A system dynamics approach to analyze a power industry facing unstable demand

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Abstract

We have spent more than one year using system dynamics approach to construct a model for a power company, a monopoly electricity supply company, from 1 September, 2001 to 31 November, 2002. The model focused on the collocation of three main instruments in power industry including power generation, transmission, and distribution system.

From the simulation we found strategically when the power industry faces continuous growth demand situation, the main strategies it must consider is optimal invest decisions, how to optimally allocate its resources and make the electricity supply as smooth as possible. When power industry faces demand decline, especially continuous demand decline, there will be no solutions for the whole industry to make profit and match stable electricity supply at the same time. Capacity lies idle, revenue will decline, the only thing you can do is to sell the power generation capacity.

The most influencing point is the bottleneck that will be created from the collocation of the three main instruments. The structural reasons that created the bottleneck is the different delay time each instrument must take to complete the construction and the long delay time the power generation capacity must take to complete the construction.

The only way to resolve this dilemma is to redesign the structure: that is, to construct the new power generation capacity near the demand end such as the industrial zone as the demand happened. Current design tries to satisfy the demand from building big capacity; an alternative way is to build smaller capacity just near the demand side. That will avoid the big investment waste in growing demand period that leaves unused capacity in decline demand time.

Key words: power industry, collocation of instruments, system dynamics, strategy, and redesign the structure.

Introduction

According to the Ford's (1997) description, there already existed several well- built system dynamics models for electricity industry like Fossil2, Ideas, Energy 2020, CPAM, RPSM, and etc. Each model was built based on each special case to solve different problem. There is no model talking about the Asian phenomenon. We believe electricity companies in different countries might have different characteristics. Although this study is not focused on comparing system dynamics models of electricity industry between different areas or countries, we must first study the dynamic behavior of Asian case. The second step of comparison might be possible in another day.

To fully understand the structure of the electricity will help government deal with the issue of electrical price control and electrical supply policy decision-making. All of them have tremendous impact with national energy supply and economic development.

This study has focused on the collocation of three main electricity instruments, power generation, transmission, and distribution systems, to examine what the main dynamics structure was in the electricity industry that was occupied by a monopoly supplier. To look what the phenomenon our agent faced and the underlying structural reasons. This study described a general and integrated model about an Asian country. The background of the project, modeling process of this case, simulation, discussion, and conclusion would be reported orderly in this article.

To extend our understanding of electricity industry, we take a system dynamics approach: we cooperated with staffs of our agent company, our proje ct agent, to clarify the dynamic structure. We interviewed members of departments including financial, accounting, research, power generation planning, system planning, and so on to cover the mental models of as widely as the whole company. We believe by this approach the model will as exactly as possible to reflect the big picture of the whole company. Our approach is designed to make sure the completeness and consistency of the casual loop and the mathematic model.

After several one to one interviews, grouping meetings including discussions between modelers and our agent and internal analysis within modelers, and tremendous papers and documents reading, we refined the strategic content of electricity industry into several key concepts. The nest sec tion will be focused on these key concepts we found.

Question formulating of project

What elements will the long-term strategic planning process concern most? From the resources-base view, what costs most will have the most influence of the long-term strategic planning process. Our agent is a monopoly electricity firm in the industry, so we check the electricity industry what resources cost most. By the physical process, we see the firm generated the electricity from the power generation. The electricity then must flowed from the generation capacity to the transmission system. Again from transmission system to the distribution system before the end users can get the electricity. So we think the power generation capacity, transmission, and distribution system are all indispensable from the whole system. All of them constructed the sufficient power supply system to satisfy the power demand in the whole market. After identifying the core elements of long-term strategy, the next question is what important phenomenon or behavior now the electricity industry has. Were they the results from the collocation of these instruments? The latter sentence is the hypothesis of our answer to the phenomenon of the whole industry. If we clarified the dynamic structure of the collocation of the three instruments, we could explain most of the industry behavior. On the basis of these understanding, we could predict the future behavior of the electricity industry our agent will face in some scenarios. From the model playing process, both modelers and our agent will get the better treatments to handle these futures. We believe that will greatly improve the predict- ability of long-term strategic planning process and also enhance the responding ability of our agents. That is the purpose of the long-term strategic simulation model construction project.

Research approach

Interview, document reading, and related reference

We formulated the model by refer the structure concepts from the related paper (Bunn & Dyner, 1996; Ford, 2001, 2000, 1999; Nail, 1992) and check the initial structure with the company participants in this project. When consensus of the structure of the model arrived, the numbers and functions of parameters and equations draw from the documents and internal report dropped in. This was the main process we formulated this model.

Guideline for formalizing the model

The purpose of this model emphasized the ability of the real application. So we decided to start the model construction from the flow-rate concepts.

To calibrate the model, history and prediction data of behavior from our agent's internal report are compared with model output. Descriptions of behavior over time from the internal report form the power company, that are predictions of the dynamics generated by the strategic model, are providing hypotheses against which the model's performance can be judged.

Several principles of simulation modeling are important for obtaining interpretable results. Units of measurement help to enforce dimensional consistency or equivalence of units on each side of the equation. Variables must relate to real-world phenomena that can be perceived and measured and state variables representing quantities that accumulate over time must be distinguished from other variables that may change instantaneously.

Finally, because all models necessarily omit many aspects of the real world, it is important to recognize which phenomena lies outside the model boundary. For the present model, we focused on the strategic collocation of three instruments, excluding materials not relevant to the collocation dynamics. For instance, the regional difference may present different style of collocation. The present model, however, does not represent explicitly the dynamics between the maximum expenses of the fuel and the different firepower generation structures that affect this expenses; rather, it depicts the broad outcomes of their interaction within the organization.

The model framing

Now we described the main structure of our long-term system dynamic strategic model including critical level and flow variables and the relationship between each variable. This time we used the modules to construct the smaller system then linking them together to form our entire structure. Following descriptions will depict by modules including not only the quantitative and descriptive relationships but also mathematic functions.

The model is divided into four main modules that represent physical flow, policy, financial, and market scenario. Physical flow module formulated the physical state variables including power generation, transmission systems, and distribution systems. Policy module expressed variables of demand and price. Financial module defined the income and outcome of monetary change. Market scenario module (Emera, 2000; Nobuya Minami, 2002; The Tokyo Electric Power Company) describes the assumed scenario our agent will face after early deregulation. Each variable includes its own equation that governs the behavior of the state, or flow variable. Standard continuous-time notation represents differential equations that describe this behavior. Because the modeling project has privacy protection, we can't list the values detail. We could not list all the equation functions, but we would list the relation or definition of each important variable. That is the relative methods to decide each important level and rate variables.

Physical flow module

Power generation (installed nameplate capacity): present and future prediction quantity. Power generation here include s five main kinds of power generation: hydraulic power, firepower, nuclear power, independent power provider, and cooperation. When top management decided to invest new one, power generation will move into the state of capacity under construction. After construction time was due, the power generation increased as the newly invest capacity jump into the pool of the power. With the operating time due, the power generation removed from the pool of the power and the power generation decreased. We use the matrix function built in the powersim , our simulation software, to represent the five powers in one stock chart and mark 1 to 5 to represent each power in the previous order. INC (1) is a stock representing the quantity of the hydraulic power. Each kind of power has similar equation described as follow: at time t, INC is simply the integral of all previous changes in INC, plus its initial value.

Stock variable: INC
Matrix dimensions: i =1..5 (represents 5 state in one stock chart)
Equation: INC = initial values + dt*(INC complete rate)-dt*(INC out)

Where dt express the unit simulation time (here we defined as one year), INC complete rate express inflow of the INC each time, and INC out express the outflow of the INC each time.

Transmission and Distribution sys tem. The transmission and distribution system all measured with unit of kilometers. New transmission and distribution system investment both need to collocate with the new power generation investments. So transmission and distribution system invests at the same time with the new power generation. Following a period of construction delay time or lead time which name be used by our agent, the new ones can work and increase the total transmission (or distribution) length. The total transmission (or distribution) length would not decrease for every broken one will be repaired and work again. The equation to calculate these two state variables will be expressed as follow:

Equation: transmission system = initial values +dt*(transmission complete rate)
Equation: distribution system = initial values +dt*(distribution complete rate)

Where transmission (or distribution) complete rate expresses inflow of the transmission (or distribution) system each time.

But the construction of the transmission and distribution system also must consider the demand side need. For example, as we invest new transmission system, we must consider how many electricity change facility we have for each facility has its limits to change the electricity translated from the transmission system. If we didn't have enough facility, we could not build as many transmission systems as we want. This model we assume there is always enough facility. If the situation was changed, there must be some variables reflect this reality. Distribution system with the same kind of limit must consider the demand side situation. Each demand side has its limit to use the electricity. If the demand was not huge enough, we could not add as many transmission systems as we can.

Policy module

Demand prediction. In present model, peak load and average demand are two important state variables need to be calculated. Because this model simulated by years, we use the peak load to compare with present company electricity supply to point out the stability situation of electricity supply. Average demand will be used with electricity price together to decide the revenue income. We now present the both equations as follow:

Equation: peak load = initial values + dt*(PL increment)-dt*(PL D)
Equation: average demand = initial values + dt*(AD increment)-dt*(kwh D)

Where PL increment (AD increment) express inflow of the peak load (average demand) each time, and PL D (kwh D) express the outflow of peak load (average demand) each time.

General Electricity Price. Here we present the electricity price as an exterior variable. Presently the relative government department must permit the electricity price before the company can charge it. This way makes the company difficult to change the price for reflecting its cost raising. To show the reality, our model let the price decided by model player or ruled by previous setup of the modeler. Previous setup will be no change in the price. Only when we switch the model to the scenario of market liberty, the power company can reflect its cost as it want in this situation. Because we assume in this situation, the market is a private enterprise and the company's equity is spread from the government to the private department. The price's equation was stated below.

Equation: General Electricity Price= IF(price_could_change=0,IF(liberty_or_not=0, FEP, alleged_revenue/electricity_production),could_change_average_price)

Where we use the built function, if a then b or c which powersim presents as if(a, b, c), to setup the price. Price could change and liberty or not are two switches. They have two values, zero or one. For price could change, zero means price could change as the model player want and one presents price sets up by modeler in advance. For liberty or not, zero implies the market is not liberal, one indicates the market is liberal. FEP is the previous setup price by modeler. Alleged revenue is the total cost plus the previously decided capital return revenue. It will be divided by electricity production, total electricity supply measured by KWH, to decide the electricity price in liberal situation. Could change average price is the input icon for the player to enter their decisions.

Financial module

The inflows and outflows of monetary items listed by suggestions from the accounting department and recognized by the whole company members. The critical variables were similar with the income statement. Financial outputs of this model were following the same concept of editing income statement.

Revenues. Real demand supply times general electrical price is revenue. Where real demand supply is the minimum value of the supply and demand. It means that the real demand could not exceed what the power system could supply. The equation of revenue is as follow.

Equation: revenue=real_demand*general_electrical_price

Real demand = MIN (could_run_INC , demand_capacity_per_year) * (10000*8760)/100000000

Fuel expenses. The maximum expense of the company is the fuel expenses. The yearly firepower supply, average load (2), times average cost of power supply, average cost per KWH generation (2), decide the fuel expenses.

Equation: fuel expenses = ((average_load(2) * 10000* 8760/1000000) * average_cost_per_KWH_generation(2))

Staff, Maintenance, and Other operating expenses. The three expenses expressed as some percentages of the revenue. We assume the staff number, maintenance schedule, and other operating activities are not the main topic of this model. If any of them has significant impact to this model, the model would be necessary to include the dynamic s in which the important impact might happen.

Nuclear backend and purchased power expenses. The former is decided by the numbers of the nuclear power generation. Latter is determined by the numbers of the independent power providers. Both expenses will grow as the influencing numbers grow up.

Depreciation expenses. We use the accounting principle to calculate the expense. First we compute the capital value of different depreciated instruments. Then we depreciate each instrument with its accounting years.

Interests and Tax expenses. Total credit times interest rate equals interest expense. Revenue plus some percentage will be the tax expense.

Market scenario module

Market share. We assume there would be a competitor in the market in the initial liberalized period. About ninety-three percentage of market share would be dependant on the relative electricity price attraction to the users, our agent's price relative to the competitor's price. That is the future contract agreed before the need happen. Another three percentage of market share would be dependant on the real quality our agent provides. The electricity quality would be influenced by the system emergency, which was influenced by natural disasters and system broken, which was influenced by the quality of the hardware and the treatment ability of the software. That would decide the real contract as the need happen.

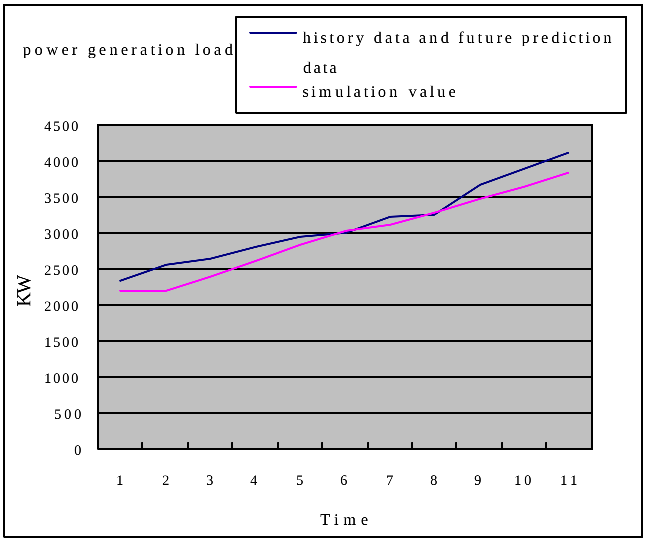
Model verification and calibration

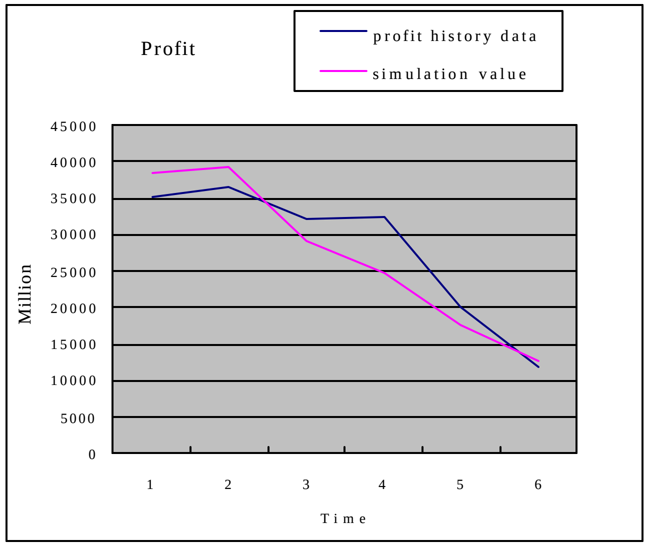
From the interview and related papers reading, we found our agent has two operating objectives, required profit performance made by related government department and maintaining stable power supply. So we now test the model with several different scenarios to try to look for the best treatment the company could do to get the better performance of these objectives.

Verification

For verifying the model, we compare the simulation value with the history data and the future prediction data our agent made and written in their internal report. The simulation and comparing time scale expands from six years before now to five years after now. The assumptions of the model were created from observing the behavior of this time scale. If this model's behavior could match the behavior of our agent's prediction, we could then change the assumptions of the model to test the scenarios we consider most. But in order to our agent's insist the financial data have only use the history data to comparison that means we only compare six years before now. We have tested behaviors of many variables including power generation load, gap between power supply and demand, total cost, revenue, profit. Now we would show the profit and power generation load comparison graphs in graph 1 to present our verification work. We could compare each the power generation load and profit curves. The report written value and the simulation value have the similar trend. Because our model still an initial and gross one, we have accepted the trend match of this model. At the last of this article, we would discuss our shortages. If in other days we could improve the model to cover all the shortages we have, the model might be more perfectly matching the real behavior.

Graph 1: variables comparison for model verification





Calibration

There is no perfect model. But we still want the model responds with the reality and decreases the unr easonable behavior. So we use some methods listed in the, Business Dynamics (Sterman, 2000,) to test the model. Here we discuss two typical tests: extreme condition tests and structure assessment tests.

Extreme condition tests

We use the extreme condition tests, tremendous electricity demand growth of 10% growth rate and zero capacity investment including all the instruments, finding the revenue pattern still keep increase trend and that is not reasonable. Revenue can't keep enlarge when the electricity capacity supplies do not satisfy the electricity demand. Revenue must reach its high peak when demand reach capacity limit then its will at least keep no change given other factors equal in this scenario. For solving this problem, we reset the revenue func tion from original setting, price times demand, to new setting, price times minimum between demand and capacity could supply KWH.

Structure assessment tests

One time we met with our agent members to jointly run some scenarios and test the model. One of the scenarios is cycle pattern demand growth. We let our agent members knew exactly the demand growth pattern in advance. We found when we stop building power generation capacity in the demand-declining period. The fuel and depreciation expenses still grew up. That's not possible because if we don't start the power generation, we would not use the fuel. Then the fuel would not lift up anymore. Depreciation expenses will decrease if we do not add any new instrument in the capacity. So we changed the fuel expenses function as firepower generation times fuel price. We also account the capital value of physical instruments and the depreciation expenses will be capital value divides depreciation years that are based on accounting principles. The calibration results summarize in table 1 as follow.

Testing methods	***Bug findings: Unreasonable phenomenon***	***Solutions***
Extreme condition tests: 10% growth rate and zero capacity investment	Revenue pattern still keep increase even when the electricity capacity supplies do not satisfy the electricity demand.	Revenue equals price times minimum between demand and capacity could supply KWH.
Structure assessment tests: cycle pattern demand growth	The fuel and depreciation expenses still grew up.	Fuel expenses function equals fire power generation times fuel price. Depreciation expenses will be capital value divides depreciation years.

Table 1: calibration result

Scenario planning and results

We chose three most common scenarios to discuss the interaction between these demand scenarios and supply instruments. About demand scenario planning, here we use optimistic, pessimistic, and cycle pattern demand growth scenarios to play the model and try to find out the high leverage solutions we can do to improve the performance. The summary would be shown in table 2.

Normally predicted growing demand

Optimistic demand growth of 3 percent expansion per year is the forecast of power company strategy planning department, but we observe the power company suffered from the decrease revenue behavior. In the present power company controllable decision points, this is a no-answer dilemma because we can't improve it without raising the price. It just the difficult situation power company faced. The company didn't have the power to set the price as it wants. The relative government department must permit the electricity price before the power company started to do any change. Due to politic consideration, it will face huge pressure resistance from the public, common people and members of Congress, as long as the government has the power to supervise the operation of this state-run company and freely change the electricity price as the top managers want.

Optimistic demand growth

Now we raise the growth ratio to increase gradually from zero to near one in these eleven simulation years. We observed the profit declined. And the supply can't meet the demand. Profit decline because the cost continues growing, but revenue stop when the supply can't meet all demand. The shortage of the supply is due to insufficient transmission and distribution systems.

Pessimistic demand

This time we changed the demand growth ratio from zero to zero point fine down decline ratio and observed the industry behavior. We found the electricity supply would doubtless satisfy all the need but the revenue would down to minus situation. The decision points now could do nothing to improve the terrible problem. When we change the electricity price of the model scenario assumption to free flow scenario, the revenue could improve to positive number. But the price would continuously increase to unreasonable high point of nearly one hundred thousand. This could not happen in the real world. For other approach of solving the problem, we try to largely decrease the power generation capacity by pretend we could sell the capacity each period. This way the revenue could rise to positive numbers and company still sustained stable power supply.

Cycle demand growth

We let the growth ratio vibrate from minus zero point zero fine to zero point zero fine and run two simulations. First simulation we started the initial growth ratio from the zero point zero fine. Both profit and supply performed well. Although revenue would decrease below zero than back to positive numbers due to the different amplitude of vibration between revenue and cost. The amplitude of vibration of revenue was bigger than of cost and former kept rising so the profit performed still well. But when we expand the demand growth interval from zero point one to minus zero point one. The profit will down to minus when the supply performed well. The solution is to raise the price. But if the interval expanded from zero point two to minus zero point two. The price would rise doubly than the interval of zero point one to minus zero point one. Second simulation we start from the minus zero point zero five in the first year. We found both the profit and supply performance were good for the demand was always below the initial supply capacity. Demand down below the power supply capacity and back to the power initial value a few years latter. But when we expand the demand growth interval between zero point two to minus zero point two, the profit continuously down to minus numbers for the finish of power capacity under construction, that is the initial value previous set in the model to respond the reality. About one thousand KW capacity would joint the power supply capacity when the demand continuously declined. That would increase too much cost and decline the profit. If we raise the price, the highest price number would be the same as the first simulation.

Scenario testing	***Dilemma***	***High leverage solutions***
Normally predicted growing demand and Optimistic demand growth	Decreasing profit behavior	Raising the price
Pessimistic demand	Decreasing profit behavior	Selling the power generation capacity
Cycle demand growth	Revenue got worse when the vibration interval of the demand expanded.	Raising the price

Table 2: summary of scenarios planning and results

Discussion

From the simulation results we observed raising the electricity price is the most efficient solution in the optimistic and cycle demand scenarios. In the pessimistic demand scenario the usefully way to get through the problem is to sell the power generation capacity. But these solutions are impossible and not realistic to our agent. First, the price is not freely changeable for the state-run company. In reality, the process of permitting the price and the public reaction about the price change all increase the difficulty to raise the price. In the short time period of our simulation the price could change, but in the reality the price could not change so large in the short time period. Second, the state-run company is a monopoly company and just in the beginning of liberalizing the market. To sell the power generation capacity means there must be some long-pocket power companies that want to buy the capacity. Even you can sell the capacity, you must make sure your competitors would not grasp your market share. But it is impossible. Since now you are the market owner, any new entry competitor must grasp your market share to survive. If your market share down, your revenue must down. The cost you reduce for selling the capacity and the revenue you decrease for the market share down would decide your profit number. And that is still an unknown number.

Why the situation our agent face is so difficult to get through. In the system dynamics approach, we assume the structure decide the behavior. So we must go back and see what the system dynamic structure our agent face. And how the structure caused the phenomenon our agent faced.

Supply bottleneck, long hardware construction delay, and unstable demand

The electricity industry is composed by three main capacity- power generation capacity, transmission system, and distribution system. The electricity must be generated by power generation capacity at first. Then it would flow through transmission system and distribution system to reach the user end. The collocation of the three capacities caused the bottleneck of the electricity industry. Power generation capacity has its limit to generate the electricity. Transmission and distribution system also has their limit to carry the electricity. Minimum of the three capacities decides the real electricity the company could produce to satisfy the demand. The bottleneck exists when each of three is too large that other two capacities could not collocate with it. For example, if power generation capacity generate too much power and transmission and distribution system could not carry all the electricity that power generation produced, the power generation must lower down its electricity produced until the other two capacity raise to the point that could carry all the produced electricity. The bottleneck is the critical point that sustains the stable power supply of the power system.

Another important structure characteristic is the long hardware construction delay. The average construction delay of the power generation, transmission system, and distribution system are about five years. If the demand was predictable, that would be no problem to plan exactly how many capacity to produce to satisfy the need. However, when the demand is unstable, i.e. predictable, that would be a disaster. Our agent must plan five to ten years early before the real need happen. If the company predicts the five years latter there would be 100 KW new increasing demand, the company would begin to produce now. But when the time being, it observes that the external factors caused demand unchanged. The company would lose lots of money for construction including interest expenses, sink cost, and human resource expenses. That would reduce the company's next invest ability including bank credibility and useable capital.

Long hardware construction delay would also influence the speed of capital return rate. The agent must entirely consider how to efficiently allocate the capital to the power generation capacity, transmission system, or distribution system. Each new investment of three instruments means lots of capital usage. Lots capital usage causes capital crowd out effect that is if our agent spend lots of money in power generation investment, he might not have enough money to invest in another two instruments investment or he might pay lots more cost to get them.

Demand uncertain and long hardware construction delay would cause the vibration of the agent's power generation capacity. As the above description, demand uncertain would make the exactly prediction and planning of the power supply impossible. Long hardware construction delay would make change of the construction not as quickly as change happen.

Vibration of the power supply and capital crowd out effect would increase the difficulty of business operation. Good financial performance and stable power supply would be very difficult to reach in this kind of system dynamics structure. You must know exactly what the bottleneck causes the problem of the power shortage, how the future demand really is, and how the collocation of three instruments should be. Then you could decide the capital allocation timing. One of the understanding make trouble means all of the system make trouble.

What is the high leverage answer in this situation?

Take beer game as an example. For longer treatment process of the beer game, every decision point is related. Independently treating each decision point would make the overall result out of control. We must know the high leverage answers of the structure like beer game. That is understands the behavior of up, meddle, and down stream and the effect of time delay of the system.

What the high leverage answer now? According to the model, we know:

- Collocation of three instruments is important. The agent should simultaneously construct the instruments than one after another.
- Unstable demand and long hardware construction delay cause difficult invest decision. More investment causes more sink capital and more interest expenses and debt cost. Less investment would probably be unable to satisfy the suddenly raising power demand.
- Timing influences the priority of strategy selection. According to the implying causal loop, the dominant loop would change as time change and the priority of the strategy selection would change. Should our agent fist invest power generation capacity, transmission system, or distribution system? In different timing, most caring decision point of our agent would be different.

Another approach- redesigning the structure: Direct supply & Closed to the customers

Supply bottleneck, long hardware construction delay, and unstable demand make dynamic structure of investment operating and raise the decision difficulty. According to the above understanding and the simulation we make, we know even we build a system dynamics model and play with it trying to generate better strategy. It is difficult to create a better strategy. The high leverage answer doesn't exist. The operating dynamics of the system structure our agent faces makes our agent making strategy very difficult.

Because our agent faces very difficult strategy making in the present system structure, we might consider another approach, redesigning the structure to efficiently take care present electricity industry problem.

Another approach means building small power generation capacity and change the central kitchen kind of operating of totally electricity dispatch. Our agent could build power generation capacity for each smaller demand zone like industrial zone. Our agent might transform to consulting company. Selling the power generation capacity to the user. Our agent consults and guides the buyer how to efficiently generate the power. In sum, direct supply and closed to the customers are the better treatment. Smoothing the supply from the demand end to improving the vibration problem that is caused by the long hardware construction delay and unpredictable demand change.

Conclusion

According to the simulation and discussion, we know the structure of our agent. The important decision points are collocation of three instruments and timing influences the priority of strategy selection. However, unstable demand and long hardware construction delay cause difficult invest decision. We suggested our agent might try another approach- redesigning the structure: Direct supply and closed to the customers.

We must admit that our model is a simple and initial structure. We omit some dynamics for research resource, time and cost, limits. The regional and detail collocation of three instruments are not discussed here. Power generation divided too simple. Only discussing nuclear, water, and fire generation capacity. Each one could be discussed more detailed that would be more closed to the reality. How human resource expenses and other operating expenses influence the capacity still need more research. All of the shortages could be extended to future research. But we still have the initial insight found from the research process and from the model playing. And that would be a good start to get more deeply into the understanding of the electricity structure. To improving the strategy making for similar electricity economic unit and other industry facing the same structure.

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