SOFTWARE SYSTEM FOR CALCULATION AND ANALYSIS OF ELECTRICAL POWER, DERIVED FROM RENEWABLE ENERGY SOURCES

Katerina Gabrovska, Nicolay Mihailov

Abstract: The software system for modeling and analysis of the processes of electric power conversion of renewable energy sources (solar radiation and wind velocity) is described. The characteristics of the generators and specific climatic conditions of the geographical region are considered. The application of the developed system is for research of the processes of electricity supply and is intended for agricultural farms. It can be utilized in designing of the real farms as well as in the process of students’ education.

Key words: Programme models, Photovoltaics and wind turbine generators, Graphical dependences.

INTRODUCTION

In the last years the application of renewable energy sources (RES) in electricity supply systems rapidly increase. The limited resources and high cost of conventional energy sources (oil, gas, coal), as well as the continued environmental pollution are some of the main reasons for their widespread introduction in electrical power systems. Bulgaria possesses a rich potential of RES like solar and wind energy. The basic findings for the future implementations of RES technologies in Bulgaria, according to the numeric investigations of energy centers like Balkan Opet (Organisations for the Promotion of Energy Technologies), Energoproekt, etc. are [1,2]:
- The part of the RES in the total electrical consumption has to reach (8-10)%, according to the standards of the European ‘green’ book ‘Energy in the near future’;
- The need for new technological decisions in the field of effective RES utilization.

The main stage in building of autonomous systems for electricity supply, converting alternative energy, is the system components design and estimation of climatic resources of the selected geographical region. A large variety of specialized software systems for modeling and simulation of such electrical systems (for instance HOMER, PVSYST etc.) exists. The electrical and mechanical parameters of solar and wind energy generators, and detailed data base of weather data such us solar radiation, wind velocity, atmospheric temperature are taken as the basis in development of the programme algorithms. However in these programmes peculiarities of agricultural system for electricity supply, working terms and regimes of their main electrical equipment, etc. are not taken into consideration. The software system for modeling and analysis of electricity conversion of RES (solar radiation and wind velocity) for the region of Rousse is described in the paper.

LAYOUT

The aim of the research is developing the software system for analysis and investigation of the electrical conversion processes of RES (wind velocity and solar radiation) with respect to characteristics of wind turbine and photovoltaic semiconductor generators, as well as specific regional climatic conditions.

The following problems have been solved:
- Developing a one-diode PV generator model in accordance with frequently altering climatic parameters;
- Building an electrical power model of a wind turbine generator relating wind turbine power output to wind speed;
- Working up the algorithm for calculation and analysis of produced RES electrical power;
- Collecting meteorological data for the specific geographical region;
Photovoltaic system

Transformation of sunlight into electricity is performed in semiconductor silicon elements called photovoltaic (PV) cell modules. The solar cell module acts as a constant current source for most of its I-V curve. It can provide a constant current from zero to around 15V even with a changing resistive load. As the resistance continues to increase, the curve reaches a breakdown point and starts to drop to zero.

As demonstrated in Figure 1, an increase in solar radiation causes the output current to increase and the vertical part of the curve to move to right. An increase in cell temperature causes the voltage to drop, while decreasing temperature produces the opposite effect. Thus the I-V curves display how a solar cell responds to all possible loads under a certain set of radiation and cell temperature conditions.

An operating point of a solar cell will move by varying radiation, cell temperature, and load values. For a given solar radiation and operating temperature, the output power depends on the value of a load resistance. As the load increases (or the resistance decreases), the operating point moves along the curve toward the right. So only one load value makes the PV generator produce maximum power. A maximum power point (MPP) trajectory, which is positioned at the knee of the I-V curve, represents the nearly constant output voltage of the PV generator at varying solar radiation condition. When the temperature varies, the maximum power points are generated in such a manner that the output current stays approximately constant.

A solar cell usually uses a p-n junction diode in a physical configuration to produce photovoltaic electricity. As the I-V curve demonstrates, a solar cell acts like a constant current source under low load conditions and the current drops to zero at high loads. Thus it can be presented as an ideal current source. Its equivalent circuit shown in Figure 2 precisely explains what occurs in a solar cell.
The circuit consists of a light-dependent current source and a group of resistances, including internal shunt resistance, $R_{sh}$, and series resistance, $R_s$ [3,5]. The series resistance should be as low as possible and its shunt resistance should be very high, so that most of the available current can be delivered to the load. Having made this assumption, the characteristics of a solar cell can be expressed by the following equations:

$$U = \frac{AKT}{q} \ln\left(\frac{I_{ph} - I + I_o}{I_o}\right) - IR_s,$$

where $U$ is terminal voltage for a PV cell, V,

$A$ - ideality factor (1,6),

$K$ - Boltzmann’s constant (1,38.10^{-23}), Nm/ K,

$T$ - PV cell temperature, K,

$q$ - electron charge (16.10^{-19}), C,

$I_{ph}$ - light-generated current in a PV cell, A,

$I$ - PV cell output current, A,

$I_o$ - PV cell saturation current, A,

$R_s$ - series resistance of a PV cell, $\Omega$.

$$I = I_{ph} - I_d - I_{sh} = I_{ph} - I_o \left[\frac{U + IR_s}{AKT} - 1\right] - \frac{U + IR_s}{R_{sh}},$$

where $I_d$ is current flowing into the inverter from the PV array, A,

$I_{sh}$ - shunt current, A,

$R_{sh}$ - internal shunt resistance of a PV cell, $\Omega$.

Wind energy conversion system

Wind energy can be used to power mechanical devices, to provide heat or thermal energy, and to generate electricity. The wind energy conversion into electricity is performed in wind turbine generators (WTG). Moving air molecules have mass and speed, and, therefore kinetic energy. This energy can be extracted by the blades or rotor of a wind turbine. Wind power is related to the wind speed by the following formula:

$$P = \frac{1}{2} \rho A V^3,$$

where $P$ is the total instantaneous power available in the wind, W,

$\rho$ - air density (0.05 at 1 atm and 20°C), kg/m$^3$,

$A$ - cross-sectional area of WTG, m$^2$.

Selecting the proper type of wind energy conversion system, depending on its application and specific climatic conditions of the region, is important. The set of electrical and mechanical characteristics of WTG (provided by manufacturers) in the process of estimation of generated wind power are needed:

- the rotor diameter;
- cut-in wind speed, at which the wind turbine begins producing electricity;
- cut-out wind speed, at which wind turbine turns off to protect itself from damage caused by high winds;
- dependence relating wind turbine power output to wind speed $P=f(V)$. The producer provides it in a graphical way. The following polynomial is derived through approximation of a graphical dependence:

$$P = a_1V + a_2V^2 + a_3V^3 + a_4V^4,$$

where $P$ is produced power by hours, $W$, $a_1..a_3$ – coefficients of polynomial.

A brief flow-chart of the programme is shown in Fig.3.

![Fig.3. A simplified flow-chart of the programme algorithm](image)

The software system for determination and analysis of solar beam radiation falling on a horizontal and perpendicular plane, generated photovoltaic power, as well as the produced wind electrical power, are based on the above described methods. The developed programme is open - it can be expanded with other dependences so that it can solve different problems, connected with statistic analysis of the data. It is a part of a system for managing and control of electrical energy resources of a small agricultural plants using conventional and alternative energy sources. For the development of the program the product Borland Delphi 6.0 is used. A database is developed, containing the daily hour-values of the solar radiation, which are included in further calculations of produced PV power. The database contains data for PV module characteristics, obtained from different manufacturer catalogues. To calculate the wind turbine power output, the data for wind velocity and WTG’s parameters, which are stored in database, are used. The climatic data for the region of Rousse for a period of two years are obtained from the
Laboratory of Meteorology, where the weather parameters are measured in a period of every three hours. For an exact calculations in the programme an interpolation is made every hour for the measured data [4].

CONCLUSIONS AND FUTURE WORK
Developed software system has the following features:
- an open software system, which has the ability of further expansion. It is adopted to specific research tasks of autonomous electrical power supply systems, using alternative energy sources;
- the programme provides calculation of an energy balance of investigated system, depending on electrical generators’ parameters and specific weather conditions;
- the programme allows using other complementary software systems for calculation and graphical presentations of the data;
- the software system is applicable to autonomous renewable energy supply systems’ design, as well as in the process of students’ education.

Fig.4. Snapshots of modules for estimation of solar radiation and produced photovoltaic power, accompanied with I-V characteristics of PV generator

Fig.5. Snapshot of module for calculation of generated wind electrical power
REFERENCES

ABOUT THE AUTHORS
Katerina Gabrovska, PhD student, Department of Computer Systems, University of Rousse, e-mail: kgabrovska@ecs.ru.acad.bg
Assoc.Prof. Nicolay Mihailov, PhD, Department of Electrical Power Engineering, University of Rousse, e-mail: NMihailov@ru.acad.bg