Applying the Paraconsistent Annotated Evidential Logic Eτ in a Solar Tracker for Photovoltaic Panels: An Analytical Approach

Álvaro Prado, Marcelo Nogueira, Jair Minoro Abe, Ricardo J. Machado

Applying the Paraconsistent Annotated Evidential Logic $E\tau$ in a Solar Tracker for Photovoltaic Panels

Álvaro A. C. Prado[1], Marcelo Nogueira[1,2], Jair Minoro Abe [1], Ricardo J. Machado [2]

[1] Paulista University, São Paulo, Brazil
py2alv@gmail.com
[2] University of Minho, Guimarães, Portugal
rmac@dsi.uminho.pt

Abstract. Large urban centers and other isolated locations shows a panorama of increasing contrast nowadays, where even the most basic resources may be scarce, leading the development of self-sustainable solutions, in which the electrical power is an important demand to be supplied. Through Bibliographic and Experimental research, plus practical implementation and testing, it was possible to develop a solution which fits within the proposed needs. This paper aims to present a self-oriented solar panel based on Paraconsistent Annotated Evidential Logic $E\tau$, its construction and practical tests, where an average yield of 3.19W was obtained against 2.44W from a fixed panel of same type, representing an increase of 31.56% in the overall power.

Keywords: Solar energy· Photovoltaic· Power optimization· Energetic sustainability· Paraconsistent Annotated Evidential Logic E*tau*

1 Introduction

Nowadays, despite the development of new technologies being a constant activity, many cases of very scarce resources are not rare, particularly in locations far from urban centers.

One of the most important of these resources is the electricity, often unavailable because of large distances between distribution networks and the locations itself, or even because the great importance of local ecosystems [1].

The difficulties in bringing rural electrification to these places, and the need to limit the use of fossil fuels, replacing them with non-polluting and renewable energy alternatives, make urgent investments in research and development of improved alternative energy sources [2].

Fossil fuels are the main source of energy in the world and are at the center of the world's energy demands. However, its avaliability is limited, and its large-scale use is associated with environmental degradation. The negative effects known from use of these fuels include acid rain, depletion of the ozone layer and global climate changes [3].

Following this panorama, an important method for obtaining electricity without burning fossil fuels is through a photovoltaic solar panel [4]. Supply only implies in the cost of equipment itself, with no carbon liberated during operation.

However, an important problem is related to the positioning of the solar panel, which is often fixed and does not have the ability to follow the natural movement of the sun throughout the day, which is related to the question of Maximum Power Point (MPP) of the panel [5], as seen on Figure 1.

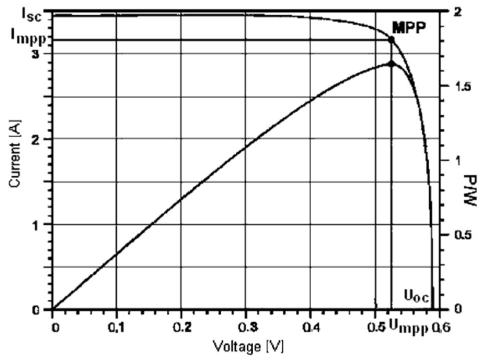

Fig. 1. Typical curve of a solar cell (Source: [5])

Many systems are proposed to circumvent this problem, but without the ability to handle situations of inconsistency or contradiction in the collected data [6,7].

By using embedded software, a controller board and a sample from the voltage provided by the photovoltaic panel, it is possible to obtain a correct positioning with a stepper motor mechanically attached to it.

The Paraconsistent Annotated Evidential Logic Eτ aims to reach an optimal performance by the decision-making process, by handling situations where the signals from the panel are not conclusive or contradictory

2 Paraconsistent Logic

2.1 Historical Background

The Genesis of Paraconsistent Logic originated in 1910, by the work of logicians N. A. Vasil'év and J. Łukasiewicz. Although contemporaries, they developed their research independently. In 1948, Jaskowski, encouraged by his professor Łukasiewicz, discovered Discursive Logic. Vasil'év wrote that "similar to what happened with the axioms of Euclidean geometry, some principles of Aristotelian logic could be revisited, among them the principle of contradiction"[8].

Going beyond the work of Jaskowski, the Brazilian logician Newton C. A. Da Costa has extended its systems for the treatment of inconsistencies, having been recognized for it as the introducer of Paraconsistent Logic; Abe [8], also a Brazilian logician, set several other applications of Annotated Systems, specially Logic E*tau*, establishing the basic study of Model Theory and the Theory of Annotated Sets.

2.2 Certainty and Uncertainty Degrees

By using the properties of real numbers, it is possible to build a mathematical structure with the aim of materializing how to manipulate the mechanical concept of uncertainty, contradiction and paracompleteness among others (Figure 2). Such mechanism will embark the true and false states treated on classical logic, with all its consequences. Therefore, several concepts are introduced which are considered "intuitive" for the purpose above:

Perfectly defined segment AB (Eq. 1):

$$\mu + \lambda - 1 = 0; 0 \leq \mu, \lambda \leq 1 \tag{1}$$

Perfectly undefined segment DC:

$$\mu - \lambda = 0; 0 \leq \mu, \lambda \leq 1 \tag{2}$$

The constant annotation (μ, λ) that focus on the segment has completely undefined the relationship $\mu - \lambda = 0$, ie $\mu = \lambda$ Thus, the evidence is identical to the positive evidence to the contrary, which shows that the proposition p(μ, λ) expresses a blurring. It varies continuously from the inconsistency (1, 1) until the paracompleteness (0, 0). Since the constant annotation (μ, λ) that focus on the segment has clearly defined the relationship $\mu + \lambda - 1 = 0$, ie $\mu = 1 - \lambda$, or $\lambda = 1 - \mu$.

Therefore, in the first case, the favorable evidence is the Boolean complement of contrary evidence and, second, the contrary evidence is the Boolean complement of favorable evidence, which shows that the evidence, both favorable and contrary 'behave' as if classic. It varies continuously from the deceit (0, 1) to the truth (1, 0).

The applications are introduced as follows:
G_{ic}: $[0, 1]x[0, 1] \rightarrow [0, 1]$, G_{pa}: $[0, 1]x[0, 1] \rightarrow [-1, 0]$, G_{ve}: $[0, 1]x[0, 1] \rightarrow [0, 1]$, G_{fa}: $[0, 1]x[0, 1] \rightarrow [-1, 0]$.

Defined by:

Inconsistency Degree:	$G_{ic}(\mu, \lambda) = \mu + \lambda - 1$, since $\mu + \lambda - 1 \geq 0$
Paracompleteness Degree:	$G_{pa}(\mu, \lambda)\ \mu + \lambda - 1$, since $\mu + \lambda - 1 \leq 0$
Truth Degree:	$G_{ve}(\mu, \lambda) = \mu - \lambda$, since $\mu - \lambda \geq 0$
Falsehood Degree:	$G_{fa}(\mu, \lambda) = \mu - \lambda$, since $\mu - \lambda \leq 0$

It is seen that the Accuracy Degree "measures" how an annotation (μ, λ) "distances" from the segment perfectly defined and how to "approach" of the state, and the true degree of Falsehood "measures" how an annotation (μ, λ) "distances" from the segment perfectly defined, and how to "approach" the false state.

Similarly, the inconsistency degree "measures" how an annotation (μ, λ) "distances" from the segment undefined and how "close" it is from the inconsistent state, and degree of Paracompleteness "measures" how an annotation $(\mu, \lambda$ "distances" of the segment undefined, and how "close" it is from paracomplete.

Is called Gin uncertainty degree (μ, λ) from an entry (μ, λ) to any of the degree of inconsistency or paracompleteness. For example, the maximum degree of uncertainty is in an inconsistent state, ie $G_{ic}(1, 1) = 1$. It is called the Certainty Degree Gce (μ, λ) of an annotation (μ, λ) to any of the degrees of truth or falsity

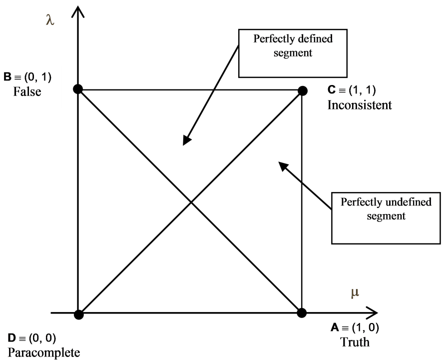

Fig. 2. Reticulate (Source: [8])

2.3 Decision States: Extreme and Not-Extreme

With the concepts shown above, it is possible to work with ”truth-bands” rather than the ”truth” as an inflexible concept. Perhaps more well said that truth is a range of certainty with respect to a certain proposition. The values serve as a guide when such a proposition is considered; for example, “true” in order to make a decision positively, and so on. The extreme states are represented by Truth (V), False (F), Inconsistent (T) and Paracomplete (⊥); and the not-extreme logical states by the intermediate areas between the states. The areas bounded by not-extreme values depend on each project.

2.4 Para-Analyzer Algorythm

An important point for the embedded software responsible for handling the panel, the Para-analyzer algorithm reflects the paraconsistent analysis by treating the values of favorable and unfavorable evidence, resulting in certainty and uncertainty degrees, plus a logical state [8]. Embedded Software and Paraconsistent Controller.

2.5 Embedded Software and Paraconsistent Controller

The embedded software was developed upon the spiral model, being followed by a risk analysis for all the following steps, since the adoption of software engineering and its assumptions are critical to project success [8]. Both evidence values are obtained with an interval of 500 milliseconds between them, which allows a proper distinction and the capture of the logic states Paracomplete (⊥) – with low intensity and uniform λ and μ, representing a dimly lit room – and Inconsistent (T), with high-intensity and uniform μ and λ, representing an external environment with nuisances like shadows of trees, birds or other moving obstacles.

In order to optimize the output states of the para-analyzer algorithm, the non-extreme logic states were conveniently chosen, according to the application requirements [9]. Taking into account that in most of the time the solar panel is exposed to light levels close to its maximum, the closest non-extreme states from truth (V) were elected.

3 Practical Implementation and Results

A single-axis traction system with a stepper motor was chosen, since it proved itself enough to provide a noticeable gain in performance combining simplicity, robustness and simplified maintenance [10]. The prototype assembly is constituted basically of a mobile holder for the solar panel, moved by a stepper motor through a belt system, built upon a base support, as seen on Figure 3.

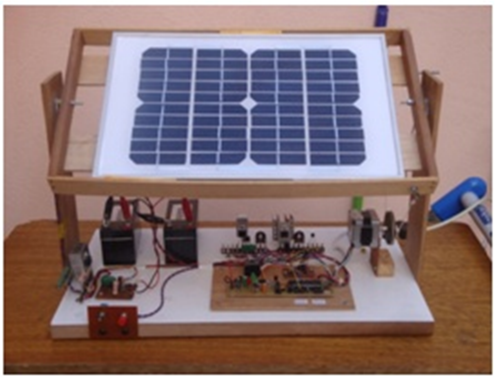

Fig. 3. Prototype assembly

For sensing purposes, it was used a sample of the voltage supplied by the panel itself – which varies between zero and 17V – adequately attenuated in 90% through an adjustable resistive divider, to be applied to the input of the controller boar – which supports a maximum voltage 5V – and subjected to an inverter, as part of the embedded software, to obtain the favorable (μ) and contrary evidence degrees (λ).

In addition to the solar panel itself, the prototype has a set of batteries (for power and load circuits) with their respective charge controllers, a driver circuit to the stepper motor and a homemade Arduino based controller board.

When operating under proper conditions, the prototype remains powered only by the panel, while both batteries are charged. Power consumption only occurs when the stepper motor is running. An increase of 31.56% could be achieved in this particular days specially during the morning hours and late afternoon, when the fixed panel has its performance greatly reduced.

4 Conclusion

This paper aims to propose a low-environmental impact alternative for places where electricity is not available, by using a self-oriented solar photovoltaic panel. The Paraconsistent Annotated Evidential Logic E*tau* was used in the decision-making process by the embedded software, allowing the panel to be more accurately positioned in situations of inconsistency or contradiction in the data collected.

According to the practical tests, it was found an average yield of 3.19W provided by the proposed system against 2.44W obtained from the fixed panel, which represents an increase of 31.56%. This shows that the results are compatible with other similar systems [9,10] and demonstrates that the actual implementation is perfectly feasible and capable of being implemented as a solution for manufactures of any type.

This result is similar to others found in the literature, specially in Huang et al. [11] (35,8%) and Salas et al. [12] (2.8% ~ 18.5%), when compared with fixed panel systems.

Aknowledgements

This work has been supported by COMPETE: POCI-01-0145-FEDER-007043 and FCT – Fundação para a Ciência e Tecnologia within the Project Scope: UID/CEC/00319/2013 by Portugal and University Paulista - Software Engineering Research Group by Brazil.

References

1. Bursztyn, M.: Difícil Sustentabilidade: Política Energética e Conflitos. Editora Garamond (2001)
2. Dantas, J.M.: Sistema Fotovoltaico para Comunidades Isoladas utilizando ultracapacitores para Armazenamento de Energia. Ph.D. thesis, Univesity of Ceará (2013)
3. Manzano-Agugliaro, F., Alcayde, A., Montoya, F., Zapata-Sierra, A., Gil, C.: Scientific Production of Renewable Energies Worldwide: An Overview. Renewable and Sustainable Energy Reviews 18, 134–143 (2013)
4. Centro de Referência para Energia Solar e Eólica Sérgio de Salvo Brito: Energia Solar: Princípios e Aplicações (2006)
5. Santos, J.L., Antunes, F., Chehab, A., Cruz, C.: A Maximum Power Point Tracker for PV Systems using a High Performance Boost Converter. Solar Energy 80(7), 772–778 (2006)
6. Da Costa, N.C., Abe, J.M., da Silva Filho, J.I., Murolo, A.C., Leite, C.F.S.: Lógica Paraconsistente Aplicada. São Paulo (1999)
7. Ishaque, K., Salam, Z.: A Review of Maximum Power Point Tracking Techniques of PV System for Uniform Insolation and Partial Shading Condition. Renewable and Sustainable Energy Reviews 19, 475–488 (2013)
8. Abe, J., Silva, F., João, I., Celestino, U., Araújo, H.: Lógica Paraconsistente Anotada Evidencial Eτ. Comunicar (2011)
9. Nogueira, M., Machado, R.J.: Importance of risk process in management software projects in small companies. In: International Conference on Advances in Production Management Systems. pp. 358–365. Springer Berlin Heidelberg (2014)
10. Torres, C.R.: Sistema Inteligente Baseado na Lógica Paraconsistente Anotada Eτ para Controle e Navegação de Robôs Móveis Autônomos em um Ambiente não Estruturado. Ph.D. thesis, University of Itajubá (2010)
11. Huang, B., Ding, W., Huang, Y.: Long-term Field Test of Solar PV Power Generation Using One-axis 3-position Sun Tracker. Solar Energy 85(9), 1935–1944 (2011)
12. Salas, V., Olias, E., Lazaro, A., Barrado, A.: Evaluation of a New Maximum Power Point Tracker (MPPT) Applied to the Photovoltaic Stand-alone Systems. Solar energy materials and solar cells 87(1), 807–815 (2005)