A methodology of module portfolio planning for service solution layer of Product-service System

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Abstract: The key to solving contradiction between personalization and low cost is to realize the modularity of PSS. In order to achieve maximum customer satisfaction andthe lowest lifecycle cost for PSS, module portfolio of services solution layer of Product-service System(PSS) should be planned reasonably. Firstly, a methodology of module portfolio planning for PSS service solution layeris proposed, the methodology consists of four phases (including five steps), which namely are service needs acquisition phase, finding principle solution and building modular rough structure phase, configuring principle solutionportfolio phase and evaluating modular solution phase. Detailed technical steps and implementation methods for each stage are presented. Secondly, a evaluation method for PSS module portfolio solution based on utility price ratio is proposed. Based on customer utility and lifecycle costs of PSS,the solution was carried out with the maximum ratio between customer satisfaction and the usage. Finally, a case study onPSS solution of a power transformer is carried out to validate the methodology proposed in the paper.

Key words: Product-service System; Modular design; Service solution layer; Utility; Portfolio planning

1. Introduction

In recent years, the traditional business model that only manufacturing and sale of physical products shows its obvious drawbacks:profit margins continues to decrease. The product providing model toward"value-added services" has gradually become a mainstream, this is the product service systems (PSS). PSS concept appeared in the 1990s, which is a "physical product and/or product services"value delivery systemoriented-to consumer,and by providing various types of physical and services combination solution portfolio to consumers to achieve the added values (Goedkoop et al.,1999;Mont,2002). PSS consists of physical products, integrated service product, function-oriented PSS and result-oriented PSS (Tukker and Tischner, 2006; Li et al, 2012).

Although PSS can bring more profits for the enterprises, get a reasonable PSS configuration solution so that achieves the maximum profitat the lowest cost is the real purpose of implementing the PSS for enterprises. As customer’s individual needs of PSS intensifies, the costs of providing PSSincreaserapidly. However,the key to solving the conflict between personalization and low cost is to fulfill the modular design for physical product and service aiming to customer needs.By establishing a series of standard physical product and service modules can make internal modules less diversified, which also can reduce production costs and reduce environmental influences(Ulrich, 1991).In order to enhance the potential after the integrationof physical product and service, Aurich first proposed a modular design framework for PSS, and established modular principles for technical PSS(Aurich et al., 2006; Aurich et al., 2007; Aurich et al., 2009). Then, Li presented a modular generalized product and service system with four levels, were namely customer requirement layer, service solution decision layer, parts layer, and instance implementation layer (Li, 2013).The customer requirement layer mainly obtainsinformation on user needs, and classifies the needs into functional service needsand non-functional service needs. The service solution layer contains various components to meet customer needs, including physical product components, function-oriented service components, result-oriented service components, other types of components.By combining and planning customer's needs for these components, they can get the best service solution with customer's highest satisfaction and manufacturer's maximum profit. The main function of parts layer is to configurebest solution with the lowest-cost products and services in the configuration design system, which based on the optimal customer demand solution in service solution layer. The instance implementation layer is to carry out the supply and operation of modular instance after getting modular PSS in the product platform (Li, 2013). For the product provider, the optimization and positioning for PSS is very important step. Therefore, in the four-lever structure of PSS(customer requirement layer, service solution decision layer, parts layer, and instance implementation layer), the service solution layer is the connection point between the users and manufacturers,through the primary optimization configuration of service solution in this layer, we can get the maximum customer satisfaction, whichprovides personalized customer service solution; at the same time, It can determine the lowest cost. So the optimization configuration in service solution layer is the most important stage in achieving product configuration and planning. Researches on the service solution layer of PSS has the main problems in two aspects:

(1)Lack aportfolio planning methodology for the PSS service solution layer. Currently, The research on the portfolio planning methodology for the PSS service solution layer is still insufficient. Firstly, the methodology can guide how to get the customer's needs, and to find principle solution.Then, build the modular rough structurebased on the functional structure mapping principle, and achieve the principle solution portfolio planning and solution evaluation. The whole process is the basis for the establishment of PSS modular platform.

(2) Lack an evaluation method on PSS module portfolio solution. In PSS planning stage, we must consider user preferences on physical products and services in the market, and only by providingPSS that the customerslove, they will have the desire to buy it. Meanwhile, the fierce market competition makes the price of PSS also become an important factor to determine whether the customerswill purchase. Therefore, It is necessary to establish an evaluation method on PSS module portfolio solutionbased on customer preferences and PSS lifecycle cost, and obtain the a series of optimal module portfolio solution with optimal utility price ratio, which provides decision making on building product platform and the module division on parts layer.

Based on the above analysis on the problems of module portfolio planning for PSS service solution layer, this paper presents a portfolio planningmethodology on PSS service solution layer, and achievesa reasonable evaluation on the combination of PSS module solution. The main structure of this paper is as follows. The second section summarizes the research overview on PSS module portfolio planning methods; the third section proposesa four-stagereference modelon the portfolio planning process of PSS service solution layer; the fourth section acquires and classifies the PSS service needs; the fifth section finds principle solution for service needs and builds modular rough structure; the sixth section achieves the module combination of PSS principle solution; the seventh section puts forward a modular solution evaluation method; the eighth section takes transformer equipment as an example to verifythe proposed methodology. Finally, discusses and summarizes the proposed methodology.

2. Research overview

2.1 Modular configuration design of PSS

Currently, modular design is an effective method to achieve the rapid implementation of PSS with low cost, PSS modular design has become a hot topic in the field of PSS. In recent years, with increasingly customer's demands for personalized products and services, physical products and services needed to be provided with more and more individuation and variability, mainly reflected in the individuation of physical productsindividuation, the individuation of service content and the variability of service selection and use (Jiao et al., 2003; Sundin et al., 2007).With the emergence of PSS strategy, the individuationand variability of products and servicesin PSS will inevitably lead to the increase of costin enterprise's management, design, manufacturing and supply chain (Sundin et al., 2007), the traditional modular design methodology needs to be extended into the PSS field(Aurich et al., 2006).

Aurich first proposed a modular design framework, principles and configuration designmethods of PSS system;establisheda set of modular realization principle for technical PSS, and proposed a process library to design and manufacture of technical PSS, also to select and combine process modules (Aurich et al., 2006; Aurich et al., 2007; Aurich et al., 2009). The key to solving the conflict between the personalization and low cost is to achieve the physical product and service modularity oriented to customer, product and service modularity strategy can be applied to reduce the complexity of product engineering (Welp et al., 2008).Hara analyzed and modeled eight well-known types of PSS from three viewpoints: the state of receivers, functions, and attributes of entities, which contributed to configuring modules of product-service combination toward a design of new PSS(Hara and Arai,2010).Wang did research on the parallel PSS modular development and understanding the relationship between physical products and services. Heproposed a modular PSS development framework, in which the modular development process can be divided into three partsby order: functionality, product and service modularity, QFD method and Portfolio technology were used to achieve the modular development of PSS(Wang et al., 2011). In the modular design of PSS, clarifying the relationship and interaction design process of the physical module and service module is the most difficult and most important point. In this aspect, Li established a general modularization process for integrated service product, and presented a three-phaseinteractive module partition method of integrated service product.The product service was divided into functional services and non-functional services, andused the functional services to clarify the interaction relationship between the physical module and service module, and achieved the organic integration between the physical module division and service module division (Li et al., 2011).

2.2 Product planning and positioning

For the product providers, productoptimization positioning is a very important decision step. To solve this problem, Shocker and Srinivasan developed a conjoint spatial model framework based on consumer preferences to identify and optimize new products in 1979(Shocker and Srinivasan, 1979). After that, scholars began to do extensive research on product positioning. The main study was divided into four phases(Shockerand Srinivasan, 1979; Kwong et al., 2011)：(1) Target market segmentation need to be identified. The method is based on market segments and product replacement (Urban et al., 1993). (2) existing products and competitive products of the enterprise can be seen as the product space pointswith lower latitudes, the market positioning method includes conjoint spatial analysis method, such as the key factor analysis, discriminate analysis and simulation (Huber and Holbrook, 1979; Shocker and Srinivasan, 1979). (3) Through the consumer selection model of existing product to predict the consumer's potential demands for new products (Ben-Akiva et al., 1997). (4) In the early stage of product development and planning, use product selection model to optimize and position new products, the common methods are branch-and-bound (McBride and Zufryden, 1988),divide-and-conquer (Green and Krieger,1989), dynamic planning (Kohli and Sukumar,1990), game theory(Chan,1994),GA searching algorithm (Gruca and Klemz, 2003; Jiao and Zhang,2005) and house of quality function (Kwong et al., 2011).

The above research overview provides us with some information on two aspects: (1) The research object of product positioning and optimization is traditional physical product; (2) research contents expand to quantitative evaluation model oriented to user preferences and cost, the cost estimationmainly based on the manufacturing costs of physical products (Jiao and Zhang, 2005; Kwong et al., 2011). However, the concept and aim of PSS has great difference with traditional physical product, so that the customer experience and satisfaction, value-added and other constraints goalsbecome more important for PSS, the cost extends to the whole life cycle of product and service. Thus, the conventional optimization and positioning decision methods need to improve and extend.

3.A four-stage reference model on the portfolio planning process of PSS service solution layer

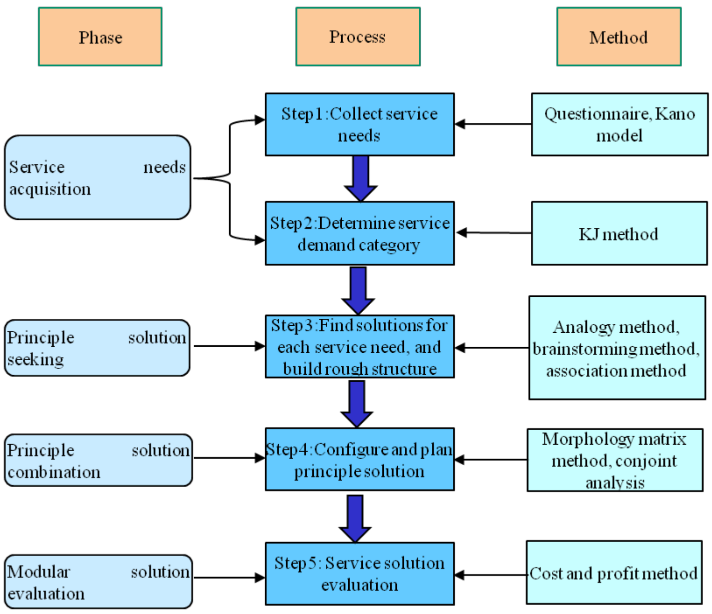

Fig.1 A four-stage module portfolio planning process model for PSS service solution layer

The module portfolio planning methodology of PSS service solution layer contains module portfolio planning process and corresponding methods, the methodology consists of four phases , which are service needs acquisition phase, principle solution seeking and modular rough structure building phase, principle solution portfolio phase and modular solution evaluation phase. Every stage consists of several technical steps and methods,the four stages consists of five steps, the specific process are as follows.

Step 1: Collect service needs. In order to meet customer's service needs, It is necessary to to acquire the service needs of different levels and different groups through effective methods. Firstly, obtain quantitative customer needs information usually through questionnaires. Then, by using Kano model to segment and understand customer needs, customer needs can be divided into basic needs, performance needs and excitement needs, classify and organize customer needs for the product planning of different types of PSS (Kano et al., 1984).

Step2: Determine service needs category. Customer demands obtained from market research, which are usually expressed in their own ways, so it need to be further selected and classified. KJ method can be used to organize and merge customer needs, customer needs usually organized into a multi-level tree structure, the lower level of customer demands are used to define and describe the customer demand items of upper level (Che and Yang, 2008).

Step3: Find solutions for each service need, and build rough structure. For each service need, it needs to find some principle solutions, and forms a congregation contains several principle solutions. Solution congregation can be managed by using the morphological matrix, in which the principle solution are stored according to the type and complexity. Solution congregation is used as a reference when carrying out service solution combination, acting as the role of seeking the principles and building solutions field for service needs(Pahl and Beitz, 1996). According to the principle solution, build rough modular structure of PSS, which provide support for the module division of PSS parts layer.

Step4: Configure and plan principle solution. In order to achieve the user's service needs, the principle solution for each service needs from the principle field must be combined into a PSS product structure.The process that combines the principle solution into a whole PSS solution can be carried out by morphological matrix methods.

Step5: Evaluate the PSS combination solution. A variety of service solution portfolios can be obtained by morphological matrix method. However, each solution portfolio has its own characteristics, it is important to determine which is the most optimal combination to meet the customer's needs (Pahl and Beitz, 1996). In this paper, the optimization method (maximum utility price ratio method) is used to evaluate services solution portfolio, and obtains a series of optimal solutions.

4.Collect andclassify service needs of PSS

4.1 Collect service needs of PSS

PSS service needs mainly includes three parts: the description on customer demand, the importance of customer demand, customer satisfaction on the product needs of this company and other competitors.In three parts, the description on customer demand are qualitative information, the latter two parts are quantitative information (Che and Yang, 2008; Chaudha, et al., 2011). The collection of PSS service needs includes four steps.

(1) Determine a reasonable investigation object. PSS respondents include physical product and product life cycle services related to the physical product. Not only considering needs and market of external customers (the survey objects should include customers of this company and other competitors), but also doing research on related departments in the enterprise, including the service department, the business department and senior manager. Ensure that the company have

the ability to provide a variety of PSS businesses.

(2) Use some reasonable investigation methods. The quantitative information of customer demands are usually obtained through questionnaires, design the questionnaire according to the survey objects.

(3) Carry out market research. Carry out market research according to selected survey methodology and questionnaire, finish the investigation and get enough data.

(4) Classify customer needs. Kano model is used to collate and classify all information obtained from the survey. Kano's quality model divides customer needs into three types: basic needs, performance needs and excitement needs (Kano, et al., 1984).

- ◆ The basic needs.The basic needs are that the customer think they are basic or essential in the product functions or needs,the basic needs are no longer mentioned in the survey basic needs by the customers under normal circumstances. If the product does not have some basic needs, the customer will be not satisfied; on the contrary, when the product fully meets the basic needs, the customers just think it is necessary.
- ◆ The performance needs. The performance needs are usually discussed by customer in market survey, the more the product carries out, the more customer will be satisfied. Take the car as example, driving comfortable and low fuel consumption belongs to performance needs.
- ◆ The excitement needs provide the customer some product features that unexpected. If the product does not provide this kind of needs, the customer will be not unsatisfied; on the contrary, if provide, the customer will be very satisfied with the product.

4.2 Classify service needs of PSS

KJ method is a kind of quality management method proposed by Kawakita. KJ method aims to a particular problem, collects all kinds of documents and information on experiences, knowledge, ideas and opinions, collates and analyzes the information according to their mutual affinity, and obtains a unified understanding and grouping(Kawakita, 1986). In the collection and classification process of PSS services demand, Kano model and KJ method can be integrated together for the needs classification. PSS service needs classification based on Kano model and KJ method shown in Figure 2.The second level are three different needs types of Kano model (basic needs, performance needs and excitement needs), while the third level is the congregation for each type of needs (Che and Yang, 2008).

PSS can be divided into four types, pure physical product and integrated service product are the basic needs, function-oriented product is performance need, result-oriented product is excitement need(Mont, 2002, Li et al., 2012).In Figure 2. In the third level, the needs congregation for each type of PSS is different. For example, customer demand for integrated service product is composed of physical functions and service functions; and for result-oriented product, customers only care needed service functions, without regard to the composition of the physical product. Thus, service needs of PSS must be classified reasonably and scientifically, so as to ensure the combination of PSS that enterprises provide more reasonable and better meet customer needs.

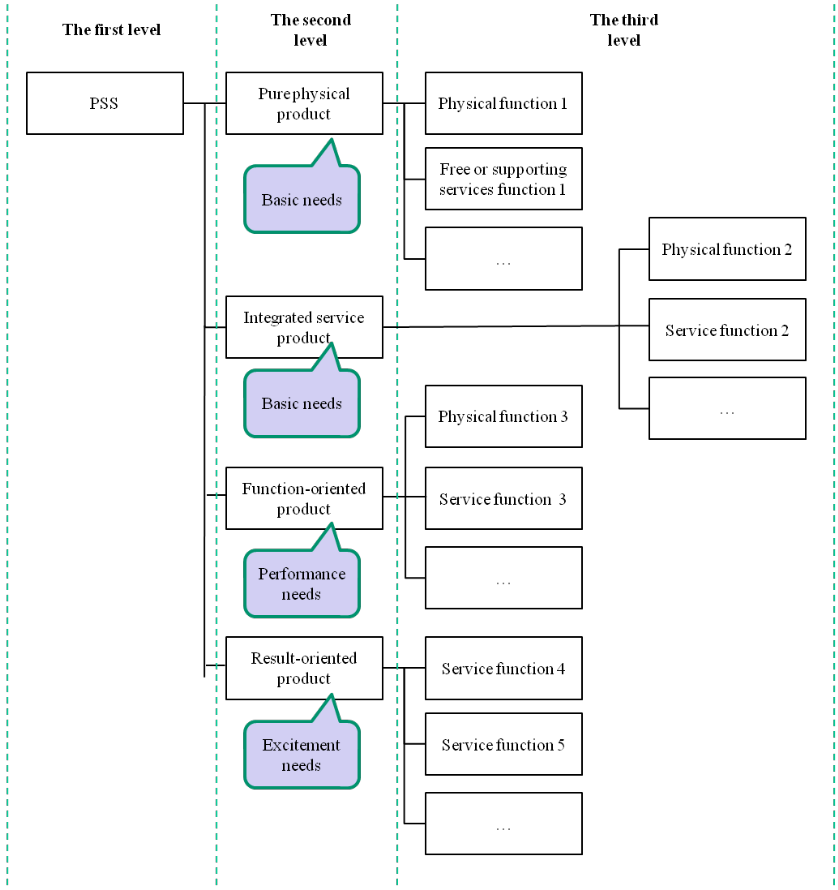

Fig. 2 Classification of PSS service needs

5. Findthe principle solution of each generalized service needs and build rough structure

5.1 Find the principle solution of each generalized service needs

For each sub-function of generalized service demands, the principle solution need to be found, then they are combined into a product structure, then you can get the principle solution. The principle solution contains the physical effects or service module characteristic that are required for the realization of a requirement. Many tasks only have structural design problems, it is not necessary to find new physical effects; some tasks can be solved by a service business; while some tasks can be achieved by multiple physical products, or can be achieved by the integration of physical product and service. Therefore, the principle solution we try to find, not only includes necessary geometry and material characteristics of physical product, but also includes some service businesses (Pahl and Betiz, 1996; Li et al., 2012). Building the solution domain through the variations of physical effects, geometric and material characteristics and service characteristics, in order to achieve a sub-function, may be several physical or service effects occurs on one or more function carriers. The method of finding the principle solution for service needs are literature searching method, analyzing natural systems, analyzing existing technology systems, analogy method, brain storming method, association method, display method, 635 method, etc. (Pahl and Betiz, 1996).

5.2 Build PSSmodular rough structure

Analyze the principle solution of generalized service needs, and build modular rough PSS structure. PSS modular rough structure generally consists of one or two levels, which are composed of the physical product ontology, physics module, free (of charge) service module and value-added service module. In PSS modular rough structure of Figure 3, the dotted lines express respective modules of the pure physical product, integrated service product, function-oriented product and result-oriented products constitute respective modules. The type is different, the modules of PSS are different. Some modules are basic modules, which exist in any type of PSS, such as the physical module ontology, free service modules, while others are optional modules.

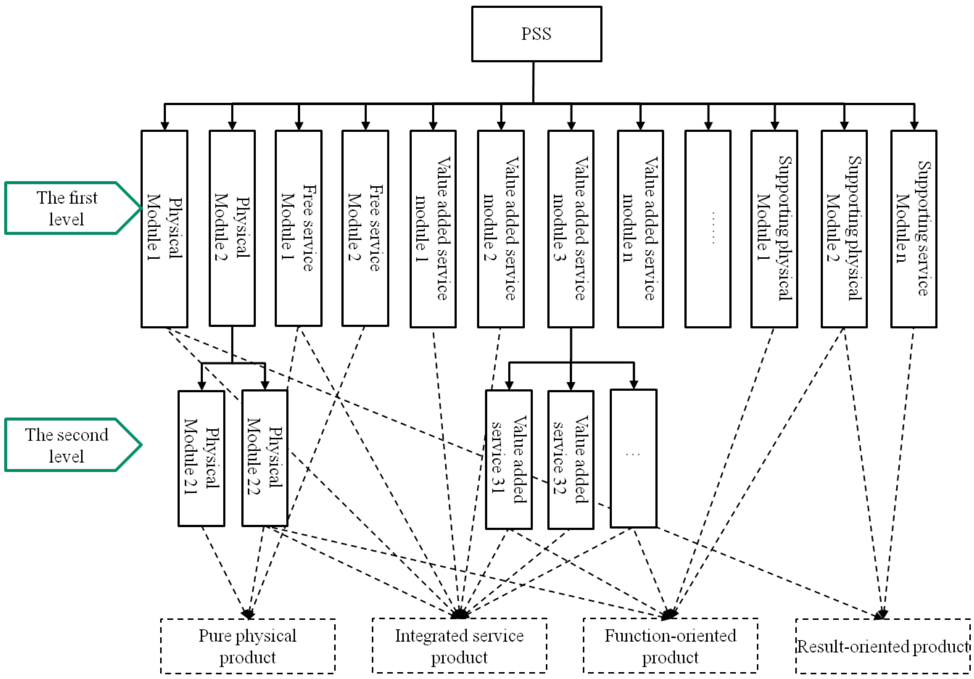

Fig.3 PSSmodular rough structure

6. Configure and plan PSS principle solution

In order to achieve the total function of PSS, it must be realized by building the product structure which is combined according to the principle solution field. The main object of combination is to identify whether the principles of physical functions or service functions are compatible, in order to realize an undisturbed life cycle of energy flow, material flow and (or) information flow (Pahl and Betiz, 1996). One method is morphological matrix method. If we get the PSS principle solution by using morphological matrix method, we need to select a principle from more than one sub-functions (in one line), and in accordance with the order of functional structure to combine into a total solution (Figure 4). If a sub-function F_1 has m_1 principles, sub-function F_2 has m_2 principles, ..., we can get $N = \prod_1^n m_i$ principle solutions theoretically, but it can not accurately determine which solution is reasonable from these combinations (Pahl and Betiz, 1996).

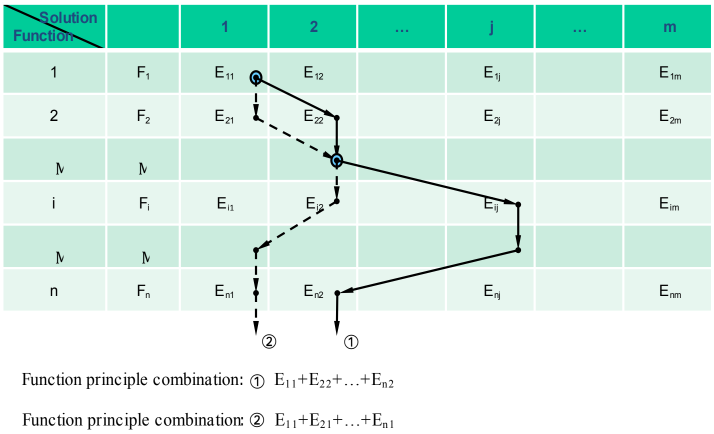

Fig.4Configure PSS principle solution (Pahl and Betiz, 1996)

7. Evaluate the PSS combination solution

7.1 The description of PSS module portfolio planning problem

In PSS planning stage, we must consider the user preferences for physical products and services, and only when customers are provided with the products and services that they like, the customers will have the desire to buy. Meanwhile, the fierce market competition makes the price of PSS becoming an important factor to determine whether the user will ultimately purchase. Therefore, for the module portfolio planning of PSS service solution layer, the constraint target is to minimize the purchase price, and maximize the user experience and satisfaction.Through module combination planning and evaluation of PSS service solution, and gets a series of PSS solution with maximum utility price ratio, which provides decision making for module division of the parts level and product platforms establishment. The description of portfolio planning issues of PSS service solution as follows.

Assume that, if the company can provide m kinds of products and services a_i ,the collection of products and services can be expressed as $A = \{a_1, a_2, \cdots, a_m\}$. A service portfolio z_j is a collection that contains several products and/or services. From the manufacturer's point of view, these service portfolios have a greater profit; from the user's point of view, these service portfolios can meet user’s demands to some extent, and with the low cost in the purchase and use stage.All service portfolios can be formed PSS service portfolio collection Z , $Z = \{z_1, z_2, \cdots, z_n\}$ .For every PSS,if the price of purchasing and using PSS for users is recorded as p_i , the price collection of PSS can be expressed as $P = \{p_1, p_2, \cdots, p_m\}$. In the planning process of PSS, PSS can be divided into three categories, which are integrated service product, function-oriented product and result-oriented product (Li, et al., 2010). Because there are three types of PSS, the calculation method of the product life cycle cost of them are different, so the costs of them must be calculated respectively. Therefore, the combination solution evaluation of PSS also were carried out respectively, this will make the evaluation results have the similar comparability and user choice accuracy.

To solve the planning problem of PSS service portfolio solution, we must address the following four questions: (1) establish constraint function and objectives; (2) determine the purchasing price of PSS; (3) calculate the utility of the principle solution; (4) standardize the constraint function.

7.2Constraint functions and objectives

(1)User preferences utility

Users expect the highest satisfaction in product life cycle, it can be shown as follows(Green and Krieger,1985).

$$Max\sum_{i=1}^{m}\sum_{j=1}^{n}U_{ij} \quad (1)$$

U_{ij} is the utility value for users purchase a product or service.Utility refers to a measure of satisfaction for consumers through consumption or enjoyment to make their own needs and desires to get satisfied. If the satisfaction for user purchasing the product is the higher, the utility becomes higher(Jiao and Zhang, 2005).

(2)The cost constraints that the user buys and uses the product

PSS users expect to buy PSS with the lowest price,the product cost that the user buys and uses is P_{ij} . Since PSS has different types, because PSS is provided at various stages of the product life cycle, so users not only the purchase costs of PSS related to the product life cycle services, but also mentioned to different types of PSS prices.The PSS cost can be divided into three categories respectively, which are integrated service product, function-oriented product and result-oriented product, the cost calculation method is shown in section 7.3.

$$Min\sum_{i=1}^{m}\sum_{j=1}^{n}P_{ij} \quad (2)$$

(3) The total objective function

Users expect the lifecycle costs of PSS for customersis P_{ij} ,the utility of purchasing PSS is U_{ij}, The importance of i-th module or business in the entire PSS is ω_i. Integrate the formula (1) and formula (2) together, and obtain the overall objective function, it is as follows (Jiao and Zhang, 2005).

$$Max\ OT = Max\sum_{i=1}^{m}\omega_i\sum_{j=1}^{n}\frac{U_{ij}}{P_{ij}} \quad (3)$$

7.3 Determine the purchasing price of PSS

7.3.1The cost of integrated service product

The life cycle cost of integrated services product for customers includes the purchase cost, various types of maintenance service costs and recycling cost(Asiedu and Gu, 1998).

$$P_i = P_i^{PC} + \sum_{j=1}^{n}\delta_{ij}P_{ij}^{S} - RV_i \quad (4)$$

Where, P^{PC} is the purchase cost for physical product, P_i^S is maintenance service cost, RV_i is recovery cost. When $\delta_i = 1$, it means module i belongs to this service solution, When $\delta_i = 0$, it means module i does not belong to this service solution.

Service modules includes transportation service, testing service, maintenance service, financial service, installation service, recycling service and so on. The costs of PSS service modules are given in the following steps.

(1) Financial service cost

The cost of financial service is to the interest that customers payfor finance loans, it is calculated as follows:

$$P_i^{FS} = M_i \times \psi \times T_i \quad (5)$$

Where, M_i is the principal of loan, ψ is the loan interest rate, T_i is the the loan term.

(2) Recycling cost

Recycling cost (RV_{ij}) of physical product is equipment salvage value, it refers to the recoverable costs after physical product discards.The determination of RV_{ij} is generally based on the value of the precious materials. For example, the transformer is a material-intensive product, the recycling cost of which depends mainly on primary materials, such as silicon steel sheets, copper and transformer oil. and therefore the recycling cost of transformer is very high, it usually totals to 30%-40% of present value.

$$RV_i = \mu P_i^{PC} \ (6)$$

Where, P_i is the price of i-th modules；

μ is the salvage value rate.

(3) Maintenance service cost

Maintenance service cost P_{ij}^{MC} mainly has relation to the cost of basic service cost, service time, replacementcost for parts or materials, the failure rate, it can be calculatedby using equation (7) **(**Park and Seo,2004; Dahmus et al.,2001**)**.

$$P_{ij}^{MC} = (LC_{Fixed} + L_T L_R + \mathrm{C}_R) F_R \ (7)$$

Where, LC_{Fixed} basic service costs (yuan), L_T is the service time(hour), L_R is the service efficiency (Yuan / hour), C_R is replacement cost for parts or materials, F_R is the failure rate.

However, since this formula is very complex in actual services, in product and service planning stage, it is unable to get accurate fault information and service time. Therefore, in the calculation formaintenance services costs, statistical method is often used as formula (8).

$$P_{ij}^{MC} = {P_{ij}^{T}}\Big/{N} \quad (8)$$

Where, P_{ij}^{T} isthe average total costs of maintenance services in life cycle of physical module, N is the average service life.

(4)Other service module costs

We also need to determine other service module costs such as transportation service, testing service, monitoring service. Because of the cost of transport service related to the weight of physical product, the transport distance and ways, but these factors can not be determined before the selling of PSS Under normal circumstances, the average cost of of transportation service is determined based on historical records. The transportation service of transformer is generally provided free of charge by enterprises, namely transportation service cost is ¥0. Installation services cost is generally determined also based on historical records.

For testing services, servicing costs are generally determined according to the category of service items. For different types of testing services, testing services have been given clear prices by enterprises.

The implementation of monitoring services mainly through monitoring components, but the structure and layout of monitoring component will affect the manufacturing costs of physical products. To simplify the calculations, the cost of monitoring service is determined generally in accordance with the monitoring component types selected by the customer.

7.3.2The cost of function-oriented product

Function-oriented product refers to physical product oriented leasing services, the cost of function-oriented product is the annual rent DC_i plus maintenance costs C_{ij}^{MC} (Day, 1981).

$$P_i^F = DC_i + \sum_{j=1}^{n} \delta_{ij} P_{ij}^S \quad (9)$$

Where, the annual rent $DC_i = {P_i}\big/{N}$, P_i is the purchase price for the physical module, N is the average service life, this is the formula for static investment recovery period, the paper will use the formula for static investment recovery periodto determine the annual rent.

7.3.3The cost of result-oriented product C_i^R

The result-oriented product is a kind of product service that providing product function using services as the main purpose. As the result-oriented product not only needs to lease PSS, but also needs to maintain equipment to ensure that the equipment failure rate is lower than the contract requires. Therefore, the cost of results-oriented product includes rental price P_i^F and fixed service costs SC_i.

$$C_i^R = P_i^F + SC_i = DC_i + \sum_{j=1}^{n} \delta_{ij} P_{ij}^S + SC_i \quad (10)$$

Where, j the number of basic maintenanceservices that the result-orientedPSS must provide.

7.4 Calculate the utility of principle solution

The approach to obtain customer preferences commonly uses conjoint analysis method(Shen and Ke, 1998). The conjoint analysis method is widely used in the product market analysis, product platform planning, product portfolio planning and conceptual design.By using the conjoint analysis method, customers can obtain quantitative preferences or utility of the attributes or attribute levels of PSS, it also can be used to search best product/service combination for customers (Kohli and Sukumar, 1990). The main steps of the conjoint analysis method are as follows (Green and Krieger, 1985).

(1)Determine the attributes and attribute levels of product or service

For the conjoint analysis method, the attributes and attribute levels of the product / service should be identified firstly, the attributes and attribute levels must be significant factors that affect customers to buy PSS. In the planning of PSS service solution layer, the attributes are PSS function needs, the property levels are the collections of principle solution.

(2) Product analog

The conjoint analysis consider all product attributes and attribute levels together, and uses the orthogonal design method to combine these attributes and attribute levels, and generates a series of analog products. The conjoint analysis is usually carried out by full profile method, a combination with a certain level of all attributes is called a profile, each profile is represented by a card. Since all possible combinations of several solution may be tens of thousands, so we do not need to evaluate all combinations. In the paper, we use orthogonal design method to reduce the number of combinations and reflect the main effects.

(3)Market research for customer preference

Survey customers or potential customers and evaluate all analog products (profile), by scoring and sorting methods to survey the product preferences and the possibility of buying for analog products.

(4) Calculate the utility of the attribute of all service solutions

Separate from the survey information, and get consumer preference value for each attribute and attribute level, the values of these preferences are attribute utility. There are several models and methods to calculate attribute utility, commonly are the least square regression model, multivariate variance analysis model(MONANOVA), LOGIT regression models (SPSS, 2012). In the quantitative calculation of customer preferences of principle combination, Conjoint module of the statistics package for social science (SPSS) is often used to carry out the orthogonal designing, and create the required orthogonal table, and finish conjoint analysis of possible principle combinations (SPSS, 2012).

7.5Standardize constraint function

According to the performance cost ratio $\frac{U_{ij}}{C_{ij}}$ of constraint functions*OT*,Since the utility is a value that describe user preferences, and the price of PSS(C_{ij}) is the price dimension, the different dimension makes it impossible to compare utility value and price. Therefore, the two must be normalizedbefore the comparison , the specific formula is as follows.

$$U_{ij}^{'} = \frac{U_{ij} - U_{i\min}}{U_{i\max} - U_{i\min}} \quad (11)$$

$$C_{ij}^{'} = \frac{C_{ij} - C_{i\min}}{C_{i\max} - C_{i\min}} \quad (12)$$

The standardization of the utility value and purchase price should be finished in the same attribute group, $U_{ij}^{'}$ and $C_{ij}^{'}$ are the normalized values, which are put into the formula (11) and (12) to get the optimal utility price ratio.

8. Case study

8.1 Collect and classify service needs of power transformer PSS

Power transformer is a long lifecycleproduct, of which the effective life lasts approximately 20 years. In its sales, operation, maintenance, recycling and re-manufacturing phases, there are various types of product services, such as testing services, remote fault diagnostic services, monitoring services, et al. The presence of these product services will affect the modular structuredesign of the transformer physical product.Product services will integrate in physical products, and bring a higher addedvalue for transformer manufacturing companies, which improves product margins and sustainability.

Questionnaires are used to collect customer's service needs for power transformer, Kano model is used to segment and understand customer's needs, which are basic needs, performance needs and excitement needs. KJ method is used to classifyandmerge customer needs and forms a multi-level tree structure. Through applications of requirements elicitation, Kano and KJ methods, requirements elicitationand classification results of the transformer PSS are shown in Fig.5.

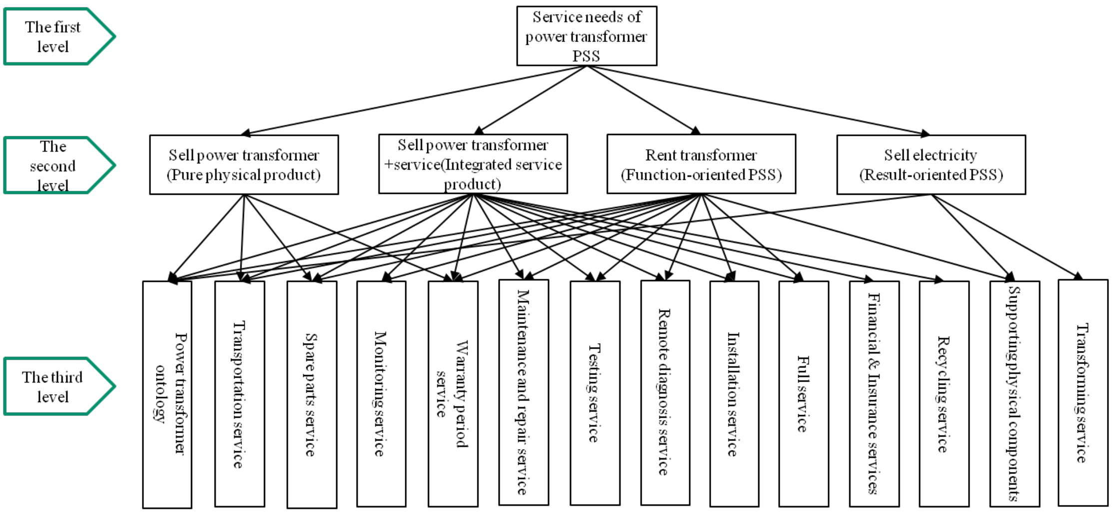

Fig.5Service requirements elicitation and classification of power transformer

8.2 Seek principle solution and build modular rough structure

(1) Seek principle solution of transformer PSS

Assuming that all products and services are made by transformer manufacturers. 10kV power transformers is the current mainstream for small groups of customers, the main types include S9, S9-M, SG10, S11 and S11-M. S9 is a larger energy consumption transformer, while S11- M is the most energy-efficient transformer. When customers buy a transformer PSS, they can choose to buy a transformer, can also choose to lease a transformer or purchase the electricity service. However, High voltage and low voltage switchgear and other auxiliary equipment are necessary for leasing a transformer or purchasing the electricity service.

According to the classification of transformer PSS in Fig. 6, service needs should be given in details and forms more types of services. A variety of methods are used to principle solution of transformer PSS, such as analogy method, brainstorming method, association method, etc., principle solutions of each transformer service need are finished and forms the solution set shown in Table 1.

Table 1 Solution set for each transformer service need

Service needs \ Solution			S_1	S_2	S_3	S_4	...
F_1	Transforming service	Purchase transformer	S9	S9-M	SG10	S11	...
F_2		Lease transformer	S9-M +High voltage and low voltage switchgear	SG10+High voltage and low voltage switchgear	S11-M+High voltage and low voltage switchgear	…	…
F_3		Purchase electric power	S9-M +High voltage and low voltage switchgear	SG10 +High voltage and low voltage switchgear	S11-M +High voltage and low voltage switchgear	…	…
F_4	Financial services needs		Manufacturer loan	The third party loan	Bank installment loan	…	…
F_5	Transportation services needs		The third party transporting	Seller transporting	Customer transporting	…	…
F_6	Installation needs		The third party installation	Seller installation	…	…	…
F_7	Remote monitoring needs		Body monitoring	Drivepipe monitoring	Core monitoring	Winding monitoring	...
F_8	Equipment testing needs		Routine testing	Typical testing	Special testing	…	…
F_9	Maintenance and repair services	Warranty service	One-year warranty	Two-year warranty	Three-year warranty	…	…
F_{10}		Non-warranty service	Routine maintenance	Full service	…	…	…
F_{11}	Recycling needs		Old for new	Full recovery	Non-recovery	…	…

(2) build modular rough structure for transformer PSS

Principle solution of transformer PSS foreach service demand sometimes is not an independent module, some solution set is designed to meet diverse customers’needs, such as warranty services include "One-year warranty", "Two-year warranty" and "Three -year warranty", which are three parameter variations for service module"warranty service", so this type of solution set can be grouped into one module. Some solution setsaredesigned to understand customer’s needs, such as the"The third party installation"of installation needs, does not existin transformer PSS, it is not a module. According to the above principles, a rough structure of transformer PSS can be concluded, as shown in Fig. 7.

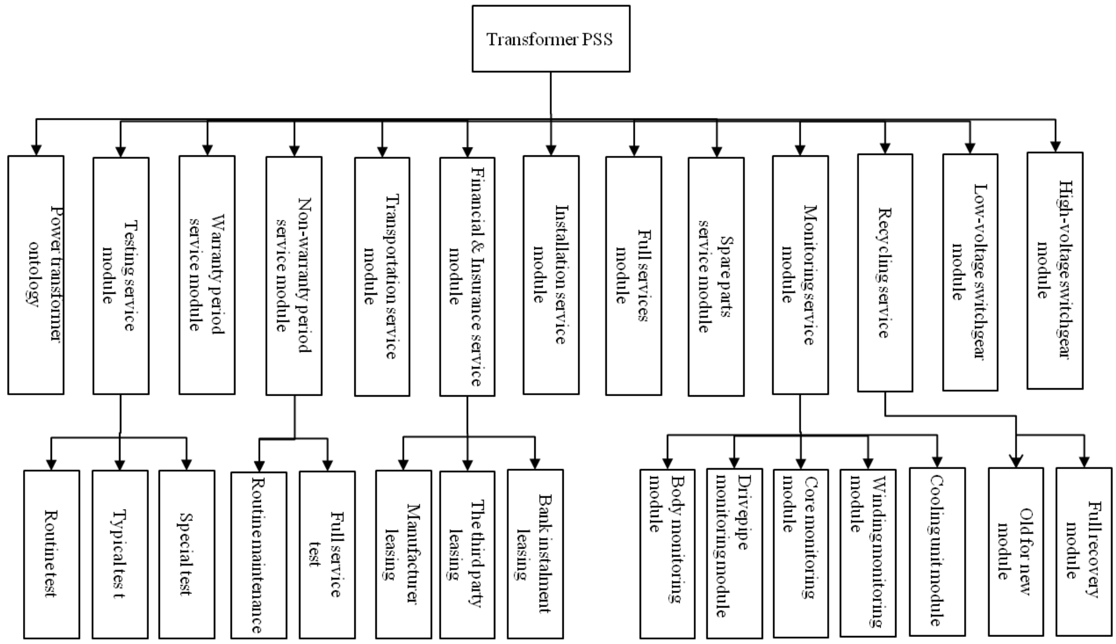

Fig.7 A rough structure of transformer PSS

8.3 Build principle solution portfolio

(1) The principle solution sets for customer's needs

Portfolio planning and analysis of function principle solution of transformer PSS is totally a combination process of modular physical products and services in product life cycle. According to solutions of all the service needs, considering "do no choice" items and price factors, and forms a most complete collection of function principle solution for customer needs.

Table2Transformerservice needs which customers can choose

Service needs / **Solution**			S_1	S_2	S_3	S_4	S_5	S_6
F_1	Transforming service	Purchase transformer	S9	S9-M	SG10	S11	S11-M	
F_2		Lease transformer	S9-M+High voltage and low voltage switchgear	SG10+High voltage and low voltage switchgear	S11-M+High voltage and low voltage switchgear			
F_3		Purchase electric power	S9-M +High voltage and low voltage switchgear	SG10 +High voltage and low voltage switchgear	S11-M +High voltage and low voltage switchgear			
F_4	Financial services needs		Manufacturer loan	The third party loan	Bank installment loan	Not loan		
F_5	Transportation services needs		The third party	Seller transporting	Customer transporting			
F_6	Installation needs		The third party	Seller				

			installation	installation				
F_7	Remote monitoring needs		Body monitoring	Drivepipe monitoring	Core monitoring	Winding monitoring	The cooling unit monitoring	No monitoring
F_8	Testing needs		Routine test	Typical test	Special test			
F_9	Maintenance and repair services	Warranty service	One-year warranty	Two-year warranty	Three-year warranty			
F_{10}		Non-warranty service	Routine service	Full service				
F_{11}	Recycling needs		Old for new	Full recovery	Non-recovery			
F_{12}	Price(Thousands yuan)		20-50	80-100	100-130	130-150	150-180	More than 180

Table3Symbolize service needs andsolutions

Solution / **Service needs**	S_1	S_2	S_3	S_4	S_5	S_6
F_1	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}
F_2	E_{21}	E_{22}	E_{23}	E_{24}		
F_3	E_{31}	E_{32}	E_{33}	E_{34}		
F_4	E_{41}	E_{42}	E_{43}	E_{44}		
F_5	E_{51}	E_{52}	E_{53}			
F_6	E_{61}	E_{62}				
F_7	E_{71}	E_{72}	E_{73}	E_{74}	E_{75}	E_{76}
F_8	E_{81}	E_{82}	E_{83}			
F_9	E_{91}	E_{92}	E_{93}			
F_{10}	E_{101}	E_{102}				
F_{11}	E_{111}	E_{112}	E_{113}			
F_{12}	E_{121}	E_{122}	E_{123}	E_{124}	E_{125}	E_{126}

(2) Conflict analysis and elimination of principle solution portfolio

Calculated theoretically, $6\times4\times4\times4\times3\times2\times6\times3\times3\times2\times3\times6=4,478,976$, a total of 4,478,976 kinds of combinations. However, in the actual product planning, there are some conflicts between modules, and cannot be configured into a solution portfolio. Therefore, conflicts between modules needs to analyze, and redundant combinations needs to remove in advance. When customers choose "Transformer services", they can choose only one type from F_1, F_2 and F_3.If transformer services F_2or $F_3$is selected, the choice of other service modules would be tightly constrained. Therefore, the transformer services F_2 and F_3should be listed separately. Possible combinations of F_1 and F_2 are shown in Table 4 and Table 5separately. F_3 is a result-oriented PSS, in which includes all types of service modules provided to customers, so only have E_{31}, E_{32} and E_{33} in F_3 .

Table4. Possible solutionset when choose transformerserviceF_1

Solution / **Service needs**	S_1	S_2	S_3	S_4	S_5	S_6
F_1	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	
F_4	E_{41}	E_{42}	E_{43}	E_{44}		

F_5	E_{51}	E_{52}	E_{53}			
F_6	E_{61}	E_{62}				
F_7	E_{71}	E_{72}	E_{73}	E_{74}	E_{75}	E_{76}
F_8	E_{81}	E_{82}	E_{83}			
F_9	E_{91}	E_{92}	E_{93}			
F_{10}	E_{101}	E_{102}				
F_{11}	E_{111}	E_{112}	E_{113}			
F_{12}			E_{123}	E_{124}	E_{125}	E_{126}

Table 5. Possible solutionset when choose transformerserviceF_2

Solution / Service needs	S_1	S_2	S_3	S_4	S_5	S_6
F_2	E_{21}	E_{22}	E_{23}			
F_5	E_{51}	E_{52}	E_{53}			
F_6	E_{61}	E_{62}				
F_7	E_{71}	E_{72}	E_{73}	E_{74}	E_{75}	E_{76}
F_8	E_{81}	E_{82}	E_{83}			
F_9	E_{91}	E_{92}	E_{93}			
F_{10}	E_{101}	E_{102}				
F_{12}	E_{121}	E_{122}				

Table6. Possible solutionset when choose transformerserviceF_3

Solution / Service needs	S_1	S_2	S_3	S_4	S_5	S_6
F_3	E_{31}	E_{32}	E_{33}			
F_{12}	E_{121}	E_{122}				

8.4 Evaluate modular portfolio solution

8.4.1 Calculate the utility value and importance PSS

The utility value of attributes levels of modular physical products and servicescan be calculatedby using SPSS software, and score for each service solution by investigators. Score range as shown in Table 7, 9 means “Buy”, 1 means “not buy”, from 9 to 1, the possibility of buying is gradually reduced.According to random survey from potential customers, and obtain scores for each solution, then the utility value of the solutions can be calculated.

Table 7 purchases possibility

Not buy	1	2	3	4	5	6	7	8	9	Buy

A total of 30 potential customers are selected for the survey, they are requested to score for for every service solution independently. Corresponding to F_1, F_2 and F_3, random card sets generated from orthogonal experiment are 64, 27, 9 respectively. In 30 potential customers, 16 customers choose to purchase transformers (F_1), 9 potential customers choose to lease transformer (F_2), and 5 choose to purchase transforming service directly (F_3). The orthogonal card and scoring results of F_1 services solution are shown in Table 8 below.

Table8 Orthogonal card and its scoring results of F_1 services solution

Card ID	Purchase transformer	Financial services	Transportation services	Installation needs	Remote monitoring	Equipment testing	Warranty service	Non-warranty service	Recycling needs	Price	Score 1	Score 2	Score 3	Score 4	…	Score 15	Score 16
1	E_{12}	E_{41}	E_{52}	E_{62}	E_{74}	E_{82}	E_{92}	E_{102}	E_{112}	E_{124}	9	9	8	9	…	8	9
2	E_{12}	E_{44}	E_{51}	E_{61}	E_{72}	E_{82}	E_{92}	E_{101}	E_{113}	E_{124}	8	8	8	7	…	9	8
3	E_{12}	E_{41}	E_{53}	E_{62}	E_{71}	E_{81}	E_{91}	E_{101}	E_{113}	E_{126}	6	5	6	5	…	6	5
4	E_{14}	E_{43}	E_{51}	E_{62}	E_{75}	E_{82}	E_{91}	E_{102}	E_{112}	E_{123}	9	9	8	9	…	8	9
5	E_{11}	E_{42}	E_{53}	E_{61}	E_{72}	E_{82}	E_{91}	E_{102}	E_{111}	E_{125}	8	9	8	8	…	9	9
6	E_{13}	E_{41}	E_{52}	E_{62}	E_{76}	E_{82}	E_{91}	E_{102}	E_{112}	E_{126}	7	6	7	6	…	7	6
7	E_{11}	E_{43}	E_{52}	E_{61}	E_{76}	E_{82}	E_{92}	E_{101}	E_{113}	E_{126}	8	8	8	9	…	9	8
8	E_{15}	E_{42}	E_{53}	E_{61}	E_{76}	E_{81}	E_{92}	E_{102}	E_{112}	E_{125}	8	8	7	7	…	8	8
9	E_{12}	E_{44}	E_{51}	E_{61}	E_{73}	E_{83}	E_{91}	E_{102}	E_{112}	E_{126}	8	8	7	8	…	9	8
10	E_{11}	E_{42}	E_{51}	E_{62}	E_{76}	E_{83}	E_{92}	E_{102}	E_{113}	E_{124}	8	7	7	7	…	8	7
11	E_{13}	E_{41}	E_{51}	E_{61}	E_{72}	E_{81}	E_{92}	E_{102}	E_{112}	E_{123}	9	9	8	8	…	8	9
12	E_{11}	E_{43}	E_{52}	E_{61}	E_{72}	E_{81}	E_{92}	E_{101}	E_{111}	E_{124}	8	8	8	8	…	8	8
13	E_{14}	E_{44}	E_{51}	E_{61}	E_{74}	E_{81}	E_{92}	E_{101}	E_{111}	E_{126}	8	9	9	8	…	8	9
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
63	E_{13}	E_{43}	E_{51}	E_{62}	E_{71}	E_{83}	E_{92}	E_{102}	E_{111}	E_{123}	9	8	9	9	…	8	9
64	E_{15}	E_{41}	E_{52}	E_{62}	E_{73}	E_{82}	E_{91}	E_{101}	E_{111}	E_{124}	9	8	8	9	…	9	8

Scoring for 64 solution of F_1, and scoring results are put in the conjoint analysis program of PSS software, utility value and importance of the attribute levels are obtained finally, as shown in Fig 7.

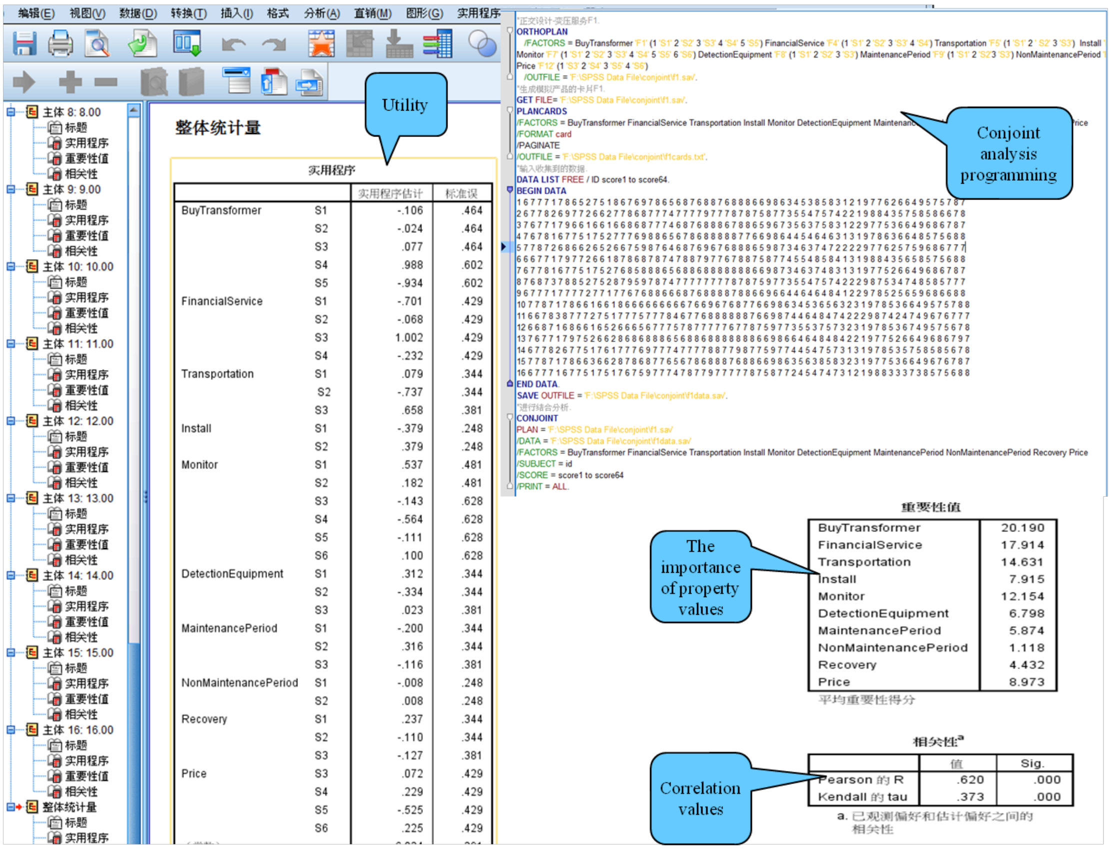

Fig.7 the conjointanalysis program of properties, utility valueandimportance based onSPSS

Scoring for F_2 and F_3 respectively follow the above steps, and get the utility value and importance of each attribute level. The attribute values are shown in Table 9, 10 and 12.

Table9 Utility valueandimportance of theservicesolution F_3

The servicesolution F_3		**Utility（U）**	**Importance, %**
Purchase electric power	S9-M + High voltage and low voltage switchgear	-1.400	47.9
	SG10 + High voltage and low voltage switchgear	-0.200	
	S11-M + High voltage and low voltage switchgear	1.600	
Prices (thousand yuan)	20-50	1.633	52.1
	80-100	-1.633	

8.4.2 Calculate the price of PSS

(1) The average prices of transformers for customers P_i^F

According to the prices analysis about sales history, average price of S9 of10KV transformers is 50,000yuan, average price of S9-M of 10KV transformers is 53,000yuan, average price of SG10 of 10KV transformers is 58,000yuan, average price of S11 of 10KV transformers is 65,000 yuan, average price of S11-M of 10KV transformers is 67,000yuan.

(2) The average price of high voltage and low voltage switchgear is 10,000 yuan .

(3) maintenance services prices

Warranty service prices: “One-year warranty”is basic service configurationand free services, and referred to as 0; “Two-year warranty”and “Three-year warranty”are value-added services, usually 1,000 yuan and 2,000 yuan per year respectively.

Routine maintenance price is the average annual maintenance costs, the average service costs in life-cycle of transformer for 10KV is 33,000 yuan according to the statistics, the average service lifespan is 20 years; the average price of routine maintenance is 33,000/ 20 = 1,650 yuan.

The prices of full services are higher compared to routine maintenance services, the main purpose of full services is to ensure the normal operation of the power transformer.According to the statistics,the average price offull services is about 2200 yuan per year.

(4) monitoring services prices

The prices of body monitoring of 10KV transformer is about 3,000 yuan, and drivepipe monitoring is 3,000 yuan, and core monitor is about 4,000 yuan, and winding monitoring is about 4,000 yuan, and cooling unit monitoring is approximately 4,000 yuan.

(5) Installation Services

Compared to other equipment, installation service of power transformer is a special service, transformer installation service is often carried out by companies with professional qualification certificate. Under normal circumstances, for the 10KV transformer, the price of by the third party companies is 2,000 yuan, the price of seller installation is about 1,000 yuan.

(6) Equipment testing services

Transformer testing services generally have a fixed price, the customer needs to choose according to its equipment running status. Under normal circumstances, the price of routine testing is 5,000 yuan, the prices of typical testing and special testing are 15,000 yuan respectively.

(7) Transportation Services is 0 yuan, transformer seller provide free transporting services. The prices of the third party transporting is 600 yuan, and customer transporting is about 800 yuan.

(8) Financial Services

The purpose of financial services for companies or banks is to make money from loan interests, so customers will need to pay extra loan interest beyond the principal. According to the formula, Interest = Loan principal×interest rate×loan period. If loans 50,000 yuan for 10KV transformer and spends 5 years to pay off the money, the bank's loan interest rate is assumed to be 6.4%, the total interest is 50,000×6.4%×5 = 16,000 yuan. For the manufacturer loan and the third party loan, if interest rates are 7.0%,the annual interest is 50,00×7.0% ×5 = 17,5000 yuan.

(9) Recovery cost

Recovery cost of the transformeris calculated as $RV_{ij} = \mu P_i^F$, according to the actual residual value of the transformer, μ is 0.3 for“Old for new” , μ is 0.25for “Full recovery”. To simplify the calculation, the average price for five kinds of transformer ontology is 58,000 in case. After the calculation according to the above formula, the price of“Old for new”is 17,400 yuan, the price for “Full recovery” is 14,500 yuan.

(10) The average price for renting transformer

The renting transformer has three types, the price of “S9-M+High voltage and low voltage switchgear” is 60,000 yuan, the price of “SG10+High voltage and low voltage switchgear” is

63,000 yuan, and the price of “S11-M+High voltage and low voltage switchgear” is 68,000yuan.Generally, the payback period for renting transformer is 5 years, by using thestatic formula to calculate investment payback period, the result as follows. The annual rent for “S9-M+High voltage and low voltage switchgear” is 60,000/5=12,000 yuan, and the annual rent for “SG10+High voltage and low voltage switchgear” is 63,000/5=12,600 yuan, and the annual rent for “S11-M+High voltage and low voltage switchgear” is 68,000/5=13,600 yuan.

8.4.3 Service solution portfolio planning decisions of PSS

According to data normalization formula, normalize the approximate prices and utility value. It should be noted that the approximate cost and utility values were normalized to [0,1], and because the customers purchase prices as the denominator in decision-making model, so it can not be zero. However, if theactual standardization price man be 0, the utility value and prices ratio can be set as 1.Then, based on the decision-making model (Equation 3), writes a program in Java development environment, and makes analysis and decision on the possible portfolio of the PSS, and ultimately obtains the optimal service solution portfolio. the best 10 groups servicesolution for F_1 and F_2 are given in table 11 and table 13. Service solution F_3consists of only one property, the optimal solution can be determined by the utility value in Table 9, that is “S11-M + High voltage and low voltage switchgear” and the price range of the service solution within 20,000-50,000yuanare most popular. Because the S11-M is the highest level of energy-saving transformer, thePSS preferences for customers is the most energy-efficient and lowest price of the transforming service.

Table 10 Planning parameters of the services solution F_1

The services solution class of F1		**Cost estimation(thousand yuan)**	**Utility（U）**	**Importance ,%**
Service class 1:Transformer ontology	S9	50	-0.106	20.190
	S9-M	53	-0.024	
	SG10	58	0.077	
	S11	65	0.988	
	S11-M	67	-0.934	
Service class 2:Financial services	Manufacturer loan	17.5	-0.701	17.914
	The third party loan	17.5	-0.068	
	Bank installment loan	16	1.002	
	Not loan	0	-0.232	
Service class 3:Transportation services	The third party transporting	0.6	0.079	14.631
	Seller transporting	0	-0.737	
	Customer transporting	0.8	0.658	
Service class 4:Installation services	The third party installation	2	-0.379	7.915
	Seller installation	1	0.379	
Service class	Body monitoring	3	0.537	12.154

5:Remote monitoring services	Drivepipe monitoring	3	0.182	
	Core monitoring	4	-0.143	
	Winding monitoring	4	-0.564	
	Cooling unit monitoring	4	-0.111	
	Not monitoring	0	0.100	
Service class 6:Equipment testing services	Routine testing	5	0.312	6.798
	Typical testing	15	-0.334	
	Special testing	15	0.023	
Service class 7:Warranty services	One-year warranty	0	-0.200	5.874
	Two-year warranty	1	0.316	
	Three-year warranty	2	-0.116	
Service class 8:Non-warranty services	Routine maintenance	1.65	-0.008	1.118
	Full services	2.2	0.008	
Service class 9:Recycling services	Old for new	-17.4	0.237	4.432
	Full recovery	-14.5	-0.110	
	Non-recovery	0	-0.127	

Table11 Planningresults of module portfolio solution F_1

Constitution / Solution	Renttransformer ontology	Financial services	Transportation services	Installation services	Remote monitoring services	Equipment testing	Warranty services	Non-warranty services	Recycling services
Solution1	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Typical testing	Three-year warranty	Routine maintenance	Old for new
Solution2	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Routine testing	Three-year warranty	Routine maintenance	Full recovery
Solution3	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Routine testing	Three-year warranty	Routine maintenance	Old for new
Solution4	S9-M	Bank installment loan	Customer transporting	Seller installation	Body monitoring	Typical testing	Three-year warranty	Full services	Full recovery
Solution5	S9-M	Bank installment loan	Customer transporting	Seller installation	Body monitoring	Typical testing	Three-year warranty	Full services	Old for new
Solution6	S9-M	Bank installment loan	Customer transporting	Seller installation	Body monitoring	Routine testing	Three-year warranty	Full services	Full recovery

Solution7	S9-M	Bank installment loan	Customer transporting	Seller installation	Body monitoring	Routine testing	Three-year warranty	Full services	Old for new
Solution8	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Typical testing	Three-year warranty	Full services	Full recovery
Solution9	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Typical testing	Three-year warranty	Full services	Old for new
Solution10	S9-M	Bank installment loan	Seller transporting	Seller installation	Body monitoring	Routine testing	Three-year warranty	Full services	Full recovery

Table 12 Planning parametersof the services solution F_2

The service solution class of F_2		**Cost estimation (thousand yuan)**	**Utility（U）**	**Importance ,%**
Service class 1：Rent transformer ontology	S9-M +High voltage and low voltage switchgear	1.2	0.358	10.488
	SG10 +High voltage and low voltage switchgear	1.26	-0.519	
	S11-M +High voltage and low voltage switchgear	1.36	0.160	
Service class 3: Transportation services	Seller transporting	0.06	-0.580	23.076
	Seller transporting	0	1.235	
	Customer transporting	0.08	-0.654	
Service class 4:installation services	The third party installation	0.2	-0.111	3.513
	Seller installation	0.1	0.111	
Service class 5:Remote monitoring needs	Body monitoring	0.3	-0.407	13.233
	Drivepipe monitoring	0.3	-0.037	
	Core monitoring	0.4	0.167	
	Winding monitoring	0.4	0.537	
	Cooling unit monitoring	0.4	-0.315	
	Not monitoring	0	0.056	
Service class 6:Equipment testing needs	Routine testing	0.5	1.173	22.009
	Typical testing	1.5	-0.481	
	Special testing	1.5	-0.691	
Service class 7:Warranty services	One-year warranty	0	-0.630	16.202
	Two-year warranty	0.1	-0.173	
	Three-year warranty	0.2	0.802	

Service class 8:Non-warranty services	Routine maintenance	0.165	-0.389	8.870
	Full services	0.22	0.389	

Table13 Planningresults of module portfolio solution F_2

Constitution / Solution	Rent transformer ontology	Transportation services	installation services	Remote monitoring	Equipment testing	Warranty services	Non-warranty services
Solution1	S9-M +High voltage and low voltage switchgear	Seller transporting	The third party installation	Not monitoring	Routine testing	One-year warranty	Full services
Solution2	S9-M +High voltage and low voltage switchgear	Seller transporting	The third party installation	Winding monitoring	Routine testing	Three-year warranty	Full services
Solution3	S9-M +High voltage and low voltage switchgear	Seller transporting	The third party installation	Winding monitoring	Routine testing	One-year warranty	Full services
Solution4	S11-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Not monitoring	Routine testing	Three-year warranty	Full services
Solution5	S11-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Not monitoring	Routine testing	One-year warranty	Full services
Solution6	S11-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Cooling unit monitoring	Routine testing	Three-year warranty	Full services
Solution7	S11-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Cooling unit monitoring	Routine testing	One-year warranty	Full services
Solution8	S9-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Not monitoring	Routine testing	Three-year warranty	Full services
Solution9	S9-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Not monitoring	Routine testing	One-year warranty	Full services
Solution10	S9-M +High voltage and low voltage switchgear	Seller transporting	Seller installation	Winding monitoring	Routine testing	Three-year warranty	Full services

8.5 Result analysis

8.5.1Analysis on customer's choices about PSS models

30 potential customers are investigated in case study, in which 16 customers choose to buy a transformer products and services (F_1 service solution), 9 customers choose to lease transformer

(F_2 service solution), 5 customers choose to purchase transforming service (F_3service solution). That is about 53% of the customers belongs to market segment F_1, 30% of the customers belongs to market segmentF_2 , 17% of the customers belongs to market segmentF_3 .The results shows that half of the population in the this region are engaged in long-term production and living, because mainly purchase F_1 service solution to meet the long term needs. Themarket segment F_2mainly focus on customers with 1-3 years production period, such as building construction companies and road construction companies.The market segment F_3 mainly focus on customers who carry out temporary works in a local or commercial activities, the case indicates there are a little temporary works to be done in this district. With the changes of development modes and ways of thinking, more and more long-term transformer customers will turn to using F_2 and F_3service solutions. Therefore, based on the analysis on customer's choices about PSS models can provide a reference on the PSS platform planning and production capacity building of the manufacturer.

8.5.2Analysis onthe utilityprice ratio

F_1servicesolution is an integrated servicedelivery model which providesmodular physical transformers and services.From the viewpoint of business importance, transformer body, financial services, transporting services and monitoring services occupy an important position in all modules. From the analysis of utility value, customers prefer better S11 transformer, because it hasgood energy-saving ability, and want to reduce their capital pressure by banks loans when buying the F_1servicesolution. However, because the price of S11 much higher than S9, customers pay more emphasis on the utility price ratio when buying F_1 service solution. From the planning results of module portfolio solution F_1 of Table 11, the optimal module portfolio is {S9-M model, the bank installment lease, Seller Transporting, Seller installation, Body monitoring, Typical test, Three-year warranty, Routine maintenance, Old for new}(See solution 1 of table 11), this group has the maximum utility price ratio. In this portfolio,customers can get free transportation services, and the manufacturer will offer the lowest price of installation services, as well as good cost performance service modules such as"Three-year warranty", "Routine maintenance" and "Old for new".

F_2service solution is leasing transformer services, according to the classification of the importance, due to the price of renting transformer is relatively lower, so customers prefer to the transformer services with good quality and security, such as transport services, equipment testing services, equipment monitoring services and warranty services. The implementation of these service modules help to reduce the burden for customers, and reduce the running failure rate of the transformer. From the planning results of module portfolio solution F_2 of Table 13, the optimal module portfolio for F_2 service solution is {S9-M+High voltage and low voltage switchgear, Seller transporting, The third party installation, Not monitoring, Routine test, One-year warranty, Full services}.The optimal module portfolio solution meets the shorterleasing period characteristics (One-year warranty) in F_2 service solution, and after using the warranty service, even though there is no monitoring service, high-quality services can still be obtained by using "full services" module.

Since service solutionF3 consists of only one property, it cannot be combined. The optimal solutions are shown in Table 9, F3 Service Solution utility value, that is {S11-M + High voltage and low voltage switchgear, 20,000-50,000yuan}. Because S11-M is the highest level of energy-saving transformer, customers prefer to the most energy-efficient and lowest price of the power transforming service.

9. Conclusion

The authors put forward a methodology of module portfolio planning for PSS service solution layer, the methodology consists of four phases (including five steps), which are namely service needs acquisition phase, finding principle solution and building modular rough structure phase, configuring principle solution portfolio phase and modular solution evaluation phase. Finally, a case study of power transformer PSS is carried out to validate the methodology proposed in this article. The novelty of this paper are as follows: (1) A four-stage module portfolio planning process model for PSS service solution layer is proposed; (2) The evaluation method on modular service solution is proposed based on utility price ratio, from the perspective of customers' utility and PSS life cycle total cost, the optimal modular portfolios with maximum customer satisfaction and the lowest cost ratiofor three kinds of PSS are achieved.

The methodology proposed in this paper provides a guidance for module partition and module portfolio planning for the four types of PSS (pure physical product, integration service product, function-oriented product and result-oriented product). The methodology also can guide manufacturer to build a modular platform to develop all kinds of PSS portfolio to achieve value-added products and services. In the era of globalization and increasingly fierce competition, the combination on customer's personalized preferences and the lowest price of PSS is the magic weapon to win the customers and market segments.

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