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COMPUTER-BASED MODEL FOR STUDYING THE OPERATION OF THE PHOTOVOLTAIC STATION WITH FUZZY REGULATOR OF THE GRID INVERTER

Computer-based model of 250 kW photovoltaic station, consisting of 88 parallel strings, each of which contains 7 serially connected modules of SunPower SPR-415E-WHT-D type, connected to the local electric grid was developed, applying Matlab programs. Such model enables to carry out the study of the operation of the station with fuzzy regulator of the grid inverter, based on the mathematical model of the electric energy generation process optimization in the grid at photovoltaic station, applying fuzzy sets tool.

For the verification of operation adequacy of the photovoltaic station fuzzy regulator the modeling was performed for two cases of electric station operation: with fuzzy regulator and without it. The following condition was met - the loading, climatic conditions and their change was identical for both cases. The greatest impact in the process of electric energy generation by photovoltaic station has the sudden cloud coverage, that leads to the decrease of the amount of solar radiation per unit of the surface area. As a result, electric energy generation drastically drops. That is why, in the process of modeling this parameter played the most important role. Besides the climatic factors, the carrying capacity of the grid has great impact on the process of photovoltaic station generation. Thus, in the process of modeling such modes as electric energy consumers load drop, load increase and simulation of drastically changing climatic factors, for instance, sudden cloud coverage were simulated.

Modeling was performed in the time interval from 0 to 0.2 sec. This was sufficient for the assessment of photovoltaic power plant operation in the above- mentioned modes. In the computer model active-inductive loading was used for obtaining the conditions, maximally close to real conditions, in its turn, this enabled to obtain information, regarding the generation of active and reactive power by photovoltaic power plant. For the correct assessment of the grid parameters phase currents and linear voltage of photovoltaic power plant were evaluated.

The obtained results prove the efficiency of the fuzzy regulator application, the correctness of the mathematical model and the necessity of taking into consideration the impact of the climatic factors, carrying capacity of the grid on the control of the process of the electric energy transmission by the power plant into the grid.

Key words: *computer model, regulator, inverter, photovoltaic power plant, simulation.*

Introduction

Global warming and other negative phenomena, caused by the usage of the conventional sources of energy, their limited resource and pursuit of energy independence, led to the profound study, development and introduction of the renewable sources of energy, in particular, photovoltaic power stations [1].

It is known, that one of the main functional units of the photovoltaic installation are self-contained inverters which match the parameters of photovoltaic modules and the network. To improve the efficiency of the direct current conversion into the alternative current, the inverter control system must perform the monitoring of the maximum power take --off point of the photo element [2] and provide the operation of the power station in the contracted range of daily generation curve [3]. Development of the new methods of the inverter and algorithms operation optimization requires the verification of their operation capacity. Development of modern computers enables to use efficiently simulation modeling in scientific research, production sphere, engineering and other applied branches of human activity. By means of specialized software, that stimulates various phenomena and processes, the user can construct virtual complex experiments, studying unusual and impossible in real life, actions. Application of the computer-based simulation modeling gives the possibility to

perform the unlimited number of the experiments, without spending money for the raw material and products.

In the process of studying the systems of automatic regulation, computational mathematical problems the most efficient is the usage of the applied program package MATLAB with the wide range of subject-oriented libraries (Toolbox) and the visual simulation tool Simulink [4]. In the MATLAB system there exist wide possibilities for programming. Its library C Math (MATLAB compiler) is the objective and contains more than 300 procedures of data processing, using C language. Within the package both MATLAB procedures and the standard procedures of C language can be used, this makes the tool efficient for the applications development (using C Math compiler any MATLAB procedures can be built in the applications).

Aim of the research: development of the computer-based model for studying the operation of the photovoltaic power plant with fuzzy regulator of the grid inverter.

Analysis of the previous research. In [5] the development of the model and the results of modeling of the solar photovoltaic panels functioning in the process of operation with matching converters is suggested. These converters, as the authors state, prevent surges of current and voltage in case of step-by-step load change . As such method does not provide the regulation of the output power for the set operation modes of the grid, this makes it useless for the solution of our problem. In [6] the system of the converters control for the solar modules on the base of the inverter with PWM is considered. The authors suggested mathematical model, functional diagram and the algorithm of the inverter regulator operation, which provide the search of the maximum power take-off point. However, in the model they do not take into account the limitations, imposed during the operation of such inverter, namely: climatic factors, influencing the generating capacity of the solar modules and the characteristic features of energy market, which impose the limitations in case of the deviation from the schedule, declared by the energy company. Regulation method of the grid inverter output current, shown in [7], is intended to provide stable transmission of the maximum active power into the grid. The drawback of the method is that the regulation is performed only in case, when the current in the frequency area is taken into account (ωt).

Materials of the research. In [8] the mathematical model for the optimization of energy conversion process at solar power plant, using fuzzy logic tool was suggested, adjustment of fuzzy regulator in MATLAB Fuzzy Logic Toolbox was realized.

For the verification of the adequacy of the suggested mathematical model of energy conversion process optimization at solar power plant, using fuzzy logic tool the computer model of 250 kW solar photoelectric power plant, consisting of 88 parallel strings, each of which contains 7 serially connected modules of SunPower SPR-415E-WHT-D (Fig. 1) was developed in Matlab environment.

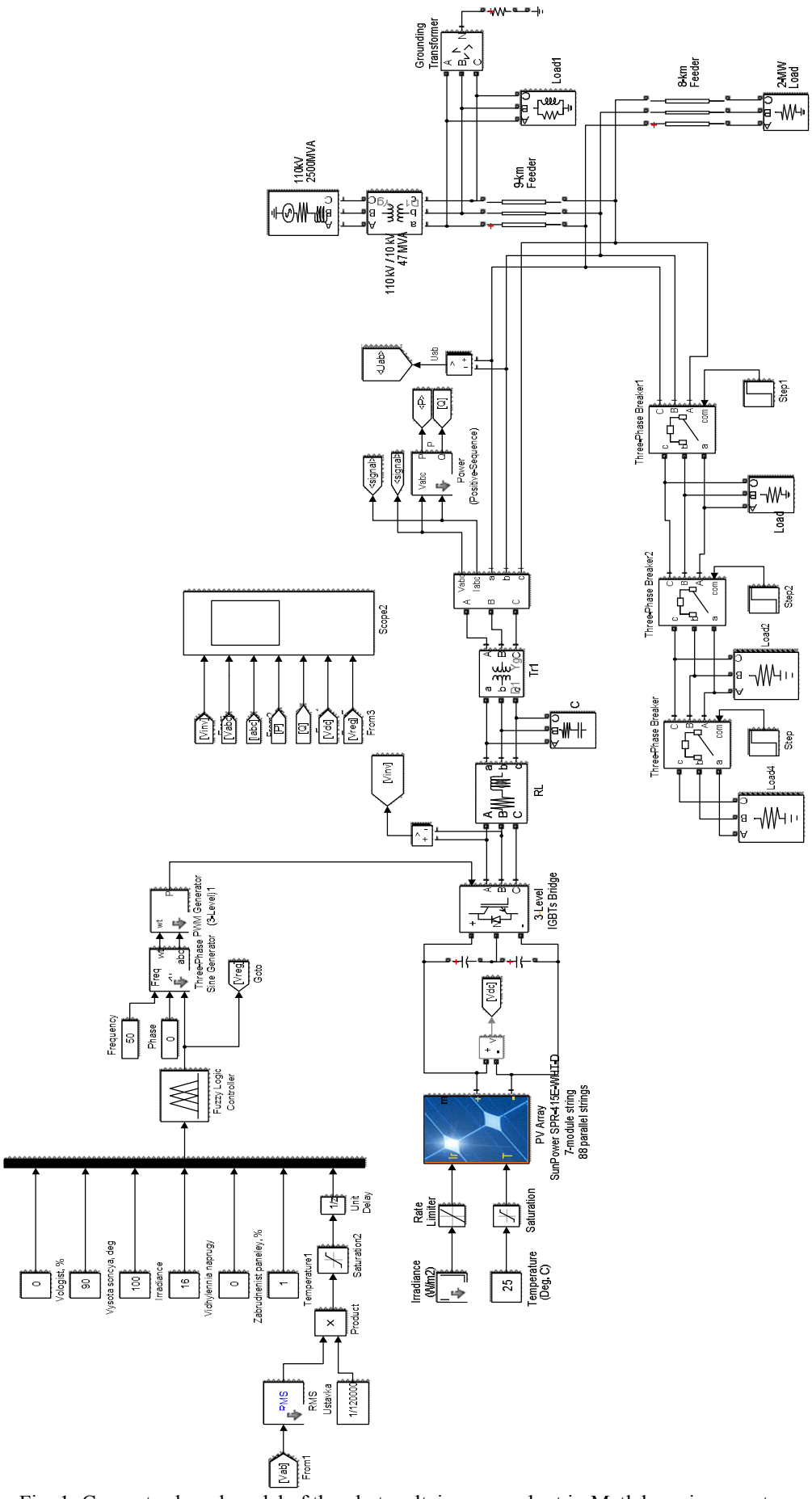

Fig. 1. Computer-based model of the photovoltaic power plant in Matlab environment

When the load in the grid increases, the voltage drop takes place, it indicates the necessity of increasing the carrying capacity of the grid. When the load decreases, the inverse process takes place. As a result of the research, carried out, the simulation of photovoltaic power plant operation mode in case of the grid carrying capacity change was performed, the obtained graphs of the transient processes are shown in Fig. 2.

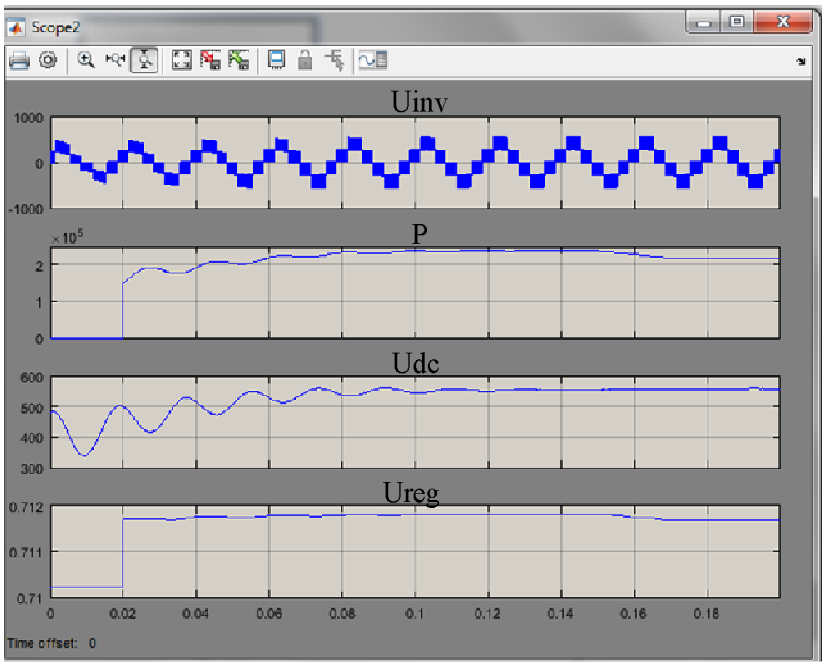

Fig. 2. Results of the simulation of photovoltaic power station with fuzzy regulator operation

In Fig. 2: Uinv – voltage at the output of the inverter; P – active power, generated by the photovoltaic power plant; Udc – voltage in the d. c. circuit of the inverter; Ureg – control signal at the output of the fuzzy regulator.

As it is seen from the graphs of the transient processes (Fig. 2), at the moment of 0.02 sec the connection of the photovoltaic power plant to local grid takes place. At 0.15 sec load shedding takes place, as a result, the carrying capacity of the grid decreases and, as it is seen from the graphs of transient processes, the signal from the regulator decreases, consequently, power generation of photovoltaic power plant decreases. It is worth mentioning, that the simulation of this mode was carried out at the invariable climatic conditions.

As the next step, the simulation of the photovoltaic power plant operation mode at variable climatic condition was performed. In the example, the decrease of solar radiation intensity was considered, in real conditions – the sudden cloud coverage of the sky. The results of this operation mode modeling are shown in Fig. 3.

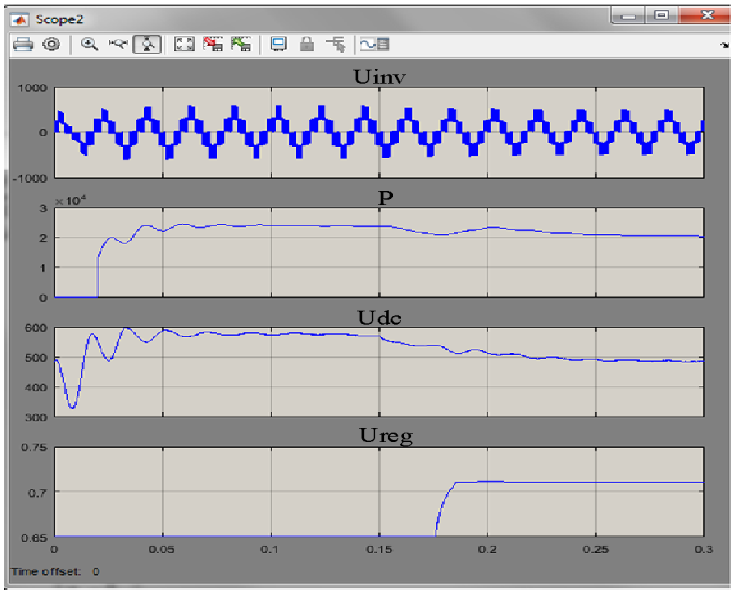

Fig. 3. Results of the operation modeling of photovoltaic power plant with fuzzy regulator at the change of the climatic conditions

It is seen from the graphs of transient processes (Fig. 3) that at the moment of 0.02 sec the connection of photovoltaic power plant to local grid takes place. At 0.15 sec the voltage drop in d. c. circuit takes place, it is the result of the climatic conditions change, for instance, sudden cloud coverage of the sky. Thus the regulator increases the control signal Ureg and, as a consequence, after minor reregulation the power remains in the corridor of the carrying capacity of the local electric grid.

At the next stage of the operation, the modeling of the operation of photovoltaic power plant without fuzzy regulator was performed. The results are shown in Fig. 4 .

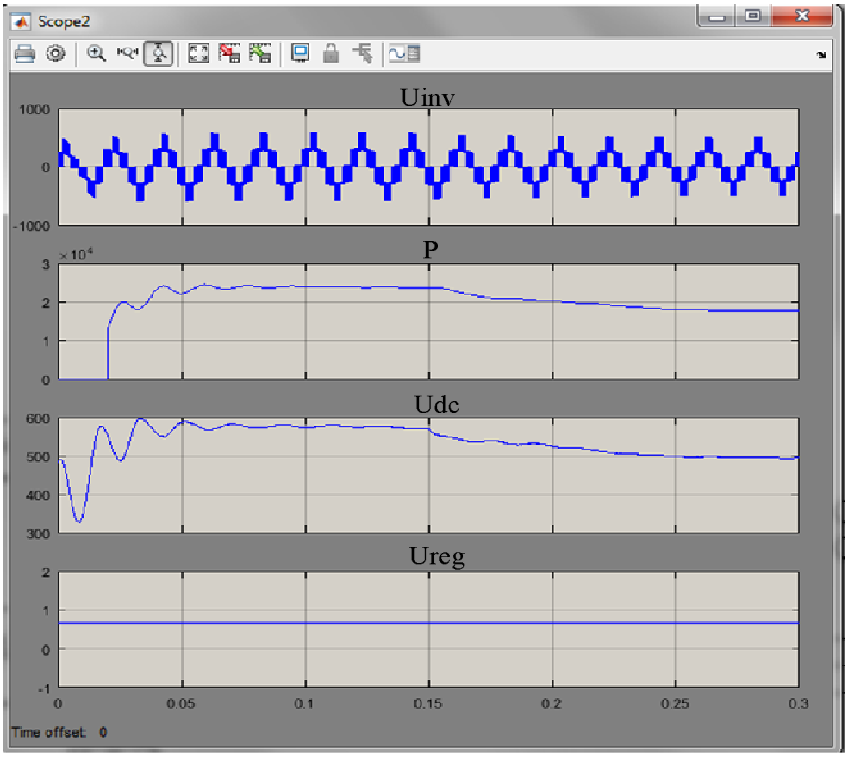

Fig. 4. Results of modeling of photovoltaic power plant without fuzzy regulator operation at the change of the climatic conditions

From the graphs of the transient processes (Fig. 4) it is seen that at the moment of 0.02 sec the connection of photovoltaic power plant to the local electric grid takes place. At 0.15 sec voltage drop in d. c. circuit takes place, it is connected with the change of climatic conditions (sudden cloud coverage of the sky). It is obvious that if the fuzzy regulator is missing, the generation power of photovoltaic power plant decreases proportionally to the voltage drop in d. c. circuit of photovoltaic power plant.

Conclusions

Computer model of 250 kW photovoltaic power plant with fuzzy regulator was developed, applying Matlab Simulink Library Simscape Power Systems environment . The suggested model enables to perform the adjustment of photovoltaic power plant regulator operation, carry out the correction of the weight coefficients and verify the adequacy of the proposed optimization model.

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