

1. Conduct a comprehensive analysis of the problem of determining the integral indicator of efficiency of intellectualization of distribution systems and to establish key characteristics determining the effectiveness of their functioning.

2. Develop methodological aspects and tools for the creation of an integral indicator of intellectualization by assessing the performance of DSO to formalize decision-making for planning the development of distribution systems.

3. Formalize the task of assessing the impact of DSO activities on the development of the electricity distribution system in the context of Smart Grid.

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1. Kopchykov O.M., Frolenkov K.D. Intellectualization of the electrical network in the formation of a smart system // The III Scientific and Technical Conference of Masters of IEE - November 26, 2020. – 477 p.

2. Kopchykov O.M. Features of risk assessment and forecasting the efficiency of implementation of smart systems. // XIII Scientific and Technical Conference of IEE “Energy. Ecology. Man” - May 13–14, 2021. – 184 p.

3. Kopchykov O.M. Intellectualization of the electrical network in the formation of a smart system // The IV Scientific and Technical Conference of Masters of IEE - November 17–18, 2021. – 241 p.

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5.	Adapting indicators for the possibility of working with intellectualization	01.05.2022-10.05.2022	
6.	Formation of DSO characteristics and analysis of the feasibility of using	10.05.2022-01.06.2022	
7.	Application of the methodology for calculating indicators and calculating weighting factors	10.05.2022-01.06.2022	
8.	Analysis of results and conclusions	10.05.2022-01.06.2022	
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ABSTRACT

Structure and scope of work. The Master's thesis on the topic «Improving the efficiency of implementing smart systems in distribution networks» consists of an introduction, 4 sections, conclusions and list of references. The total volume of work is 92 pages, including 15 figures, 14 tables and 51 bibliographic references, 3 annexes on the 7 pages.

Relevance of research. The adoption of the Law of Ukraine «On Electricity Market» has set a new task for all subjects of the power industry - to form the market of electric energy. One of the important conditions for stable operation of the market is the speed of exchange of relevant information between the subjects of electric power industry. Today there is an urgent need to increase the level of informatization of electrical networks, namely the implementation of Smart Grid.

The concept of Smart Grid in this research should be understood the ability of the electric grid to receive and process information of the maximum possible number of characteristics of its activity and on their basis to independently make quick decisions. And the process by which Smart Grid is implemented is called the process of intellectualization.

Today, there are many different solutions and innovative technologies that in the context of electrical networks can be allocated to a certain ideology Smart Grid. Therefore, different options for implementing such networks need to be considered.

Another important factor is the wear and tear of equipment, which each year increasingly affects the general state of Ukraine's electrical networks. On the part of the State there are requirements for the modernization of worn-out networks. Investment projects and development plans of DSO electrical networks include modernization, but do not give a full assessment of the level of influence of Smart Grid on the performance of the network. The State currently lacks the tools for such analysis.

Relationship of work with scientific programs, plans, themes. The research performed corresponds to the direction «Energy and energy efficiency», the

Law of Ukraine «On Electricity Market», the direction of research (R&D) of the Department of Power Supply of the National Technical University of Ukraine "Kyiv Polytechnic Institute".

Purpose and tasks of the research. Improving the efficiency of distribution grids through appropriate assessment of their intellectualization and the introduction of measures for the formation of smart systems. To achieve this, the following objectives were set:

1. Make a comprehensive analysis of the problem of determining the integral indicator of efficiency of intellectualization of distribution systems and to establish key characteristics determining the effectiveness of their functioning.

2. Develop methodological aspects and tools for the creation of an integral indicator of intellectualization by assessing the performance of DSO to formalize decision-making for planning the development of distribution systems.

3. Formalize the task of assessing the impact of DSO activities on the development of the electricity distribution system in the context of Smart Grid.

Object of the research. Operating modes and features of electrical distribution grids.

Subject of the research. Methods and means of the efficiency increasing of distribution grids in the smart systems implementation.

Practical value of the results obtained lies in their use in the development of normative documents of the Ministry of Energy and Coal Industry of Ukraine. It may be used for system of conventional units of electrical grids, technological design standards and for implementation of the latest technologies and equipment into new construction, reconstruction and technical reequipment.

The results of the work in the part of creation of an approach to formation of the indicator will be used in formation of the proposal of the State Inspection of Energy Control of Ukraine to «Methods of assessment of energy efficiency potential of the electric energy distribution system».

Scientific novelty of the obtained results. The system of indicators and criteria for assessing the development of electricity distribution systems in terms of key characteristics is scientifically substantiated. This is done in terms of key

characteristics, considering the impact of intellectualization, which, in contrast to existing ones, allows to assess the effectiveness of DSO in terms of implemented Smart Grid technologies and investments.

The method of assessment of the intellectualization indicator has been improved, which considers the change of key characteristics of each DSO and allows to determine the level of intellectualization for further use of stimulating regulation.

Approbation of the Master's thesis and publications. The results of the research were made public at two scientific and technical conferences and included in the collections of works:

1. Kopchykov O.M., Frolenkov K.D. Intellectualization of the electrical network in the formation of a smart system // The III Scientific and Technical Conference of Masters of IEE - November 26, 2020. – 477 p.

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Key words: *intellectualization, electric grid, Smart Grid, informatization, risks, cybersecurity of electric grids.*

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LIST OF ABBREVIATIONS

DSO – Distribution Systems Operator.

TSO – Transmission System Operator.

NCSREPU – National Commission for State Regulation of Energy and Public Utilities.

OHL – Overhead Line.

CL – Cable Line.

TS – Transformer Substation.

RES – Renewable Energy Sources.

ASCAER – Automated System for Control and Accounting of Energy Resources.

SG – Smart Grid.

INTRODUCTION

The adoption of the Law of Ukraine «On Electricity Market» has set a new task for all subjects of the power industry - to form the market of electric energy. One of the important conditions for stable operation of the market is the speed of exchange of relevant information between the subjects of electric power industry. Today there is an urgent need to increase the level of informatization of electrical networks, namely the implementation of Smart Grid.

The concept of Smart Grid in this research should be understood the ability of the electric grid to receive and process information of the maximum possible number of characteristics of its activity and on their basis to independently make quick decisions. And the process by which Smart Grid is implemented is called the process of intellectualization.

Today, there are many different solutions and innovative technologies that in the context of electrical networks can be allocated to a certain ideology Smart Grid. Therefore, different options for implementing such networks need to be considered.

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The system of indicators and criteria for assessing the development of electricity distribution systems in terms of key characteristics is scientifically substantiated. This is done in terms of key characteristics, considering the impact of intellectualization, which, in contrast to existing ones, allows to assess the effectiveness of DSO in terms of implemented Smart Grid technologies and investments.

The method of assessment of the intellectualization indicator has been improved, which considers the change of key characteristics of each DSO and allows to determine the level of intellectualization for further use of stimulating regulation.

1 INTELLECTUALIZATION OF THE ELECTRICAL GRID DURING THE FORMATION OF THE SMART SYSTEM

1.1 Analysis of the current state of distribution grids and possible ways of their modernization

Modern electrical grids provide processes of transmission and distribution of electrical energy by connecting them to high voltage transmission systems, which in turn provide power to medium and low voltage local grids.

An established power system ensures the flow of electricity in one direction, from power plants (generation) through transmission and distribution systems to the final consumer. Dispatch and management of the grid are carried out by the respective dispatching points controlling several regions.

Traditional approaches to designing electric grids are based on the location of large centralized production complexes and geographical distribution of generating resources. Thus, the grids were designed and optimized to meet regional or national needs.

As of 2021, more than 837098,21 km of overhead and cable power lines of all voltage classes are operated in the electric power industry of Ukraine [2]. A significant proportion of these lines are in very poor condition (Table 1.1), and 60.64 per cent of the main equipment of the substations have used their estimated technical life (25 years and older) [2].

Table 1.1 - Condition of overhead lines of the power system of Ukraine.

Type	Voltage level, kW	Condition	Length, km	Percentage of total length
OHL	220-330	40 and more years of operation	13421,78	64,45%
OHL	220-800	require full replacement or renovation	1124,39	4,95%
OHL	0.4-110 (150)	require major repairs, renovations, and replacement	316145,10	-
CL	0.4-35 (110)	require major repairs, renovations, and replacement	23688,19	-

The energy sector in Ukraine is undergoing significant and rapid changes that pose certain threats to the reliability and security of the energy system.

According to [3] the reliability of power supply is characterized by the following indicators:

- Energy Not Supplied (ENS);
- System Average Interruption Duration Index (SAIDI);
- System Average Interruption Frequency Index (SAIFI);
- Momentary Average Interruption Frequency Index (MAIFI).

Referring to the open information of the DSO «DTEK Kyivski Elektromerezhi» [4] and considering SAIDI/SAIFI indicators, there are no positive tendencies for these indicators. The comparison of the SAIDI/SAIFI emergency and planning indicators [4] is shown in Figure 1.1.

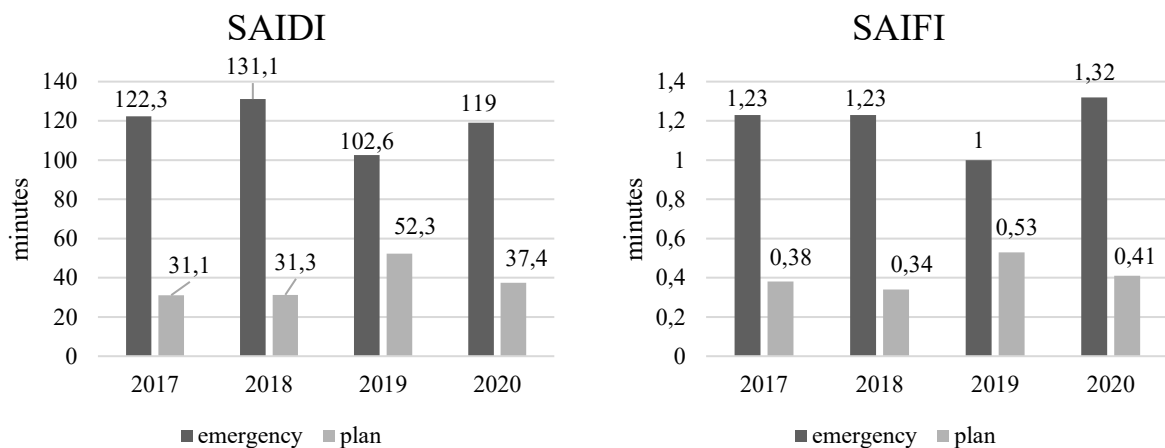


Figure 1.1 - Comparison charts of SAIDI/SAIFI indicators for DSO «DTEK Kyivski Elektromerezhi».

Unfortunately, the ENS indicator has a similar trend. The total volume of consequences of technological failures of electrical grids for 2020 [2] is presented in Figure 1.2.

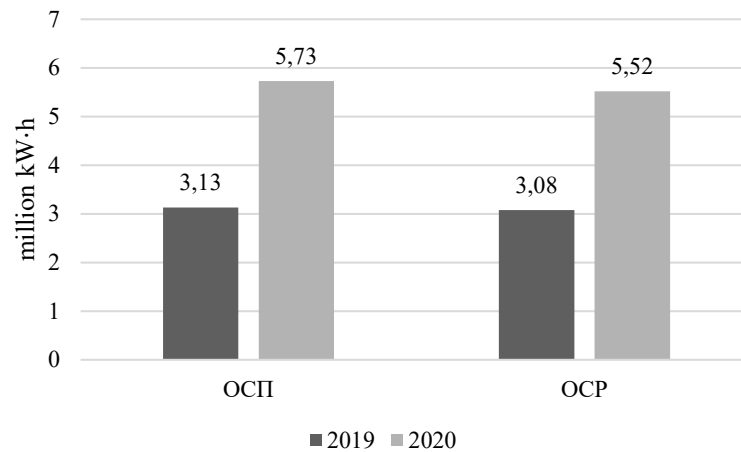


Figure 1.2 - Electric Power Supply Shortfall Diagram.

When analyzing the reliability of the electric power system, it is necessary to highlight the rapid development of RES, which are characterized by an unpredictable generation schedule, which creates problems for the energy system from the point of view of adequacy of generation. Distributed RES can also have a significant impact on local distribution grids, resulting in reversal of power flows, changes in voltage in local grids and influences other technical parameters necessary for the safe operation of the grid.

On the other hand, such distributed inverter-based generation sources can improve system reliability services, such as faster frequency regulation, flexible and rapid power changes, and maintenance of voltage regulation in the grid. Also, energy storage systems (CHP) can reduce uncertainty in the adequacy of generating resources, «cutting» of consumption peaks and excessive generation.

The electric power industry of Ukraine operates within the framework of the market model, where power plants (generating units) are dispatched in accordance with market requirements, and the network control center performs the overall control role that is active power balancing and providing support services such as voltage stability.

The plans of development of the electric power sector of Ukraine [5] are presented in the diagram, which is shown in Figure 1.3.

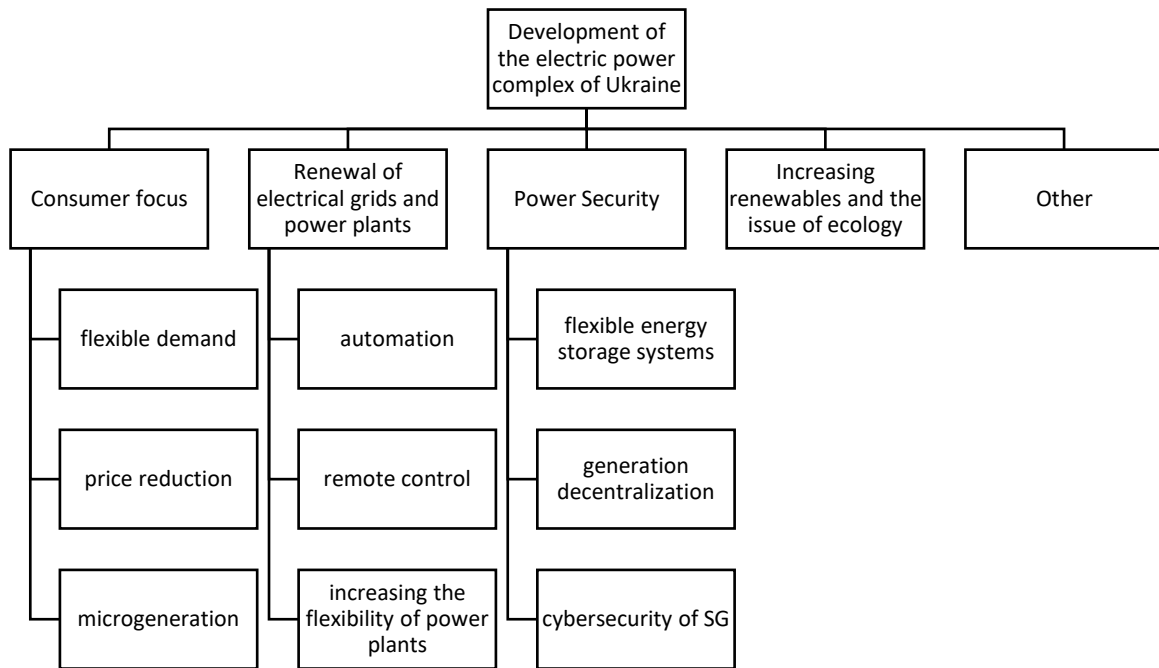


Figure 1.3 - Electric Power Development Scheme of Ukraine.

Given the consumer of electric energy, there is a need for his interest in the opportunities of the electricity market, flexible demand, low prices, and opportunities for microgeneration. In turn, the electrical grid requires considerable renewal and modernization. In this context it is necessary to speak about the concept of «intellectualization» of the energy system, as a process of modernization and transformation in the «mind of the grid» already existing.

Thus, to summarize the above, it can be argued that the process of power transition to SGs should consider the current state of the electrical grid, the wear and tear of equipment, as well as the need to replace a grid element.

1.2 Comparative analysis of concepts of construction of Smart Grid

The system shall be understood to mean a system in which a role in the work is determined by the widespread adoption of innovations, among which the main role belongs to information technologies and artificial intelligence [6]. The SG should be able to control as many different technical and non-technical indicators as

possible, manage this system, independently make rational and optimal decisions in real time.

The first step to intellectualization can be considered the process of informatization [6]. The basis of this process should be to ensure communication in both directions and to enable the collection, exchange, and processing of data among all components of the system.

In the process of building a SG, it is necessary to implement communication infrastructure and ensure its security according to any concept. A simplified such infrastructure is presented in Figure 1.4. All components of the electrical system, even if they are not electrically connected, must be connected by information. This idea is the basis of any concept of an SG.

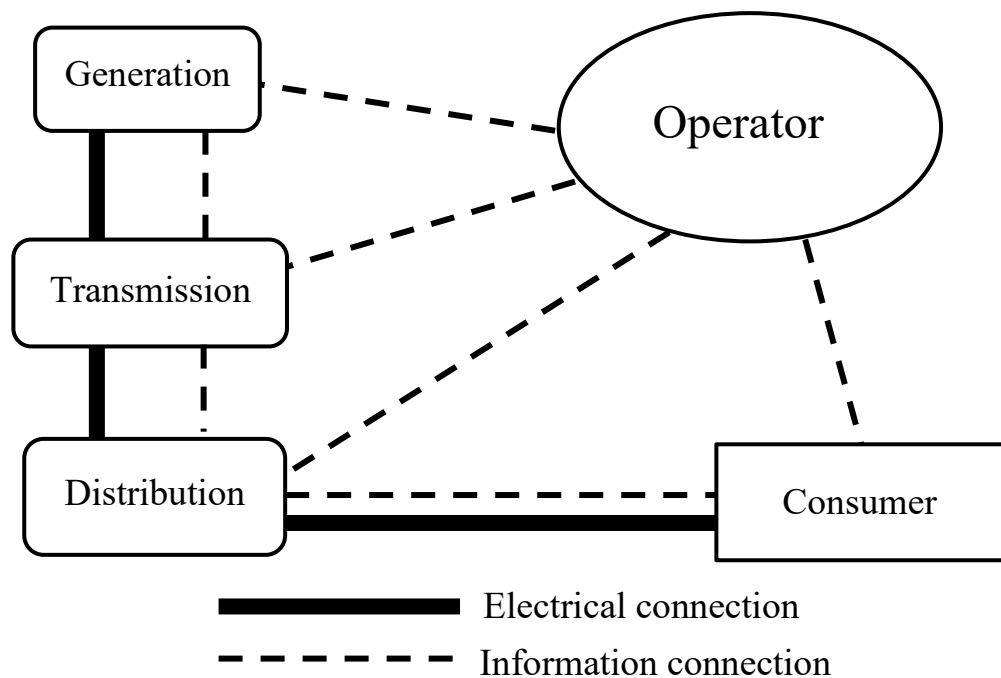
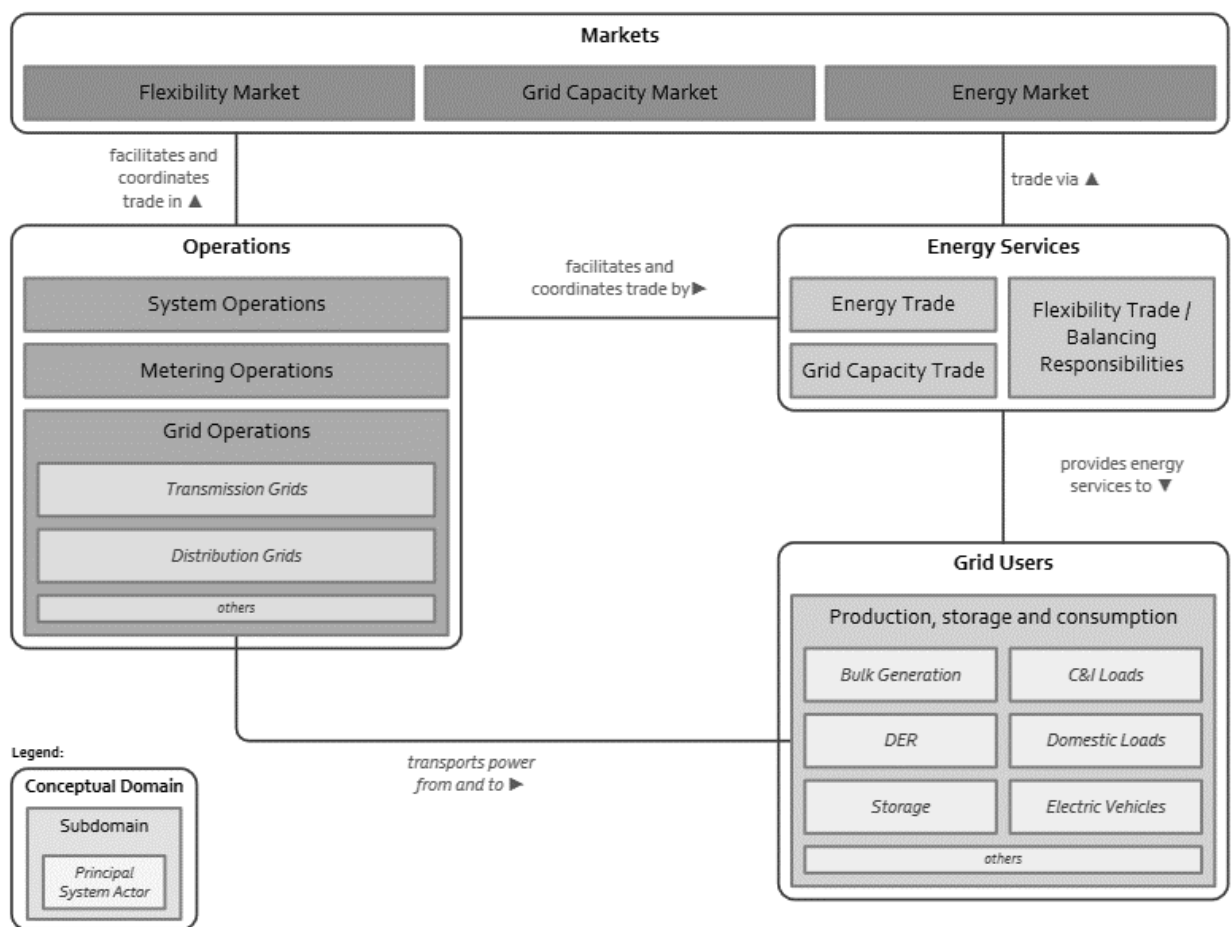


Figure 1.4 - Simplified representation of the communication infrastructure of electrical grids.

Of course, for communication infrastructure and for building an smart system based on it, there is a need to define the standards that govern its implementation. This requires the adoption of some conceptual models on the basis of entire

electricity markets for which these standards will be developed. They can distinguish the dependencies and influence of different elements of SGs and reasonable markets on each other. An example is the European Conceptual Model for the Smart Grid (Figure 1.5). The model consists of four main conceptual areas: operations, grid users, markets, and energy services. Each of these conceptual domains contains one or more sub-domains grouping market roles from the European electricity market [7].



1.5 – European Conceptual Model for the Smart Grid. [7]

It can be argued that there are now two basic models based on European and United States approaches.

The EU and the US have different approaches to promoting SG technology:

1. EU definition of Smart Grid: A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators,

consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. [8]

2. U.S. definition of Smart Grid: A Smart Grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources. [9]

When analyzing the development of SGs in the EU, we can say about the significant influence of concerns related to the diversity and evolution of electric grids in European countries, while the US seeks to improve security and respond quickly and qualitatively to the projected growth in demand for a long-term vision.

On this basis, we can talk about SGs as a specific ideology of the development of electrical grids. That is, we have a development trend, not the only clear standard.

To solve various problems today there are different blocks of implementation of various technological solutions. According to the Catalog of Standards Navigation Tool [10] only for distribution grids can be given 87 standards, which are generally related to both component and operational level.

It should also be noted that an SG cannot be unified. Each country recognizes its own priority for a level of intellectualization that is sufficient to maximize efficiency. It is therefore necessary to understand how to estimate the amount of intellectualization.

With the development of the availability of innovative technologies, the process of intellectualization will accelerate, which will allow the energy system and the market to get all its advantages. The implementation of such technologies is necessary for the Ukrainian power system, considering the problems that may arise in its various branches.

1.3 Methods and means of intellectualization

Any device based on traditional technology used in the electrical grid is a mechanical device controlled by electric current. Such technologies lack communication between devices and very limited internal adjustment. A SG uses digital technology to enhance communication between devices and facilitate remote control and self-regulation.

First, the smart energy system of Ukraine requires the modernization of DSO control centers with the implemented systems OMS, MDMS, GIS, Distributed energy resources management system (DERMS), Virtual power plant (VPP), monitoring and control of charging stations of electric vehicles. Such solutions will allow for maximum flexibility in responding to possible problems in the energy system, which will improve, first of all, the quality of dispatch services [5].

At the level of substations and switchgears it is necessary to provide the maximum possible digitalization and automated system of control of distribution grids. As the main and important means of automation of distribution grids of 6-35 kV can be considered a recloser [5]. The installation of reclosers will provide full automation of the process of emergency disconnection of overhead lines of the grid.

Another important factor is reactive power compensation and voltage adjustment. Here, there is a great need to be able to rapidly regulate reactive energy flow on the basis of new monitoring algorithms at all levels of distribution grids. In addition, FACTS technologies can be used to dynamically compensate and generate reactive power based on power electronics [5].

From the point of view of the market and transparency for the consumer of electric energy, it is necessary to introduce "Smart Metering Electric Power" Advanced Metering Infrastructure (AMI) [5]. This will allow a shift to the consumer as a customer who receives quality services and will allow for flexible consumption demand.

If we consider the stability and safety of the grid, we should note the need to use power storage, which will allow high-quality work with RES. For information

systems, the main solution is the cybersecurity of power grids, electricity metering systems and communication networks. It is also possible to use Dynamic Line Rating (DLR) technology to determine the dynamic boundaries of the OHL [11].

To evaluate signals, considering the conditions of SGs, it is important to process them. Using measurements from different locations, it is possible to solve the problems of voltage level control, equipment diagnostics or power quality and reliability control.

When analyzing using advanced signal processing techniques, the time and frequency of these signals can reveal unique patterns - models that can be very useful in diagnosing and predicting the occurrence of malfunctions in high voltage power supply systems.

Powerful mathematical tools, such as Machine Learning (ML) and Convex Optimization, are used to remove noise signals that can successfully process signals [12].

Signal processing makes it possible to observe defects in high-voltage systems in real time, which makes it possible to monitor the state.

When creating a decision-making system, fuzzy logic can be used. It is also important to note: the application of fuzzy logic to create a decision-making system; the using different methods of analysis of transient processes of the electrical grid.

Consequently, today the development of innovative means of intellectualization is taking place. The process of renewal is getting faster. If we look back, we see only small and uncertain steps for the development of information systems in the energy sector, but every year the demand for such technologies grows and their cost decreases.

Today, there is a positive dynamic associated with the growth of smart technologies in electricity supply systems, but the risk of external interference in the system is also increasing. The use of the global grid carries both positive and negative risks, namely, the issue of cybersecurity is increasingly being raised.

1.4 Issues of cybersecurity in the operation of Smart Grid

The security structure of the SG can be divided into three levels: the power system level, the information and communication level [13].

The grid level is responsible for the expanded generation, supply and consumption of electricity. It describes the two-way flow of an interconnected electrical grid transmitting electricity and digital information from electricity production systems to consumers for efficient and reliable management of various appliances on the consumer's side [14].

The Information Layer is responsible for advanced information measurement, monitoring and management in the context of the SG. The main components of the electricity information system are shown in Figure 1.6.

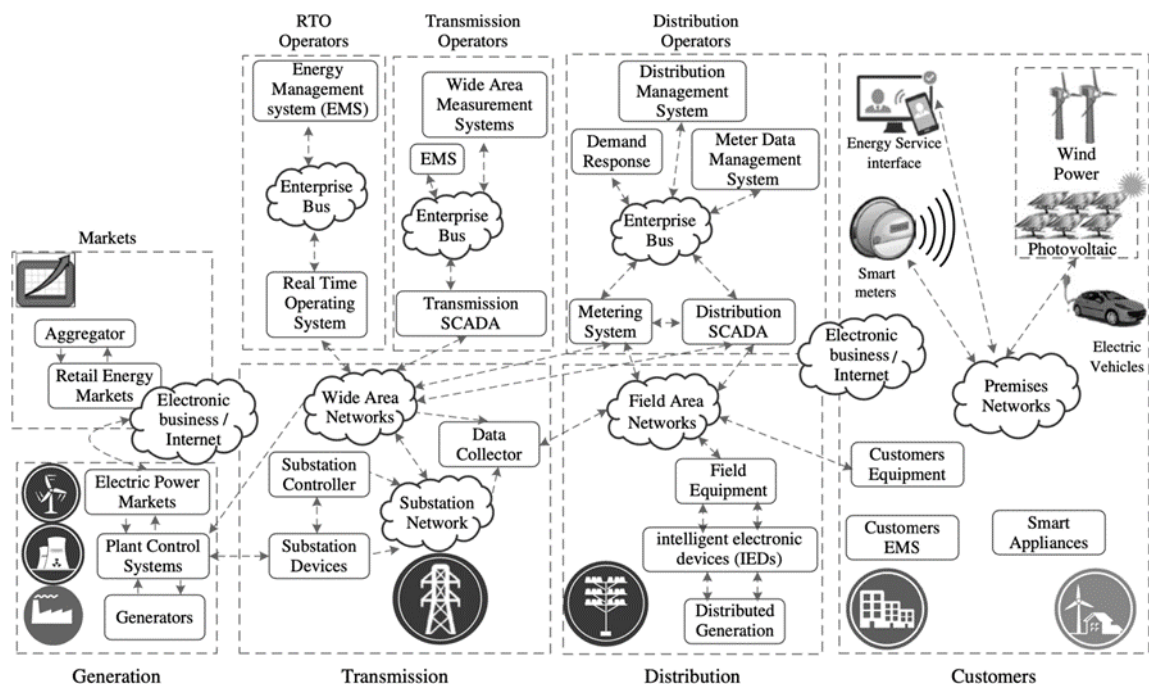


Figure 1.6 - Example of an information level [13].

The communication layer is responsible for communication and information transfer between systems, subsystems, individual devices and different applications. The level of communication should support the quality of data service, be highly reliable, widely accessible and have high coverage with guaranteed security and

confidentiality. The communication layer is based on a centralized and/or distributed data topology. Data obtained in smart meters are fed into the data hub by other nodes in the network. The data hub transmits this data to the network access point, after which the data is transmitted to centralized or decentralized control centers or service providers [15], as shown in Figure 1.7.

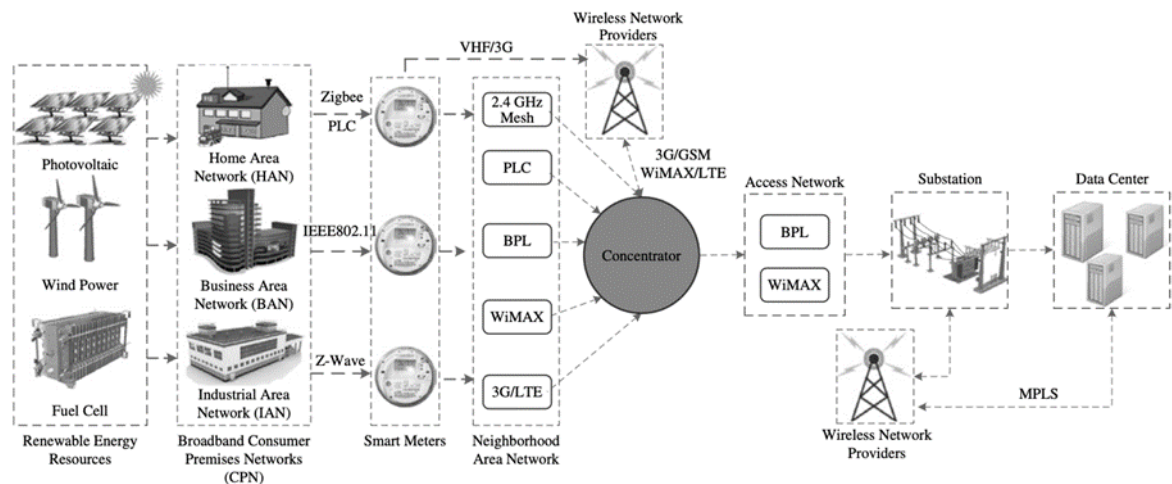


Figure 1.6 - Example of a communication level [13].

Since the SG is primarily responsible for communication and control, it is the information security of both physical and communication networks that is fundamental to improving the efficiency, reliability of the network, considering confidentiality.

Cyber threats are mainly divided into two types: cyber-attacks via communication networks and network attacks.

For communications network attacks, the Information Systems Auditing and Control Association (ISACA) defines the type of malicious communication cyberattacks and classifies them into targeted and non-targeted attacks. This includes hackers, insiders, nations, phishers, spammers, malware authors, criminal groups, bot-network operators [16].

Network attacks or physical attacks in power systems can be defined as power input attacks that alter the generation and load in the network. The main risks of such physical attacks are power line poles and transformers. In addition, malicious codes

have the ability to directly control switches and switches of electrical substations, as well as to disconnect the distribution of electricity or damage equipment in the network [17].

Considering the SG, we can conceivably distinguish three types of information resources to be protected [18]: Personal Data; Technical Data; Failures Data.

Also looking at the energy system as a whole, there are threats in the impact of a significant level and above significant level:

- related to balance sheet affiliation;
- increased import dependence of coal and gas supply on electricity production;
- connected with the market of electric energy;
- related to operational safety (risk of late implementation of maneuvering and regulatory capacities, risk of delay of competitions for creation of capacity reserves, etc.);
- related to the quality and level of maintenance of electrical grids;
- related to cybersecurity and the protection of critical infrastructure in the electricity sector.

Therefore, it should be noted that the process of intellectualization is very close to the issues of protection and cybersecurity, and the necessary equipment that can withstand cyberattacks already exists.

Conclusions to Section 1

This section considers the main conceptual apparatus of research, the concept for the construction of SG, analyzes the differences in the approaches of other countries to the formation of such systems. Elements of connections have been established; procedural issues related to the intellectualization of electrical grids have been identified.

Intellectualizations is considered as a process that aims to create a system that will meet the criteria of intellectualism as much as possible. From this point of view, SG can be considered as a smart system that covers both the grid and users connected to it and includes both technical and non-technical building blocks.

The issue of the inability to fully combine all processes and ensure the assessment of the results of the implementation of SGs remains problematic. Although now there are algorithms for assessing certain components of such a system, but it is necessary to be able to comprehensively assess as a whole, such as SAIDI or SAIFI, so that without touching economic activity it is possible to evaluate this process from the outside. Since today there is virtually no possibility on the part of regulatory authorities to regulate the level of intellectualization of the electrical grid. But in turn, there is a need to stimulate energy companies to modernize their grids, namely as smart ones.

Taking into account the changes in the legislation of Ukraine and the general trends that occur in the state in the respective direction in the work is a comprehensive consideration of issues related to the characteristics and organization of the work of the DSO in the implementation of smart systems. It is also important to assess the risk that may be in the DSO power system when implementing these systems, since this will ultimately affect their effectiveness.

2 METHODOLOGICAL BASES FOR THE ASSESSMENT OF ELECTRIC GRID INDICATORS

2.1 Economic assessment of the implementation of Smart Grid projects

Any project for the development of electrical grids can be presented as a specific project that needs financing and may have the characteristics of an investment project.

An investment project in electrical grids may be a modernization and reconstruction project or a development project (new construction). Such projects may differ in size, duration, quality, resources, end goal and purpose. Such projects have many parameters that cannot be calculated, but they can be assessed. Modified expert methods can be used for such an assessment. In particular, it is possible to combine classical algorithms of expert estimates with elements of fuzzy logic. Especially when forming certain questionnaires to determine the assessment characteristics of a project.

The various methods can be combined into one that can accumulate methods of analysis and forecasting. There may be a scripted way.

The peculiarity of SG projects lies in the need to consider them in the breadth and depth. A dynamic model can be built for each project, this can be presented as a specific scenario for which maximum implementation horizons and minimum project performance limits will be defined.

The typical life cycle of a project can be represented as five consecutive phases [19] (Figure 2.1).

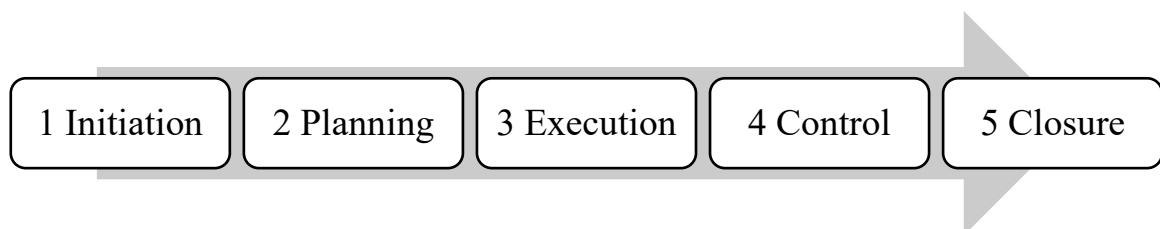


Figure 2.1 - Investment project life cycle

The profitability of the investment project of electrical grids should be not only economic, but also social. It happens when even the project has no profitability, but the social influence is very large, which compensates the profit in another way.

Each investment project should be divided into regulatory, organizational, and technical components.

As an example of innovative projects of intellectualization of electrical grids in Ukraine can be:

- implementation of transient monitoring systems in the power system;
- grid and load control center (modernized control room for DSO);
- advanced distribution management system [20];
- management of reactive energy flows at all levels of electrical grids based on new monitoring algorithms;
- creating opportunities for a self-healing grid;
- microgrids;
- digitalization of substations.

For a comparative analysis of a typical investment project for an electrical grid intellectualization project, certain characteristics are summarized in a table (Table 2.1).

At the same time, it is desirable to note that they are very similar in ideology. This similarity is particularly important in a market environment where there is some alternative to decision-making. For example, you can use conventional tariffs on elective energy without entering smart meters. Now we have such a requirement for most industrial powerful facilities. Thus, modernization of the electric grid towards its intellectualization becomes a normative requirement and implementation of economic assessment becomes more complicated.

The assessment indicator of the investment project as part of the modernization of electrical grids should be considered in two dimensions: the width of the project and the depth of the project scope.

Table 2.1 - Comparison of the Investment Project with the Project of Intellectualization of Electrical grids

Characteristic	Investment Project	Project of Intellectualization of Electrical grids
Result (goal)	improved cost-effectiveness and efficiency of the design facility	increase of reliability and efficiency of use of electrical grids
Total cost	is not decisive	is decisive due to limited financial resources
Sources of funding	any source	DSO investment program funds, company's own funds, attracted investments
Planned profit	depends on the efficiency of its implementation and operation	depends on the efficiency of its implementation and operation of the electrical grid
Duration (life cycle)	completion time is clearly defined	the time of completion may be determined by existing plans as well as the current situation of network operation
Efficiency	use of funds	the indicator ranges from cost-effectiveness to the desired level of continuity of power supply to consumers

The scope of the project may be the area of coverage by direct technology of SGs of a certain territory. It can be a separate DSO in the region or a separate district in which smart technology is implemented.

The depth of coverage can be described as the voltage levels to which modernization and implementation of SGs are applied.

When analyzing the results of the economic assessment of the investment project, you can use indicators: Net present value (*NPV*), Days Sales Outstanding and Weighted Average Cost of Capital (*WACC*).

NPV for longer-term project can be calculated by the formula [21]:

$$NPV = \sum_{t=0}^n \frac{R_t}{(1+i)^t}$$

where R_t – net cash inflow-outflows during a single period t ;
 i – discount rate or return that could be earned in alternative investments;
 t – number of time periods.

The positive features of *NPV* are precise decision criteria, there is an indicator that considers the risks of the project through various discount rates and the cost of money over time. This indicator does not consider the probability of the outcome of the event, although it has predictive values in the form of cash flows. Also, considering a multidisciplinary project, the correct calculation of the discount rate is difficult.

Based on the indicator *NPV* can be carried out an assessment of the relative return on investment of the intellectualization project using the Profitability Index (PI). It is calculated as the ratio of an indicator *NPV* to project investment (I):

$$PI = \frac{NPV}{I}$$

The indicator that describes the period of time from the sale until payment is received is the Days Sales Outstanding and it can be calculated by the formula [22]:

$$\text{Days Sales Outstanding} = \frac{\text{Accounts Receivable}}{\text{Total Credit Sales}} \cdot \text{Number of Days}$$

This indicator provides cash flow forecasting, monitoring of credit policy and accounts receivable. The drawbacks are that it is not very useful to use separately, and the use compared to another industry cannot be used at all.

And such an indicator as *WACC* can be calculated with such a general formula:

$$WACC = \frac{\sum_{i=1}^N r_i \cdot MV_i}{\sum_{i=1}^N MV_i}$$

where N – the number of sources of capital (securities, types of liabilities);

MV_i – the market value of all outstanding securities i

r_i – the required rate of return for security i

This is the average rate a business pays to fund its assets. It is calculated by averaging the rates of all sources of capital of the company, weighted by the share of each component.

The greatest advantage of using *WACC* as a barrier to assess new projects is simplicity. And the calculation is not too complicated. The manager should apply the finance weight of each source for its cost and aggregate the result.

One single rate of interference for all projects saves a lot of time in assessing new projects. Moreover, if projects have the same risk profile and no changes in the proposed capital structure, the current *WACC* can be applied and used effectively. Since the single bet is used for all new projects, decisions can be made faster, and the new feature can be used and used.

From the point of view of the analysis of SGs it is possible to speak about the appropriateness of using *NPV*. This indicator will depend heavily on how the research process is constructed.

An example of such an assessment is the economic assessment of the ACEA [23] project, which focused on enhanced network management. The project considered automatic fault detection, selective shutdown, monitoring and remote control of the network at the level of medium voltage. Innovative algorithms for network management were implemented, the possibility of increasing the share of renewable energy, electric mobility, energy storage, reduction of energy consumption and so on were included.

The result of the study is that the *NPV* of the project is positive from the point of view of the individual investor (i.e., Days Sales Outstanding), if and only if the additional compensation of the Italian regulator for the investment of the SG is considered. However, if only the standard normative *WACC* for electrical assets were applied, the *NPV* would be negative [23].

From the study that determined the optimal size of the thermal power plant, auxiliary boiler, absorption cooler, and transformer unit, A comprehensive cost-benefit analysis was proposed to optimize these elements and apply the learning algorithm to solve the optimization problem.

Similar to the previous one, the study proposed the use of an *NPV* indicator, as well as two others: Rate of Return (*ROR*) and Dynamic Payback Period (*DPP*).

Another study of the cost of components [24] suggests that among the types of equipment used in the study, the most significant investments are in electronic measuring transformers and condition control equipment. At the same time, the cost of construction of «smart» substation is 5.9%-10.1% more than usual [24].

By summarizing the decision-making process for financing SG projects, it is possible to define this order (Figure 2.2).

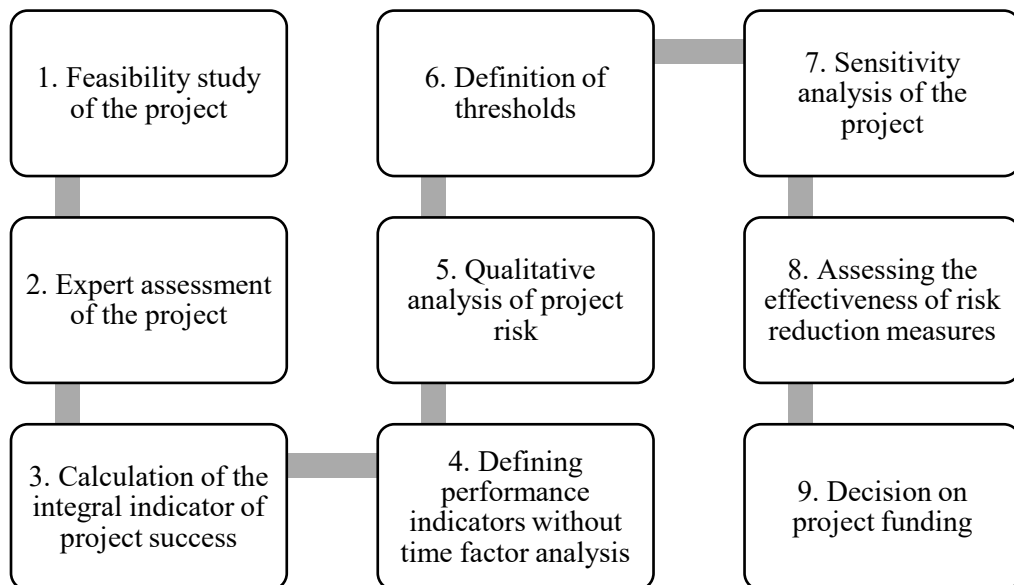


Figure 2.2 - Decision-making process for financing an investment project

In our case, the qualitative analysis of the project risk can be described considering the objectives of the electric energy market. And the definition of thresholds is important, especially when we talk about the possibility of gradual implementation of the project.

Sensitivity is the protection of information and possible negative effects of external factors on the project. The assessment of the effectiveness of risk mitigation measures should consider project specificities and the ability to mitigate risks. But first you need to identify, classify and analyze them.

2.2 Organization of assessment of technical condition of electrical grids

A methodology for recording and analyzing the technical status of distribution grids was implemented to provide uniform criteria for the comprehensive quantitative and qualitative assessment of the technical state of the OHL [25].

The technical condition of the facility can be determined by the cumulative defects of its elements registered during maintenance - inspections, examinations and measurements, etc.

Currently, the choice of measures for the maintenance of electrical grids is carried out on the basis of a qualitative assessment of the technical condition of the facilities. The following qualitative criteria are used to determine the technical condition of the facility [25]:

- good technical condition;
- major repairs are required;
- requires reconstruction;
- complete replacement required.

Reconstruction of power lines includes such works as increasing their capacity by increasing the cross section of wires, increasing the second circuit, or switching to a higher voltage class, increasing its mechanical strength (by installing additional poles to reduce the length of spans, etc.) [25].

Reconstruction of TS includes works on modernization or replacement of main equipment with equipment of higher power or higher rated voltage, changes in the electrical circuit of the substation, its expansion, as well as work on equipping the substation with automation and telemechanic devices [25].

Comprehensive qualitative assessment of the technical condition of the OHL is determined considering the technical condition of the following main elements of the OHL: poles, insulators and wires.

The technical condition of the poles of one OHL is established on the basis of the poles defect coefficient CDP of this OHL [25]:

$$CDP = \frac{0.87 \cdot \sum_i^l n_{w_i}^D \cdot V_{w_i} + \sum_i^m n_{s_i}^D \cdot V_{s_i}}{0.87 \cdot \sum_j^l n_{w_j}^I \cdot V_{w_j} + \sum_j^m n_{s_j}^I \cdot V_{s_j}}$$

where 0.87 – coefficient of reduction of the volume of energy-wood to the volume of reinforced concrete;

$n_{w_i}^D, n_{s_i}^D$ – the number of defective wooden (i) and reinforced concrete (j) elements of OHL poles registered on this OHL, respectively, pcs.;

$n_{w_i}^I, n_{s_i}^I$ – the number of installed wooden (i) and reinforced concrete (j) elements of the OHL poles, respectively, pcs.;

V_{w_i}, V_{s_i} – estimated volume of one element of poles with voltage OHL, m³;

l, m – the number of wooden (i) and reinforced concrete (j) elements of OHL, respectively;

The technical condition of insulators of one OHL is established on the basis of the insulators defect coefficient CDI of this OHL [25]:

$$CDI = \frac{n_I^D}{n_I^I}$$

where n_I^D – the number of defective OHL insulators, pcs.;

n_I^I – number of installed OHL insulators, pcs.

The technical condition of the wires of one OHL is established on the basis of the wires defect coefficient CDW of this OHL [25]:

$$CDW = \frac{L_{wire}^D}{L_{wire}^I}$$

where L_{wire}^D – length of defective wires of the OHL, km.;

L_{wire}^I – length of installed wires of the OHL, km.

Comprehensive qualitative assessment of the technical condition of one OHL is established on the basis of the defect coefficient CDO of this OHL [25]:

$$CDO = 0.48 \cdot CDP + 0.07 \cdot CDI + 0.45 \cdot CDW$$

where 0.48; 0.07; 0.45 – weighting coefficients reflecting the influence of technical condition of poles, insulators and wires on cost of repair works on replacement of all defective elements of overhead lines with serviceable elements.

The next step is to determine the defect of transformer substations. The coefficient of defect TS can be calculated by the formula [25]:

$$CD_i = \sum_{j=1}^9 k_j \cdot CD_{ij};$$

where CD_i – the defect coefficient for i -th type of TS;

CD_{ij} – the defect coefficient for j -th element of i -th type of TS;

k_j – weighting factors reflecting the influence of the technical condition of the TS elements on the cost of repair works for the replacement of all defective elements with serviceable similar elements [25].

Next, by the defect coefficients, the technical condition of the object is determined.

To determine the technical condition of the facility, the defect factor must be translated into human-friendly terminology. For this we will apply fuzzy logic, which will allow to transfer values from zero to one into clear criteria («Good»,

«Satisfactory», «Unsatisfactory», «Unsuitable»). The ownership function of the fuzzy set to determine the technical condition should be determined from expert estimates.

2.3 Methods overview of formation of an integral indicator

In order to form an integral indicator, it is necessary to define the requirements for the methods to be used in its formation.

The elements of an integral indicator should be differentiated according to certain topics, and the value of its components should be in general units.

When considering conventional units, it is necessary to specify document [26], which has the system of conventional units of electrical grids for the purpose of analysis and regulation of production and economic activity of subdivisions of electric grids. It's a volume-generating system for electricity companies. The development of this system is based on the current regulatory documents containing the nomenclature of electrical equipment used by enterprises of electric power industry and volumes of labor costs for repair and maintenance of power grid facilities.

Considering intellectualization as an improvement of efficiency, it is possible to analyze the integral indicators of the study of efficiency of production. Therefore, we consider ways to form an integral indicator of efficiency, and specifically production efficiency.

Solving the problem of building an integral indicator of production efficiency (E_p) is proposed to begin with the definition of integral indicators of efficiency of use of used and consumed resources [27]. One of the indicators is the resources use indicator (E_{IR}). This indicator depends on [27]:

- the volume of products sold in the accounting year fewer material costs, resource fees, interest on the loan;
- the number of employees at the enterprise;
- the average annual volume of fixed assets at replacement cost;

- the cost of working capital of the enterprise;
- a certain coefficient of total labor costs, which is determined by the ratio of the number of workers in the field of material production to the amount of national income.

Summary indicator of consumed resources (E_{CR}) is an indicator of costs per 1 UAH sold products.

To summarize the information obtained use an integral indicator of production efficiency, which can be naturally summarized using the index method [27]:

$$I_E = I_{E_{IR}} \cdot I_{E_{CR}}$$

where I_E – index of change in economic efficiency of production;

$I_{E_{IR}}$ – performance index of applied resources;

$I_{E_{CR}}$ – index of changes in resource efficiency.

This indicator reflects trends in resource efficiency and current costs and provides a summary picture of the level of production efficiency.

Based on the development of a large number of methods for defining integral indicators, new proposals for its construction are based on the analysis, synthesis and modification of existing ones.

This indicator should show the average impact of the use of resources. Performance should be considered (E_A), which, in turn, depends on performance [27]:

$$E_A = \sqrt{E_{MR} \cdot E_{FR} \cdot E_{WR}}$$

where E_{MR} – material resources;

E_{FR} – financial resources;

E_{WR} – labor force.

The efficient use of material resources is the efficient use of fixed and revolving funds. The efficiency of monetary resources, in turn, can be the ratio of

profit to the value of the main funds, the balance of working capital and the wage fund. Labor efficiency can be defined as the ratio of total activity to the wage bill.

The above-mentioned methods of measuring indicators allow working with production and its volumes. But in the context of information smart systems, in which the basis of development is precisely innovation activity, it is necessary to derive an indicator that allows to analyze the innovation activity of enterprise.

On the example of metallurgical complex we consider the following indicators of innovative activity of enterprises, which relate to the criterion of breadth of coverage of enterprises. [28]:

- the share of innovative active enterprise in their total number;
- the share of the size of the shipped innovative products in the total size of industrial products.

Similarly, consider indicators for the range criterion for the allocation of types and subjects of innovation [28]:

- the average number of new types of industrial products per innovative active enterprise;
- average number of new technologies per innovative enterprise.

It is also necessary to consider separately the degree of financial provision of innovation activity of enterprises involved in the development and implementation of innovations [28]:

- the average size of innovation costs per innovative active enterprise;
- the level of funding for research and development.

A generalized utility function (or Harrington scale) can be used as an integral measure of efficiency.

The proposed indicator is based on the idea of transforming the natural values of each innovation activity into a dimensionless form, followed by the definition of partial functions on the Harrington scale d_{r_i} and based on it the conclusion of the integral indicator of innovation activity of industrial enterprises [28]:

$$E_{IA} = \sqrt[r]{\prod_{i=1}^r d_{r_i}}$$

where r – number of indicators used to measure innovation activity;

d_{r_i} – partial function defined on the Harrington scale.

Similarly, hierarchy analysis can be used. Using this method, we can present our system as an inverted tree in which each element will depend on the elements below. Elements should reflect certain criteria and characteristics. The high tree element is the target value, and the elements a step lower influence their value and are part of the element above. Conventionally, such a tree can be depicted as elements of certain criteria and alternatives (Figure 2.2).

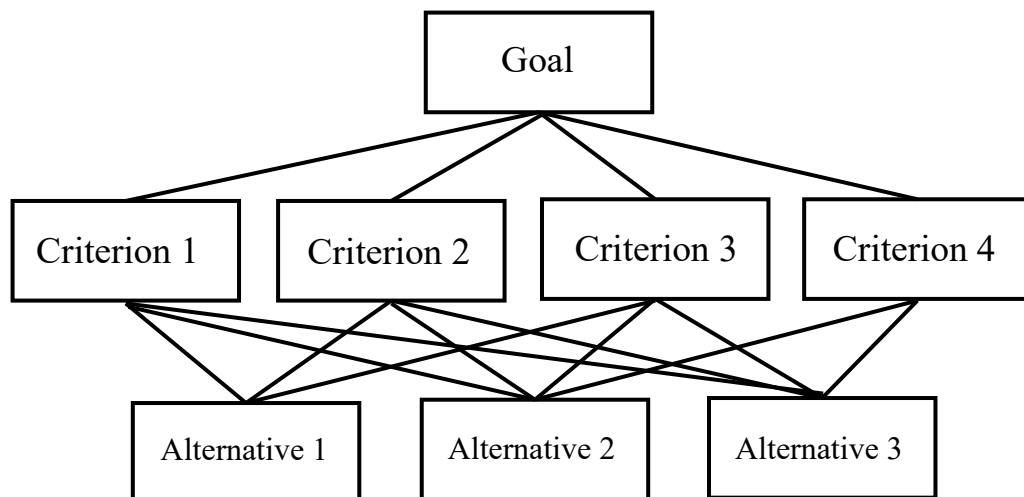


Figure 2.2 - Example of a hierarchy of criteria and alternatives

This method allows to determine the different number of criteria with its own weight coefficient. Which actually meets the requirements of differentiation. It is important that the actual value of each component can be reduced to the value of the conventional units. Therefore, in order to construct an intellectualization indicator, it is necessary to adapt the various methods on the basis of which the methodology for its calculation will be created.

2.4 Formation of intellectualization assessment integral indicator of electricity grids

Calculation of the integral indicator of intellectualization during realization of the project requires maximal research. It should give an answer to the result of the performance of the idea. At least what the result of innovation in cost terms is generalized by the economic effect. The scientific, technical, social, environmental and other results that can be valued are not absorbed by economic effects and exist on their own.

Thus, economic, scientific and technical, resource, social, environmental, marketing, organizational and management technologies are singled out among the types of effects depending on the results and costs of the implementation of innovative technologies.

To assess the effectiveness of the implementation of smart systems in an innovation project, it is necessary to identify effects and develop a system of performance indicators.

Given that we have a large number of indicators, it is necessary to bring different types of certain effects to the same units of measurement. After that, it will be possible to define the indicator as the sum of its different components, and each component, in turn, is characterized by its own integral indicator. Figure 2.3 shows the diagram of the definition of the integral indicator of network intellectualization.

Intellectualization indicator (E_I) depends on different components (C_i). Each component, in turn, will have its own indicators that affect it. Indicators that affect the component are different, so it is necessary to determine the impact of each indicator (α_{ij}) on i -th component. Each component can be defined by the formula:

$$C_i = \sum_{j=1}^{m_i} \alpha_{ij} \cdot I_{ij}$$

where I_{ij} – indicators affecting the component C_i , $C_i = \overline{0,1}$;

α_{ij} – impact j -th indicator on i -th component, $\alpha_{ij} = \overline{0,1}$;

m_i – number of indicators for the i -th component.

And each i -th component has its own impact on α_i on general indicator, in our case, the integral indicator of assessment of grids intellectualization.

The target value of the integral indicator will be 1. The total integral indicator itself should be in the range from 0 to 1. Therefore, the value approximated to 1 will mean the greatest efficiency of the project with the implemented smart technologies.

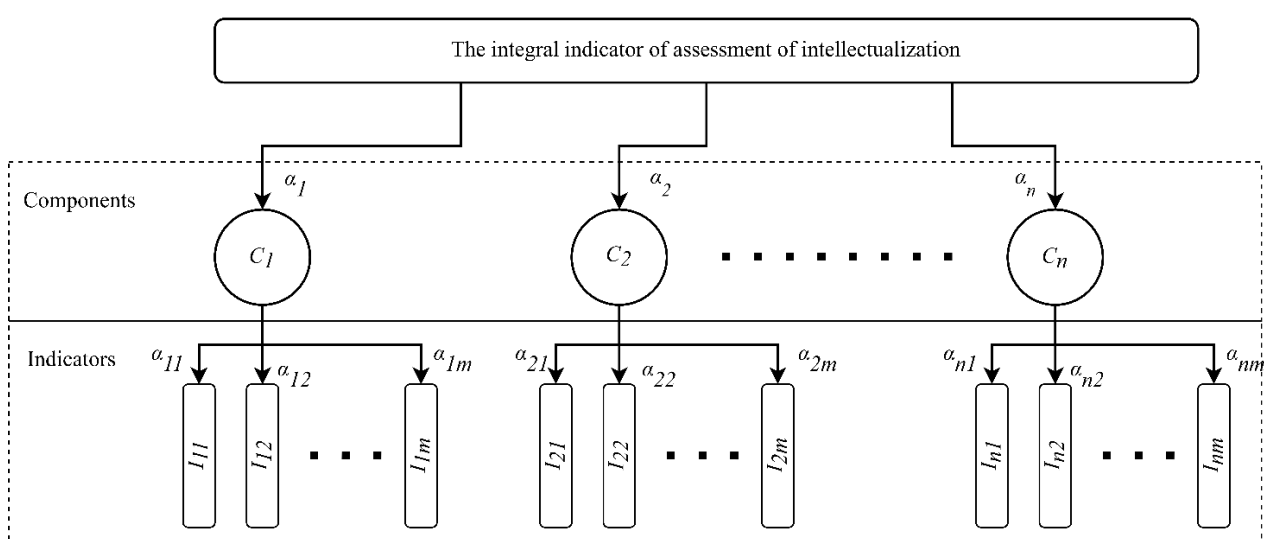


Figure 2.3 - Schema for determining the integral indicator of network intellectualization

The general formula for defining the integral measure of network intellectualization can be presented as follows:

$$E_1 = \sum_{i=1}^n \alpha_i \cdot C_i$$

where C_i – aggregate indicator of i -th component, $C_i = \overline{0,1}$;

α_i – the impact of i -th component on general indicator, $\alpha_i = \overline{0,1}$;

n – the number of components that impact on general indicator.

To sum up, the creation of a single measure of intellectualization requires not only the definition of the indicators themselves, but also the construction of dependencies and the impact of each indicator on each other.

Formalizing the task, let us represent the above in matrix form. We get a vector of values of all possible indicators (I), a matrix of the impact of these indicators on their possible components (A_I) and the vector of the impact of components on the integral indicator of intellectualization (a_C):

$$I = \begin{pmatrix} I_1 \\ I_2 \\ \dots \\ I_m \end{pmatrix};$$

$$A_I = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \dots & \alpha_{1m} \\ \alpha_{21} & \alpha_{22} & \dots & \alpha_{2m} \\ \dots & \dots & \dots & \dots \\ \alpha_{n1} & \alpha_{n2} & \dots & \alpha_{nm} \end{pmatrix};$$

$$a_C = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \dots \\ \alpha_n \end{pmatrix}.$$

where I_i – Indicators affecting the components, $I_i = \overline{0,1}$;

α_{ij} – the impact of j -th indicator on i -th component, $\alpha_{ij} = \overline{0,1}$;

n – the number of components that impact on general indicator;

m – the number of all possible indicators from all the components characterizing the general indicator.

If there is no influence of the indicator on the component, its value is 0.

Using matrices A_I and vectors I , it is actually possible to enter a vector c , that will contain all the values of the indicators of specific components and is based on the expression (1):

$$c = A_I \cdot I \tag{1}$$

Then, in order to find an integral indicator of assessment of network intellectualization, considering the vectors \mathbf{c}, \mathbf{a}_c it is necessary to apply the following expression (2):

$$E_1 = \mathbf{c} \cdot \mathbf{a}_c \quad (2)$$

Conclusions to Section 2

In this section, a study of the common characteristics of investment projects and projects for the implementation of smart systems was conducted. According to the results of the comparative analysis, it was found that the investment project for the implementation of SGs in the DSO can be considered in the context of investment projects and characteristics can be applied to it, as well as for a classic investment project.

There is a need to identify additional characteristics that will show efficiency, and which will be the indicators by which performance can be determined. Because the classical economic indicators that are characterized for an investment project, in this case, are impossible to fully use. So, it is necessary to make indicators that will more effectively show changes and will be able to more clearly deduce the opportunities that this or that project gives us.

3 METHODOLOGICAL APPROACHES TO THE ORGANIZATION OF THE INTEGRAL INDICATOR CONSTRUCTION FOR THE ASSESSMENT OF GRIDS INTELLECTUALIZATION

3.1 General requirements for constructing an indicator

General requirements to construct intellectualization assessment integral indicator of electricity grids are formed for search of those indicators that will be able to affect the accuracy of the integral indicator of intellectualization most effectively. This will formalize the objectives and allow for the selection of indicators according to clear criteria.

First, it should be said that the calculation of the integral indicator of intellectualization should be relatively easy and should not require additional complex methods to calculate it. Thus, the first criterion for measuring such an indicator is simplicity of calculation.

There is also a need to calculate this indicator within a specific period. After all, it is better to analyze the indicators of enterprise performance in the dynamics, since the absolute value cannot be compared with alternative values.

The calculated value of the indicator should be in the range from zero to one.

Thus, three criteria to the indicators have been formed: simplicity of calculation, possibility to present it in the dynamics recorded in its base model, and to have a value from zero to one.

3.2 General analysis of energy enterprise performance indicators

The implementation of intellectualization for an energy company is the process of network renewal, therefore, affects the fixed assets of this enterprise. In general, intellectualization implies improvement of technical condition of equipment.

Renewed fixed assets can improve the working conditions of employees, which has a significant impact on the economic efficiency of the enterprise and more efficient use of energy resources. Figure 3.1 shows the impact of intellectualization on the energy company.

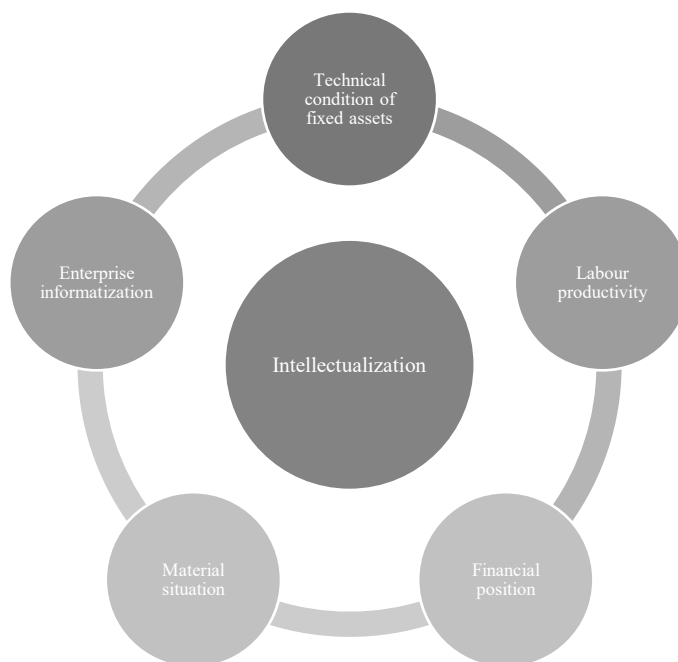


Figure 3.1 - Possible impact of intellectualization on the components of energy companies

Therefore, the performance of the DSO needs to be considered in the context of the five main components (Figure 3.2). In a generalized integral indicator, such components will have their own weight.

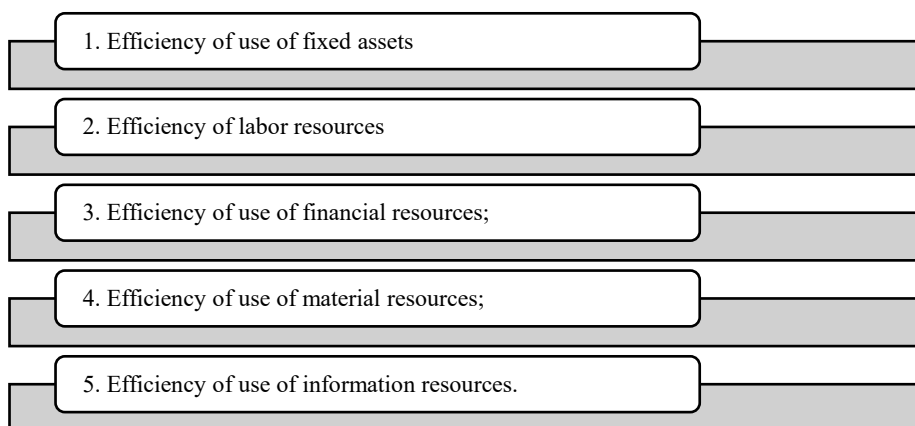


Figure 3.2 - The main components of the integral indicator.

3.1.1 Indicators of the efficiency of fixed assets use

The assessment of the efficiency of the use of fixed assets is carried out with a view to determining the level of the technical condition of the fixed assets of the DSO, which allows to see the rate of renewal and the breadth of coverage of innovative technologies.

First, you need to see the efficiency of using the company's main funds. The main assets of the DSO are buildings, installations, machinery, equipment, intangible assets, and other tangible assets. The main means of the electric grids consist of overhead lines, cable lines, substations, distribution points, automated systems for control and accounting of energy resources. The technical characteristics of the fixed assets are shown in Table 3.1.

Table 3.1 - Indicators of technical condition of fixed assets

Indicator	Formula	Parameter description
The depreciation coefficient [29]	$C_{dep} = \frac{A_{dep}}{A_{end}}$	A_{dep} – the value of depreciation of fixed assets
The applicability coefficient [29]	$C_{app} = \frac{A^{end} - A_{dep}}{A_{end}}$	A^{end} – the value of fixed assets at the end of the reporting period
The renewal coefficient [30]	$C_{ren} = \frac{A_{rec}}{A_{end}}$	A_{rec} – the value of received fixed assets A^{end} – the value of fixed assets at the end of the reporting period
The fixed assets renewal rate [30]	$R_{ren} = \frac{A^{begin}}{A_{rec}}$	A^{begin} – the value of fixed assets at the beginning of the reporting period A_{rec} – the value of fixed assets received for the reporting period
The retirement coefficient [30]	$C_{ret} = \frac{A_{ret}}{A^{begin}}$	A_{ret} – the value of retired fixed assets A^{begin} – the value of fixed assets at the beginning of the period
The increment coefficient [30]	$C_{inc} = \frac{A_{rec} - A_{ret}}{A^{begin}}$	A^{begin} – the value of fixed assets at the beginning of the reporting period

It is also very important to assess the coverage of fixed assets by innovative technologies and enter new indicators such as the innovation coefficient and breadth of coverage of innovation activities (Table 3.2).

Table 3.2 - Indicators of coverage of fixed assets with innovative technologies

Indicator	Formula	Parameter description
Capital-labor ratio [31]	$C_{CL} = \frac{A^{end}}{N_{empl}}$	A^{end} – the value of fixed assets at the end of the reporting period N_{empl} – average number of employees
The innovation coefficient	$C_I = \frac{A_{inn}}{A_{rec}}$	A_{inn} – the value of received innovation fixed assets of the reporting period A_{rec} – the value of received fixed assets
Breadth of coverage of innovation activities	$BCI = \frac{N_{inn}}{N_{total}}$	N_{inn} – the number of implemented innovative solutions N_{total} – the total number of implemented solutions

3.1.2 Indicators of the labor efficiency

The Labor Efficiency Assessment is designed to assess the quality of labor and the working conditions of workers and to show the changes in their productivity and the impact of the human factor on the work of the DSO.

An indicator of labor efficiency is the productivity of workers. This indicator is the ratio of the time spent by all employees of an enterprise to the actual supply of electrical energy and is calculated by the formula:

$$C_{PSE} = \frac{t_{WH}}{W_{PS}}$$

where t_{WH} – the actual working time, hours;

W_{PS} – actual supply of electrical energy, kW·h.

Factors that have a significant impact on the labor resources of an enterprise, in particular on their development, is a decrease in the level of motivation for work. It is therefore necessary to enter an indicator to calculate staff turnover [32].

The staff turnover rate is calculated using the formula:

$$R_{TO}^{staff} = \frac{N_{work}^{fired}}{N_{work}}$$

where N_{work}^{fired} – number of employees dismissed for reasons of turnover;

N_{empl} – average number of employees.

Based on innovative activity, it is necessary to consider the «human factor», and to analyze the erroneous actions of workers from all possible erroneous actions at the enterprise. In order to do this, enter a human error rate. It will depend on erroneous actions of operational personnel, staff of services, staff of laboratories, staff of workshops, staff of departments, senior staff:

$$EA_h = \frac{\textit{Erroneous Actions Dependent On Human}}{\textit{All Erroneous Actions}}$$

Similar to the human error rate, an indicator of the error caused by undetected defects of employees, and it should be calculated by the following:

$$EA_{UD} = \frac{\textit{Erroneous Actions Dependent On Undetected Defect}}{\textit{All Erroneous Actions}}$$

3.1.3 Indicators of the efficiency of the financial resources use

The main purpose of the assessment of the efficiency of the use of financial resources is the possibility of further analysis of the financial activity of the

enterprise, that allows you to see the impact of the implementation of innovative technologies on the financial situation of the DSO and the efficiency of sales of its products or services.

The efficiency of the use of its financial resources is an important step in assessing the performance of the enterprise. In order to carry out its activities, the DSO requires a certain amount of financial revenues, appropriate means of financing, certain sources, and uses of finance. Its activities should therefore be geared towards their effective use. Indicators of estimation of financial activity of an enterprise can be divided into the following groups: turnover, liquidity, profitability [33].

The analysis of turnover consists in the study of levels and dynamics of financial turnover coefficients, which are relative indicators of financial results of activity of an entity. The overall turnover of all funds consists of the turnover ratios of the individual elements of the funds. Possible turnover indicators [34] are given in Table 3.3.

The average turnover of an asset can be used for the turnover analysis:

$$T_{TO_i} = \frac{T_{days}}{C_{TO_i}}$$

where T_{days} – calendar time fund for the period, days;

C_{TO_i} – turnover indicator i -th type of asset over a certain period.

Liquidity shows the speed of turnover and can be characterized by three indicators: *Current Ratio*, *Quick Ratio* and *Cash Ratio*. Formulas for calculating the three types of liquidity [36]:

$$\text{Current Ratio} = \frac{\text{Current Assets}}{\text{Current Liabilities}};$$

$$\text{Quick Ratio} = \frac{\text{Liquid Assets}}{\text{Quick Liabilities}};$$

$$\text{Cash Ratio} = \frac{\text{Cash and Cash Equivalents}}{\text{Current Liabilities}};$$

Table 3.3 – The main turnover indicators of the enterprise.

Indicators	Formula	Parameter description
Total Asset Turnover	$TAT = \frac{RV}{A_{total}^{end}}$	RV – revenue. A_{total}^{end} – the average value of total assets at the end of the period.
Equity Turnover	$ET = \frac{RV}{A_{eq}^{end}}$	A_{eq}^{end} – the average value of equity at the end of the period.
Working Capital Turnover	$WCT = \frac{RV}{A_w^{end}}$	A_w^{end} – the average value of working capital at the end of the period.
Material Working Capital Turnover	$MCT = \frac{RV}{A_{mat}^{end}}$	A_{mat}^{end} – the average value of material working capital at the end of the period.
Finished Product Turnover	$FPT = \frac{RV}{A_{fin}^{end}}$	A_{fin}^{end} – the average value of finished product at the end of the period.
Accounts Receivable Turnover	$ART = \frac{RV}{AR}$	AR – the average value of receivable at the end of the period.
Accounts Payable Turnover	$APT = \frac{RV}{AP}$	AP – the average value of payable at the end of the period.
Fixed-asset turnover [35]	$FAT = \frac{RV}{A^{total}}$	A^{total} – the average value of fixed assets.

Profitability ratios reflect the profitability of the company. It is possible to distinguish three main groups of indicators of profitability analysis: capital, sales and production [37].

Capital profitability is characterized by return on total capital (R_{ROA}) and equity (R_{ROE}) [37]:

$$R_{ROA} = \frac{\text{Pretax Profit}}{\text{Total Sources of Funds}}$$

$$R_{ROE} = \frac{\text{Net Profit}}{\text{Equity}}$$

Sales profitability is characterized by indicators of gross (R_{GPM}), operating (R_{OIM}) and net (R_{NPM}) profitability of the implemented product [37].

$$R_{GPM} = \frac{\textit{Gross profit}}{\textit{Revenues from sales}}$$

$$R_{OIM} = \frac{\textit{Operating profit}}{\textit{Revenues from sales}}$$

$$R_{NPM} = \frac{\textit{Net profit}}{\textit{Revenues from sales}}$$

When considering DSO, it is necessary to note the absence of the production process in its activities, but it is necessary to assess the process of providing additional services. Therefore, the profitability of providing services is characterized by indicators of gross (R_{GS}) and net (R_{NS}) profitability of the services being delivered.

$$R_{GS} = \frac{\textit{Gross profit}}{\textit{Service cost}}$$

$$R_{NS} = \frac{\textit{Net profit}}{\textit{Service cost}}$$

3.1.4 Indicators of the efficiency of material resources use

The assessment of the efficiency of material resources is carried out to analyze the energy effect of the material resources used and to show the effectiveness of their distribution.

The material costs of DSO include raw materials and basic materials (cables, fasteners, etc.), auxiliary materials (chemical solutions, lubricants, etc.), components (power and measuring transformers, ASCAER devices, etc.), fuel and transport.

General indicators of the use of material resources are Material Productivity and Material Intensity. They analyze the efficiency of all material resources. Selected indicators of material intensity allow to examine the level of use of individual materials. The Material Productivity indicator is inversely proportional to the Material Intensity. For DSO, the overall Material Intensity will look like:

$$MI = \frac{\textit{Actual Material Cost}}{\textit{Power Suply Amount}}$$

It is also necessary to have an indicator to compare the actual value of the materials used with the value from the planned calculations. There is a utilization factor for all material costs and calculate the value by the formula:

$$R_U = \frac{\textit{Actual Material Cost}}{\textit{Plan Material Cost}}$$

3.1.5 Indicators of the efficiency of information resources use

The assessment of the effectiveness of the use of information resources is carried out in order to analyze their impact on the electricity grid and gives an opportunity to see how effectively invested in them and how these resources can be protected.

The effectiveness of information resources should be analyzed on the basis of the number of information products and the effect of their implementation. The effect of the implementation should be considered to be a reduction in time, which can significantly improve management efficiency and allow more correct decision-making.

Therefore, the coefficient that considers the effect of the implementation of information resources and the amount of investment in them. The efficiency ratio of investments in information resources will be calculated as follows:

$$C_{IR} = \frac{\textit{Impact of the information resources implementation}}{\textit{Level of investment in information resources}}$$

In order to determine the impact of the implementation of information resources, the following quantitative indicators [38] are proposed: rhythm coefficient of production (carrying out the main inspection activity); the efficiency of the control apparatus; quality coefficient of performance of managerial functions; the employee's skill utilization factor. Let's see on rhythm of production, efficiency of the control apparatus and qualification of an employee.

The rhythm coefficient of production (conducting the main activity of inspection) is the characteristic of the degree of rhythm of the implementation of measures for state energy control [38] and may be calculated by the following:

$$C_{ryth} = \frac{\textit{Value of Completed Activity}}{\textit{Value of Planning Task For The Period}}$$

The efficiency of the control apparatus characterizes the timeliness of the relevant tasks and is determined [38]:

$$C_{OW} = \frac{\sum_{i=1}^n \left(\sum_{j=1}^{m_i} (D_{ij} - d_{ij}) \cdot K_{ij} \right)}{\sum_{i=1}^n \left(\sum_{j=1}^{m_i} D_{ij} \cdot K_{ij} \right)}$$

where D_{ij} – decision deadlines set respectively by the highest organization, management of the enterprise, production and functional departments, days;

d_{ij} – delays in the completion of tasks, days;

m_i – number of tasks;

K_{ij} – coefficients of significance that conditionally characterize different types of tasks in order of importance.

The employee's skill utilization factor is defined as the ratio of time spent on the activity (according to his or her qualifications) to the amount of time actually worked [38]:

$$C_{wq} = \frac{\textit{Time Spent On The Activity}}{\textit{Time Actually Worked}}$$

The next step should be to consider the effectiveness of investment in cybersecurity of the implemented information resources. We are entering an indicator to assess the cost-effectiveness of implementing, maintaining, and developing information security systems [39]:

$$C_{CS} = \frac{D_{SA} - I_{CS}}{I_{CS}}$$

where D_{SA} – possible harm from cyber-attacks, thousand UAH;

I_{CS} – investment in information security systems, thousand UAH.

3.3 Justification of the use of energy enterprise performance indicators

The level of accidents in electrical grids with a voltage of 0.4-110 (150) kV remains quite high, including significantly increasing the time of elimination of damage to elements of electrical grids and restoration of power supply to consumers. In order to prevent the occurrence of such technological violations in the future, the DSO should monitor the technical condition of its own electrical grids to identify "bottlenecks" and implement emergency measures developed on the basis of a systematic analysis of the causes of technological violations. [40].

Therefore, the analysis of the technical condition of fixed assets is important, and indicators of the technical condition are extremely priority in the direction of intellectualization, because the technical condition greatly affects the quality of all smart systems, and the priority direction of modernization should be a comprehensive modernization of the network of unsatisfactory or unsuitable state with the implementation of smart technologies.

Indicators of the technical condition of fixed assets include the depreciation coefficient or the applicability coefficient of fixed assets. The applicability coefficient of fixed assets reveals what proportion their residual value is from the original value. So, it is advisable to use it in the analysis as one of the indicators of the integral indicator of intellectualization.

The assessment of the technical condition of individual components of the electrical grid, namely overhead lines, and transformer substations, should be carried out according to the method of determining defective coefficients and the use of fuzzy logic, and on the basis of it the volume of equipment wear is calculated.

The use of such an indicator will motivate the energy company to introduce SGs in areas that already need to be modernized.

The following are the indicators of the movement of fixed assets, namely the renewal coefficient, which characterizes the share of new fixed assets commissioned in the reporting period as part of all fixed assets available at the end of the reporting period. And the fixed assets renewal rate, which shows the share of fixed assets at the beginning of the period compared to the entry.

Similar to the update indicator, the retirement coefficient is introduced. It shows how much of the fixed assets available at the beginning of the reporting period were eliminated during this period due to aging and wear.

Such an indicator as the increment coefficient shows the dynamics of the growth of the entry of new funds. In order for this indicator to be able to be used in the future, it is necessary to clarify.

Due to the fact that intellectualization requires to renew fixed assets with innovative technologies, and therefore it is necessary to introduce indicators that will allow to assess the coverage of innovative technologies of the main.

Regarding the coverage of fixed assets with innovative technologies, the use of the capital-labor ratio indicator is proposed, which shows the ratio of the entire number of fixed assets to workers in the enterprise. But given the fact that there is a need for innovative weaponry, therefore, a decision was made in favor of the innovation coefficient. This indicator is the ratio of the average cost of innovative funds of an energy company to the total volume of funds.

Referring to the example of indicators for assessing the innovative activity of the metallurgical complex (see 2.3), we can highlight such an indicator as the breadth of coverage of innovation activities. This indicator should show the overall weight of innovative technological solutions within the DSO.

Innovative technical solutions should be considered such solutions that meet the requirements of technical policy in the field of development and operation of main and interstate electrical grids.[41]. This technical policy is designed to summarize the existing experience of operation, to establish uniform technical requirements. It spells out the practices and features of the use of modern electrical equipment and design solutions of world and domestic manufacturers. The choice and updating of certain innovative solutions are entrusted to TSO electric energy.

The labor resources of DSO include all people working in the enterprise. These can be full-time employees, external part-timers or employees working under civil law contracts.

From the point of view of labor resources, innovative technologies should reduce the burden on employees, which leads to a decrease in the risk of the “human factor” and allows you to optimize the workflow with increasing efficiency. Therefore, it is necessary to introduce an indicator that could analyze the productivity of employees working in the field of electrical grid management. But the existing indicator of employee productivity requires changes, namely bringing it to the supply of electricity for the previous period and the maximum possible time

of work of existing personnel. The changed productivity indicator of workers, considering bringing it to the worst-case scenario, is calculated by the formula:

$$C_{PSE} = 1 - \left(\frac{t_{WH}^{fact}}{t_{WH}^{max}} \cdot \frac{\min(W_{PS}^{prev}, W_{PS}^{fact})}{W_{PS}^{fact}} \right)$$

where t_{WH}^{fact} – actual working hours, hours;

t_{WH}^{max} – maximum possible working hours, hours, $t_{WH}^{fact} \leq t_{WH}^{max}$;

W_{PS}^{fact} – actual supply of electrical energy, kW·h;

W_{PS}^{prev} – electricity supply for the previous period, kW·h.

t_{WH}^{max} is defined as the product of the number of normative number of staff for the maximum time (we take 8 hours), for which they can be involved.

The staff turnover rate actually considers the level of attractiveness of labor but is not a priority for calculating the integral indicator of intellectualization. Although the modernization of labor means with innovative technologies can affect staff turnover, this impact is not obvious.

Indicators that directly affect the level of intellectualization are indicators of erroneous actions of a person and erroneous actions that are caused by defects undetected by employees. In the integral indicator, the indicators of erroneous actions should be presented as $E\dot{A}_h = (1 - EA_h)$ and $E\dot{A}_{UD} = (1 - EA_{UD})$. These indicators are not considered in dynamics, but they can stimulate the energy company to find problems that can occur naturally every period and look for opportunities to implement systems for predicting such problems.

One of the groups of indicators of financial efficiency of an energy company, namely turnover indicators, which make it possible to analyze the working capital of the enterprise. Turnover coefficients allow to analyze the state in dynamics, because they are tied to a certain period, and are relatively simple.

To calculate the turnover indicators, we need to have an average value of the following types of assets: total asset; equity; working capital in balance; material working capital in balance; finished product; fixed assets.

Similarly, turnover ratios can be calculated on receivables and payables.

Such indicators allow us to find the rate of profit at the expense of different types of capital. They are easy to calculate, but they do not make it possible to see the profitability of the company. Assessment of profitability is possible, but profitability indicators very accurately assess the financial side. Therefore, this indicator is not a priority for its consideration in the context of assessing intellectualization.

Using turnover indicators in the total integral indicator, it is advisable to use an indicator of the average turnover period. It can be easily compared with the same indicator of the last period, which will be able to show its positive dynamics, and in the absence or negative dynamics we will have a value limited by zero.

$$T_{TO_i}^{\cdot} = 1 - \frac{T_{TO_i}^{curr}}{\max(T_{TO_i}^{curr}, T_{TO_i}^{prev})}$$

where $T_{TO_i}^{curr}, T_{TO_i}^{prev}$ – indicator of the average turnover period i -th type of asset for the current and previous period, respectively.

Analyzing the need to calculate the liquidity indicator, namely, the fact that it shows the speed of turnover of invested funds in the company and can give an answer to whether the enterprise has the opportunity to invest in innovative development.

According to [42] DSO operating expenses may be controlled and uncontrolled. The amount of controlled costs depends entirely on management decisions, and the uncontrolled ones actually depend on the decisions prescribed by law.

Considering the investments and income of DSO, we can talk about its own (depreciation, profit on production investments, for flows of reactive electricity,

income from the imbalance of technological costs of electricity, connection fees) and attracted (loans, financial assistance, etc.) funds.

From the costs of the energy company, the tariff for the distribution of electricity for the end user is calculated [42]. Based on this tariff and the actual supply of electricity to the consumer, we have the cost of profit that the company must receive from its activities. So, we have certain liabilities to the DSO on the part of the consumer. The value of Cash Ratio will be calculated according to the formula:

$$CR = \frac{\textit{Invested Own Funds} + \textit{Invested Borrowed Funds}}{\textit{Current Liabilities to DSO}}$$

Analysis of the efficiency of the use of material resources is proposed to be carried out using two indicators material intensity and utilization factor for all material costs. In order to be able to see the value of the indicator in dynamics, it is necessary to bring the value of the indicator in the current period to the value of the indicator in the past. And since the components of the indicator of intellectualization cannot have negative dynamics, so the indicator will be limited to zero value.

$$\dot{MI} = 1 - \frac{MI_{curr}}{\max(MI_{curr}, MI_{prev})}$$

where MI_{curr} – overall material intensity indicator for the current period;

MI_{prev} – overall material intensity indicator for the previous period.

The utilization factor for all material costs can be changed similarly:

$$\dot{R}_U = 1 - \frac{R_{U_{curr}}}{\max(R_{U_{curr}}, R_{U_{prev}})}$$

where $R_{U_{curr}}$ –utilization factor for all material costs for the current period;

$R_{U_{prev}}$ – utilization factor for all material costs for the previous period.

The next indicator is the efficiency ratio of investments in information resources. It depends on the effect of information resources on labor productivity and the efficiency of the enterprise as a whole. Therefore, this indicator requires detailed selected data. The dynamics of the indicator can be obtained by comparing the current and previous periods. Then the formula for calculating the efficiency factor of investments in information resources will be as follows:

$$C_{IR} = C_{ryth} \cdot C_{OW} \cdot C_{WQ} \cdot I_{IR}^{curr}$$

where C_{ryth} , C_{OW} , C_{WQ} – the value of rhythmicity coefficients, operational work and the use of workers' qualifications for a certain period, respectively;

I_{IR}^{curr} – investments in information resources for a certain period, thousand UAH.

Then the overall efficiency ratio of investments in information resources can be found as:

$$C_{IR} = \frac{C_{IR}^{curr}}{\max(I_{IR}^{curr}, I_{IR}^{prev})}$$

where I_{IR}^{curr} , I_{IR}^{prev} – investments in information resources for the current and previous periods, respectively, thousand UAH;

C_{IR}^{curr} – efficiency ratio of investments in information resources for current period.

When analyzing the performance of investments in cybersecurity, it should be noted that possible damage that may be caused requires detailed analysis by cybersecurity experts and access to the company's sensitive data.

On the consideration of performance indicators, a list of indicators that meet the general requirements for the construction of the performance indicator has been formed. A list of such indicators is provided in table A.1 (Annex A).

3.4 Analysis of the possibilities of determining weight coefficients

Weighting is the next step after a list of all possible indicators is defined. This stage includes the definition of the method of decision-making, analysis of the data obtained and as a result, to obtain the matrices of influence of all possible indicators on the components and components on the integral indicator of intellectualization.

Different methods of decision making apply at different possibilities of access to information and computing capacity. In our case, substantiation and assessing of decisions cannot be made on the basis of accurate calculations. Therefore, we can talk about the expediency of using Method of Expert Estimations [43].

Method of Expert Estimations uses an assessment of a number of experts in their field. Such assessments may be based either on the work of the expert group or on an individual and independent opinion.

For a group of experts, methods can be used: "brainstorming", the method "635", a business game, an assessment by a commission, a "court". In order to obtain an individual opinion of an individual expert, methods are used: "Delphi", interviews, reports [43].

The organization of group work of experts is a more complex process than an individual one, because this requires the involvement of a large number of experts at one time. Therefore, for this study, methods of individual expert opinion will be used, the collection of which can take place at a convenient time for each expert.

Next, determine the method of collecting expert assessments. After analyzing the existing methods, for this study methods of pairwise (binary) comparisons or rankings are the most appropriate. [43].

Pairwise comparison allows experts not to think about numerical values, how exactly indicators affect a particular component, but to compare each of them in pairs with each other. It is most expedient with a large number of objects studied and weak differences from each other. Ranking can be performed by setting weights by an expert or when he organizes indicators by the importance of direction.

Determination of weight coefficients for indicators is proposed according to the following algorithm:

1. It is necessary to discard indicators whose impact on this component is absent or completely insignificant.
2. Rank by effect on the component for the set of remaining indicators.
3. Provide each place with a weight coefficient.

What indicators to discard and what weights to assign for each component can be decided by expert means.

When processing data, a method that allows epistemic uncertainty should be chosen. Therefore, it is advisable to use the Bayesian approach for this. There are three provisions of this approach [44]:

- the parameter of a model or system is random, and chance can be interpreted both in the generally accepted sense and in the sense of uncertainty;
- the results of observations and the a priori distribution are combined using Bayes' theorem in order to obtain a posterior distribution of the parameter;
- statistical inference or the decisive rule is adopted on the basis of maximizing the expected utility, minimizing losses associated with the application of this rule.

Thus, Bayesian theorem allows us to constantly accumulate new information, combining it with the prior (formalized in the form of a priori distribution), which in fact clarifies it with each step and actually makes the transition to posterior information.

The combination of a priori information and empirical data can be represented in the form of such a transformation [44]:

$$h(\theta|x, I_a) = \frac{h(\theta|I_a) \cdot h(\theta|x)}{\int h(\theta|I_a) \cdot h(\theta|x) d\theta}$$

where $h(\theta|I_a)$ – the priori distribution;

$h(\theta|x)$ – likelihood function;

I_a – initial information;

x – new data;

θ – distribution density parameter.

Considering a group of experts, the result of their evaluation of each object is an a posteriori probability distribution on a set of hypotheses about the rank of this object. And given that the a priori distribution is uniform, the result can be found using the formula (3) [45]:

$$P_i \left(H_l | e_{(i)}^{(l)} \right) = \frac{P_i \left(e_{(i)}^{(l)} | H_l \right)}{\sum_{s=1}^k P_i \left(e_{(i)}^{(s)} | H_s \right)}; \quad l = \overline{1, k}; i = \overline{1, N}. \quad (3)$$

where $P_i \left(e_{(i)}^{(l)} | H_l \right)$ – a posteriori probability of the truth of the hypothesis that the rank is the chosen rank for i -th object is equal to l , revised in response to available evidence $e_{(i)}^{(l)}$ about the purpose i -th object rank l a number of experts;

$P_i \left(e_{(i)}^{(s)} | H_s \right)$ – conditional probability, interpreted as the degree of correspondence to the assumption of the truth of the hypothesis that the rank for i -th object equals to s , available evidence $e_{(i)}^{(s)}$ about assigning the i -th object rank s to some (possibly empty) subset of experts.

N – the number of assessed objects, which is determined at the first stage of the algorithm proposed above;

k – the number of ranks, which in our case is equal to N .

The conditional probability is calculated as the ratio of the number of experts who assigned i -th object rank s to the total size of the expert group.

A set of N k -element posterior distributions is then formed. The final ranks of i -th object are determined after processing the posterior probability distributions according to rule (4) [45]:

$$i^* = \arg \max_{i \in \overline{1, N}} \left\{ \sum_{s=1}^l P_i \left(H_s | e_{(i)}^{(s)} \right) \right\}; l = \overline{1, k}. \quad (4)$$

At the same time, the object of which has already been assigned a rank is excluded from further consideration.

This approach allows you to flexibly and without a significant increase in computational complexity eliminate collisions that are possible during group assessment of indicators [45].

Conclusions to Section 3

This section considers methodological approaches that are associated with the formation of an integral indicator of intellectualization and identifies a certain methodological apparatus that should be involved in the consideration of individual components of this integral indicator. A sequence of actions related to the implementation of this indicator has also been formed.

In general, the methods under consideration satisfy the requirements imposed on them, but the peculiarities of indicators and statistics in the electricity sector require the identification of certain features of these methods and do not allow them to be fully used. Consequently, the methods under consideration require some adaptation to existing statistics in order to be able to find certain differences or certain opportunities for the implementation of the integral indicator of intellectualization.

Therefore, it is necessary to analyze existing statistics, identify dependencies that can be used and configure the existing mathematical apparatus for the methods used in this study.

4 APPLICATION OF THE INTELLECTUALIZATION ASSESSMENT
 INTEGRAL INDICATOR OF ELECTRICITY GRIDS

4.1 Analysis of statistical data for the development of assessment indicators

Before analyzing DSO statistics, it is important to pay attention to the interaction of entities of state and non-state influence on it. The scheme of influence of subjects involved in planning the development of electric energy distribution systems in Ukraine is shown in Figure 4.1.

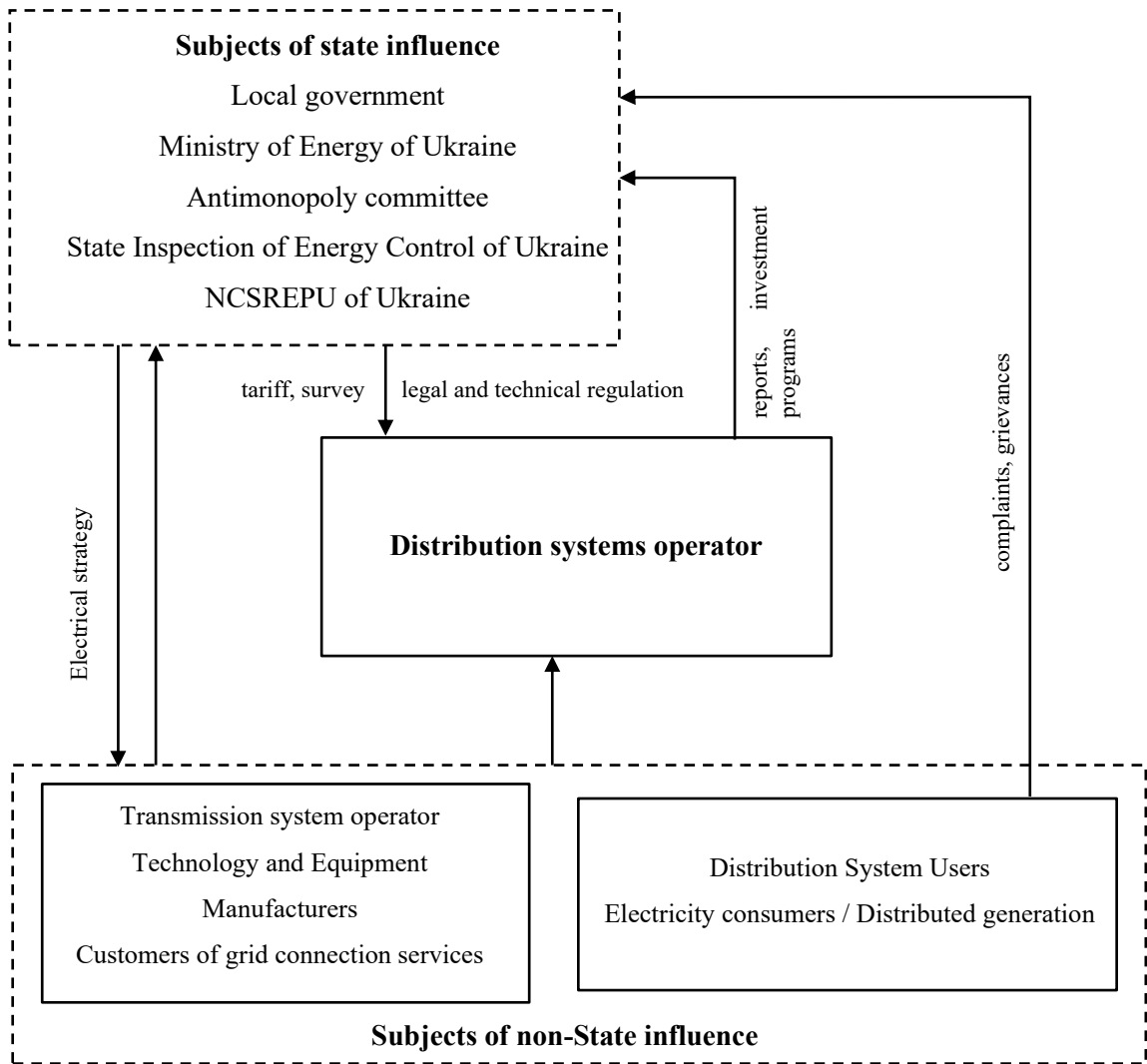


Figure 4.1 - Scheme of influence of the entities involved in planning the development of electric energy distribution systems in Ukraine.

It is important to consider from the subjects of state influence: the Ministry of Energy, which performs the functions of management; the State Inspectorate of Energy Supervision of Ukraine, which performs the functions of control; NCSREPU of Ukraine, which performs the functions of regulation.

Ministry of Energy of Ukraine formulates state policy in the field of electricity [46]. It coordinates DSO investment programs, so the need for an integral measure of intellectualization here is extremely important. After all, such a project as intellectualization, requires an investment justification.

The State Inspection of Energy Control of Ukraine is responsible for checking the technical condition of DSO electrical grid equipment [47]. Therefore, it should be able to draw conclusions about the priority of technical solutions for the development of distribution systems envisaged by the project investment programs.

NCSREPU of Ukraine is a permanent central executive body with a special status [1, 48]. According to its terms of reference: provides licenses and monitors compliance with licensing conditions; approves and supervises the implementation of plans for the development of distribution systems and investment programs of DSO; Establishes tariffs for electricity distribution services and economic coefficients regulating the technological costs of electricity in electrical grids; Follows the requirements of DSO for non-discriminatory access to electrical grids; In particular, takes into account complaints from users of the distribution system and settles disputes; monitors the quality of service delivery [1, 48, 49].

The DSOs shall develop the plans for the distribution systems development for the following 5 years considering the transmission system development plan for the following 10 years and present them to the NCSREPU's approval. [1]. So, DSO provides detailed information about the investment program every year. [50].

According to the National Regulation on General Financial Reporting Requirements [51], each enterprise prepares a report on the financial State once a year. Thus, the DSO provides a report once a year that contains data at the beginning and end of the reporting period.

On the side of the State Inspection of Energy Control of Ukraine there is a possibility to obtain full statistics of technological violations, including their classification on certain grounds.

The types of statistical information that can be obtained from the different reporting forms are shown in Figure 4.2.

Investment program	Financial report	Report of comprehensive income
<ul style="list-style-type: none"> •Calculation of funding sources for the investment program •List of unfinished construction, modernization and reconstruction •Investment Plan for Sources of Finance •Technical condition of electrical grids •General description of the work •Stages of implementation of the investment program 	<ul style="list-style-type: none"> •Assets <ul style="list-style-type: none"> •non-current assets •current assets •Liabilities <ul style="list-style-type: none"> •equity •long-term liabilities •current liabilities 	<ul style="list-style-type: none"> •Financial results •Total income •Operating cost elements •Calculation of equity yields

Figure 4.2 - Statistical information available from different reporting forms

The value of all possible characteristics necessary for the calculation of the energy enterprise performance indicators (table A.1) and the sources of information are collected and shown in table A.2 (annex A).

4.2 Calculation of Energy Enterprise Performance Indicators

The calculation of DSO performance indicators is the next step after analyzing statistical data. The indicators applied in the integral indicator of assessment of intellectualization of the network are shown in Table A.1.

Selected object for calculation, namely DSO data which can be fully used for calculation. JSC "Poltavaoblenerho" was selected for the further analyzing.

According to Table A.2, seven characteristics are selected. The values of these characteristics for 2019 and 2020 are presented in the Table 4.1.

Table 4.1 - Main characteristics of fixed assets JSC "Poltavaoblenerho"

Characteristic	Value	
	2020	2019
the value of depreciation of fixed assets, thousand UAH	2552874	2494198
the value of fixed assets at the end of the reporting period, thousand UAH	3981082	3659495
the value of received fixed assets, thousand UAH	237796	332036
the value of fixed assets at the beginning of the reporting period, thousand UAH	3659495	3635426
the value of fixed assets received for the reporting period, thousand UAH	14639	307967
average number of employees, employees	4349	4269
the value of received innovation fixed assets of the reporting period, thousand UAH	34857,3	32621,87

We calculate the facility's technical condition and capital stock coverage for the year 2020 according to the formulas given in Table 3.1 and Table 3.2 and according to the characteristics given in Table 4.1.

The applicability coefficient:

$$C_{app} = \frac{3981082 - 2552874}{3981082} = 0,359$$

The renewal coefficient:

$$C_{ren} = \frac{237796}{3981082} = 0,060$$

The calculation for other indicators was done with Microsoft Excel spreadsheets and the summary results are presented in Table 4.2.

Table 4.2 - Values of indicators of technical condition and indicators of coverage of fixed assets of this object by innovative technologies as of 2019 and 2020.

Indicator	<i>i</i>	Value	
		2020	2019
The applicability coefficient	1	0,359	0,318
The renewal coefficient	2	0,060	0,091
The retirement coefficient	3	0,004	0,085
The increment coefficient	4	0,061	0,007
The innovation coefficient	5	0,147	0,098

Similarly, using the characteristic values from table A.2 with the help of Microsoft Excel spreadsheets the values of other indicators were calculated, and the calculation data was written into the table A.3 (Annex A).

4.3 Determination of weight coefficients of energy enterprise performance indicators

Determination of weights for performance indicators of the energy company was made for a separate group of indicators that affect the indicator of the component and the components that affect the integral indicator.

Consider the calculation of weights for one of the components of the integral indicator of intellectualization for JSC "Poltavaoblenerho", a component of fixed assets as of 2020.

According to the algorithm (see 3.4), the first step is to determine the indicators whose influence on the intellectualization of fixed assets is significant. To do this from the set of all possible indicators I , by determining the consistency of all experts, choose a subset of those indicators that have an impact on the component of fixed assets C_i .

In the context of this work, the subset of indicators affecting the fixed asset component is definite and reasonable (see 3.3). So, we're going with index numbers $i = \overline{1,5}$ according to data from Table 4.2.

The next step is to rank the indicators using Bayes theory and the method of expert estimation (see 3.4).

Each expert should rank each indicator. If the expert is not sure, he can choose a common rank for two, in his opinion, equivalent.

Representatives of specialized energy companies in the number of 10 people were involved in the examination. The expert evaluation was carried out according to the general procedure.

Next, there are five indicators for ranking I_i , $i = \overline{1,5}$. An example of expert voting for Applicability Coefficient, which has an index $i = 1$ is presented in Table 4.3. Each loyal expert voice is marked with a number "1".

Table 4.3 – Expert voting to determine the rank for the indicator I_1 .

Indicator I_1		l				
		1	2	3	4	5
Experts	1	1	1			
	2		1			
	3		1			
	4	1				
	5		1			
	6			1		
	7		1			
	8		1			
	9	1	1			
	10	1				
Sum:		4	7	1	0	0

Voting for the other four indicators was similar, and summarized results are presented in Table B.1 (Annex B).

For example, we calculate the posterior probability of the truth of the hypothesis that the indicator I_1 has a rank $l = 2$:

$$P_1 \left(e_{(1)}^{(2)} | H_2 \right) = \frac{7}{10} = 0,7$$

The next step is to determine the total conditional probability value:

$$\sum_{s=1}^5 P_1 \left(e_{(1)}^{(s)} | H_s \right) = \frac{4 + 7 + 1}{10} = \frac{12}{10} = 1,2$$

Next, posterior conditional probabilities are found $P_i \left(H_l | e_{(i)}^{(l)} \right)$. We understand them as the degree of confidence of experts in the validity of hypotheses about obtaining the indicator I_i rank l in the rating. Calculation of posterior conditional probabilities for I_1 and $l = 2$ according to the formula (3):

$$P_1 \left(H_2 | e_{(1)}^{(2)} \right) = \frac{P_1 \left(e_{(1)}^{(2)} | H_2 \right)}{\sum_{s=1}^5 P_1 \left(e_{(1)}^{(s)} | H_s \right)} = \frac{0,7}{1,2} = 0,583$$

The calculation of the posterior conditional probability for other indicators is made using Microsoft Excel spreadsheets, and the summary results are presented in Table 4.4.

Table 4.4 - Data of a posterior conditional probabilities for the indicators of component C_1 .

Component C_1		l				
		1	2	3	4	5
Indicator	1	0,333	0,583	0,083	0	0
	2	0	0,083	0,750	0,167	0
	3	0	0	0	0,167	0,750
	4	0	0	0,167	0,750	0,167
	5	0,667	0,417	0	0	0

Next, determine the ranks for each of the indicators using Microsoft Excel spreadsheets according to (4), and the data are shown in Table 4.5.

So, we have indicators that are sorted by impact. Therefore, the next step (see 3.4) is to find the weights for the corresponding rank. The expert assessment was made, and the summary results are shown in table B.2 (Annex B).

Table 4.5 - Data of ranks and posterior conditional probabilities for the indicators of component C_1 .

Component C_1		l					Rank
		1	2	3	4	5	
Indicator	1	0,333	0,917	-	-	-	2
	2	0	0,083	0,833	-	-	3
	3	0	0	0	0,167	0,917	5
	4	0	0	0,167	0,917	-	4
	5	0,667	-	-	-	-	1

According to the results of the analysis, the weights of indicators that affect fixed assets were found, namely for I_1 the weight coefficient is $\alpha_{11} = 0,182$, for I_2 is $\alpha_{12} = 0,105$, for I_3 is $\alpha_{13} = 0,048$, for I_4 is $\alpha_{14} = 0,077$, for I_5 is $\alpha_{15} = 0,588$, and the estimated value of the average deviation does not exceed 5% for each rank, so we can talk about a certain consistency of experts.

Expert estimates were similarly processed using Microsoft Excel spreadsheets, calculated all possible weight coefficients for each component indicator. So, as a result, we have a matrix of degrees of influence of these indicators on possible components A_I (see 2.4). All data is summarized in the Table 4.6.

The last step is an expert assessment of the impact of each of the five components on the integral indicator of intellectualization, summarizing the results in Table B.3 (Annex B). Assessment results are processed using Microsoft Excel spreadsheets. The estimated value of the standard deviation does not exceed 5%, so we can talk about a certain agreement of experts. Based on the evaluation, the following weights were determined $\alpha_1 = 0,24$, $\alpha_2 = 0,198$, $\alpha_3 = 0,122$, $\alpha_4 = 0,043$, $\alpha_5 = 0,397$.

Table 4.6 – Summarized data of weight coefficients for all components.

Indicators	Components				
	C_1	C_2	C_3	C_4	C_5
I_1	0,182	0	0	0	0
I_2	0,105	0	0	0	0
I_3	0,048	0	0	0	0
I_4	0,077	0	0	0	0
I_5	0,588	0	0	0	0
I_6	0	0,170	0	0	0
I_7	0	0,404	0	0	0
I_8	0	0,427	0	0	0
I_9	0	0	0,133	0	0
I_{10}	0	0	0,132	0	0
I_{11}	0	0	0,122	0	0
I_{12}	0	0	0,119	0	0
I_{13}	0	0	0,100	0	0
I_{14}	0	0	0,038	0	0
I_{15}	0	0	0,219	0	0
I_{16}	0	0	0,138	0	0
I_{17}	0	0	0	1	0
I_{18}	0	0	0	0	0,687
I_{19}	0	0	0	0	0,313

4.4 Calculation and analysis of the integral indicator

The final stage is the calculation of the integral indicator of intellectualization. Using weight coefficients A_I (Table 4.6) and calculated values of indicators I (Table A.3), Microsoft Excel spreadsheets calculate values of component indicators of intellectualization indicator according to the expression (1). This calculation is presented in Table 4.7.

At the end, having the values of all components (Table 4.7) and components weight coefficients $\alpha_i, i = \overline{1,5}$ according to (2), the value of the integral indicator of

the assessment of intellectualization E_I was calculated. Therefore, the calculation itself for JSC "Poltavaoblenerho" in 2019 and 2020 years is presented below:

$$E_I^{(2020)} = 0,24 \cdot 0,163 + 0,198 \cdot 0,446 + 0,122 \cdot 0,024 + 0,043 \cdot 0,737 + 0,397 \cdot 0,488 = 0,356$$

$$E_I^{(2019)} = 0,24 \cdot 0,130 + 0,198 \cdot 0,449 + 0,122 \cdot 0,77 + 0,043 \cdot 0 + 0,397 \cdot 0,522 = 0,421$$

Table 4.7 – Calculation data of all indicators of components of intellectualization indicator for 2019 and 2020 years.

Indicators	Indicator Value		Indicator Weight	Component	Component Value	
	2020	2019			2020	2019
I_1	0,359	0,318	0,182	C_1	0,163	0,130
I_2	0,06	0,091	0,105			
I_3	0,004	0,085	0,048			
I_4	0,061	0,007	0,077			
I_5	0,147	0,098	0,588			
I_6	0,781	0,767	0,170	C_2	0,446	0,449
I_7	1	1	0,404			
I_8	0,012	0,012	0,427			
I_9	0	0,781	0,133	C_3	0,024	0,770
I_{10}	0	0,777	0,132			
I_{11}	0	0,876	0,122			
I_{12}	0	0,751	0,119			
I_{13}	0	0,964	0,100			
I_{14}	0,091	0,785	0,038			
I_{15}	0	0,708	0,219			
I_{16}	0,151	0,62	0,138			
I_{17}	0,737	0	1	C_4	0,737	0
I_{18}	0,71	0,76	0,687	C_5	0,488	0,522
I_{19}	0	0	0,313			

The entire calculation algorithm (see 4.1, 4.2) is repeated for two another DSOs and using Microsoft Excel spreadsheets, the values of the integral indicators of the assessment of intellectualization E_1 for these DSOs were calculated. Calculated data was summarized in Table 4.8.

Table 4.8 – Comparative table of integral indicators of intellectualization assessment between different DSOs.

DSO	E_1	
	2020	2019
JSC "Poltavaoblenerho"	0,356	0,421
PJSC "PEEM "TSEK"	0,316	0,265
JSC "Chernivtsioblenerho"	0,395	0,233

According to the results of this assessment we can see that PJSC "PEEM "TSEK" and JSC "Chernivtsioblenerho" have a positive trend of improving the state of the network and the introduction of intellectualization objects into it. The indicator JSC "Poltavaoblenerho" for the year decreased, which may indicate a decline in the dynamics of the Use of smart systems.

The decline in the dynamic of intellectualization of the DSO may indicate that its policy has changed somewhat in relation to intellectualization, giving priority to technical support of its networks (for example, restoration or replacement of wooden poles of power lines).

The behavior of the integral indicator of intellectualization when performing the investment program on introduction of innovation funds for 5 years has also been studied. That is, a certain forecast was modeled, taking data on investments in information resources from the investment program JSC "Poltavaoblenerho". Let's compare the forecast data with this model of DSO development. We believe that electricity supply is increasing every year due to investments by 10% compared to the previous year, and these comparisons are presented in Figure 4.3.

That is, there is an opportunity to easily set the target value of the rate of intellectualization and be able to adjust the targets for the best result.

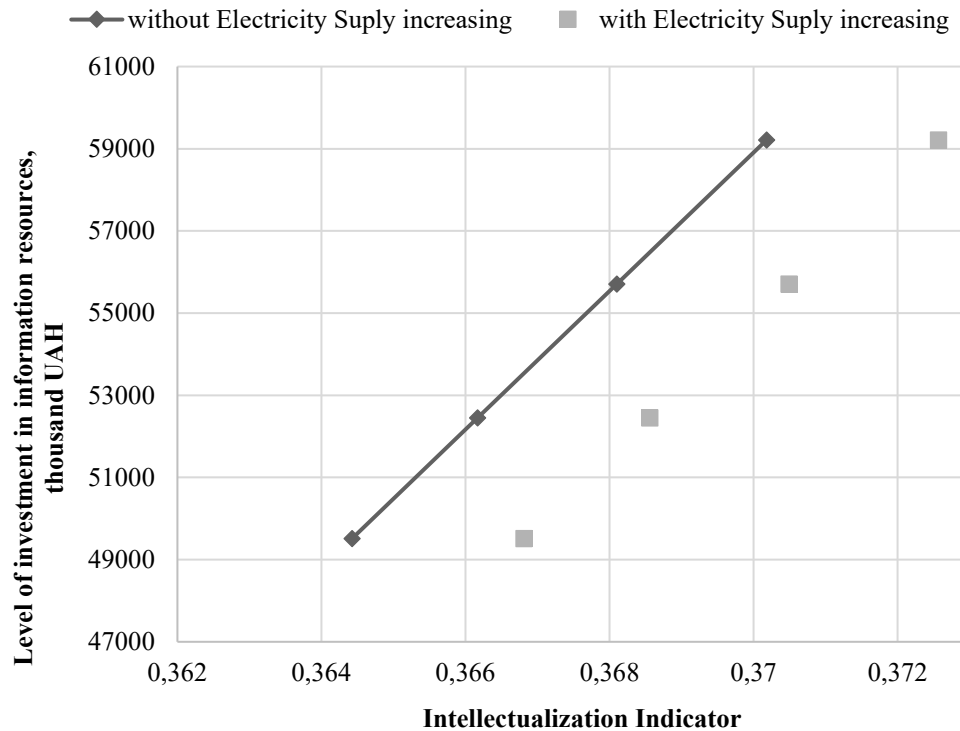


Figure 4.3 - Graph of the dependence of the integral indicator on the projected values of investment in information resources.

In addition to quantitative assessment, it is important to be able to assess this indicator qualitatively. To do this, a scale should be developed that would allow the output to relate the value of the integral indicator of intellectualization to certain categories.

As already discussed earlier (see 2.2) under the categories of qualitative assessment of intellectualization «Good», «Satisfactory», «Unsatisfactory», «Unsuitable» were accepted.

In order to differentiate the result, it is necessary to create a certain scale, which would be able to analyze on the basis of the real state of the power grid.

At the initial calculation stage, a uniform scale has been established for the purpose of creating a verbal scale, which is presented in Table 4.9.

But this scale does not fully reflect the real situation. If values of 0 and 1 are estimated, the probability that the indicator will accept these values may be very small. According to this data (Table 4.8), we can say that the rate of intellectualization does not go beyond 0.2 to 0.5.

Table 4.9 – Uniform rating scale.

Verbal category	Value change range
Good	$75 \leq E_1 \leq 100$
Satisfactory	$50 \leq E_1 < 75$
Unsatisfactory	$25 \leq E_1 < 50$
Unsuitable	$0 < E_1 < 25$

Conclusions to Section 4

In this section, statistics were collected, and the methodologies discussed in the previous section were applied to the calculation of indicators. With the help of such approaches as Bayesian and Expert Estimation Method the weighting coefficients were calculated, which actually provided an integral measure of grid intellectualization estimation for the three DSO. This enabled a comparative analysis of these indicators.

But it must be said that there are certain features of working with this indicator. Due to the ability to obtain certain characteristics in the amount that will be sufficient for analysis.

At the initial calculation stage, we can ignore and use a uniform scale for the purpose of verbal evaluation, but for the future use it is necessary to further study the values of indicators to analyze their location on the axis of the intellectualization indicator and then to transform the existing scale of assessment into a more accurate one.

Consequently, increased access to information resources, greater computerization of processes will allow a more accurate and more comprehensive assessment of this value and ultimately will get an indicator that will more adequately assess the performance of the company itself.

CONCLUSIONS

The master's thesis contains the results of improvement and further development of the process intellectualization assessment methods of DSO, which solve the urgent task of increasing the electrical energy distribution systems efficiency in the context of the implementation of the Smart Grid. The conclusions are summarized as follows.

1. A comprehensive analysis of the problem of determining the integral indicator of intellectualization efficiency showed that the available data do not fully realize all the capabilities of the indicator, and the accuracy of such data has a certain error.

It has been established that one of the main problems is the formation of monitoring system, which will provide the obtaining of characteristics in a given interval and a given sequence.

It is necessary to create a systematic process of obtaining characteristics with a concrete step, which will allow to study the issue of intellectualization level much more accurately. The data collection system should be based on the criteria of consistency and regular updating of data over time in order to avoid uncertainty and significantly minimize inaccuracies.

2. Formalization the intellectualization DSO assessment task was carried out on the basis of determining the effectiveness of its work in terms of changing the characteristics of technical condition, turnover, informatization and efficiency of labor resources that determine the work of DSO in the direction of intellectualization of its main production processes. Each indicator needs to be carefully designed to detect the impact on the intellectualization of production processes.

3. It is proposed to use an integral indicator to assess the process of intellectualization of the electric power distribution system.

According to the analysis of the result and considering the peculiarities of statistical data, we can say that this indicator is not a final assessment, it is a certain

indicator that allows us to start the analysis process and identify problem areas to work on further grid intellectualization.

4. The use of the Bayesian approach in combination with fuzzy logic and the use of expert assessments allows, with the input of new data, to refine the indicator of intellectualization assessment, thus this indicator can be called flexible. The use of such approaches eliminates complex and heavy modelling by engaging experts for such assessment.

5. It should be recognized that the use of such indicator allows to build a system of management (regulation) of GEO activities, to ensure the possibility of distribution of material resources in solving problems of development of electric energy distribution networks.

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ANNEX A

Table A.1 - Indicators that meet the requirements of the integrated indicator of intellectualization assessment

Mark	Name
I_1	The applicability coefficient
I_2	The renewal coefficient
I_3	The retirement coefficient
I_4	The increment coefficient
I_5	The innovation coefficient
I_6	Indicator of labor efficiency
I_7	Human error rate
I_8	Indicator of the error caused by undetected defects of employees
I_9	Total Asset Turnover
I_{10}	Equity Turnover
I_{11}	Working Capital Turnover
I_{12}	Material Working Capital Turnover
I_{13}	Accounts Receivable Turnover
I_{14}	Accounts Payable Turnover
I_{15}	Fixed-asset turnover
I_{16}	Cash Ratio
I_{17}	Material Intensity
I_{18}	The efficiency ratio of investments in information resources
I_{19}	The indicator to assess the cost-effectiveness of implementing, maintaining and developing information security systems

Table A.2 - Sources of information and values needed to calculate energy enterprise performance indicators for JSC "Poltavaoblenerho".

Source	Characteristic	2020	2019
Statement of Financial Status	the value of depreciation of fixed assets	2552874	2494198
Statement of Financial Status	the value of fixed assets at the end of the reporting period	3981082	3659495
Statement of Financial Status	the value of received fixed assets	237796	332036
Statement of Financial Status	the value of fixed assets at the beginning of the reporting period	3659495	3635426
Statement of Financial Status	the value of fixed assets received for the reporting period	14639	307967
Statement of Financial Status	average number of employees	4349	4269
Investment program	the value of received innovation fixed assets of the reporting period	34857,3	32621,87
Workforce report	the actual working time	34792	34152
Investment program	normative number of staff	5568	5568
The proposed indicator	the maximum time for involving workers	44544	44544
Investment program	actual supply of electrical energy	4960086	4978079
Investment program	actual supply of electrical energy (previous)	4978079	5179175
Workforce report	number of employees dismissed for reasons of turnover	-	-
Technological violations	erroneous actions dependent on human	41	41
Technological violations	erroneous actions dependent on undetected defect	132945	132945
Technological violations	all erroneous actions	134514	134514
Statement of Financial Status	revenue	2203541	7607272
Statement of Financial Status	the average value of total assets at the end of the period	1350867	1845069
Statement of Financial Status	the average value of equity at the end of the period	1347718	900687
Statement of Financial Status	the average value of working capital at the end of the period	555222	479743
Statement of Financial Status	the average value of material working capital at the end of the period	38302	88221
Statement of Financial Status	the average value of receivable at the end of the period	115267	85620
Statement of Financial Status	the average value of payable at the end of the period	247948	941629
Investment program	invested own funds	183837,72	247770
Investment program	invested borrowed funds	0	0
DSO Inner Statistic	current liabilities to DSO	1218260,56	399502,79
Statement of Financial Status	actual Material Cost	673639	2574151
Investment program	level of investment in information resources	34857,30	32621,87
Investment program	investment in information security systems	2200	0

Units of each characteristic are accepted as indicated in its source. The calculation of some indicators requires data from the previous year. Data for 2018 are taken from similar documents for 2018.

Table A.3 – Calculated values of enterprise performance indicators for JSC "Poltavaoblenerho".

Mark	Name	Value	
		2020	2019
I_1	The applicability coefficient	0,359	0,318
I_2	The renewal coefficient	0,060	0,091
I_3	The retirement coefficient	0,004	0,085
I_4	The increment coefficient	0,061	0,007
I_5	The innovation coefficient	0,147	0,098
I_6	Indicator of labor efficiency	0,219	0,233
I_7	Human error rate	0,999	0,999
I_8	Indicator of the error caused by undetected defects of employees	0,012	0,012
I_9	Total Asset Turnover	0	0,781
I_{10}	Equity Turnover	0	0,777
I_{11}	Working Capital Turnover	0	0,876
I_{12}	Material Working Capital Turnover	0	0,751
I_{13}	Accounts Receivable Turnover	0	0,964
I_{14}	Accounts Payable Turnover	0,091	0,785
I_{15}	Fixed-asset turnover	0	0,708
I_{16}	Cash Ratio	0,151	0,620
I_{17}	Material Intensity	0,737	0,000
I_{18}	The efficiency ratio of investments in information resources	0,710	0,760
I_{19}	The indicator to assess the cost-effectiveness of implementing, maintaining, and developing information security systems	0	0

ANNEX B

Table B.1 – Expert voting to determine the rank for the indicators I_2, I_3, I_4, I_5 .

Indicator I_2		Rank				
		1	2	3	4	5
Experts	1			1		
	2			1	1	
	3			1		
	4			1		
	5			1		
	6		1			
	7			1		
	8			1	1	
	9			1		
	10			1		
Indicator I_3		Rank				
		1	2	3	4	5
Experts	1					1
	2					1
	3					1
	4					1
	5					1
	6				1	1
	7					1
	8					1
	9					1
	10				1	
Indicator I_4		Rank				
		1	2	3	4	5
Experts	1				1	
	2			1	1	
	3				1	
	4				1	
	5				1	
	6				1	1
	7				1	
	8			1	1	
	9				1	
	10					1
Indicator I_5		Rank				
		1	2	3	4	5
Experts	1	1	1			
	2	1				
	3	1				
	4		1			
	5	1	1			
	6	1				
	7	1				
	8		1			
	9	1	1			
	10	1				

Table B.2 – Expert voting to determine the weight coefficients for indicators of component C_1 .

Component C_1		Rank				
		1	2	3	4	5
Experts	1	0,6	0,19	0,13	0,05	0,03
	2	0,62	0,2	0,07	0,06	0,05
	3	0,55	0,22	0,1	0,08	0,05
	4	0,6	0,23	0,07	0,06	0,04
	5	0,64	0,17	0,08	0,06	0,05
	6	0,6	0,15	0,1	0,08	0,07
	7	0,61	0,13	0,12	0,09	0,05
	8	0,59	0,16	0,11	0,1	0,04
	9	0,51	0,19	0,16	0,1	0,04
	10	0,56	0,18	0,11	0,09	0,06
	α_{1i}	0,588	0,182	0,105	0,077	0,048

Table B.3 – Expert voting to determine the weight coefficients for components C_1, C_2, C_3, C_4, C_5 .

E_1		Components C_i				
		1	2	3	4	5
Experts	1	0,25	0,2	0,11	0,05	0,39
	2	0,24	0,18	0,12	0,04	0,42
	3	0,27	0,15	0,11	0,03	0,44
	4	0,25	0,23	0,1	0	0,42
	5	0,26	0,22	0,13	0	0,39
	6	0,26	0,12	0,15	0,07	0,4
	7	0,21	0,28	0,09	0,02	0,4
	8	0,27	0,18	0,14	0,05	0,36
	9	0,18	0,19	0,14	0,11	0,38
	10	0,21	0,23	0,13	0,06	0,37
	α_i	0,24	0,198	0,122	0,043	0,397

ANNEX C

Table C.1 - Sources of information and values needed to calculate energy enterprise performance indicators for PJSC "PEEM "TSEK".

Source	Characteristic	2020	2019
Statement of Financial Status	the value of depreciation of fixed assets	64251,84	60248,19
Statement of Financial Status	the value of fixed assets at the end of the reporting period	188976	194349
Statement of Financial Status	the value of received fixed assets	11889,8	16601,8
Statement of Financial Status	the value of fixed assets at the beginning of the reporting period	188976	194349
Statement of Financial Status	the value of fixed assets received for the reporting period	731,95	15398,35
Statement of Financial Status	average number of employees	699	650
Investment program	the value of received innovation fixed assets of the reporting period	10 551,56	9319,74
Workforce report	the actual working time	699	650
Investment program	normative number of staff	699	650
The proposed indicator	the maximum time for involving workers	5592	5200
Investment program	actual supply of electrical energy	739,65	738,53
Investment program	actual supply of electrical energy (previous)	738,53	1343,82
Technological violations	erroneous actions dependent on human	41	41
Technological violations	erroneous actions dependent on undetected defect	132945	132945
Technological violations	all erroneous actions	134514	134514
Statement of Financial Status	revenue	0	0
Statement of Financial Status	the average value of total assets at the end of the period	-	-
Statement of Financial Status	the average value of equity at the end of the period	-	-
Statement of Financial Status	the average value of working capital at the end of the period	-	-
Statement of Financial Status	the average value of material working capital at the end of the period	-	-
Statement of Financial Status	the average value of receivable at the end of the period	-	-
Statement of Financial Status	the average value of payable at the end of the period	-	-
Investment program	invested own funds	37036	37036
Investment program	invested borrowed funds	2645	2645
DSO Inner Statistic	current liabilities to DSO		
Statement of Financial Status	actual Material Cost	33681,95	128707,55
Investment program	level of investment in information resources	10 551,56	9 319,74
Investment program	investment in information security systems	0	0

* The data is modeled relative to DSO with similar indicators of electricity supply. Units of each characteristic are accepted as indicated in its source. The calculation of some indicators requires data from the previous year. Data for 2018 are taken from similar documents for 2018.

Table C.2 - Sources of information and values needed to calculate energy enterprise performance indicators for JSC "Chernivtsioblenerho".

Source	Characteristic	2020	2019
Statement of Financial Status	the value of depreciation of fixed assets	92641457*	92641457*
Statement of Financial Status	the value of fixed assets at the end of the reporting period	97682560*	97682560*
Statement of Financial Status	the value of received fixed assets	82483*	111274*
Statement of Financial Status	the value of fixed assets at the beginning of the reporting period	97524703*	97524703*
Statement of Financial Status	the value of fixed assets received for the reporting period	43309*	5308*
Statement of Financial Status	average number of employees	1443	1443
Investment program	the value of received innovation fixed assets of the reporting period	53253	44706,48
Workforce report	the actual working time	11544	11544
Investment program	normative number of staff	2130	2130
The proposed indicator	the maximum time for involving workers	17040	17040
Investment program	actual supply of electrical energy	1 556	1 591
Investment program	actual supply of electrical energy (previous)	1 591	1595
Technological violations	erroneous actions dependent on human	41	41
Technological violations	erroneous actions dependent on undetected defect	132945	132945
Technological violations	all erroneous actions	134514	134514
Statement of Financial Status	revenue	0*	0*
Statement of Financial Status	the average value of total assets at the end of the period	-	-
Statement of Financial Status	the average value of equity at the end of the period	-	-
Statement of Financial Status	the average value of working capital at the end of the period	-	-
Statement of Financial Status	the average value of material working capital at the end of the period	-	-
Statement of Financial Status	the average value of receivable at the end of the period	-	-
Statement of Financial Status	the average value of payable at the end of the period	-	-
Investment program	invested own funds	93438	93438
Investment program	invested borrowed funds	0	0
DSO Inner Statistic	current liabilities to DSO	-	-
Statement of Financial Status	actual Material Cost	33681,95	36280,7
Investment program	level of investment in information resources	53253	44706,48
Investment program	investment in information security systems	202,5	0

* The data is modeled relative to DSO with similar indicators of electricity supply. Units of each characteristic are accepted as indicated in its source. The calculation of some indicators requires data from the previous year. Data for 2018 are taken from similar documents for 2018.