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It is certified that the work contained in the thesis titled **MPPT Design Techniques for Stand-Alone PV System Using SEPIC Converter** by **Vipin Kumar** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree. It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy and SOTA for the award of Ph.D. Degree.

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DECLARATION

I, **Vipin Kumar**, certify that the work embodied in this thesis is my own bonafide work and carried out by me under the supervision of **Prof. S. K. Nagar** and **Prof. R. K. Saket** from July-2014 to July-2020, at the Departement of Electrical Engineering, Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

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Abstract

Due to increased electricity energy demand and shortage of fossil fuels reserves motivated researchers to focus on renewable energy sources and photovoltaic (PV) power generation because of its benefits like pollution free, less maintenance, no noise. This thesis is focused on improvement of tracking performance of maximum power point tracking (MPPT) algorithms and development of MPPT algorithms with single sensors to reduce the overall cost of the PV systems.

The maximum power point tracking efficiency of the PV system primarily depends on the operating point on the V-I characteristics curve of the PV module. To improve the efficiency of the PV system large number of MPPT algorithms have been developed. Among the existing MPPT algorithms, perturb and observe (P&O) and hill climbing (HC) algorithms are the most widely used because of its simple and efficient tracking performance under uniform insolation conditions. However, with P&O and HC method the operating point drift away from maximum power point (MPP) in case of an sudden increase in insolation. In this thesis a novel MPPT algorithm is developed to avoid this drift phenomena.

In this thesis, we concern for a efficient maximum power point tracking (MPPT) is an important problem for renewable power generation from photovoltaic (PV) systems. In this work, a current sensor based MPPT algorithm using an adaptive step-size (ASS) for a single ended primary inductance converter (SEPIC) based solar PV system is proposed. Due to lower sensitivity of power to current perturbation as compared to the voltage one, such a scheme is shown to yield better efficiency at steady-state. A new adaptation scheme is also proposed for faster convergence of the MPPT technique. Hence, the proposed scheme yields better transient as well as steady-state performance. A prototype converter is used along with digital implementation of the proposed MPPT technique to demonstrate the superiority of the proposed algorithm over the fixed step-size (FSS) and voltage based

ones. Simulation and experimental results corroborates the same.

The PV systems generally contain a battery , where the load voltage and load current are to be measured for the implementation of charge controller. Therefor by sensing only the load parameter (load voltage (V_L)), the objectives such as MPPT and charge controller can be achieved. In this thesis a load voltage based (LVB) maximum power point tracking (MPPT) technique using adaptive step-size (ASS) for standalone photovoltaic (PV) systems has been developed. The technique improves the convergence speed of the MPPT using a single voltage sensor to measure the load voltage (V_L) regardless of the nature of load type. The ASS of the MPPT controller is varied according to the slope $\left(\frac{dV_L}{dD}\right)$ of V_L versus duty ratio (D) characteristic. The effectiveness of the proposed technique is tested for different insolation level conditions. This ASS based control scheme improves the convergence performance over fixed step-size (FSS) scheme under varying insolation condition. A single-ended primary inductance converter (SEPIC) is used for interfacing the PV system with the resistive load, which increases the operating range of the PV system. The tracking performance of the proposed technique is compared with FSS MPPT, perturb and observe (P&O) and incremental-conductance (IncCond) techniques by simulation. Experimental verification using a developed laboratory prototype is also carried out.

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Nomenclature

List of Symbols

V_{pv}	Output voltage of PV module
I_{pv}	Output current of PV module
P_{pv}	Output power of PV module
V_L	Load voltage of PV system
I_L	Load current of PV system
R_L	Load resistance
I_{rs}	Reverse saturation current
R_{se}	Equivalent series resistance of PV module
R_p	Equivalent parallel resistance of PV module
n_s	Number of series connected PV cells in a module
b	Ideality factor of the diode
v_t	Thermal voltage
T	Module temperature in Kelvin (K)
e	Charge on single electron
k	Boltzmann's constant
I_p	Photo-current

G	Solar insolation
k_{isc}	Short circuit current temperature coefficient
I_{STC}	Short circuit current at $G_{STC} = 1000\ W/m^2$, $T_{STC} = 298\ K$
G_{STC}	Solar insolation at standard test condition
D	Duty ratio of the SEPIC converter
η	Efficiency of the SEPIC converter
R_{eq}	Equivalent resistance of the converter
S	Switching function of converter
α	Scaling factor for CSB MPPT
ΔD	Perturbation step-size
ΔD_{min}	Lower limit of ΔD
ΔD_{max}	Upper limit of ΔD
D_{max}	Maximum duty-ratio for continuous conduction mode (CCM)
V_D	Voltage drop across the diode
$V_{pv(min)}$	Minimum output voltage of PV module
$V_{pv(max)}$	Maxmum output voltage of PV module
f_s	Switching frequency of the SEPIC converter
L_1	Input inductor of SEPIC converter
L_2	Output inductor of SEPIC converter
ΔI_L	Ripple current flowing through inductors L_{in} and L_o
C_1	Coupling capacitor of SEPIC converter
C_o	Output capacitor of SEPIC converter

C_{in}	Input capacitor of SEPIC converter
V_r	Ripple voltage on capacitor C
V_{oc}	Open circuit voltage of PV module
I_{sc}	Short circuit current of PV module
V_{mpp}	Voltage at maximum power point
I_{mpp}	Current at maximum power point
T_s	Perturbation time
$I_{Cin}(rms)$	RMS current in the input capacitor (C_{in})
ΔP_{pv}	Change in power for one perturbation
ΔV_{pv}	Change in voltage for one perturbation
ΔI_{pv}	Change in current for one perturbation
$\eta_{mpp(avg)}$	Average MPP tracking efficiency
$P_{mpp(avg)}$	Extracted average maximum power from the PV module
$P^*_{mpp(avg)}$	Available average maximum PV power
β	Scaling factor for LVB MPPT

Abbreviations

MPPT	Maximum power point tracking
MPP	Maximum power point
PV	Photovoltaic
SEPIC	Single ended primary inductance converter
ASS	Adaptive step-size
FSS	Fixed step-size
P&O	Perturb and Observe
SMC	Sliding mode control
HC	Hill climbing
IncCond	Incremental conductance
FL	Fuzzy-logic
NN	Neural network
PDE	Partial differential equation
ZOH	Zero-order hold
MIMO	Multi-input multi-output
AVI	Affine-variational inequality
GAS	Global asymptotic stability
HOSM	Higher-order sliding mode
DMPPT	Distributed MPPT
PWM	Pulse width modulated
CSB	Current sensor based

CCM	Continuous conduction mode
RMS	Root mean square
VSB	Voltage sensor based
LVB	Load voltage based
DCM	Discontinuous conduction mode