www.ijarp.com ISSN 2456-9992 Page: 01-09

International Journal Advanced Research Publications

Research Article

Volume: 02
Issue: 08

OUTPUT CONTROL STRATEGIES OF PHOTOVOLTAIC SYSTEM USING FUZZY-LOGIC

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Article Received: 04 July 2026, Article Revised: 24 July 2026, Published on: 11 August 2026

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Doi: https://doi-doi.org/101555/ijrpa.7741

ABSTRACT

In India not only is there a large gap between Demand and supply of electricity but also almost 60,000 villages are un-electrified. To overcome this problem solar energy is the best option with effective control schemes either on load side or source side. This work is carried out to demonstrate fuzzy-logic as a effective tool for output control of standalone PV system where there is no alternative source of power to maintain reliability of the system, Optimal control strategy for a grid independent photo-voltaic system consisting of a PV collector array, a storage battery, and loads (critical and noncritical loads) is designed and validated using Fuzzy-logic.

KEYWORDS: Photo-voltaic System, Intelligent Techniques, Battery Storage, Energy Dispatch, Fuzzy Logic, Optimal Control, membership function, critical load.

I. INTRODUCTION

In India there is a large gap between Demand and supply of electricity. Still there are many small villages in India which are without electricity supply and it is not possible physically and economically to provide electricity to these villages by present Distribution System.

Secondly, the growth of the population has created several problems. One of them is global warming caused by the abundance of CO2 in the atmosphere. Many of these gases are produced from electrical plants burning fossil fuel all over the world. To reduce these emanations out into the atmosphere alternative sources of energy must be used.

Solar energy is the best option to overcome these difficulties as it is a very large and inexhaustible source of energy. The power from the sun intercepted by the earth is approximately $1.8X10^{11}$ MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. In addition to its size, solar energy has two other advantages. Firstly, it is an environmentally clean source of energy. Secondly, it is available free in adequate quantities in almost all parts of the world where people live.

II. PHOTOVOLTAIC SYSTEM

The Photovoltaic system constitutes Photo-voltaic cells, Storage battery, controllers as well as load which are connected to utilize the generated power as explained below.

A. *Components in Photovoltaic System*

A.

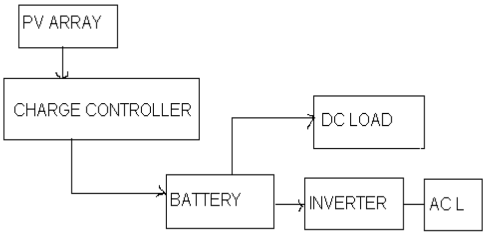

Figure 1. Components of photovoltaic system.

Photovoltaic cells represent the fundamental power conversion units. Photovoltaic cells are composed of semiconductors and transform sunlight into electricity. A single photovoltaic cell is generally quite small, usually generating 1 to 2 watts of power. To enhance the power output of these cells, they are linked together to create larger units known as modules. These modules are then combined in both parallel and series configurations to form larger entities called panels and arrays, capable of generating electrical power that satisfies nearly any electrical demand.

Battery bank is used as a storage medium and involved in the system to make the energy available at night or at days of autonomy (sometimes called no-sun-days or dark days), when radiation obtained from the sun is not enough. The typical batteries utilized in solar systems are lead-acid batteries, known for their excellent performance, durability, and affordability.

A voltage regulator or charge controller is a crucial component of almost all power systems that recharge batteries, regardless of whether the power source is from photovoltaic systems or the utility grid. Its purpose is to keep the batteries properly fed and safe for the long term. Charge controllers block reverse current and prevent the battery from getting overcharged.

Other functions of the controller include, prevent battery over discharge, protect from electrical overload, and/or display battery status and the flow of power.

An inverter is an important device in the solar energy system, whose function is to change a low dc-voltage into usable ac- voltage as the solar panels generate dc-voltage. Inverters are different by the output wave format, output power and installation type. It is also known as a power conditioner because it changes the form of the electric power. There are two types of inverters for installation, stand-alone installation and grid-connected installation.

Electrical loads are AC or DC appliances (such as lights and radios), and the components (such as fridges, water pumps, washing machines and microwaves) which consume the power generated by the photovoltaic array.

B. Problems Associated With Solar

Though the solar energy is available in large quantity there are many problems associated with its use as follows:

The main problem is that solar energy is a dilute source of energy. Even in the hottest regions of the earth, the solar radiation flux available rarely exceeds 1kW/m^2 and the total radiation over a day is at best about 7 kWh/m^2**.** These are low values from the point of view of technological utilization. Consequently, large collecting areas are required in many applications and these result in excessive costs.

A second problem associated with the use of solar energy is the variation in the availability of sunlight with time. The variation in availability occurs daily because of the day-night cycles and also seasonally because of the earth's orbit around the sun. Furthermore, variations can happen at certain locations due to local climatic conditions. As a result, energy gathered during sunny periods needs to be stored for times when it isn't accessible. This requirement for storage also greatly increases the overall expense of any system. Thus the real challenge in utilizing solar energy as an alternative is of an economic nature. It is essential to work on developing more affordable techniques for gathering and storing data, as this will help lower the significant upfront costs currently needed for many applications.

III. PV-PRIORITY CONTROLLER AND PROBLEMS ASSOCIATED WITH IT

Before charging the battery, the standard controller, known as the "PV-Priority" controller, always attempts to satisfy the loads (first the critical, then the non-critical). If the PV array cannot provide enough energy to meet the loads at any given moment, the battery is used to make up the difference. If there is an excess, the battery receives whatever is left over after the loads are supplied. If instead there is an excess, then whatever is left over after supplying the loads is dispatched to the battery. In this way, the controller will attempt to power all loads and charge the battery as best it can, without any considerations given to the time varying states of the system. When there is enough PV energy, this controller functions effectively. On the other hand, loads will be reduced and the battery won't be entirely recharged if there is insufficient PV energy.

The PV priority strategy can be improved by designing an optimal controller that, for example, only powers the critical load when the PV arrays are not producing enough energy. By doing this, an ideal controller can save battery energy when solar radiation is low, ensuring that energy is accessible to power the important load when needed. By prioritizing the system loads, an optimal fuzzy logic-based controller can be created that can fulfill more critical loads than the non-critical loads. This will also try to keep a higher battery state of charge in case of lengthy periods of unfavorable weather.

IV. SYSTEM DESCRIPTION AND METHODOLOGY

B. System Components

The work proposed here is to design a grid independent photovoltaic power generation system which can be implemented in an area where it is not possible to supply power through the existing grid.

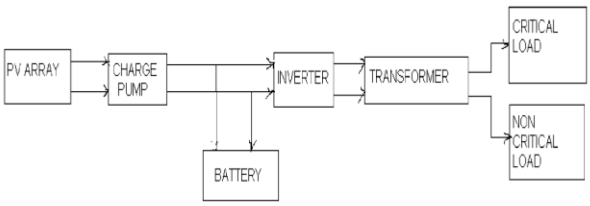

Figure 2. Components of Photovoltaic System.

For developing a model for such a system 20W CFL lamp load is considered assuming equal critical and non-critical load. The PV panel and battery used for the model is 12V. All circuit components such as step up transformer, transistors, and relays are selected according to the above rating. The fuzzy rules developed so as to maintain full load, half load or no load condition without altering the battery charge. According to the time of critical load should remain ON, battery Ah rating is selected. An example of a critical load would be the refrigeration of vaccines and medication in remote locations without access to a reliable electrical grid.

C. Fuzzy-Logic Controller

In any fuzzy logic system, the system takes a value and first passes it through a Fuzzification process. Then it is processed by an inference engine (or fuzzy rule set). Finally, it goes through a defuzzification process.

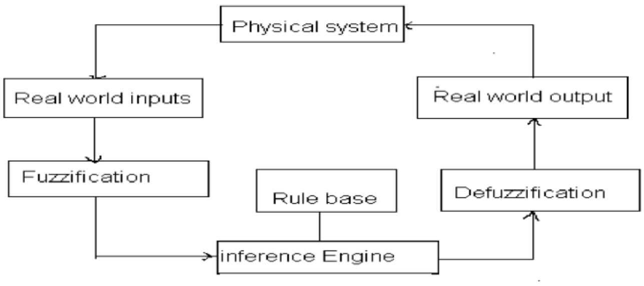

Figure 3. Fuzzy-Logic Controller.

V. FUZZY RULE BASE DEVELOPMENT

A. Input and Output Variables

The input variables sensed in actual demonstration circuit are three in number:

a) PV panel voltage

b) Battery voltage

c) Load status

The output variable is which load is to be kept on after defuzzification of inputs.

The input and output variables are represented by triangular membership functions as shown in figure.4 and figure.5.The input and output variables are divided into five different ranges, each range corresponds to a linguistic variable.

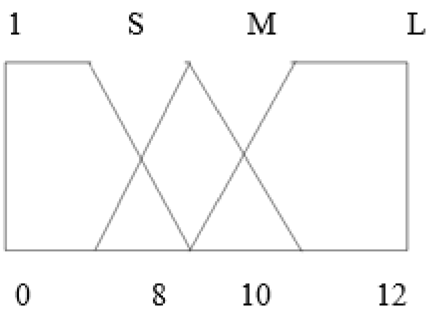

Figure 4(a). Membership functions for PV and Battery.

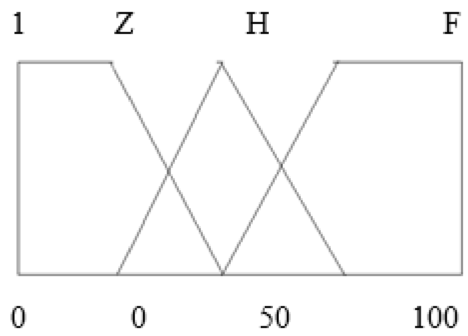

Figure 4(b). Membership functions for load status.

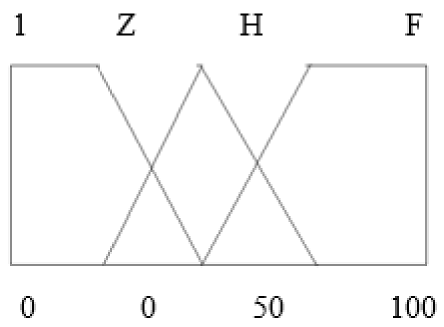

Figure 5. Membership functions for output load condition.

Table 1. Input membership function for pv and battery.

Voltage Level	Fuzzy Variable
Less than 10 volts	Small(S)
8 Volts to 12 Volts	Medium(M)
Above 10 Volts	Large(L)

Table 2. Input and output membership function for load.

Load status	Fuzzy Variable
Less than 50%	Zero(Z)
0 to 100 %	Half(H)
50 % and above	Full(F)

B.Rule Base

The table of rules, called the rule base which is prepared on expert knowledge. The rule base is the backbone of this controller according to which the whole system is operated and output is controlled. The rule base is shown in Table 3.

Table 3: Rule Base.

Rule No	If Input is			Then Output is
	PV Voltage	Battery Voltage	Load Status	
1	S	S	Z	Z
2	M	M	Z	H
3	L	L	Z	F
4	S	M	Z	H
5	M	L	Z	H
6	L	S	Z	H
7	S	L	Z	H
8	M	S	Z	H
9	L	M	Z	H

The rules are based on IF-THEN statements such as IF ‘PV Volt’ is ‘L’ AND ‘Battery Volt’ is ‘L’AND ‘Load’ is ‘Z’ THEN ‘Output Load’ is F. The Fuzzifier, gives the degrees of membership values and the knowledge base, gives the corresponding output linguistic variable. The Fuzzy output variable is converted to crisp value by the process of defuzzification. The defuzzified output is fed to the further circuit to obtain the control signal. The implementation of FLC is carried out through software.

VI. EXPERIMENTAL SET UP AND RESULTS

Figure 6. shows an experimental set up for the demonstration unit. It is placed at a location where solar insolation is available for maximum daytime hours.

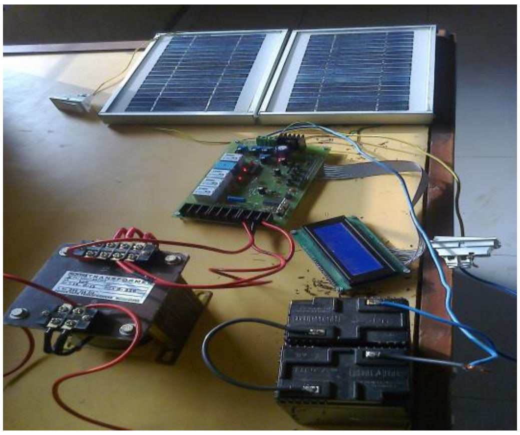

Figure 6. Experimental Setup.

The readings are taken by creating conditions as per rules developed to check the performance of the unit.

Table 4: Readings at Different Voltage Conditions.

Time of Day (Hrs)	PV voltage (Volts)	Battery Voltage (Volts)	Load %
7.00	2.3	8.0	00
9.00	9.3	8.3	50
12.00	15.5	12.1	100
14.00	15.6	12.0	100
16.00	11.6	12.0	100
18.00	7.2	9.5	50
19.00	0.0	7.8	00

VII. CONCLUSION

The work carried out concludes that Fuzzy-logic can be implemented as an effective tool for load control of photovoltaic systems. This system can be used for the rural areas where electricity is not available till date.

The demonstration unit design proves that fuzzy rules developed works properly and gives required output results for 10W CFL lamps considering 50% critical load.

The solar insolation varies with different weather conditions; hence for consistency battery Ah rating should be selected considering days of autonomy.

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