TÉCNICO LISBOA

Fast response MPPT switched charger for the Técnico Solar Boat

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Introduction to the Research in

Electrical and Computer Engineering

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Abstract

Resumo do trabalho
Keywords: MPPT, MPPT topology, DC-DC Converter

Contents

Acronyms

IST	Instituto Superior Técnico
TSB	Técnico Solar Boat
MPPT	Maximum Power Point Tracker
MPP	Maximum Power Point
PCB	Printed Circuit Board
CAN	Controller Area Network
USB	Universal Serial Bus
GUI	Graphical User Interface
PV	Photovoltaic

1 Introduction

1.1 Motivation

As the world is reaching a point where pollution is taking over the news, solar panels are one of the main solutions available. In 2024, 7% of the energy produced in the world comes from solar panels, and in Portugal this number rises to 14.5% [1]. Solar energy still plays a miniscule role that it is listed behind the other sources of energy in terms of the contribution for meeting the world's energy demand. But as the years go by, solar energy is becoming more and more relevant, with the cost of solar panels dropping significantly in the last decade.

In comparison to other forms of alternate energy, Photovoltaic energy is relevant due to its availability, simplicity, lower maintenance, environmental friendliness, reliability and many other benefits. More recently, is becoming more and more relevant in the automotive industry, with solar powered cars, boats and robots. The CO2 emissions of automotive sector is one of the main contributors to global warming. More than 30% of total CO2 emissions in the EU in 2018 came from transport, with 3% of global pollution coming from the maritime sector alone [2] [3]. And that is where the Técnico Solar Boat (TSB) project fits in.

In 2015, TSB was created with the goal of designing and building a solar powered boat to compete in international competitions. Since then, the project has growth and built several vessels. It begined with the construction of the first prototype, São Rafael 01 wich had a lot of room to improvement and so São Rafael 02 and 03 were built.

All of these prototypes used solar energy to maximize their range and efficiency. In the first years the energy produced was not much and the all system were commercial available. But as a team of students that want to push the limits of solar power boats and the overall technology, the ”built your self” philosophy was presented all over the years. And that is why we started building our own solar panels in 2020 for São Rafael 03. As the years went by, a lot of other systems were designed and built in house but there is still one system that is yet to be developed, the Maximum Power Point Tracker (MPPT).

The MPPT is a fundamental part of any solar energy system. Its main goal is to maximize the energy extracted from the solar panels by operating them at their Maximum Power Point (MPP). This is done by adjusting the electrical operating point of the modules or array.

1.2 Objectives

This project aims to design and implement a MPPT system for solar panels used in the TSB project. The MPPT will convert the energy produced by the solar panel as efficiently as possible with the use of a quality DC-DC converter and the implementation of MPPT algorithms.

So the main objectives of this project are:

- Study and understand the operation of solar panels and MPPT techniques.
- Chose the most suitable DC-DC topology for the MPPT system.
- Design and simulate the MPPT system.
- Implement a fast response control algorithm for MPPT.
- Implement the MPPT system in hardware and develop a Printed Circuit Board (PCB).
- Test and validate the performance of the MPPT system.
- Ensure the safety and reliability of the MPPT system for its integration in the TSB project.
- Provide data to the user about the performance of the solar panel and MPPT system through a Controller Area Network (CAN) communication interface.

By achieving these objectives, the project will contribute for a better control of the system, maximizing the data received from the solar panels to later improve the energy efficiency of the MPPT or even take conclusions about the manufacture quality of the solar panels build by TSB project.

1.3 Outline

Explain how the work is organized by chapters.

2 Background

Before entering into the specific details about the project, in this chapter i will explain some general concepts that will help to understand better the following chapters.

2.1 Solar Panels

Solar panels, also know as Photovoltaic (PV) panels are devices that convert sunlight into electrical energy. Each solar panel is made of multiple solar cells connected in series and/or parallel. As in electrical circuits, the connection type will affect the voltage and current output of the panel. More specifically, series increases voltage and parallel increases current.

Each cell is made of semiconductor materials, usually silicon. This semiconductor is doped with phosphorus, a group V element, to create a negative type layer. On the other side, a layer is doped with boron, a group III element, to create a positive type layer. This creates a p-n junction, which is essential for the photovoltaic effect.

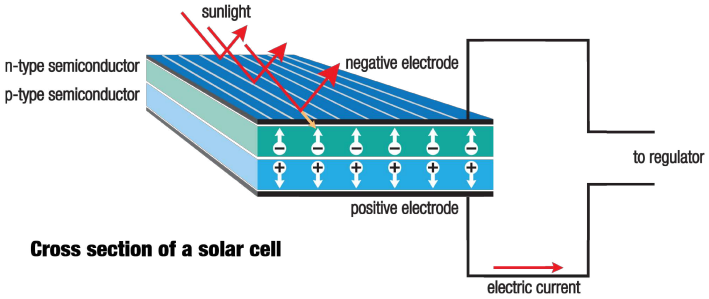

Figure 2.1: Principle of operation of a solar panel

When sunlight hits the solar cell, photons from the light energy are absorbed by the semiconductor material. This energy excites electrons, allowing them to break free from their atoms and create electron hole pairs. The electric field at the p-n junction drives these free electrons towards the n-type layer and holes towards the p-type layer, generating a flow of electric current when the cell is connected to an external circuit, [4].

This energy produces a direct current (DC) voltage and current output, which are not constant. Both voltage and current can are codependent, so if one suffers variation the other will too. This variation

is not linear and can be represented in an I-V curve, as in Figure 2.2. Also, the power output suffers variations, which can be represented in a P-V curve.

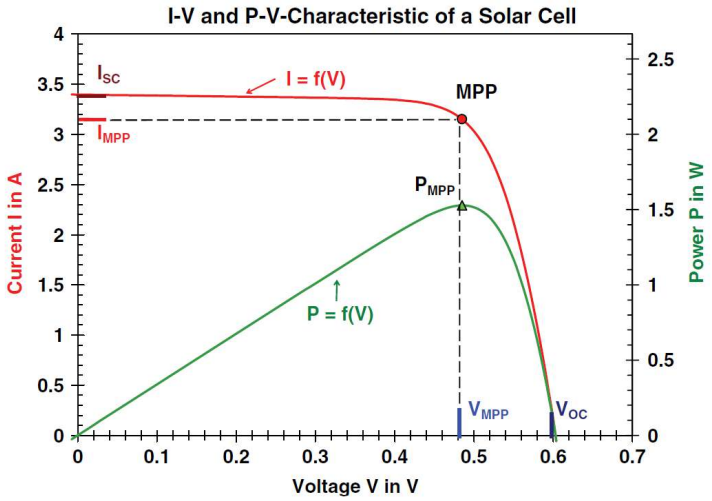

Figure 2.2: I-V and P-V curves of a solar panel [4]

The efficiency of a solar panel depends on various factors, including the quality of the materials used, the design of the cells, and environmental conditions such as temperature and irradiance.

Add more details about solar panels, like I-V curve, power curve, and cganges with irradiance and temperature.

2.2 MPPTs

2.3 TSB Project

3 State-of-the-Art

Intro if needed

3.1 MPPT algorithms

Escolher algumas para falar

3.1.1 Constant Voltage (CV)

3.1.2 Fractional Open Circuit Voltage (FOCV)

3.1.3 Fractional Short Circuit Current (FSCC)

3.1.4 Perturb and Observe (P&O)

3.1.5 Incremental Conductance (IncCond)

3.1.6 Method beta

3.1.7 Method based on temperature

3.2 MPPT converter topology

Intro..

Escolher algumas para falar

3.2.1 Buck Converters

3.2.2 Boost Converters

3.2.3 Buck-Boost Converters

3.2.4 Sepic Converters

3.2.5 Half-Bridge Converters

3.3 Comercial MPPTs

Table with comercial MPPTs and some of their carateristics.

3.4 Battery charging unit

3.5 Protection circuits

4 Solucion Proposal

4.1 Microntroller

Explicar a escolha do microcontrolador, o que ele faz, etc

4.2 Communication

sensors, CAN, USB, GUI

4.3 Current and Voltage Sensing

pq que é necessarion, e o que é que escolhi

4.4 Power electronics

Topologia escolhida, pq, vantagens e componentes

5 Preliminary Work

6 Planning and Scheduling

Fazer um planeamento com um gantt chart e explicar as decisoes

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A Appendix Name