SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 209

THE POSSIBILITIES OF USE INFORMATION TECHNOLOGY TO IMPROVE THE PROCESSES OF ENERGY ENTERPRISES

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Purpose: The objective of this paper is to examine the potential of selected information technologies to facilitate the implementation of business processes in power sector companies during the energy transition.
Design/methodology/approach: The stated objective was achieved through an in-depth examination of the challenges that energy companies are facing as a result of the transformation, a comprehensive analysis of the core processes of these companies, beginning with their current state, and the identification of information technologies that can facilitate these processes. In order to achieve the stated objective, a case study method and a critical literature analysis method were employed. Additionally, complimentary unstructured interviews were conducted. The scope of the paper encompasses the analysis of scientific and industry literature, the execution of the research, a discussion of the results, and the formulation of theoretical and practical conclusions. Furthermore, the paper presents the author's perspective on the issues raised.
Findings: The work identified and evaluated selected elements of the application and development of the process approach in energy companies during the transition period. It also identified the information technologies and the scope of their use. The effectiveness of the case study method for solving this type of problem was practically proved.
Research limitations/implications: The work carried out indicates the need to extend the quantitative scope of the research and to cover different categories of energy companies in the energy supply chain. The results obtained can be applied primarily to electricity system operators involved in electricity distribution, in terms of planning and operation processes of the electricity grid, and RES producers.
Practical implications: The findings indicate the necessity for enterprises to promptly identify, develop and implement novel processes. Without such implementation, enterprises will be inadequately prepared to meet the legal, regulatory and factual requirements for ensuring the continuity of energy supply to consumers in a transition environment. Furthermore, the core business processes of these enterprises will not be effectively implemented.
Social implications: The failure to implement the proposals could result in a disruption to the supply of electricity to consumers and businesses. This could have a detrimental impact on the quality of life of residents and impede the operational capacity of businesses, thereby reducing their competitiveness.

http://dx.doi.org/10.29119/1641-3466.2024.209.25 http://managementpapers.polsl.pl/

Originality/value: The primary focus of the paper is to identify the essential processes that must be put in place during the transition period and to suggest the most appropriate information technologies that can be used within these processes. The paper is intended for researchers engaged in the field of process management in power sector companies and for managers of these companies who are responsible for planning and operating the power grid.
Keywords: process approach, power sector companies, energy transition, information technology.
Category of the paper: case study, point of view.

1. Introduction

The energy sector, in conjunction with the armed forces, security services, and those responsible for the protection of public health and safety, constitutes a vital component of the infrastructure necessary for the continued functioning of the state. The primary objective of the energy sector is to guarantee the uninterrupted and dependable delivery of fuels and energy to consumers, encompassing citizens, businesses, and institutions. This entails guaranteeing the sufficient provision of a specific energy carrier and ensuring the availability of the means of transporting this energy carrier. It is imperative that sufficiency is guaranteed at all times, both at the point of supply and in the future.

The energy sector could be comprised of two subsectors: fuel and electricity. The fuel subsector encompasses the supply of liquid, gaseous, and solid fuels, while the electricity subsector is responsible for the generation and distribution of electricity. The electricity subsector, within the broader context of the energy supply chain, encompasses a range of activities, including fuel supply, electricity generation, energy transmission and distribution, and wholesale and retail energy trading. The subject of this paper is mainly energy distribution, which encompasses the transportation of energy from the transmission network to consumers connected to the distribution network.

For a number of years, the energy sector, and in particular the electricity subsector, has been undergoing a process of energy transition. In essence, the objective of energy transformation is to enhance the utilization of energy derived from renewable sources, optimize energy efficiency and mitigate adverse environmental impacts. The specific goals and scope of the transformation in different countries are the result of political decisions. In Poland, for example, the implementation of EU and national climate policy (NECP, 2019) has been a significant driver of change. The energy transition has a very strong impact on the business processes implemented in power sector companies. This encompasses both the generation of electricity from primary fuels and the control of these sources, the collection and analysis of process data, the provision of IT security, and the support of energy trading.

Information technology has been a key enabler of business processes in power sector companies for many years. This includes database systems, production planning and optimization systems, and dedicated control systems, including real-time systems (SCADA). In the present era, advancements in information technology have facilitated the integration of novel technologies, including cloud computing, artificial intelligence, machine learning, and the Internet of Things. Furthermore, it is possible to develop and enhance existing technologies, for instance, towards their autonomization.

In this context, it is essential to identify the key research and practical needs. The research needs may include the selection of appropriate methods and the execution of studies to identify the expected extent of support for the implementation of business processes in power sector companies by modern IT technologies and the possibilities for their implementation. Practical needs may include the identification of conditions that facilitate the effective and efficient utilization of technology within enterprise contexts, particularly in the context of market conditions. The following paper seeks to provide responses to these needs and suggest avenues for further research.

A suitable starting point for analyzing the current state of affairs in terms of classifying and detailing the processes carried out in power sector companies would be the classification developed and elaborated by the organization *American Productivity & Quality Center* (APQC Cross-Industry, 2024). This classification identifies and describes more than a dozen groups of processes, ranging from vision and strategy development to production and sales management and business capability development. Furthermore, the proposed classification can be adapted to a specific class of companies belonging to the utility category. In this category, a dozen process groups are also defined, most of which overlap with the general classification. These are the following processes (APQC Utilities, 2023):

1. Develop Vision and Strategy.
2. Develop and Manage Products and Services.
3. Market and Sell Products and Services.
4. Manage Procurement and Logistics.
5. Manage Customer Service.
6. Develop and Manage Human Capital.
7. Manage Information Technology.
8. Manage Financial Resources.
9. Acquire, Construct, and Manage Assets.
10. Manage Enterprise Risk, Compliance, Remediation and Resiliency.
11. Manage External Relationships.
12. Develop and Manage Business Capabilities.
13. Operate Utility Assets.

The aforementioned classification is of a general nature and, in practice, should be adapted to the specifics of the activity carried out by a given energy company under given market and regulatory-legal conditions. In the Polish context, three principal categories of energy market participants can be identified: generation companies, system operators (at the distribution and transmission levels) and electricity trading companies (IRiESP, 2024).

Among the generation companies, a distinction can be made between those that utilize conventional energy sources and those that utilize renewable energy sources (RES), the latter of which have emerged as a direct consequence of the energy transition.

The principal business processes of each of these groups of companies are aligned with their core business activities. For conventional generators, the principal business processes are those associated with the procurement of fuel, the generation and sale of electricity in the energy market, and the sale of system balancing services in the balancing market. In the case of renewable generators, the aforementioned processes pertain to the injection of energy into the electricity grid. In the case of distribution system operators, the processes in question pertain to the operation of the grid. In the case of transmission system operators, the processes relate to the planning and operation of grid operations and system balancing (Biolcheva et al., 2022).

The energy transition gives rise to the necessity of defining the processes of RES generators and of redefining and complementing the processes of other utilities. For conventional generators, the processes of maintaining production assets, which are subject to gradual decommissioning as the transition progresses, assume greater importance. For system operators, the processes of network operation planning and system balancing present a challenge due to the increase in the share of RES sources. In essence, the power balance, and for RES generators, all business processes must be defined and enhanced in the energy market, which is undergoing transformation as a result of the transition (Mihailova et al., 2023; Bryant, 2018).

The novel and modified processes are distinguished by markedly elevated quantitative complexity. These processes entail a considerably larger number of generation sources (distributed and relatively small-scale RES sources), the necessity of making them observable and controllable, the requirement for secure transmission of a substantial amount of data, including commercial transaction data, and an increase in real-time activities (Losada-Agudelo et al., 2024).

The aforementioned characteristics of the processes in question necessitate the utilization of efficacious information technology. To date, energy companies with a direct involvement in the operation of the electricity system and the functioning of the energy market (exclusive of the broader corporate processes) have predominantly utilized database technologies, real-time systems (SCADA) and dedicated data teletransmission systems (Wu, 2006). As the energy transition progresses, there is an increasing need for data processing, secure data transmission and the autonomization of parts of the processes. This necessitates the utilization of

contemporary information technologies, whose characteristics are aligned with these requirements (Arévalo et al., 2024; Nambiar et al., 2022; Singh et al., 2023).

The literature on the subject does not contain comprehensive and detailed analyses, both in the area of defining or redefining business processes in the aforementioned groups of power sector companies during the transition period, nor has there been any cross-sectional research on the selection of new technologies that could support these processes. The research gap thus identified is very extensive and requires a great deal of research and analysis, which is significantly beyond the scope of a single paper. For this reason, the intention of the paper is to start filling the research gap first of all by proposing key processes in the area of electricity system and energy market functioning in Poland, the emergence or change of which is a result of the transformation. The second proposed element is to identify IT support needs and to propose IT technologies that can support these processes, complementing the currently used technologies.

The scope and layout of the paper is as follows. Chapter 2 characterizes the research methods used to address the problem. Chapter 3 presents the results of the research. Chapter 4 discusses the results and presents the author's position on the issues raised. The final chapter deals with the evaluation of the research and its practical relevance. Directions for further work are also presented.

2. Methods

The findings of the literature review revealed a dearth of a systematic methodology for the delineation of novel processes in energy enterprises and the discernment of information technologies that can facilitate them. It was thus decided to conduct original research in a number of selected energy companies. It was assumed that the nature of the research conducted in the enterprises should meet the following premises:

1. Focus on energy transformation.
2. Examine different enterprises simultaneously.
3. Analyze the phenomenon in the context of the company's functioning in the business environment.
4. Explore in depth the complexity of the phenomenon under study.

The characteristics of the study thus defined correspond to the typical features of the case study method (Benbasat et al., 1987), which was chosen as the primary research method. Case studies focus on the study of real-life phenomena (Yin, 2018) and their methodology is strictly defined and homogeneous (Goffin et al., 2019). Unstructured interviews were adopted as a complementary method due to the reciprocal impact of processes in one group of companies on other companies. This research method should provide information to capture the broader context of the phenomenon under study (Flyvbjerg, 2006).

The basic research procedure – the case study method runs as follows (Czakon, 2006):

1. Formulation of research question.
2. Selection of case/cases.
3. Development of data collection tools.
4. Field research.
5. Data analysis.
6. Formulation of generalizations.
7. Confrontation with the literature.
8. Closure of the study.

The complementary research procedure, the unstructured interview method, is conducted in the following manner (Babbie, 2020; Silverman, 2017):

1. The formulation of issues for discussion is initiated.
2. The motivation of the respondent to answer honestly and extensively is elicited.
3. Responses are obtained and recorded.
4. The responses are analyzed to formulate conclusions.

3. Results

A single distribution system operator (DSO) in Poland was selected for the study using the case study method. The unstructured interview method was employed to conduct research on three companies: one distribution system operator in Germany and two national power companies. The research was confined to the domains of power grid operation management and source control for the system operators and power companies, respectively. The research procedures utilized were delineated in the methodology, as presented in Chapter 2.

For the case study (Method 1.), the subsequent steps of the procedure are illustrated in Table 1.

Table 1.
Steps of the case study procedure

No	Step	Description
1.	Formulation of research question.	(a) What is the impact of the energy transition on the company's operations in the context of process management in the area of grid operation management? (b) What new processes are being identified and what modifications to existing processes are needed in the area under analysis? (c) What are the related business needs and which IT technologies can be applied to support the implementation of these processes?
2.	Selection of case/cases.	In the case study, information was available on the power grid operation management process currently in place, the resources and the IT tools used in the process. The study emphasized the level of detail of the business requirements for the target process flow.
3.	Development of data collection tools.	Typical data sources used in network operation management were used. Data was extracted in several successive iterations, according to the state of knowledge of the process.
4.	Field research.	The research was carried out primarily during visits to the company, interviews with staff responsible for network traffic management, ICT tools and development, desk research and analysis of publicly available company data.
5.	Data analysis.	The analysis of the data consisted of isolating changes or additions to the ongoing process and identifying the resource support needs of the process implementation. On this basis, it was determined what IT support would be needed. A set of modern IT technologies that are currently in commercial use was then identified. Using the review method, technologies were matched to the expected scope of IT support. The technology proposals were then confronted with the company's expectations and the necessary adjustments were made. Finally, a preliminary analysis was made of the possibilities of implementing the technologies in the enterprise.
6.	Formulation of generalizations.	On the basis of the analysis carried out, technology was assigned to the processes carried out in the company.
7.	Confrontation with the literature.	The results obtained were related to the conclusions of the literature review on new or modified processes in energy companies in transition and the use of modern information technologies.
8.	Closure of the study.	

Source: own study.

For the unstructured interviews (Method 2), the next steps of the procedure are shown in Table 2.

Table 2.
Steps of the unstructured interview procedure

No	Step	Description
1.	The formulation of issues for discussion is initiated.	(a) What is your view of the impact of the energy transition on the company's operations in the context of process management in your area of responsibility? (b) What new processes are being identified and what modifications to existing processes are necessary in the area under review? (c) Which information technologies can be applied to support the implementation of these processes?
2.	The motivation of the respondent to answer honestly and extensively is elicited.	Free conversation, referring to the respondent's experience and competence.
3.	Responses are obtained and recorded.	Form of notes.
4.	The responses are analyzed to formulate conclusions.	On the basis of the analysis carried out, changes or additions to the implemented process were identified, IT support needs were identified and technology was assigned to the processes implemented in the company.

Source: own study.

For the 4 companies, a total of 8 new processes or processes in need of change, 7 requirements for information systems and 6 technologies that can support process implementation were identified. The results are summarized in Table 3.

Table 3.
Results of the study

No	Company (Method)	Indicated processes	Requirements	Technology proposed
1.	System Operators (Method 1. and Method 2.)	(A) Identification of technical constraints (B) Identification of balancing limitations (C) Data security	(01) Real-time processing of large data sets (02) Securing the integrity and sequencing of data transmission	(i) Technological cloud (iii) Integrated cybersecurity tools
2.	RES Producer (Method 2.)	(D) Generation forecasting and planning (E) Data exchange with system operators (F) Ongoing control of the installation	(01) Real-time processing of large data sets (03) Ensuring observability of individual generation plant components (04) Predictive generation of power plants (05) Autonomous control of RES plant operation	(i) Technological cloud (ii) IIoT (iv) AI and ML (v) Autonomous control systems (vi) Blockchain
3.	Conventional Power Plant (Method 2.)	(G) Continuous assessment of facility availability	(01) Real-time processing of large data sets (03) Ensuring observability of individual generation plant components	(i) Technological cloud (ii) IIoT
4.	Trader (Method 2.)	(H) Commercial balancing of resources	(01) Real-time processing of large data sets (02) Securing the integrity and sequencing of data transmission (06) Autonomous balancing of customer demand (07) Customer demand forecasting	(i) Technological cloud (iii) Integrated cybersecurity tools (iv) AI and ML (v) Autonomous control systems (vi) Blockchain

Source: own study.

A schematic illustration of the results can be found in Figure 1.

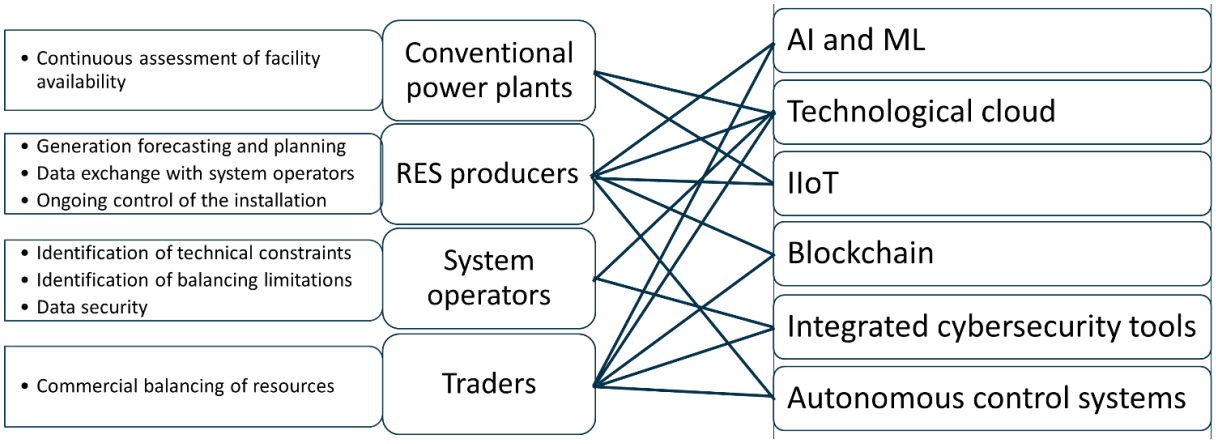

Figure 1. Assigning modern technologies to companies (processes).

Source: own study.

4. Discussion

The study conducted for system operators revealed the necessity for the implementation of three novel processes. Process (A) pertains to the identification of potential constraints that may emerge on the grid as a consequence of renewable energy generation exceeding the grid's capacity. Process (B) pertains to the necessity of maintaining equilibrium between the generation of energy from renewable sources and the demand for it, in instances where the former exceeds the latter. Process (C) pertains to the necessity of ensuring the confidentiality and integrity of data transmitted regarding the control of renewable energy installations.

The necessity for ensuring adequate capacity to process substantial quantities of system state data and to determine suitable control signals for system users is an inevitable consequence of these processes. Given their volume and the necessity of access via open communication systems, these signals must be adequately secured.

To facilitate the implementation of these processes, two technologies were identified as adequate: (i) Technological cloud and (iii) Integrated cybersecurity tools. The private technological cloud on the operators' side, for the sake of cybersecurity, is to ensure adequate data processing parameters (performance, speed, no errors). Cybersecurity tools should be integrated on the operators' and RES Producers' side.

Additionally, three processes have been identified for RES producers. Process (D) pertains to the forecasting of the operational status of the entire renewable power plant, as well as the determination of the actual quantities of energy that are scheduled to be fed into the grid. Process (E) pertains to the transmission of data regarding the operational status of the power plant to the system operators, accompanied by the receipt of control signals from said operators. Process (F) pertains to the routine supervision of the operational status of the discrete generating units within the power plant.

These processes imply the necessity for the processing of extensive data sets pertaining to the operational status of the plant, for the purposes of forecasting and planning. It is therefore essential to ensure the collection and assembly of data on individual installations (e.g. wind generators). Forecasting generation requires the consideration of variable and uncertain meteorological and historical data for analogous power system operating conditions. The complexity and quantity of data necessitates the use of adaptive and/or self-learning algorithms, according to the incremental information about the power plant's operating history.

In order to facilitate the implementation of these processes, five technologies have been identified as being suitable for this purpose. (i) Technological cloud, (ii) Industrial Internet of Things, (iv) Artificial Intelligence and Machine Learning, (v) Autonomous control systems, and (vi) Blockchain. The processing of large data sets will be most efficiently conducted in the technological cloud. The Industrial Internet of Things will facilitate two-way communication between individual plants and the central system. Artificial intelligence (AI) tools will support

forecasting processes, and the autonomous control system will be oriented towards optimizing the operation of the entire power plant, taking into account system and market conditions.

For conventional generators, a process (G) has been identified for the ongoing monitoring of the status of individual generation facilities in a situation of anticipated plant decommissioning and the minimization of resources for plant maintenance. The objective of this process is to ensure the collection, gathering and processing of data on individual generation plant components, primarily to identify components that may fail and lead to curtailment or cessation of operation.

In order to facilitate the implementation of this process, two technologies have been identified as being suitable: (i) The technological cloud, and (ii) the Industrial Internet of Things. The Technological Cloud will perform analogous functions to those previously discussed, while the Internet of Things will facilitate bidirectional communication between individual installations and the central system.

For traders, process (H) has been identified as a necessity for the ongoing balancing of source generation and customer demand within the customer portfolio managed by these operators.

One consequence of this process is the necessity for the processing of data, including forecasting, at an extremely short notice, of the instantaneous demand of groups of customers and groups of generation sources, with due consideration of historical profiles and information on the current status of the system and weather conditions. The complexity of the issue requires the use of self-learning algorithms. The transmitted data, due to its commercial sensitivity, requires protection in terms of both integrity and confidentiality.

In order to facilitate the implementation of this process, five technologies have been identified as being suitable for this purpose. (i) Technological cloud, (iii) Integrated cybersecurity tools, (iv) AI and ML, (v) Autonomous control systems, and (vi) Blockchain. It is anticipated that the technological cloud and AI tools will facilitate the expeditious processing of extensive data sets pertaining to both customers and generators within the portfolio of a trader. The implementation of autonomous control systems will facilitate the rapid balancing of customers and generators, while cybersecurity and blockchain tools will ensure secure and integrity-compliant data communication between participants in the process.

In conclusion, the greatest number of new processes were identified at RES generators and system operators, with the greatest support from modern IT technologies expected by RES generators and traders. Furthermore, cloud technology was identified as the most popular technology.

For companies, this signifies the necessity to alter existing business models in order to align them with the requirements of the energy transition. This entails the development and implementation of new processes, as well as modifications to existing ones. It also necessitates a significant investment in the implementation of IT systems and the training of employees in their utilisation.

From a social perspective, this will entail an increase in electricity prices, potential disruptions in energy supply until businesses become more stable, a deepening of a kind of 'dependence' on IT tools and an increase in competence requirements for business employees. Alternatively, it may initiate a process of autonomization of business operations. The aforementioned factors can be described as the social cost of achieving the political objectives of the transformation. However, it is important to consider the benefits of the energy transition as declared by politicians in order to achieve a balanced perspective.

5. Summary

The objectives set forth in the paper were successfully achieved. The research was conducted effectively in a number of selected energy companies. The research methods were appropriately selected to meet the stated objectives.

The discussion of the results indicates the necessity for enterprises to identify, develop and implement new processes. In the absence of such implementation, enterprises will be ill-prepared to meet the legal, regulatory and factual requirements for ensuring the continuity of energy supply to consumers under transformational conditions. Furthermore, the core business processes of these enterprises will remain ineffective. From a social perspective, the energy transition, in addition to its purported benefits, may also result in some tangible costs for consumers, primarily in the form of increased electricity prices and uncertainty regarding the continuity and reliability of supply.

It should be noted that the research was conducted with a limited scope and that the conclusions may require revision once a more comprehensive quantitative analysis is conducted, encompassing a wider range of energy companies within the energy supply chain. This does not diminish the qualitative significance of the conclusions, particularly for electricity system operators.

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