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OPTIMAL CONTROL OF POWER PROSUMER BASED ON SWARM INTELLIGENCE ALGORITHMS

The work is devoted to the problem of optimal control of a power generating consumer in Smart Grid. The distinctive research features are the solution of the optimal control problem in conditions of difficult prediction of wind power plant generation, the usage of Swarm Intelligence algorithms to build a system of control rules, and the study of the obtained models on data from two different generating consumers.

Introduction. The development of renewable energy and Smart Grid leads to the emergence of prosumers or power generating consumers (GP), which are involved in the processes of bidirectional exchange of electricity and information [1]. GP controls not only its electrical load but also the flow of generated power. It significantly increases the complexity of its control tasks [2, 3]. Modern studies primarily consider the principles of constructing the entire Smart Grid power system and the interaction rules for multiple GPs [4, 5, 6]. This paper focuses on optimizing the control rules for a single GP with a difficult prediction of generation using Swarm Intelligence algorithms.

Problem Statement. Two GPs are considered: one on about Russkiy island, the second on Popov island (Far East). Both power plants, according to the project, have wind power plants (WPP) of 16 and 20 MW [7] and can exchange power both between themselves and with an external system. The optimal GP control problem can be written as follows: (1)

Aopt(t) is the desired optimal control;

Apos is the area of allowable values of A(t);

f(t, S(t), A(t)) is a function that determines the profit (may be < 0 – loss) from the actions A(t) selected at time t when the GP is in state S(t);

t0 and tT specify the period under review.

The control A(t) consists of three functions of time: a1(t) is the amount of purchased (sold) electricity exchanging with an external system, a2(t) is the same for trading with a neighboring GP; a3(t) is the amount of electricity charging or (discharging) from a battery.

Three functions of time characterize state S(t) of a GP: s1(t) is own consumption, s2(t) is a generation of the WPP, s3(t) is the battery charge level.

GP makes control decisions every hour. As a result, it is possible to replace the integral in Expression (1) by the sum of electricity trading profit for each hour.

Methodology. We select a list of priority rules as a decision-making model. Every hour ti, the control A(ti) is formed based on the state S(ti) and the hour of the day h = i mod 24. Models built based on simple rules have a priori higher robustness and scalability compared to more complex control methods, for example, reinforcement learning or predictive control [8]. It is crucial in the situation under consideration since the WPP generation several hours ahead for the coastal zone of the Far East is very difficult or impossible to predict with high enough accuracy.

An example of a control rule:
IF (s1(ti) > s2(ti) AND h > h1 AND h < h2) THEN (A(ti) = accum_sale)
where accum_sale is a subprogramme or function that calculates the amount of electricity that will be stored in the battery for sale and the amount of electricity for sale.

An expert initially builds the list of rules, but the resulting control model is far from the optimal one. The expert cannot determine the priorities for applying the rules and the numerical values used in the rules. For example, when it is better to sell electricity, when - to charge; what is a better proportion between purchase and discharging in case of shortage. And the priorities of the rules are necessary for situations when a condition is satisfied for several rules and you need to choose which one of them to implement.

In this research, we have applied Swarm Intelligence (SI) algorithms to optimize the list of rules (priorities and numerical values of the model coefficients). SI algorithms show high accuracy in solving complex optimization problems in the electric power industry [8].

Experiment and results. To conduct computational experiments, we have taken the hourly data on the generation and consumption of both GPs for two months and a two-part daily tariff. The rule base created by the expert was optimized on this data with three different SI algorithms, while the control model was chosen the same for both GPs to avoid overfitting the rules to one GP.

The simulation showed the revenue increase for the GP of Russkiy island by 7 % and Popova island by 2.5 % compared with the rules build by experts.

Conclusions.
1. The proposed control model based on expert rules allows you to get not the best control in a particular situation, but the robust control, which can be easily transferred to other climatic conditions and GP features.
2. It is possible to use the SI algorithms to reduce the complexity of building expert rules, increase their accuracy, and perform adaptation to a given GP.

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