

# FACILITIES OF MATLAB ENVIRONMENT FOR SIMULATION, OPTIMIZATION AND SENSITIVITY ANALYSIS

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## **ABSTRACT**

*The paper presents the modeling of a solar-wind-hydroelectric hybrid system in Matlab/Simulink environment. The application is useful for analysis and simulation of a real hybrid solar-wind-hydroelectric system connected to a public grid. Application is built on modular architecture to facilitate easy study of each component module influence. Blocks like wind model, solar model, hydroelectric model, energy conversion and load are implemented and the results of simulation are also presented. As an example, one of the most important studies is the behaviour of hybrid system which allows employing renewable and variable in time energy sources while providing a continuous supply. Application represents a useful tool in research activity and also in teaching.*

**Keywords: Modelling, Simulation, Renewable Energy.**

## **I INTRODUCTION**

In this paper we are using the facilities of Matlab environment for simulation, optimization and sensitivity analysis of small power generating systems based on renewable energies. To allow, however, the modeling, simulation and analysis of a large variety of systems based on renewable energy and to manage these systems, the software Matlab was expanded with the RegenSim library. This library was designed to implement the above functions for hybrid systems based on renewable energy sources, but also their components interfacing with components from other libraries, particularly those of MatlabSimPower Systems library.

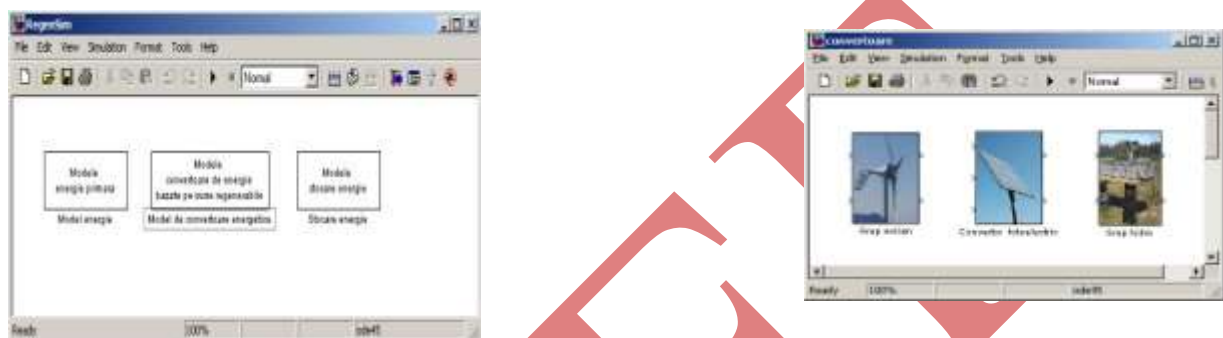
Basic components of RegenSim library are: Wind generators, PV generators, Hydro generators and Storage devices (Fig.1). Each of these components was basically modeled on studies of mathematical models and has associated specific parameters.

The interfacing with Matlab libraries components was realized in order to make a thorough study of the modeled hybrid system from local automatic control systems to the centralized operational management system. Except for Storage device component, each of the other three components has, as input parameters, the specific primary source of energy and, through interconnection with different types of measurement and display blocks of Matlab, voltages, currents, powers and energy flows from the system, depending on the nature of the consumer, can be watched. The Storage device component was designed with the primary function of serving as a buffer to store the energy produced by renewable sources, from its terminals being directly supplied the DC consumers and the AC through the inverter blocks.

At the batteries level can be monitored by using measure and display blocks from Matlab, the size and state of

battery charge (SOC), the terminal voltage or currents absorbed by consumers.

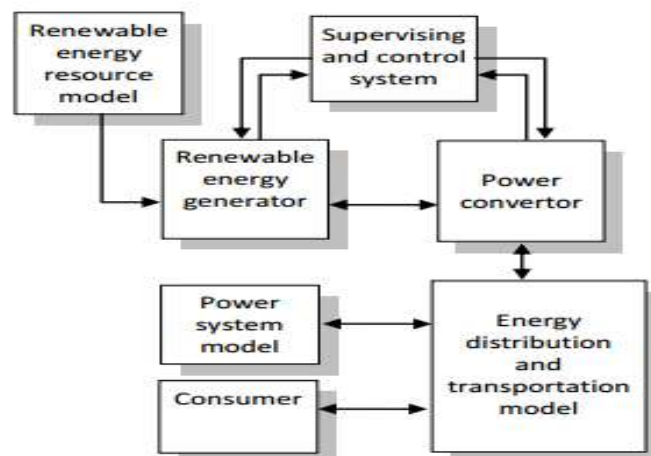
One of the advantages of Matlab software is that libraries offer a wide range of basic components for modeling the consumers. Thus, it can be modeled both single-phase or three phased consumers with different powers, nature and types (e.g.: resistive, capacitive or inductive consumers).



**Fig. 1. Matlab/Simulink RegenSim library components**

## II SIMULATION SOLAR-WIND-HYDROELECTRIC HYBRID SYSTEM ARCHITECTURE

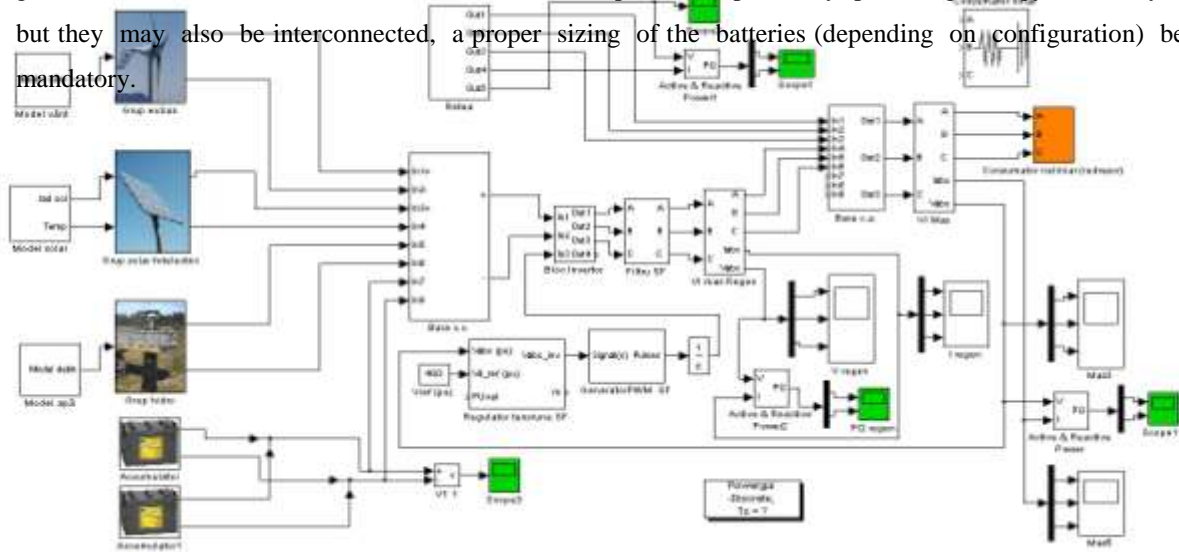
The simulation model was implemented according to the system architecture presented in Fig. 2. Using this architecture we can model any system based on renewable energy sources. One or more types of primary sources with different parameters, different energy and power converters with specific parameters, different topologies of the local distribution system and last but not least different types of consumers with linear or nonlinear characteristic can be chose in the simulation model, depending on the version that is meant to be studied.



**Fig. 2. Simulation Model Architecture based on RegenSim library**

### III MATLAB/SIMULINK MODEL IMPLEMENTATION

Using the RegenSim library a renewable energy hybrid system shown in Fig. 3 was developed. As shown, the simulation system contains power generation blocks from renewable energy sources such as sun, wind or water, battery blocks (providing the energy storage), measurements blocks for electrical parameters (voltage, current, power), inverter blocks (for power generation in DC voltage), voltage regulator block, AC and DC voltage bus bars and AC and DC consumers blocks. It should also be specified that each of the power generation simulated blocks can be sized and can operate independently providing energy in the system, but they may also be interconnected, a proper sizing of the batteries (depending on configuration) being mandatory.



**Fig. 3. Matlab/Simulink Simulation Model of a hybrid system based on renewable energy**

### IV SIMULATION RESULTS

Based on data provided by National Meteorological Administration and ANAR for the availability parameters of renewable energy that can be considered in Mureş County, and taking as a starting point the simulation model developed in Matlab, which is based on the mathematic models, a study of the hybrid system behaviour, with availability or not of the local power network, under different circumstances and for different configurations of the consumer can be performed.

The simulation model was primarily designed for the opportunity analysis of renewable energy resources usage, for their management in the design phase and for the study of problems that may occur due to the adopted solution. The adopted solution concerns the management solutions that can be adopted, but also the monitoring, control and command of renewable energy sources and of the consumer.

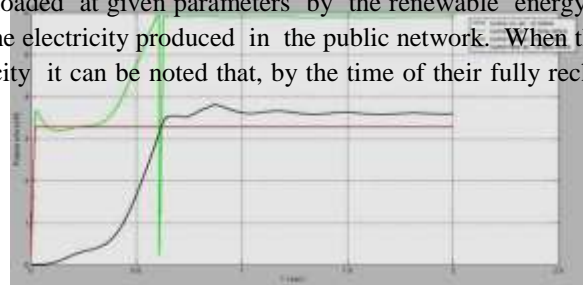
In addition to the above functions, the model was designed and developed for the study of real-time system operation and for power quality analysis of the studied system. After running of the simulation, power flow

graphs among hybrid system based on renewable sources and the public power network and instantaneous voltages and currents graphics can be obtained.

In the performed study were considered different configurations and situations of renewable energy sources availability and different types of consumers. In this paper the renewable energy resource availability was taken within the range of  $0.8 - 3\text{kWh/m}^2$  for solar resource, a variable wind speed from 2 to 20 m/s and a water flow between 30 and 100 l/s at 50m level difference from the hydro resource. A linear and a nonlinear consumer ( $P_i=33\text{kW}$ ) were also considered.

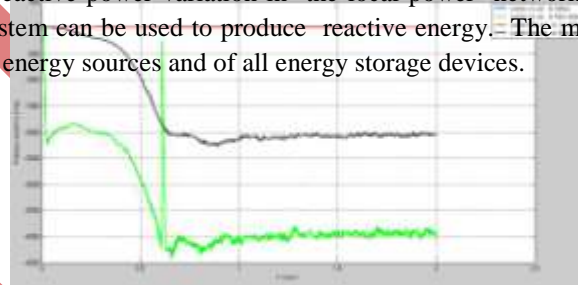
#### 4.1. Small Domestic Power System Based On Hybrid Renewable Energy

In Fig. 4 is presented the active power variation in the local power network. It can be noted that if the energy storage elements are loaded at given parameters by the renewable energy availability, the system provides about two fifths of the electricity produced in the public network. When the energy storage elements are not loaded at rated capacity it can be noted that, by the time of their fully recharge, energy is absorbed from the public network.



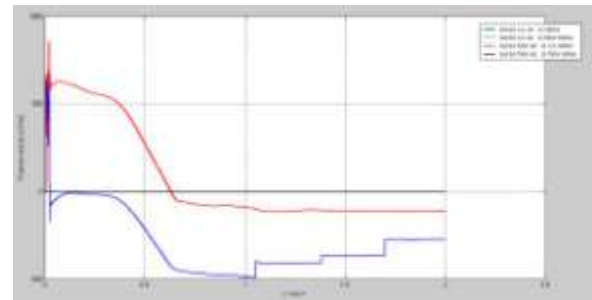
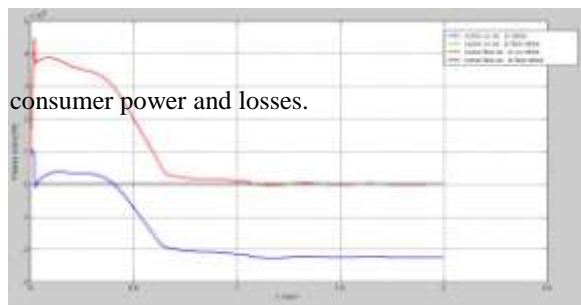
**Fig. 4. Evolution of active power transit between the hybrid system based on renewable energy sources and the public network**

In Fig. 5 is presented the reactive power variation in the local power network. It can be observed that the renewable energy hybrid system can be used to produce reactive energy. The most favourable situation is the availability of all renewable energy sources and of all energy storage devices.



**Fig. 5. Evolution of reactive power transit between the hybrid system based on renewable energy sources and the public network**

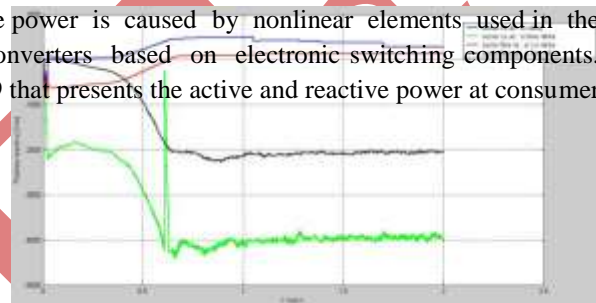
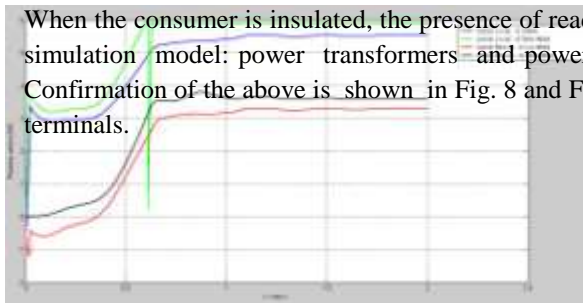
In Fig. 6 and Fig. 7 the active and reactive power produced by renewable energy sources are presented. It can be noticed that the power generated from renewable energy sources is used for charging the energy storage devices, at the consumers or to cover losses and the surplus is injected into the local public network. If the consumer is insulated power evolution is stabilized following an equivalent constant level according to



**Fig. 6. Renewable energy sources active power variation**

**Fig. 7. Renewable energy sources reactive power variation**

When the consumer is insulated, the presence of reactive power is caused by nonlinear elements used in the simulation model: power transformers and power converters based on electronic switching components. Confirmation of the above is shown in Fig. 8 and Fig. 9 that presents the active and reactive power at consumer terminals.

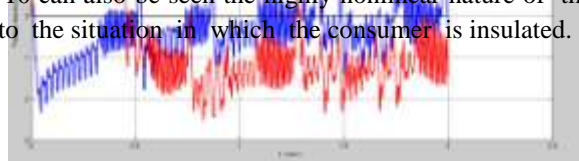


**Fig. 8. Consumer active power variation**

**Fig. 9. Consumer reactive power variation**

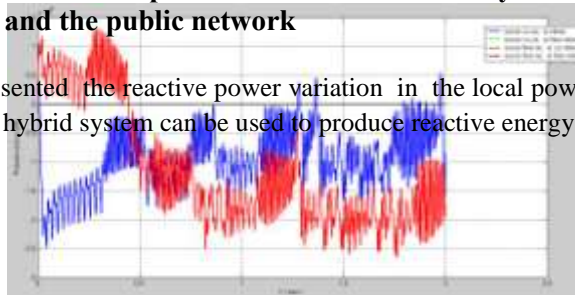
#### 4.2. Small Industrial Power System Based On Hybrid Renewable Energy

In practice, consumers are geographically isolated, and use in their activities variable speed drives (i.e.: mills, fans, circular saws, conveyors). To analyze such a case, a consumer which has a system based on variable speed drives that use controlled rectifiers (fan whose speed varies depending on temperature) has been modelled. In Fig. 10 is presented the active power variation in the local power network. It can be noted that if the energy storage elements are loaded at given parameters by the renewable energy availability, the system provides the produced energy in the public network. When the energy storage elements are not loaded at rated capacity it can be noted that, by the time of their fully recharge, energy is absorbed from the public network. In Fig. 10 can also be seen the highly nonlinear nature of the consumer. Dark and green characteristics correspond to the situation in which the consumer is insulated.



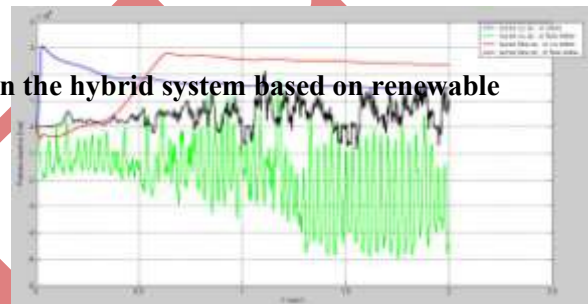
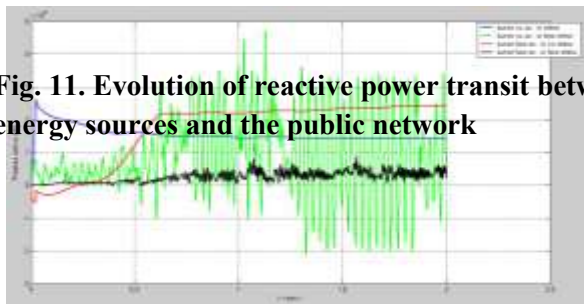


**Fig. 10. Evolution of active power transit between the hybrid system based on renewable energy sources and the public network**

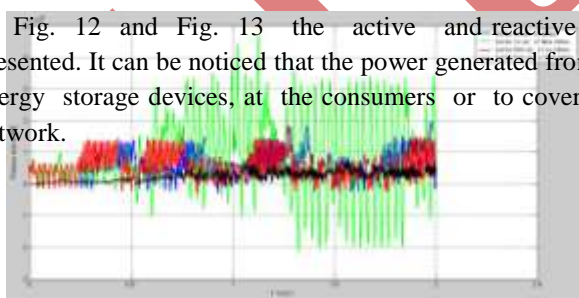


In Fig. 11 is presented the reactive power variation in the local power network. It can be observed that the renewable energy hybrid system can be used to produce reactive energy in the considered cases.

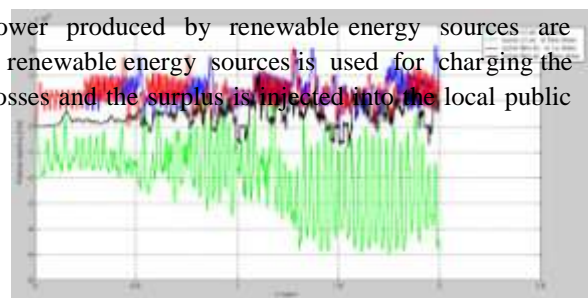
**Fig. 11. Evolution of reactive power transit between the hybrid system based on renewable energy sources and the public network**



**Fig. 12. Renewable energy sources active power variation**



**Fig. 13. Renewable energy sources reactive power variation**



In Fig. 12 and Fig. 13 the active and reactive power produced by renewable energy sources are presented. It can be noticed that the power generated from renewable energy sources is used for charging the energy storage devices, at the consumers or to cover losses and the surplus is injected into the local public network.

**Fig. 14. Consumer active power variation**

**Fig. 15. Consumer reactive power variation**

When the consumer is insulated, the presence of reactive power is caused by nonlinear elements used in the simulation model: power transformers and power converters based on electronic switching

components, but is also caused by the highly nonlinear nature of the consumer as seen in Fig.13. Confirmation of the above is shown in Fig. 14 and Fig. 15 that presents the active and reactive power at consumer terminals.

## V CONCLUSIONS

The paper presents a simulation model useful for the study of small power systems based on renewable energy. For the simulation model development a collection of objects organized in a new Matlab/Simulink library named RegenSim was built. The realized simulated model based on the new RegenSim library is compatible and can be interconnected with components of the dedicated SimPowerSystems library that is used for power systems functioning, simulation, modeling and analysis.

The author's proposed simulation model is extremely useful in the present circumstances allowing studies considering the identification, the type of usage opportunity and the implementation for power systems based on renewable energies that are available in a certain area.

To exemplify this feature in the paper was considered the Mureş County area and was performed a study for the appropriateness of using solar, wind and hydro resources available here. Other important studies allowed by the developed simulation model refer to steady or transient regimes, with the possibility of active and reactive power flowing evolution.

The presented simulation model also represents a useful tool in energy management system domain. For future developments and facilities is considered the opportunity of current and voltage waveforms analysis and power quality studies, which represent a common issue in distributed generation.

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