# Modeling and Simulation of Product Service Systems for Design and Innovation*

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**Abstract:** This paper addresses the process of designing new product service systems (PSS). The product service systems mean wide range of businesses which include physical products and intangible services such as software. For design and innovation, this paper proposes a modeling and simulation methodology of a system of a hardware and software. The process to promoting new PSS contains five steps. First step is to have a creative mind so that designer himself surely can start an innovation. Second step is to find good PSS idea. Third step is to select and choose the best idea. Forth step is to describe clear blueprint and to visualize the architecture of PSS. The clear blueprint helps to evaluate the technical and economical possibilities. Last step is to realize the PSS idea into this world by managing teams and projects. Based on a modeling method of hardware-software-systems based on SysML (System Modeling Language), a blueprinting methodology is proposed and confirmed by describing electric power supplying business.

**Key Words:** Product service systems (PSS); System modeling language (SysML); Creative design.

## *1 Introduction*

This paper discusses how to realize new product service systems (PSS). The product service systems includes wide range of businesses such as airline, automobile, hotel, travel agency, electrical energy supplying system, and so on. Launching new product service systems is one of the most important and really desired activities in this world.

New PSS creates not only new customer, new satisfaction, but also new employee, new social value, and even if new technology, new academia, and new future. How difficult the designing new PSS is well known especially for young students and young business person. On the other hand, we can recognize that in this world has some excellent PSS creator such as Steve Jobs[1]. For example, Konosuke Matsushita, who is a founder of Panasonic Corp, created more

than thousands of companies which manufacture electric products and provide services[2]. What is the difference of normal PSS designer and such excellent PSS creator? This paper assumed that there should be key issues for creating new PSS business.

Some people create a lot of companies, new business, and new product-service-systems. There are many people who do not create any company even if he has excellent abilities and is excellent as an employee. What is the difference between just an employee (even if he is quite excellent) and such innovative designer of product-service-systems?

### *2 Process of Designing New Product-Service-Systems*

This paper focuses on the difference between innovative promoter of new creative product-service-systems and normal people. An important assumption is that the difference never comes from how much money they have. In other word, this paper ignores the difference from parents, assets, academic record, nationality, regions, and genders, because the historical great innovator did not always have them.

This paper proposes the process of promoting new product-service-systems as figure 1.

There are two different kinds of product-service-systems. First is creative PSS such as airline service, bike rental system, internet service, mobile phone, and auto mobility services. Creative PSS provide new customer satisfaction to increase social happiness. Second is not creative PSS such as short selling attack, financial alchemy, reckless derivative (such as subprime loan), gambles in stocks, and zero-sum money game. These PSS do not create new value itself. Not creative PSS compete for the created value by creative PSS with each other.

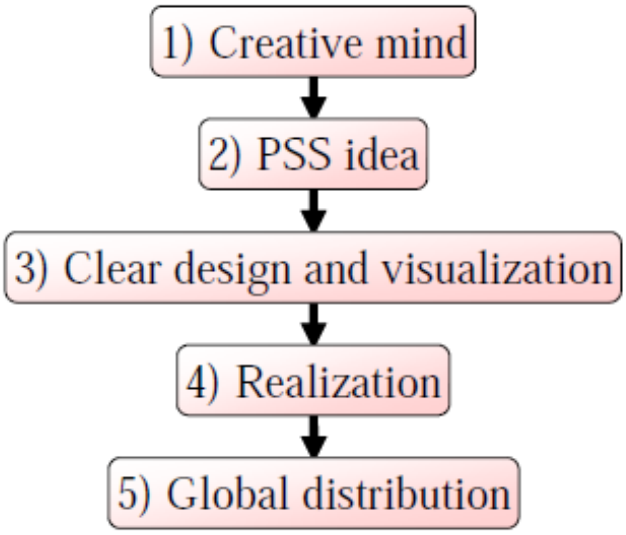


**Figure 1** - Process for Realization of New Product-Service-Systems

**Creative business**
= create new customer satisfaction and happy society
(Examples: airline service, bike rental system, internet service, mobile phone, and auto

mobility services, etc. )

**Not creative business**

= compete for created value by creative PSS

(Examples: zero-sum money game, reckless derivative (such as subprime loan), gambles in stocks, selling short of hedge fund, etc.)

### *2.1 Step1: Having creative mind*

First step is to have creative mind. The creative mind means that you believe that you can achieve an innovation. The first step of having creative mind is decomposed into three steps as shown in Figure 2.


**Figure 2** - Step 1: Having Creative Mind

There are two different kinds of minds. One of them is a competitive mind. The other is creative mind. The creative mind precedes everything.

1) Competitive mind

2) Creative (Collaborative) mind

Today's school teachers teach mainly based on competitive mind. In junior school, high school, and sometime even in the university; students are forced to compete with the other students. Beating other person is often a reason of getting his personal high score.

In order to achieve high score of product-service-systems by customer, there are no personal score. Always customer evaluates the performance of the PSS providing team. Hence, creative product-service-systems require highly collaborative team. The creative idea requires collaboration, wide vision, and throughout improvement. The creative mind focuses on collaboration and creation of new value. Hence, changing from competitive mind to creative mind is very important first process.

In order to keep creative, at first we are going to have to forget the passive mind. Most of people pretend like they are victim. Joblessness, economic slowdown, bad recession, credit crunch such as Leman's shock, disaster of an earthquake, are sometime frequent excuse of the passive victim's mind. First important step to be a creative is to forget the bad uncontrollable issues, and change the passive mind to an influencing mind.

Next important step to have a creative mind is to find enjoyment in a designing and creating activities. It is necessary to believe that you yourself can create some valuable product or services, and change the world.

The final goal never should be a meaningless goal or nothing but a zero-sum money game. The final goal should be a valuable goal for both of yourself and society. All effort toward meaningless goal is also meaningless. Automatic algorithm for wining zero-sum money game or technique for imitating product is one of the examples of the meaningless goal. Only worthwhile, happy-related, through-life valuable goal derives great inherent creativity in human kind.

### *2.2. Step2: Finding business ideas*

After first step, the creative mind was installed. Next we have to find good ideas of product-service-systems.

Finding new PSS idea is the most creative and interesting work. Almost all business people like to do it. The number of ideas is infinite. In our society, we can find infinite number of ideas. The PSS idea can be found in every area, every field, every hierarchy, every firm, and every customer. Because all needs, troubles, and ideal gaps can be ideas. Almost all people can stand to searching good idea in 24 hour a day, every day.

For finding new PSS idea, there is no one way, but if this paper propose how to find the PSS idea, steps 2-1) to 2-3) in figure 3 might contribute.

1) reconsider an ideal as they should be (to-be )

Observing products and services in real world, and reconsider an ideal per se. For example:

a) should automobile burn fossil oil?

b) should we always carry all of a mobile-phone, a lap-top PC, a digital-camera, and an IC recorder?

2) find gap between 'As-Is' and 'To-Be'

Next step is to find the gap by comparing between 'To-Be' world and the 'As-Is' world. From the gap, we can find many ideas.

3) create an idea from the gap

If the gap is unsolved problem, it might be an idea.

For example, from 'To-Be' 1.1)-1.2):

a) light personal infomechatronics mobility with lithium battery

b) next generation smart phone

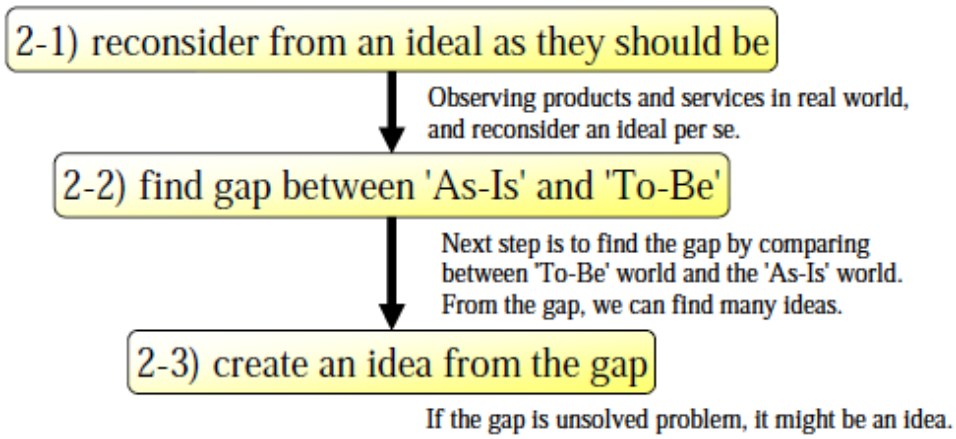


**Figure 3** - Step 2: Finding Original Interesting Idea

### *2.3 Step3 Choosing one good idea*

When we finished listing the ideas, next task is to choose the best one. Question 'whether you need the realization of the idea from the heart or not' sometimes provides a good information for making a decision.

The checking must include at least following three aspects:

1) timing,

2) possibility, and

3) impact.

In order to evaluate the validity of the idea, the discussion with specialists who comes from different domain about whether we can collaborate to realize the idea can provide a good indication.

Negative feedbacks from the specialists mean that the idea cannot over the financial / technical / team issues.

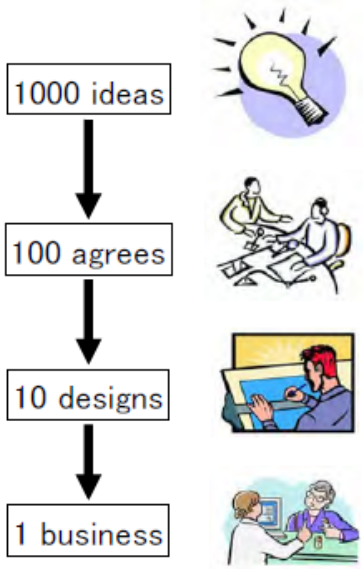


**Figure 4** - Choosing What Is Good and Leaving What Is Bad

The ideas which passed the validation by the specialists are the candidates of the realization. In this step, speed of creating ideas and the number of evaluation is very important. There is one question, how much this evaluation process is going to cost? The answer is, almost zero. Rapid creation and evaluation process derives better ideas.

Figure 4 shows an example of the ratio. 100 ideas is agreed from evaluating 1000 ideas (or more than that). 10 ideas is decomposed into detailed design blueprint from choosing 100 agreed ideas. 1 business is survived from 10 design results.

Before creating real product or service, the idea should be virtually designed as a model. The modeling process is also same with a thinking process. The modeling process contains processes of describing, thinking, adding, and again thinking the idea. In this step, speed is very important.

Also, concentrating to core concept and forgetting digressional topic is a key factor. Elimination of waste effort which has no relation with customer value is one of the purposes of the clear visualization.

The clear model helps to prevent a try-error process after real actual manufacturing. The clear model also helps to prevent an unwanted realization after real actual manufacturing.

The idea blueprint helps to evaluate the technical and economical possibilities. The integrated visualization and overview provides the total social acceptance as a system. The idea blueprint can also help to allocate required resources: capital, human, and time.

### *2.5 Step5 realizing PSS in this world*

Next important task is to collect required resources for realizing product-service-systems. The required resources include engineering specialists, a banker, a funder in government, and a legislator. Our society always strongly desires next-generation excellent business plan. Because new PSS creates new employment, new value, new happiness, new activation of the industry, and improve GNP.

The clearly visualized business plan has strong power to move business persons. Serious energetic businessman always has strong curiosity for new interesting business idea. If the business plan had enough quality to convince the specialists, the specialists would be glad to help the realization. When the banker realizes the idea have a stable profit, they are glad to provide financing.

When the specialists realize the idea is challenging and technically interesting, they are glad to join in the project. Hence, the convincing plan can collect required resources: specialists, finance, time, and even low.

These resources allow us to form a team. The team realizes the PSS plan into this world. The best and effective team has to be organized. There are three important factors: 1) the team has to share what are the purpose, and 2) enough time, and 3) enough reward. Without these three factors, even best excellent employee would not be able to realize the good PSS.

The best team is organized is the time when the PSS idea is realized in this world. The best team can produce, install, and operate the designed PSS. In this production stage, the ‘improvement’ idea is very important. It is very difficult to achieve perfect quality. The ‘KAIZEN’ mind in improving process can increase the perfectibility. The increasing perfectibility can be also done by providing the products and services to the customer.

### *2.6 Global launch*

The last step is to provide the PSS into all over the world. Only local products and services are very hard to survive in this age. The systemizing approach is required.

### *3 Modeling method of PSS*

The PSS business has following five actors:

1) customer
2) employee
3) investor
4) owner, and
5) stakeholder.

The customer becomes happy by value provided by business. The employee becomes happy by employment provided by business. The investor is happy if the business creates fortune by business. The owner is happy when the appropriate reward comes from the business. Lastly, the stakeholder is happy when the business opportunity is brought from the business.

All actors will behave to minimize their own benefits. The benefits always conflict, because their positions are different. Hence, it is very difficult to control the business.

Figure 5 shows the modeling idea for design, blueprinting, and visualize the business based on hierarchical system modeling. This paper considers a modeling technology for mechatronics product can represent the PSS business. The PSS includes hardware systems as a product, and also includes software systems as a service. Every PSS have software and hardware.

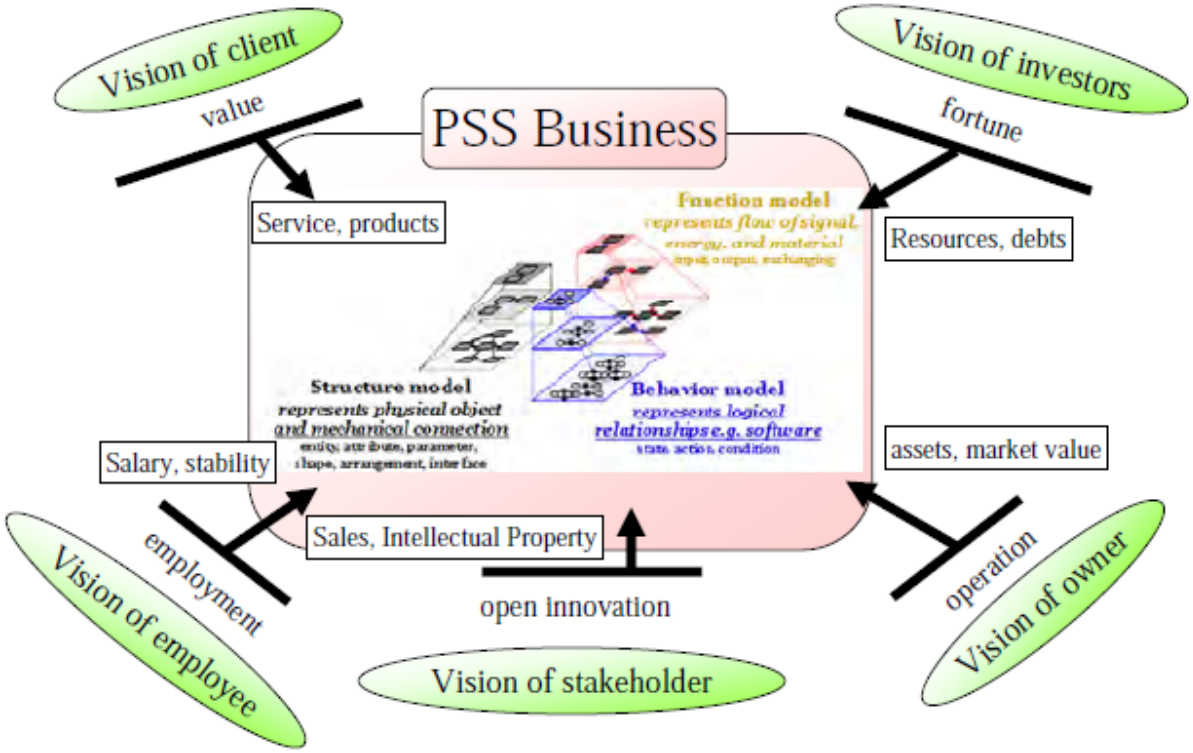


**Figure 5** - PSS Business Modeling for Design, Blueprinting, and Visualization

Authors propose a modeling method of hardware-software systems based on SysML (System Modeling Language). Based on the modeling method of requirement [3] [4]. this paper assumed that the PSS business such as hotel, traveler, and electrical energy supply business can represent the PSS business. Detailed discussion is proposed in the concurrent engineering tool [5] [6].

### *4 Design Example: Electric Power Supplying System*

#### *4.1 Current state and problem of electric power supply system*

In 2011, redesign of the initiative electric power supply is strongly required for because of the disaster of large earthquakes in Japan and the diversification of energy resources. New national energy strategy by resources energy agency of METI represents orientation of the switch to renewable energy from non-renewable energy. Especially, renewable energy such as wind and solar has a variety of problems such as stability of supply and cost. But it tends to expand the introduction. It is required system design of the conceptual level for electric power supply such as Micro-grid.

This paper discusses an example of better system design which is intended for electric power supply system. Especially, this paper discusses system modeling method.

#### *4.2 Modeling of electric power supply system*

Electric power supply system is considered network which have intercross with electrical generating plant, storage equipment and consumption element through electric power transit networks. Therefore, we will define or model electrical generating plant, storage equipment and consumption element and attempt to simulation in entire network. From simulation results, we support deciding necessary capacity of equipment logically after discussing about deficiency in electrical generation capacity. In addition, we enable to estimate for cost, stability and robustness of disaster.

#### *4.3 Outline of electric power supply system design approach*

Figure 6 shows outline of electric power supply system design approach. The process for network design of electric power supply and demand system is process in the following. At the first, designer selects and set up element from template which is registered electrical generating plant (e.g. wind power, geothermal heat), demand element and storage element. In addition, create a correlation as electric power transit networks.

We simulated each element which is defined generating capacity and behavior and distribution of electric power between those elements in conformity with time history. So, we are able to simulate entire situation of supply and demand harboring fluctuating element. From result of this simulation, curve of supply and demand gap is led. We can calculate event such as the following from this gap. Those are enough design of electricity generated capacity, design of storage element capacity and risk of electric power shortage. From modelling functional failure as damaged network in disaster, robustness of disaster risk on the simulation base is made sure. Economical rationality which is checked in entire system is make decision from generating electricity element, storage element, set and maintenance cost of electric power cable and power loss. If we consider new set and part of improvement or elimination as business, we can estimate that it leads to benefit.

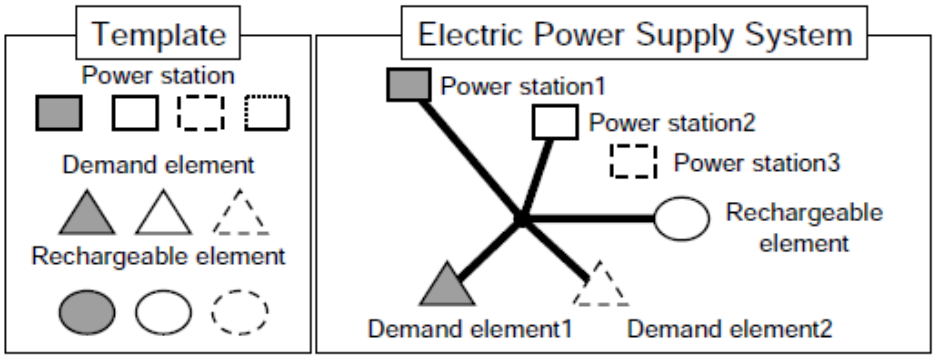


**Figure 6** - Concept of System Design for Electric Power Supplying System

***4.4 Model of generating plant***

Figure 7 shows depiction example of solar power plant as example of involuntariness generation plant which beyond the reasonable control of fluctuation. Solar power plant (Solar Power Plant) has production of electricity generated from installation area as attribute. Amount of solar radiation is determined by weather element (Sunny Cloudy Rainy). Day length is determined by seasonality element (Spring Summer Autumn Winter). Production of electricity is determined by amount of solar radiation and day length. Hourly amount of solar radiation is accommodated by cycle of solar irradiation. Production of electricity is determined by hourly amount of solar radiation. But, data hourly amount of solar radiation removes for sake of simplicity from model of Figure 7.

Term and percentage which can't generate electricity for periodic maintenance are shown by state transition.

Wind power and tidal power have a place as example of plant which beyond the reasonable control of fluctuation. Above exanple is shown by analogical model.

Controllable plant of fluctuation is modeled. Fluctuation element can be controlled, but is not external factor. Case in point is electric generation plant which use fire power (e.g. coal, LNG, biofuel etc).

4.5 Model of demand elements

Figure 8 shows model description example of electrical power which be used as byword of demand elements in home. From electrification modern dwelling, most of electrical power is used by air conditioning and hot-water supply (e.g. bath). From angle of making effective use of nighttime electric power, the following is given an account. Above are laying heat in stock by nighttime water heater, using daytime hot-water, and laying electric power in stock for battery car. Entire consumed power at home is determined by the following. Above is superposition which includes consumed power at each home by probabilistic behavior.

We propose commercial installation (e.g. factory, location) and infrastructure (e.g. rail, traffic signal, street lamp) as element of demand.

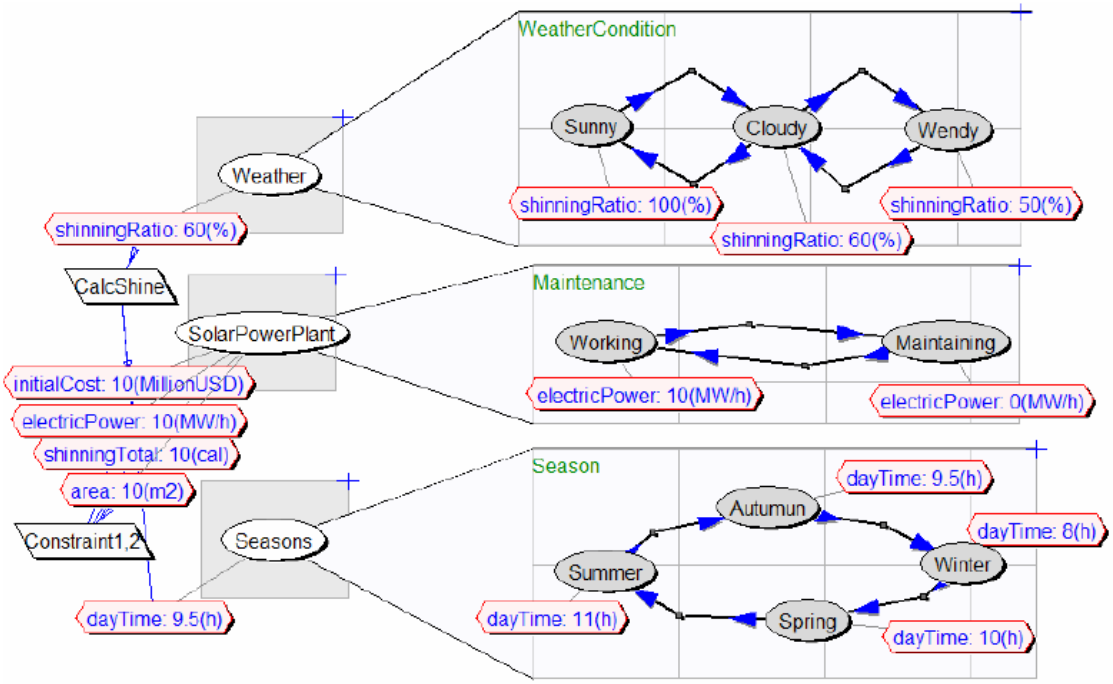


**Figure 7** - System Model for Uncontrollable Changing Energy Source

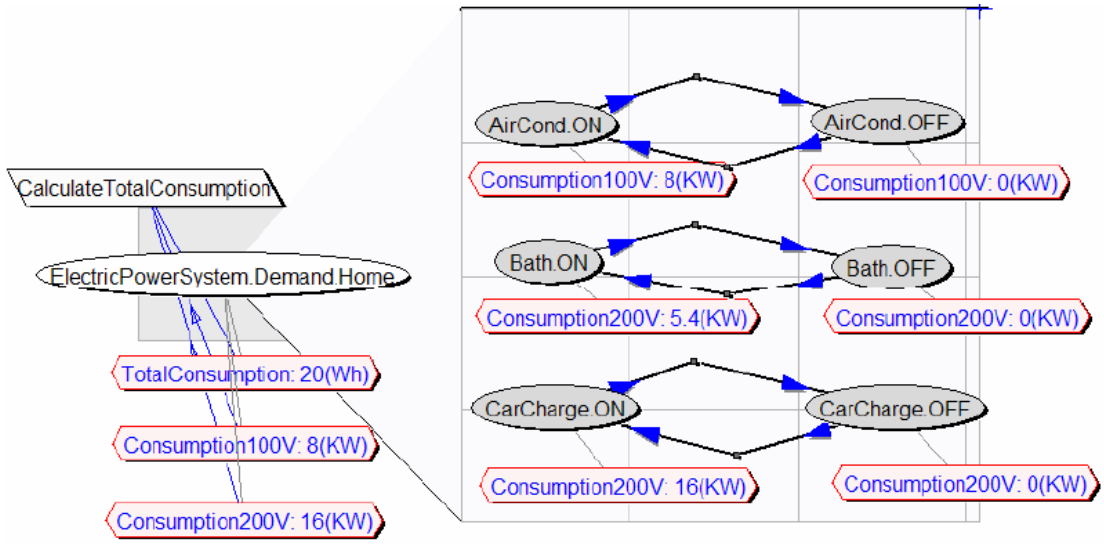


**Figure 8** - System Model for Consuming Element

### *4.6 Model of stock element*

Figure 9 shows model description example of secondary battery which be equipped in home as byword of stock elements. Value of model is approximate calculation of 1,000 rechargeable batteries for detached individual residence. Secondary battery is considered can cater for primary demand of discharge and charge as behavior of electrical power supply. Secondary battery start discharge when it is full charge and demand of electrical power supply exceed current supply.

And secondary battery keeps discharge until definite remaining amount. If secondary battery lost remaining amount of battery charge and demand exceed supply, generating electricity make the shift to generating using controllable energy such as biofuel which is possessed stockpile.

Pumped storage generation and hydrogen storage are considered of as similar element of stock type.

### *4.7 Service activities in power supply system*

The electric power supplying system consists of not only physical hardware, but also services. The service includes maintenance and operation. The proposed FBS model represents the operation/maintenance activities as service aspect. For example, the generic coal fire plant must exchange its catalyst almost once per three months. It is defined as service activities. The service activities also affect to the costing, availability, and robustness of the electric power supplying system. Hence the power supply system can be recognized as one of the PSS (Product Service Systems).

## *5 Simulation Result and Discussion*

### *5.1 Simulation result of generating electricity*

Figure 10 shows simulation result. Figure 10 shows electrical energy generated by a lot kinds of electric power plant (solar, wind, bio, geothermal heat, ocean thermal energy conversion [OTEC]) and stockpiles of secondary battery (fluctuation amount is discharge amount). Figure 10 shows information in a 24-hour period at summer days within simulation for a year. Information of all supply is all amount of electric power amount which is gotten from different energy sources.

Solar have features which generate many electric power in daytime. But solar generate low electric power in nighttime. Wind have tendency to change depending on season. Wind has behavior close to random on a day-to-day basis. OTEC and geothermal heat seem have tendency such as the following. While there are a number of efficiency changes by air temperature change, above electrical generation is keeping approximately-constant generating power.

### *5.2 Comparing of supply and demand*

Curve of all demand on figure 10 shows electrical energy needs for 170,000 houses. Most of consumed power in summer day is constructed by refrigerated air conditioning. Peak of consumed power is seen 1.5 hour late than curve of insolation value. And consumed amount degrade in nighttime which debase amount of activity.

When we compare all demand and all supply, difference of both sides correspond deficiency and excess of electric power. Hatched time zone on figure 10 shows time zone of power shortages which demand is outstripping supply. Electric power network of trial design have the followings. Above are secondary battery and power-generating equipment for emergency. Secondary battery fills the role of stockpile. Power-generating equipment operates by biofuel. Electric power supply system has two-phased behavior at electricity shortage. First phase is covering shortfall by discharge of storage electric power in secondary battery. In accordance with degradation of remaining amount, second phase is switching to generating electricity by biofuel.

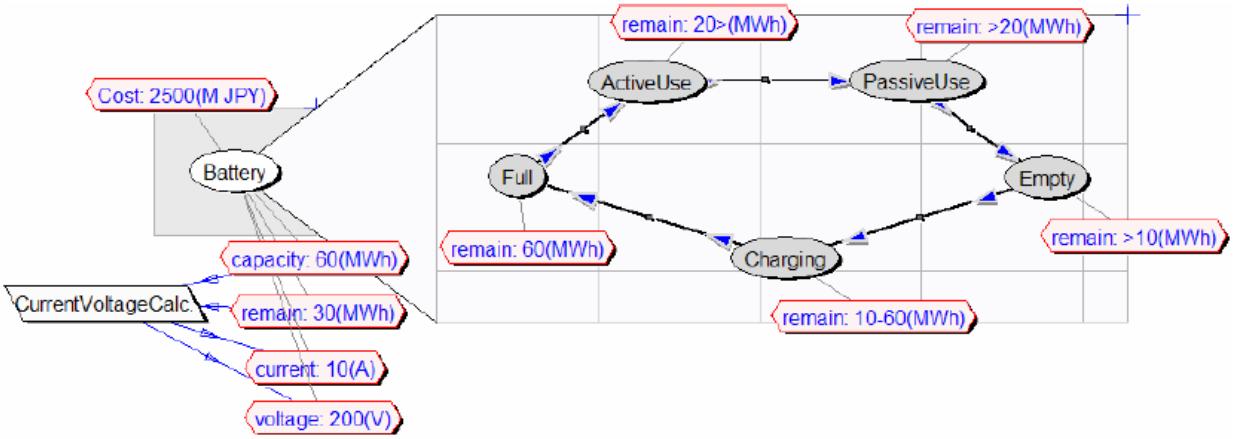


**Figure 9** - System Model for Energy Stock

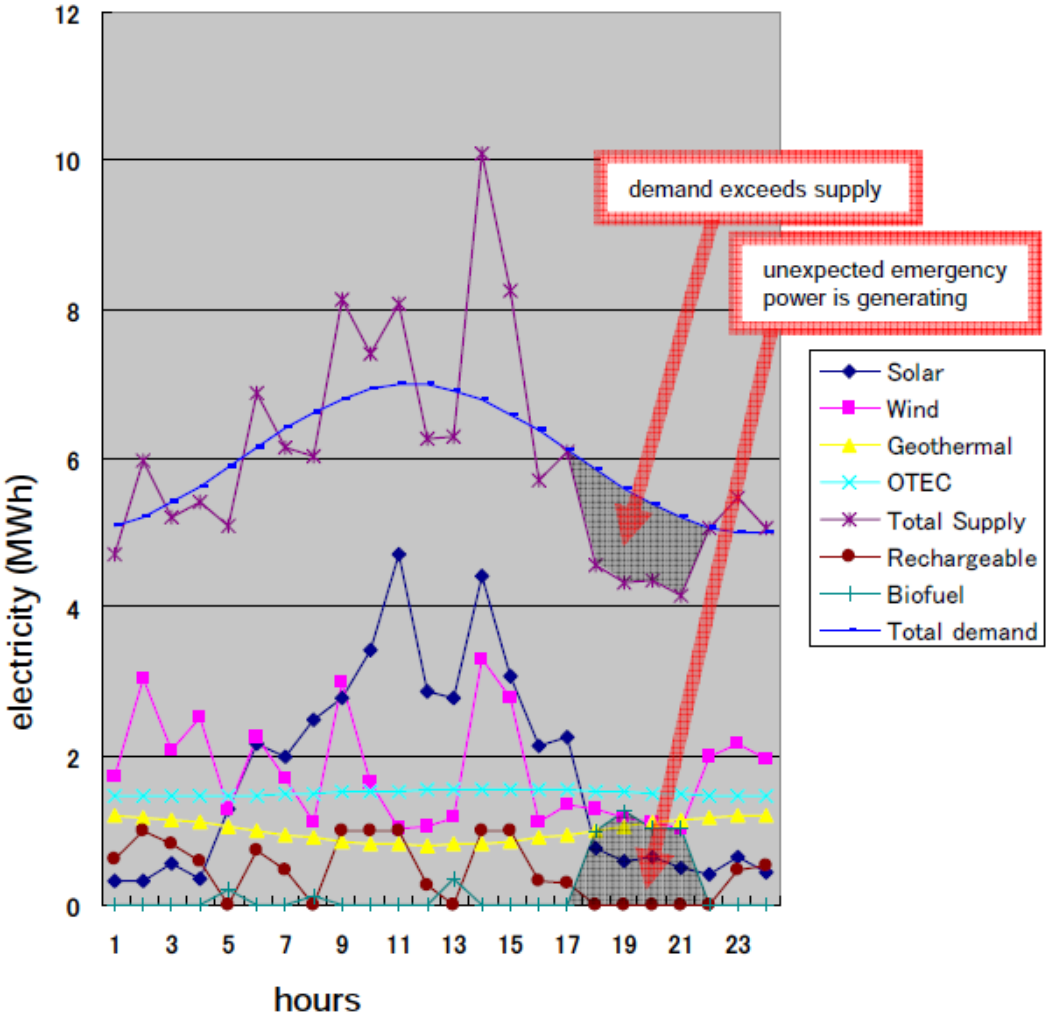


**Figure 10** - Comparison Between Demand and Supply Based on Simulation Result

Secondary battery storage amount is empty among 17- 21 hour by degradation of insolation amount form process of secondary battery storage amount at figure 10. Factor is deep electricity shortage by crossover between time zone which not blows wind and time zone which electrical requirements is heavy. Figure 10 shows depending on emergency generator by biofuel in the wake of running down storage of secondary battery in 1 hour.

### *6 Conclusion*

This paper proposed five steps for realizing new product-service-systems. A creative mind plays fundamental role in the early step of the creation stage. In the early design stage, finding many business ideas and choosing one good idea is important. Fast creation of different ideas and quick evaluation using advices by other specialists are key drivers of the finding and choosing processes. In order to realize the PSS idea, detailed planning and clear visualization of PSS is required. The modeling technology will help the creator to describe, evaluate, improve, and visualize the PSS business idea. A modeling methodology is proposed based on author's mechatronics modeling methodology. An analogy is found in this paper - hardware and software in mechatronics systems, and physical products and intangible services in PSS.

In the future, concrete PSS systems such as energy supplying systems, hotel service, airline service, and medical service will be designed and clearly visualized using proposed creation processes and modeling method.

### *Notes*

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