SYMBLOG ASSIGNMENT

Fuzzy Logic in Maximum Power Point Tracking

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ABSTRACT

The report discusses about fuzzy logic, a non-classical logic. The report builds up with basic definition of fuzzy logic. It also discusses the basic history and advancement of the logic. The major part of report is a detailed analysis of an application of fuzzy logic in maximum power point tracking (MMPT). It majorly throws light on the usage of MMPT in solar cells and how it is far more efficient than using classical logic. The latter part of report contains conclusions and references of the report.
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NON CLASSICAL LOGIC

According to Wikipedia, non-classical logic is defined as ‘Non-classical logics (and sometimes alternative logics) are formal systems that differ in a significant way from standard logical systems such as propositional and predicate logic.’
Examples of non-classical logics are computability logic, modal logic, quantum logic and of course, fuzzy logic.

FUZZY LOGIC

Fuzzy logic is the kind of logic in which truth values can assume more than one values i.e. it’s a many-valued logic. In contrast to boolean logic where the truth values are only 0 and 1, fuzzy logic allows values ranging from 0 to 1. It essentially means that fuzzy logic allows the idea of partial truth where the truth value of a statement is not just completely true (1) or completely false (0); but it can carry certain “amount” of truth or falsity to it. In fuzzy logic everything is or is allowed to be a matter of degree. A crisp boundary is substituted by gradient.

It is based on the perception that individuals settle on choices dependent on loose and non-numerical data. Fuzzy models or sets are scientific methods for speaking to unclearness and uncertain data, hence the term fuzzy. These models have the capacity of perceiving, speaking to, controlling, deciphering, and using information and data that are unclear and need assurance.

Fuzzy Logic has certain advantages over the conventional classical logic. For instance, modification by adding or removing rules becomes easy due to the flexibility of the fuzzy logic. Also fuzzy logic systems can take imprecise, distorted, noisy input information. Moreover, fuzzy logic is a solution to many complex human problems as it imitates human rational and decision making. On a downside fuzzy logic is not suitable for problems that require a high level of accuracy.

HISTORY

The first person to think of an alternative to the traditional two-valued logic was the Polish philosopher Jan Lukasiewicz. He first proposed a three valued logic by adding ‘possible’ to ‘true’ and ‘false’. But it didn’t gain much acceptance or fame. Later he also proposed four

and five valued logics and then eventually came to a conclusion that an infinitely valued logic is possible. With the publication of Lofti Zadeh's first paper on this topic in 1965, fuzzy logic was born. Zadeh reasoned that people don't require precise numerical input to make decisions. However, initially the theory was met with skepticism and hostility. Its name also, was perhaps a problem. To quote Lofti Zadeh, 'I knew that fuzzy was not a good word. The image is that some sort of logic that is not precise, is muddy.' Once when Zadeh had met with executives from IBM, they told him that his discovery was of no interest or use.

But, by the early 70s, the theory began to gain acceptance and took off quickly. Intelligent appliances based on fuzzy logic started to pop up everywhere. It was integrated into everything, from civil engineering machines to household appliances. Today most consumer products use some form of fuzzy logic. In 2009, Zadeh was awarded the Benjamin Franklin medal in electrical engineering for his invention and development of fuzzy logic.

ADVANCEMENT

Fuzzy logic took off initially in Asian countries, especially Japan and then was adopted by the whole world. In the West though, fuzzy logic was accepted slowly. Even today there are more relatively more number of researchers about fuzzy logic in China and Japan.

Some early notable application of fuzzy logic are:

- Hitachi's design of the metro system in 1987 in Sendai, Japan
- S. Assilian and E. Mandani in the United Kingdom developed a controller for a steam engine in 1974.

As mentioned, Japan readily accepted the idea of fuzzy logic. Japanese electronic companies like Sony, Hitachi etc. started incorporating fuzzy logic to modify various products like cameras, washing machines etc. For example, fuzzy logic in the new camcorder allows it to evaluate lighting conditions and focus more quickly than other models. In water heater, instead of just heating the water at a fixed temperature you can now heat it at a specific temperature.

APPLICATION

FUZZY LOGIC IN MAXIMUM POWER POINT TRACKING

- What is Maximum Power Point Tracking?

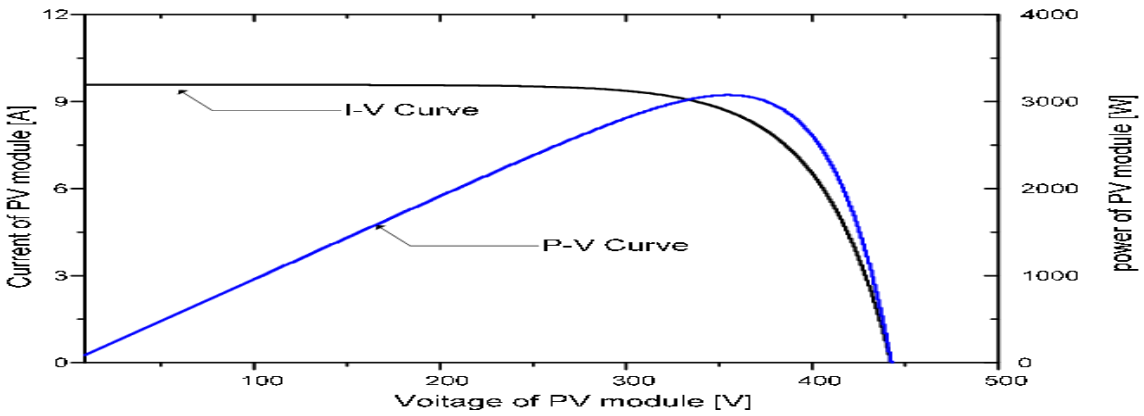
  Maximum Power Point Tracking is a method to track the voltage at which a solar cell delivers maximum power. To understand how the method works we will first have a look at characteristics of solar cells.

- **Solar Cells**

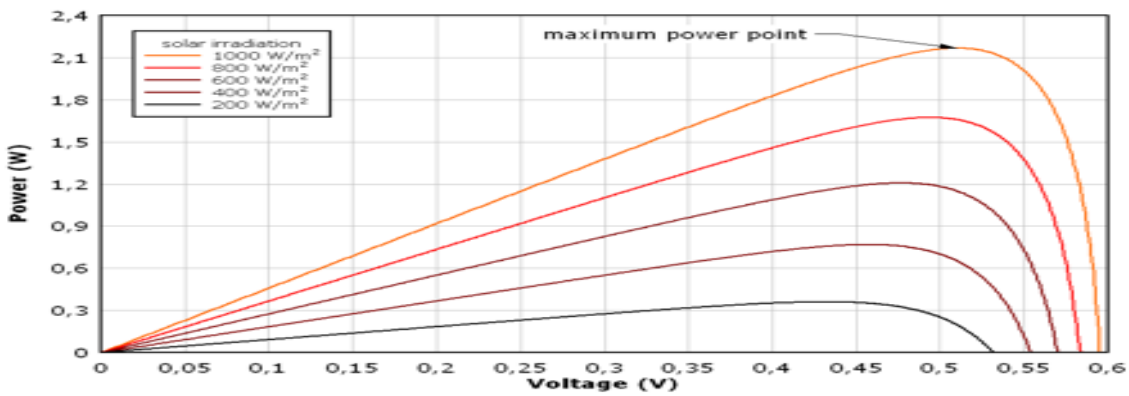
  Solar Cells are photodiodes are used to convert light energy into electrical energy. They act as current sources and the current is a function of the incident light energy and the voltage across the solar cells. Unlike an ohmic resistor the solar cell is a non linear device and hence the current does not vary linearly with voltage.

  The power delivered by a solar cell can be calculated as

  POWER = VOLTAGE X CURRENT



A GRAPH OF CURRENT/POWER VS VOLTAGE



POWER vs VOLTAGE at different radiation levels

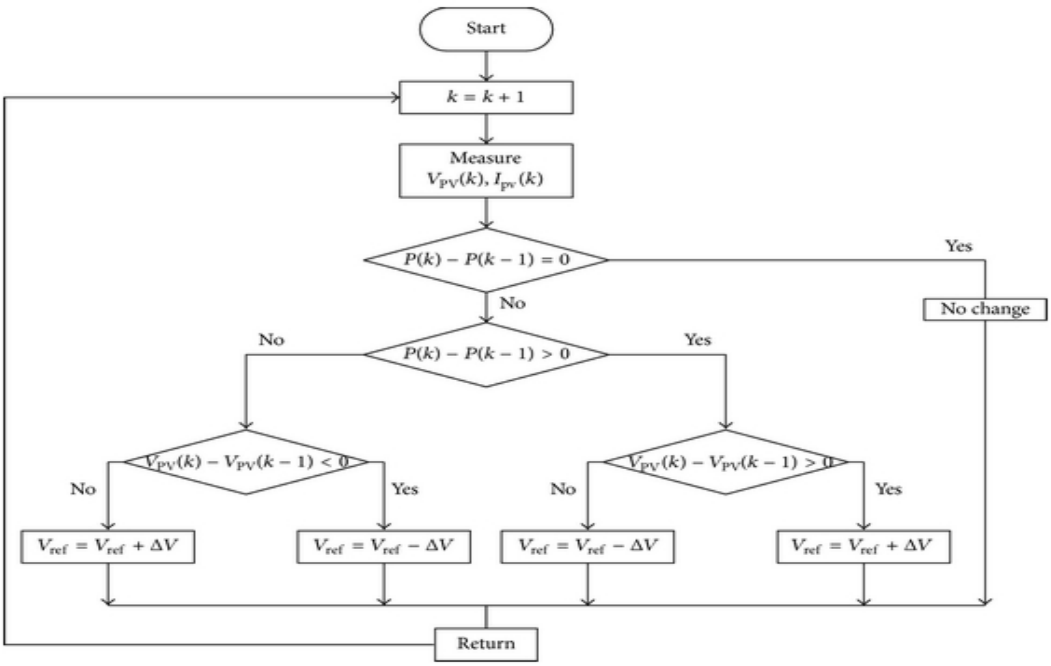
As we can see the maximum power delivered by the solar cell peaks at a particular value of voltage and falls as we move away from this point.

- **THE PROBLEM**

As seen the maximum power point changes with the amount of irradiance. This becomes particularly notable in satellites as the orientation of the satellite may change, changing the irradiation on the solar panels. It is even more important to track the maximum power point for nanosatellites as these have a small surface area and tight power constraints.

One of the algorithms to track the maximum power point is called Perturb and Observe.

Perturb and Observe is an iterative algorithm which seeks to find the maximum power point by iteratively perturbing the voltage across solar cells and observing its effect on the power delivered.



FLOWCHART OF THE PERTURB AND OBSERVE METHOD

The problem with the normal Perturb and Observe algorithm is that it takes time for the Maximum Power Point controller to reach the Maximum Power Point, also the system always oscillates about the maximum power point.

We can improve the control scheme by considering how much the power has changed rather than just considering whether it has increased or decreased. The same applies for voltage. Hence we are moving from a binary decision making system to a multivalued decision making scheme.

- **FUZZY LOGIC MPPT CONTROLLER**

  We observe that the P-V graph is non-linear and has a different slope. We divide the graphs into 4 regions as shown.

  In region 1: The change in power and the change in voltage is almost equal.

  In region 2: The change in power is small (positive) as compared to the change in voltage.

  In region 3: The change in power is small (negative) as compared to the change in voltage.

  In region 4: The change in power is large (negative) as compared to the change in voltage.

We now define 2 inputs for the controller.

And

where *E(k)* is the error signal which tells us whether we are on the left or right side of the MPP.

While *C(k)* is the change in error which tells us whether the movement of the operating point is in the direction of the MPP or not.

An example of a fuzzy control scheme.

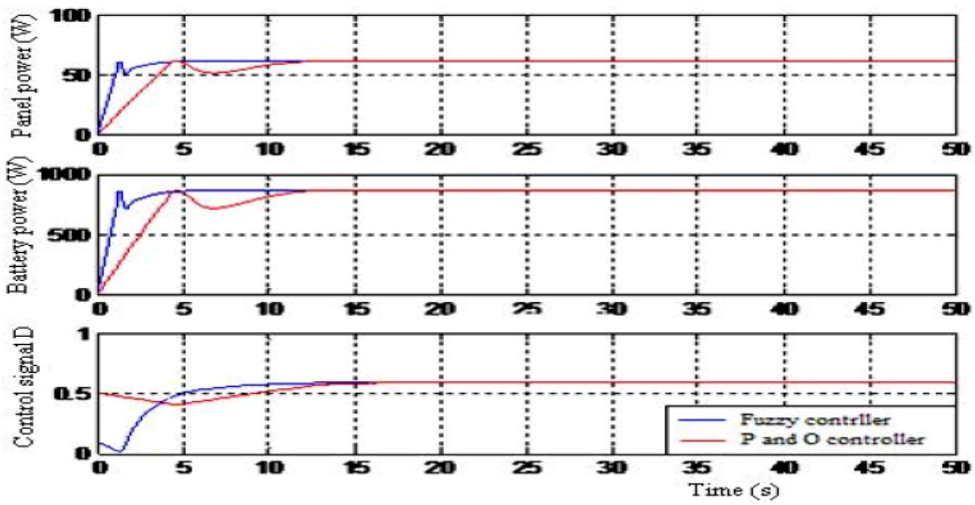
E/ΔE	Very Low	Low	Neutral	High	Very High
Very Low	VH	VH	H	VL	VL
Low	H	H	H	VL	L
Neutral	H	H	N	L	L
High	H	H	L	L	VL
Very High	H	H	L	L	VL

Fuzzy Logic Based MPPT Controller for a PV System

Low stands for a negative value and high for a positive. Very low implies highly negative value and so on. The solar panels are connected to the battery/load through a voltage converter which changes the voltage across the solar panels for a fixed battery voltage.

Where D ranges from 0 -1. Hence a decrease in the value of D will cause an increase in the output voltage and vice-a-versa.

The fuzzy control scheme speeds up the tracking of MPP by identifying which part of the P-V plot it lies in and hence suggesting a suitable change in the voltage. This also leads to smaller oscillations about the MPP point.



Comparison of 'P and O' and 'P and O' with fuzzy logic.

(Maximum power point tracking using a fuzzy logic control scheme, M.S. Aït Cheikh, C. Larbes†, G.F. Tchoketch Kebir and A. Zerguerras)*

CONCLUSIONS

- Non-classical logic allows to increase the range of possibilities which helps us in solving problems with greater complexity.

- Initially rejected, people realized the real uses of this logic in the late 1970s.

- Across the various types of non-classical logics, fuzzy logic is highly modifiable, imitates human thought process and decision-making.

- Maximum power point tracking in solar cells of nano-satellites can be made highly efficient with the help of fuzzy logic.

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