ICIC Express Letters
Part B: Applications
Volume 7, Number 5, May 2016

ICIC International ©2016 ISSN 2185-2766
pp. 1043–1048

DEVELOPMENT OF A MANUFACTURING SYSTEM SIMULATION FOR ELECTRICAL POWER TRANSFORMER SYSTEMS

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Received October 2015; accepted January 2016

Abstract. *This paper performs a simulation design and development method: combining an aspect-oriented approach and an object-oriented approach. This study has used an object-oriented approach to modularize the common actions of every process and an aspect-oriented approach to design and analyze a simulation that traces crosscutting concerns. The simulation, which was developed based on company A's actual electric power transformer system, is going to perform an evaluation analysis for the manufacturing process. The object-oriented approach allowed for the development of a control module for the manufacturing process, product characteristics, manufacturer management and operating hours.*

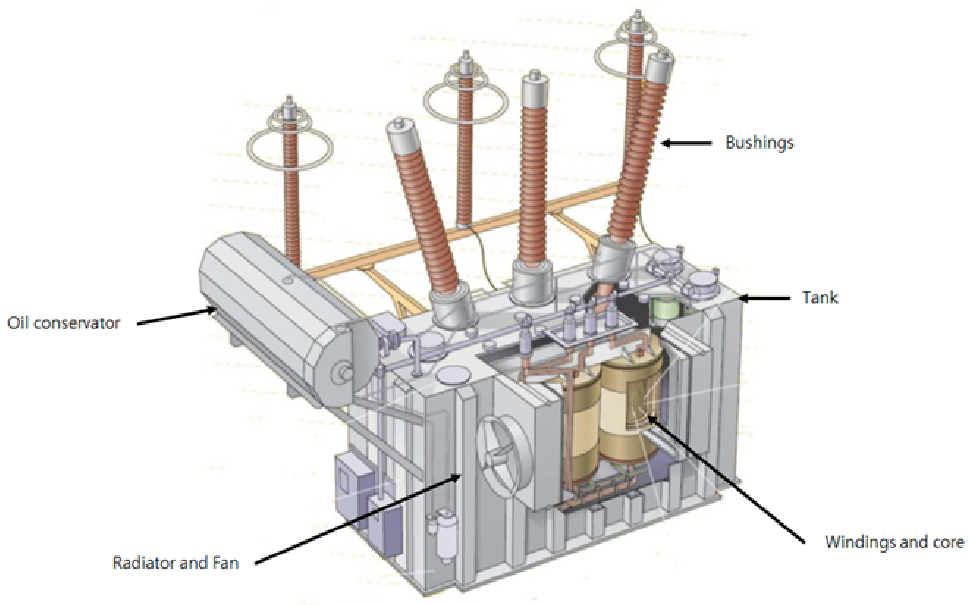
Keywords: Simulation, Electrical power transformer systems, Performance, i-AOMA

1. **Introduction.** Electrical power transformer systems are of great importance, especially for the developments of both plant and national core electrical industries. This is due to the fact that transformer systems themselves are core equipment in heavy electrical industries. While the manufacturing of electrical power transformer systems is a high-value added industry from the layout and design of the production process to its assembly techniques, it requires support at a national level to attain a competitive advantage. This support enables the effective control of electrical power based on the achievement of systematic development and manufacturing processes. However, since the manufacturing process for the system is based on multi-product and small-sized production on demand, the conditions of manufacturing are likely to influence output [1]. Therefore, it requires building a comprehensive manufacturing process to take design, analysis and operation into account to produce competitive products. Specifically, for a multi-product and small-sized production, systemic analysis of the manufacturing process is required. Accordingly, a recent analysis points to the necessity to adopt a system that is able to unitize the process to maximize profit margins and improve productivity. Such a system could be achieved by using simulation technology to develop a virtual manufacturing process simulation and real time performance analysis. The reason for using simulation technology is that it is easy to analyze the current manufacturing status and seek alternatives for improvements [2,3]. While current electrical power transformer systems are only focused on improving efficiency of power facilities in electrical fields, studies on effective manufacturing processes are way behind, overall. Also, studies on the systems applying simulation techniques to analyzing real systems considering various factors for design and plans for operation are not being actively discussed [4]. Therefore, this paper performs a

simulation design and development method: combining an aspect-oriented approach and an object-oriented approach. This study has used an object-oriented approach to modularize the common actions of every process and an aspect-oriented approach to design and analyze a simulation that traces crosscutting concerns [5]. However, considering that an aspect-oriented approach cannot perform the crosscutting concerns between developed modules, the study presented i-AOMA: the improved Aspect-Oriented Modeling Approach [6,7]. In other words, the main purpose of this study is to develop a manufacturing process simulation using the i-AOMA so that it can analyze the process systematically. The simulation, which was developed based on company A's actual electric power transformer system, is going to perform an evaluation analysis for the manufacturing process. This study is composed of four chapters. Chapter 2 describes the definition of transformer systems for electrical power; Chapter 3 presents the basic concept of i-AOMA, operations data required for the manufacturing process, and also performance evaluations conducted to simulate the manufacturing process. Lastly, Chapter 4 draws a conclusion.

2. **Transformer System for Electrical Power.** A transformer system for electrical power is the system that controls electrical power effectively to minimize the electrical loss, maintain the power load with a stable supply of electrical power, and eliminate unnecessary factors to extend the lifetime of an electrical facility. We focus on the LPT (Large Power Transformer) which is a kind of transformer system. LPTs are large, heavy pieces of capital equipment. LPTs are used to increase or decrease voltage in the electric transmission system. Power, as measured in volt-amperes, is typically transmitted at a high voltage and low current because transmission at higher amperages requires more cable, resulting in greater power losses, and is more expensive. LPTs have an "active part" where the electromagnetic induction occurs that consists of the core, the windings, and electrical insulation between the windings as Figure 1 [8].

LPTs are large, made-to-order products that are manufactured to the individual specifications of the customer. Once a producer receives an order, the first step is designing the transformer. The design of LPTs is complex, with optimum transformer design balancing the costs of materials electrical losses, manufacturing labor hours, plant capability



Source: U.S. International Trade Commission, 2011

Figure 1. Large power transformer showing major internal components

constraints, and shipping constraints, such as tunnel and bridge dimensions. LPT manufacturers work with customers starting with the design phase through the shipment and installation phases.

The steps in the general manufacturing process of this system are:
① Entrance of materials
② Assembly of medium plate and connection of wire
③ Assembly of outer box and connection of wire
④ Inspection
⑤ Shipment of products

Through this process, the products are to be manufactured. The first step is to identify the specification and amount of resources based on an order draft. The second step is to attach the electrical facility of the system to the medium plate by marking, drilling, and tapping. The outer box is attached to the medium plate, then numbered, and compressed together. Once the outer box and medium plate are wired, the transformer system for the electrical power is complete. After inspection to ensure quality, they are ready to be shipped. The outer box, which is designed to protect the circuit board and electric power control system, is heavy and large, which delays the processing time for assembly and wiring to days. Aside from the long processing time, the system starts its process after the order is placed by customers and related resources are put in the manufacturing process according to amount and when the orders are placed. Every step of the manufacturing process is given a classification code based on components, which enables each step to be controlled. Therefore, when the order is placed, the components are classified by GT (Group Technology) and the products enter the process.

3. Virtual Manufacturing Process for Transformer System of Electrical Power.

3.1. Definition of i-AOMA.

The current simulation applied in the study used an object-oriented approach for analysis. While the object-oriented approach expresses an implementation of the system in vertical structure enabling an effective simulation of modeling and design, this approach only considers vertical or primary factors. Therefore, it is ineffective at accommodating the crossing concern of where numbers of modules can spread. Considering this weakness, an aspect-oriented approach has been utilized to present an alternative way to modularize the common area, eliminate repetition, as well as change and reuse the model such as Figure 2. As a result, it will improve efficiency. The

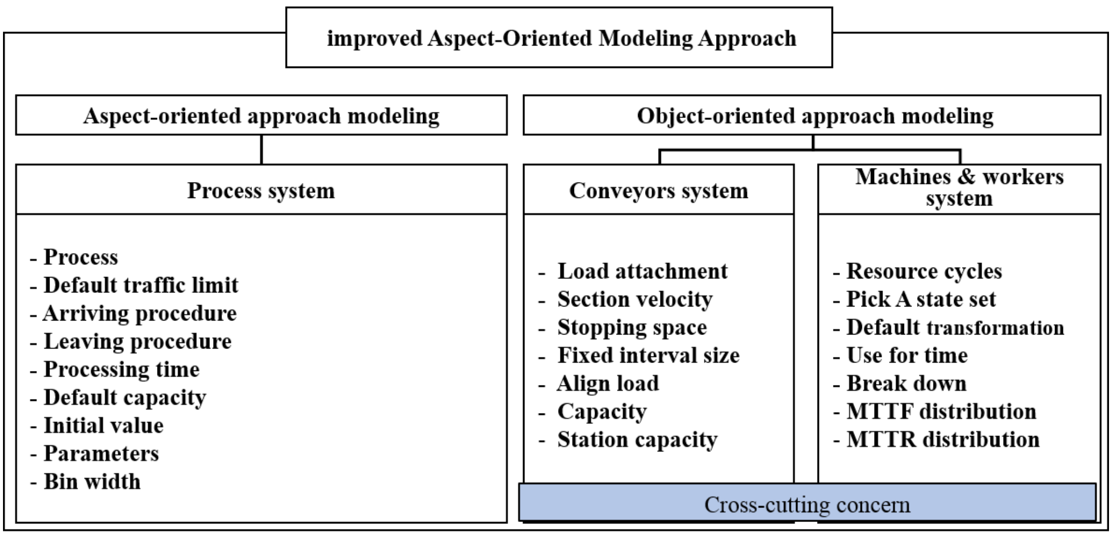


Figure 2. Concept of the i-AOAM

object-oriented approach will still be used to develop physical control over the system, while managing the system will be developed by the aspect-oriented approach.

3.2. **Analysis of manufacturing process of transformer system of electrical power.** First, this study on the purpose of developing a manufacturing process simulation was developed after conducting a manufacturing process analysis on Company A, which produces transformer systems for electrical power. The resulting data was used as raw data for the simulation. There were four kinds of products produced in the manufacturing process, whose production time varied from 16 to 39 hours. The monthly average amount of products produced is 46.5 units; therefore, an average of 2.3 units are produced each day. The total processing time is 8 hours, which consists of an average net working time of 6.5 hours and a rest time of 1.5 hours. The number of people working on each process is three persons for receiving, evaluating and shipping, and four persons for medium plate and outer box wiring assembly. Overall, there are 17 people involved in the manufacturing process. The concurrent processing ability is to be three units for receiving the resources, four for medium plate and outer box assembly, and three for evaluating quality.

This manufacturing process is to produce an overweight transformer system which needs one overhead traveler and one tow forklift. The overhead traveler has a speed of 1.5 km/h and is used to move between each process. The forklift has a speed of 20 km/h and is used to transfer control panels, raw materials and intermediary goods.

3.3. **Implementation of simulation.** The simulator developed through this study can be applied to analyze the operational ability of the manufacturing process in the Windows operating system through AutoMod [9]. The AutoMod program shows physical limits precisely in three dimensions in terms of distance, size and space. Also, it is software that provides various libraries that are able to implement the systems of manufacturing, resources and shipments, and enables users to design simulations easily and quickly. Therefore, the simulator based on AutoMod can improve visual effects by implementing the manufacturing processes in real time, and its three dimensional modeling enables users to monitor the flow of processes in any direction. In addition, an object-oriented approach helps to develop the controlling system overseeing the manufacturing process, product characteristics, manufacturers and operating time. The simulator is easily able to adjust variables in the manufacturing processes, such as resetting the process or adding

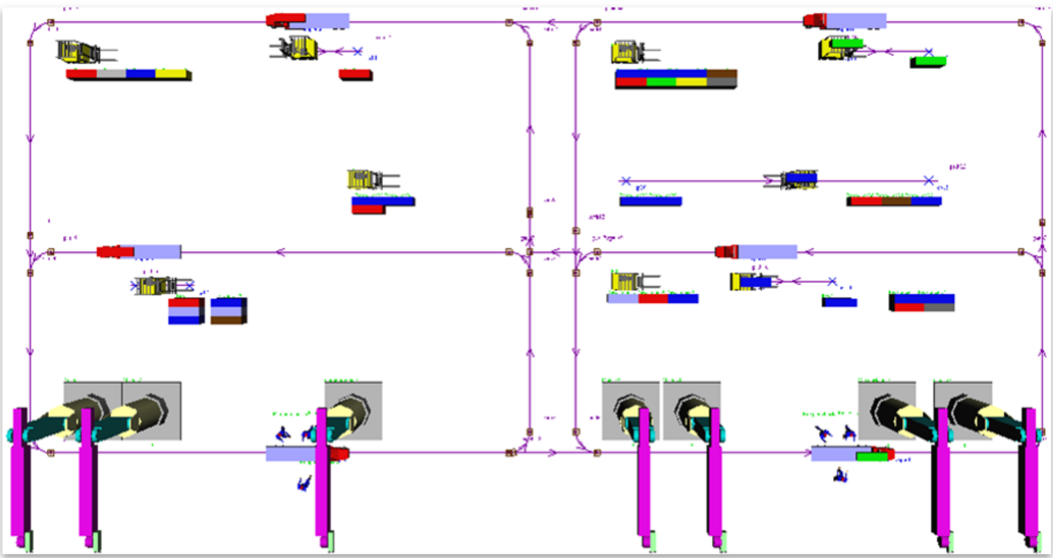


FIGURE 3. Simulation realization

a new process. Setting the process and entering the data follows a GUI (Graphical User Interface), which is easy to move or change using a computer mouse on a Windows screen.

In addition, the various input data is subject to the users' demands, which allows for different scenarios in the manufacturing process to conduct a capability analysis. The actual operating data – the amount of manufacturing, working hours, working space and arrangement of manufacturer – from Company A was used in the simulators. The entire simulation period was applied over 260 days per year; after 30 days, the system went into stable status. Receiving resources had 580 simulators processed with a waiting time of 5.3 minutes. Assembling medium plates and wiring had 570 systems completed. Product shipping had the longest waiting time of 23.2 minutes, while receiving resources had the least with 5.3 minutes. Calculating the manufacturers' working efficiency for each process resulted in the highest percentage, 69.5%, in the process of shipment, while the lowest was in receiving resources. The workload in this study is to consider the net working hours excluding break time. Thereafter, the workload assigned to each shipment is larger than the other processes, which can result in the highest work efficiency. The overhead traveler used for the manufacturing process was utilized 2,100 times in total, while the forklift was used 730 times, which is the daily equivalent of having the former operate 7 times a day and the latter operate 2.4 times a day. Accordingly, simulator results varied only slightly from actual results from the manufacturing process.

4. **Conclusions.** The primary purpose of this study was the development of a manufacturing system simulation for electrical power transformer systems. To achieve this, a simulator was developed by applying the i-AOMA method which combines an aspect-oriented and an object-oriented approach. The aspect-oriented approach helped to develop a way of conducting a consecutive process based on events, from the entrance of components to production and shipment. Also, the object-oriented approach allowed for the development of a control module for the manufacturing process, product characteristics, manufacturer management and operating hours. The simulator developed through this study was designed to change the process or data by clicking on a Windows screen, which was composed of the GUI method. Various input data can be altered to suit the needs of users, which allow different scenarios to be applied in order to analyze the change of process capabilities. Specifically, the process considered in this study is based on GT; therefore, there is much difficulty in estimating the capability of the process. However, the simulator overcame this limit and thus was able to comprehend various operating information for a new process design and determine the capability of the system for electrical power. Further research will be conducted to find out the most effective input variables that maximize the output variables. The experimental plan for further research is to reduce the experimental trials of simulations and to estimate the best input variables.

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