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Online SOC estimation and Intelligent Battery Charger for Solar PV System

S.Saravanan, R.Vidhya, S.Thangavel

Abstract— In this paper, the state of charge of the battery is determined and the battery is allowed to charge or discharge by standard reference current, since the overcharging and undercharging would affect the battery performance. So a battery should not be fully charged or discharged, because overcharging of a battery will affect the life time of the battery and undercharging of a battery will increase the initial charging time. Online estimation to determine SOC of battery is attempted in the proposed work with the electrical parameters which is developed using an intelligent controller.

I. INTRODUCTION

A grid connected/stand alone solar PV system essentially consists of utility, PV array as primary sources, battery bank as external leveling agent to sink/sources the primary source power and load. Hence a power flow management system is required to balance the power flow among these sources, which controls the bidirectional converter connected to battery operating under buck or boost mode, so that the battery can be charged or discharged. Slip-in and slip-out of battery from conduction is an imperative function performed by the power flow management controller and it is based on the state of charge of battery.

II. STATE OF CHARGE

The state of charge (SOC) is defined as the available capacity expressed as a percentage of its rated capacity. The SOC of the battery is so important for the selection of various modes of operation by the controller. The SOC estimation is mainly done by any of the following methods.

- *Specific Gravity* - Specific gravity is proportional to state of charge. So by measuring the specific gravity, charging condition of lead acid batteries can be determined.
- *Voltage* - By measuring the voltage of the battery the SOC and the capacity of the battery can be predicted. A digital voltmeter is required for the measurement and it is least accurate method.
- *Direct Measurement* - An amp hour meter counts the rate and time of current flow from a battery being discharged and does the same when the battery is being charged back up. The charge in a battery is equal to the current multiplied by the time for which it flowed.

Normally the battery charger which is in existence does not incorporate any of the state of charge measurements so as to limit the charging rate of the battery based on SOC to improve the life period of the battery. Hence effort had been made to measure the SOC of battery online estimation based on the electrical parameters such as battery terminal voltage and charging/discharging current.

III. STATE OF CHARGE OF A BATTERY

As per the lead acid battery hand book, [2] the terminal voltage can be used as the index for determining the SOC of battery. The SOC of a 100V battery shall be estimated from the terminal voltage shown in table I, II at various charging, discharging or resting condition. The current state of the battery in the simulation is judged by the direction of battery current. The battery current is zero while floating and positive for discharging and vice-versa for charging. The SOC estimator first senses the direction of battery current and also measures the voltage across the terminal and based on the two parameters the SOC of the battery is estimated for all the three cases which is one of the input parameter for the power management controller. Here state of charge for different standard charging and discharging currents with respect to voltage is been shown in the table I, II. Similarly SOC for the rest voltage is also been.

Table I
State Of Charge Chart for Discharging

SOC	AT DISCHARGING				
	Voltage (C/100)	Voltage (C/20)	Voltage (C/10)	Voltage (C/5)	Voltage (C/3)
10	99.13	97.04	94.13	88.30	83.30
20	100.79	99.13	95.80	90.80	86.63
30	102.46	100.79	97.46	93.30	89.55
40	103.29	101.63	98.29	94.13	91.63
50	103.71	102.46	99.96	96.21	93.30
60	104.54	103.29	100.79	97.46	94.13
70	104.96	104.13	101.63	98.29	95.80
80	105.37	104.96	102.46	99.13	97.04
90	105.37	104.96	103.29	99.96	97.46
100	105.37	105.37	104.13	100.7	98.29

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* Correspondence Author (s)
S.Saravanan, Assistant Professor (Senior Grade), Department of Electrical and Electronics Engineering, Kongu Engineering College, erode, Tamil Nadu – 638052, India.
R.Vidhya, PG Scholar, Department of Electrical and Electronics Engineering, Kongu Engineering College, erode, Tamil Nadu – 638052,India.
Dr.S.Thangavel, Professor and Head, Department of Electrical and Electronics Engineering, K.S. Rangasamy College of Technology, Tiruchengode, TamilNadu, India.

Table II
SOC Vs Terminal Voltage Chart For Charging And At Rest Condition

SOC	AT FLOAT State	AT CHARGING			
		Voltage (C/40)	Voltage (C/20)	Voltage (C/10)	Voltage (C/5)
10	97.46	98.29	100.79	103.29	104.96
20	99.13	102.46	103.29	104.96	105.79
30	100.79	104.96	104.96	106.62	107.46
40	101.63	105.79	107.46	108.29	109.96
50	102.46	106.62	108.29	109.96	111.62
60	103.29	107.46	109.12	110.79	112.46
70	104.13	107.87	109.96	111.62	114.12
80	104.54	108.29	110.79	114.12	116.62
90	104.96	109.96	113.29	117.45	127.45
100	105.37	112.46	117.45	127.45	132.45

The recommended charging rate for lead acid battery is 80-90% for charging and 40 % for discharging[1]. The above voltage,current and the corresponding SOC is obtained from the given SOC curve of battery handbook. That is explained as follows:

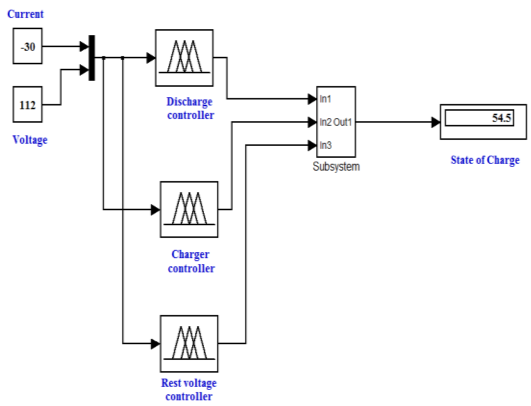

Figure 1.Estimation of SOC

The graphs show a variety of recharge and discharge rate is represented as C/XX number in Amperes proportional to the capacity of the battery. For example, consider a battery of 150 Ampere-hours. If Ampere hour capacity is divided by 10 hours, then the charge rate will be of 15 Amperes. In this the direction of the current and voltage is sensed by the fuzzy controller. According to the direction of current and voltage the SOC value is being determined.

IV. BATTERY CHARGER

Charging and discharging of a battery with standard reference current will improve the life time of a battery.

If the Excess Power in the Battery is 780 W

Charging current pertaining to 780W is

$$I_{BATT\ CHAR} = (780 / 156)$$
$$= 5\ A$$

The charging current of the battery is varied by varying the output of the duty cycle of the chopper. Based on the excess power, the controller varies the duty cycle to load the excess power.

V. BATTERY CHARGER USING EMBEDDED MATLAB FUNCTION

The circuit model of the battery charger, the standard reference current is given as input which is determined by the battery voltage and the excess power available from the renewable energy resource[4][5]. In order to make the battery to charge as per the standard charging current, a triangular wave generator of high frequency is being compared with the reference signal. Accordingly the duty cycle of the buck converter will be adjusted. This in turn will change the battery charging current.

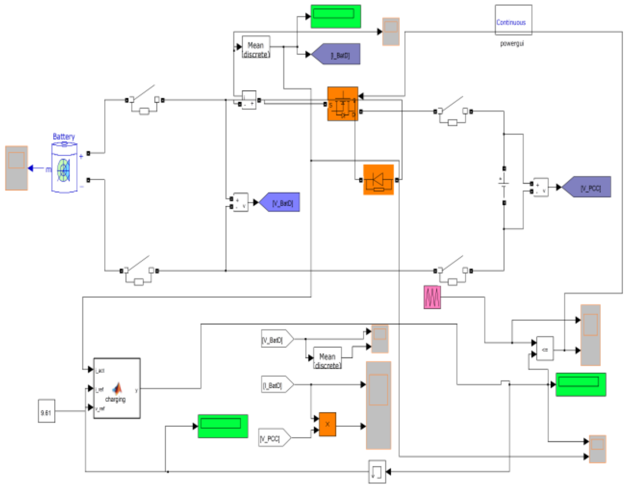

Figure 3.Battery Charger Model using MAT Lab Model

This is implemented with the help of embedded mat lab function. So the loop continues to execute until the battery tends to charge for standard charging current.

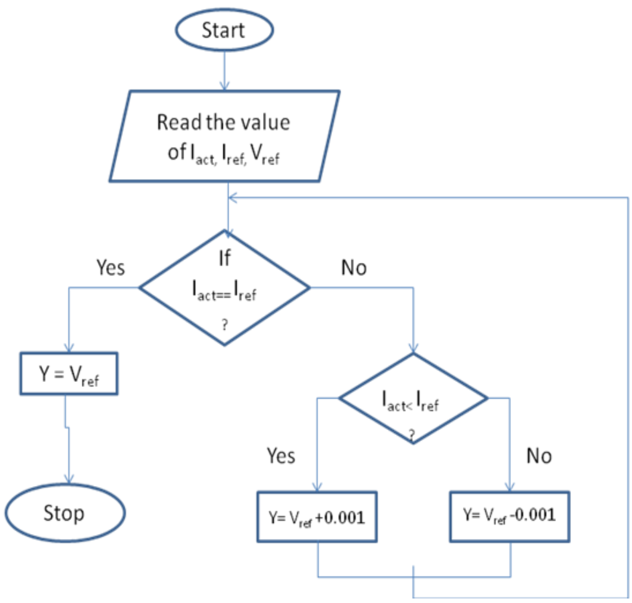

Figure 4.Flowchart for charging circuit

VI. OUTPUT OF BATTERY CHARGER

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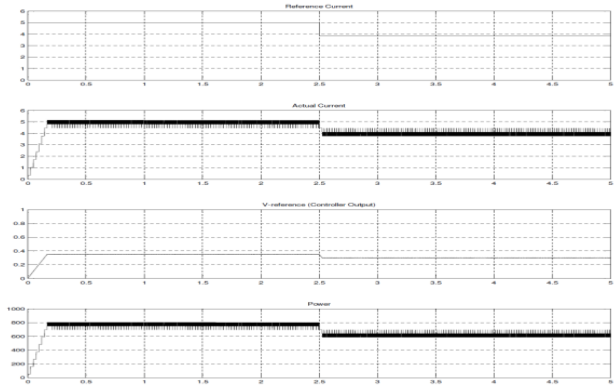

Figure 5.Output of the Battery Charger using MAT Lab Model

VII. OUTPUT OF THE BATTERY CHARGER

In the given below circuit, intelligent controller is used instead of embedded mat lab function for charging the battery, since when embedded mat lab function is used there will be delay to attain standard charging current since because of loop execution.

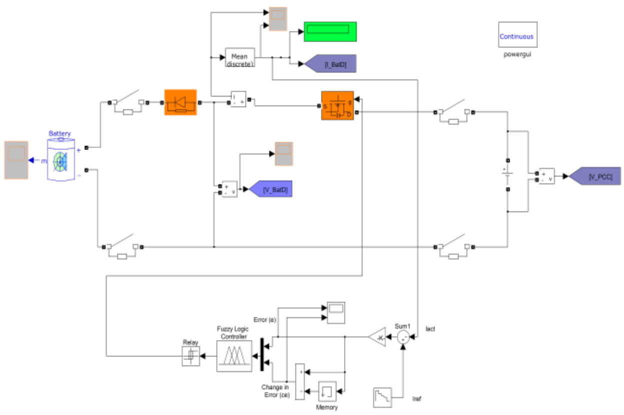

Figure 6.Battery Charger Model using Fuzzy Controller

In the above circuit, the error and the change in error are obtained from the deviation that occurs in actual and reference current. According to that error and change in error, the fuzzy controller is made to select the appropriate duty cycle of the converter. So this intelligent controller will make the battery to charge immediately with the standard charging current.

VIII. INPUT MEMBERSHIP FUNCTION

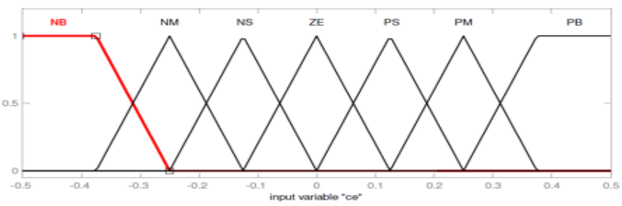

Figure 7.Input Membership function for change in error

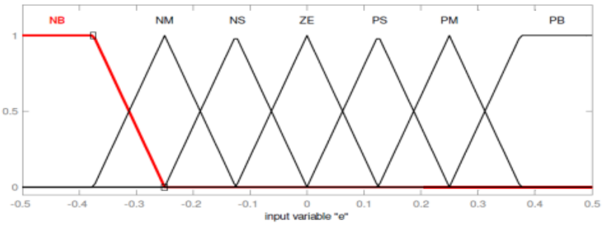

Figure 8.Input Membership function for given error

IX. OUTPUT MEMBERSHIP FUNCTION AND FUZZY TABLE

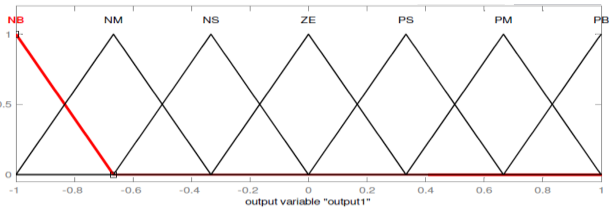

Figure 9.Output Membership Function

CHANGE IN ERROR/ ERROR	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Figure 10.Fuzzy table

Fuzzy controller has two inputs, i.e. error and change in error. Each input have seven linguistic variables as NB (negative big), NM (negative medium), NS (negative small), ZE (zero error), PS (positive small), PM (Positive medium), PB (positive big). Consider that the actual current is high compared with reference current, so the error obtained is negative. If the change in error is also negative then the fuzzy controller is made to operate in negative region. Now the duty cycle of the converter is reduced to minimize the error so that the battery tends to charge as per the standards. It is also applicable for the other combinations shown in above figure 10.

X. OUTPUT OF A BATTERY CHARGER USING FUZZY CONTROLLER

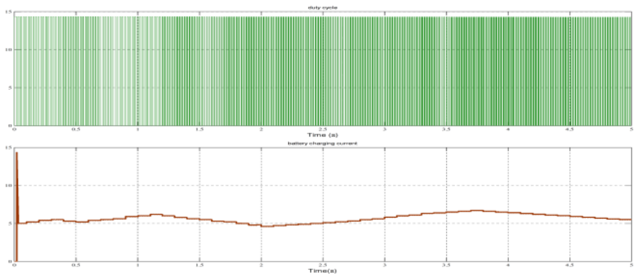

Figure 11.Output waveform for battery charger using fuzzy controller

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XI. FUZZY CONTROLLER INTEGRATED WITH BATTERY CHARGER

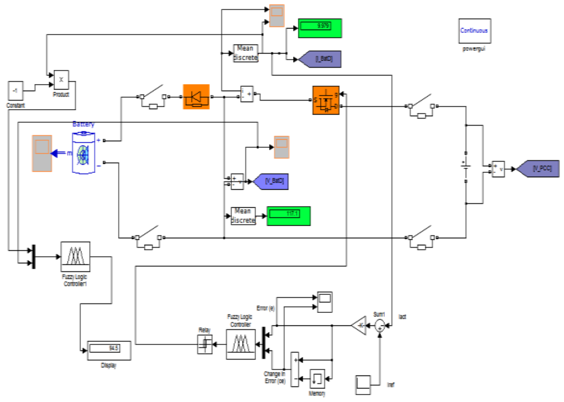

Figure 12.Fuzzy controller integrated with Battery charger

Here the fuzzy controller is integrated with the battery charger. The output from the buck converter as voltage and current is being measured. Then the measured voltage and current is given as input to that of the fuzzy logic controller to determine the state of charge.

XII. CONCLUSION

With this charging and discharging current the SOC of the battery is predicted and the charger is allowed to charge and for standard charging current. Thus the batteries life can be improved by charging the current with standard reference current. And the influence of temperature will also influence the state of charge of the battery. But the influence of the temperature which will affect the state of charge cannot be accurately determined.

REFERENCES

[1] Indu Rani, G.Saravana Ilango, C.Nagamani, "Control Strategy for power flow management in a PV system supplying DC loads", *IEEE,2011*

[2] Yazdani, and Prajna Paramita Dash, "A control methodology and characterization of dynamics for a photovoltaic system interfaced with a distribution network," *IEEE.*, vol.24(3), 2009, pp.1538-1551.

[3] Mukhtiar Singh, Vinod Khadkikar, Ambrish Chandra, and Rajiv K. Varma, "Grid interconnection of renewable energy sources at the distribution level with power-quality improvement features", *IEEE.*,vol.26(1), 2011, pp.307-315.

[4] Benjamin Kroposki, Christopher Pink, Richard DeBlasio, Holly Thomas, Marcelo Sim˜oes, and Pankaj K. Sen, "Benefits of power electronic interfaces for distributed energy sources", *IEEE.*,vol.25(3), 2010, pp.901-908.

[5] Enrique Romero-Cadaval, María Isabel Milanés-Montero, Eva González-Romera, and Fermín Barrero-González, "Power injection system for grid-connected photovoltaic generation systems based on two collaborative voltage source inverters", *IEEE,vol.*56(11), 2009,pp. 4389-4398

[6] Y.K. Lo, H.J.Chiu, T.P.Lee, I. Purnama, and J.M. Wang, "Analysis and design of a photovoltaic system connected to the utility with a power factor corrector", *IEEE.*,vol.56(11), 2009, pp.4354-4362.

[7] Jung-Min Kwon, Bong-Hwan Kwon, and Kwang-Hee Nam, "Grid-connected photovoltaic multistring pcs with pv current variation reduction control", *IEEE.*, Vol.56(11), 2009, pp.4381-4388.

Subramanian Saravanan was born in Salem, Tamilnadu. He obtained his bachelor degree in Electrical and Electronics Engineering from Bharathiar University, India in 2001 and master degree in Power Electronics and Drives from PSG College of Technology, Coimbatore, India in 2002.He is currently working for his PhD degree. He was with SASTRA University, Thanjavur till 2008.He is presently working as Assistant Professor (Senior Grade) in Kongu Engineering College, Perundurai. He had published papers in the area of multiple-input converters for renewable energy integration in various International Journals and Conferences. His specific area of interest includes Intelligent controllers for renewable energy aggregation, MPPT techniques and Power Management in standalone and grid connected renewable energy systems.

R.Vidhya was born in Salem, Tamilnadu. She obtained his bachelor degree in Electrical and Communication Engineering from Avinashilingam University for women, Coimbatore, India in 2010 and currently pursuing his Master degree in Power Electronics and Drives in Kongu Engineering College, India.

Dr S. Thangavel obtained his bachelor degree in Electrical and Electronics Engineering from Bharathiar University, India in 1993.He obtained his M.E., degree in Control and Instrumentation and Ph.D. for the thesis titled ' Intelligent controllers to Industrial Drives' from Anna University, Chennai in 2002 and 2008 respectively. He is working as Professor and Head in the Department of Electrical and Electronics Engineering, K.S.R college of Technology, Thiruchengode, Tamilnadu, India. He had published papers in the area of Intelligent controllers for industrial drives in various International Journals and Conferences. His specific area of interest includes Intelligent controllers for Drives, Renewable Energy Sources. He also Completed an AICTE sponsored project "Strengthening of the Existing Microprocessor Lab with Emphasis on Micro controller and Embedded System Facilities" under MODROBS scheme as Principal Coordinator Dr S.Thangavel is a member in ISTE, India and IEEE, USA.

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