Juni Khyat
(UGC Listed Journal)
ISSN: 2278-4632
Vol-9 Issue-10 No.01 October 2019

Differentiation of two different MPPT Algorithm for PV System

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Abstract: **In this paper, MPPT methods such as Perturb andObserve (P&O), Incremental Conductance and FractionalOpenCircuitVoltagemethodhasbeenstudiedandsimulatedwithMATLABsimulationsoftwareandtestedwithdifferentirradiancecondition.Also,twoconvertertopology, Buck and Synchronous buck converter has beenstudied. Hard implementation of the solar charge controlleris done based on the software simulation data and results. Hardwareisdevelopedfor1kWsystemand48V, 100Ahbattery is going to be charged with it. Two MPPT methodwith synchronous buck converter has been implemented inhardware.Thisdesignedhardwarehasbeentestedwithdifferent irradiance condition. This proposed system can beused in golf cart to make it a stand-alone system with takingcareof allprotectionmeasures.**

Keywords—Solar charge controller, MPPT, synchronous buckconverter,batterycharger,chargecontroller

I. INTRODUCTION

Solar energy is one of the promising sources of renewableenergy.That'sthereasonwhynewinnovationsareevolving using day by day using solar. But this renewableenergy is depended on the atmospheric condition such assunirradianceandtemperature.AndduetothisasolarPV panel has tobe operatein specific condition in orderto get maximum power from it. So, operating the solar PVpanelatitsmaximumpowerpointistheoneofthetrendingtopicsforresearchoverthedecades.

For solar power generation efficiency is major concern.Due to the less efficiency of solar PV panel, a propermaximumpowerpointtracking(MPPT)methodisnecessary. There are many MPPT techniques available tofindthemaximumpowerpointinwhichtheaimofmethodistooperatethePVpanelatitsavailablemaximumpower[1].

B振usingsolarPVpanel,converterandbattery,standalonesystem can beformedwhichwork by itself.ByapplyingpropercontrollingcircuitandMPPT(maximum power point tracking) method, efficiency ofsystem & performance can be boost up. In stand-alonesystem, battery storage plays an essential part [2]. Thebatteriescanbeuseddduringdaytimewhensolarenergyis Available to store energythatcanbeutilizedduringthenighttime tosupplythe loadsor dc-microgrid.

II. PROPOSEDSYSTEM

SolarPVPanel

Solar panel with 320 W power capacity, 45 Volt of opencircuit voltage (V_{OC}) and 9.28 A short circuit current (I_{SC}),four such solar PV panels have been connected in seriesconnectioninordertomake1kW system.

Battery

Lithium-ionbatterywith48Vand100Ahcapacityisgoingtobechargewiththissolarchargecontroller.

MPPTChargeController

It is an algorithm comprised in the micro controller forbringoutthemaximumavailablepowerfromthePVpanel and transfer maximum available power from the PVmodule to the battery (as load). MPPT is an electricalarrangementthatchangesthemodule'selectricaloperatingpointsothatthemodulescanofferthemaximumavailablepower[1],[3]&[4].Thiswouldincreasesolar panelcapacityand usableelectricity.

The developed MPPT charge controller is placed betweenthe solar panel and the battery. MPPT charge controller isacontrollerwithMPPTtechniqueinsideandsensingparameter[4].Fig.1showsblockdiagramofthesystem.

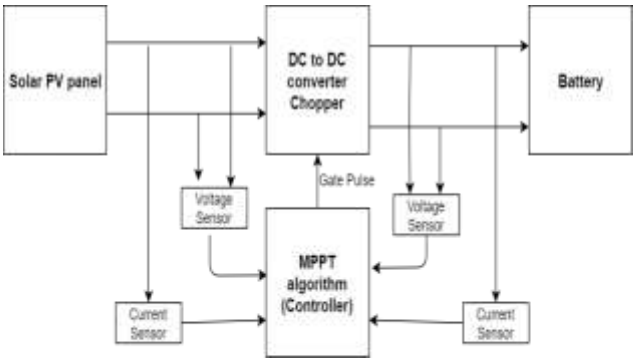

Fig. 1 Functiondiagramofsolarbatterycharger

PerturbandObservemethod(P&O)

In this method, a small perturbation is added to cause thepower variation of the PV module[1], [3], [5] & [6]. Theoutputofsolarpanelisperiodicallymeasuredandcompare dwithpreviouspower.Inthisprocesstheoutput powerofthesolarpanelisincreases,thenthesameprocess continue otherwise perturbation is reversed. Fig. 2showstheflowchartofthe P&Omethod.

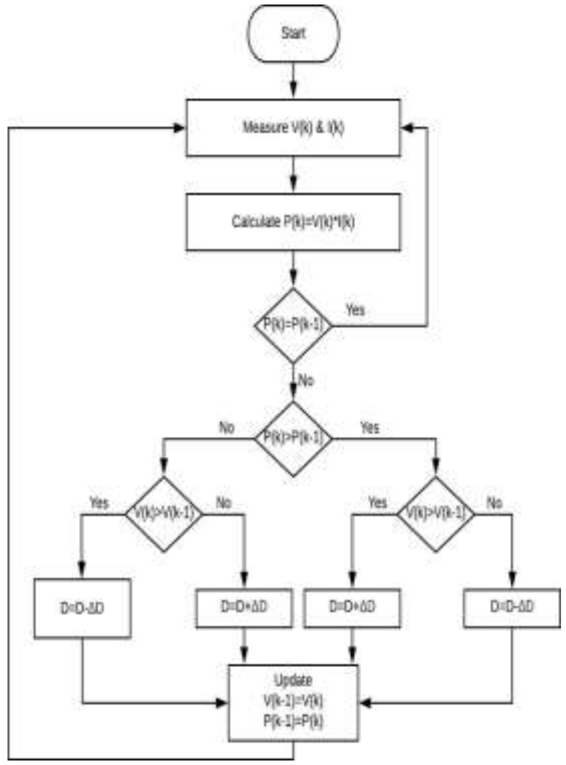

Fig. 2Flowchart algorithmofP&O

IncrementalConductancemethod(IC)

ThedrawbackofthePerturbandObserve(P&O)methodforme asuringmaximumpowerunderincreasingly changing atmospheric conditions is resolvedby the Incremental Conductance method. The principle ofthe Incremental Conductance method is that the point atwhich the slope of the PV panel power curve is zero iscalledasthemaximumpowerpoint[1],[6], [7], [8]&[4].

$$\frac{dP}{dV} = 0 \quad (1)$$

As $P = I_{(V)} * V \quad (2)$

$$\frac{dP}{dV} = I\left(\frac{dV}{dV}\right) + V\left(\frac{dI}{dV}\right) \quad (3)$$

$$\frac{dP}{dV} = I + V\left(\frac{dI}{dV}\right) \quad (4)$$

Usingequation(1)and(4),

$$I + V\left(\frac{dI}{dV}\right) = 0 \quad (5)$$

$$\frac{dI}{dV} = -\frac{I}{V} \quad (6)$$

Here, Instantaneous conductance is the ratio of the currentand voltage at instant and Incremental conductance is theratio of the difference of the current and voltage [1], [4],[9]. Equation (2) gives the condition of maximum powerpointforICmethod.AttheMPPincrementalconductan ceisnegativeofinstantaneousconductance.This algorithm has benefits over P&O, as it can evaluatewhentheMPPThitstheMPP,whereP&Ooscillatesar ound the MPP [7], [9] & [10]. Flow chart of this methodisshownintheFig. 3.

FractionalOpenCircuitVoltagemethod(FOCV)

It is one of the indirect methods to find maximum powerpoint tacking method. This approach uses the idea that theratio of the array voltage to the maximum power point(V_{mp}) and the open circuit voltage(V_{oc}) is almost constant[1], [3],[11]&[4].

$$\frac{V_{mp}}{V_{oc}} \approx 0.78 \quad (7)$$

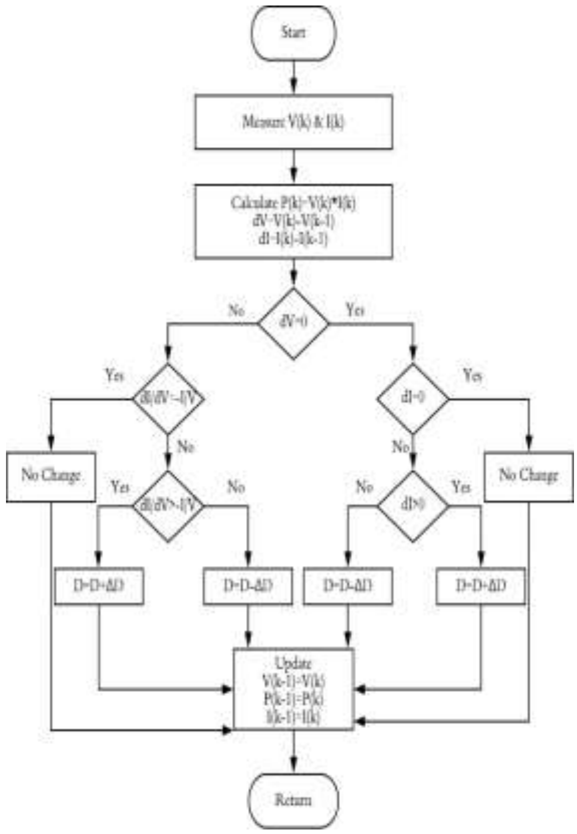

Fig. 3Flowchart algorithmofIC method

ISSN: 2278-4632
Vol-9 Issue-10 No.01 October 2019

III. SOFTWARESIMULATION

MATLAB simulation/Simulink model of the solar batterycharge with Incremental Conductance MPPT method andSBC (Synchronous Buck Converter) is shown in Fig. 4.All three MPPT methods with buck converter and SBC (Synchronous Buck Converter) have been simulated in the MATLAB simulink.

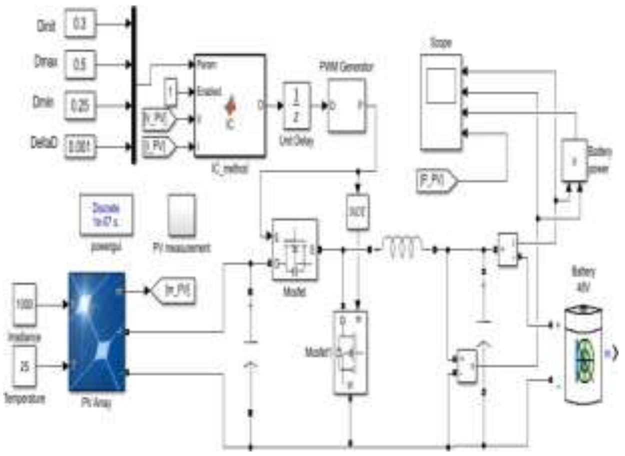

Fig.4 SoftwareSimulation ofSolarbatterycharger

Different MPPTmethod with two converter topologieshave been simulated using MATLAB Simulink softwareand simulation results have been stated in below table.Also,thissimulation,MPPTmethodswithsyncbuckconverter[12] is tested with different irradiance conditiontorealizetheperformanceofthesolarbatterycharger withdifferentatmosphericcondition.ItisshowninTableII.

Table I Simulation results of different MPPT methods with twoconvertertopologies

MPPT techniques	Complexity	Sensedparameters	Convergesspeed	Settling time (sec)	η(%)
P&O withBuck converter	Low	V	Moderate	0.366	95.5
P&O withSyncBuck converter	Low	V	Moderate	0.374	96.6
IC withBuck converter	Moderate	VandI	Fast	0.362	95.3
IC withSyncBuck converter	Moderate	VandI	Fast	0.361	97.1
FOCV with Buckconverter	Low	V	Low	0.46	93.5
FOCV					

Table II Comparison of different MPPT methods with SBC anddifferentirradiancecondition

Irradiance (W/m^2)	FOCVmethod		P&Omethod		ICmethod	
	Settling time (sec)	η(%)	Settling time (sec)	η(%)	Settling time (sec)	η(%)
1000	0.46	93.7	0.36	96.4	0.30	97.1
800	0.79	92.5	0.62	96.3	0.56	96.4
600	1.19	92.0	1	95.5	0.95	96

IV. HARDWAREIMPLIMENTATION

Hardware design is done based on the software simulationresultsandpracticalcircuitconsideration.

Voltagesensor

Resistancedividercircuitisfollowedbyop-ampisusedas voltage sensor circuit. Here op-amp is used to provideisolation and it will prevent circuit from signal loading.LM358IC isusedasop-amp.In this IC twoop-ampcircuit is there. One is used in solar side and another isusedin battery side.Inputvoltagefrom solarpanel isvaryingbetween140Vto180V.TheADCpinofmicrocontrollerhavethemaxvoltagecapacityupto5Vor3.3V accordingtothemicrocontroller.

Currentsensor

ACS712currentsensorisusedforsensingofcurrentwhich is a hall effect-based sensor. The sensed currentgenerates an analog signal as output which is proportionalto the corresponding current and the output analog signalisfedtothemicrocontroller board.

IsolatedPowerSupply

In order to make standalone system, power supply to theauxiliaryorcontrollingcircuitisprovidedviabatterywhich isultimatelyaload.So,supplytotheTLP250driver IC, voltage and current sensor is provided with thehelp of battery. As we connect battery to the controllingcircuit, isolation must be provided in order to protect thecontrolling circuit. Also, battery voltage is higher than therequired voltage to supply the auxiliary. So, step downconverter is needed with higher input voltage range andgive constant output voltage. For that purpose, MEANWELL dc to dc isolated converter is used. This modulehas the input range of 35V to 70V and gives the constantoutputof±15V.

Microcontroller

Choosing the right microcontroller for a project is alwaysa complex decision to make, because it is the core of theproject and it depends on it for system success or failure.So single chipofmicrocontroller is not usedin everyapplication. All of these microcontrollers have identicalfeatures and comes with different package size, differentsize of RAM and ROM, various instructions set, differentarchitecture, register etc.According to the requirementandperformanceofthecontroller,ArduinoMEGA2560

ISSN: 2278-4632
Vol-9 Issue-10 No.01 October 2019

microcontrollerisusedintheapplication.

SystemFlow-chart

ProgrammingofIncrementalconductanceandPerturbandObserveMPPTmethodsisdoneonthemicrocontroller to compare the performance of the bothmethod with synchronous buck converter. PWM (PulseWidthModulation)signalgenerateswiththehelpofMPPT method to control the firing of the MOSFET whichis used in the synchronous buck converter. Solar chargecontroller will work on the following flow chart. CC andCV mode of charging is decided according to the batteryvoltage. First battery voltage is measured and the mode ofchargingisdecided.

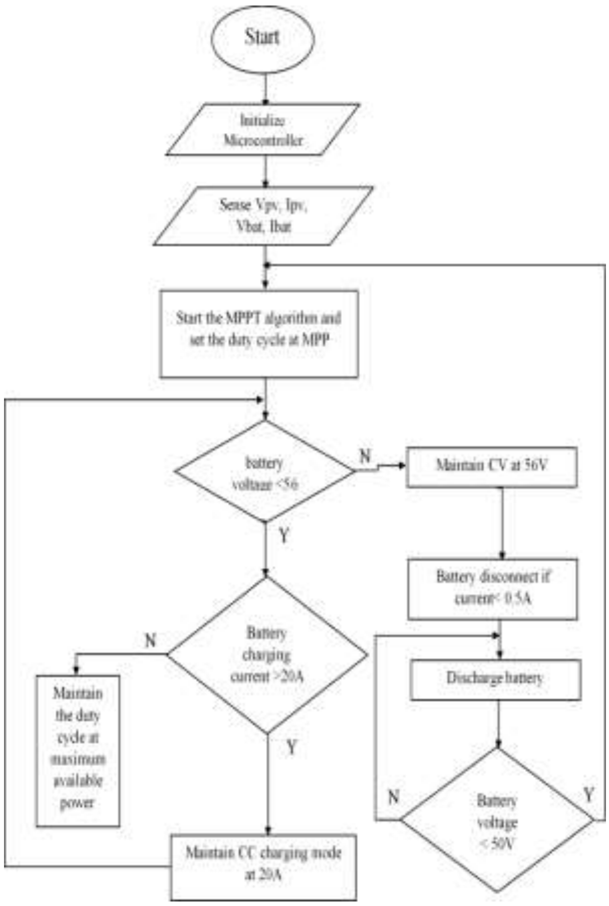

Fig. 5 SystemFlowchartofSolarchargecontroller

V. EXPERIMENTALSETUPANDRESULTS

Laboratorysetup

The Fig. 6 shows the laboratory setup for the hardwaretesting. As shown in Fig. 6 input to the power circuit isgivenbySolarsimulatorandoutputofthecircuitisattachedto thelithium-ionbattery.Synchronousbuckconverter is the mediator for transferring of power fromsolartobattery.Powercircuitissynchronousbuckconverterandcontrollingcircuitcontainsthesensorcircuit,MOSFET drivercircuit,connectiontothe microcontroller and isolated power supply for sensor anddriver IC.

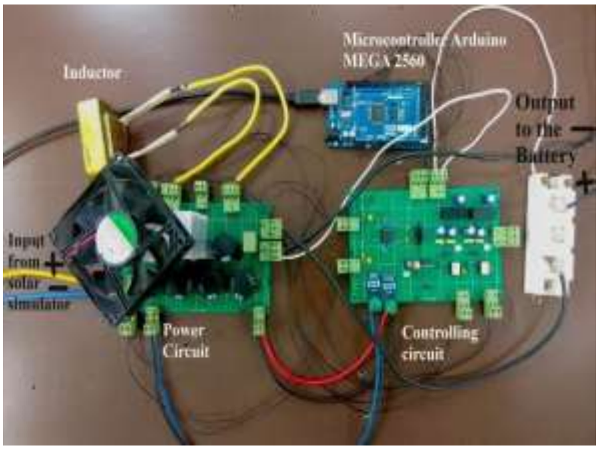

Fig.6Experimentalsetupofproposedsystem

TestingandResults

Solar array simulator is set to 1kW to charge 48V, 100 Ahbattery. System is analyzing with 1kW power and withdifferent irradiance condition. Fig. 7 shows the solar sunsimulatorsoftwareinterfacewith1kWpowerwhilerunning. Also, P-V and I-V curve of solar PV panel isshown in Fig. 7. Red dot on curve shows the operatingpoint of system so by looking at the operating point it isobserved that system is running at maximum power point.Solarpanelvoltage,current,powerandtrackingefficiencyisalsodisplayedon the screen.

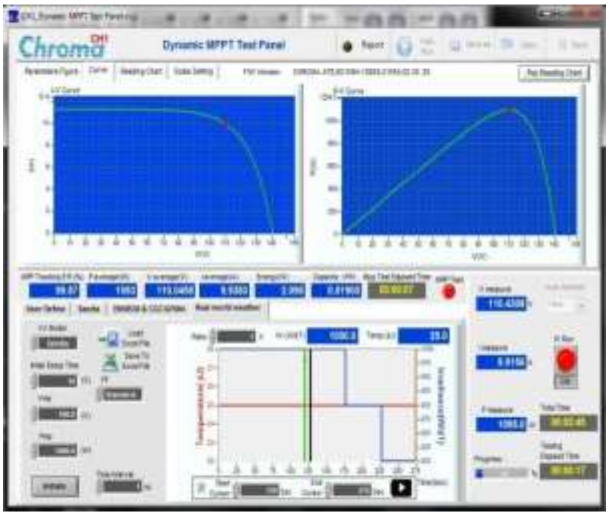

Fig. 7 I-V and P-V curve set on PV simulator for IC method at1000W/m^2irradiance

Two MPPT method have been tested with 1kW system.Testing results of IC and P&O method with synchronousbuck converteratdifferent irradiancecondition is statedin the Table III. and Table IV respectively. Experimentaldataoftheirradiancecondition,panelvoltage,panelcurrent,panelpower,batteryvoltageandcurrent,

ISSN: 2278-4632
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efficiency and device temperature while running is showninthe table.

TableIII.Experimentalresultsofsolarbatterycharger withICmethod

Irradiance(W/m²)	Panel Voltage(V)	Panel Current(I)	PanelPower (W)	BatteryVoltage (V)	BatteryCurrent (I)	Efficiency(%)	Devicetemp(°C)
1000	111	9.8	1090	51.61	19	89.96	31.6
800	108	8.02	875	51.44	15.01	88.24	34
600	102	6.4	655	51.20	11.2	87.54	36

TableIV.Experimentalresultsofsolarbatterycharger withP&Omethod

Irradiance(W/m²)	*Panel Voltage(V)*	*Panel Current (I)*	*PanelPower(W)*	*BatteryVoltage(V)*	*BatteryCurrent (I)*	*Efficiency(%)*	*Devicetemp(°C)*
1000	*111*	*9.8*	*1090*	*51.81*	*18.1*	*84.98*	*32*
800	*109*	*8*	*872*	*51.63*	*14.2*	*84.07*	*35*
600	*104*	*6.3*	*655*	*51.41*	*10.6*	*83.19*	*36*

VI. CONCLUSION

Following MPPT methods such as Perturb and Observe (P&O),IncrementalConductance(IC),Fractionalopencircuit voltage (FOCV) methods and converter topologies,buck and synchronous buck converter have been studiedand simulated using MATLAB Simulink. By observingthesoftwaresimulation,IncrementalConductance(IC)MPPT method with synchronous buck dc to dc converteris best suitable combination for the solar battery chargerapplication. Fromthehardwareimplementationofthesystemandtesting,wecansaythatforthesolarbatterychargerapplication incremental conductance MPPT method withdctodcsynchronousbuckconverterhasgivenbestdesirable result. By using this hardware, we can charge48Vbatterywith19Acurrentwith89.96%efficiency.

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