module

The following figure shows the series architecture with a string of two PV Module.

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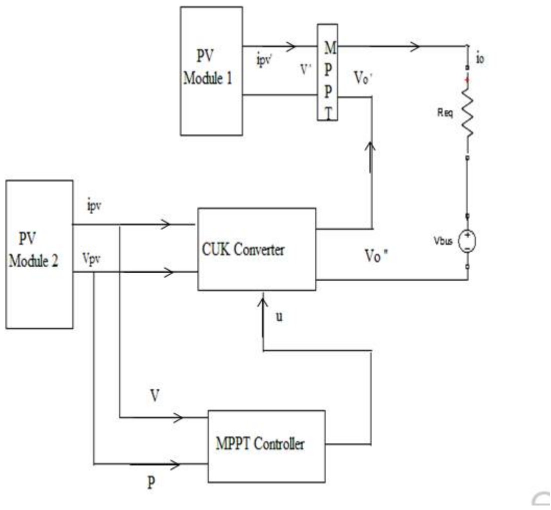

Fig.4 Series Architecture with a string of two PV Module

The following figure shows the Flow chart for sliding mode controller.

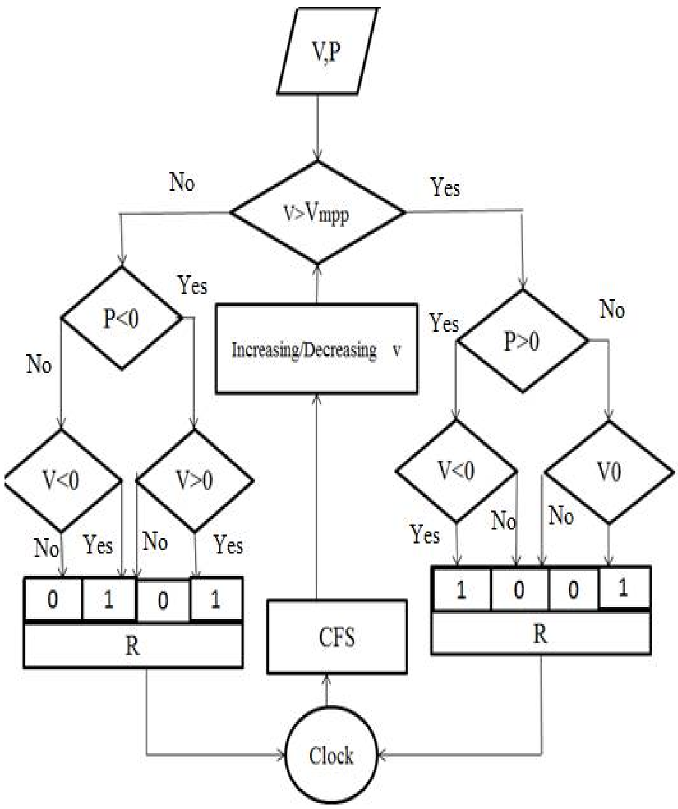

Fig.5 Flow chart for sliding mode controller

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The following figure shows the PV Output Power of the Proposed System.

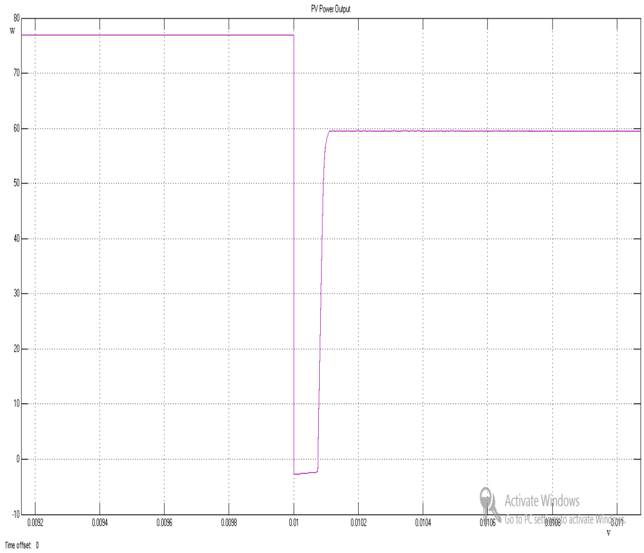

Fig.6 PV Output Power

The following figure shows the PV Voltage Ripples of the Proposed System.

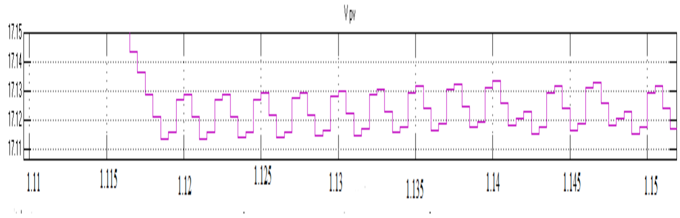

Fig.7 PV Voltage Ripples

The following figure shows the MPPT Controller Output of the Proposed System.

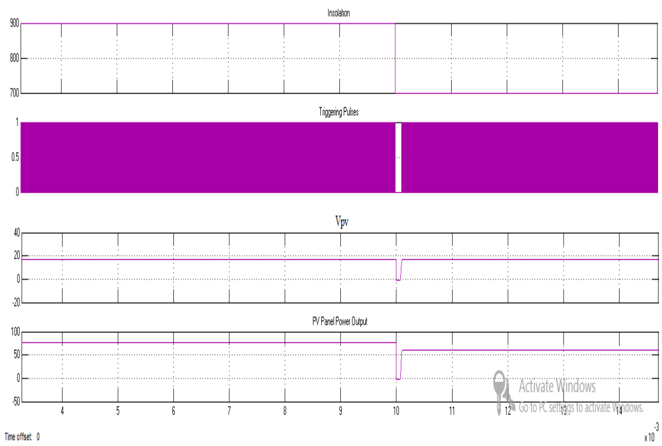

Fig.8 MPPT Controller Output

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The following figure shows the PV Output Power of the Existing System

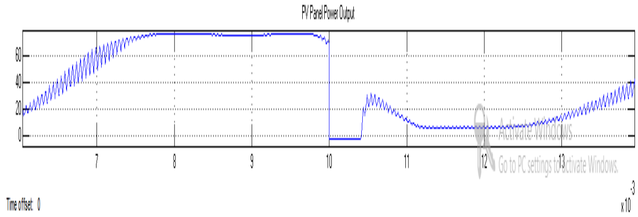

Fig.9 PV Output Power of the Existing system

The following figure shows the PV Voltage Ripples of the Existing System

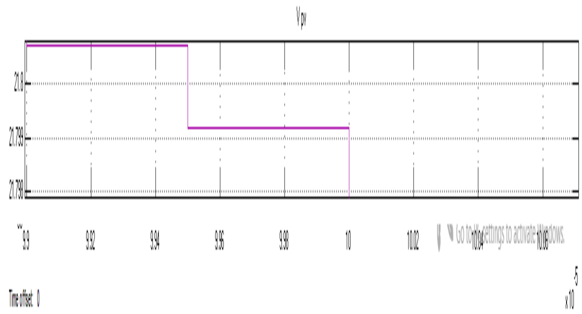

Fig.10 PV Voltage Ripples of the Existing system

The following figure shows the MPPT Controller Output of the Exposed System.

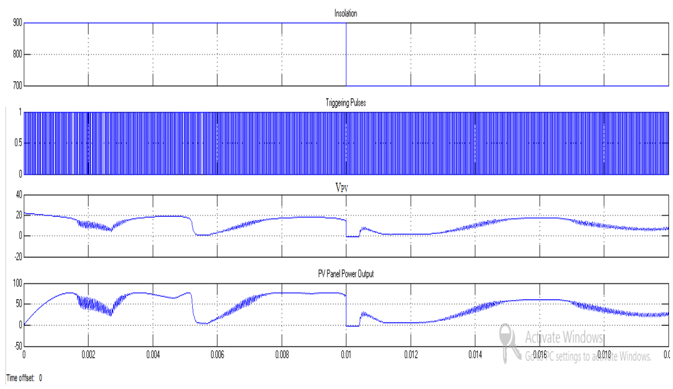

Fig.11 MPPT Controller Output of the Existing System

IX. CONCLUSION

A fast and robust sliding mode controller (SMC) for higher order converter is proposed for solar PV system. .The fast dynamic performances with absolute robustness are ensured here by integrating the concepts of SMC law and fast-scale stability analysis of actual switched converter. The analytical results have been verified using MATLAB simulation. The performance characteristics of Cuk converter using sliding mode controller compared with incremental conductance algorithm have improved efficiency of solar PV system. The bilateral module of CUK converter is compared with Incremental conductance. The simulation results shows sudden irradiance fluctuations and the tracking performance of MPP tracker employing SMC.SMC is faster but also exhibits less steady state oscillation with less ripples.

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