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IMPLEMENTATION OF THE INSTALLATION MONITORING PLAN IN AN ENERGY COMPANY

WDROŻENIE PLATFORMY MONTAŻOWEJ W FIRMIE ENERGETYCZNEJ

Abstract

The work presents five stages of implementation of the assembly platform in an energy company. It focuses on indicating the adaptation of the assembly platform for the final product, which are low, medium and high voltage switchboards in the energy company. The first two chapters present the definition and application of the assembly platform. The next chapter deals with the research carried out on the introduction of the assembly platform to the energy company. The work ends with a summary and conclusions.

Keywords: assembly platform, assembly areas, efficiency, low-, medium-, and high-voltage switchboards

Streszczenie

W pracy zostało przedstawione pięć etapów wdrożenia platformy montażowej w firmy energetycznej. Praca koncentruje się na wskazaniu dostosowania platformy montażowej dla produktu końcowego, jakim są rozdzielnie niskich, średnich i wysokich napięć w firmie energetycznej. Pierwsze dwa rozdziały przedstawiają definicję i zastosowanie platformy montażowej. Kolejny rozdział przedstawia wykonane badania nad wprowadzeniem platformy montażowej w firmie energetycznej. Pracę kończą podsumowanie i wnioski.

Słowa kluczowe: platforma montażowa, obszary montażowe, wydajność, rozdzielnice niskiego, średniego i wysokiego napięcia

1. Introduction

In the 21 century manufacturers are considerably challenged by low production costs. They focus on delivering products as soon as possible in order to satisfy varied consumer demands. Adapting products to these demands, which combines aspects of economies of both scale and scope, seems to incrementally depend on an industrial production mode. Researchers and companies concentrate on the end product which is a strategy element in mass product adaptation project. The end product may increase competitive power, promote sustained development and improve innovative skills [5, 17].

The concept of product platform has become a key term in the entire innovative process of end product development. Such an approach may have a tremendous effect on the entire process of end product development, including relations between a supplier and a customer [12].

Developing a model of the end product family manufactured on the basis of the same product platform is considered to be an effective solution. More and more companies are using such an approach in the manufacture process of their end products, which indicates substantial economic benefits in the face of the ever-changing global production market. Those benefits mainly arose from a higher quality of end products, a faster response to market demands and lower manufacturing costs. Using product platforms and studying their architecture or structure are attracting more and more attention from both research community and industry [8, 9, 22].

2. Definition of product platform

The concept of product platform has become the key term in innovation process. Such an approach can have a tremendous effect on the entire product manufacture including relations between a supplier and a customer [12].

By definition, product platform, which the author develops, is a relatively large set of product components whose elements are connected with each other as

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a stable component and are common for various end product models. Some of the components serve the same function; however, it does not apply to all the components. By using such a product platform, a company may create a substantial group of various end products. Generally speaking, potential benefits resulting from using a product platform can be summarised as follows:

- lower production costs,
- reducing construction time and end product assembly time,
- reducing the complexity of the whole construction and end product assembly system,
- facilitating a constant end product improvement [12].

Using a product platform influences the organizational structure of companies in which such a platform is implemented [12].

McGrath defines a product platform as "a set of similar elements, especially technological ones, used in a particular set of products" [10].

Robertson and Ulrich emphasise that "by division of components and production processes on a product platform, companies may manufacture varied end products successfully, increasing flexibility of manufacturing processes and taking market shares from the manufacturers that make one product at a time" [16]. What is more, a product platform facilitates end product adaptation, which makes it possible to develop different products in an easy and rapid manner in order to satisfy needs of different market niches [15, 19]. The influence of product family and product platform structure on the variety of products obtained from a given platform and their mass adjustment is still the topic of extensive studies [3, 6, 7, 20, 21].

The essence of product platform development lies in acquiring as many end products as possible by using standardized components and different manufacturing processes. Therefore, adjusting a product platform involves discovering common elements of a specific product family (such as shared functions, parameters, characteristics, components, subsystems or sufficient amount of information related to manufacturing of a specific product family) and subsequent adjusting and standardization of the aforementioned common elements or parameters [11, 22].

The use of a product platform consists in:

1. Analysing the usefulness of a product platform in manufacturing a given set of end products.

a) Developing a product family and a suitable structure of the product platform in the way which allows obtaining the final platform that stands out among others in terms of design or construction.

b) Discovering restrictions which impact the parts manufactured by the most frequently used product platforms, which includes:
   - identifying both common modules/subsystems in a given product platform and the correlations between their interfaces,
   - identifying both common components of a given end product developed on the product platform and the correlations between them.

Product platform standardization is made primarily by using the elements of a given platform as well as its components and subsystems.

This process involves the standardization of:

a) components of a product platform, including its structure and parameters,
b) subsystems and interfaces,
c) the process of production and product system managements, etc. [22].

Using product platforms has become the priority in competition between companies, and therefore many businesses accept the concept of such a product platform. However, they interpret it differently and vary in the way they make us of it. Japanese companies have introduced a strategic programme of using a product platform in the process of manufacturing end products, which, thanks to further efforts, resulted in simplifying the end product model. Different functions of a platform need to be examined if one wants to understand why the strategic programme has been adopted [12].

Table 1 shows strengths and weaknesses of product platforms.

The significance of a product platform can be examined both from strategic as well as from organizational or technical point of view. Implementing a product platform strategy has an effect on the course of product manufacturing process, and particularly on the costs, reduces the end product design time as well as the time of its introduction onto the world markets. The programme of strategic use of product platforms improves the management of companies in which such they are implemented. The product platform strategy is closely connected with the way in which a platform is developed in relation to other elements of the product. The process of product platform development is also subject to technical correlations because it involves the use of various troubleshooting aspects related to further stages of end product manufacturing such as its construction or its modularisation. The significance of product platform does indeed have a close relationship with both end product modules and its construction or appearance [12].

Table 1. Strengths and weaknesses of product platforms, the author's own compilation based on [1, 2, 12, 18]

Product platforms	
Strengths	**Weaknesses**
Strategic phase - various products reach the market faster, - entering niche markets, - implementing new technologies, - lower technological risk, **Design phase** - lower development costs, - reusing components and systems designed earlier, - reusing well-tried technologies, **Product managment phase** - possibility of using the same tools in the production of various products, - economical manufacturing, - possibility of bulk purchasing of the same subsystems used for manufacturing various products, - reduction in warehouse stock, - lower quality-related expenses, - flexibility in the number of product variants, **Phase of testing and putting into operation** - reduction in the time devoted to testing and putting product into operation for the first time, - shared testing equipment of various products, - reduction in the number of certification tests, **Phase of operating and maintaining the product** - reduction in fixed costs of maintaining products due to their shared functions, - lowering costs of staff training, - lowering variable costs due to more efficient logistics activities.	**Strategic phase** - restrictions on future investment in extending the platform, - risk of the market being monopolized by a company developing the product manufacturing strategy, **Design phase** - the necessity to do research into the technical and economic feasibility of developing a product, - extra costs connected with the necessity to design additional product-differentiating components of the product platform, - overhead costs connected with commonality management of the product platform elements, **Production management phase** - increased complexity of product configuration management on the assembly line, - increase in the costs of subsystems production, **Phase of testing and putting into operation** - increase in the costs of developing the methods of verifying and validating the product and the product platform, **Phase of operating and maintaining the product** - risk of failure in manufacturing common elements for a variety of end products, - increased complexity of operating multi-purpose elements, - increase in the costs of operating subsystems, - increase in the costs of product platform management.

End product construction involves setting functional elements of the product into physical blocks. The goal of end product construction is to define basic structural blocks of the end product in terms of both their performance and their cooperation with the remaining elements of a piece of equipment. Therefore, a module can be described as a large group of physically interrelated parts forming a component, which often has a standardized design interface. Modules can be the same in different projects, but they can be specific only for one end product model as well. In such case, using modularisation has many benefits, including:

- possibility of manufacturing various end products which has little effect on manufacturing end product components,
- reducing the number of manufactured end product components,
- better effectiveness resulting from automation [12].

The significance of a product platform can be examined in terms of organization. A product platform is essentially a method of creating a functional set in the process of end product development. However, integrating such a set can be limited to technical decision-making or can involve some responsibility for commercial aspects of the end product. Looking at the significance of a product platform from organizational perspective, requires different criteria of aggregation (the process of combining elements into a larger whole) which are significant for the platform operating team.

Technical criteria usually have priority in selecting the 'universal' product platform. Nevertheless, factors such as a market segment and a method of market saturation should be considered as well.

There are many similarities between various types of product platforms, as a result of which organizational and technical aspects of product platforms can overlap with each other [12].

3. Research product platforms

Research on the implementation of the assembly platform has been carried out in an energy company. He provides comprehensive construction and assembly services for investments related to the energy, petrochemical, mining and public utilities industries in the turnkey system [4].

The significance of product platform is more and more visible in various industry sectors and many companies have to make a number of decisions on this matter. Work is heading towards elaboration of the five basic stages of the product platform development.

Stage One – creating the product platform as a physical structure of the product. This raises two essential questions. Firstly, how should a product platform be defined from a technical perspective when complexity of the product is considered? Secondly, in what way does the product platform relate to other concepts connected with end product planning process such as product construction or modularisation? To illustrate this stage Table 2 enumerating the components of low and medium voltage switchboards is complied and Figure 1 showing a diagram of the product platform for low and medium voltage switchboards is presented.

Table 2. The components forming low and medium voltage switchboards

Equipment (Safeguards)							
Supplier \ **Component**	**Current and voltage transformers**	**Breakers**	**Contactors**	**Circuit breakers**	**Disconnectors**	**Earth switches**	**Safeguards**
Elektrobudowa	-	-	-	-	-	MV	-
ABB	LV & MV	LV & MV	LV & MV	LV & MV	LV & MV	-	LV & MV
Siemens	-	LV & MV	LV & MV	-	LV	-	LV & MV
Schneider Electric	-	LV & MV	LV & MV	-	-	MV	LV & MV
ZWAE	-	LV & MV	LV & MV	MV	MV	-	-
Drive							
Manual	LV & MV						
Motor	LV & MV						
Conductor rails							
Rectangular (30 x 3)	LV						
Rounded (10 x 80)	LV & MV						
Rounded - Special (24 x 33, 30 x 15)	LV & MV						
Channel Section and T Section (45 x 45)	LV						
Cables & cable cross-sections							
power 75 – 240 mm^2, control 1,5 – 4 mm^2, in auxiliary circuits 1 – 4 mm^2	LV						
power 75 – 400 mm^2, control 1,5 – 4 mm^2, in auxiliary circuits 1 – 4 mm^2	MV						

Source: the author's own study (LV – low voltage, MV – medium voltage).

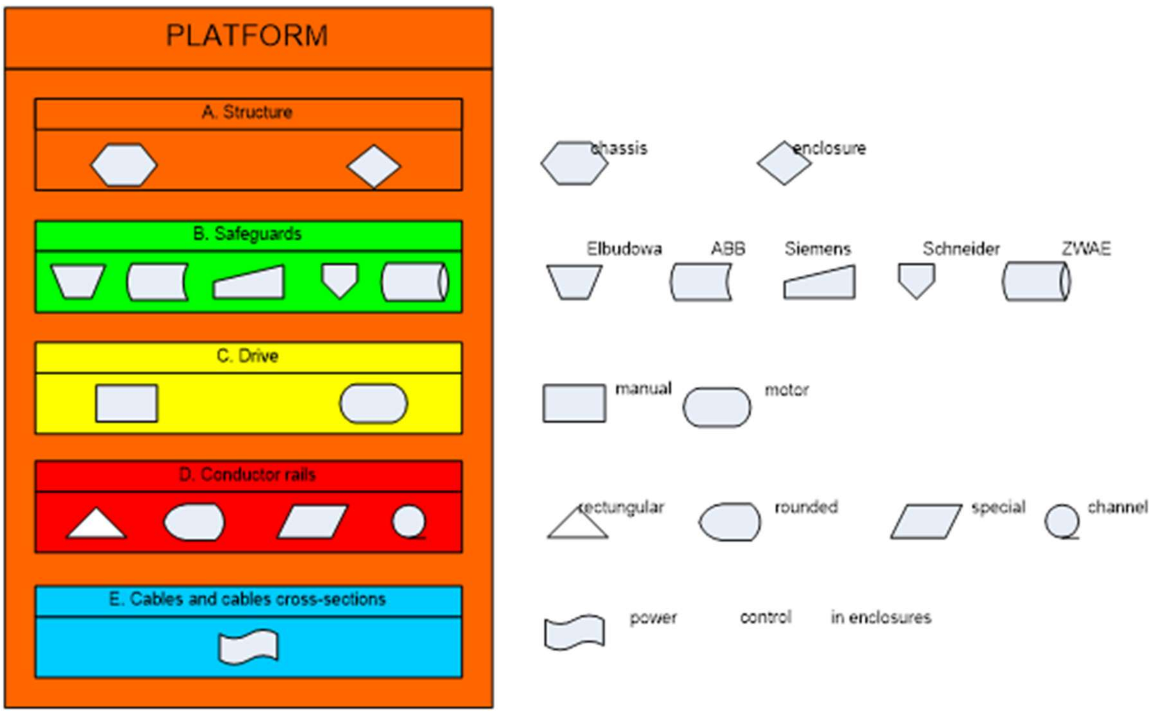

Fig. 1. Diagram of a product platform for low and medium voltage switchboards (the author's own study based on [13, 14])

Below there are combination matrices (i.e. all the possible customer choice combinations for a given product; lines of a matrix represent switchboard components while columns of a matrix represent variants of switchboards possible to manufacture) of variants for manufacturing low and medium voltage switchboards. 16 variant choices are available for manufacturing both low and medium voltage switchboards (Fig. 2 & Fig 3).

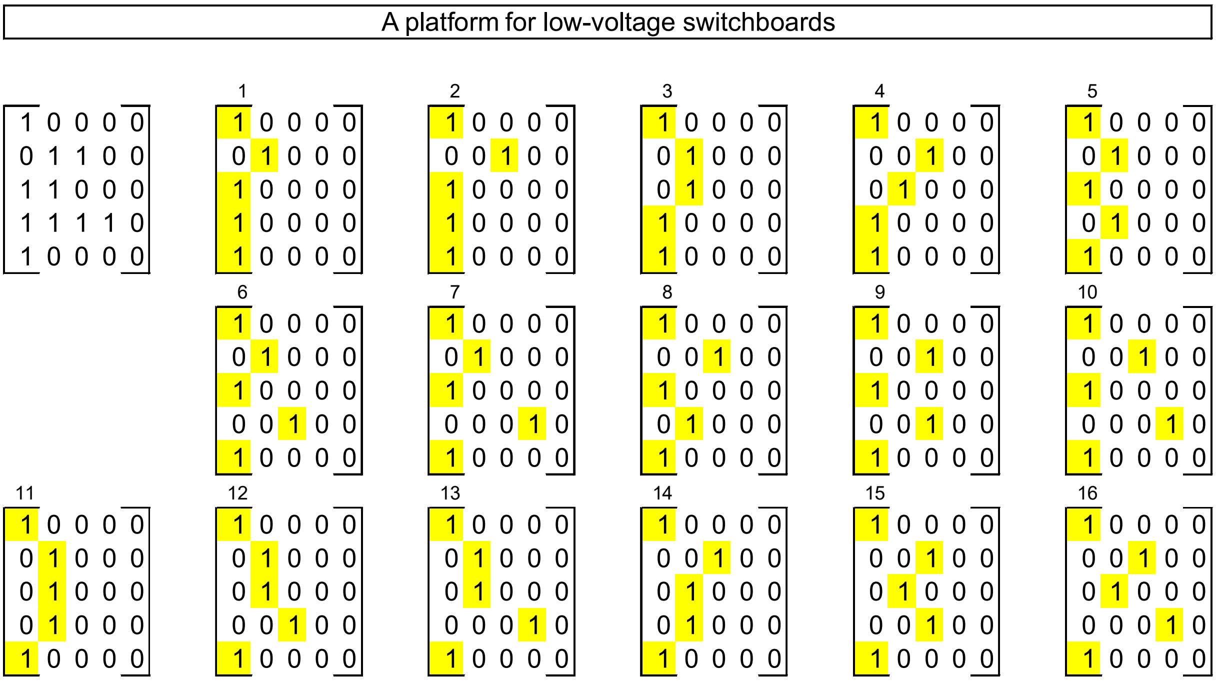

Fig. 2. Matrix of combinations for manufacturing low voltage switchboards [the author's own study]

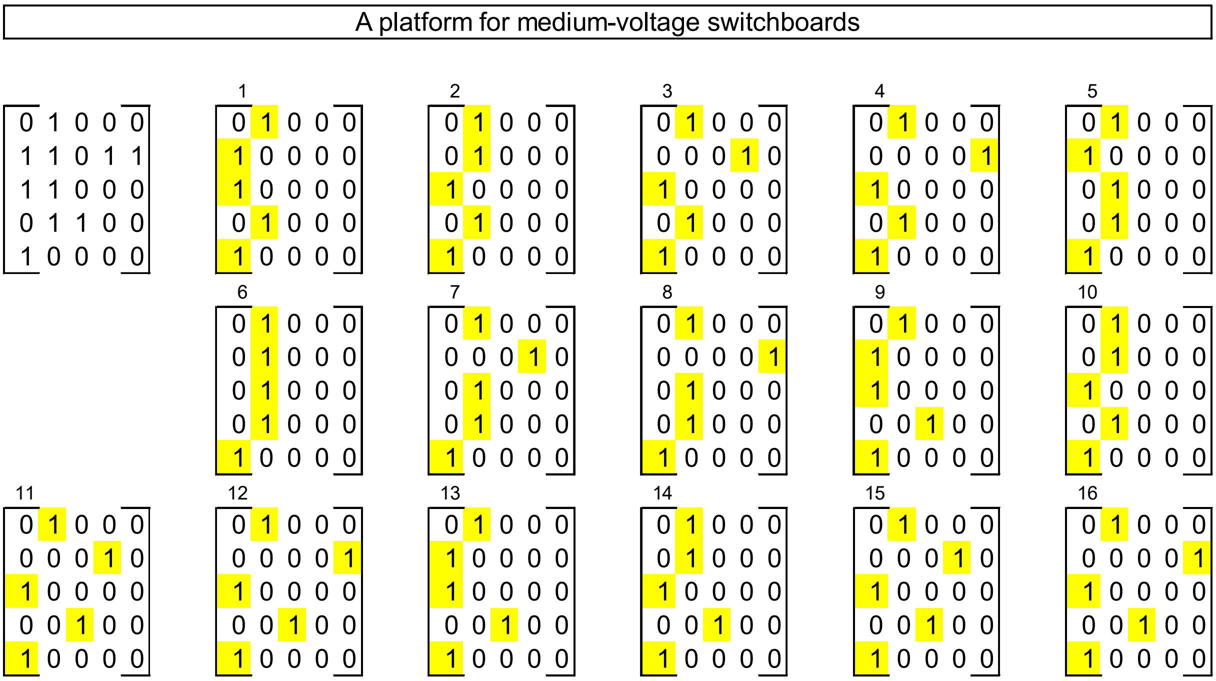

Fig. 3. Matrix of combinations for manufacturing low voltage switchboards [the author's own study]

An example of the matrix is shown below:

Columns represent feasible variants of switchboards (e.g. frame or enclosure)

Lines of the matrix represent switchboard components (e.g. design, safeguards, drive, conductor rails, cables and cable cross-sections)

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Authors used binary system in combination matrices in which 1 represents an occurrence of a specific component while 0 represents no occurrence. The matrix consists of five columns, which is determined by five types of safeguards. As regards the number of lines, it is connected with the number of switchboard components.

Stage Two – grouping operations in order to define the technological similarity or commonality of the manufactured products. This raises two essential questions. Firstly, how should operations involved in installation of a particular switchboard be grouped (Table 3)? Secondly, how is the product platform connected with other operations related to the process of manufacturing the end product such as the construction of a given product?

Table 3. Operations performed in making low, medium and high voltage switchboards

No.	Summary	LV	MV	HV
1	Manufacturing essential structural elements	1	1	1
2	Adhesive bonding of bushing insulators on stainless steel sheets	0	0	1
3	Combining the detailed parts of the tank and priming with switchgear	0	0	1
4	Filling the tank	0	0	1
5	Switchboard buses assembly	1	1	1
6	FOBOX box assembly	1	0	0
7	Upper earth switch box or voltage measurement box assembly	0	1	0
8	Slide-out modules assembly	1	1	0
9	Earth switch modules assembly	1	1	0
10	Assembling modules for drying the motor or measuring the transformers	0	1	0
11	Lower measurement modules assembly	0	1	0
12	Hub assembly	0	1	0
13	Bus bar assembly	0	1	0
14	Control gear assembly	1	0	0
15	Screwing the FOBOX enclosure together	1	0	0
16	Assembling the post for modules	1	0	0
17	Switchboard access platform assembly	0	1	0
18	Back or side attachment for switchboards	0	1	0
19	Testing the proper functioning and technical state of the switchboard before shipment	1	1	1
20	Final assembly of external front and back shields	1	1	1
21	Packaging and shipping	1	1	1
	Total	**11**	**14**	**8**

Source: the author's own study (LV – low voltage, MV – medium voltage, HV – high voltage).

It was assumed that the basic grouping criterion should be the technological commonality of the manufactured parts, thus on a scale from 0 to 1 it was assigned weight of $w_T = 1$. For the mass of the product (switchboard), a weight of $w_M = 0{,}75$ was assigned, and for the external dimension (width), significant because of the amount of the occupied space, a weight of $w_{DZ} = 0{,}2$ was assigned.

The next stage of the procedure is the normalisation of the value of a feature. It was assumed that the numerical value representing a particular feature should be placed between 0 and 1. In such a case, the normalised value of a feature:

- for a technological process of product 1 is equal to a ratio of 11 operations performed on the LV switchboard to a maximum number of operations, that is 11/21 = 0,52; this value multiplied by weight $w_T = 1$ results in a final value of 0,52,
- for a technological process of product 2 is equal to a ratio of 14 operations performed on the MV switchboard to a maximum number of operations, that is 14/21 = 0,67; this value multiplied by weight $w_T = 1$ results in a final value of 0,67,
- for a technological process of product 3 is equal to a ratio of 14 operations performed on the HV switchboard to a maximum number of opera-

tions, that is 8/21 = 0,38; this value multiplied by weight $w_T = 1$ results in a final value of 0,38.

The comparison performed on the basis of these calculations indicates that basing solely on the criterion of technological commonality, the deviation between features of product 1 and 3 amounts to 0,14, that of product 1 and 2 amounts to 0,15, and that of product 2 and 3 amounts to 0,29.

Under these circumstances, if one intends to perform a division of operations into two groups, group A can consist of operations of product 1 and 2, whereas one should attempt to incorporate operations of group 3 into another group (obviously, one can also decide to incorporate it into group A, but this commonality is a slightly lower than for operations for products 1 and 2). An additional criterion was introduced into the grouping example. The criterion was a switchboard mass: LV = 760 kg, MV = 600 kg and HV = 11100 kg. Assuming that there is a ratio of 760/11100 = 0,07 for LV, then the feature multiplied by weight of 0,5 has a value of 0,03. The values of the feature of external dimension (width) were calculated in a similar manner. Thus, every operation has defined feature values (Table 4).

Table 4. Feature values for low, medium and high voltage switchboards

No.	Feature	L	M	H
1	Technological process	0,52	0,67	0,38
2	Switchboard mass	0,03	0,03	0,50
3	External dimension (width)	0,21	0,19	0,25

Source: the author's own study (LV – low voltage, HV – medium voltage, HV – high voltage).

Applying a distance classifier (KO – abbreviation derived from the initials of the Polish name) in which every part is represented by a matrix of feature value, the value of KO was calculated for each pair of products.

- for product 1 and 2:

$$KO_{1-2} = \sqrt{\left[\begin{pmatrix}0{,}52\\0{,}03\\0{,}21\end{pmatrix} - \begin{pmatrix}0{,}67\\0{,}03\\0{,}19\end{pmatrix}\right]^T \cdot \left[\begin{pmatrix}0{,}52\\0{,}03\\0{,}21\end{pmatrix} - \begin{pmatrix}0{,}67\\0{,}03\\0{,}19\end{pmatrix}\right]} =$$

$$\sqrt{\left[\begin{pmatrix}-0{,}15\\0{,}00\\0{,}02\end{pmatrix}^T \cdot \begin{pmatrix}-0{,}15\\0{,}00\\0{,}02\end{pmatrix}\right]} = \sqrt{0{,}025 + 0 + 0{,}0004} = \sqrt{0{,}0229} = 0{,}15 \quad (1)$$

- for product 2 and 3: $KO_{2-3} = 0{,}55$,
- for product 1 and 3: $KO_{1-3} = 0{,}49$.

The lowest value of a distance classifier for products 1 and 2 indicates the highest level of commonality from the perspective of the analysed features.

Stage Three – performing the cost analysis of manufacturing products by means of a product platform. This raises two essential questions. Firstly, what factors should be taken into account for determining the cost of a product manufactured by means of a product platform? Secondly, what will be the value of a coefficient for the cost analysis?

First, the analysis of the time required for the switchboard assembly was performed in to the energy company. The time study was divided into three stages: preparation, the measurement of the time consumed by the operation and the calculation of the results (of the time study). Steps taken during the time study were as follows:

1. familiarizing with the employees performing the researched operation, as well as with the organization and operation of the workstation and the device on which it will be performed (table 5),

Table 5. Analysis of an assembly workstation, the author's own study

Company employees responsible for research	Research time	Researched workstation
technologist	6^{00} - 14^{00}	Work team of engineers and electricians who were responsible for assembling the product

2. Familiarizing with the correctness of the working methods, the usefulness and sequence of actions performed, groups of operations and actions,
3. Preparing observation worksheet of the time study,
4. Determining the number of essential measurements dependent on how much time is consumed by particular operations or its elements as well as the production volume,
5. Performing the measurements of time consumed by the product assembly by means of continuous observation or random observation using instruments selected for this task (duration times of each operations for every product were measured by stopwatches manufactured

by German company Hanhart MODUL featuring the accuracy to one second).

6. Entering the values of the time consumed by product assembly into the observation worksheet prepared beforehand (which form a series of timings).
7. Analysing the series of timings by rejecting values grossly deviating from the average values calculated by means of the so-called 'integrity coefficient',

$$K_s = \frac{x_{\max}}{x_{\min}} \tag{2}$$

where:
$x_{\max}$ – the longest measurement duration,
$x_{\max}$ – the shortest measurement duration [30],

8. calculation of the average measurements (arithmetic averages) of time required for performing specified tasks (only percentage values are shown due to trade secret policy of the company) (Fig. 4).

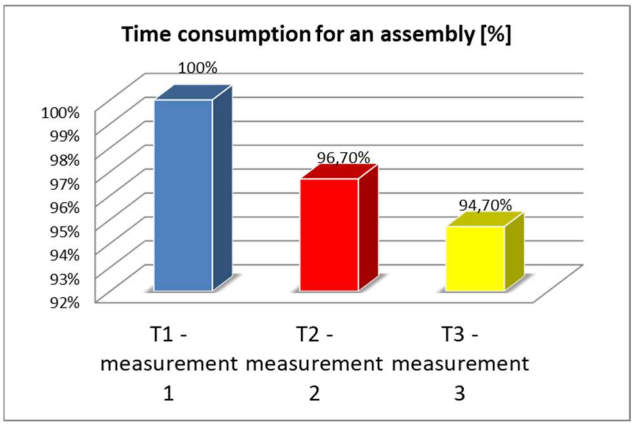

Fig. 4. Presentation of time consumption of switchgear assembly in an energy company (the author's own study, T1 – measurement 1, T2 – measurement 2, T3 – measurement 3)

The conducted research shows that the time required for switchboard assembly is inversely proportional to the number of repeated operations performed by a particular employee. As for cost-effectiveness and profitability of manufacturing, it was proved that both indicators are directly proportional to the number of repeated operations. In short, the more particular operation is repeated, the less time is required for assembly with a simultaneous rise in cost-effectiveness and profitability of the manufacturing.

This analysis indicates a possibility of implementing the rule known as 'practice makes perfect' in the technological process and implementing the learning curve (Fig. 5) since performing repeating operations, which is training, causes a reduction of the time required for performing a particular action. In Figure 5, R value specifies the expertise rate which is 'learning' rate; it means improving efficiency in relation to each succeeding execution cycle of a particular operation. Obviously, the listed methods of production capability adjustment are presented as examples. With creativity of managers in this regard, the range of these possibilities is constantly expanding [13, 14].

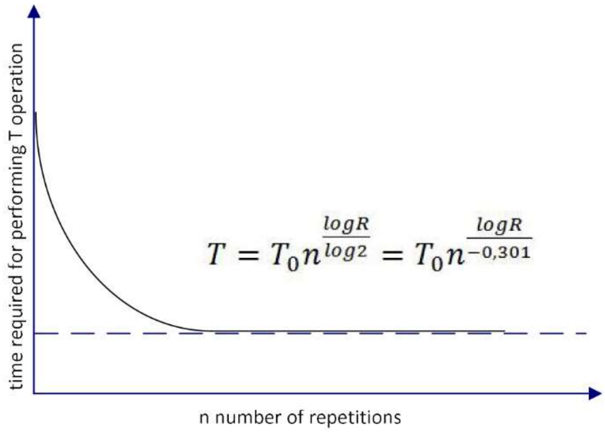

Fig. 5. A typical learning curve: T_0 – time required for manufacturing the first unit, R – expertise rate [13, 14]

On the basis of research performed in the company it was determined that the basic indicators for a cost analysis for the manufactured products will be:

- **runtime ratio**

$$W_t = \frac{T_m}{T_o} \cdot 100\% \tag{3}$$

where:
T_m – direct working time for switchboard assembly,
T_o – standard working time for switchboard assembly,

- **cost-effectiveness ratio**

$$W_o = \frac{P}{K} \cdot 100\% \tag{4}$$

where:
P – production value,
K – production costs,

- **profitability ratio**

$$W_r = \frac{D_{cz}}{K} \cdot 100\% \tag{5}$$

where:
D_{cz} – company income „net profit",
K – production costs,

- **material consumption ratio**

$$W_m = \frac{N_m}{P} \cdot 100\% \qquad (6)$$

where:
N_m – materials required,
P – production value.

Using the data from the company about the runtime, cost-effectiveness, profitability and material consumption ratios, a comparison of manufacturing with and without the product platform was made. Thanks to an analysis performed on the basis of the "learning curve" it was estimated that in case of the application of the product platform, production effectiveness will increase by **4,3%,** and that there will be a decrease in timing and material use factors and increase in cost-effectiveness and profitability factors at the same time, compared to the standard manufacturing.

Stage Four – defining the structure of the elements used in the product platform. First, it should determine what elements will be required for developing the given product platform. The process of designing every new element can be divided into three steps: preparation, design of the model in the CAD/CAM software selected by worker or by company and calculation of the performance results. The project procedure may be as follows:

1. familiarizing with the employees performing the researched operation, as well as with the organization and operation of the workstation on which it will be performed (Table 6),

Table 6. Analysis of an assembly workstation, the author's own study

Company employees responsible for product platform research	Product platform research time	Researched workstation
e.g..: technologist	e.g.: 6^{00} - 14^{00}	e.g..: Work team of engineers and electricians

2. familiarizing with the structure of assembly tools present in the assembly hall which can facilitate the design of new elements of the product platform structure,
3. analysing the evolution of the tools selected by the employees,
4. defining, in cooperation with the technologist, the requirements the new elements of the product platform will have to comply with,
5. designing the model of the element for the product platform in CAD/CAM software which is selected either by worker or by the company,
6. doing the strength test calculations essential to design the element for the product platform in CAD/CAM software selected either by worker or by the company,
7. working out the whole manufacturing process on operation and instruction sheets.

Fifth Stage – developing the product platform. This stage involves implementing the action strategy for the given product platform in the company. In this stage, the presentation of all elements of the given product platform on the CAD/CAM software selected either by a worker or by the company, as well as putting it into operation in the selected manufacturing plant. Additionally, the authors will perform timing measurements via several methods of working time regulation. On the basis of these measurements, it will be possible to specify time saved after the implementation of the whole product platform in the chosen workplace.

4. Conclusions

The principles of making product platforms is the topic of further research conducted by engineers in every manufacturing company of national and international scope.

The main purpose of the article was to develop the assumptions for the creation of an assembly platform in an energy company.

In order to effectively use product platforms in the manufacturing process, one should start using them at the stage of product development. Presented by the author in this paper, the five stages of developing a product platform allow creating the plans of production lines, which decrease the cost of end product design and result in products which satisfy customer demands better.

The platform developed in the energy company can be extended with the use of more and more elements such as pre-assemblies workstation. In the next stage of the assembly platform implementation, a cost estimate and a launching schedule will be developed. Due to the usage of additional elements in the platform, the costs incurred by the company will be reduced. The analysis of the assembly platform shows that the efficiency of production in an energy company will increase by 4.3%.

In order to find out that product platforms can rightly be used by engineers, they can be analysed with regard to more complicated technological assembly processes.

References

1. Camron B.G., Crawley E.F., *Crafting Platform Strategy Based on Anticipated Benefits and Costs,* Springer Science+Business Media New York 2014, s. 51.

2. Cieślak, R., Wysocki, I., 2015, Analiza kosztów platformy montażowej w firmie Elektrobudowa SA, Technologia i Automatyzacja Montażu, nr 1 (2016), s. 29.
3. Du, X., Jiao, J., Tseng, M.M., *Architecture of Product Family: Fundamentals and Methodology,* Concurrent Engineering: Research and Applications, 9(4): 309-325, (2001).
4. Katalogi firmy 2015 r.
5. Gao F., Xiao G., Simpson, T.W., *Module-scale-based product platform planning,* Springer-Verlag London Limited 2009, Res Eng Design (2009) 20:129-141, s. 129, 131.
6. Jiao, J., *Design for Mass Customization by Developing Product Family Architecture,* Ph.D. Dissertation, Industrial Engineering and Engineering Management, Hong Kong: Hong Kong University of Science and Technology, (1998).
7. Jiao, J., Tseng, M.M., *Understanding Product Family for Mass Customization by Developing Commonality Indices,* Journal of Engineering Design, 11(3): 225-243, (2000).
8. Juniani, A.I.; Singgih, M.L., Karningsih, P.D., *Design for Manufacturing, Assembly, and Reliability: An Integrated Framework for Product Redesign and Innovation*. Designs 2022, 6, 88. https://doi.org/ 10.3390/designs6050088
9. Li, Y., Zhou, M., Wu, X., Product Innovation Redesign Method Based on Kansei Engineering and Customer Personality Type. Commun. Comput. Inf. Sci. 2020, 1226, 663-670.
10. McGrath, M.E., *Product Strategy for High Technology Companies,* New York: Irwin Professional Publishing, (1995).
11. Meyer, M.H., Lehnerd, A.P., *The Power of Product Platforms: Building Value and Cost Leadership,* New York: Free Press. (1997).
12. Muffatto, M., *Introducing a platform strategy in product development,* Int. J. Production Economics 60-61 (1999) 145-153, s. 145, 146.
13. Pająk, E., *Zarządzanie produkcją,* PWN, Warszawa 2006, s. 217, 221.
14. Pająk E., *Zarządzanie produkcją,* PWN, Warszawa 2021, s. 219.
15. Pine, B.J., *Mass Customizing Products and Services, Planning Review,* 22(4): 6(8)., II (1993).
16. Robertson, D., Ulrich, K., *Planning Product Platforms, Sloan Management Review,* 39(4): 19–31, (1998).
17. Sąsiadek, M., Mazur, Ł., *EASYASSEMBLE – komputerowe wspomaganie generowania sekwencji montażu,* Metody i narzędzia w inżynierii produkcji, 2016. / red. T. Nahirny, T. Belica. T. 1, Zielona Góra: Uniwersytet Zielonogórski, s. 123-136, (2016).
18. Simpson, W.T., Jiao, J., Siddique, Z., Hölttä-Otto, K., *Advances in Produkct Family and Produkct Platform Design,* Springer, New York 2014.
19. Simpson, T.W., Nanda, J., Halbe, S., Umapathy, K., Hodge, B. (2003). Development of a Framework for Webbased Product Platform Customization, ASME Journal of Computing and Information Science in Engineering, 3(2): 119-129.
20. Tseng, M.M., Jiao, J., *Design for Mass Customization By Developing Product Family Architecture,* ASME Design Engineering Technical Conferences – Design Theory and Methodology, Atlanta, GA, ASME, Paper No. DETC98/DTM-5717, (1998).
21. Tseng, M.M., Jiao, J., Merchant, M. E., *Design for Mass Customization,* CIRP Annals, 45(1): 153-156, (1996).
22. Qin, H., Zhong, Y., Xiao, R., Zhang, W., 2005, *Product platform commonization: platform construction and platform elements capture,*Springer-Verlag London Limited 2004, Int J AdvManufTechnol 25: 1071-1077.