

Decision making in transformer manufacturing companies with help of ERP business software

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Abstract—This paper describes the idea of using ERP business software in transformer manufacturing companies for decision making improvement process. A new model combines technical calculations (basic dimensions and elements of vector diagram) with business analysis (MRP, CRP, Cost estimate) in one system, SAP ERP.

Keywords — decision making, power transformer; SAP ERP

I. INTRODUCTION

Decision making in the manufacturing environment is a strategic topic [1]. In order to have efficient decision making, high-level managers must have a proper tool for tracking information related to the current and upcoming business events and opportunities. All available data should be collected in “one place” and evaluated in relatively easy and quick way, so decision makers could have enough time for their main job – decision making. The decision making process in companies for the production of electrical machinery can be improved by including rough designing procedure in ERP systems.

II. DECISION MAKING AND ERP

Decision making is a process where a variety of options should be considered. According to [2], process of decision making is generally quicker if less people are involved and if main actors use a proper and familiar tool. Our wish to establish a new procedure is connected with cognition that managers in manufacturing companies regularly use some kind of ERP software, and that for every serious analysis they must use the services of specialized designing software (PLM, PDM, ...) used by engineers specialists. Because managers are more familiar with using of business than design software, this paper tries to justify the desire for incorporating additional design functionalities in standard ERP software so decision makers will have one common tool for rough analysis of new potential projects.

III. QUANTITY, COSTING AND CONFIGURATION STRUCTURES

In order to have proper object processing in any ERP system, both quantity and costing structures should be established. Also, in order to be able to do needed technical calculations, proper configuration structure should be established: Characteristics, Object dependencies and Variant tables.

A. Production Quantity structure

Power transformers are complex products. They are usually described in ERP systems as multi-level materials, with almost hundred of assemblies and phantom items. However, for

purpose of our method, it is enough to use simple, one-level structure with precisely defined routing. All critical production operations must be defined and included in several parallel sequences. In order to have this in our model, standard elements of SAP Production Planning module are used [3]: Bill of materials, Production Work Centers and Routings (list of manufacturing operations with work centers and required production time assigned).

B. Costing structure

For the purpose of calculating the production costs, in addition to specified production structure the proper cost structure must be defined: Cost Centers with Activity types (prices for machine and labor work), including all needed structural elements [4] (valuation variants, costing sheets,...).

Cost centers are organizational units that use internal financial accounting with purpose of planning and collection of all costs. Cost centers used in this example are: Production preparation, Winding workshop, Insulation, Montage, Testing station and Production overhead. Activity types assigned to Cost centers are: Handwork, Winding work, Winding preparation, Final assembly, Insulation, Drying, Cutting, Installation and Testing. Work centers are assigned to Cost centers, including assignment of Activity types for valuation of machine and labor work. In our model eighteen Work centers are used, from Cutting sheet machine to the Testing station.

C. Configuration structure

Proper analytical model of power transformers should be available in order to check the behavior of the transformer, depending on its load nature. The same model should be able to do basic design steps: calculation of basic dimensions and required material quantities.

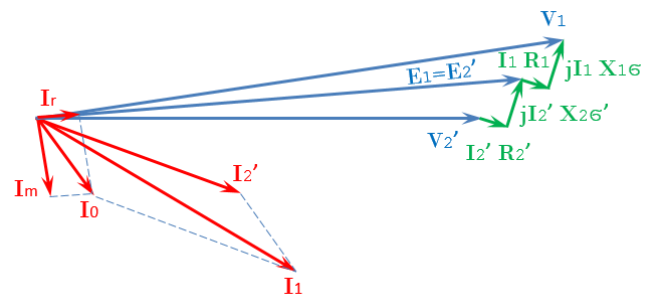


Fig. 1. Vector diagram of Power transformer with inductive load. All elements presented here should be calculated by configuration model in ERP system.

All requirements for technical calculation are fulfilled with functionalities of characteristics and object dependencies. In case when using the table with specific empirical parameters was mandatory, Variant tables were created.

The whole procedure is visible on Fig. 2. Based on the input parameters (nominal power, the primary and secondary voltage, number of phases, connection type and frequency), and through a series of empirical factors, the following numbers are finally calculated:

- the main dimensions of the core and windings,
- reactance, resistance and impedance,
- weight of the core, windings and oil.

Following the variant configuration process [5], almost one hundred of different characteristics and object dependencies are created in SAP. The proper way of using SAP for rough technical calculation related to electrical machines is described in [6] and [7]. An example of technical equation for Core diameter calculation and created dependency and characteristics

$$D = \sqrt{\frac{4 A_i}{k_i k_s \pi}}$$

| Object | Description | Status |
|----------------|--------------------------------|--------|
| 0000 Z_KPT_32A | D - Core diameter | ■ |
| • Z_KPT_14 | ki - Iron space factor | |
| • Z_KPT_15 | ks - Stacking factor | |
| • Z_KPT_31 | Ac - Cross-section of the Core | |
| • Z_KPT_32 | D - Core diameter | |

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$self.Z_KPT_32 = SQRT ( $self.Z_KPT_31 * 4 /
                      $self.Z_KPT_14 / $self.Z_KPT_15 / 3.14159265 )

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Fig. 3. Example of Core diameter calculation by using characteristics and dependencies. For each mathematical equation one dependency is created. For all parameters inside equation specific characteristic must be created first.

is given in Fig. 3. All created characteristics are grouped and separated from other “normal” characteristics used by business.

After basic dimensions, impedances and weight of main materials (copper, iron and oil) are calculated, system is ready for next step. With known parameters of equivalent circuit, system can start with calculation of all elements of vector diagram. This is needed for checking of transformer’s behavior in all possible circumstances. Procedure for this step is the same as before: characteristics and dependencies are needed.

Having all data ready, method assumes using of dependencies in Bill of material (BOM) and in Routing. To be able to do this, several additional characteristics are created with special reference to standard SAP tables which are used to store BOM items and operation details information:

- table STPO, field MENGE (for materials in BOM)
- table PLPO, fields VGW01 to VGW06 (for machine and labor time in routing)

With these steps, configuration structure is ready, and the simulation can start.

IV. SIMULATION PROCESS

As explained, procedure starts with entry of new transformer specification. Model will have as first results the required quantities of main materials. In table I we can see the comparison of results given by our model and results given by original design [8], for one 5 MVA transformer. It is visible that the differences for two materials with the biggest influence on price (copper and iron) are less than 10 %.

Common conclusion after communication with designers and managers was that all differences not bigger than 10 % could be acceptable.

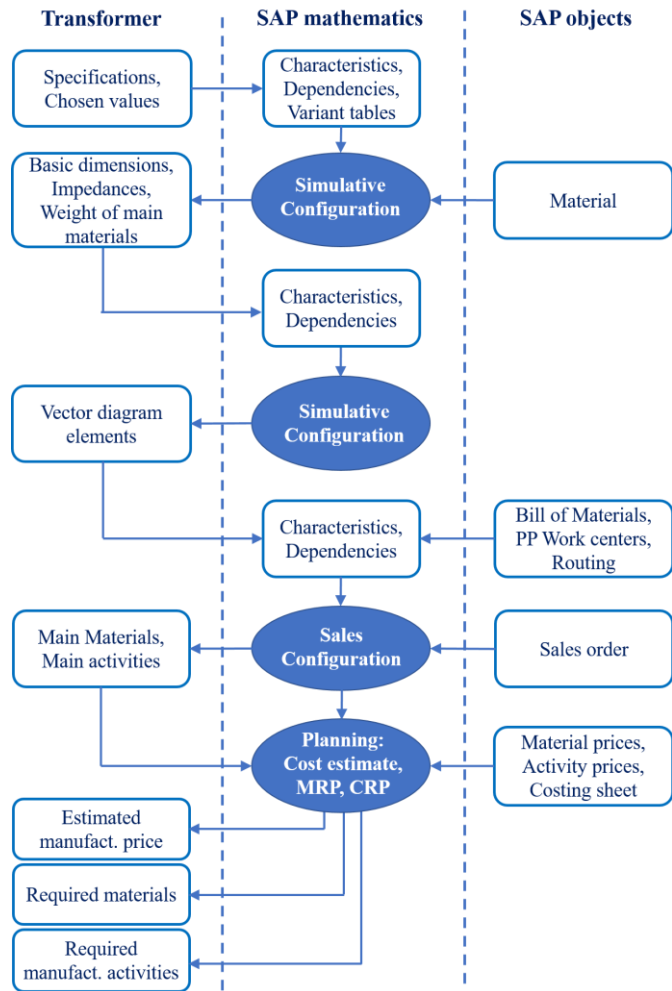


Fig. 2. Procedure for the full evaluation of new transformer. Procedure starts with technical calculation of basic dimension and ends with business calculation of manufacturing price followed by MRP and CRP

TABLE I
COMPARISON OF MATERIAL REQUIRED CALCULATION

| Parameter | SAP ERP calculation | Original calculation | Difference |
|---------------|---------------------|----------------------|------------|
| Iron Weight | 4.963 kg | 5.283 kg | 6,06 % |
| Copper Weight | 1.493 kg | 1.629 kg | 8,34 % |

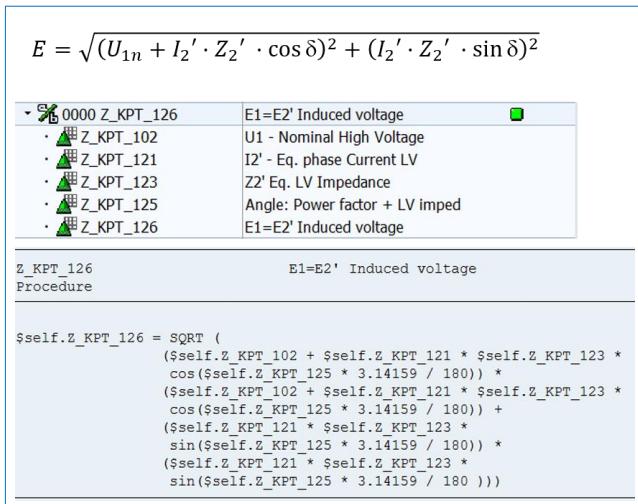


Fig. 4. Example of Induced voltage calculation by using characteristics and dependencies. Dependency Z_KPT_126 is created and all parameters inside equation must be created first as separate characteristics.

Next step after basic dimensions calculation can be vector diagram elements calculation. Calculation cannot be perfect, because it is not possible to have exact numbers for all six elements of equivalent circuit without proper measurement. However, results can be informative enough for the time being. Example for Induced voltage equation ($E_1=E_2'$ on Fig. 1) is given on Fig. 4. All results for one 150 kVA transformer [9] is shown in list form on Fig. 5.

| | |
|----------------------------------|----------------|
| Sn - Power (VA) | 150.000 VAM |
| U1 - Nominal High Voltage | 2.400 V |
| U2 - Nominal Low Voltage | 240 V |
| Cos phi Power factor | 0,800 F1 |
| R1 HV Phase Resistance | 0,200 Ohm |
| X1s Leakage Reactance | 0,450 Ohm |
| Resistance Ro | 10.000,000 Ohm |
| Reactance Xo | 1.550,000 Ohm |
| R2' Eq. LV Phase Resistance | 0,200 Ohm |
| X2s' Eq. Leakage Reactance | 0,450 Ohm |
| I2' - Eq. phase Current LV | 62,50 A |
| Angle: Power factor | -36,86993 deg |
| Z2' Eq. LV Impedance | 0,492 Ohm |
| Angle: LV Impedance | 66,03757 deg |
| Angle: Power factor + LV impeded | 29,16764 deg |
| E1=E2' Induced voltage | 2.427 V |
| Angle: Induced voltage | 0,35413 deg |
| Im - Magnetizing Current | 1,57 A |
| Angle: Magnetizing Current | -89,64587 deg |
| Ir - Core Losses Current | 0,24 A |
| Angle: Core Losses Current | 0,35413 deg |
| Io - No Load Current | 1,58 A |
| Angle: No Load Current | -80,83513 deg |
| I1 - HV Current | 63,65 A |
| Angle: HV Current | -37,86013 deg |
| V1 - Real High Voltage | 2.454 V |
| Angle: Real High Voltage | 0,70047 deg |
| Power Loss R1 | 781 W |
| Power Loss Ro | 589 W |
| Power Loss R2 | 1.758 W |
| Efficiency | 0,975 F1 |

Fig. 5. Results of Vector diagram calculation for distribution transformer 150 kVA, by using characteristics and dependencies.

Before starting of “Sales configuration”, the standard routing should be checked, especially for scheduling results. As mentioned before, for our model will be used the simple, one-level BOM approach. It means, all manufacturing activities should be defined in only one routing, as separate operations grouped in sequences. As many activities can start in the same time (sheet cutting and winding preparation, for example) more parallel sequences should be used to specifically define connections and relations between particular operations. Example of Gantt chart for one routing is given on Fig. 6.

Sales configuration starts by Sales order creation. This sales order is not for real, of course. It must be simulative, like the whole process. During the sales order creation, transformer should be precisely defined / configured, because after order is created, the business calculations can finally start.

Cost estimate is the first step in the business part of our model. Based on estimated number of working hours and unit prices for machine and labor activities, cost estimation for manufacturing activities can be created. Working hours defined in the Master Routing are multiplied by unit price defined for each production line and activity type.

With MRP (Material Requirements Planning) functionality it is easy to check availability of all materials required according to Master BOM. In order to use this functionality it is mandatory to have all important materials defined in BOM used in our configuration process. MRP will check the availability of all materials according to rule specifically defined for each material, in material master data. The main result of MRP is set of Planning orders. In our case, there will be one Planning order for production (with all operations included) and several Planning orders for purchasing, for not available materials. Planning order for production can be converted to Production order, but this is not mandatory for our model.

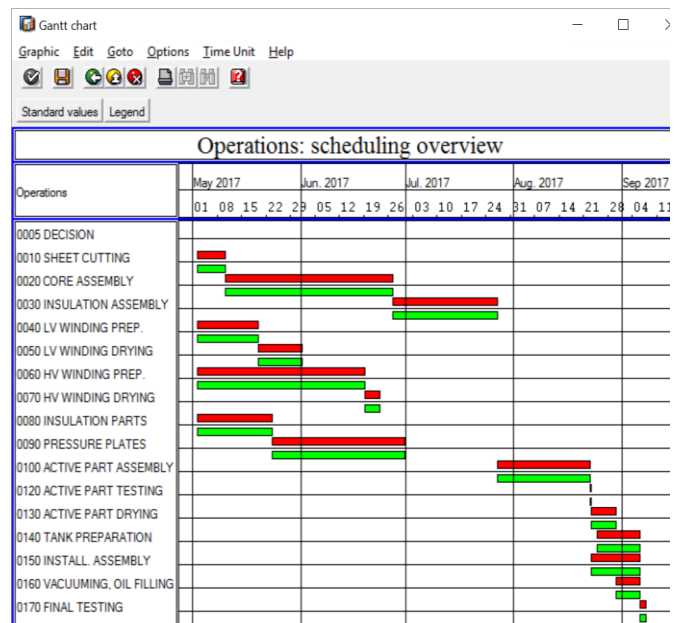


Fig. 6. Gantt chart as scheduling checking point for the Transformer Master Routing. Several main activities can start in the same time. Final testing is the last production activity.

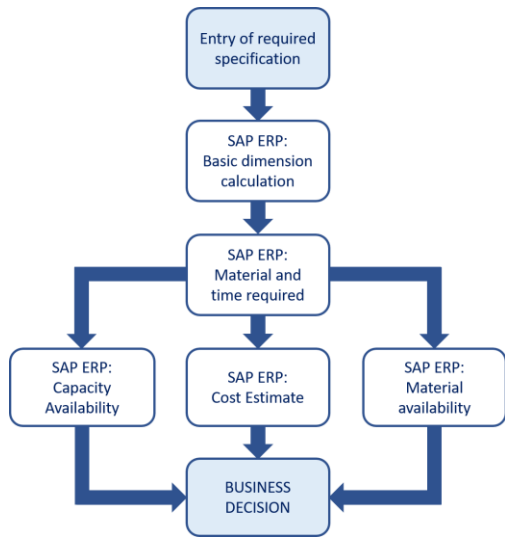


Fig. 7. The way from specification to Business decision using ERP as the only system needed.

Production dates defined in Planning or Production order are result of the Required date in Sales order and production time defined in the routing, for each operation. Of course, connections between operations are important too. However, production capacities are not checked at all.

SAP ERP system uses Capacity Leveling method for Capacity planning. This method consists of two steps. In the first step system uses unconstrained work centers. It means, any load can be placed on work center (defined in Production order) onto any period of time [10]. Then, in the second step there is a real capacity planning: system is checking the availability of required work centers and operations are dispatched to work centers according to availability and parameters defined in dispatching strategy. The name of this step in SAP is CRP (Capacity requirements Planning). With this functionality it is possible to check availability of all critical production work centers required, according to Planning or Production orders. This can be done by using Tabular or Graphical planning board for capacity leveling. In this way all critical manufacturing phases basic can be checked (and dispatched) quickly: core construction, winding, insulation, active part assembly, tank preparation, final assembly, testing, shipping, ...

Having all previous steps done, managers have all information needed for making quick decision: cost estimate, material availability and capacity availability (Fig. 7). They can decide if this possible project is good opportunity or not and if

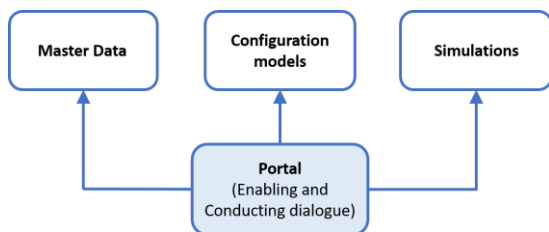


Fig. 8. Portal as a solution for easy using the complex procedure. All needed steps will be visible in one screen, so there will be no need for managers to have a skill of SAP specialist.

they maybe should assign part of the production process to subcontracting partner.

However, the whole story is not so simple to be handled. Model consists of many steps in different SAP ERP areas and functionalities, and person who would like to use it, must be a SAP specialist. This is not aligned with our basic wish, to have all required steps for quick analysis of new business opportunity in one system, to be used by managers, in an easy and simple way.

Possible solution for this challenge is to create a portal. Portal (Fig. 8) should have a link to all used functionalities, master data and configurations model. It should enable users to quickly do any simulation by simply choosing the correct icon on the screen and by defining the correct option. Portal should be created in the same ERP system as the whole model. If SAP ERP is used, then this can be done by ABAP programming. This part of the model is still not completed and we can only estimate what effort will be needed.

V. CONCLUSION

The decision making process in power transformer manufacturing companies can be improved by including technical calculations for rough designing procedure and forming the analytical model of transformer in ERP systems.

SAP as an ERP Business software is suitable tool for this idea. It is possible to create one (not so simple) model with integrative functionalities of basic technical and business calculations: Basic dimensions, Vector diagram elements, Cost Estimate and Availability checking for materials and capacities.

Regarding needed SAP modules, in this paper an option with standard elements of Production Planning, Controlling and Variant Configuration modules is used. Further improvements are possible by including some elements of PS (Project System) and CO-ABC (Activity Based Costing) SAP modules.

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