Innovative technologies.

Viktor Denisov
researcher, Institute of General Energy
National Academy of Sciences of Ukraine, Kyiv

Sergey Denisov
university lecturer, Taras Shevchenko National University of Kyiv

MATRIX ALGORITHM FOR THE SETTING OPTIMAL MODES OF TECHNOLOGICAL COMPLEXES ON THE LIFE CYCLE HORIZON

Matrix algorithm for the setting optimal modes of technological complexes on the life cycle horizon. The functional of economic and technological influence used.

Keywords: matrix algorithm, optimal modes, technological complexes, life cycle horizon, functional of economic and technological influence.

https://orcid.org/0000-0002-3297-1114

In [1, 2], an algorithm was proposed for selecting the optimal vector of generating and accumulating powers on a subset of available technological solutions, based on estimates of possible relative and absolute changes in the consumption vector $\{\boldsymbol{vc}^{\boldsymbol{min}} < \boldsymbol{vc} < \boldsymbol{vc}^{\boldsymbol{max}}\}$ and generation. To solve the problem, the reflection and matrix transformation algorithm was used. The following matrices were needed for this algorithm to work::

- $(\boldsymbol{c}_{\boldsymbol{jf}})$ – prime cost of technology $\boldsymbol{j}$, in mode $\boldsymbol{f}$, used during simulation for several set values of discount $\boldsymbol{i}$;
- $(\boldsymbol{t}_{\boldsymbol{jf}})$ – technological parameters;
- $\{\boldsymbol{e}_{\boldsymbol{jf}}(\boldsymbol{P}_{\boldsymbol{j}}^{\boldsymbol{MAX}}, \boldsymbol{YH})\}$ – the accessible annual generation volumes;
- $\{\boldsymbol{p}_{\boldsymbol{jf}}(\boldsymbol{P}_{\boldsymbol{j}}^{\boldsymbol{MAX}}, \boldsymbol{ICU}_{\boldsymbol{jf}})\}$ – accessible loads;
- $\{\boldsymbol{c}_{\boldsymbol{jf}}^{\boldsymbol{ti}}(\boldsymbol{P}_{\boldsymbol{j}}^{\boldsymbol{MAX}}, \boldsymbol{ICU}_{\boldsymbol{jf}})\}$ – cost of electricity supply for $\boldsymbol{ti}$ interval;
- $(\boldsymbol{b}_{\boldsymbol{jf}}^{\boldsymbol{ti}})$ – binary matrix of optimal sets of modes of generating and accumulation technologies, in terms of minimizing the total cost of electricity supplied during $\boldsymbol{ti}$ interval.

Elements of the cost matrix $(\boldsymbol{c}_{\boldsymbol{jf}})$ for the technology $\boldsymbol{j}$ in $\boldsymbol{f}$ mode were calculated by the formula (1):

$$(\boldsymbol{c_{jf}}) = \frac{\sum_{\tau}^{T_j} \frac{\left\{c_{\tau}^{cap} + c_{\tau}^{const(f)} + c_{\tau}^{var(f)}\right\}}{(1+i)^{\tau}}}{\sum_{\tau}^{T_j} \frac{e_{jf}}{(1+i)^{\tau}}}, \tag{1}$$

where: $\boldsymbol{e_{jf}}$ – annual energy amount; $\boldsymbol{c_{\tau}^{cap}}$ – investment; $\boldsymbol{c_{\tau}^{const(f)}}$ – constant operating expenses; $\boldsymbol{c_{\tau}^{var(f)}}$ – variable operational costs; $\boldsymbol{T_j}$ – of the $\boldsymbol{j}$-technology life cycle, years; $\boldsymbol{\tau}$ – current year.

The accessible loads volume $\boldsymbol{p_{jf}}$ was determined by the formula:

$$\boldsymbol{p_{jf} = P_j * ICU_{jf}}, \tag{2}$$

Annual generation volumes $\boldsymbol{e_{jf}}$ – by the formula:

$$\boldsymbol{e_{jf} = P_j * ICU_{jf} * YH}, \tag{3}$$

where: $\boldsymbol{P_j}$ – $\boldsymbol{j}$-technology installed power; $\boldsymbol{ICU_{jf}}$ – installed capacity utilization rate; $\boldsymbol{YH}$ – annual hours.

Cost of electricity supply $\boldsymbol{c_{jf}^{ti}}$ for $\boldsymbol{ti}$ interval:

$$\boldsymbol{c_{jf}^{ti} = c_{jf} * e_{jf}}, \tag{4}$$

The binary matrix elements $\boldsymbol{b_{jf}^{ti}}$, which provides the optimal set of modes of generation and accumulation in terms of minimizing the total cost of energy on the $\boldsymbol{ti}$ interval, were defined as the solution to the optimization problem (5):

$$\boldsymbol{\sum_j c_{jf}^{ti} * b_{jf}^{ti} \Rightarrow min}, \tag{5}$$

if performing restrictions of technological admissibility.

The result of solving the formulated optimization problem is the matrix $\left\{\boldsymbol{p_{jf}^{opt}}\,(\boldsymbol{vc}, \boldsymbol{b_{jf}^{ti}})\right\}$ of the optimal modes of using generating and accumulating powers, defined on the set $\{\boldsymbol{vc^{min} < vc < vc^{max}}\}$ of possible values for energy consumption.

The generalization of the described procedure for calculating the forecast scenario of the optimal energy system using at life cycle horizon is below.

For this purpose, time series of results obtained by formulas (6 - 10) are calculated, which taking into account quasi-dynamism and are modifications of formulas (1 - 5). In particular, to calculate the values of the parameters of the functional of economic and technological influence [3] next formulas are used: $\boldsymbol{F(j,\tau) = F[PPF(\tau), ET(j,\tau), FCF(j,\tau), EGR(\tau)]}$, where $\boldsymbol{PPF}$ – regional purchasing power factor, $\boldsymbol{ET}$ – efficiency of technology, $\boldsymbol{FCF}$ – final cost factor, $\boldsymbol{EGR}$ – economy growth rate.

In turn, each of the parameters, which is included in formula, is now a member of the stochastic time series. It conventionally denote with $\boldsymbol{m_{jf\tau}}$ and calculate as $\boldsymbol{m_{jf\tau} = m_{jf} * F(j,\tau)}$, for example, $\boldsymbol{P_{j\tau} = P_j * F(j,\tau)}$.

The conditional dynamics of components of the functional of economic and technological influence is shown in Figure 1.

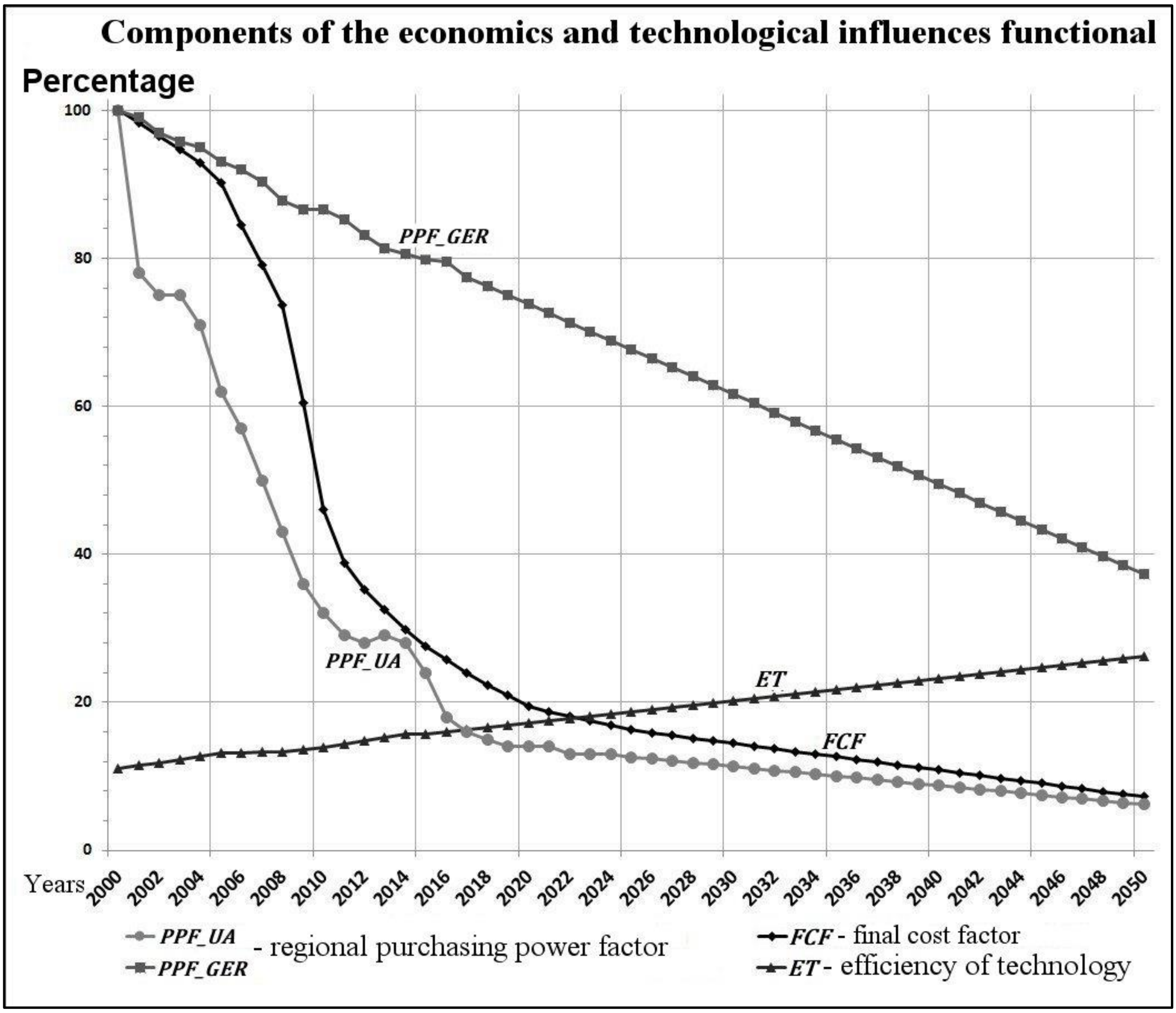

Figure 1

Now, using the modified formulas, the following stochastic elements of matrices are calculated:

$$(\boldsymbol{c}_{\boldsymbol{jf\tau}}) = \frac{\sum_{\tau}^{T_j} \frac{\left\{C_{\tau}^{cap} + C_{\tau}^{const(f)} + C_{\tau}^{var(f)}\right\}}{(1+i_{\tau})^{\tau}}}{\sum_{\tau}^{T_j} \frac{e_{jf\tau}}{(1+i_{\tau})^{\tau}}}, \tag{6}$$

$$\boldsymbol{p}_{\boldsymbol{jf\tau}} = \boldsymbol{P}_{\boldsymbol{j\tau}} * \boldsymbol{ICU}_{\boldsymbol{jf\tau}}, \tag{7}$$

$$\boldsymbol{e}_{\boldsymbol{jf\tau}} = \boldsymbol{P}_{\boldsymbol{j\tau}} * \boldsymbol{ICU}_{\boldsymbol{jf\tau}} * \boldsymbol{YH}_{\boldsymbol{\tau}}, \tag{8}$$

$$\boldsymbol{c}_{\boldsymbol{jf\tau}}^{\boldsymbol{ti}} = \boldsymbol{c}_{\boldsymbol{jf\tau}} * \boldsymbol{e}_{\boldsymbol{jf\tau}}, \tag{9}$$

and at each step of the life cycle horizon τ, the problem of finding the optimal set of generation and accumulation modes (10) is solved:

$$\sum_{j\tau} \boldsymbol{c}_{\boldsymbol{jf\tau}}^{\boldsymbol{ti}} * \boldsymbol{b}_{\boldsymbol{jf\tau}}^{\boldsymbol{ti}} \Rightarrow \boldsymbol{min}. \tag{10}$$

The result of the solution of the formulated optimization problem is the set of matrices $\left\{\boldsymbol{p}_{\boldsymbol{jf\tau}}^{\boldsymbol{opt}}\left(\boldsymbol{vc}_{\boldsymbol{\tau}}, \boldsymbol{b}_{\boldsymbol{jf\tau}}^{\boldsymbol{ti}}\right)\right\}$ of optimal conditions of generation and accumulation.

The procedures proposed in the work can be used to optimize the modes of similar technological complexes on the life cycle horizon.

1. Viktor Denisov. Simulation and comparative estimation of electricity cost for generation and storage technologies. // SCIENCE, RESEARCH, DEVELOPMENT. Technics and technology.#7 – Valletta (Republic of Malta) – 2018. – p. 5-8.
2. Viktor Denisov. Optimal vector of generating and accumulation capacities modeling at a subset of available discrete technological solutions for load following regimes. // SCIENCE, RESEARCH, DEVELOPMENT. Technics and technology.#11 – Rotterdam – 2018. – p. 45-47.
3. Viktor Denisov. Optimization model of the power generating technology with energy storage system. // SCIENCE, RESEARCH, DEVELOPMENT. Technics and technology.#2 – London – 2018. – p. 21-23.