REGENSIM – MATLAB TOOLBOX FOR RENEWABLE ENERGY SOURCES MODELLING AND SIMULATION

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ABSTRACT

This paper deals with the implementation and development of a Matlab Simulink library named RegenSim designed for modeling, simulations and analysis of real hybrid solar-wind-hydro systems connected to local grids. Blocks like wind generators, hydro generators, solar photovoltaic modules and accumulators are implemented. The main objective is the study of the hybrid power system behavior, which allows employing renewable and variable in time energy sources while providing a continuous supply.

Keywords: renewable energy sources modeling and simulation, visual library, hybrid power systems

1. Introduction

The importance of hybrid systems has grown as they appeared as the right solution for a clean and distributed energy production. Hybrid power systems consist on a combination of renewable energy sources such as: photovoltaic (PV), wind generators, hydro, etc., to charge accumulators and provide power to meet the energy demand, considering the local geography and other details of the place of installation.

In this paper, the development of visual modelling tools based on Matlab functions for simulation, optimization and sensitivity analysis of small power generating systems based on renewable energy was considered useful by authors. Matlab software is built as a computer-aided design (CAD) application for modelling and simulation that allows adding new features for engineering applications.

To allow the modeling, simulation and analysis of a wide variety of systems based on renewable energy and a proper management of these systems, into the libraries of Matlab software the RegenSim library was added.

2. RegenSim library

This library was designed to allow visual modeling functions fulfilling the above conditions for hybrid systems based on renewable energy sources, but also to permit its components interfacing with components from other libraries, especially those of Matlab SimPowerSystems library to assure facilities in modeling and simulation of components and power systems.

RegenSim library was designed as a set of basic components shown in Fig.1. These basic components are: Wind group, Solar photoelectric panel, Hydro group and Accumulators. Each of these

components was developed by considering their own mathematical models and specified parameters.

Interfacing with Matlab library components was performed in order to make an elaborate study of modeled components of hybrid systems from local automatic control systems to centralized management systems. Each component of the RegenSim library has as input the primary energy source parameters. As output, different types of measurements can be tracked and displayed such as instantaneous voltages, currents, active and reactive powers or generated energy flows by interconnecting different blocks of Matlab libraries depending on the nature of the consumer.
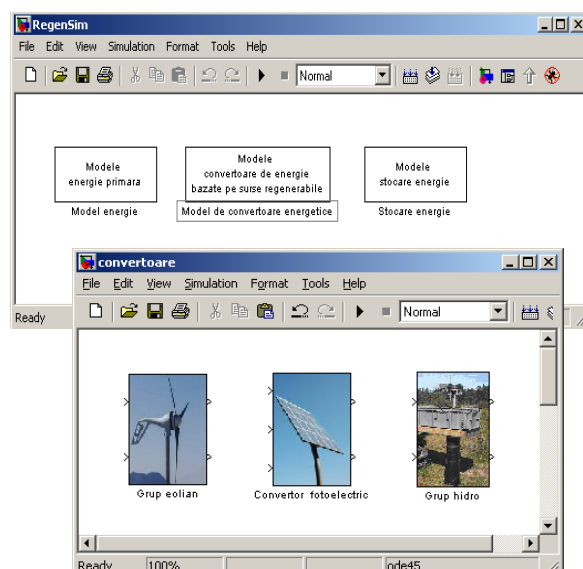

Fig. 1 – RegenSim Library blocks

3. Wind group block

Wind group model was developed by

assimilating the idea of permanent magnet synchronous generator functioning with that of a DC generator with permanent magnets. The aim is to deduct a mathematical model that can be implemented as a simulation model based on physical equations of operation. This aim was achieved by using the modelling principles of automated systems theory. Deduction of the mathematical model is based on electrical circuit's law and mechanical equilibrium law provided by (1) and (3) [1].

$$u_g = -R_g i_g - L_g \frac{di_g}{dt} + e \qquad (1)$$

where: u_g – generated voltage, [V];

R_g, L_g – resistance and inductance of stator circuit, [Ω],[H];

e – induced voltage in the rotor [V], given by:

$$e = k_e \Omega \qquad (2)$$

where: Ω – angular velocity of the blades, [rad/s];

k_e – electric constant of proportionality.

$$C_m = k_m i_g + J \frac{d\Omega}{dt} + b\Omega + C_r \qquad (3)$$

where: C_m – mechanical torque at generator shaft, [Nm];

C_r – resistant torque, [Nm];

k_m – mechanical constant of proportionality;

J – rotating masses moment of inertia, [kg m^2];

b – viscous friction coefficient.

Thus, the Wind group block with its mechanical and electrical input parameters graphical interface is presented in Fig. 2.
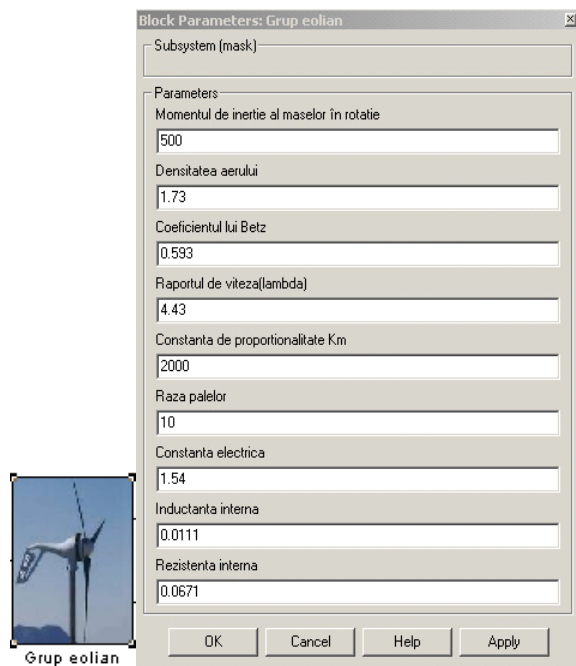

Fig. 2 – Wind group block with mechanical and electrical parameters input window

4. Hydro group block

The hydro group can assimilate the mathematical model derived from the model of the wind group (relations 1 and 2) with the specification that the electrical and mechanical parameters of the hydro group are considered.

Thus, for the hydro group block was designed a GUI (graphical user interface) for the introduction of electrical and mechanical modeling parameters as those presented in Fig. 3.
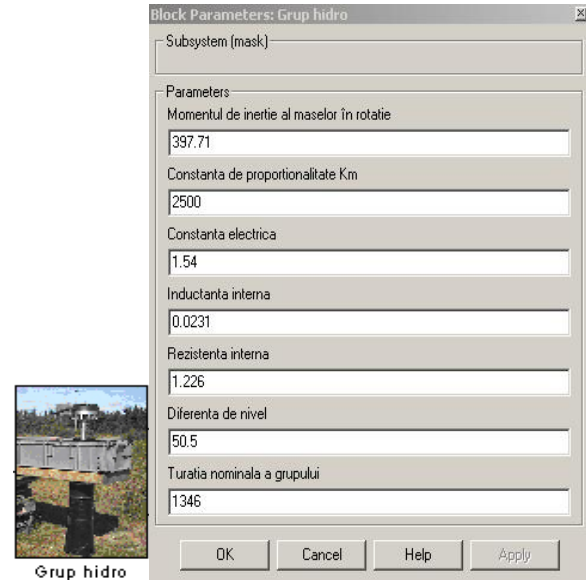

Fig. 3 –Hydro group block with mechanical and electrical parameters input window

5. Solar photoelectric panel block

The model of the solar cell can be realized by an equivalent circuit that consists of a current source in parallel with a diode as in Fig. 4. [2], [5]
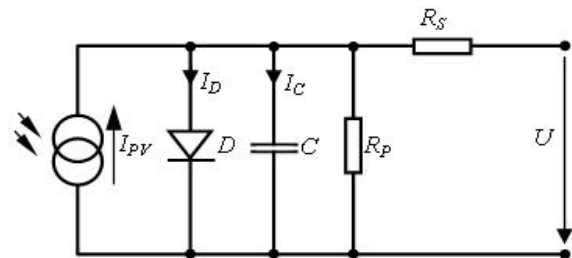

Fig. 4 – Equivalent circuit diagram of a solar cell

The diode is the one which determines the current-voltage characteristic of the cell. The output of the current source is directly proportional to the light falling on the cell. The open circuit voltage increases logarithmically according to the Shockley equation (relations 4 and 5) which describes the interdependence of current and voltage in a solar cell [2], [3], [4].

$$I = I_f - I_0 \left(e^{\frac{qV}{k_B T}} - 1 \right) \; [A] \qquad (4)$$

$$U_{oc} = \frac{k_B T}{q} \ln\left(1 + \frac{I_f}{I_0}\right) [V] \qquad (5)$$

where, k_B - Boltzmann constant, [J/K];

T – reference temperature of solar cell, [^oC];

q – elementary charge, [As];

V – solar cell voltage, [V];

I_0 – saturation current of the diode, [A];

I_f – photovoltaic current, [A].

Thus, the Solar photoelectric panel block with its physical and electrical input parameters graphical interface is presented in Fig. 5.

Fig. 5 – Solar photoelectric panel block with physical and electrical parameters input window

6. Accumulator block

Accumulator block was developed with the main function to serve as a buffer for storing energy produced by renewable sources. It feds directly the DC consumers, but also the AC consumers through inverters blocks.

The mathematical model deduction of this block was based on Thevenin equivalent electrical model shown in Fig. 6 and on the corresponding equations model, also presented in relations (6) and (7).
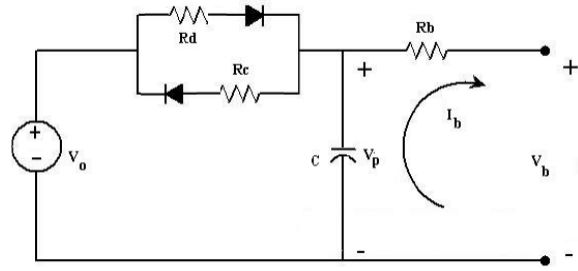
$$\dot{V}_p = \frac{1}{C}\left(\left(\frac{V_0 - V_p}{R_d}\right) - I_b\right) [V] \qquad (6)$$

$$V_b = V_p - I_b R_b [V] \qquad (7),$$

where, V_0 – open circuit voltage [V];

V_p – internal capacitor voltage [V];

V_b – terminal voltage [V];

Rc – charging resistance [Ω];

Rd - discharging resistance [Ω];

Rb - internal resistance of the accumulator [Ω]

C - polarization capacitance of the

accumulator [μF].

The current I_b is taken as positive if discharging and negative otherwise.

Fig. 6 – Thevenin equivalent accumulator model [6]

Thus, the Accumulator block with its electrical input parameters graphical interface is presented in Fig. 7.

Fig. 7 – Accumulator block with electrical parameters input window

At the accumulator level can be monitored, measured and displayed parameters such as accumulator state of charge (SOC), terminal voltage or currents absorbed by consumers using compatible blocks from the Matlab's SimPowerSystems library.

7. Conclusions

Paper presents the modeling in Matlab Simulink environment of a library named RegenSim

developed for solar-wind-hydro hybrid system applications. Based on the presented mathematical models the RegenSim library represents a useful tool for analysis and simulation of real hybrid solar-wind-hydro systems connected to local grids.

The RegenSim library contains blocks like wind generators, solar photovoltaic modules, hydro generators and accumulators. It also represents a useful tool in research activity and also in teaching. RegenSim Library has the advantage of being a tool that can be used to analyze renewable energy sources and also for designing management systems based on renewable energy technologies.

Also, based on RegenSim library, theoretical models of renewable-based systems can be built to identify problems such as renewable resource availability, power flows or the energy power quality problems. In this idea RegenSim can be used as a tool for assisting the design process of electro energetic systems based on renewable resources.

Matlab's software platform evolution does not allow for the moment the RegenSim library portability from one version to another. In the near future is intended to ensure this portability.

The team currently works to develop a library that can be used on open source platforms such as Octave.

Acknowledgment

References
[1] Dumitru, C.D. and Gligor, A. - *Modeling and Simulation of Renewable Hybrid Power System Using Matlab/Simulink Environment*, in: Scientific Bulletin of the „Petru Maior" University of Târgu Mureş, Vol. 7 (XXIV), no. 2, pp. 5-9, România, 2010;
[2] Kaltschmitt, M., Streicher, W., Wiese, A. - *Renewable Energy, Technology, Economics and Environment*, Springer-Verlag, Berlin Heidelberg, 2007;
[3] Patel, M. R. - *Wind and solar power systems*, CRC Press LLC, Boca Raton, Florida, USA, 1999;
[4] Dumitru, C.D. - *Identificarea Surselor de Producere a Energiei Electrice din Surse Regenerabile*, Referat de doctorat, Universitatea Tehnică din Cluj Napoca, România, 2007;
[5] Markvart, T. and Castaner, L. - *Practical Handbook of Photovoltaics, Fundamentals and Applications,* Ed. Elsevier, Oxford, UK, 2003;
[6] Vairamohan, B., *State of Charge Estimation of Batteries*, A Thesis Presented for the Master of Science Degree, The University of Tennessee, Knoxville, U.S.A., 2002;
[7] Dumitru, C.D., Gligor, A. - *Software Development For Analysis Of Solar-Wind Hybrid Systems Supplying Local Distribution Networks*, Acta Electrotehnica, Special Issue: Proceedings of the 2nd International Conference on Modern Power Systems MPS 2008, 12-14 nov. 2008, pp. 220-223, România, 2008.