An Application of System Dynamics in Electricity Supply Systems: Case of Yazd Regional Electricity Company in Iran

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Abstract:

Due to the existing complexities in the recent energy systems, energy planning is known as an essential task for the governments in different countries. Among different techniques in energy planning, system dynamics is a valuable technique in the simulation of complex systems and analysis of their existing dynamism. In this paper, the electricity generation system is considered as a comprehensive dynamic model to analyze the results of different scenarios and policies. The effectiveness of the model in handling the dynamism of the system and analyzing the policies is validated with a real case in province of Yazd in Iran. For this purpose, 5 different scenarios and policies are analyzed based on different technical, economical and environmental indices. The results show that the balanced growth and the environment-oriented policies have represented the best results among different policies. Even though the application is to the Iranian Case, the implications are much wider, especially in developing countries.

Keywords: Energy planning; Electricity Supply System; System Dynamics; Developing Countries; Policy Analysis

1- Introduction

The importance of electricity energy in the new world in general, and the uncertainties in the future demands of electricity in particular, make electricity energy planning as a main concern for electricity stakeholders in different countries. In recent years, there have been various attempts in the field of energy planning which have lead to some novel and valuable models. As a result of different points of view in handling the energy planning problem, these models can be categorized in four groups as follows:

- Econometric Models: These models are mainly generated based on econometric techniques (Dementjeva, 2009). They are long-term or mid-term models with a low level of considered details which have a top-down approach in the analysis of the energy planning problem. One of the main econometric models is E3MME. The fact that these models do not consider a remarkable amount of details and the existing dynamism of energy systems, the results of these models do not have enough degree of accuracy.
- Energy Equilibrium Models: these models, with mid-term or long-term horizon and an almost low level of details, are created based on the equilibrium and game theories; the most popular models are ENPEP and SGM. These models have a top-down approach in the analysis of the energy planning problem (Dementjeva, 2009). The main drawbacks of these models are the lack of accuracy and the low level of details.
- Optimization Models: these models, which are generated based on mathematical programming, are short-term or mid-term models with a high level of details. On the contrary of the above-mentioned models, these models have a Bottom-Up approach. Some of the main optimization models are MARKAL, MESSAGE and EFOM (Dementjeva, 2009; Wenying, 2005 and Fenhann, 2008). Even though these models have a high level of considered details and accuracy, they are not flexible enough in dealing with different variables and have not enough capability in the analysis of the dynamisms of the system.
- Simulation-based models: these models are based on the model-based simulation principals. In most cases, these models are short-term or mid-term with the highest amounts of details and have a Bottom-Up approach in system analysis. These models are the best models according to the consideration of system dynamisms and they have also a high level of accuracy and flexibility in system analysis. As a result of these advantages, simulation-based models are the most popular models in energy planning. LEAP (2006) and MIDAS (1996) are some of the most popular simulation-based models in energy planning (Dementjeva, 2009).

Even though, the simulation-based models have an acceptable capability to handle the energy systems, they have not enough flexibility in analyzing the dynamics of the more complex energy systems, especially in developing countries.

System Dynamics, which is a simulation-based approach, studies the relationships between variables and makes a good understanding of the considered system. Because of the complexity of energy systems with a huge number of variables in developing countries, SD is an appropriate approach to make a domestic energy model with the consideration of specific characteristics of these countries. While SD has the advantages of the simulation-based models, it also has a great flexibility in facing the complexity of energy systems. This is in spite of the fact that the previous applications of SD in electricity energy planning have not considered all the related subsystems and variables of the system. In other words, these researches have focused on the analysis of some parts of system such as regulating, price and tariff, demand and so on and no comprehensive model has been developed so far.

In this study, the system dynamics approach is applied to analyze the effect of different scenarios and policies and make a strategic energy plan in the Iranian electricity energy system. The proposed SD model is a comprehensive model which is taken all the relevant subsystems of electricity supply system into account. The effectiveness of the model in handling the dynamism of system and analyzing policies is validated with a real case in province of Yazd in Iran. The results of the model are evaluated based on different economical, technical and environmental criteria. Even though the application is to the Iranian Case, the implications are much wider, especially in developing countries.

The rest of the paper is organized as follows: in section 2, the previous related publications are reviewed. A brief review on the structure of electricity energy market in Iran is represented in section 3. Section 4 takes the main structure of the proposed SD model into account. In section 5, the validation of the proposed model and the results of policy analysis are stated. Finally, the concluding remarks are represented in section 6.

2- Literature Review

The pioneering work in the application of system dynamics models in energy planning was represented by Naill (1973) who developed a model for United States gas industry. In another study, Sterman (1981) developed a system dynamics model with mutual relationship between energy and economy. Naill, in another study, described the conceptual development of FOSSIL2, which is an integrated model of U.S. energy supply and demand and its application in energy policy analysis (Naill, 1992). His conceptual model only focused on supply and demand relations and had less attention on the other parts of energy system. Again, Nail and his co-workers analyzed the effect of U.S. policies in the mitigation of global warming using the FOSSIL2 integrated energy model (Naill et al, 1992). Although SD is a useful technique in energy planning, there are scarce researches that have considered it, especially in electricity systems. Moreover, most of the related researches have not considered all the subsystems in energy systems.

The first attempts in the application of SD in electricity energy planning were performed by Rahn (1981) and Ford (1997). Generally, they represented conceptual models for electricity provision system with minimum amount of details in their works. In another paper, Moxnes prepared a SD model to analyze the fuel substitution policies in OECD- European electricity production systems (1990). Qudratollah (2001, 2005), in two different papers, represented a model for understanding the dynamics of electricity supply, resources and pollution and applied it in Pakistan. In his model named MDESRAP, 4 different scenarios including base case, environment-oriented, market-oriented and self-oriented scenarios were analyzed considering economical and environmental indices. For this purpose, the gross domestic production (GDP) and the amount of CO2 emission were considered as the appraisal criteria for a period of 2000 to 2030. Again, Ford applied SD as a tool for analyzing different policies in CO2 reduction for western electricity plants in U.S (Ford, 2008). In another paper, Kilank and Or (2011) presented a SD model, focused on the role of Distributed Generation technologies (DG) on which the results of different scenarios were analyzed.

The most comprehensive study in this field was represented by the European Institute for Energy Researches (EIFER) which showed the application of SD for the German Electricity Market. In their SD model named ZERTISM, the effect of different policies were evaluated based on economical and environmental aspects (price and CO2 emission). For this purpose, they have considered 8 likely scenarios for German electricity market (Jäger et al, 2009).

3- Iranian Electricity Market (Yazd Province)

In the electricity provision structure of Iran, there are some regional electricity companies that manage all of the electricity value chain throughout the region. Moreover, these regional companies have some subordinate companies that deal with supplying, transferring, dispatching and the other parts of electricity value chain. Up to now, all the parts of electricity value chain are exclusively handled with the government sector. Only in recent years, private sector has invested in some new power plants, but the share of private sector in electricity supply market is not comparable with the government sector’s ones. In addition, the electricity selling tariffs are lower than the total cost of electricity generation. In other words, government sector have paid an enormous amount of subsides for electricity. Due to the reasons, the regional electricity companies are not profitable and thoroughly depend on the government budget. Moreover, the government- oriented electricity generation in Iran causes a lower energy and capital productivity in comparison with the world average (Yazd electricity Statistics, 2000-2008)

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From another point of view, Gas and water have the main contribution in the energy portfolio of electricity generation in Iran. Although, there are remarkable deposits of coal in Iran, the coal-fired power plants have not any share in electricity generation. Moreover, in spite of a great potential in electricity generation with renewable energies such as solar, wind and geothermal, there are little efforts in this area.

Yazd which is located in central Iran is among the driest cities in Iran, with an average annual rainfall of only 60 mm, with summer temperatures very frequently above 40 ℃ in blazing sunshine with no humidity. Although, Yazd has the greatest deposits of coal and numerous numbers of sunny days, Gas which is prepared from the southwest regions of Iran (Khuzestan) is the only consumed energy in the electricity generation. Hence, In addition to Gas consuming power plants, the coal-fired and solar power plants are the other more applicable ways for electricity generation in Yazd (Yazd electricity Statistics, 2000-2008).

4- The SD Model

The proposed SD model is consisted of 10 main subsystems. Fig.1 illustrates the macro-structure of the proposed model with the subsystems and three main exogenous variables. The main exogenous variables in this model are GDP (Gross Domestic Production), inflation rate and technology change which makes a remarkable effect on the behavior of the electricity supply system. As it is shown in Fig.1, the considered subsystems and their main variables have many interactive relations.

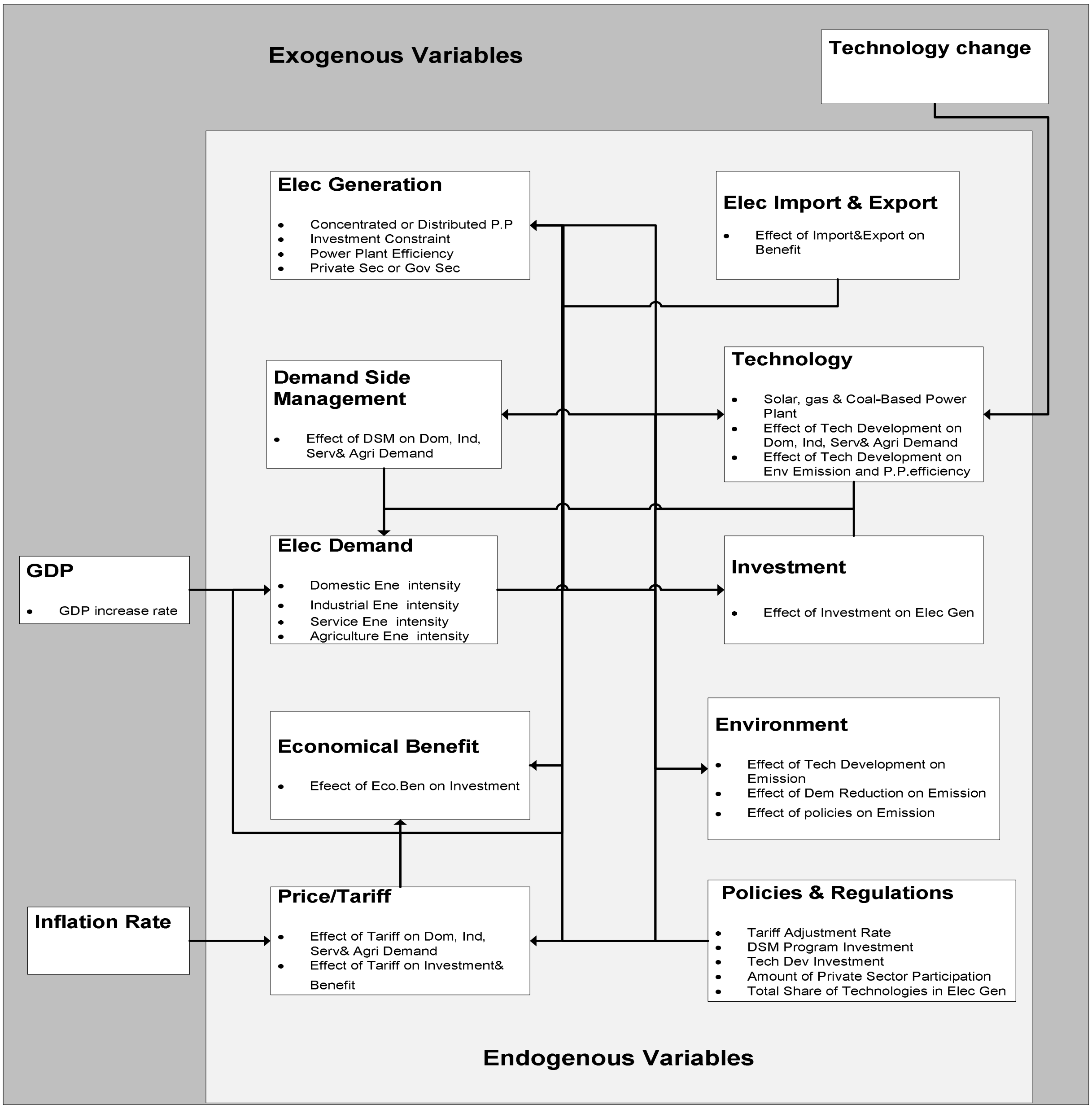

Fig.1: Proposed SD Model

The subsystems are described as follows:

4-1- Electricity Demand Subsystem

The main variables of the electricity demand subsystem are as follows:

- GDP: GDP is an index that shows the amounts of production in different economies. As it is obvious, the amount of energy consumption (especially electricity) has a straight relation with GDP. Due to this relation, in this paper, GDP has been considered as an important input variable to analyze the future demand of electricity.

- Electricity Demand Intensity: Demand intensity which is the other main variable in this subsystem shows the amount of electricity that is consumed to obtain one unit of GDP. It is obvious that the lower amount of Demand intensity indicates the higher degree of electricity energy efficiency. In this research, the amounts of demand intensity in different sectors included domestic, industrial, service and agricultural sectors are considered to analyze the electricity demand in different sectors and the total electricity demand.

In addition to the above-mentioned variables, three significant variables are the effect of technology development (TD), the effect of demand side management (DSM) and the effect of tariff on the electricity demand of different sectors. These variables also have a significant effect on the amount of electricity peak demand which is the other main variable in this subsystem. Fig.2 shows a general view of the main variables and their relations in the electricity demand subsystem. It must be noted that for the sake of simplicity, the other related variables in the subsystem are not represented.

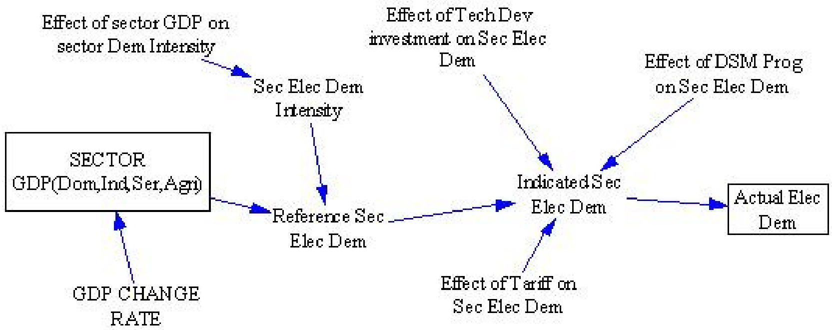

Fig.2: Electricity Demand Subsystem

4-2- Electricity Generation Subsystem

The main variables of the electricity generation subsystem are as follows:

- The Considered power provision methods are Concentrated Generation (CG), Distributed Generators (DG), Demand Side Management (DSM) and energy importing (EI). One of the main objectives of this study is to determine the shares of different methods of power provision. In other words, defining the portfolio of power provisions are one of the main desired outputs.
- Capital Constraint: The amount of investment is one of the main variables in the electricity generation subsystem. The fact that some of the required electricity generation capacities are not fully accessible due to the capital constraint, decrease the reliability of power generation.

- Power Plants Efficiency: Power plant efficiency is the other effective variable in power generation subsystem that shows the amount of time that a power plant is in use in a year. Obviously, higher degrees of power plant efficiency cause lower amounts of new electricity generation capacities.
- Depreciation: Depreciation shows that what share of current electricity generation capacities are depreciated every year.
- Private Sector share in Power Generation: due to the limitation of government for investment in new power generation capacities and the low level of productivity in government power plants, the contribution of private sector is an undeniable part of power generation subsystem. So far, the participation of Iranian private sector in power generation is not significant. However, in coming years, the increasing trend of power demand and the lack of government financial resources will enforce the government sector to give more roles to the private sector.

The main variables of the electricity generation subsystem are illustrated in Fig.3.

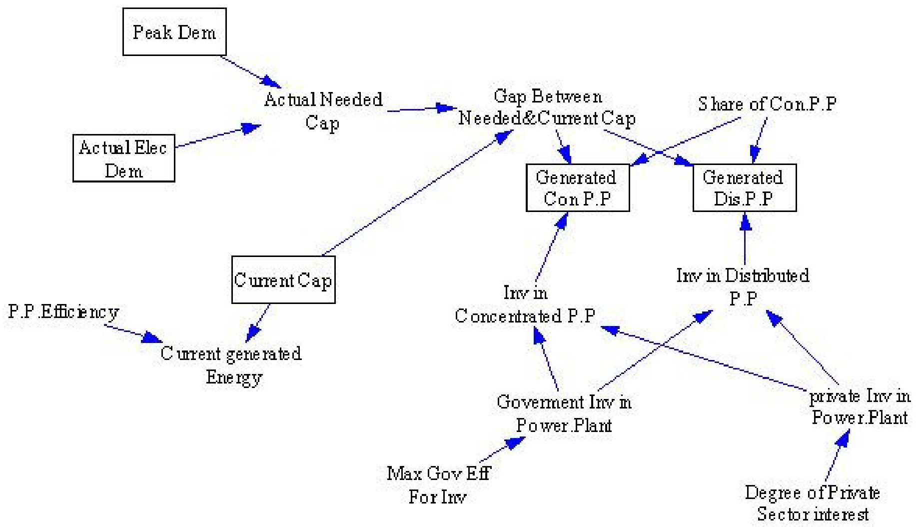

Fig.3: Electricity Generation Subsystem

4-3- Technology Subsystem

Defining the weights of different technologies in the portfolio of power generation technologies is one of the main variables in this subsystem. In this paper, the gas, coal and solar based power plants are considered as the most appropriate options in Yazd. Moreover, the amounts of investment in different technology development programs such as demand reduction, pollution reduction and increasing power plants efficiencies are the other important variables. Fig.4a shows a general view of the main variables and their effects in the technology subsystem.

4-4- Environment subsystem

The environment subsystem is dealt with the environmental aspects of electricity generation system. The effect of technology development programs on the pollution reduction, the share of different technologies in power generation programs and the effect of different policies on the demand reduction are the most important variables in this subsystem. A general view of the environment subsystem is represented in Fig.4b.

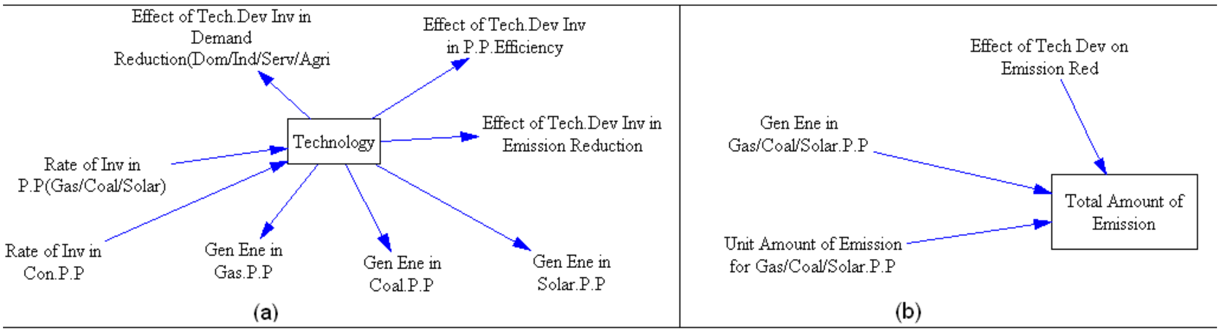

Fig.4: a) Technology Subsystem- b) Environment Subsystem

4-5- Price/Tariff Subsystem

The main purpose of price subsystem is to determine the unit price and tariff of electricity and analyze the effect of these variables on the other subsystems. The tariff adjustment rate, the unit price of electricity considering generated and imported electricity and the inflation rate, as an exogenous variable, are the main variables in this subsystem. On the other hand, the unit tariff of power has a straight effect on the amounts of demand, profit and investment. Fig.5a presents the main variables and their relations in the price/tariff subsystem.

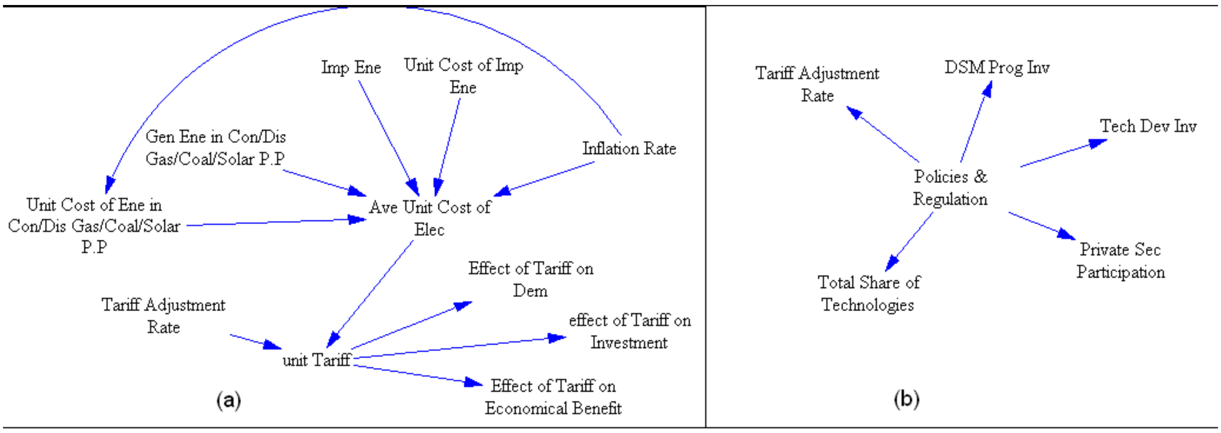

Fig.5: a) Price/Tariff Subsystem- b) Policies & Regulation Subsystem

4-6- Policies and Regulation

In this subsystem, the endogenous variables that have regulatory aspect are considered. The tariff adjustment rate, the amount of investment on demand side management and technology development, the degree of privatization (amount of private sector participation) and the shares of different technologies in power generation are the main regulatory variables. Fig.5b shows the main variables that influence on the regulatory subsystem.

4-7- Economical Profit

In this subsystem, the amounts of incomes, costs and total capital are analyzed. Variables such as tariff, electricity demand, amounts of exported electricity and the effect of economical profit on investment are the main variables in this subsystem. The main variables of this subsystem are illustrated in fig.6.

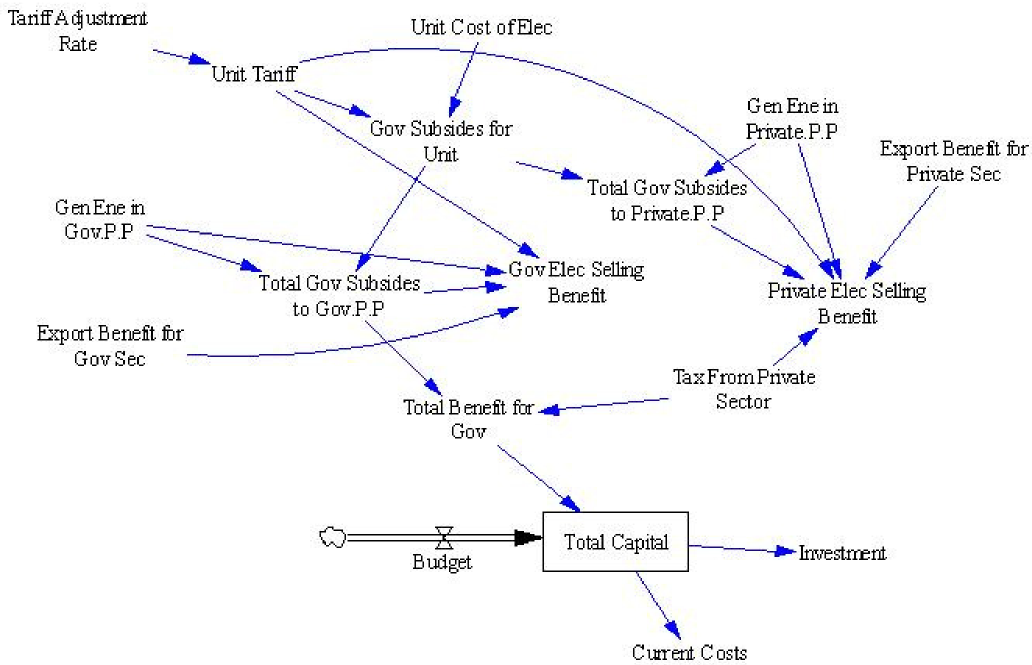

Fig.6: Economical Profit Subsystem

4-8- Export/Import Subsystem

The maximum proportion of imported power is one of the main variables in this subsystem. This variable shows that what part of electricity demand can be provided through importing. On the contrary, the maximum proportion of exported power which shows the share of out of work power plant capacities that can be exported is the other main variable in this subsystem. Moreover, the effects of power import and export on the economical profit are the other main variables in the export/import subsystem. Fig.7 shows the main variables of the export/import subsystem.

4-9- Investment Subsystem

The investment subsystem provides the required amount of capital for the other subsystems of electricity generation system. The amount of private sector participation, degree of private sector interest in investment, the amount of investment in DSM and TD programs are the most important variables in this subsystem. The main variables of the investment subsystem with their relations are depicted in Fig.8.

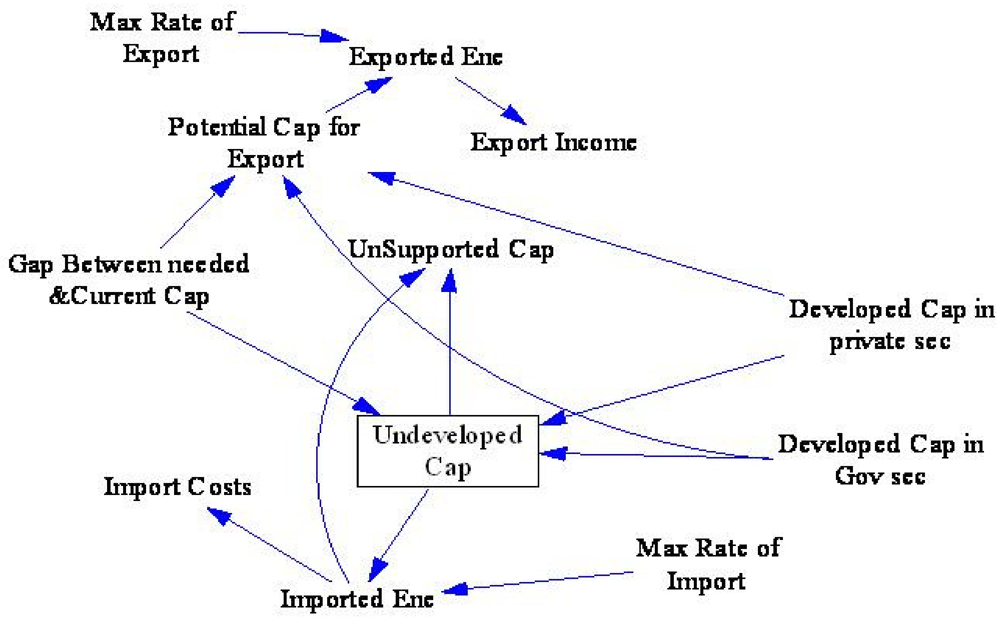

Fig.7: Export/Import Subsystem

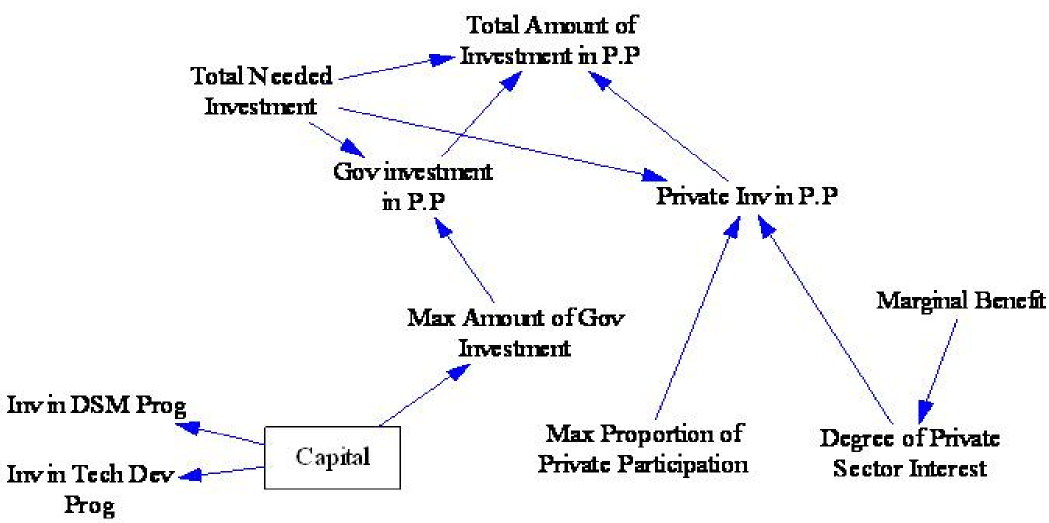

Fig.8: Investment Subsystem

4-10- Demand Side Management Subsystem

Analysis of the effect of investment in DSM programs on the electricity demand of domestic, industrial, service and agricultural sectors is the main objective of this subsystem. Even though DSM is an effective subsystem of electricity generation subsystem, the main variables of this subsystem are described in electricity demand Subsystem.

It must be noted that there are no clear and distinct boundaries between the above mentioned subsystems. These unclear boundaries with the fact that there are different interactions between the subsystems make the overall system to be complex and unpredictable.

5- Validation of the Model

In this section, the validity of the proposed model is evaluated based on the historical data for Yazd regional electricity company in period 2000-2008. For this purpose, the year 2001 is considered as the base year and the simulation results of the model for period 2001 to 2008 are compared with the real data. In this paper, for the sake of simplicity, only the real amounts of electricity demand are compared with the results of the model. As the electricity demand is the main variable which affects all parts of the model, appropriate results for electricity demand make an approximate confidence on the results of the other parts of the model. Table.1 shows the results of proposed model compared with the real data in period 2001-2008 (Yazd electricity Statistics, 2000-2008).

Table 1: The real demands compared with simulated demands

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Real Domestic demand (GWh)	492	547	601	664	720	784	843
Simulated Domestic Demand (GWh)	527	624	692	728	741	748	801
Real Industrial Demand (GWh)	1250	1500	1460	1050	1190	1360	1470
Simulated Industrial Demand (GWh)	1350	1580	1650	1530	1300	1250	1370
Real Service Demand (GWh)	334	344	369	406	445	482	460
Simulated service Demand (GWh)	337	394	438	460	470	456	494
Real Agriculture Demand (GWh)	381	424	486	525	537	544	578
Simulated Agriculture Demand (GWh)	385	439	486	526	562	600	647
Real Total Demand (GWh)	2160	2460	2810	2920	2650	2890	3170
Simulated Total Demand (GWh)	2160	2600	3040	3270	3250	3070	3050

As it is shown in table.1, the simulated results of the model have not a significant difference with the real amounts of demand; however in some cases, the model has had a lag in following the trends, but it could comprehend the trends effectively. Fig.9 which compared the real total demand with the simulated total demand, shows the power of the proposed SD model in comprehension of the behaviors of the system.

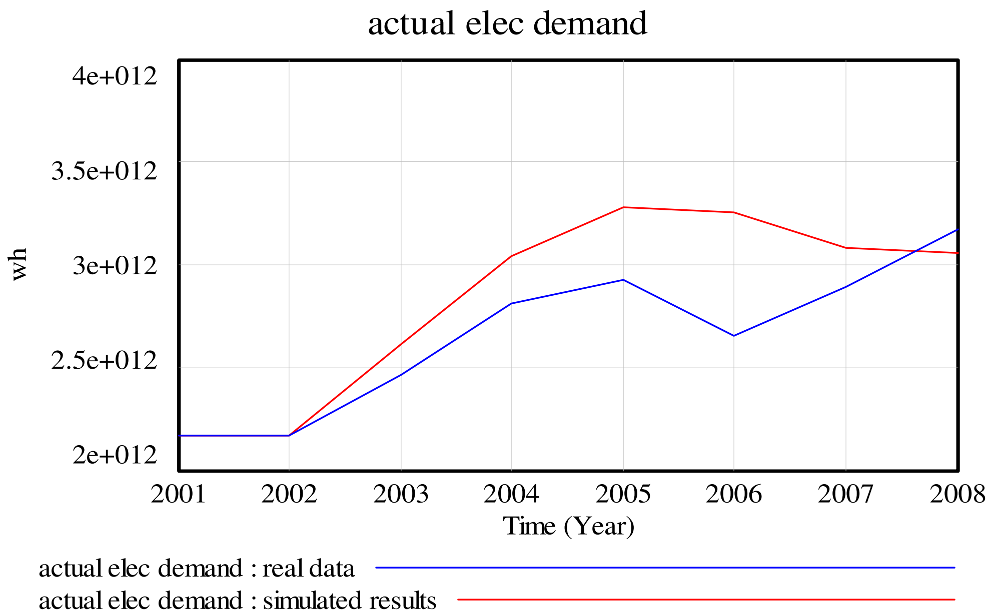

Fig.9: Real total demand- Simulated total demand

6- Policy Analysis

In this section, the results of applying different scenarios and policies on the electricity supply system of Yazd are analyzed. The scenarios are made with different amounts of exogenous variables that have significant effects on the outputs of the system. As it is shown in Fig.1, the inflation rate and the GDP growth rate are two important exogenous variables. In this study, 5 different scenarios are created based on different amounts of the exogenous variables. The policies, on the other hand, are based on different amounts of endogenous variables. In this study, 5 different policies are selected with different amounts of Tariff adjustment rate, share of government sector in power generation, the amount of investment in DSM and TD and the share of different technologies in power generation. The combination of scenarios and policies makes a comprehensive way to understand the behaviors of the considered electricity supply system.

6-1- Scenarios and Policies Description

Tables 2 and 3 show the considered scenarios and policies to analyze the electricity supply system in Yazd province.

Table.2: proposed scenarios (Yazd Statistical indices, 2000-2010)

Scenarios	**characteristics**
Scenario A (Case Base Scenario): assume that the As Is conditions are preserved in the future.	Inflation rate= 10%, Total GDP growth rate =0.263, Industrial GDP GR= 0.302, Service GDP GR= 0.257, Agricultural GDP GR=0.198.
Scenario B	This scenario assumes that the inflation rate is increased to 20%. The other variables are preserved.
Scenario C	This scenario assumes that the inflation rate is decreased to 5%. The other variables are preserved.
Scenario D	This scenario assumes 50% increasing in the GDP growth rate for different sectors. The other variables are preserved.
Scenario E	This scenario assumes 50% decreasing in the GDP growth rate for different sectors. The other variables are preserved.

Table.3: Proposed policies

Policies	**characteristics**
Policy 1 (Case base Policy): assumes that the As Is conditions are preserved.	Tariff Adjustment Rate: 43%; Share of Government investment= 100%; Share of DSM and TD Investment= 1% of budget;

	Share of Gas Power Plants= 100%
Policy 2 (Government-Oriented Policy): Assumes that government tries to preserve its dominance in power generation, But the electricity selling tariffs are adjusted in favor of government.	Tariff Adjustment Rate: 120%; Share of Government investment= 100%; Share of DSM and TD Investment= 1% of budget; Share of Gas Power Plants= 50%; Share of Coal-Fired Power Plants= 50%
Policy 3 (Private Sector-Oriented Policy): Assumes that government tries to decrease its dominance in power generation and improve its regulatory and controlling roles.	Tariff Adjustment Rate: 120%; Share of Government investment= 25%; Share of DSM and TD Investment= 1% of budget; Share of Gas Power Plants= 70%; Share of Coal-Fired Power Plants= 25%; Share of solar Power Plants= 5%
Policy 4 (Environment-Oriented Policy): environment conservation and decreasing power generation pollution are the main objectives of this policy.	Tariff Adjustment Rate: 140%; Share of Government investment= 25%; Share of DSM and TD Investment= 10% of budget; Share of Gas Power Plants= 80%; Share of Coal-Fired Power Plants= 0%; Share of solar Power Plants= 20%
Policy 5 (Balanced Growth Policy): Assumed balanced amounts for different variables to obtain balanced results in different aspects.	Tariff Adjustment Rate: 100%; Share of Government investment= 50%; Share of DSM and TD Investment= 5% of budget; Share of Gas Power Plants= 75%; Share of Coal-Fired Power Plants= 25%; Share of solar Power Plants= 0%

In order to analyze the performance of different scenarios and policies, 4 different performance indices are taken into account. Accordingly, the amounts of pollution and the amount of capacity shortage are considered as the environmental and technical performance indices. Moreover, the unit cost of electricity and the amount of economical profit are the economical performance indices. In addition to these indices, the electricity demand and the amount of supplied capacities are the other variables that have been considered for the analysis of the results.

6-2- The Scenarios and Policies Analysis

Considering 5 different scenarios and policies, there are 25 different instances of the combination of scenarios and policies. According to the 6 mentioned performance indices and 25 different instances, 150 different results should be represented in this section. In this section, for the sake of simplicity, a brief review of the results of 6 performance indices for different 25 instances in period 2010-2020 are represented.

6-2-1- Electricity Demand

Table.4 shows the maximum and minimum amounts of electricity demand in 2020 for different scenarios. As it is shown in Table.4, the maximum amount of electricity demand in all scenarios is happened in policy A (Case base policy). On the contrary, the environment-oriented Policy (policy D) which has had maximum share of DSM and TD investment and maximum amount of tariff adjustment rate has minimum amounts of electricity demand in all scenarios. For instance, in the case base scenario, the amount of electricity demand for policy 4 is 40% lower than case base policy.

Table.4: The Results of Electricity Demand in Different Scenarios

Scenario	**Max expected Demand (wh)**	**Max Related Policy**	**Change (%)**	**Min expected Demand (wh)**	**Min Related Policy**	**Change (%)**
Scenario	8.7E12	case base	0%	5.22 E12	Policy 4	- 40%
Scenario B	8.23E12	case base	-5%	5.22E12	Policy 3,4	- 40%
Scenario C	1.01E13	case base	16%	5.27E12	Policy 4	- 39%
Scenario D	2.87E13	case base	>200%	1.72E13	Policy 4	98%
Scenario E	3.72E12	case base	-57%	2.28E12	Policy 4	-74%

On the other side, scenarios D and E, which have had the maximum and minimum GDP growth rate, have maximum and minimum amounts of electricity demand, respectively. The minimum expected demand of these scenarios show 98% and -74% change compared with the case base scenarios. Moreover, scenario C which has had minimum inflation rate, have also a high amount of electricity demand.

6-2-2- Supplied Capacity

Apart from the amounts of electricity demand and peak demand, the capital constraint is the main effective variable on the amount of supplied capacity. As it is obvious in Table.5, the minimum amounts of supplied capacities in all scenarios are occurred in the case base policy which has inclined on the government financial resources. According to the existing capital constraints in the government sector, a noticeable amount of needed capacities have not been developed in the case base and government-oriented policies; nevertheless, the maximum amount of supplied capacities is obtained in balanced growth policy (policy 5). Moreover, among different scenarios, the maximum and minimum amounts of supplied capacities are in scenarios D and E, respectively.

Table.5: The Results of Supplied Capacity in Different Scenarios

Scenario	**Max Supplied Capacity (w)**	**Max Related Policy**	**Change (%)**	**Min Supplied Capacity (w)**	**Min Related Policy**	**Change (%)**
Scenario A	1.43 E09	Policy 5	>125%	6.33 E08	Case base	0%
Scenario B	1.39E09	Policy 5	>100%	6.33 E08	Case base	0%
Scenario C	1.47E09	Policy 5	>125%	6.33 E08	Case base	0%
Scenario D	2.46E09	Policy 5	>275%	6.33 E08	Case base	0%
Scenario E	1.43E09	Policy 5	>125%	6.33 E08	Case base	0%

6-2-3- Capacity Shortage

As it is mentioned in the analysis of supplied capacity that the case base and government-oriented policies have had the minimum amounts of supplied capacities, these policies have also the huge amounts of capacity shortage in all scenarios. As it is shown in Table.6, the maximum amounts of capacity shortage are obtained in case base policy; indeed, the maximum amount of capacity shortage in case base scenario is 380 MW which is increased to 1050 MW in scenario D. Conversely, there are no amounts of capacity shortage in the other policies which have the private sector participation.

Table.6: The results of capacity shortage in different scenarios

Scenario	**Max capacity Shortage**	**Max Related Policy**	**Change (%)**	**Min capacity Shortage(w)**	**Min Related Policy**	**Change (%)**

	(w)					
Scenario	3.58 E08	Case base	0%	0	Policies	-100%
Scenario B	3.12E08	Case base	-13%	0	Policies	-100%
Scenario C	3.87E08	Case base	8%	0	Policies	-100%
Scenario	1.05E09	Case base	>175%	0	Policies	-100%
Scenario E	3.51E08	Case base	-2%	0	Policies	-100%

6-2-4- Unit Cost of Electricity

Based on the results of case base scenario, the Maximum and minimum unit cost of electricity in 2020 will be 2490 (R/KWh) and 2020 (R/KWh), respectively. Table.7 shows the amounts of unit cost of electricity for different scenarios and policies. As it is obvious in Table.5, the minimum and maximum unit cost of electricity will occur in balanced growth policy and case base policy, respectively. The high amount of cheap coal-based power plants with the lack of expensive solar electricity tends the balanced growth policy to the lowest unit cost of electricity. On the contrary, although case base policy has only focused on gas power plant, but the high amounts of imported electricity makes a high unit cost of electricity.

Table.7: unit price of electricity in different scenarios

Scenario	**Max Price(Rial/Wh)**	**Max Related Policy**	**Change (%)**	**Min Price(Rial/Wh)**	**Min Related Policy**	**Change (%)**
Scenario	2.49	Case	0%	2.02	Policies	-19%
Scenario	6.84	Case	175%	6.28	Policies	150%
Scenario	1.48	Case	-41%	1.1	Policies	-56%
Scenario	2.79	Case	12%	2.02	Policies	-19%
Scenario	2.49	Case	0%	2.02	Policies	-19%

In another view, the minimum and maximum unit price of electricity will be in scenario C and B with 5% and 20% inflation rate, respectively. Based on the results, the minimum unit price of electricity in 2020 will be 1100(R/KWh) in scenario C and the maximum ones will be 6840 (R/KWh) in scenario B.

6-2-5- Economical Profit

The low level of tariff in the case base policy which is lower than 50% of unit cost of electricity causes a huge amount of government subsidies. In other words, by the case base policy in all the scenarios, the regional electricity company has a great amount of loss. Moreover, a higher amounts of electricity demand leads to a higher amount of loss; therefore, the amount of loss is maximized in scenario D. On the other hand, the other policies which their tariffs are higher than the unit cost of electricity, convert the Yazd electricity market to a profitable market. As it is shown in Table.8, the maximum amount of profit is occurred in the environment-oriented policy. Even though the 140% tariff adjustment rate in the environment-oriented policies has decreased the amount of electricity demand, it leads to a higher amount of marginal and total profit.

Table.8: economical profit in different scenarios

Scenario	**Max Profit(Rial)**	**Max Related Policy**	**Change (%)**	**Min Profit(Rial)**	**Min Related Policy**	**Change (%)**
Scenario	9.2E 12	Policy 4	>150%	-1.46E 13	Case base	0%
Scenario	2.82E 13	Policy 4	>275%	-3.81E 13	Case base	>-150%
Scenario	5.28E 12	Policy 4	>125%	-9.07E 12	Case base	38
Scenario	1.82E 13	Policy 4	225%	-2.83E 13	Case base	-94%
Scenario E	9.2E 12	Policy 4	0%	-1.46E 13	Case base	0%

On the other side, the high amount of unit cost of electricity and tariff adjustment rate cause the scenario B to have the highest amounts of profit. Scenario D, which has a highest amount of electricity demand, also has a high level of profit. On the other hand, scenario C with a low level of demand and tariff has the minimum amounts of profit as well as the minimum amounts of loss in case base policy.

6-2-6- Amounts of pollution

As it is shown in Table.6, as expected, the environment-oriented policy will have the minimum amounts of pollution. As it is represented in Table.9, this scenario causes a 30% reduction in the amount of pollution in comparison with the balance growth policy, which has the highest amount of pollutants. It must be noted that the balance growth policy, which have the highest amount of pollutions, have provided all the amounts of electricity demand; while in the case base policy, more than 50% of needed electricity in 2020 will be imported or will not be provided. Considering the scenarios, scenarios B and D have maximum amount of demand and consequently maximum amounts of pollution.

Table.9: Amounts of pollution in different scenarios

Scenario	Max pollution (gr)	Max Related Policy	Change (%)	Min pollution(gr)	Min Related Policy	Change (%)
Scenario	8.33 E12	Policy 5	0%	5.8E 12	Policy 4	-30%
Scenario B	8.16E 12	Policy 5	-2%	5.63E 12	Policy 4	-32%
Scenario C	8.54E 12	Policy 5	3%	5.95E 12	Policy 4	-29%
Scenario	1.43E 13	Policy 5	72%	9.2E 12	Policy 4	10%
Scenario E	6.2E 12	Policy 5	-26%	4.4E 12	Policy 4	-47%

6-2-7- Optimal Policy

As it is shown in Tables 4-9, two policies 4 and 5 (environment-oriented and balanced growth policies) represent the best results among different policies. Table.10 shows the best and worst values of different indices in 25 different instances of the model. As it is obvious, environment-oriented policy has minimum amounts of pollution as well as minimum amount of electricity demand, maximum amounts of total profit and minimum amounts of capacity shortage. In other words, the minimum amounts of pollution in environment-oriented policy is not only because of application of solar power plants and omission of coal-fired power plants, but also because of demand reduction resulting from maximum amount of investment in DSM and TD and maximum amount of tariff adjustment rate.

Table.10: Pessimistic and optimistic Values of different indices

Performance index	Pessimistic Value	Related Scenario &Policy	Optimistic Value	Related Scenario &Policy
Energy Demand	2.78E13	Scenario D, Case	2.28E12	Scenario E, Policy 4
Supplied	6.33E8	All Scenarios , Case	2.46E9	Scenario D, Policy 5
Capacity	1.05E9	Case base scenario,	0	All Scenarios,
Unit Cost	6.84	Scenario B, Case	1.1	Scenario C, Policy 5
Total Profit	-3.81E 13	Scenario B, Case	2.82E13	Scenario B, Policy 4
Pollution	1.43E 13	Scenario D, Policy 5	4.4E 12	Scenario E, Policy 4

On the other hand, as the balanced growth policy has not huge amounts of electricity demand and pollution, it has minimum unit cost of electricity as well as maximum amounts of supplied capacity and minimum amounts of capacity shortage among policies.

Considering case base scenario as the more likely scenario, Fig.10 compares the environment-oriented and balanced growth policies for different performance indices.

Although the environment-oriented and balance growth policies are the best policies, the final decision on the optimal policy is thoroughly dependent on the decision maker's preferences. In other words, the selection of optimal policy is a multiple criteria decision making problem according to the weights of different indices.

7- Concluding Remarks

In this paper, a comprehensive system dynamic model comprising all different subsystems of electricity supply system is introduced. The validity of the proposed model was evaluated based on the historical data for Yazd regional electricity company in period 2000-2008. Five different scenarios and five policies were taken into account to analyze the considered electricity supply system. The results of the model were evaluated based on different environmental, technical and also economical criteria. The results show that the environment-oriented and balanced growth policies have the best results among different policies. The results of environment-oriented policy in comparison with the case base policy show 40% reduction in the electricity demand, 100% decrease in the capacity shortage, more than 150% increase in economical profit and 30% reduction in the amount of pollution. Instead, the balanced growth policy causes more than 125% growth in the supplied capacity, 100% decline in the capacity shortage and 19% decrease in the unit cost of electricity. In addition to the obtained results, it is possible to apply other scenarios and policies on the proposed model and analyze the behavior of electricity supply system. In other words, the proposed model is a flexible model to analyze a wide variety of problems in the domain of electricity supply system.

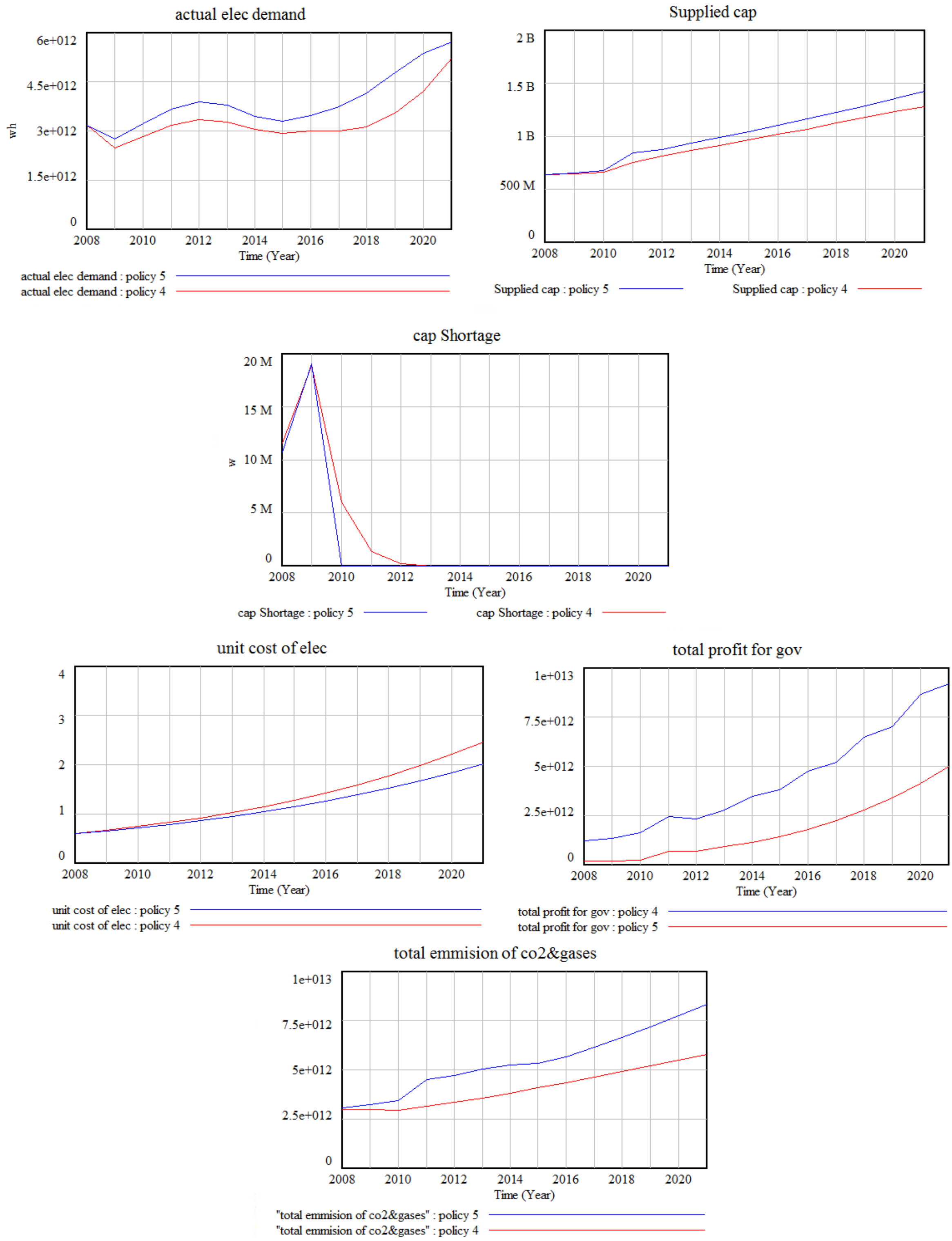

Fig.10: Environment-Oriented V.S Balanced Growth Policy

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