## SUMMARY OF THE THESIS

## ENERGY AND ECONOMIC EFFICIENCY USE OF RENEWABLE SOURCES FOR LOCALITIES SUPPLY

Systems for electricity production using renewable resources (especially wind and solar) occurred due to the need of reducing emissions of conventional power plants.

With awareness of the factors that adversely affect the environment and network penetration due to wind and solar systems, these systems have been developed and continuously evolved; there are currently a variety of such systems, from the point of view of the installed power and used schemes. The emergence of new policies and even philosophers energy such as sustainable development further boosted the renewable energy electricity production.

Knowledge of these renewable resources in terms of potential, advantages, disadvantages, technical and economic impediments and prospects is of particular importance, especially for some conversion systems that are using intermittent resources for the supply of consumers with lower electricity demand but powerful variable.

The studies conducted so far do not show a uniform synthesis of all the problems and peculiarities that occur in the electrification of localities: the causes and factors where there is no electricity, energy management in rural electrification, rural electrification criteria, establishing clear steps for the implementation of renewable energy systems, algorithms and design patterns, and factors that influence the total initial costs and lifetime costs.

The objectives of this thesis: to analyze different configurations that includes wind turbines and solar panels in order to obtain an efficient supply of a locality. Are presented different hybrid systems with and without storage batteries and their economic analysis.

The issues dealt in terms of analytical and numerical application summary focuses on the following objectives:

- Identification of significant issues in terms of trends in the use of renewable energy for sustainable development and in particular the combined use of those;
- Summarize aspects of the evolution, structure, renewable energy classification, application areas and the problems introduced in the Power System;
- Mathematical models systematization that are describing the characteristics of the basic components of renewable energy systems and energy management strategies;
- Sizing the components of a system with renewable energy sources including specific aspects of photovoltaic and wind subsystems using linear programming.

The PhD thesis is divided into 8 chapters, bibliography and appendices and also combines the theoretical and practice aspects as well regarding the developing of a renewable energy system for supplying a city with electricity compliance with grid connection requirements and national and international environmental standards.

In this paper, are used specialized software programs for analyzing and processing dates.

As a result of the research activity, the PhD student has published 12 articles, by exposing national and international results obtained within the thesis.

Two of these papers were made as single author, and the remaining works in collaboration with experts in the field. From the 12 papers, 2 were presented at the workshop organized by the contract POSDRU/88/1.5/S/50783, Strategic Project ID 50783 (2009), co-financed from the European Social Fund - Investing in People, the Sectoral Operational Program human Resources Development 2007-2013.

The ***first chapter*** has an introductory character. This includes a brief history, the current state of renewable energy sources, classification and thematic justification that constitute the subject of the thesis, in the current context of renewable energy development and existing concerns worldwide and in our country, and continues by presenting summary of each chapter of the thesis. Finally it highlights the number of published articles during the preparation of the thesis and some aspects of future research directions.

Each chapter includes a final chapter that highlights the conclusions and personal contributions.

***Chapter 2*** provides a summary of the current situation regarding the evolution of the energy sector, in general, and renewable energy, in particular.

In the first part of the chapter the attention is focused on the current state of primary energy sources and the development of legislation and policy in the field of Renewable Energy Sources (RES). Are also reviewed the main aspects of trends and achievements in the field of RES in Europe.

The second part of this chapter focuses on policy and implementation strategy of RES in Romania. There are presented the legislation, national achievements and prospects in the production of electricity sector from renewable sources.

***Chapter 3*** presents concepts regarding the wind power, advantages and disadvantages of wind turbines, the most used wind turbines widely, the developed power of a wind turbine and affecting factors.

It is presented a mathematical model of a wind turbine and the control mode in order to obtain the maximum power. Also it is described the economic analysis of a group that includes 10 wind turbines of 100 kW and it is calculated the payback period.

In ***chapter 4*** are presented the advantages and disadvantages of solar panels. It is described the method to estimate the solar radiation available on an inclined plane and the installed power plants in Romania.

The chapter includes a mathematical model of photovoltaic simple circuit panels with a single or double diode in parallel with or without resistance. The model is implemented in Matlab Simulink modeling a panel of Kyocera KD240GH-2PB and where obtained the VP and VI characteristics for different irradiation and different ambient temperatures.

Also this chapter includes the author's own vision of a renewable energy system sizing using linear programming. Were dimensioned systems with two types of wind turbines and two solar panels, placing restrictions on their number.

Linear programming mathematical model is implemented in Matlab and the produced power during a year of wind turbines and solar panels are made with Homer program.

The final part of this chapter includes an economic analysis for choosing the optimal power supply of a locality. Were analyzed three variants: Wind Turbines- Network, Photovoltaic Panels -Network and, Wind Turbines - Photovoltaic Panels - Storage Batteries-Network.

To purchase electricity from the grid were considered three time zones: top, goal and normal zone. For choosing the optimal variant were considered fixed solar panels, inclined at 35 degrees. Of the three analyzed cases the resulting minimum energy cost was for case 3: $ 0.216 / kWh.

***Chapter 5*** describes some notions regarding the need to storage electricity from renewable energy sources and also presents a classification of energy storage systems from these sources and their brief description. The chapter includes the characteristic parameters of a battery and some mathematical models used in the literature.

The second part of the chapter presents the performed tests on a lithium battery in the endowment of the Faculty of Applied Sciences Hochschule Darmstadt in Germany. These tests were performed in an internship period for 3 months.

Various tests were done loading and unloading the battery from the public network and the network parameters monitoring was performed in the presence of the battery.

Online monitoring parameters and storing the dates obtained were performed using the software imcPolares. The measurements were compared to limits imposed by the European standard EN 50160. Analyzing the results of performed measurements on the battery system results that the electricity quality parameters fall generally within accepted norms.

***Chapter 6*** presents the technical conditions for connection the wind farms and photovoltaic plants SEN and voltage levels to which they are connected.

Are presented optimization techniques used in the energy. Solving an optimization problem requires first, the mathematical model formulating for the mathematical programming problem, model that should represent as accurately as possible the process technically and/or economically optimized.

The mathematical model of any optimization problem has a common structure that includes the following elements: variables and sizes optimized, objective function called also optimization function or criterion function and restrictions of the optimized variables.

Next steps in resolving the optimization problem are representing by: solving the mathematical model using specific methods and techniques of operational research and finally verify the results obtained through calculations. Are shown the components of the mathematical model and methods of solving these optimization problem regarding the optimized sizes, restrictions and objective functions in the general case.

Fuzzy control algorithm is presented, the operations that can be achieved with this technique. It is described using the Matlab program controlling a hybrid power system. This is done by using Matlab software control system with renewable energy sources used for a group of consumers.

As input load variation are considered: the power produced by wind turbines, the variation of energy produced by solar panels and battery charging status of battery. The output is the energy acquired from the network. When the energy produced by wind turbines and solar panels is not enough to supply the group of consumers then it can be used the storage batteries.

If batteries are not charged enough to provide electricity the deficit is taken from the network. There is the possibility for the renewable energy to provide enough electricity and the storage batteries to be fully charged, in this case an excess of energy is injected into the network. Fuzzy technique is used when there are no accurate dates regarding all the network parameters.

***Chapter 7*** presents general concepts on power quality.

Power quality is influenced by the work of the manufacturer, carrier, distributor, supplier and electrical energy consumer activity. Are presented the power quality components, electromagnetic disturbances affecting power quality and major national and international standards and regulations.

Were summarized the following problems that can occur when connecting photovoltaic and wind units into the power grid:

- Voltage variations in the grid;
- Voltage dips and temporary over voltage when connect and disconnect the wind and photovoltaic installations;
- Voltage fluctuations / flicker;
- Harmonics emissions and inter harmonics;
- Unbalance.

Standards produced by the specific energy systems (IEEE. IEC and EN) indicates the principal conditions were the wind and photovoltaic units can be connected to the public electricity network not to affect power quality. At the end of the chapter it is presented a case study using Homer program regarding a system consisting of photovoltaic panels, wind turbines and diesel generator.

***Chapter 8*** includes the overall conclusions of the thesis, the author's original contributions and future research directions and perspectives.

Appendices provide a number of additional elements regarding the climate dates used in the simulations and the types of photovoltaic panels and wind turbines used in the thesis.

## CONCLUSIONS, CONTRIBUTIONS AND PERSONAL PERSPECTIVE

### Conclusions

The last chapter summarizes a number of general conclusions resulting from the PhD thesis entitled ″Energy and economic efficiency use of renewable sources for localities supply″, original contributions made in the thesis, how to exploit the results and possible directions to continue and depth research on approach.

Promoting renewable energy sources involves solving problems, including: need not to affect the quality of electricity supplied to end users or safe operation of the power system and reduce the negative impact of pollutants on the environment.

Wind turbines and solar panels are considered as energy sources of the future. Interest in these fields is increasing in recent years due to negative consequences identified using conventional fuels to produce electricity. Among these consequences an important aspect is the environmental impact.

Renewable electricity production is not only modern, sustainable, low pollutant emissions, but is also a contributing factor to increased independence from fossil fuels, regardless of our opinion of them, are limited and eventually will be exhausted.

Increasing the share of renewable energy production is predictable, but depends on the reduction of production costs and finding new energy storage solutions.

This is not just a passing trend - the need to use renewable energy sources has become imperative for even the biggest economic powers.

Power electronics has grown significantly, increasing the number of receivers with nonlinear characteristics in electrical networks. These receivers, frequency converters used in RES systems are the main source of power harmonic which induces harmonic voltage at the PCC.

At the end of 2012, wind power covering 8% of total energy demand in the EU. Global installed capacity in CEE increased in 15 years from 6.1 GW (1996) to 283 GW (2012).

In the last years, new trends in energy have propelled in Romania the development of an explosive rate of wind turbines. As known, in our country has been approved installation of approximately 3,000 MW by the end of 2012, the facilities are located mainly in Dobrogea.

A hybrid system with renewable energy sources depends on the location where you want to implement it, being different from one area to another because the wind speed and solar radiation varies in Romania. So optimally sized system in Romania southern may be inadequate in Romania northern, weather conditions are different from one area to another. Therefore when using a renewable energy system it must be taken into account the local weather conditions.

Renewable energy systems can use the method of storage allowing energy production instead of reducing the transmission losses. For small accumulator batteries, was demonstrated that are not influencing the parameters of the connected network, the only problem is the cost of such a system.

The development of new energy storage systems leads to a better scenario in terms of energy production from renewable energy.

Using advanced technologies (single or coupled) optimizes electricity generation thereby reducing costs. In addition, a higher penetration of renewable and clean sources means a further reduction of power plants based on fossil fuels.

Power quality is influenced by the activity producer, carrier, distributor and supplier and also the energy and consumer activity.

Due to their variability, solar and photovoltaic disrupt power quality. To reduce these problems, a solution is to use methods that allow the use of energy storage on-site, no need for transport and energy distribution. Another solution is, besides the use of storage, presence of Diesel generator, which allows an exchange as reduced as possible with the energy grid.

From the analyzes performed in this thesis results that the renewable energy can supply a locality with electrical energy and reduce the CO2 emissions. The use of the on-site improve the quality of electricity.

**Personal contributions**

The author has managed to make a number of contributions, of which the most important are:

1) Achieving a documentary synthesis in the author's own vision on the role and place of renewable energy in sustainable development, globally, national and European plan;

2) Identify the benefits of wind turbines and photovoltaic panels that make them attractive in their use as power sources;

3) Highlight the contribution that wind turbines and solar panels can bring in order to limit greenhouse gas emissions and mitigate climate change:

- Making a documented summary, advantages and disadvantages of solar panels and existing mathematical models;
- Modeling using Matlab/Simulink of a photovoltaic panel for different values of radiation and temperature;
- Sizing a renewable energy system using linear programming, implemented in MATLAB;

4) Achieving an economic comparison of the power supply possibilities for a locality. Comparative analyses of these systems were performed using Homer program which is a program to optimize the operation of renewable energy;

5) Providing an overview on energy storage technologies from renewable energy sources and mathematical models used for model batteries modeling;

6) Measurements on a lithium storage battery during the internship research conducted at the University of Applied Sciences Hochschule Darmstadt, Germany within three months. Measurements were made for loading and unloading the battery from the public network and verify whether the network parameters are according to European standard EN 50160;

7) Processing and interpretation of the dates obtained from experiments and the influence of the battery on the public network;

8) Making applications using Matlab/Simulink for a solar panel;

9) Detailed presentation of mathematical models in the literature that reproduce the most closely behavior of a wind turbine and a solar panel;

10)Using Matlab to implement a technique for sizing renewable systems sizing techniques with renewable systems;

11) Highlighting the limitations in the operation of wind turbines and photovoltaic panels and the need to integrate them in hybrid systems both in the presence and absence of storage methods and the development of control strategies for these systems using fuzzy logic;

12) Investigate the economics of wind turbine systems using photovoltaic panels in various configurations for networked applications;

13) Establishment the prospects for further development of the research carried out in the paper.

**Possibilities for further research in the field:**

- Analysis of hybrid systems with renewable energy sources other than those used in this paper;
- Economic analysis using different orientations of photovoltaic panels;
- Mathematical modeling and control of converters used for wind turbines and photovoltaic panels using optimization algorithms;
- Analyzing the impact of the different networks combinations of renewable energy using optimization techniques and comparison with classical solutions.

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