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# Optimising PV System Utilisation with Energy Storage Systems: Control Strategy

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**Abstract:** The use of autonomous solar photovoltaic (SPV) systems has emerged as a viable method for addressing the challenge of providing electricity in locations where traditional power grids are absent. The primary obstacles encountered in the process of creating such systems are outlined below: 1) The optimisation of power extraction from photovoltaic systems in response to rapidly fluctuating irradiance levels. 2) The achievement of a substantial increase in voltage gain through the implementation of a DC-DC converter. 3) The design and implementation of an effective power management strategy for seamless integration between solar photovoltaic systems and energy storage systems. Due to the need to fulfil several objectives, current autonomous system designs need a minimum of three conversion processes, resulting in a notable decrease in system dependability and efficiency. Various control techniques are employed to tackle the concerns. A modified non-iterative Incremental Conductance Maximum Power Point Tracking (MPPT) approach has been created in order to optimise power extraction. This method generates a finely adjusted duty cycle to accommodate rapid changes in irradiance, ensuring that the intersection point of the load line and the I-V curve consistently reflects the Maximum Power Point (MPP). A high voltage gain DC-DC converter is typically necessary for industrial applications. This may be accomplished by utilising a high duty ratio, which can lead to challenges such as reverse recovery issues and increased voltage stress on power switches. In order to address this issue, a proposed solution is the implementation of a soft switch interleaved boost converter (SSIBC). This converter operates by utilising zero current switching to activate the active switches, hence enabling it to attain a large voltage gain even at lower duty ratios. The lead acid battery is a type of energy storage technology commonly employed in solar photovoltaic (SPV) systems. To effectively control power, an algorithm is devised that utilises a variable direct current (DC) bus voltage system, using both a super capacitor (SC) and a battery (BAT) as energy storage systems (ESS). The effectiveness of the proposed control techniques is assessed and confirmed by experimentation conducted across a range of circumstances.

**Keywords:** battery protection, high voltage gain DC-DC converter, standalone solar PV system, energy storage system, power management scheme.

## Introduction

The performance and efficiency of medium and large scale Photovoltaic (PV) plant mainly depends on power conversion process through power electronic converter interfaced between PV plant and the distribution grid or load[1]. The power conversion system used in the existing Solar PV (SPV) plant involves high cost and reduced efficiency, due to more than one power conversion stage [2]. The existing single stage power conversion system has low voltage gain, common mode leakage current problem and requires a greater [3]number of PV panels to get the desired output[4]. Moreover, the output power from PV plant is intermittent which affects the reliability of supply and performance of power converters [5].

The fluctuating power leads to the harmonic injection into the grid and affects[6] real and reactive power flow resulting in the reduction of efficiency of the power conversion system[7]. To overcome the above problems and to improve the performance of PV power conversion system this research work develops [8]a multistage DRSS and SDC algorithms to enhance the performance of PV systems This research work also investigates Maximum [9]Power Point Tracking (MPPT) for PV system. MPPT controller is used to extract the maximum available power from PV plant, [10] so that efficiency of PV system can be increased. In this research work power electronic based MPPT controller is used [11]. The conventional MPPT algorithms have large oscillations due to continuous perturbation, sluggish response, and low efficiency[12].

## 1. Problem Statement and Objectives of Research Work

The solar-powered system introduces [13]a variety of issues based on climate conditions. These problem formulations are listed as follows: 1) the conductance of solar cell[14] was non-linearly fluctuating with climatic changes[15], which had produced in false Maximum Power Point. To overcome this problem modified Incremental Conductance MPPT method[16] is developed to generate a fine-tuned duty cycle[17] and regulates that always the intersection point of load line and I-V curve represents MPP under fast varying irradiance; 2) Normally a DC-DC boost converter can provide a high voltage with high duty ratio[18], but this voltage gain is limited by inductor, capacitor, and main switches in the converter[19]. Another problem with high duty ratio is reverse recovery problem which increases the switching losses; 3) there will be wide variations in DC bus voltage in standalone PV system and mismatch power between generation and demand[20]. To overcome this problem hybrid ESS (super capacitor + battery) is connected in parallel [21]with PV system and a highly efficient

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variable DC[22] bus voltage-based power management algorithm is proposed between PV, SC, BAT and utility grid[23].

## 2. Proposed Control Strategies

### 2.1 Modified Incremental Conductance MPPT under fast varying irradiance:

To extract the maximum power from solar PV systems [24]MPPT technique is used. Several MPPT methods are there to track[25] maximum power with high efficiency under constant irradiance such as P&O [25], INC [26], PSO [27], ANN [28] , Open circuit voltage, short circuit current etc. Among above methods P&O, INC methods are most popular[29].

Figure 1 show the conventional INC method algorithm, which operates with high efficiency under steady irradiance.

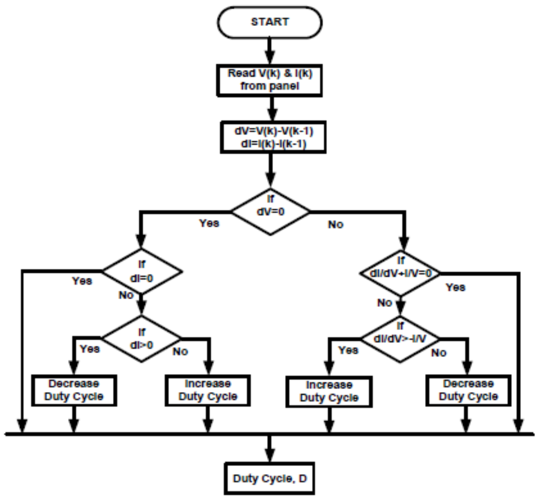


**Figure 1.** Conventional INC MPPT Algorithm.

For varying irradiance[30], the response of fixed step size is slow. So, variable step size is proposed which decreases the step size and convergence of MPP is slow when it reaches to near the peak [31]of P-V curve. A modified INC algorithm is proposed to increase the converging speed with fast varying irradiance [32].

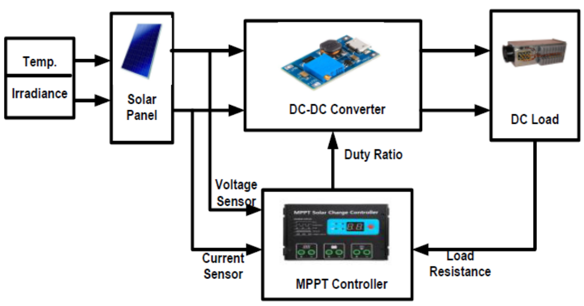

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**Figure 2.** Block diagram of proposed DC/DC converter with modified INC Algorithm.

The fast-acting MPPT method used the relation between load line and MPP locus. Figure 3 shows the I-V curves at different irradiance with MPP line which is approximately a straight line. When PV system is fed to load; load line is imposed on the I-V curve as shown in figure 3. The intersection point of the load line and I-V curve represents the MPP.

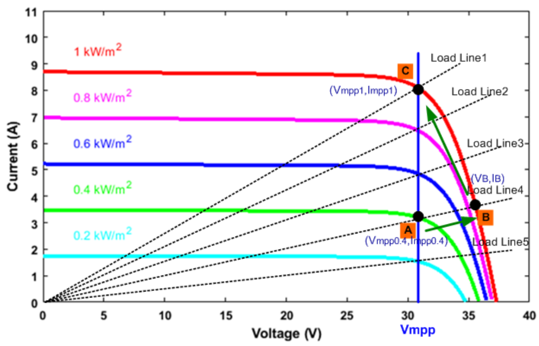


**Figure 3.** I-V curves at different irradiances with load line and MPP line.

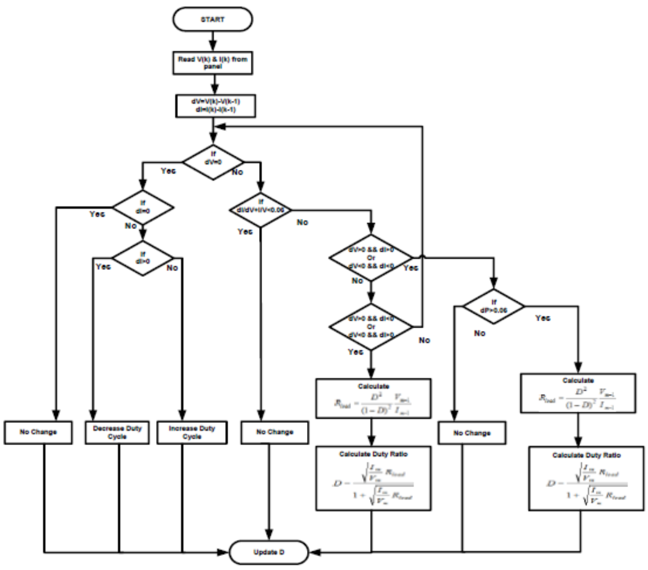


**Figure 4.** Proposed modified INC MPPT method under fast varying irradiance.

Initially if the PV module is operating at 200 W/m2 and load line 1, the operating MPP is at point A as shown in figure 3. Then if the solar radiation is increased to 800 W/m2, load line 1 cuts the I-V curve at point B, which is far away from the MPP of 800W/m2, point C. The new MPP is calculated by using the equation (7)

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Where $I_{PV}$ is the short circuit current at increased radiation, $V_{pv}$ always operates at $V_{MPP}$ of previous point ($V_{pv}$ at point A).

The simulation results for conventional and proposed MPPT method is shown in figure 5 and figure 6. In simulation a variable irradiance is of 500 W/m$^2$ from 0 to 0.3, 1000 W/m$^2$ Where IPV is the short circuit current at increased radiation, $V_{pv}$ always operates at $V_{MPP}$ of previous point ($V_{pv}$ at point A).

The simulation results for conventional and proposed MPPT method are shown in figure 5 and figure 6. In simulation a variable irradiance is of 500 W/m$^2$ from 0 to 0.3, 1000 W/m$^{2.}$

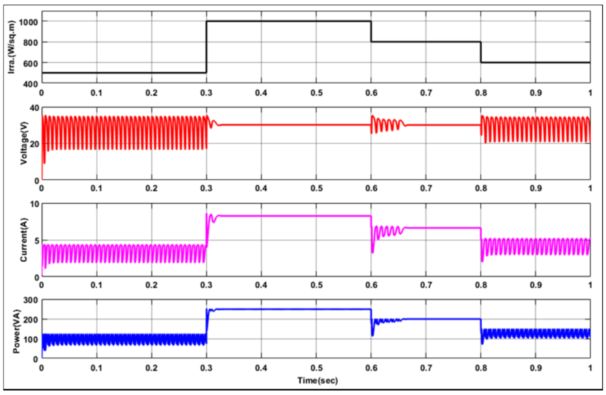


**Figure 5.** Simulation results for conventional INC MPPT method under fast varying irradiance

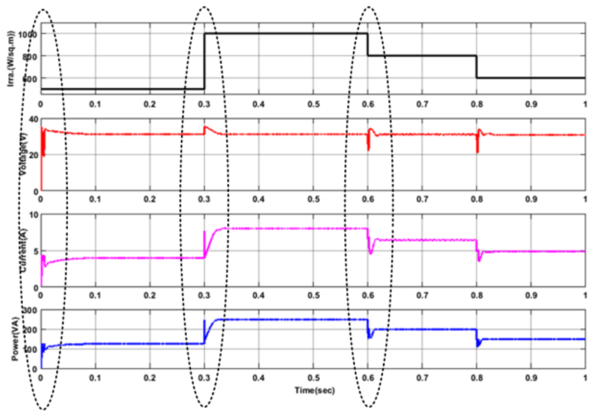


**Figure 6.** Simulation results for proposed modified INC MPPT method under fast varying irradiance.

The proposed modified INC method shows better response for fast varying irradiance and the steady state oscillations is also reduces which improves the dynamic performance of the overall system.

## 3. Conclusion

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Different control mechanisms are examined for a DC microgrid with an energy storage system. In order to track the maximum power under rapidly variable solar irradiation, a novel MPPT approach is first developed. The suggested MPPT records the MPP when there is a change in irradiance or load because it is not an iterative technique. The outcomes demonstrate that the suggested system's operation lowers steady state oscillations, which enhances the system's overall dynamic performance. A solution for the second issue is the SSIBC, which has several modes of operation.

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