Advanced control for renewable energy systems

Nowadays renewable energy is a long term solution for replacing the conventional sources of energy. It is known that the sun provides our planet enough energy to sustain the modern life style of its inhabitants. Many countries reoriented their policies regarding the production of energy and embraced the production of “green energy”. The use of photovoltaic (PV) arrays and wind turbines has become very popular.
Nevertheless this “free energy” arises new challenges. Some of the big inconveniences of these alternatives are represented by a low conversion rate of the energy and the necessity of using an energy storing system. Another drawback is the reduced transfer efficiency between the PV arrays or/and wind turbines and the consumers. Since the energy provided by the sun should be sufficient to cover all the world’s energy consumption, if captured and stored at reasonable costs, the use of photovoltaic panels will have an increased popularity in time. The “green energy” sector comes with new challenges such as low conversion rates, additional energy storage systems and transfer inefficiency between the PV array and its connected load. Photovoltaic power stations up to 500kw both in isolated areas and in urban zones will have an exponential development, as many countries reorient their policies regarding the production of energy embracing the use of “green energy”. As such, the global tendency is to promote the concepts of energy optimization and energy independence through renewable sources, and among these, the photovoltaic panels are the most favorable. In this sense, the European Union has set the directive 2010/31/UE, in which, by 2021, all new building should be “nearly zero-energy buildings”, suggesting that a significant amount of energy should be covered by renewable sources, local or nearby.Because PV panels still have a reduced conversion rate, a strong and fast power variation and a wide geographical distribution of PV generators, it is implicitly obvious that an optimal energy management is essential. There are two important solutions for achieving this: the first one consists in the construction of a large energy grid, spread on geographical regions with variable power generation conditions, whereas the second approach implies the use of Smart Storage solutions [7]. Three main types of storage exist: Mechanical storage, as for example: water pumping systems (ex: storage by water pumping in Ludington: 110m, 1.87 GW, 15h, 27 million kWh); battery based solutions with different types of batteries used, each with its own advantages and disadvantages [8],[13]; and, finally, hydrogen based storage, bringing a high energy density, good conversion efficiency and physical robustness [10].The goal of this thesis is to present and compare different control strategies for systems that are powered by renewable sources of energy. A prototype for testing purposes was designed.This thesis treats different aspects such as PV panel modelling, buck converter

modelling, building a non-linear observer, a control algorithm based on maximum power point tracking (MPPT),a polynomial control algorithm, the stability of the system.

Chapter 2 presents different photovoltaic cell models that can be further used in control loops. A graphic user interface is created for facilitating the computation of certain parameters and of the power-voltage / current-voltage characteristics of a PV panel. Furthermore a state space model and a transfer function model of some DC/DC converters are presented.

Chapter 3 focuses on elaborating a Takagi-Sugeno (T-S) observer which will provide the estimated voltage of the PV panel. The latter will later be used in the control block or it can serve for diagnosis purposes.

Chapter 4 compares different classical MPPT algorithms, as well as advanced control algorithms which may be later used to improve the performances of the control loops. A case study on a supervisory control that uses fuel cells is proposed.

Chapter 5 is oriented on a rather practical approach. It presents a distributed control system that is managed via an OPC server. A data acquisition system stores the data sent by each of the control loops and is able to plot data in real time.

Chapter 6 is dedicated to the conclusions.

Chapter 7 presents the code of the developed software and some schematics that were used during simulations.

Chapter 8 lists the bibliography.