Studies on intelligent model of circuit breaker

W. Zhu\textsuperscript{1,2}, B. Eynard\textsuperscript{1}, M. Bricogne\textsuperscript{1} & W. Wan\textsuperscript{2}

\textsuperscript{1}Sorbonne Universities, University of Technology of Compiegne, France
\textsuperscript{2}Institute of Smart City (Sino-France), Shanghai University, China

Abstract

Aiming at the requirements of customization, design quality, and design efficiency, this paper studies the techniques of intelligent model in order to reuse the knowledge of historical accumulation. First, the definition of intelligent model is presented. Second, the paper studies the process of how to realize intelligent model, including extracting key geometric parameters, defining feature control parameters, controlling topological structure, and reasoning model rule. Finally, an application case of a molded case circuit breaker (MCCB) demonstrates the feasibility of intelligent model. The results show that intelligent model techniques have realized the intelligent design effectively. These techniques can automatically access the design knowledge, and significantly improve the reliability of product design. The human–machine interface (HMI) can greatly improve the design efficiency. Therefore, intelligent model techniques can significantly enhance the competitiveness of enterprises.

Keywords: intelligent model, molded case circuit breaker, human machine interface, knowledge, parameter

1 Introduction

An electric power system is a network of electrical components used to supply, transmit, and use electric power, the transmission system that carries the power from the generating centers to the load centers and the distribution system that feeds the power to nearby homes and industries [1]. Circuit breaker manufacturing is a key part of the power equipment manufacturing industry. It plays a very important role in the whole electric power industry.

Circuit breaker is an important equipment of a power grid. In terms of the individual components, it is second only to the generators and transformers; In terms of
need, number, and the percentage of power equipment investment, it comes before them [2]. Thus, electrical switches play a crucial role in building a country’s electricity, the molded case circuit breaker (MCCB) is one of the most commonly used components in circuit breakers [3]. MCCB is used by electrical engineers in power distribution system designs primarily to protect low-voltage electrical equipment and circuits [4]. An MCCB has three operation modes: ON, OFF, and TRIP. MCCBs are one of the most widely used circuit protection devices in low-voltage (less than 1,000 V) applications [5], which is used in low-voltage distribution circuit, motor, or other electrical devices, and it performs the functions of make-on, carrying, and breaking current in normal or abnormal conditions such as short circuit [6]. When a short circuit current comes, the movable contact will separate from the fixed one rapidly and an arc will occur in MCCB [7].

With the development of power construction and diverse needs, customized demands of MCCB are growing. The technical requirements for each batch products are different, enterprise have to adjust the product model according to customer requirements. Therefore, MCCB has become a kind of typical multi-varieties products that are manufactured in small batches, this shows that the MCCB customization demands become higher and higher. The requirements of one-time design accuracy, reducing manufacturing cost, and raising the product quality and stability to higher levels bring great pressure to the product design, manufacturing, and production management; this shows that the customer demands become higher and higher in MCCB design quality and efficiency.

The digital model techniques have made many achievements recently; intelligent design is also applied in many related fields, for example aircraft, engineering machinery etc. However, the techniques in MCCB design are still relatively outdated. A new approach to designing MCCB could be brought about through studies on the intelligent model techniques of MCCB. This is necessary to enhance the core competitiveness of enterprises.

Intelligent model techniques are studied by authors. These techniques not only can rapidly and flexibly complete the design of MCCB, but also can meet the requirements of customization. Therefore, these techniques can greatly enhance the competitiveness of enterprises and improve the independent development ability as well as the overall technology level. Finally, through these techniques, the transformation and upgrading of traditional products can be promoted.

2 Review of related work

In the research field of MCCB, the United States, France, and Japan have more advanced technology. The development trend of MCCB mainly is modular, high breaking capacity, intelligence and security, etc. [8]. The MNSiS MCCB product developed by Swiss ABB Company is highly modular, the design can be easily changed to meet the requirements of customers, and without any hardware device replacement its protective function can still be upgraded according to customer requirements [9]. OKKEN, Blokset series MCCB developed by the French Schneider Inc., partly use intelligent design, their design and installation is very simple and
safe [10]. Wolfgang Hauer and Peter Zeller did the tests of low-voltage MCCB, and the test results indicate that MCCB performance can vary significantly even though using the same design principle due to other design variations [11].

However, in China studies on MCCB began relatively later, the technique concerned is also relatively outdated. By 1958 China developed the first generation of universal circuit breaker DW0 type, the rated voltage DC 440 V, 380 V AC [12]. Tao Liu of the Xi’an Jiaotong University presented the optimum design method of moving characteristics of 126 kV vacuum circuit breaker (VCB) with spring operation mechanism, virtual prototype of 126 kV VCB are set up, and the dynamic and kinetic characteristics are described as well [13]. Du Taihang of Hebei University of Technology summed up the basic requirements of instantaneous protection of reliability test on MCCB, put forward the design idea, which adopted the main circuit of computer-controlled and the detection control circuit, designed a voltage and current control system with a voltage regulator of position feedback [14]. Degui Chen of Xi’an Jiaotong University regarded that pressure rise of the gas due to high current arc in the arc chamber of MCCB, which may accelerate the arc movement and improve the corresponding interruption performance. They calculated the pressure rise and analyzed its characteristics; they demonstrated that the pressure rise in the arc chamber will be increased with the higher arc current, less venting, and the existence of gassing material [15].

In the field of intelligent design, research activities are active, mainly as follows. Texas A&M University studied a new and efficient collaborative intelligent computer-aided design technology, under the collaborative design, through the analysis of the history of the design to reduce redundant design stage, at the same time to generate an effective reverse engineered processes, identify and prevent unnecessary design, and thereby achieve the goal of the final design [16]. Duffy Sandra and Duffy Alex of University of Strathclyde present and explore the possibility of realizing “learning” assistance in Intelligent Computer Aided Design, “Controlled” computational learning is proposed as a means by which the Shared Learning concept can be realized. The viability of this concept is explored by using a system called PERSPECT. PERSPECT is a preliminary numerical design tool aimed at supporting the effective utilization of numerical experiential knowledge in design [17]. A knowledge-based system is called Sheet Metal Advisor and Rule Tutor (SMAART), and acts as an advisor to engineers that can design sheet-metal parts for high volume – low-cost production using progressive dies. When SMAART discovers the violation of a design rule, the engineer is alerted via an advisory window and then has the opportunity to change that part of the design to improve its manufacturability [18]. Nomaguchi, Taguchi and Fujita propose a concise and comprehensive format for describing the knowledge of engineering analysis, called Engineering Analysis Modeling Matrix (EAMM). EAMM is a matrix of two axes, that is, a modeling aspect axis and a modeling level axis. The design of a water heater is used as an example to demonstrate the capability of EAMM for description and management of engineering analysis modeling knowledge [19]. Hamraz, Hisarciklilar and Keyvan Rahmani et al. propose a physical interface data model to define the interface design space and thus support interface
definition. This data model is integrated into the system architecture definitions and uses shared design parameters to detect risk and conflicts in collaborative design [20]. Young-Jae Ryoo of Mokpo National University described a platform design of agricultural robots inspired by farmer assistance (AGRIFA). The AGRIFA has functions of an automatic driving, a farmer following, and an automatic agrochemical job. It would replace farmers that have to work in a hazardous and harmful environment [21].

In view of the MCCB and intelligent design research, these researches mainly focus on the reliability of the MCCB and improve related parts technology, but researches on the intelligent modeling of MCCB is relatively less. In the aspect of intelligent design, these researches in the HMI and integration of engineering knowledge are less. This paper studies on intelligent model techniques, it can achieve internal model association and external models associations, also can integrate knowledge rules into the model, at the same time provide users a customized interface. At the time of design, engineers only need to input the requirements indicators in the interface to meet the needs of user, knowledge rules will invoke knowledge base according to these indicators, and then automatically changes the specific parameters, and finally the model is automatically generated. Through the intelligent model techniques, design efficiency and quality will be improved to meet higher customer demand.

3 Studies on intelligent model

Intelligent model techniques will provide for users to customized human machine interface, automatic access to the knowledge base. According to user input indicators, it will automatically seek solutions, through the solution of specific parameters to complete model shape and topology changes.

According to the above definition, intelligent model techniques can capture design and process information, at the same time they define various engineering product specifications. It provides a set of characteristics of the adaptive process, which is far more than the traditional scope of geometric characteristics. These characteristics have two different types, one is the application characteristic, which encapsulates the product and process information; the other is the behavioral characteristic, which includes engineering and functional specification. The adaptive process characteristic provides a lot of information to further determine the design intention and behavior, and is an integral part of the product mode that makes the intelligent model techniques have a high degree of flexibility, and thus respond quickly to environmental changes (Fig. 1).

Intelligent model techniques are mainly done through defining geometric parameters and topological structure. Geometric parameters are divided into two parts, one is key geometric parameters; the other is feature control parameters. Key geometric parameters mainly control the size of the model, such as the length–width–height of the model, by changing the value of the geometric parameters such as length–width–height, can change the size of the model, and meet the design requirements. Although the key geometric parameters can change
the model specification size, but cannot change the shape of the model. Change the shape of the model is done by defining feature control parameters, through feature control parameters to suppress or display the feature of the model and complete the changes of the model shape. Topological structure is also divided into two parts, one is topological structure control and the other is model rules control. Topological structure control is similar to feature control, by selecting different values to hide or display parts corresponding to the topological structure. Model rules control is integrated knowledge rule into model, through knowledge rule access into knowledge rule base, drive the change of model parameters.

Figure 2: Framework of intelligent model of product design system.

The framework of intelligent model techniques product design system is shown in Fig. 2. Designers through the HMI enter the customer requirements initial information, management system will access the knowledge base to obtain products information and find the best solution. And product design plan, in turn,
will make up the knowledge base to improve more information for use next time. Knowledge base stored in a large number of standard data, examples, engineering data, experience of experts in this field, knowledge and knowledge rules. When the product design scheme to achieve the best, intelligent model techniques will drive CAD application, the system will automatically complete the design, thus realizing the intelligent modeling design.

The available intelligent model techniques tools include Siemens/NX software and NX WAVE Techniques. Establishment of intelligent model includes building parametric model, then extracting the key parameters, defining feature control parameters and defining topological structure control parameters, finally defining rules parameters. The development of HMI is through NX/Menu Script and Open UIStyler Technology. Menu Script is a special module NX that provides for custom menu and can generate your own menus. Open UIStyler is used to create a dialog module provided by NX; this technology can generate many dialog boxes, for example, buttons, radio buttons, text boxes, list boxes, etc.

Intelligent model technology is mainly based on the parametric model to extract the key parameters, define feature control parameters, define topological structure control parameters, and define rules control parameters. Specific needs have to be fulfilled, as shown in Fig. 3. But between these four steps there are isolated, extract

![Parameterized Model Diagram](image)

**Figure 3:** Intelligent model flowchart.
key parameters that can be controlled by feature control parameters, topological structure control parameters or rules control parameters, that is to say can establish relationship in key parameters, rules control parameters, topological structure control parameters, and rules control parameters, and achieve more intelligence.

4 Application case of intelligent model techniques

In this paper, MCCB overall design as an example to validate the intelligent model techniques. MCCB is also over-current protection devices often with thermal and magnetic elements for overload and short circuit fault protection (Colin Bayliss & Brian Hardy, 2012). General MCCB mainly includes the plastic shell, institutions, trip, arcing chamber, dynamic contact mechanism, static contact and nut screw gaskets and other parts. According to the division of parts, MCCB intelligent design programs contain plastic shell design, mechanism design, tripping device design, design of static contact, arcing chamber design, and the overall design (Fig. 4).

![Intelligent model techniques application menu.](image)

The overall design of MCCB is in complete design of plastic parts, action mechanism parts, and release component parts, which is based on the previous work. The overall design of MCCB divided into six steps, the first step is to select the function type according to manufacturing standards, manufacturing standards for MCCB is created primarily for the purpose of setting performance criteria of manufactured products, the function type mainly have basic plastic shell type circuit breaker, with residual current circuit breaker, intelligent adjustable circuit breakers. The second step is to select frame current parameters, mainly includes the frame size rated current $I_{\text{nn}} = 100, I_{\text{nn}} = 160, I_{\text{nn}} = 250, I_{\text{nn}} = 400$ etc. The third
step is to choose breaking capacity; competence rated limit can choose the C type, S type, R type etc. The fourth step is to choose rated current, when frame current parameters is selected as 250, rated current should be less than frame current and can be selected as 250, 225, 200, or 180. The fifth step is select affix, can choose appropriate operation type, have two kinds of operation type: electric operation and turn the handle operation, at the same time can be chosen affix type, affix type have shunt tripping device, under voltage tripping device, auxiliary contacts, alarm contacts four types. The last step is to show previous design information to determine whether the design meets the requirements, if met can select the option to generate the model, then model design is completed.

Operation: Circuit breaker design – the overall design, as shown in Fig. 5.

Figure 5: Function type selection dialog

This step chooses the SM50 function type, clicks it when meeting requirements; click on the different labels dialog into the design of the various steps, the corresponding dialog box shown in Fig. 6.

The last step as shown in Fig. 7, the purpose is to look at MCCB related information, choose whether to generate models, information will be shown after click the check information button, reaction in the design of information; click OK button, it will generate the model.

When selecting the following two sets of parameters, as shown in Fig. 8, will in turn generate two models.
Figure 6: Dialog of the overall design.

Figure 7: Collect information dialog box.
Model 1 parameters: Basic molded case circuit breaker, \( \text{Inm} = 250 \), C type, rated current 250, turn the handle operation, choose the shunt tripping device, under voltage tripping device and auxiliary contacts, select generate model.

Model 2 parameters: Intelligent adjustable circuit breakers, \( \text{Inm} = 160 \), C type, rated current 160, turn the handle operation, choose the shunt tripping device, under voltage tripping device and auxiliary contacts, select generate model.

Through the application of MCCB intelligent modeling techniques, verify the feasibility of intelligent modeling techniques. Through extracting the key parameters, defining feature control parameters, defining topological structure control parameters, and defining rules control parameters, complete the MCCB intelligent model. This intelligent model techniques increase the HMI. The designer only needs to perform simple mouse clicks and related parameters settings can design the complicated model.

5 Conclusion

This paper studies intelligent model techniques. The techniques include defining intelligent model, extracting key geometric parameters, defining feature control parameters, controlling topological structure, and reasoning model rule. Finally, MCCB is taken as an application case to verify the feasibility of intelligent model. The results show that intelligent model techniques have realized the intelligent design effectively. The application of intelligent design techniques can significantly increase the MCCB design automation, and optimize the whole design process of MCCB products. Then it can realize the intelligent design and significantly improve the reliability of the product design. Based on a fully reusable knowledge base, using the previous design experience, when engineers design a new product, they only need to enter the relevant parameters and rules, a new model of MCCB can be quickly generated. This greatly improves the design efficiency so that design engineers can put more energy and more time into the innovation of product design.
Based on the studies of the intelligent model techniques, it can help designers free themselves from tedious repetitive modeling, it can promote the development of the product quality and efficiency, and it can shorten the product development cycle. Therefore, it can improve enterprise’s market response ability and finally enhance enterprise competitive ability.

References


