IMPROVEMENT OF BUSINESS DECISION MAKING PROCESS USING ANALYTICAL MODEL OF TRANSFORMER IN ENTERPRISE RESOURCE PLANNING SOFTWARE

Doctoral Thesis Summary

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This doctoral dissertation presents a new pragmatic way of providing additional assistance to managers in production companies in the decision-making process, by using business resource planning software for – up to now – not used purposes:

- specific technical calculations (vector diagram of power transformer, static characteristics of induction machines, basic dimensions of power transformer)
- integration of technical calculations with typical business analysis (production cost estimate, material availability, production capacity planning).

According to Herbert Simon, "every manager needs to be able to respond to situations rapidly". Also, in a recent survey published by Harvard Business Review (May-June 2017 issue: "What Sets Successful CEOs Apart"), it was stated that "decisive CEOs recognize that they can't wait for perfect information".

When it comes to making decisions, previous numerous researches points to two important things: first, the process is faster if the smaller number of people is involved, and second, if the main actors use the appropriate, knowing tool.

In manufacturing companies, we can usually find a multitude of fantastic specialized engineering software. However, managers use business software: Enterprise Resource Planning software, abbreviated ERP. In this way, the initial research assumption was that the decision-making process can be positively influenced by the inclusion of additional technical analysis and rough design procedures in the standard form of ERP system.

The first hypothesis of the research was that the standard form of business software could be used for rough analysis of complex technical facilities. Standard form means: without programming, only customizing (having software, setting parameters, and building a model). The second hypothesis was that business-modeling could be carried out sufficiently well in order for the manager to gain a correct insight into the design and production process.

An analogy with the induction machine torque curve was used here. Matlab as an example of top mathematical software provides a detailed dynamic image based on a well-known nonlinear differential equations system. However, it is well known that for a large number of analysis and conclusions using simplified static characteristics is quite enough. The same approach is used in this research: with the help of simplified methods, it is possible to achieve results needed for rough managerial decision-making.

This research has achieved three scientific contributions:

- analysis of standard business software capability for mathematical modeling of power transformers
- development and verification of an analytical model of power transformer in ERP business software
- model of business decision making process in power transformer factory using an analytical model of power transformer in ERP business software, taking into account the availability of production capacities.

Within the first scientific contribution, four individual models were created:

- calculation of the parameters of equivalent circuit for an induction machine and transformer from the measurement results
- creation of static characteristics of the induction machine from the parameters of the equivalent circuit
- calculations of all elements of the vector diagram of power transformer from the parameters of the equivalent circuit
- calculation of the basic dimensions of power transformer, based on the required transformer specifications.

The second scientific contribution is the integration of the previous individual models and their inclusion in the two required ERP elements: bill of materials and production routings. The calculated material quantity is included in the bill of materials, and in parallel, the calculated production time (based on the additional model for the processing of the actual historical postings) is included in the production routing. In this way all data needed to calculate the production cost, the availability of materials and the availability of production capacities are collected.

The third scientific contribution is the whole business model that allows a manager to have in one system all three key elements needed to make a decision: required/available production capacity, required/available basic material and rough estimation of production price, all based on the individual models presented in the first two scientific contributions.

As the basis for the research, currently the most powerful business software, SAP ERP is used. Three major SAP ERP business modules have been used in this paper: Production Planning, Variant Configuration and Controlling. One of the most important initial questions was how to set in SAP ERP all needed parameters, formulas and tables that are an integral part of all technical calculations, to define the desired model. There are three possible options for parameters and constants: SAP User Parameters, Production Work Centre Parameters and Characteristics. Two suitable alternatives are found for mathematical equations: Formulas for cost calculation in production work centers and Object dependencies. Without the programming, the tables can be entered in SAP only in the form of Variant tables.

When it comes to the transformer display mode in this SAP model, instead of the normally used multilevel principle (with a multitude of true and false assemblies), in this model a simplified "one-level" bill of material is used, having inside the main components only. Connected to one bill of material, one routing with several sequences is used. Sequences were needed for a more precise linking of the major operations.

The Torque curve was obtained in such a way that the parameters of the equivalent circuit in SAP were defined as Constants of the production work center formula. The production center in SAP is related to the Cost Centers and Controlling, and then the cost calculation formulas are used as formulas for calculating slip, torque and current. As a result of the simplified Kloss equation, it is obtained by simulating the function of confirming production orders of multiple torque values depending on the slip. All dots are linked by additional ABAP program and a graphical representation is obtained.

In the case of a vector diagram, as a result there is a print of input parameters and all computed elements of the vector diagram. The comparison of the SAP calculation with the original calculation is presented in the table format.

The calculation of the basic dimensions of power transformer was done according to the procedure defined in the book Design and testing of Electrical Machines, by professor M. V. Deshpande. The procedure is defined in 19 steps. After defining the required specifications, by computing all the core and winding elements, the final data is obtained based on three results: the mass of copper, the mass of the magnetic sheet and the mass of the oil.

For the previous model, a lot of Characteristics and Object dependencies are created. For each parameter that appears in the process, one SAP characteristic is created, and if that parameter should be calculated then SAP object dependency is also created, with a defined formula for calculating the value of the characteristic / parameter itself.

This model, as part of its first scientific contribution, allows to easily print all results, including our three key figures for the mass of copper, magnetic sheet and oil, after simply entering the required specifications.

A comparison of the results of the original calculation from the book and our model is presented in table form. The difference in material quantities is less than 10%.

The calculations were also made for five reference transformers from power transformer factory. There is also noticeable eligibility for results - numbers do not differ more than 10%.

For defining the production time of the main operations, historical data was available in the existing SAP ERP system of the transformer factory. In this case, data for twelve transformers of the same type and different power are taken. To obtain a mathematical equation that would later be included in the routing, the principle of linearization was used. This has been done for the sheet cutting, the manufacture of insulating elements, winding and the final assembly.

One routing with six sequences was used to analyze the manufacturing process: one central and five parallel sequences. Each sequence consists of a series of production operations, and for each operation it is defined by the object dependency that it is related to the historical data. Functionality of the Simulation Production Orders was used to get a Gantt Diagram, needed to check the calculated operating time and mutual relations.

Once the material quantity and production time are calculated, the production cost estimate can start. The most important conclusion based on literature and real historical data of the transformer factory is that the main materials in power transformers makes about one third of the production cost. So, if we calculate the amount of copper, magnetic sheet and oil sufficiently well, we can estimate the total production cost. SAP cost estimate is a very clear and simple way to calculate all material and activities, as the key cost components. The cost of the material is obtained as a product of the quantity of material and the current price. The cost of production activities is obtained as a multiplication of the calculated time and machine/labor cost per hour. The cost of production overhead is obtained by a predefined key. It is mostly a percentage of the cost of materials or some production activities.

To check the availability of materials, a standard MRP procedure is used, which compares the calculated quantity required with the current stock and takes into account both active purchasing documents and existing reservations. As a result, the proposed purchasing documents are obtained.

Capacities are checked through production orders. The system compares calculated production times and dates with total available and currently available production capacities. For a better view of the process of capacity checking, a graphical planning board can be used.

All of the above-mentioned actions could be quickly done with the use of several different ERP functionalities. Given that managers do not need the skills of an ERP consultant, it was proposed to create a management portal where user / manager will have all the functions she needs on a single screen.

At the end a presentation of the required actions to implement the proposed model into a factory with the already introduced SAP ERP software is given. There are four groups of actions in SAP:

- new categories of master data (generic materials, sequences in routings)
- activation of additional standard SAP functionalities (Variant Configuration, Capacity Requirements Planning)
- creating the entire model (SAP characteristics, Object dependencies, integration)
- creating a portal

As the conclusion, it was emphasized that a pragmatic solution was presented to facilitate the decision-making process. The analysis of the possibility of a specific business software for the needs of rough analysis of electrical machines has been explored and analyzed, from the calculation of the elements of the equivalent circuit to the basic dimensions of the machine. Also, research was done for the possibilities of unification of technical calculations and business functions into a single, decision-making model by checking the availability of materials, capacity and production costs.

Further work in this area can go in two directions, in the direction of further scientific research and in the direction of project implementation of the findings that have been made so far. When it comes to possible scientific research, there are at least two things that can be done:

- improving the model for calculating basic transformer dimensions
- expanding the dimension model for rotating electrical machines.

In the case of implementation of the solution presented here, three major actions are possible:

- optimization of the model for calculating the production price, in order to increase the accuracy of the calculation of unit prices of production activities and to improve the selection of cost-effective production operations
- optimization of the production capacity planning model, where the choice of production operations and key product line production calendars should be addressed
- creation of a management portal.

Thesis has been divided into seven chapters. The introductory chapter presents the basic idea of the research and three achieved scientific contributions.

The second chapter analyzes the business software used in the power transformer factory. The five basic ERP postulates and main functionalities are listed, as well as the multilevel structure of power transformers normally used by power transformer factories.

The third chapter presents the process of making an analytical model of two types of electrical machines (induction machines and transformers) in the SAP ERP system. In the case of an induction machine, a method of calculation of static characteristics is shown with the torque curve. In the case of a transformer, the procedure for calculating the elements of the equivalent circuit is shown on the basis of the measurement results and the procedure for calculating all the elements of the vector diagram and the procedure. In the case of a transformer, the process of calculating the basic dimensions is also shown.

In the fourth chapter, a new model for managerial decision-making was proposed, ranging from single-level bill of materials, through simulation explanations, to three key results: production costs, material availability and capacity evaluation.

The fifth chapter presents a proposal for the implementation of the improvement of the business decision-making process, including the development of the portal, the establishment of new process and the presentation of the implementation method.

In the sixth chapter, a review of the entire doctoral work and a proposal for future research are given.

In the seventh and eighth chapters, the literature, figures, formulas, and tables are listed.

Keywords: transformers, electrical machines, ERP, analytical model, dimension calculation, capacity planning, cost estimate.