Power Optimization in Photovoltaic Panels Through the Application of Paraconsistent Annotated Evidential Logic Eτ

Álvaro André Colombero Prado[1(✉)], Marcelo Nogueira[1,2], Jair Minoro Abe[1], and Ricardo J. Machado[2]

[1] Software Engineering Research Group, Paulista University, UNIP, Campus Tatuapé, São Paulo, Brazil
py2alv@gmail.com, marcelo@noginfo.com.br, jairabe@uol.com.br

[2] ALGORITMI Centre, School of Engineering, University of Minho, Campus of Azurém, Guimarães, Portugal
rmac@dsi.uminho.pt

Abstract. The contrast between large urban centers and other isolated locations where even the most basic resources are scarce, leads the development of self-sustainable solutions, a panorama 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 presents a self-oriented solar panel based on Paraconsistent Annotated Evidential Logic Eτ, its construction and practical tests, where an average yield of 3.19 W was obtained against 2.44 W from a fixed panel, representing an increase of 31.56 % in the overall power.

Keywords: Solar energy · Photovoltaic · Power optimization · Energetic sustainability · Paraconsistent annotated evidential logic eτ

1 Introduction

In present times, where the development of new technologies and enhancements for various aspects of daily life is 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].

Most of the solutions adopted in these cases normally results in high environmental impact, by using generators and combustion engines, offering physical risks to those who handle them in addition to its high greenhouse gas emissions. Following this panorama, an important method for obtaining electricity without burning fossil fuels is through a photovoltaic solar panel [2]. Supply only implies in the cost of equipment itself, with no carbon liberated during operation.

S. Umeda et al. (Eds.): APMS 2015, Part I, IFIP AICT 459, pp. 655–661, 2015.
DOI: 10.1007/978-3-319-22756-6_80

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 [3]. Many authors propose the use of simple timer-based systems or even “perturbation and observation” algorithms to circumvent this problem, but without the ability to handle situations of inconsistency or contradiction in the collected data [4, 5].

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. This alternative combined with the use of Paraconsistent Annotated Evidential Logic Eτ on the decision-making process by the embedded software seeks to provide an optimal performance by handling situations where the signals from the panel are not conclusive or contradictory. The self-sustainable design now proposed is intended to power small devices of everyday use, by charging batteries with good performance, plus a reduced environmental impact.

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” [6].

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 [6], also a Brazilian logician, set several other applications of Annotated Systems, specially Logic Eτ, establishing the basic study of Model Theory and the Theory of Annotated Sets.

2.2 Certainty and Uncertainty Degrees

Founded on the cardinal points, and 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, according to Fig. 1. Such mechanism will embark the true and false states treated within the scope of classical logic with all its consequences. To this end, several concepts are introduced which are considered “intuitive” for the purpose above:

Perfectly defined segment AB: $\mu + \lambda - 1 = 0; 0 \le \mu, \lambda \le 1$
Perfectly undefined segment DC: $\mu - \lambda = 0; 0 \le \mu, \lambda \le 1$

The constant annotation (μ, λ) that focus on the segment has completely undefined the relationship $\mu - \lambda = 0$, i.e. $\mu = \lambda$. Thus, the evidence is identical to the positive evidence to the contrary, which shows that the proposition $p_{(\mu, \lambda)}$ 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 $\mu + \lambda - 1 = 0$, i.e. $\mu = 1 - \lambda$, 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] × [0, 1] → [0, 1], G_{pa}:[0, 1] × [0, 1] → [−1, 0], G_{ve}:[0, 1] × [0, 1] → [0, 1], G_{fa}:[0, 1] × [0, 1] → [−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,

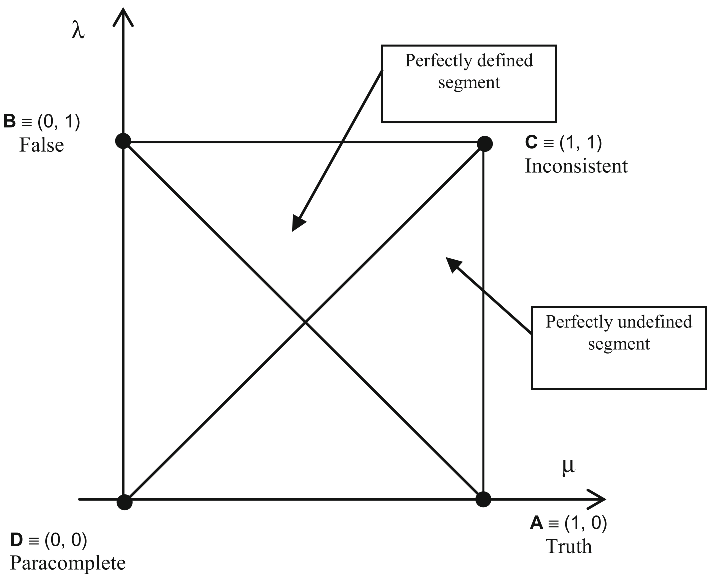

Fig. 1. τ reticulate [6]

and degree of Paracompleteness "measures" how an annotation (μ, λ) "distances" of the segment undefined, and how "close" it is from paracomplete. Is called G_{in} 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, i.e. G_{ic} (1, 1) = 1. It is called the Certainty Degree G_{ce} (μ, λ) of an annotation (μ, λ) to any of the degrees of truth or falsity.

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 Embedded Software

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 [7].

Both evidence values are obtained with an interval of 500 ms 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 (Fig. 2), according to the application requirements [8]. 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.

Once switched on, the panel starts a 135° full scan, stopping where it finds the strongest favorable evidence (μ). From this point, the corresponding logic state found in this position will indicate the following action to be taken.

- Logical state Truth (V): the panel stays in the same position.
- Logical states Inconsistent and Paracomplete (T and ⊥): run a second full scan of 135°.
- Logical states Almost-Truth tending to Paracomplete (QV → ⊥) and Almost-Truth tending to Inconsistent (QV → T): run a partial scan of 81°.
- Logical state False (F): after a second full scan, the system enters in Standby mode.

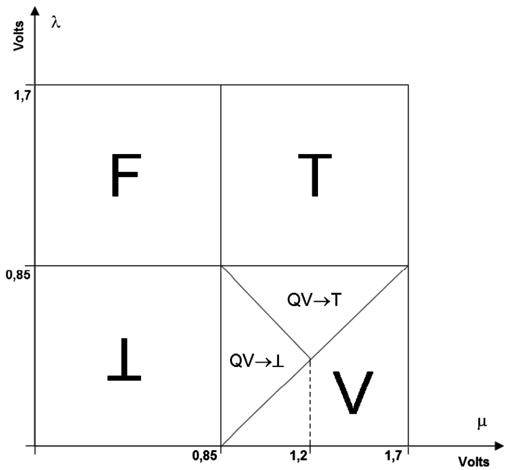

Fig. 2. Aspect of the lattice with corresponding voltage levels to the logic states.

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

In order to validate its operation, a series of daytime tests were done in a rooftop environment in November 2013, with good weather.

During three days the generated power was measured and compared with a fixed panel of the same type as the one used in the prototype. An increase of 31.56 % could be achieved in this particular days (Fig. 3) specially during the morning hours and late

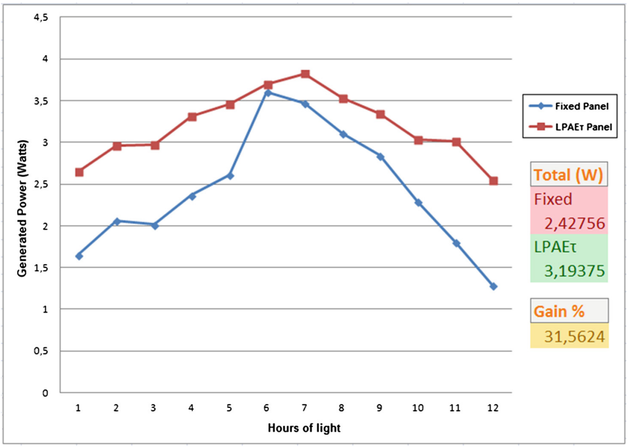

Fig. 3. Results obtained with the prototype.

afternoon, when the fixed panel has its performance greatly reduced. This result is similar to others found in the literature, specially in Huang et al. [9] (35.8 %) and Salas et al. [10] (2.8 %–18.5 %), when compared with fixed panel systems.

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 Eτ 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 3.19 W provided by the proposed system against 2.44 W 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.

Acknowledgements. This work has been supported by FCT – Fundção para a Ciência e Tecnologia in the scope of the project: PEst-OE/EEI/UI0319/2014 by Portugal and University Paulista - Software Engineering Research Group by Brazil.

References

1. Bursztyn, M.A.: Difícil Sustentabilidade: Política Energética e Conflitos Ambeintais. Garamond, Paris (2001)
2. CRESESB, Centro de Referência para Energia Solar e Eólica Sérgio de Salvo Brito. Energia Solar: Princípios e Aplicações (2006)
3. Santos, J.L., Antunes, F., Chebab, A., Cruz, C.: A maximum power point tracker for PV systems using a high performance boost converter. Solar Ener. **80**, 772–778 (2005). Elseiver
4. Da Costa, N.C., Abe, J.M.: Lógica Paraconsistente Aplicada. Atlas, London (1999)
5. Ishaque, K., Salam, Z.: A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition. Renew. Sustain. Ener. Rev. **19**, 475–488 (2012). Elseiver
6. Abe, J.M., Silva, F., João, I., Celestino, U., Araújo, H.C.: Lógica Paraconsistente Anotada Evidencial Eτ, Comunicar (2011)
7. Nogueira, M., Machado, R.J.: Importance of risk process in management software projects in small companies. In: Grabot, B., Vallespir, B., Gomes, S., Bouras, A., Kiritsis, D. (eds.) Advances in Production Management Systems, Part II. IFIP AICT, vol. 439, pp. 358–365. Springer, Heidelberg (2014)
8. Torres, C.R.: Sistema inteligente baseado na lógica paraconsistente anotada Eτ para controle e navegação de robôs móveis autônomos em um ambiente não estruturado. Doctoral thesis, University of Itajubá (2010)

9. Huang, B.J., Ding, W.L., Huang, Y.C.: Long-term field test of solar PV power generation using one-axis 3-position sun tracker. Solar Ener. **85**, 1935–1944 (2011). Elseiver
10. Salas, V., Olías, E., Lásaro, A., Barrado, A.: Evaluation of a new maximum power point tracker (MPPT) applied to the photovoltaic stand-alone systems. Solar Ener. Mater. Solar Cells **87**, 807–815 (2004). Elseiver