Issues regarding the modelling and simulation of hybrid micro grid systems

I Szeidert\textsuperscript{1}, I Filip\textsuperscript{1} and O Prostean\textsuperscript{1}

\textsuperscript{1}Politehnica University of Timisoara, Automation and Applied Informatics Department, Vasile Parvan str., no. 2, 300223 Timisoara, Romania

E-mail: iosif.szeidert@aut.upt.ro

Abstract. The main followed objectives within control strategies dedicated to hybrid micro grid systems (wind/hydro/solar), that operate based on maximum power point tracking (MPPT) techniques are to improve the conversion systems efficiency and to maintain the quality of the produced electrical energy (the voltage and power factor control). One of the main goals of maximum power point tracking strategy is to achieve the harvesting of the maximal possible energy within a pre-set time period. In order to implement the control strategies for micro grid systems that operate at time variable parameter, there are usually required specific transducers (anemometer for wind speed measurement, optical rotational transducers, taco generators, etc.). In the technical literature there are presented several variants of the MPPT techniques, which are particularized at several applications (wind energy conversion systems, solar systems, hydro plants and micro grid hybrid systems). The maximum power point tracking implementations are mainly based on two-level architecture. The inferior level controls the primary variables, while the superior level represents the MPPT control structure. In the paper, authors present some micro grid structures proposed at Politehnica University Timisoara within the frame of a research grant. The paper is focused on the application of MPPT strategies on hybrid micro grid systems. There are presented several structures and control strategies and are highlighted their advantages and disadvantages, together with practical implementation guidelines.

1. Introduction

In technical literature, the micro grids are defined as aggregates/clusters of different generation systems that are interconnected together under a common control system стратеги. In those clusters there can be found solar/wind/hydro aggregates and/or other energy sources, storage devices and other additional equipment. In present, there are in progress numerous researches regarding the domain of hybrid micro grids [1], [2].

Also, at Politehnica University of Timisoara, there have been performed researches in afferent domains, since 1980 in domain of wind energy conversion systems. The authors of the present paper are one of the members of research grant that is focused on the hybrid conversion systems for renewable energies integrated into a micro-grid (research grant’s acronym MICOREN).

The researchers are focused on the research, design and testing of flexible and intelligent micro grid, based on the integration of three types of renewable resources of energy: wind, solar and hydro. One of the main activities involves the study of the micro grid behavior under different operating conditions. In this order of idea there are required to be modeled and simulated all the component elements of different micro grid type structures.
In the paper there are presented issues on the above mentioned problematic, together with a proposed and analyzed control strategy of MPPT (maximum power point tracking) type.

2. Issues on modelling, simulation and control of micro grid elements/components

The increasing concerns of environmental issues require for the search for new and more sustainable electrical sources. Wind turbines, solar energy, hydro energy combined with fuel cells can be considered as possible answers for the environmental-friendly electrical energy production. Wind turbines are systems that include a rotor, a generator, turbine blades, and a drive or a coupling device. Mainly, those are equipped with squirrel cage induction generators, doubly fed (winded) induction generators or synchronous generators [3], [4], [5].

The authors present in Figure 1 a structure for a wind turbine emulation used in the research laboratory at the Politehnica University of Timisoara.

![Figure 1. Schematics of the wind turbine emulator — experimental stand at Politehnica University Timisoara](image)

The authors have performed the mathematical modeling and simulation of the wind energy conversion system in the Matlab environment. Some issues that must be considered in the case of the electrical machine modelling is to linearize the mathematical models in some operating regimes in order to reduce their order (as example in the case of the double wined induction machine the model has at least 7th order). The photovoltaic (PV) generation systems are also expected to increase significantly at worldwide level. PV’s are an attractive source of renewable energy for distributed urban power generation due to their relatively small size and noiseless operation (versus wind turbines) [6], [7].

Photovoltaic aggregates present the major advantage that there can be easily added supplementary units. Photovoltaic systems convert the sunlight directly to electricity. The technology is quite well established and widely used for power supplies. The PV cells can be modeled as a diode in parallel with a constant current source and a shunt resistor (this being the most common model). They have been also modelled in Matlab-Simulink. The issues are similar in the case of hydro aggregates. Another important problematic in the case of hybrid micro grids is the establishing of the operation modes / regimes for the entire energy conversion system. Usually, electronic power converters are used to connect DG systems in parallel with the power network grid or other sources, but it may be useful for the power converters to operate in stand-alone mode, when the other sources become unavailable to supply certain loads. Electronic power converters connected to batteries or other storage devices will also need to be bidirectional to load/unload those devices/equipment. Main operating regimes that can be identified in the case of micro grids are usually: nominal grid connection mode and stand-alone modes.
The future evolution of the electrical energy system should certainly get a higher degree of
decentralization concerning specially regarding the production and control issues. Therefore, the study
through modelling and simulation of integrated micro grid systems completed with their validation on
experimental setups should be of a high importance [8], [9], [10].

Regarding the control strategies there should be considered modern approaches such as the
maximum power point tracking (MPPT) techniques. The authors proposed and implemented such
structure as presented in Figure 2. The MPPT control strategy is placed on an upper hierarchical level
fulfilling the control structure placed on the lower hierarchical level. So, the outputs of the MPPT
control strategies are used as prescribed values for the control structure situated on the lower
hierarchical level [11], [12].

![Figure 2. MPPT structure for hybrid micro grids (two hierarchical level diagram)](image)

The proposed control strategy / structure was implemented and tested on laboratory setup. There
was used dedicated hardware based on PLC (programmable logic controller). The solution considered
the usage of a PLC from SIMATIC family and specific interfacing and connecting elements. The
structure of the used equipment is consisted from: central unit PLC – SIMATIC S7, digital input
module, digital output module, analog input module, analog output module, Ethernet communication
module, other related accessories. The chosen architecture assures the local control of the laboratory
setup (wind-solar hybrid system) and also the communication with the superior hierarchical
supervisory level of the assembly’s component elements. Through the mean of a SCADA system the
entire micro grid is controlled and is assured a correct functioning of the assembly. The system is
equipped with two data input/output devices constituted from a local touch panel and a remote
SCADA system, the communication between them being assured via internet (through Ethernet
modules). The programming language was STEP7 specific to the PLC from S7 family. There was
assured the optimal functioning of the entire system so that the obtained electrical energy to be
maximized in the given operating conditions.

The system control is performed by a power management unit. The hybrid system has three main
nominal operating regimes:
  - Regime 1: the wind turbine operates with power regulation and the PV is inactive;
- Regime 2: the wind turbine operates by MPPT and the PV completes the energy requirement, being integrated in the power loop;
- Regime 3: the both two renewable sources are operating by the mean of MPPT strategy.

3. Conclusions

In the paper, authors present some micro grid structures proposed at Politehnica University Timisoara within the frame of a research grant. There are presented issues regarding the modeling, simulation and control of small hybrid micro grids.

The main objectives to be achieved in the case of micro grid hybrid systems (wind/hydro/solar) that operate under the principle of maximum power point tracking (MPPT) is to increasing of energy conversion system’s efficiency, meanwhile assuring that the delivered electrical energy into the power grid is maintained at required quality levels. The main goal of any MPPT strategy is to reach a maximum of harvested/converted energy in nominal operating regimes within a certain time period.

There are presented several structures and control strategies and are highlighted their advantages and disadvantages, together with practical implementation guidelines. There is considered the implementation using SCADA and PLC equipment. There are presented issues regarding practical implementation solution on laboratory rigs.

There can be must be considered, that the MPPT strategy is proper for micro grid systems, because those systems are complex and present high order mathematical models (in this cases there can be difficult to use classical control strategies).

4. Acknowledgement

This paper was developed through the Partnerships in Priority Areas - PN II, with the support of ANCS, CNDI—UEFISCDI, Project no. 36/2012.

References

[1] Venkateswarlu K and Krishna J 2012 Modeling and Simulation of Micro Grid System Based on Renewable Power Generation Units by using Multilevel Converter, International Journal of Engineering Research & Technology 1(6)
[2] Deshmukh M K and Deshmukh S S 2008 Modeling of hybrid renewable energy systems, Renewable and Sustainable Energy Reviews 12 235–249
[3] Simoes G and Farret F 2004 Renewable Energy Systems – Design and Analysis with Induction Generator, CRC Press, Boca Raton, Florida, USA
[4] Budisan N, Prostean O, Boraci R, Szeidert I and Muller V 2010 The Dual Induction Generator for Renewable Energy Conversion Systems. Experimental Results, Problems and Solutions, IEEE International Joint Conferences on Computational Cybernetics and Technical Informatics (ICCC-CONTI 2010), Timisoara, Romania, May 27-29, pp 445-450
[5] Budisan N, Prostean O, Robu N and Filip I 2007 Revival by Automation of Induction Generator for Distributed Power Systems, in Romanian Academic Research, Renewable Energy 32(9) 1484-1496
[6] Zhu Y and Tomsovic K 2002 Development of models for analyzing the load-following performance of microturbine and fuel cells, Electric Power System Research 62(1) 1-11
[7] Nikkhajoei H and Iravani M R 2002 Modeling and analysis of a micro-turbine generation system, IEEE Power Engineering Society Summer Meeting, Chicago, USA, July 21-25, pp 167-169
[8] Valenciaga F and Puleston P F 2005 Supervisor Control for a Stand-Alone Hybrid Generation System Using Wind and Photovoltaic Energy, IEEE Transactions on Energy Conversion 20(2) 398 - 405
[9] ***2009 European Commission website on Micro grids. [Online] http://www.microgrids.eu
[10] ***2006 European Smart Grids Technology Platform: Visions and Strategy for Europe’s Electricity Networks of the Future. European Commission: Directorate-General for Research
[11] Lasseter B 2001 Micro grids [distributed power generation], *IEEE Power Engineering Society Winter Meeting* 1 146–149

[12] Zoka Y, Sasaki H, Yorino N, Kawahara K and Liu C C 2004 *An interaction problem of distributed generators installed in a micro grid*, Proceedings of IEEE on Electric Utility Deregulation, Restructuring and Power Technologies Conference, Hong Kong, China, April 5-8, pp 795–799