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INFORMATION SYSTEMS, ELECTRONICS AND SCIENTIFIC INSTRUMENTATION

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MODELING THE ENERGY MANAGEMENT SYSTEM TAKING INTO ACCOUNT THE LOAD CHARACTERISTICS AND ECONOMIC PERFORMANCE

Electrical load management (ELM)[3] is one of the most basic and most important branches of demand side management (DSM)[3]. Energy management in the proposed system is carried out by load management. Load management techniques divided into three main categories - load shading, valley filling and load shifting. However, these methods are used depending on the load type and the desired policy of the government and also considering the possibility of the methods used, taking into account that the most effective and popular method is load shading. In the proposed method, the outputs of the optimal sizing using the algorithm of Particle Swarm Optimization (PSO)[2] allowing to choose the number of wind generator (WG)s, modules of photovoltaic (PV) and batteries. The number of variables must be optimized in such a way that the ultimate 20-year cost of using the system is equal to the lowest possible value.

Keywords: load management, hybrid system, energy efficiency, PSO algorithm (Particle Swarm Optimization).

Introduction. Because of the discontinuous characteristic of wind and solar radiation, the most important issue in designing such systems is to supply reliable load under different atmospheric conditions according to the costs involved. Due to the diversity in types of commercially available of the PVs, WGs and batteries, the aim to select the number and type of equipment intended to supply continuous load with minimum costs will be achieved.

The purpose of this study is selecting the combination from among existing commercial equipment's of the hybrid system studied for a complete coverage of the load in a period of 20 years. The best combination is a compound that has the lowest cost during the study period. These costs will include the cost of investment and maintenance. Optimization variables are the number of PV modules, number of WG turbines and the battery capacity needed. There are various algorithms and optimization techniques, but we suggest using PSO algorithm having in our opinion , a great potential. This algorithm is a relatively new algorithm and its introduction goes back to 1995 [1]. This algorithm is based on Social Intelligence of the organisms that live in mass. The advantages of PSO to the genetic algorithm, in terms of speed and in terms of not being stuck in local extremes are shown. The above interpretations were motivated that in the present study, instead of using a genetic algorithm a PSO algorithm is used. For organizing the simulation of the system energy management, we need to create formal models of the investigated object, the formulations of the system consist of the modeling systems.

Load management and methods of its application. A method applied to this system in the energy management is described below **[3]**.

Dimensions of demand side management: 1. Load management. 2.Energy efficiency. 3. Energy revival. 4. Virtual power plant

Now, we'll explain these cases:

1. Load management

The goal of load management is to adjust the load curve with one of the following methods:

- Load Shading - Valley Filling - Load Shifting

The tools needed to achieve these goals include:

Load clipping programs. This includes the following items:

1. Interruptible demands: load of this kind of clients will be disconnected remotely or other methods under the previous agreements by receiving a payment.
2. Direct load management control: in this method of operation, the system will disconnect certain loads of customers in accordance with the prior notice to the customer's address and prior agreement and pay him with this load clipping which is related to regional conditions and load curve is the final goal of the network.
3. Demand bidding/buy-back: In this way, according to previous agreements of the large customers who previously had won the bid, we do not use their capacity during the peak and get a higher price from the entity responsible.
4. Emergency demand response: These programs create incentives for customers to reduce load in the events when the load cutoff can also optionally be included. On the whole, this program is voluntary, and customers will not be fined if they do not interrupt their load and the final group of power network for its planning on these programs does not count.
5. Load reduction proportional to the capacity: in this program, customers are obliged to reduce their load with the receipt of funds in some events and otherwise are fine. But customers for this case offer a fixed price and accordingly the resources that are quickly exploited, are predicted.
6. Utilities: This program focuses on operational reliability as a source of great possibilities with regard to this issue that programmers extend the ideas of measuring the long-term and seasonal reliability in time of criteria development.

- **Dynamic pricing program:**

1. Pricing based on consumption of the Time Of Use (TOU)

2. Critical Peak Pricing (CPP).

3. Real Time Pricing (RTP).

Other load management tools can be mentioned the following:

- Storage techniques such as Ice storage, Heat Storage, Pump Storage
- Production relocation planning
- Voluntary load reduction programs
- Attachment work programs included daily and weekly

2. Energy efficiency

The goal of energy efficiency is the following figure, showing the increase in the electric energy efficiency both in production and consumption.

However, this aspect of consumption management includes the following ways:

1. Low consumption lamps
2. Lighting Control Systems
3. Water pumps and motors with adjustable speed
4. Transformers with high efficiency
5. Storage in the final consumer devices: furnishings and buildings and boiling engines and pumps and ventilation systems, etc.

3. Energy revival

In this section, methods such as the following can be considered:

1. Changing the settings of the thermostats
2. Reducing work hours

4. Virtual power plants:

1. CHP (combined Heat and power)
2. DG (Distribute Generation)

With regard to the descriptions in this section, we can say that load management techniques are the three main categories of load shading, valley filling and load shifting. However, these methods are used depending on the load type and the desired policy of the government and also considering the possibility of developing whichever method is possible, but an effective and popular method is load shading. The comparison of the energy management with the load management and without applying the load management is done by this procedure.

Modeling and simulation of system performance PV/WG (photovoltaic/Wind generator). In the study conducted as shown in [4], the system performance is simulated with time steps of 1 hour for one year. Power generated by PV and WG during each time step is assumed constant. Thus, the power generated by renewable energy sources will be numerically equal to the energy produced during the time step. Characteristics of the current – voltage and power - voltage of a PV array for each production unit shown in Figure 1[4] is composed of parallel modules NP and series modules NS. The maximum power output of the PV array $\boldsymbol{P_M^i(t)}$, on the i-th day

$(\mathbf{1 \leq i \leq 365})$ and at the t-th hour $(\mathbf{1 \leq t \leq 24})$, using the module specification in the standard test conditions (STC, cell temperature of 25 ° C and radiation of 1 kW/m2) provided by the manufacturer, is calculated. Using the ambient temperature and solar radiation, following equations[4] clearly express the behavior of a module.

$$P_M^i(t) = N_S.N_P.V_{OC}^i(t).I_{SC}^i(t).FF^i(t)\,, \tag{1}$$

$$I_{SC}^i = \{I_{SC,STC} + K_I[T_C^i(t) - 25°\mathrm{C}]\}\frac{G^i(t)}{1000}\,, \tag{2}$$

$$V_{oc}^i(t) = V_{OC.STC} - K_V.T_C^i(t)\,, \tag{3}$$

$$T_C^i(t) = T_A^i(t) + \frac{NCOT - 20°\mathrm{C}}{800}G^i(t)\,, \tag{4}$$

where $\boldsymbol{I_{SC}^i(t)}$ is the short-circuit current of module(A), $\boldsymbol{I_{SC.STC}}$ is the short-circuit current of module in the standard test conditions (A), $\boldsymbol{G^i(t)}$ is the amount of radiation that treats with the PV module level (W/m2), $\boldsymbol{K_I}$ is the temperature coefficient of short circuit current $(\boldsymbol{A}$ / °C) , $\boldsymbol{V_{OC}^i(t)}$ is the open circuit voltage (V), $\boldsymbol{V_{OS,STC}}$ is the open circuit voltage in the standard test conditions (V), $\boldsymbol{K_V}$ is the temperature coefficient of open circuit voltage $(\boldsymbol{V}$/°C) ,$\boldsymbol{T_A^i(t)}$ is the ambient temperature (°C),$\boldsymbol{NCOT}$ is the nominal cell operating temperature (°C) and $\boldsymbol{FF^i(t)}$, all these are provided by the manufacturer.

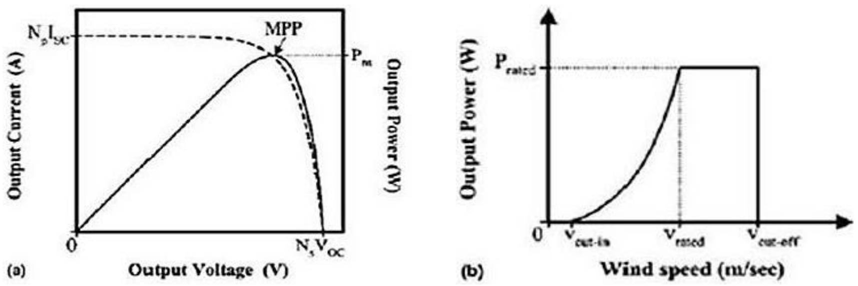

Fig. 1. The output power characteristics WG and PV: (a) current - voltage and power - voltage characteristic of the PV module and (b) power characteristic based on the wind speed WG

Real power transferred from the PV to the battery bank, $\boldsymbol{P_{PV}^i(t)(w)}$, to the maximum output power of the PV array, $\boldsymbol{P_{PV}^i(t)(w)}$ is calculated after the passage of the conversion factor of the charger battery, ns, which is obtained from the following equation[4]:

$$n_s \equiv \frac{P_{pv}^i(t)}{P_M^i(t)} = n_1.n_2\,, \tag{5-1}$$

where $n_1$is the efficiency of power electronics devices that are specified by the manufacturer and n_2 is the conversion factor that is related to the battery charging algorithm and shows the deviation of the actual power generated by PV from the maximum obtainable power.

The output power Graph based on wind speed WG is shown in Figure 1-b. Such a graph is drawn by the manufacturer and typically represents real power transferred from WG to the battery bank and includes the effectiveness of the charger battery efficiency, and if it exists, the functioning MPPT. (Maximum Power Point Tracker) Consequently, there is no need to model the charger battery characteristics in the WGs. This diagram, in the form of a lookup table in the optimization algorithm, is introduced relating the turbine output to the wind speed. The Input power to the battery bank from the wind turbine at an hour of the t-th from the day of the i-th, $\boldsymbol{P^i_{wG}(t)}(\boldsymbol{W})$ is calculated from the following equation [2]:

$$P^i_{WG}(t) = P_1 + [V^i(t) - V_1]\frac{P_2 - P_1}{V_2 - V_1}\,, \tag{5-2}$$

where $\boldsymbol{V^i(t)}$ is the wind speed (m/s) at the turbine installation place, and $(\boldsymbol{P_1}, \boldsymbol{V_1})$, $(\boldsymbol{P_2}, \boldsymbol{V_2})$ are the pairs of speed and power stored in a lookup table, with the condition that $\boldsymbol{v_1} < \boldsymbol{v^i(t)} < \boldsymbol{v_2}$ The average minimum and maximum wind speed in your region is V_2-V_1 and average minimum and maximum power in your region is p_2-p_1.[3] the total transmitted power from PV and WG to the battery bank, $P^i_{re}(t)(W)$, during the day of i-th $1 \le i \le 365$ and hour of t-th $1 \le t \le 24$, is calculated from the following equation [2]:

$$P^i_{re}(t) = N_{PV}.P^i_{PV}(t) + N_{WG}.P^i_{WG}(t)\,, \tag{5-3}$$

where $\mathbf{N}_{pv}$ is the total number of PV modules and $\mathbf{N}_{WG}$ is the total number of WGs.

Minimizing costs using intelligent algorithm PSO(particle swarm optimization). Evolutionary computation techniques (EC) benefit from a set of acceptable solutions called population and determines the optimum solution through cooperation and competition among the individual members of this population. In difficult optimization problems, these techniques often find optimal point faster than traditional optimization methods. The most common techniques of EC involve the evolution strategies, genetic algorithms, genetic programming and evolutionary programming, inspired by the natural evolutionary mechanisms [5].

Particle Swarm Optimization algorithm (PSO) is placed in the set of swarm intelligence methods. Over the past decade, PSO has become increasingly popular due to the high potential for solving difficult optimization problems.

The ideas of PSO, instead of being encouraged by the evolutionary mechanisms of natural selection, are influenced by social behavior of flock's organs like those of birds and fish. It was observed that the behavior of the constituent members of a flock is formed by a set of basic rules such as speed coordination with the nearest neighbor and acceleration based on distance. In this context, it has been claimed that the PSO is the mutation which is instinctively done.

PSO is a population algorithm, where members search for a desired area. In this bunch of population, the swarm and each member is called particle. Each particle moves with adjustable speed in the search space and keeps the best previous position itself in its memory. In the whole space of the algorithmic search, the best position achieved by the whole series is to inform all other particles.

Of course, different techniques and many approaches have been proposed to increase the efficiency of the algorithm while dealing with various problems depending on the type of issues that may affect algorithm (approaches such as the use of the constriction factor, multi start technique, deflection technique, stretching technique, …) but since in this study, there is no need to have more approaches than the mentioned ones, the further details can be avoided in this case. More information about the efficiency of the solutions mentioned is available in reference [5]. What will be applied in the present study is a simple algorithm PSO using the inertia weight that will ensure the optimized solutions obtained, the problem will be addressed to several times and with different initial populations (multi start technique).

The minimization problem using PSO. In the proposed method, the outputs of the optimal sizing using the algorithm PSO are the number of WGs, modules PV and batteries. The number of variables must be optimized so that the ultimate 20-year cost of the system should be equal to the lowest possible value.

The total cost of the system $\boldsymbol{J}(\boldsymbol{X})$(\$) is the sum of capital costs $\boldsymbol{C_c}(\boldsymbol{X})$(\$) and maintenance costs $\boldsymbol{Cm}(\boldsymbol{X})$(\$).[5]

$$\min_x\{J(X)\} = \min_x\{C_c(X) + C_m(X)\}, \tag{6}$$

where X is the vector of decision variables mentioned above.

Therefore, the aim of this multi-variable optimization is minimizing a function including the initial and ongoing 20-year costs of each of the parts used in the system.

$$\begin{aligned} J(X) &= N_{PV}.(C_{PV} + 20M_{PV}) + N_{WG}.(C_{WG} + 20M_{WG}) + N_{BAT}.[C_{BAT}.(y_{BAT} + 1) + \\ &+M_{BAT}.(20 - y_{BAT} - 1)] + N_{ch}^{PV}.[C_{ch}^{PV}.(y_{ch}^{PV} + 1) + M_{ch}^{PV}.(20 - y_{ch}^{PV} - 1)] + \\ &+ N_{INV}.[C_{INV}.(y_{INV} + 1) + M_{INV}.(20 - y_{INV} - 1)]\ , \end{aligned} \tag{7}$$

wherein:

$$X = [N_{PV}, N_{WG}, N_{BAT}]\ , \tag{8}$$

According to the conditions:

$$N_{PV} \geq 0\ , \tag{9}$$

$$N_{WG} \geq 0\ , \tag{10}$$

$$N_{BAT} \geq 0\ , \tag{11}$$

$$P_{\text{Supply}}(\text{i},\text{t},\text{X}) \geq P_{\text{Demand}}(\text{i},\text{t}) \text{ for } \begin{cases} \text{i} = 1,2,3,\ldots,365 \\ \text{t} = 1,2,3,\ldots,24 \end{cases}, \tag{12}$$

where CPV is the cost of photovoltaic, CWG is the cost of wind energy, CBAT is the cost of battery, $\boldsymbol{C_{Ch}^{PV}}$ are respectively the capital cost of a PV module, WG, battery and PV charger battery and CINV is the capital cost of inverter DC/AC required for the system. Similarly, MPV, MWG, MBAT and M_{ch}^{PV} are respectively the maintenance cost ($/year) of a PV module, WG, battery and PV charger battery and MINV is the maintenance cost of inverter DC/AC required for the system. $\boldsymbol{yINV}, \boldsymbol{y_{ch}^{PV}}, \boldsymbol{yBAT}$ are respectively the number of replacement frequency of the inverter DC/AC and each of the PV chargers battery and batteries during 20 years of the system is performance. The number of inverter replacement frequency during the system lifetime (20 years) is equal to that of the system divided by the mean time between the failures of the power electronic converter. (Note that the initial installation is considered as a replacement.

The last condition is the ability or inability of the composition obtained for the system to meet the load requirement. This condition is tested at each step of simulation and even if in one step, it fails, the composition obtained is known to be inappropriate and will be removed from the possible plans.

The simulation results. To evaluate the proposed method, a hybrid power plant of wind - solar is simulated whose results can be seen below. This plant is simulated based on the data related to the wind and radiation survey of the East region of Iran .It should be noted that the costs obtained are based on the prices in the [4] and based on the dollar ($) and the load profiles under study to test the reliability of a variable load profiles with a maximum value are 20Kw. Annual profiles of wind speed sampled at a height of 40 meters and intervals of 1-hour, an average of 24 hours in a 52-week year is shown in Figure 2. Since wind is a random phenomenon, the probability that the annual wind profiles in one year will be repeated identically next year is very low and, in fact, equal to zero. Therefore, in order to enhance the credibility of the simulation results, from the 24-hour profiles of the wind at intervals of a week are averaged. Thus, for instance, the wind speed is averaged at 12 o'clock, during the days of the first week of March, and 4.9 m/s are obtained. Now, it is assumed that in the coming years as well, at 12 o'clock of the days of the first week of March, the wind will be blowing at a speed of 4.9 m/s. This has two major advantages: first the results would be more valid because each hour, the probability of the wind blowing at a speed equal to the weekly average of the wind speed over the past year and at the same time much greater than the probability of wind blowing at a speed exactly equal to the speed for the same time of the previous year.

In conclusion, the results of simulation in terms of working with the weekly average will have more credibility than the results obtained from the simulation with exact duplicate data. Second, instead of the simulation during time step 8760 (one year of 365 days is assumed to be equal to 8760 hours), the simulation can be done in time step 52×24=1248 (one year is equal to 52 weeks and each week will also include a 24 hour profiles).

Thus, the volume and time of computations and memory requirements are reduced about 7 times. Profiles of blowing and horizontal-vertical radiation of the wind and load consumption during one year that are obtained by taking the average of 24 hours over 52 weeks are shown in Figures 2 and 3.

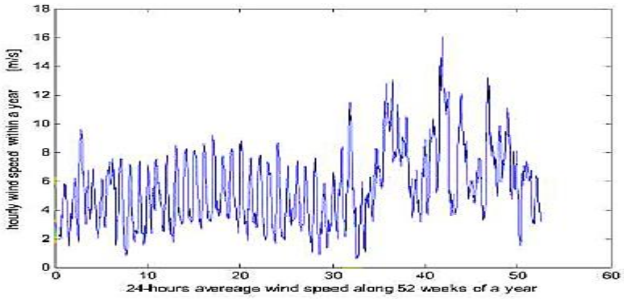

Fig. 2. 24-hour average of the wind over the 52 weeks of the year

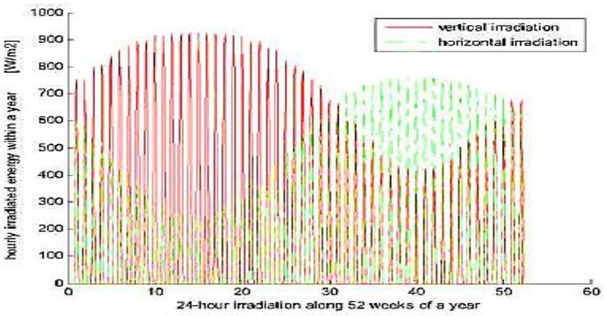

Fig. 3. 24 -hour average of the horizontal and vertical radiation over the 52 weeks of the year

An optimum combination of solar-wind a hybrid power plant. Technical and economic characteristics of equipment used in a hybrid power plant studied are as follows:

- Wind turbines with nominal power 50000W, installation height 15m, low cutoff speed 2.5 m/s, nominal speed 11 m/s, high cutoff speed 24 m/s, price 200000$.
- a PV module with nominal power 6000W, price 30000$.
- a Battery with a nominal capacity 2000 Ah, DODmax = 80%, charge and discharge efficiency 85%, lifetime 3 years, price 6000$.

The annual maintenance cost of any equipment is considered to be equal to 1% of the initial cost of buying them.

The main functions of the optimization are as follows:

Generation production. Each generation comprises a bunch containing several particles that each particle actually shows a particular combination for the hybrid power plant intended. Each particle is shown with a three-dimensional vector containing a number of WGs, PV modules and batteries (8).

Compare the particles (compounds)-conditions (9 to 12)

Determine the suitability of each combination. If a composition violates the maximum one of the conditions (9 to 12), it actually becomes an unacceptable composition for the system and very large fines are charged for it. But if, the combination is correct according to the conditions above, it is recognized as an acceptable combination for the system and based on Equation 7, the suitability (cost) of the combination is calculated.

Next generation production, and repetition of the above steps.

The algorithm stops after producing a limited number of generations (100 generations) and the best answer obtained is known as the most optimal possible combination. In the simulation part, as its name implies, to simulate the compounds produced in each generation are paid, as desired combination for one year, with data on blowing, radiation and load shown in Figures 2 and 3 are simulated. If even, in one of the steps of simulation, the system is unable to meet the load, then the condition is violated, condition (12) is violated and the combination with getting a large fine actually becomes an unacceptable combination. But if the system is able to supply the load at all stages of simulation, the simulation is over successfully and this would mean that the combination is correct in condition (12).

The above program runs with the initial population equal to 60 individuals and for 500 generations.

The operation time of the above program is approximately 3 minutes on a Pentium IV with 1024 MB RAM. Figure 4 shows the trend of convergence of the above program in five independent executions. It can be seen that almost all executions in less than 150 generations will converge to the optimal answer.

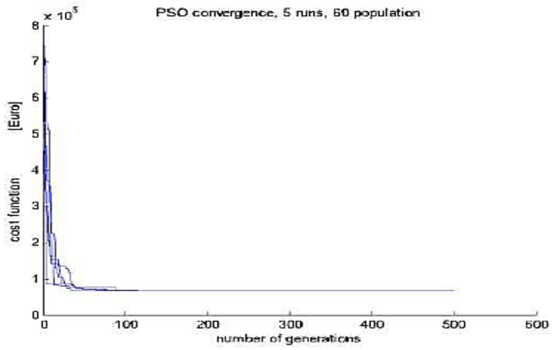

Fig. 4. The convergence trend of the program written in five independent executions (Populations equal to 60 individuals and for 500 generations)

An interesting thing is that the program execution with population of 30 individuals and 100 generations to reach the optimal solution will suffice. This, with the same previous system lasts 60 seconds, just in order to ensure the convergence program to the global optimal answer, the program had better be run several times (5 times) consecutively (multistate technique).

The last thing is, since the final composition should include correct arrays, it is better to surround the space to obtain results which are real and non-integer, the search is performed to obtain the best combination. Since, this problem has only three variables, it will be easy to do.

Conclusions. The main purposes of combining wind and solar units are to provide more reliable load consumption under different climate conditions and on the other hand, to reduce the required costs of the system and also effects of load management on the economic and energy management issue. This study focuses on a detailed examination of the costs of a wind-solar hybrid power plant independently over a 20 year period. The storage system used is a lead - acid battery bank and in addition to the cost of production and storage units, costs related to power electronic equipments such as battery systems and charger and DC/AC inverter are also considered in calculations.

Choosing the optimal combination of a power plant has been conducted using particle-bunch optimization algorithm. The condition that in the process of problem solving has always been considered is the full coverage of the load in the whole year. It seems that, since the new algorithm is used, and the effects of various factors are considered, this work is unique in its kind. Features of this algorithm include simplicity, speed and convergence to the global optimum point.

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ԱՖՐԱ ՄՈՒՍՏԱՖԱՅԵԻ

ԷՆԵՐԳԱԿԱՌԱՎԱՐՄԱՆ ՀԱՄԱԿԱՐԳԻ ՄՈԴԱԼԱՎՈՐՈՒՄԸ՝ ՀԱՇՎԻ ԱՌԱԾ ԲԵՌԻ ԲՆՈՒԹԱԳՐԵՐԸ ԵՎ ՏՆՏԵՍԱԿԱՆ ԱՐԴՅՈՒՆԱՎԵՏՈՒԹՅՈՒՆԸ

Պահանջարկի կառավարման տեսանկյունից ամենահիմնականը և կարևորը բեռի էլեկտրական կառավարումն է: Առաջարկվող համակարգում կառավարումը էներգասնուցման ասպարեզում իրականացվում է բեռի կառավարմամբ: Բեռի կառավարման մեթոդները ներկայանում են երեք հիմնական դասերով՝ բեռի անջատում, տարածքում բեռի բաշխում, բեռի փոխանջատում: Սակայն այդ մեթոդներն օգտագործվում են՝ կախված բեռի տեսակից և կառավարության վարած քաղաքականությունից, և դիտարկվում են օգտագործվող մեթոդների հնարավորությունները՝ հաշվի առնելով այն, որ արդյունավետ ու տարածված մեթոդ է բեռի անջատումը: Առաջարկվող տարբերակում ելքերի օպտիմալ չափսերը, օգտագործելով մասնակի խմբավորմամբ օպտիմալացման ալգորիթմը, հնարավորություն է տալիս որոշելու հողմագեներատորների քանակը, ֆոտովոլտային տարրերի և ակումուլյատորների քանակը: Փոփոխականների քանակը օպտիմալացված է այնպես, որ համակարգի 20 - ամյա օգտագործման արժեքը վերջնականապես ստացվի նվազագույնը:

Առանցքային բառեր. բեռի կառավարում, հիբրիդ համակարգ, էներգետիկ արդյունավետություն, մասնակի խմբավորմամբ օպտիմալացման (ՄԽՕ) ալգորիթմ:

АФРА МУСТАФАЕИ

МОДЕЛИРОВАНИЕ СИСТЕМЫ ЭНЕРГОМЕНЕДЖМЕНТА С УЧЕТОМ ХАРАКТЕРИСТИК НАГРУЗКИ И ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ

Электрическое управление нагрузкой (ELM) является одним из основных и наиболее важных для управления спросов (DSM). В предлагаемой системе менеджмент в энергопитании осуществляет управление нагрузкой. Методы управления нагрузкой разделяются на три основные категории - затенение нагрузки, распределение нагрузки по территории и переключение нагрузки. Однако эти методы используются в зависимости от типа нагрузки и проводимой правительством политики. Рассматриваются возможности используемых методов с учетом того, что столь же эффективным и популярным методом является затенение нагрузки. В предлагаемом способе выходы оптимальных размеров с использованием алгоритма оптимизации с частичным группированием (Particle Swarm Optimization) (PSO) дают нам возможность выбрать количество ветрогенератора (WG), модули из фотовольтаик (PV) и батареи. Число переменных оптимизировано таким образом, чтобы в конечном итоге стоимость использования системы за 20 лет была минимальной.

Ключевые слова: управление нагрузкой, гибридная система, энергетическая эффективность, алгоритм оптимизации с частичным группированием (PSO).