ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

Battery Charging Control using Fuzzy Logic based Controller in a Photovoltaic System

Greeshma V J[1], Revathy Sasidharan[2]

PG Student, Electrical and Electronics Dept., Lourdes Matha College of Science & Technology Trivandrum, India[1]

Asst Professor, Electrical and Electronics Dept., Lourdes Matha College of Science & Technology Trivandrum, India[2]

Abstract: Battery charging process is non-linear, time-varying with a considerable time delay so it is difficult to achieve the best energy management performance by using traditional control approaches. To achieve the optimal charging and discharging status of the battery, a fuzzy control strategy is developed. The membership function database of the fuzzy sets, the fuzzification of the input and output variables and the evaluation of the fuzzy rules are used to support the control strategy. The Fuzzy Logic Algorithm used in battery charging process improves the efficiency of battery charging process and enhances the battery life.

Keywords: Battery charge control, Dynamic modeling of battery, Conventional controller, Fuzzy Logic Controller

I. INTRODUCTION

Under the pressure of limited available energy resources and environmental policies, electrical power generation using renewable energy has rapidly increased in recent years. In China, a large number of remote rural or mountainous inhabitants have no access to the main electricity supply network so it is important to explore the local natural renewable energy resources such as wind or solar for power generation, mainly for local consumptions. Due to the nature of intermittence of renewable energy, the use of the secondary energy storage such as batteries become inevitable which will compensate the fluctuations of power generation.

Photovoltaic (PV) system is gaining increased importance as a renewable source due to advantages such as the absence of fuel cost, little maintenance and no noise and wear due to the absence of moving parts. But there are still two principal barriers to the use of photovoltaic systems: the high installation cost and the low energy conversion efficiency. A PV panel is a non-linear power source, i.e. its output current and voltage (power) depends on the terminal operating point. The maximum power generated by the PV panel changes with the intensity of the solar radiation and the operating temperature. To increase the ratio output power/cost of the installation it is important that PV panel operates in the maximum output power point (MPP). The MPPT algorithm is integrated in one of the main stages of charge of lead-acid batteries making an autonomous and intelligent system that can be used to feed any remote load or small application. It is very important to respect the correct battery charge curves because it will prolong its correct operation and live.

As we know, frequent charging and discharging will shorten the life time of a battery. With such a system, the problem is how to determine when the battery should be charged to provide the best energy efficiency and to prolong the life time. A control strategy based on fuzzy control theory has been proposed to achieve the optimal results of the battery charging and discharging performance.

II. PHOTOVOLTAIC SYSTEM

A. Equivalent circuit model of PV cell

An ideal PV cell is modeled by a dc current source in parallel with a diode. There are losses associated with the working of a PV cell or solar cell. Voltage drop due to external contacts are represented by the drop across the series and shunt resistance. Here an equivalent circuit of a solar cell or photovoltaic cell is shown in figure 1

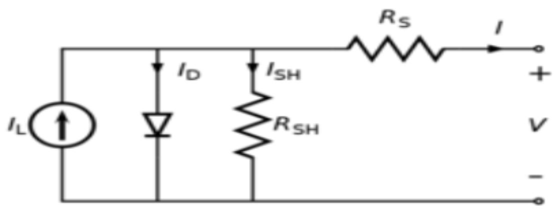

Fig.1. Equivalent circuit of a PV cell

Solar cell or Photovoltaic cell consists of a p-n junction fabricated in a thin wafer of semiconductor. There are two commonly used materials for solar cell. These are, 1. Môn crystalline silicon, 2. Polycrystalline silicon. A typical solar cell is approximately 10×10 cm in size, protected by transparent anti-reflection film. The solar panels are connected in series and parallel combination to form a solar array. Each of the PV cell produces around0.5V (for Silicon). The voltage across a solar cell is primarily dependent on the design and materials of the cell, while the current depends primarily on the incident solar irradiance and the cell

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

area. A solar array is formed by combination of series and parallel solar modules. From the equivalent circuit in fig.1 we can get the following mathematical equations of a solar cell, From the above circuit, the output current of the PV cell,

$$I = I_L - I_D - I_{sh} \quad (1)$$

$$I_D = I_0\{\exp\left[\frac{q(V + IR_S)}{AKT_C}\right] - 1\} \quad (2)$$

$$I = I_L - I_0\{\exp\left[\frac{q(V + IR_S)}{AKT_C}\right] - 1\} - \frac{V + IR_S}{R_{Sh}} \quad (3)$$

$$I_{RS} = \frac{I_{SC}}{e\left(\frac{qV_{OC}}{N_S AKT_C}\right) - 1} \quad (4)$$

where, I_L is the photocurrent or the current generated by sunlight imposed on the PV cell. I_D is the diode current. I_{sh} is the current through the shunt resistance. A is the ambient factor. K is the Boltzmann constant. q is the electron charge.

III.BATTERY WORKING CHARACTERISTICS

The energy transformation modes in the renewable energy generation system can be demonstrated in Fig.2.

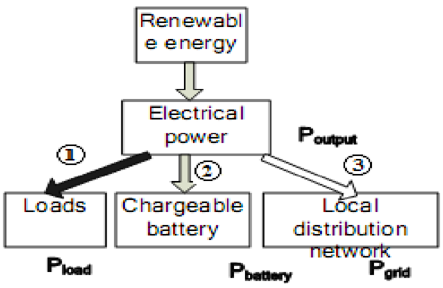

Fig 2 Energy transformation mode

In the system, the output electrical power is provided to the loads with the highest priority. If the output electrical power is excessive for the demands of the loads, the surplus is used to charge the battery. Provided that the loads can't use up the whole output power, and the battery is fully charged, the superfluous power is then sent to the local distribution network if it exists. The battery works in three statuses: disconnected from the system, charged by the system or discharged to supply power to the loads. The status of the battery is dependent on the working modes of the system, and shifts according to different modes.

In the 20th century, America scientist Mass has put forward the optimal charging curve of the Lead-acid battery based on the lowest output gas rate, as shown in Fig.3. If the charging current keeps to the track of the ptimal curve, the charging hours can be sharply cut down without any side effect on the capacity and life-span of the battery. It is designated that the charging current expressed in amperes at any moment of the charging cycle must not overpass the capacity of the battery at that moment, expressed in Ampere-hours. Formula (5) expresses the relationship between the charging current and charging time.

$$i = I_0 e^{-\alpha t} \quad (5)$$

In formula (1), the variable i is the value of the instant charging current in each moment. I_0 is the initial charging current value, namely when t = 0, i = I_0. I_0 expresses its current adoption capacity. It is apparent that I_0 is the maximum charging current value in the whole process. The constant α represents the attenuation coefficient of the battery.

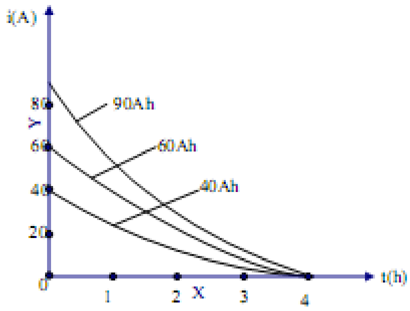

Fig.3. Optimal charging curve of the battery

The Ampere-hour rule for charging the Lead-acid batteries can be considered as the most efficient charging approach, considering the charging time and the excellent performance provided by this method to maintain the life-span of the battery. One example of the of the Ampere-hour rule to charge battery is shown in Fig.4.

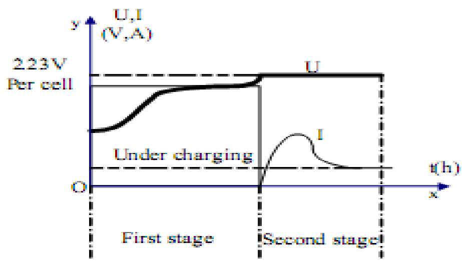

Fig.4. Application of the Ampere-hour rule to charge battery

When the battery is charged, the charging current I_c, the charging voltage (port voltage) U_c, the potential difference E_b between the positive plate and the negative plate of the battery and the internal resistor R_b of the battery has the following relationship:

$$I_C = \frac{U_C - E_b}{R_b} \quad (6)$$

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

As can be seen from the formula (6), only on conditions that $U_c>E_b$, the battery can be charged. The potential difference E_b between the plates changes with the charging process.

During the first stage, the E_b is very low, so the port voltage U_c starts with a small value, while the current keeps constant to the set value, namely the maximum current value. The set point of the charging current is closely related with the capacity of the battery. With the potential difference of the battery gradually increasing, the charging voltage rises with it so that the battery can be charged according to the formula (6), but it kept below a certain maximum level which is also defined according to the characteristics of the battery, as shown in the part one of Fig.4. The second stage starts when the battery voltage reaches a certain level, which is defined by the characteristics of the battery, depending again on the capacity and number of cells available in the battery.

Generally this is taken as 90% of the total capacity of the battery. During this phase, the control variable switches over from current to voltage. The voltage is maintained almost unchanged at a given value, while the current is gradually decreasing until it drops to a value set at the initial stage.

As we can see from the above discussion, the charging process of the battery is much complex. It is quite different to obtain the benefit of the reduction in charging time, the high efficiency of the energy transformation and the maintenance of the life span of the battery. Moreover, the control system of the battery charging and discharging process is a non-linear, time-varying system with pure time delay, multiple variables and many outer disturbances. In its charging and discharging process, many parameters such as the charging rate, the permitted maximum charging current, the internal resistor, the port voltage, the temperature and moisture, the life-span etc. vary with different battery. Some parameters change during the charging and discharging process and can't be obtained directly. Furthermore, as these parameters are coupling with each other, sometimes it is impossible to use traditional control system. Under this circumstance, a fuzzy control system is adopted to control a the battery charging and discharging process that cannot be controlled well by a conventional control system.

IV. DESIGN OF PI CONTROLLER FOR LEAD ACID BATTERY

Feedback controllers are those that control the variable behaviour of a system. These are with a closed loop arrangement, which uses feedback to control the states of the system. Negative necessarily associated with feedback controllers sense the value and subtract it from the desired value to form the error signal. Determination of the controller parameters to provide the desired response is known as controller tuning. Controller tuning can be done by using synthesis method. Design of controller by synthesis method is one of the recommended methods in process control. The synthesis controller is the combination of two parts. The first part compensates for the process transfer function and the other is used to obtain a specified closed loop response of the controlled variable to the set point. When the process transfer function does not have dead time, the closed loop transfer function becomes

$$\frac{Y(s)}{X(s)} = \frac{K_p}{\tau_c s + 1} \qquad (7)$$

V. DESIGN OF FUZZY LOGIC CONTROLLER

A fuzzy logic system is a type of approximate reasoning system. It can be considered as universal function approximate. The goal of the fuzzy logic system is to yield a set of outputs for given inputs in a non-linear system by using linguistic rules. The block diagram of a Fuzzy Controller is given in Fig. 5. In this figure, a closed loop fuzzy Controller is identified. The outputs are represented as y(t) and the corresponding inputs are represented by u(t) and r(t). Here r(t) is the chosen representation for the reference input

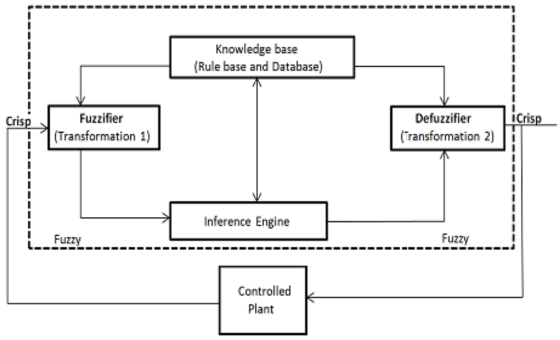

Fig.5. Block Diagram of a Fuzzy Logic Controller

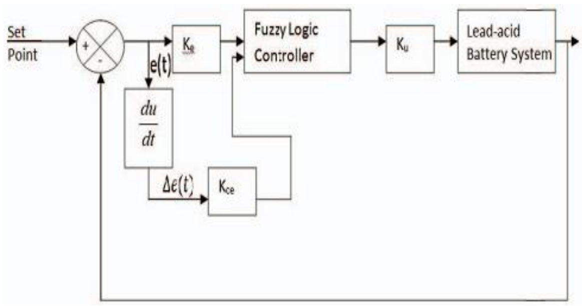

Fig 6 Fuzzy logic control system for battery charging

The fuzzy controller is inserted into the closed-loop Lead Acid battery system. Here the actual voltage of the battery is compared with the reference battery voltage. The present error e(t) and error change Δ e(t) signals are then processed by the fuzzy logic controller to create a relevant control output variable.

The input and output parameters of the fuzzy logic control system are described by the following equations

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

$$e(t)= V_B-V_B(t) \quad (8)$$
$$\Delta e(t)=e(t)-e(t-1) \quad (9)$$
$$\Delta u(t) = F(K_e e(t), K_{ce} e(t)) \quad (10)$$
$$u(t)= u_{set} +\Delta u(t) \quad (11)$$

VI. SIMULATION RESULTS

Table 1. Simulation parameters

Parameters	Values
V_{OC}	37.3V
I_{SC}	8.71A
G	$1000W/m^2$
E_g	1.12eV
T_{ref}	298K

Table 2. Rule table

Voltage \ Current	Decrease	Maintain	Increase
Low	Maximum	Maximum	Maintain
Medium	Maximum	Maintain	Minimum
High	Maximum	Maintain	Minimum

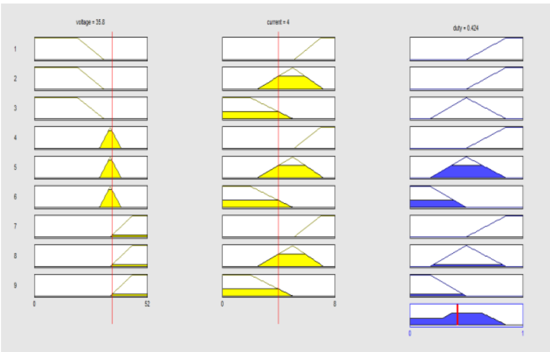

Fig.7. Rule viewer

The simulation results have shown compared to conventional techniques, fuzzy logic controller offers many important benefits. Developing a fuzzy logic controller is simpler than developing a model based controller with equivalent performance.

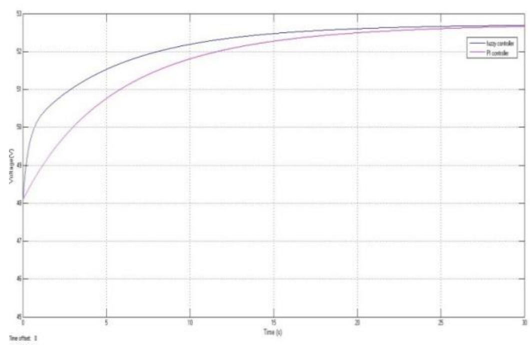

Fig.8 showing voltage-time characteristics of combined fuzzy pi controller

VII. CONCLUSION

Here, the design and implementation of conventional PI controller and fuzzy logic controller for controlling charging voltage of lead acid battery is done. A PI algorithm using synthesis method and a fuzzy logic controller were used for control purpose. The simulation results indicate that the PI based controller takes more time to settle, whereas the Fuzzy Logic controller has a good set point tracking with minimum time.

REFERENCES

[1] H. D. Lee, S. K. Sul, Fuzzy Logic based Torque control strategy for parallel type HEV, IEEE Transactions on Industrial Electronics, 1998, Vol 45, No.4, pp. 625-632
[2] B.J.huang, P.C.Hsu, M.S.Wu, P.Y.Ho., " System Dynamic Model and Charging Control of Lead-Acid Battery for Stand-alone PV Solar system",Solar Energy, 84, 822–830 ,2010.
[3] G. Balasubramanian and S. Singaravelu "Fuzzy Logic Based Controller for A Stand-Alone Hybrid Generation System Using Wind and Photovoltaic Energy" International Journal of Advances in Engineering & Technology, pp.668-679, May 2012.
[4] Florent Boico, Brad Lehman, and Khalil Shujaee "Solar Battery Chargers for NiMH Batteries" IEEE Transactions on Power Electronics, Vol. 22, No. 5, pp. 1600-1609, Sep- 2007 Armstrong, S. Glavin, M.E., Hurley, W.G. "Comparison of battery charging algorithms for stand-alone photovoltaic systems". IEEE Power Electronics Specialists Conference. page 1469-1475, 2008.
[5] Armstrong, S. Glavin, M.E., Hurley, W.G. "Comparison of battery charging algorithms for stand-alone photovoltaic systems". IEEE Power Electronics Specialists Conference. page 1469-1475, 2008.
[6] Ankur Bhattacharjee, "Design and Comparative Study of Three Photovoltaic Battery Charge Control Algorithms in MATLAB/SIMULINK Environment" International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970) Volume-2 Number-3 Issue-5 September-2012.
[7] Kim, S.C., Hong, W.H., "Analysis of the discharge performance of a flooded lead/acid cell using mathematical modeling". J. Power Sources,77, 74–82,1999.
[8] Fuzzy control system, From Wikipedia, the free encyclopedia, 2007, Accessed on February, 2008, [online]. Available: http://en.wikipedia.org/wiki/Fuzzy_system