Structural analysis and methods for development of software tool for design and energy simulation of PV- hybrid power supply systems in poultry farms

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Abstract: *A paper presents the basic stages of developing a software product RES v.1.0 for design and energy simulation of photovoltaic hybrid installations as an auxiliary power supply systems for poultry farms. Used structural analysis of a programme is described in details through Data Flow Diagrams. Also the classification of the most famous software systems for design and analysis of alternative energy devices is made and the position of developed software RES v.1.0 among them is shown.*

Key words: Structural analysis, Data Flow Diagrams, Energy software simulation, Classification.

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. Development and usage of these alternative energy technologies are still restricted in Bulgaria. Software products (such as PVS, PVSYST), using for projecting and research of alternative energy systems in our country are usually developed by European or American research centers or products supplying companies. The need for specific software product for projecting, analysis and simulation of electric power processes in technological buildings with specific electrical control exists. The electrical power supply in them is divided into conventional and alternative energy supply. This paper presents structural analysis and mathematical methods for design and development of the software system for sizing, analysis and energy simulation of photovoltaic (PV) hybrid electrical system, used for electric power supply of poultry house. The main key features of developed software are pointed in comparison with other well-known products.

LAYOUT

The aim of present research is working out a structural analysis and methods for software system RESs development. A programme can be used during the process of design, sizing, energy analysis and simulation of electrical power processes in PV-hybrid system for energy supply of poultry farm.

The following problems have been solved:

- Composing a basic stages of the mathematical modeling, which is needed for software system development;
- Accomplishment of a structural analysis and description of its results through a Data Flow Diagrams (DFDs);
- Defining a proper place of developed programme among the most popular software systems of same type by means of a table of classification. Describing the specific performances and advantages of presented software tool in the aspects of current research.

○ The performed steps during a mathematical modeling of designed PV-hybrid installation, which is implemented in developed programme, are shown on the following flow-chart [1]:

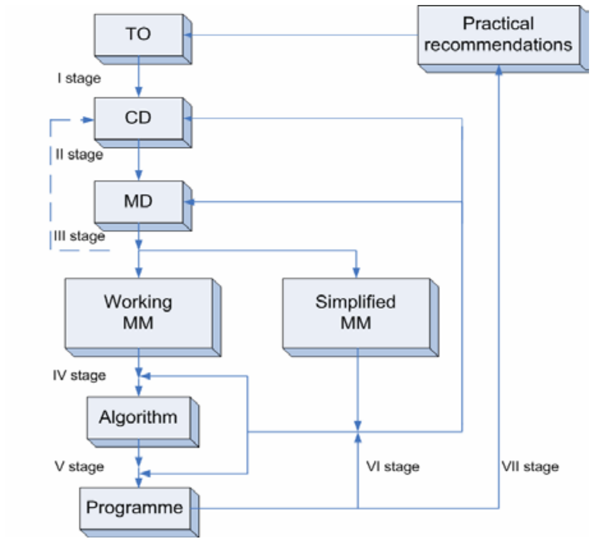

Fig.1 Flow-chart with a basic stages of chosen mathematical modeling for design and analysis of a studied technical target

Informal transition from observed **technical object (TO)** (PV-hybrid fitting for electric power supply of breeding farm for broilers) to its appropriate **contextual diagramme (CD)**, also named **model of conception (CM)**, is fulfilled at *a first stage*. Here is emphasized on these working features, particularities and operational conditions of TO, that had to be mentioned in the CM by means of specific technical parameters. The correct and comprehensive recognizing of technical object characteristics in CM is a substantial premise for future retrieving reliable mathematical modeling results. Also a typical climate of explored geographical region and electric power supply of selected building (a breeding house), characterized with hour, daily and week schedules of its electrical loads, are considered as other main technical targets during the software system development. *Second step* is a formal mathematical description of CM through **mathematical models (MM)** of the meteorological processes, electric power flow in designed PV-hybrid equipment and electric power consumption in a poultry house. At *a third stage* of modeling is implemented a qualitative and evaluation analysis of a built MM. The inconsistencies sometimes arise and that requires further precisely revision of CM (dotted line on Fig.1). *Forth step* represents the construction of **effective algorithm** of computational experiments, and *a fifth stage* – the creation of **working programme**, which implements that algorithm. Derived at *a sixth stage* (from software system) processed results are verified with a help of data, which are obtained as results from quantitative analysis with simplified version of MM of a TO. At the end of testing the failings in a programme or in algorithm, or in both can be found. After analyzing the calculated results and their interpretation occasionally is needed a reformation in CM and its corresponding MM. After failing eliminations, a triad "model-algorithm-programme" can be used for carrying out the computation experiments and formulating **practical recommendations** for TO improvement on the base of retrieved quantitative information. These procedures compose *the seventh, final stage* of "technological flow" of mathematical modeling and software development.

- Structural analysis before the implementation of software system RESs v.1.0 for automation of design and energy simulation of alternative electric power installation

In a process of structural design of a software, Data Flow Diagrams (DFDs) are used for tracing the network of data streams in a system and for providing information at different levels of significance [2]. Thus the system demands can be divided, analyzed and specified in control units. DFDs allow a system to be structured in the independent modules. A model of conception is described through DFDs at different levels. A DFD on level 0, which shows a general programme structure and is the highest level of analysis, is graphically presented on Fig 2. A numbering from 0 to 12 for the basic system processes of DFD level-0 is used.

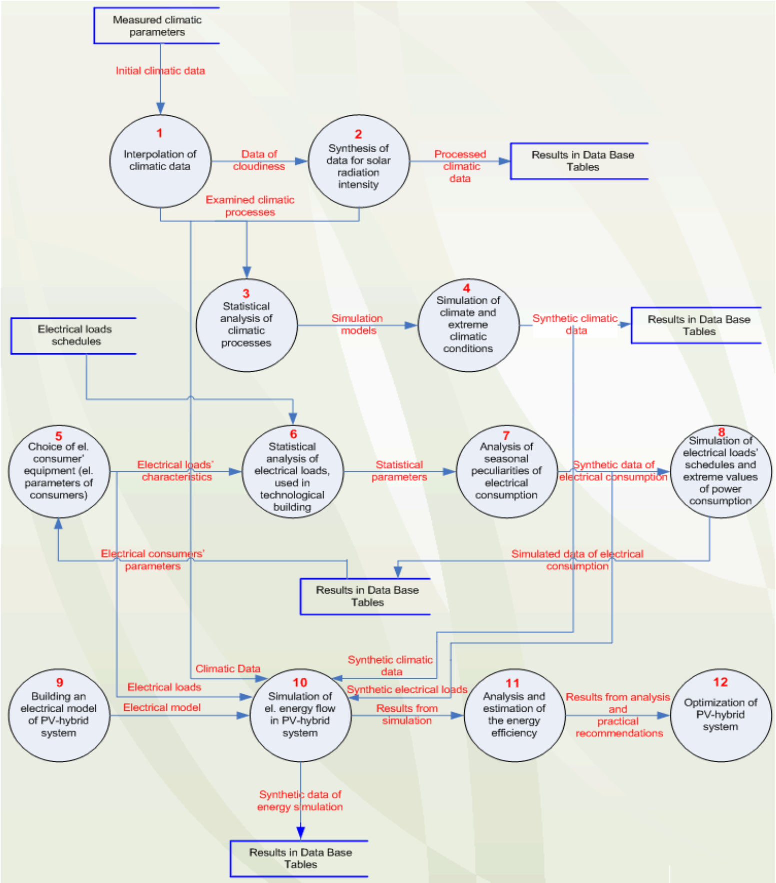

Fig.2. DFD level-0

More comprehensive explanation of each process is given as follows: **1**-Climate data interpolation (cloudiness, air temperature, wind speed) at a discrete time gap of 1 hour during the 24-hours periods of selected astronomic year, **2**- Hourly simulation of global solar radiation intensity for a period of one astronomic year, **3**- Statistical evaluations (means, density of distribution, standard deviation, auto- and cross correlations) and parameters of a probability distributions of the meteorological processes, **4**-Simulation models of synthetic climate data generation and synthesis of extreme climate conditions for system operation, **5**-Choosing a type of electrical consumer equipment–for living, for technological production. The daily and monthly electrical loads schedule determination, **6**-Analysis of schedules of electric power consumption in a technological building (breeding house for broilers) by typical months and seasons- transitional (spring, autumn), summer and winter, **7**- Calculating the statistical evaluations and parameters of a probability distribution functions of electric energy consumption, **8**-Building simulation models for synthetic generation of electric energy consumption and imitation of extreme conditions of power supply, **9**-Development of electrical model of PV-hybrid system for alternative energy production, **10**-Synthesis of algorithm for electric energy flow simulation at the time of system operation, **11**- Analyzing and estimating an energy efficiency of designed PV-hybrid installation on the basis of the software simulation results, **12**- Finding an optimal PV-hybrid system configuration and electrical performances.

More elaborate Data Flow Diagram is drawn up on a next stage of software system analysis (level 1). It represents the processes 9 and 10 of DFD level-0 for design and construction of alternative energy device functional model and software simulation of electric energy flow in details.

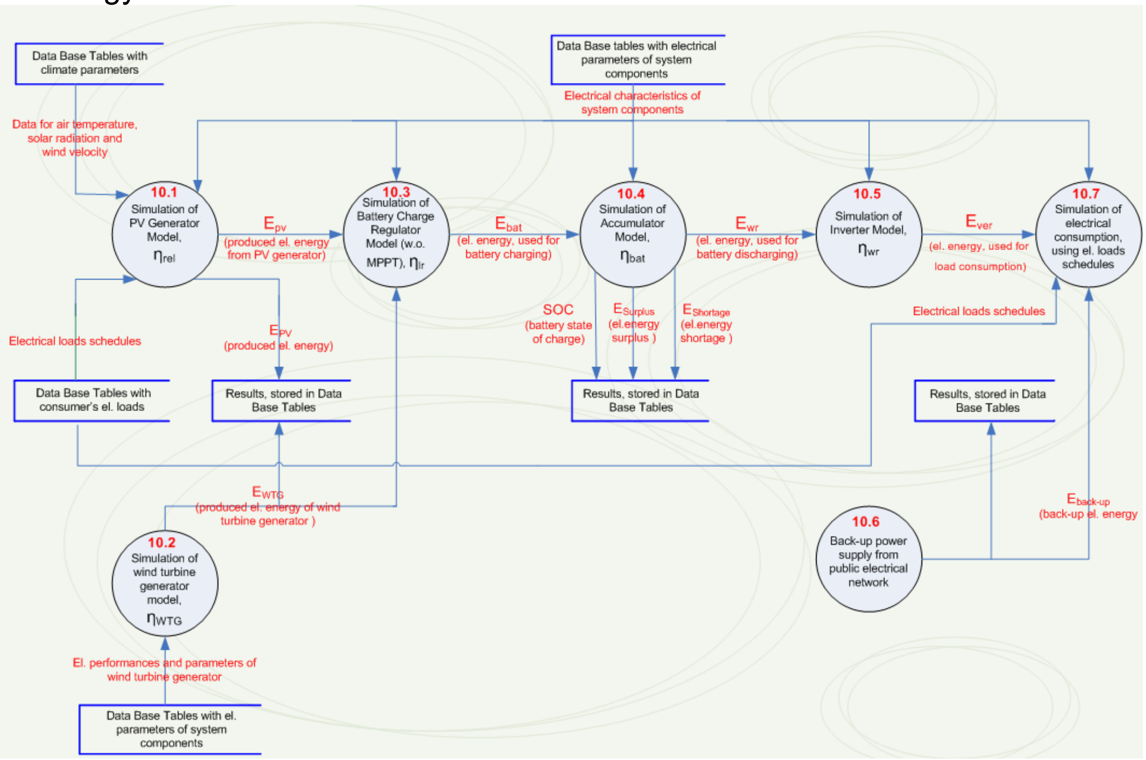

Fig.3. DFD level-1

- Position of developed programme RESs v.1.0 among other famous software tools of same type available on the market. Classification table.

The peculiar features and abilities of the developed system and other software products are given in the following comparative table (Table 1). It shows the main characteristics and advantages of RESs v.1.0, that are of great importance for the purposes and tasks of current research [3].

Table1. Comparative classification of available programmes for design, sizing, energy analysis and simulation of alternative energy devices for electric power supply.

Software Title	**PVS**	**PVSYST**	**Greenius**	**TRNSYS**	**RESs**
Actual Version	2.001	3.3	1.0	16.0	1.0
Year of Issue	1993	2000	2002	2004	
Basic Characteristics	Design, analysis and simulation of gird-connected and autonomous PV systems.	A powerful tool for simulation and analysis of PV installations. Intended for a wide range of users with different level of knowledge. Preliminary design, project design, analysis of obtained results.	Design and simulation of large electric power systems, using alternative energy sources. Detailed economic analysis. Comparison between different technological solutions.	A software environment for time –dependant simulation of alternative energy systems, adapted for buildings. Building and analysis of different technological solutions: from solar heating systems to combined alternative energy systems, using wind, solar, hydro and other types of renewable energy sources.	Design, sizing and energy simulation of PV-hybrid systems, utilizing solar and wind energy with conventional power supply (public electricity supply network).
Special Features	A possibility of expanding a data base with records, entered by users. Change the parameters of	3D tool for shadings calculation. A possibility for real- measured data entering. Synthetic hour	Various cash-flow project analysis. Calculation of PV grid-connected systems, as well as wind parks and solar thermal	Open programme code and module structure of a software product, which are accessible from user. A programme architecture, based on	Choice of electric consumer equipment (living, technological). Analysis of electrical consumption in a real technological building – broiler farm, with

	electrical consumers in autonomous PV systems. Data base updating via Internet.	data generation of solar radiation, using initial average values from measurements.	equipments.	DLL, allows easy appending of standard model components. Implementing a dynamic data simulation.	matching the conventional and alternative electric power supply for main production processes (lighting, feeding, ventilation, heating, living consumption).
Languages	**G,E**	**E,F**	**E,G,S**	**E**	**E,B**
Computations					
- Grid connected installations	**X**	**X**	**X**	**O**	**X**
- Autonomous (Stand-alone) systems	**X**	**X**	**O**	**X**	**X**
-Hybrid systems	**X**	**X**	**O**	**X**	**X**
- Other technologies	**O**	**O**	**WTG, ST**	**WTG, ST, WPS**	**WTG**
- Synthetic climate data genration	**X**	**X**	**O**	**O**	**X**
- Shading estimation	**X**	**c 3D**	**O**	**X**	**O**
- Optimal system design	**X**	**X**	**X**	**O**	**X**
-Energy efficiency estimation	**X**	**X**	**X**	**X**	**X**
- Climate processes simulation	**O**	**X**	**O**	**O**	**X**
- Energy flow simulation	**X**	**X**	**X**	**X**	**X**
- Electric power consumption by technological processes	**O**	**O**	**O**	**O**	**X**
- Cross correlation between climate and energy consumption	**O**	**O**	**O**	**O**	**X**
- Economic efficiency calculation	**X**	**X**	**X**	**X**	**X**
- A balance of harmful emissions	**X**	**O**	**X**	**O**	**O**
Libraries					
- Climate parameters	**SR**	**SR,AT**	**SR,AT,AP,RH,WS, WD**	**SR,AT,RH,WS,AP**	**SR,AT,WS,CI**
- Electrical components	**PvG, BRg, Bat, NI, AI, Cons, AG, PNet**	**PvG, Bat, NI, BRg, AG, Cons**	**PvG, WTG, NI, BRg, PNet**	**PvG, WTG, Bat, BRg, AI, SC,TA, Cons**	**PvG, WTG, BRg, Bat, AI, Cons,PNet**
- Characteristics of electrical loads and energy consumption	24-hour, weekly and monthly electrical loads schedules.	-For grid-connected systems, -For stand-alone systems.	Hour values of energy consumption for a typical year.	Solar energy usage in thermal systems for buildings with active and passive heating.	Detailed hourly, daily, monthly, seasonal, yearly statistical analysis of el.consumption
Data Maintenance					
- Adding of components	**X**	**ASCII, Meteonorm**	**ASCII**	**X**	**TXT,Excel, Paradox, Statistica**
- Data verification	**X**	**X**	**X**	**O**	**X**
- Help assistance	**X**	**X**	**X**	**X**	**X**
Representation of Results					
-Data format of results	**Graphics and tables, ASCII, Print**	**ASCII, Excel, Print version**	**ASCII,EXCEL, HTML,WMF, BMP,JPG**	**Excel,Matlab**	**TXT и BMP, Excel,STATISTICA**
- Discrete time interval of the processes	**Hour, Week, Month, Year**	**Hour, Week, Month, Year**	**Hour. Week, Month, Year**	**Hour, Day,Month**	**Hour, Day, Week, Month, Season, Year**

Legend:

X = available,
O =missing.

Languages
E = English,
B = Bulgarian,
S = Spanish,
G = German,
F = French.

Other technologies
WPS = waterpower energy system,
WTG = wind energy system,
ST = solar thermal installation.

Components
PvG = photovoltaic generator,
WTG = wind turbine generator,
BRg= battery load regulators and controllers
Bat = battery block,
I = invertor (A = stand-alone,
N = grid-connected),
Cons =electric power consumption,
AG = auxiliary generator (diesel),
PNet = public electrical network,
SC = solar collector,
TA = thermal accumulator.

Climate parameters
SR = solar radiation,
AT=air temperature,
AP = atmospheric pressure,
RH = relative humidity,
WS = wind speed,
WD = wind direction,
CI = cloudiness.

A table shows the specific advantages of developed software RESs in comparison with other available programmes. The main difference with others are: the ability for cross correlation estimations of local climate conditions of the geographical region and electrical loads of selected technological building, that has to be energetically supplied by designed PV-hybrid system. During PV device design and simulation cycles the climate parameters are considered. A product RESs offers an optimal configurations by means of a statistical analysis of long-term meteorological information and schedules of power consumption. On the base of real-measured data for a climate and electric consumption, a programme calculates the etalons of extreme meteorological parameters and characteristics of extreme energy consumption, that are very important for choosing the optimal PV-hybrid installation design.

CONCLUSIONS

A paper presents some basic stages of structural development of software system RESs. Product could be used during design of PV-hybrid and stand-alone systems for power supply of daily needs and technological processes in agriculture (breeding farms for broilers).

REFERENCES

[1] Зарубин, В.С. Математическое моделирование в технике. Москва, Изд. МГТУ им. Н. Э. Баумана, 2003

[2] Маринов, М. Информационни системи. Анализ и проектиране. Русе, Изд. “Авангард принт” ООД, 1999.

[3] http://retscreen.gc.ca/ang/g_model_a.html

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