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ABOUT THE INTELLIGENT DECISION MAKING SYSTEM FOR DYNAMIC ELECTRICITY PRICING ON RENEWABLE MICROGRIDS

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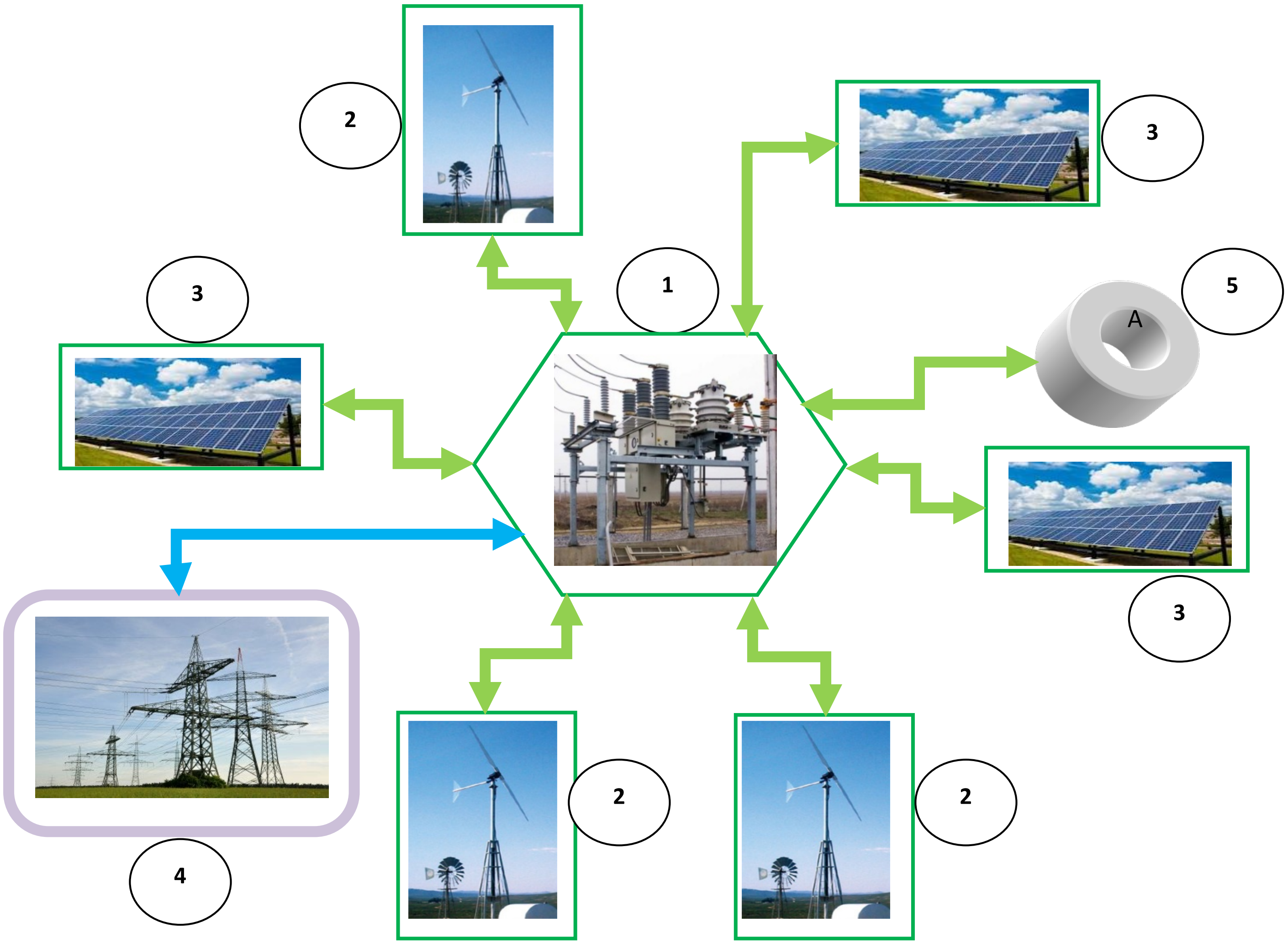
What is the micro-energy system (Microgrid)?



The General Scheme of the micro-energy systems (Microgrid):
1 – the system receiving-transmission facility (transformer); 2 – local wind power stations (WPS); 3 – local solar power stations (SPS); 4 – an external source of electricity for use; 5 – internally accumulator of electric energy

THE OBJECT, SUBJECT AND THE PURPOSE OF RESEARCH

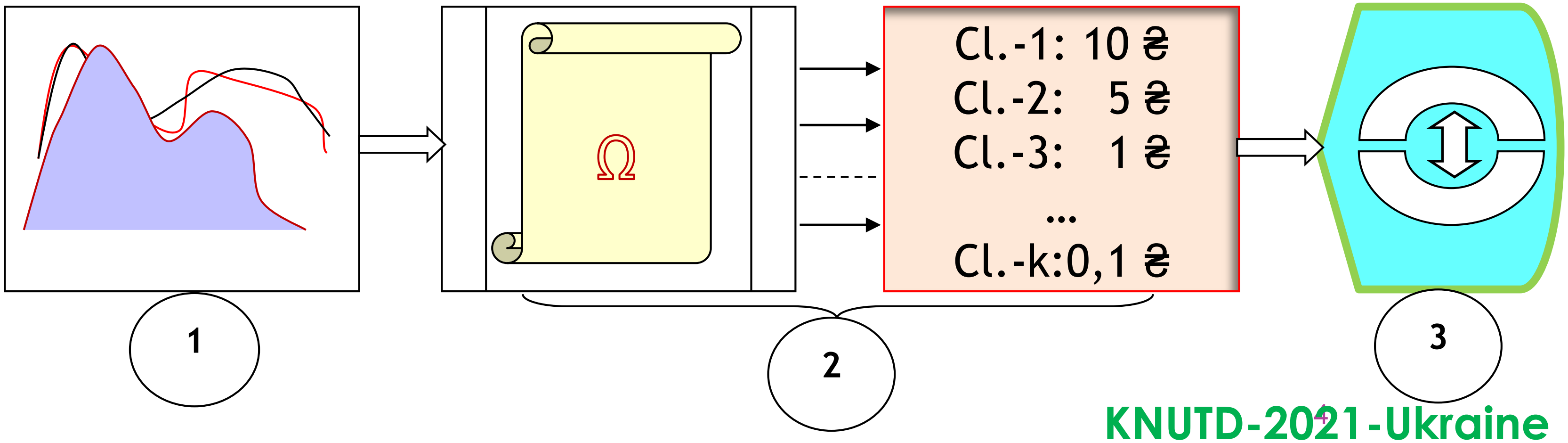
Our Research deals with an extremely complex area that concerns many aspects of the energy supply not only the population but also of local small businesses.

- ***The object of research*** – distributed generation in electricity power general using.
- ***The subject of research*** – intelligent systems of operational management of microgrids with distributed generation, as local networks of low voltage that are integrated to central power systems.
- ***The purpose of research*** – this work has the innovative, to some extent staging character and has the primary purpose to highlight one of the approaches to this important problem.

THE METHODOLOGY OF PROBLEM DESISION

The intelligent decision making system (IDMS) in the management of the question here problem, for the implementation energy systems with distribute generation must go through at least of three basic stages:

- the stage of system-information-analytical (SIA) research for particular Microgrid, including system collection of statistical information (1);
- the stage training of the system in specific conditions and concrete participants of energy market (2);
- the implementation and actual management of local power grid process: immediate switching points forecasting and their execution, etc. (3).



THE TRAINING STAGE THE INTELLECTUAL DECISION MAKING SYSTEM (IDMS) IN MODERN MICRO-GRIDS

From the standpoint of the bi-clustering complex task is:
1) constructing an optimal clustering, and
2) simultaneous designing the optimal ensemble of informative features.

Let be given the set $\{x_{0j},\ j=1,\dots,m\}$ of averaged values of gains/losses (in terms of pattern recognition "**target economical features**") measurements for each of m private or local members of the power island.

Let in the space $x_{ij} \in X$, $i=1,\dots,n,\ j=1,\dots,m$, also be introduced the following important (from the standpoint of designing the optimal models for operational management of Micro-grids) features:

- ✓ the natural potential of wind energy;
- ✓ the natural potential of solar energy;
- ✓ the impact of the season for the latitude of the facility;
- ✓ geographic latitude of the facility;
- ✓ dayparts including broken down by hours;
- ✓ outside air temperature affects;
- ✓ the reliability indexes of wind-solar systems;
- ✓ changes the efficiency value of during equipment lifetime.

Obviously, this list can be extended.

Thus, the total array of input data in our task has a formal appearance as follow:

$$\omega_{ij} \in \Omega \equiv \tilde{X} = \left(x_{0j} \vdots x_{ij} \in X\right),\ j=\overline{1,m},\ i=\overline{1,n}\ . \qquad (1)$$

It is necessary:

1) to synthesize a subset $\{x_{\eta}^{*}\} = X^{*} \subset X\ ,\eta=1,\dots,n^{*},\quad n^{*} \le n$ of the above factors, that would allow:

2) to classify all objects on $k < m,\ k = 1,\dots,\mathrm{K}$ homogenous groups and

3) to construct the decision rule of switch for one of the most efficient modes of operation for each participant of an energy island.

Step 1. Preliminary statistical data operating for each object $\omega_k \in \Omega$ in an Energy Island.

Step 2. Separating the (1) into: Ω^A and Ω^B, $\Omega^A \cup \Omega^B = \Omega$, $\Omega^A \cap \Omega^B = \varnothing$, and matrix of data $\tilde{X}$ would look like:

$$\tilde{X} = \left[\left(x_{0j} \vdots X \right)^A \vdots \left(x_{0j} \vdots X \right)^B \right], \ j = 1,...,m^A = m^B, \ m^A + m^B = m \,.. \quad (2)$$

Step 3. Using clustering independently on subsets $\omega_k \in \Omega$, Ω^A and Ω^B in space $\tilde{X}$. In this case a fairly simple criterion can be used:

$$D^2(\hat{m}) = \sum_{k=1}^{K} (\hat{m}_k^A - \hat{m}_k^B)^2 , \quad \hat{m}_k^A = \frac{1}{r_k^A} \sum_{l=1}^{r_k^A} x_{0l} , \quad \hat{m}_k^B = \frac{1}{r_k^B} \sum_{l=1}^{r_k^B} x_{0l} \quad (3)$$

Stop rule: the inductive procedure ends if:

$$D^2(\hat{m})_s \le D^2(\hat{m})_{s+1} , \quad (4)$$

As output will be the amount of clusters $k^{*(A)} = k^{*(B)} = K^*$ as well as $\{x_l^*\} = X^*, \ l = 1,...,n^*, \ n^* \le n$

Finally, it is possible to construct the decision rule for making decisions for any local participant of the energy island in system "in-out" regarding the efficiency of switching moments.

Let us suppose that the decision is as follows: new object $\omega_l^* \in \Omega$ belongs to the *k*-th cluster efficiency if

$$d(\omega_l^*, m_k) < d(\omega_l^*, m_s), \ k, s = 1, \ldots, K, \ k \ne s \quad (5)$$

for a certain ensemble of features X_p^* and appropriate clusterization S_p^*, where (X_p^*, S_p^*), $p = 1, \ldots$ will be considered as an optimal solution. However, taking into account target features the expression (7 becomes:

$$d(x_{0l}^*, \dot{m}_k) < d(x_{0l}^*, \dot{m}_s), \ k, s = 1, \ldots, K, \ k \ne s \,. \quad (6)$$

Then the criterion for minimum of the recognition error $\Delta^2(\Omega_\Delta)$ can be written as:

$$\Delta^2(\Omega_\Delta) = \sum_{\Omega_\Delta} \delta_l^2 \to \min \;, \qquad (9)$$

$$\delta_l = \begin{cases} 1, & d(x_{0l}^*, \dot{m}_{k(l)}) > d(x_{0l}^*, \dot{m}_{s(l)}) \\ 0, & d(x_{0l}^*, \dot{m}_{k(l)}) < d(x_{0l}^*, \dot{m}_{s(l)}) \end{cases}, \qquad (10)$$

where: $k \neq s,\; k,\; s = 1,\dots,K$, $\omega_l^* \in R_k$, or:

$$\delta_l = [x_{0l}^* - \dot{m}_{k(l)}(D_2)],\;\; \omega_l^* \in \Omega_\Delta \,, \qquad (11)$$

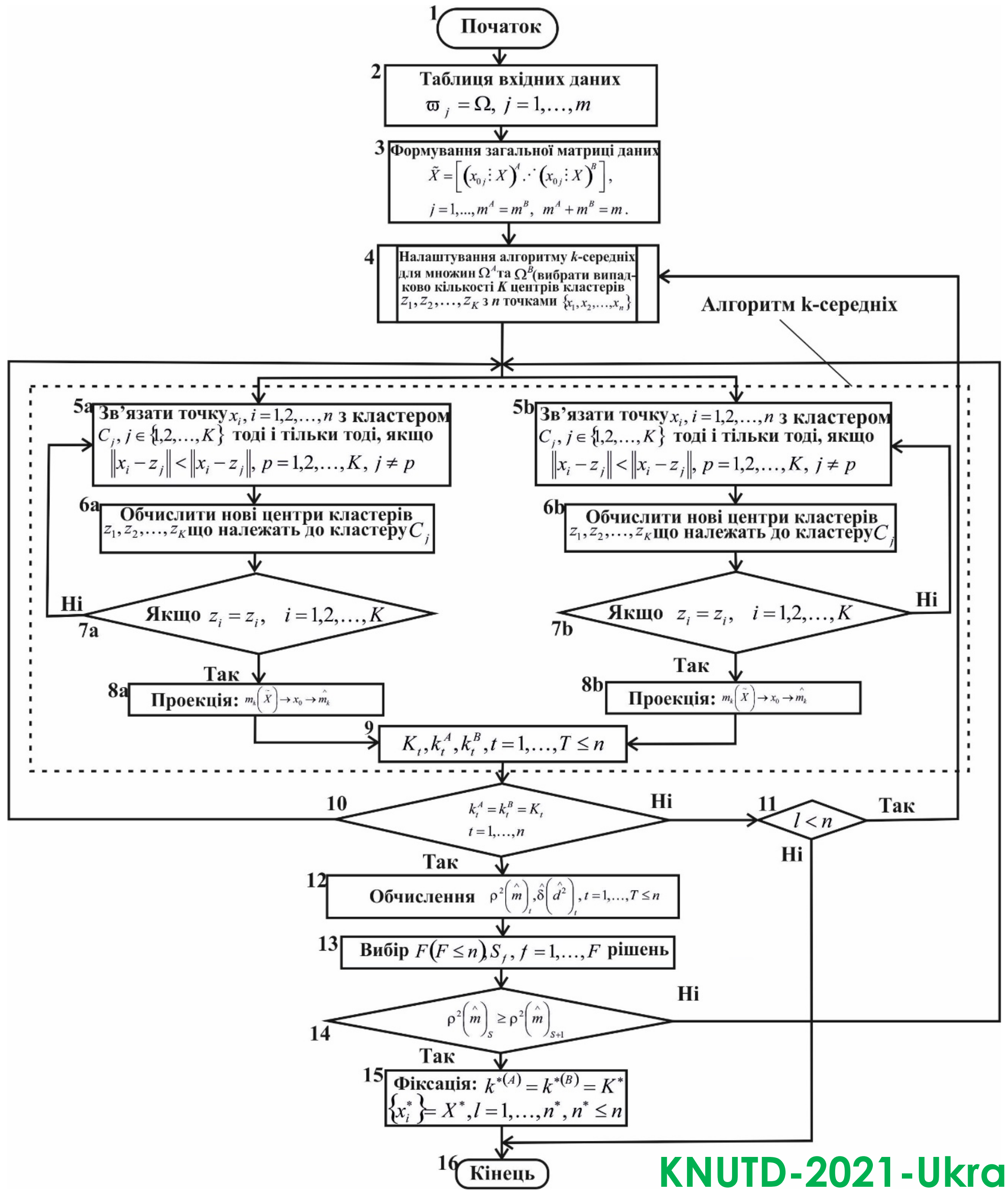
and where x_{0l}^* is the value of the target signs i.e. the electric energy cost at a given time for the particular generator/consumer $\omega_l^* \in \Omega_\Delta$; $\dot{m}_{k(l)}(D_2)$ is the assessment of center of *k*-th cluster on the axis x_0 to which enrolled the object ω_l^* according to the subset of $\{X_p^*\}$.

Hence, this value must meet revenue/loss for participant of local energy island at this time.

Thus, on the basis of the obtained solution the output value quantity x_0^* can be recognized for new object not participated in learning:

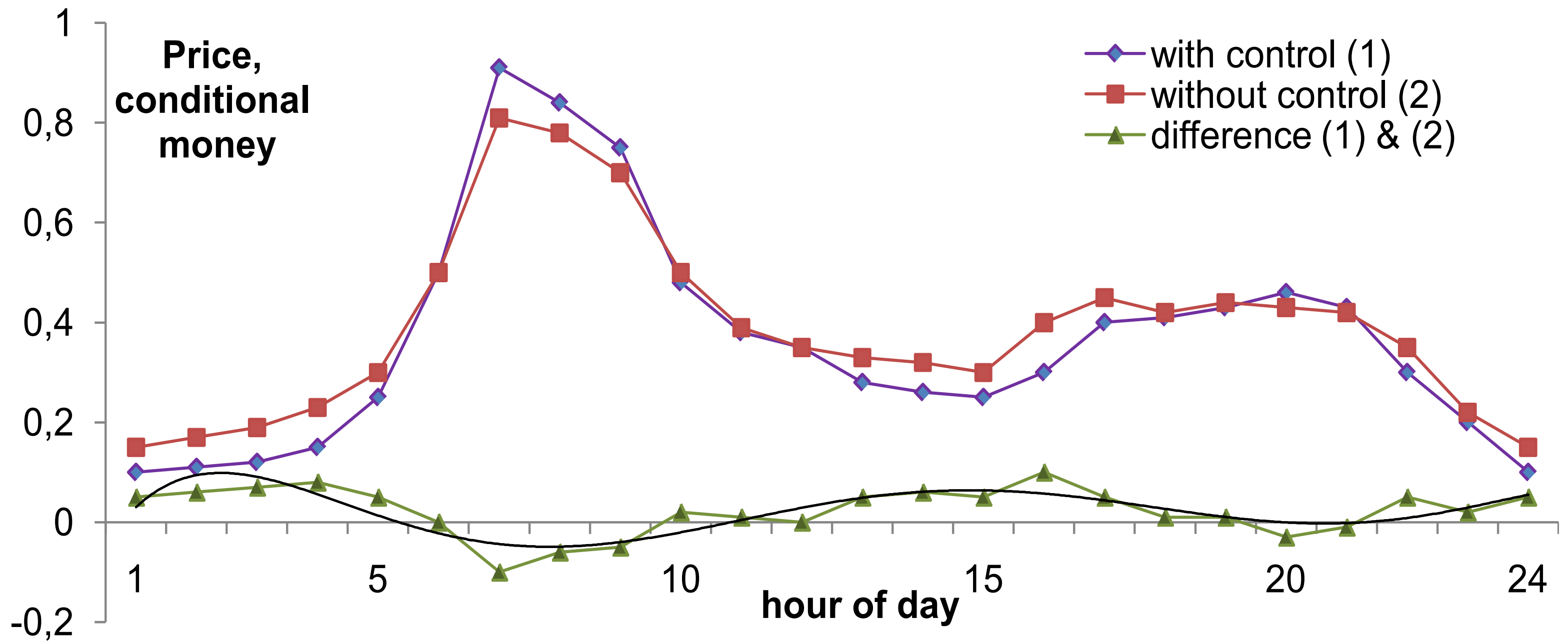
$$\min_K d[(m_k, \omega^*) / S^*(X^*)] \to x_0^*, \qquad (12)$$

Such decision in the on-line mode sends the command to remote control of any member of the power island for switching to "in-out" mode to maximize the economic efficiency of the any participant


Початок
Таблиця вхідних даних
Формування загальної матриці даних
Налаштування алгоритму k-середніх для множин Ω^A та Ω^B (вибрати випадково кількості K центрів кластерів $z_1, z_2, \ldots, z_K$ з n точками $\{x_1, x_2, \ldots, x_n\}$
Алгоритм k-середніх
Зв'язати точку $x_i, i = 1,2,\ldots,n$ з кластером $C_j, j \in \{1,2,\ldots,K\}$ тоді і тільки тоді, якщо $\|x_i - z_j\| < \|x_i - z_j\|, p = 1,2,\ldots,K, j \neq p$
Обчислити нові центри кластерів $z_1, z_2, \ldots, z_K$ що належать до кластеру C_j
Якщо $z_i = z_i, \quad i = 1,2,\ldots,K$
Ні
Так
Проекція:
$K_t, k_t^A, k_t^B, t = 1,\ldots,T \leq n$
$k_t^A = k_t^B = K_t$
$t = 1,\ldots,n$
$l < n$
Обчислення
Вибір $F(F \leq n) S_f, f = 1,\ldots,F$ рішень
Фіксація: $k^{*(A)} = k^{*(B)} = K^*$
$\{x_l^*\} = X^*, l = 1,\ldots,n^*, n^* \leq n$
Кінець

THE VIRTUAL EXPERIMENT

We assume that levels of renewable generation are considered as stochastic price-sensitive processes and in turn depend on wind and solar energetic levels. Apart from that, for virtual simulation experiment, we assume that each microgrid (or the microgrid's member) calculates the prices both in the real-time electricity pricing as well as in renewable generation prices.



The evaluation of dynamic pricing algorithm by comparing it with real statistical data and virtual modeling results.

The graph shows that a decision on switch from one source to another gives substantial savings for one of the Micro-grid subjects.

Thank you for attention!