Dynamics Simulation Model of Demand and Supply Electricity Energy Public Facilities and Social Sector Case Study East Java

Ardhya Perdana Putra[1], Riyanarto Sarno[2], Erma Suryani[3]
Department of Informatics Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
[1]ardhyaputra@gmail.com,[2]riyanarto@if.its.ac.id,[3]erma.suryani@gmail.com

***Abstract*—Electrical energy is one important factor in the development of every nation, including Indonesia. Electrical energy has an important role in the development of both the economic and social aspects. Remember so large and important energy benefits of electricity while the power generation energy sources, especially those from non renewable resource limited presence, and to ensure the sustainability of energy sources is necessary pursued strategic steps to support the provision of electrical energy in an optimal and affordable.**

This paper explores how dynamic modeling can help generate future scenarios of electricity consumption. This modeling study the structure of complex systems and to test different scenarios. This paper have 3 Scenario such as, normal condition, optimistic condition(growth increase 0.5% per month), and pessimist condition(growth decrease 0.5% per month). Also a large number of variables, which affect the behavior could be considered. Power producers, suppliers and distributors requires knowledge of the total consumption to support their business, such as investment decisions of new substations.Modeling and simulation of the results obtained to analyze the electrical energy demand Social and Public sector based on current conditions and forecast electricity demand in the field of Social and Public in the future and how the availability of electricity in the future.

***Keywords*—Dynamic Simulation; Energy; Social and Public; Econometrics;.**

I. INTRODUCTION

Electric power is the energy source is essential for human needs both for industrial activities, commercial activities as well as in the daily life of the household. The electrical energy required to meet the needs of lighting and also the production process involving electronic goods and equipment / machinery industries [1]. Given the very large and important benefits of electrical energy and a source of energy power generation is mainly derived from the resource is not renewable limited presence, and to ensure the sustainability of this energy source should be pursued strategic steps to support the provision of electrical energy in an optimal and affordable.

Currently, the availability of the source of electrical energy is not able to meet the increasing demand for electricity in Indonesia. The occurrence of temporary disconnection and distribution of electrical energy in turn is a result of lack of electrical energy that can be supplied by PLN. This happens because the rate of increase in new enegri resources and procurement of power generation is not proportional to the increase in electricity consumption [2]. The condition of the national electricity at the present time is experiencing a crisis as a result of the surge in demand for electricity is greater than the supply level .. In the sector of public facilities, consisting of users of buildings / government offices, public street lighting, and social covering hospitals, schools, places of worship etc. (Fare classes S1, S2, S3, P1, P2, and P3) [3.] The use of electricity from year to year in each group increased every year but not sesegnifikan as in the industrial sector, business, and households.

Reason The use of simulation models of dynamic systems due to the dynamic system has several advantages compared with the methods of forecasting the conventional (ie: Model System Dynamics can provide a reliable estimate of the statistical models, dynamic system model provides a way to understand the causes of system behavior, detecting the early changes in the system structure and the determination of factors that predict the behavior of significant and sensitive models [4]. The model of dynamic system allows the determination of plausible scenarios as input for decisions and policies in the system.

This paper explores how dynamic modeling can help generate future scenarios depan.Produsen electricity consumption of electricity, suppliers, and distributors requires knowledge of the total consumption to support their business, such as new capacity investment decisions. The main objective of this thesis was to study the changes in electricity consumption Social and Public sector. Long-term model is created using system dynamic approach, the model is done with the application Vensim [5]. The aim is to support decision-makers to operate in this complex environment. This approach is an alternative way to solve the problem and a deeper understanding of traditional electricity, so that we can know the possibilities that exist and do planning with mature

II. LITERATURE REVIEW

A. *Dynamic Simulation*

Dynamic simulation approach can be used to make a decision in order to find policies and some benefit decisions that could be implemented in a period of time. We can use

978-1-5090-1381-4/16/$31.00 ©2016 IEEE

dynamic simulation as an analytical method to a system model and evaluate the behavior, graph, and forecasting data in system model [5]. A model in dynamic simulation must be pass a validation test in base of system model. The purpose of validation test is that the credibility of the system model and data almost same as original data in base model. Credible model used to scenario decisions in order to make decisions in future.

Four advantages of using models in the study using a systems approach [6.: First, lets do some research which is cross with a broad scope, second, to carry out experimentation of the system without disturbing (providing treatment) specific to the system, Third, Able determine the destination management activities and improvement of the systems being studied, and the Fourth, can be used to estimate (predict) the behavior and state of the system in the future.

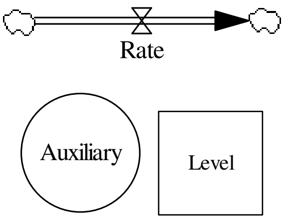


Figure II-1. Various Variabel

Stock (Level) and Flow (Rate), in representing the activity in a ring feedback, used two types of variables are referred to as stock (level) and flow (rate). Level declare state of the system at any time. Level is accumulated in the system. The equation of a variable rate structure is a wisdom that explains why and how the decision was made based on the information available in the system. Rate this is the only variable in the model that can influence the levels. Auxiliary are some things that can complement the stock and flow variables, the modeling of dynamic systems.

There are two type of model in dynamic simulation, causal loop diagrams (CLD) for conceptual model that gives a qualitative description of system problem in model and stock and flow diagrams (SFD) to explain system model in quantitave correlation between variables in model [6]. CLD is useful to represent the causal relationships between variables in model, on the other hand SFD controlling rates of flow into stocks, making the issue of adjustment mechanisms in model clearer, and shows behavior of variables in graph [7].

B. Condition of Sector Public

Electricity for Social and Public supplied from substation and distributed to industries in East Java. Ada 16 APJ (Electricity Service Area) in East Java, every APJ havedifferent demand behavior. This research menggabungkan semua electricity demand data from all 16 APJ in East Java.

Whereas in social tariff, Indonesia has three types of tariff, S1 for small social agencies, social agencies S2 for being. and S3 for large social body. While the tariff for the public there are 3 types of tariff as well, ie P1 for small and medium government buildings, P2 for large government buildings and P3 for street lighting.

C. Econometrics

Econometric method is analytical method that calculates the growth of a model of the problems associated with actual economic change based on observed data [8]. Econometric Method combines three different disciplines, namely economics, mathematics, and statistics. The relationship between the data from the model with secondary data such as economic data is translated into a mathematical function and the data is presented in the form of statistical data.

D. DKL 3.2

DKL 3.2 model is the old model used by the National Electricity Company for estimating electricity demand in East Java. DKL 3.2 Model estimates that electricity demand in social and public sector by the following equation [9]:

$$EP = EP_{-1}(1 + eP \times \frac{gP}{100\%}) \qquad (1)$$

E.P in Equation 1 represents electricity social and public of public in a time, on the other hand $E.P_{-1}$is electricity demand of social and public in one time before *E.I.* While *eI* is elasticity of electrical public and *gP*is GDP (Gross Domestic Product) growth of social and public. The result ofDKL 3.2 The model is an old model in estimating the electricity demand will be compared with the models in dynamic simulation

III. Development of Models and Scenarios

This research consists 4 step : collect electricity data and secondary data, analyze the system condition then design a conceptual model, create a valid dynamic model, and develop dynamic simulation scenarios

A. Methods

Methods necessary as a framework and guide the process of paper, so the paper processing circuit can be done in a focused, organized, and systematic. The picture will be done in this study can be seen there flowchart that has been adapted to kubutuhan to do research well and properly.

To the flowchart which will be described below is to facilitate the reader to better understand the flow of activities carried out in the research process.

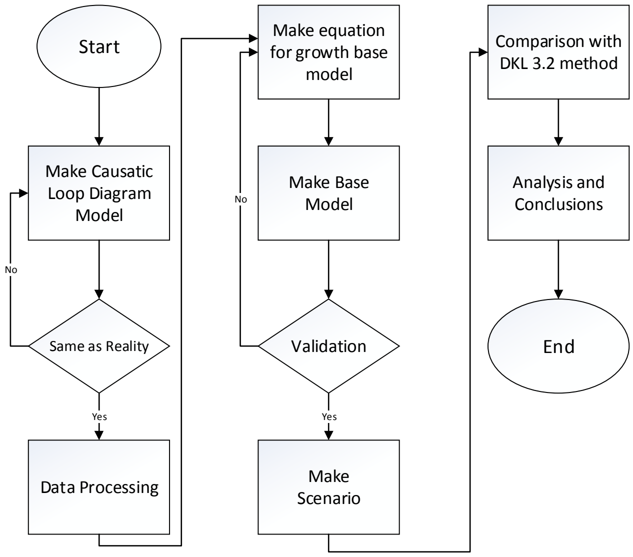


Figure III-1. Flowchart Methods

The study begins with the study of literature and then observation and data collection then manufacture causatic loop diagram of the model if it has been in accordance with the real system then proceed with processing the data, and then make the equation for the growth in the base model, and do the simulation after this to validate, then compare with the method DKL 3.2 and proceed with the creation of scenarios and then the analysis and conclusions to the conclusion then making a final report that the conclusions of this study

B. Electricity and Social - Public Data

This research uses main electricity from national electrity company in East Java (PT. PLN) and secondary data from gross domestic product or GDP from BPS in East Java.

1) PT. PLN Data

Electricity data from PT. PLN is electrical energy usage in kWh unit for electricity demand social tariff(S1,S2,S3) and public tariff(P1,P2,P3) and connected power in VA unit in East Java [10]. On the other hand, distributed electricity power from all substation or in East Java in VA unit for electricity supply in social and public sector [10]. Electricity data that used on base model is from January 2012 until February 2016 each month (Total 50 month).

2) BPS Data

GDP of industries data in East Java from BPS membagi GDP from each type of social and public[11], such as :

a) Social and Community Service
b) Non-Bank Financial Institutions
c) Transportation
d) Bank
e) General Government

GDP data used on base model is every three month data from 2012 until 2014.

C. Econometrics Method into Dynamic Simulation

The method of dynamic simulation, which is used to modelling complex system problem can be combine with a method of quantitative analysis [12]. This research use econometric method to find equation in model of dynamic simulation. The connection between variables in electricity demand and GDP of social and public must be design to find quantitative correlation that used in SFD. The result of mapping type of social and public from BPS data to social and public electricity tariff is given in Table 1. This mapping is expected to design demand conceptual model in CLD.

Table 1. Mapping Tariff to GDP

Tariff	GDP
S-1	Social and Community Service
S-2	Social and Community Service
S-3	Social and Community Service
P-1	Non-Bank Financial Institutions, Transportation, Bank, General Government
P-2	Transportation, Bank, General Government
P-3	General Government

The result of mapping in Table 1 used to determine the equation in econometric method, y-axis is tariff variables and x-axis is type of social and public. On the other side, we can find econometric equation with regression from Table 1 mapping [9], Equation 2 and 3 show the quantitative relationship between electricity social and public tariff to GDP .

$$S - 2 = 0.000313 + (0.327 * x_1) \quad (2)$$

S-2 in (2) refer to tariff S-2 electricity, x_1 is Social and Community Service.

$$\boldsymbol{P - 1 = 0.1175 - 2.28 * x_2 + 1 * x_3 - 1.88 * x_4 + 0.648 * x_5} \quad (3)$$

I-3 in (3) refer to tariff P-1 electricity, x_2 is transportation, x_3 is bank, x_4 is non-bank financial Institutions, and $x_5$is general government. Econometric equation in (2) and (3) is a quantitative relationship between growth of GDP and growth of social and public electricity demand in model.

D. Model and Dynamic Simulation

Model of dynamic simulation electricity supply and demand obtained after analyzing system from problem and knowing how supply and demand relationship. The design of the model can be created after we ensure how the system work. The first model is CLD model to describe the outline of the system, then the second model is SFD model to explain quantitative relationship and shows the graph from model. This research using month as time step in model.

1) Causal Loop Diagram

The relationship between variables in electricity demand and GDP of industries must be find in order to design electricity demand CLD, otherwise electricity supply CLD designed from substation distribution data from PT. PLN [13]. Figure 1 show the causal loop in electricity supply from substation that represented by total power GI until distributed to consumer that represented by supply APJ.

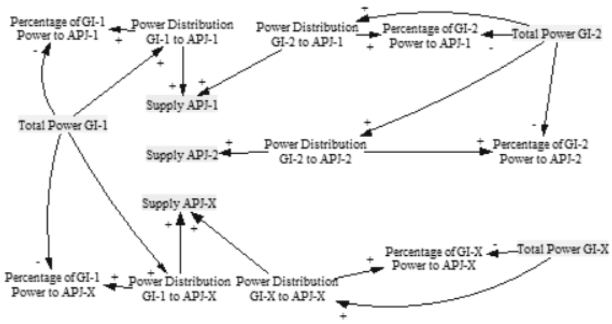


Figure III-2. Electricity Supply CLD

Electricity demand CLD shown in Figure 2 and Figure 3. Figure 2 show conceptual model from mapping we get from Table 1 before. Figure 3 show how we can get utilization of power used and power expansion needed when the supply can no longer fullfil demand in East Java.

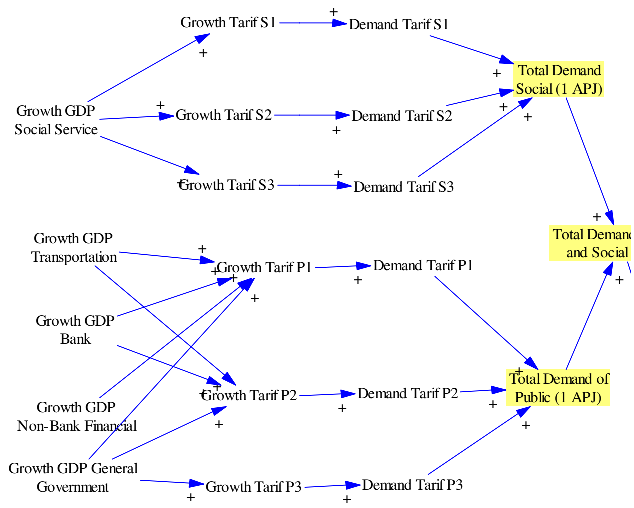


Figure III-3. Electricity Demand Mapping CLD

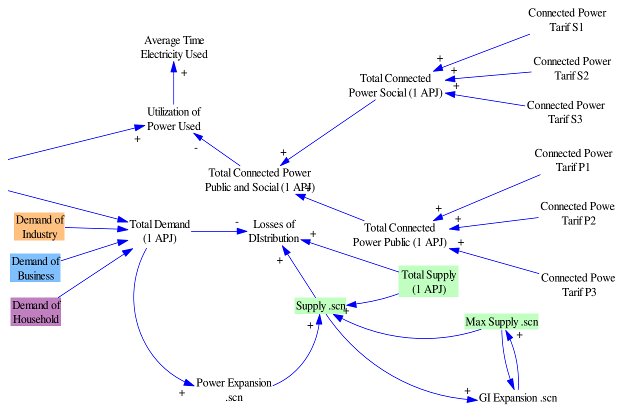


Figure III-4. Electricity Demand and Supply Relationship

2) Stock and Flow Diagram

The main dynamic simulation to forecasting electricity demand in the future created in SFD model. SFD model composed dynamic model electricity supply and demand based on CLD model. Figure 4 show the SFD model of electricity distribution from substation until electricity customer demand.

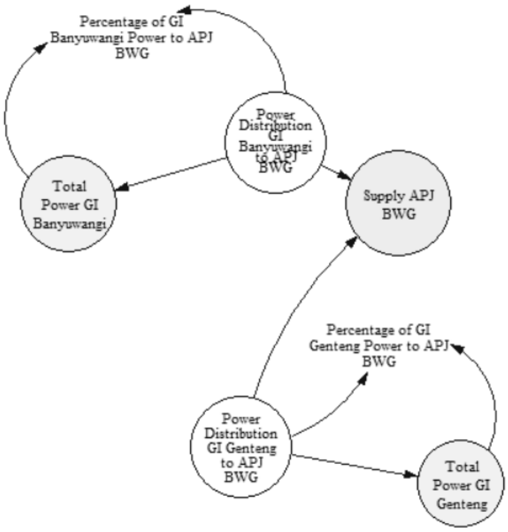
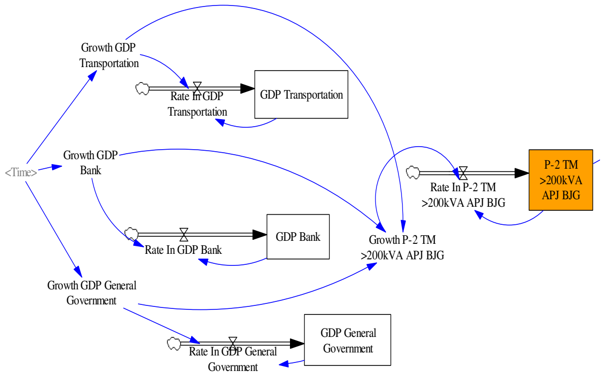


Figure III-5. Electricity Supply SFD



FigureIII-6. Electricity Demand Mapping SFD

Figure 5 show the SFD model example mapping from transportation, Bank, and General Governmentto tariff P-2 [14]. Figure 6 show the SFD model of total demand in East Java sector social and public.

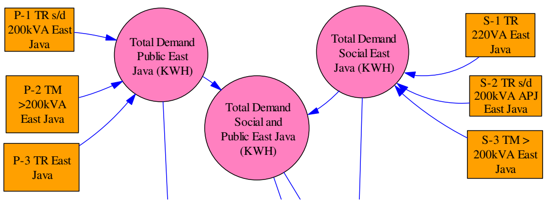


Figure III-7. Total Demand SFD

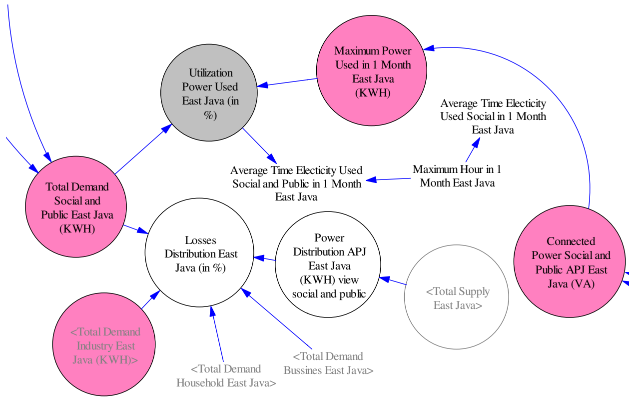


Figure III-8. Supply and Demand Relationship SFD

Figure 7 show the SFD model of quantitative relationship between electricity supply and demand.SFD model can show growth of electricity demand graph. Figure 7 show electricity growth graph. That graph not usual linier graph, but have oscilliation because electricity demand growth influenced by growth of social and public GDP [6].

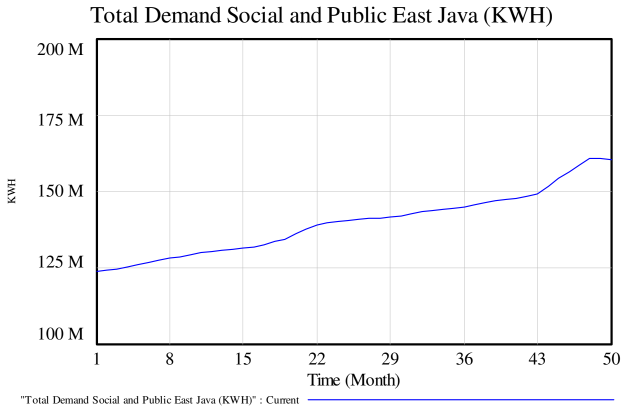


Figure III-9. Electricity Demand Growth in East Java

E. Model Validation

Validation is a process to evaluate dynamic simulation to determine credibility of the system model as an acceptable dynamic model. Historical data of electricity demand for social and public sector in East Java in 50 period of month of the base model used to test the error rate and error variance of the model. A model will be valid if the error rate smaller than 5% and error variance smaller than 30%.

There are two ways of testing validation, namely :

1) Mean Comparasion (Error Mean)

$$E1 = \frac{\left|\bar{S} - \bar{A}\right|}{\bar{A}} \quad (4)$$

Where: $\bar{S}$ = The average value of simulation results

$\bar{A}$ = The average value of data

2) Comparison of Amplitude Variation (Error Variance)

$$E2 = \frac{|S_s - S_A|}{S_A} \tag{5}$$

Where : Ss = Standart deviasi model

Sa = Standart deviasi data

We can calculate error rate of the dynamic simulation result with equation which represents in Equation 4. *E1* is mean of model and actual data comparison, *E1* should be smaller than 5%. $\bar{S}$ Refers to average mean of model data and $\bar{A}$ is average mean of actual data. On the other hand, error variance calculate in Equation 5. *E2* refers to standard deviation of model and actual data comparison and should be smaller than 30% to be valid model. Variable S_s refers to standard deviation of model and S_A is from actual data.

In below are the results of a test of the validity of each tariff and total demand in East Java

Table 2. Results of the validity of the base model

Mean Comparasion	**Validitas <5%**	**Validitas <30%**
Tariff S1	1.491%	7.004%
Tariff S2	3.566%	14.986%
Tariff S3	3.640%	6.228%
Tariff P1	4.982%	20.129%
Tariff P2	1.964%	21.703%
Tariff P3	0.040%	15.505%
Total East Java	1.547%	13.678%

F. Scenario Model

Scenario is an approach to develop probabilities might happen in the future. Several scenarios can be obtained from a valid model by increasing or decreasing some parameters value [13]. This research modify the value of electricity demand growth parameters. optimistic projection obtained by increasing electricity demand growth value by 0.5% and pessimistic projection obtained by decreasing electricity demand growth value by 0.5%. Third projection is most-likely projection, it means in the future model not changing parameters value from base model.

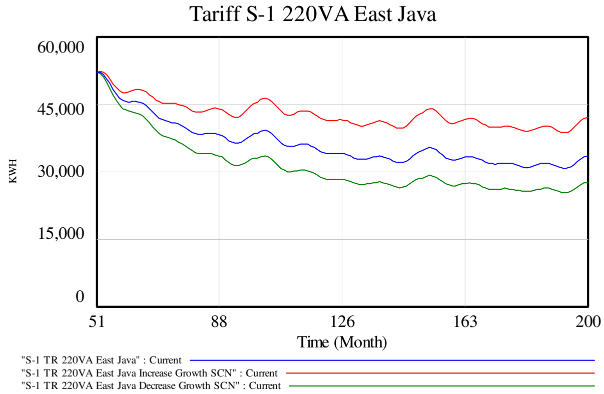


Figure III-10. Tariff S-1 Scenario

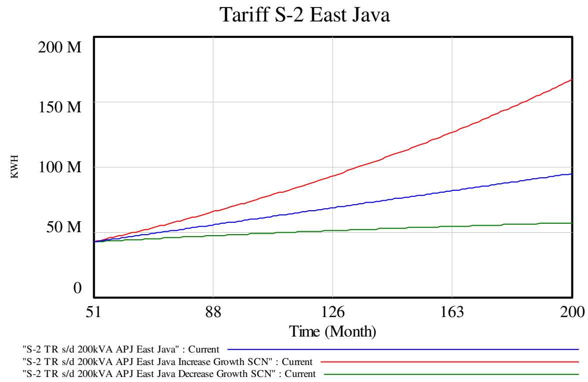


Figure III-11. Tariff S-2 Scenario

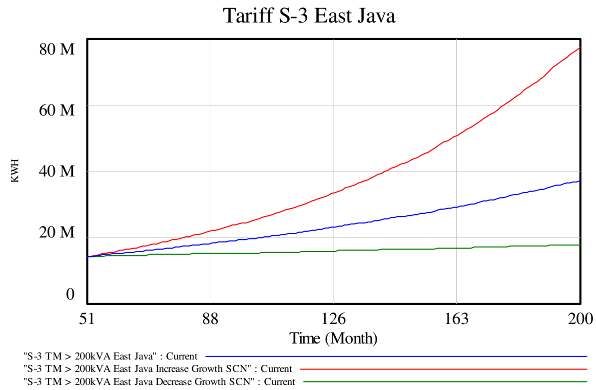


Figure III-12. Tariff S-3 Scenario

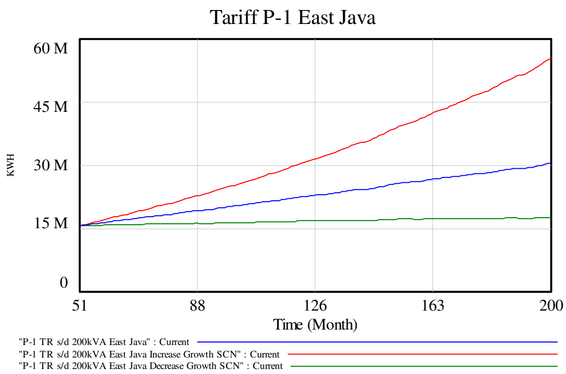


Figure III-13. Tariff P-1 Scenario

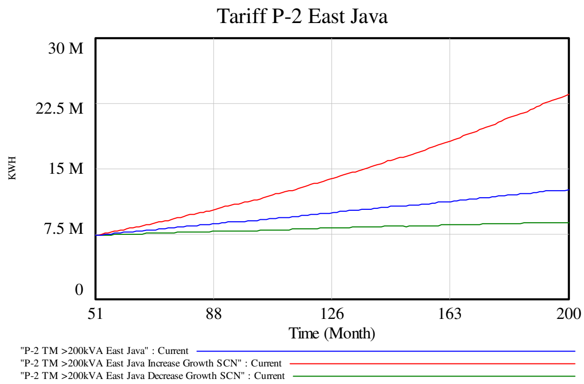


Figure III-14. Tariff P-2 Scenario

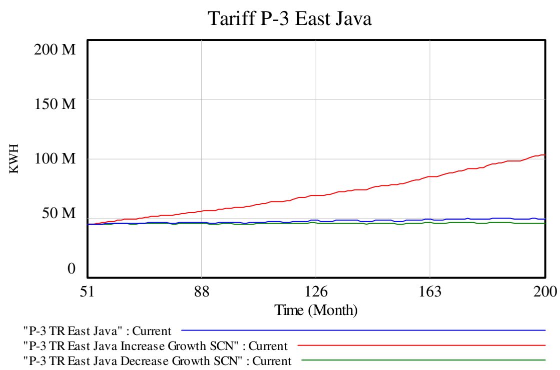


Figure III-15. Tariff P-3 Scenario

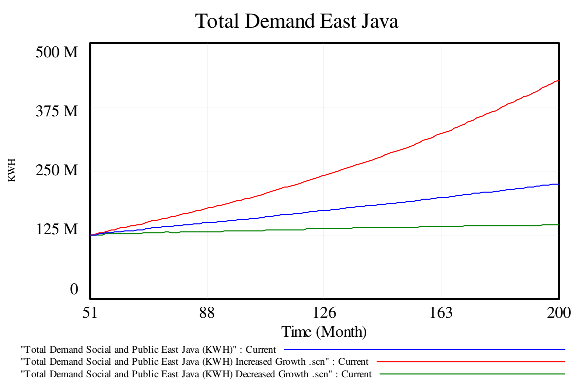


Figure III-16. Total Demand East Java Scenario

Figure 9,10,11,12,13,14, and 15 comparing data model graph from most-likely in blue lines, optimistic scenario with increased growth 0.5% in red lines, and pessimistic scenario with decreased growth 0.5% in green lines.

IV. ANALYSIS RESULTS OF SCENARIO

From the results of the scenario can be seen average growth rates in each of the different scenarios. The average growth was raised and lowered by 0.5%, equivalent to 6% over one year. Table 3 shows the results obtained when the test scenario..

Table 3. Result of scenario

Tariff	Status	Average Growth per Month	Average Growth per Year
S-1	Most-Likely	-0.221%	-2.646%
	Increased	-0.105%	-1.256%
	Decreased	-0.316%	-3.797%
S-2	Most-Likely	0.406%	4.867%
	Increased	0.692%	8.299%
	Decreased	0.149%	1.793%
S-3	Most-Likely	0.485%	5.820%
	Increased	0.859%	10.312%
	Decreased	0.111%	1.327%
P-1	Most-Likely	0.336%	4.029%
	Increased	0.639%	7.666%
	Decreased	0.060%	0.723%
P-2	Most-Likely	0.272%	3.267%
	Increased	0.590%	7.077%
	Decreased	0.093%	1.116%
P-3	Most-Likely	0.050%	0.605%
	Increased	0.425%	5.097%
	Decreased	0.013%	0.156%
Total	Most-Likely	0.298%	3.572%
	Increased	0.623%	7.480%
	Decreased	0.073%	0.879%

In the tariff S-2, S-3, P-1, P-2 and P-3 all have increased from year to year. Following the increase of the GDP and the increase in the number of customers for each tariff. While S-1 decreased due to the trend of previous years was declining. For the future policy of the government can take the decision of forecasting has been done, such as setting policies and additional.

V. COMPARASION BETWEEN DYNAMIC SIMULATION AND DKL 3.2

The best way to comparing Dynamic Simulation and DKL 3.2 Method is comparing error mean and error variance between dynamic simulations on actual data and DKL 3.2 method on actual data.

We should calculate *E1* and *E2* DKL 3.2 on actual data. The $E.I_{-1}$ value is 1,011,674,149 kWh, *eI* and*gI* is 8% and 10.16%. Substitutes all that value to DKL 3.2 equation to forecasting electricity demand in East Java. The result is shown in table 2.

Table 4. Dynamic simulation and DKL 3.2comparison

E1	Dynamic simulation	1.547%
	DKL 3.2	9.229%
E2	Dynamic simulation	13.678%
	DKL 3.2	29.187%

VI. CONCLUSION

Dynamics simulation approach is better way to forecasting electricity demand model in the future than the old method, DKL 3.2. We can experiment in scenario model, it means dynamic simulation more flexible without having error in base model than the other method. The difference between the error of dynamic simulation method with DKL method is 12.131% on average error and 19.958% for the error variance.

The result of electricity demand for social and public sector can be used to make policies and power planning in the future [15]. The result of this research also can be combined to find how many substation needed in the future to fulfill electricity demand and electricity company can make a good planning for expansion, like where and when is the possible expansion can be implemented in the future [16][17].

REFERENCES

[1] B. Georgeta, H. Nur, S. Erma and H. Rully, Analysis of Soybean Production and Demand to Develop Strategic Policy of Food Self Sufficiency: A System Dynamics Framework, The Third Information Systems International Conference, 2016.

[2] W. Diah Tri, “Pendekatan Model Ekonometri Untuk Peramalan Kebutuhan Listrik Periode 2005-2015 di Wilayah Malang”, Thesis, Institut Teknologi Sepuluh Nopember, 2005.

[3] R. Kakka Dewayana, “Proyeksi Kebutuhan dan Penyediaan Energi Listrik di Jawa Tengah Menggunakan Perangkat Lunak Leap dan Model DKL 3.2”, Diponegoro University, 2007.

[4] Nanang Yudi Setiawan, R. Sarno, “Multi-Criteria Decision Making for Selecting Semantic Web Service Considering Variability and Complexity Trade-Off”, Journal of Theoretical and Applied Information Technology, vol. 86, issue 2, 2016.

[5] Ventana Systems Inc., Vensim 5 Modelling Guide, Phasing and Oscillation page 16, 2003.

[6] L. Chen, Z. Lisha, L. Na and Z. Ming, Modelling and Simulation of Power Grid Engineering Project based on System Dynamics on the Background of Smart Grid, The 2nd International Conference on Complex Science and Information Engineering, 2011.

[7] Momodu, A. S. Oyebisi and T. O. Obilade, Modelling the Nigeria’s Electric Power System to Evaluate its Long-Term Performance, Obafemi Awolowo University, 2003.

[8] L. Cimpian, E. Lazar and M. Rozalia, Econometric Modelling of Influence on Turnover Concerning Indicators of Information Society Across the European Union, The Bucharest University, 2014.

[9] N. Yingzi and G. Yuying, Statistical and Econometric Analysis of the Impact of China’s Energy, Environment on the Economic Development, Jilin University of Finance and Economics, 2011.

[10] PT. PLN, “Rencana Usaha Penyediaan Tenaga Listrik (RUPTL)”, 2015-2024.

[11] BPS, “Berita Resmi Statistik”, No. 13/02/Th.XIII, 2015.

[12] T. Sorasalmi, Dynamic Modelling of Household Electricity Comsumption, Aalto University, 2012.

[13] T. Jager, S. Schimdt and U. Karl, A System Dynamics Model for the German Electricity Market, European Institute for Energy Research, Karlsrhe, Germany, 2009.

[14] S. Erma, C. Shuo-Yan and C. Chih-Hsien, Dynamic Simulation Model of Air Cargo Demand Forecast and Terminal Capacity Planning, 2012.

[15] R. Sarno, Y. Lu, C. B. Virendra and B. Harold, The AgentMatcher Architecture Applied to Power Grid Transactions, 2003.

[16] N. F. Ariyani and R. Sarno, “Optimasi Penempatan Gardu Induk Menggunakan Metode P-Median dan Voronoi Diagram”, Institut Teknologi Sepuluh Nopember, 2008.

[17] N.Y. Setiawan, R. Sarno, “Multi-Criteria Decision Making for Selecting Semantic Web Service Considering Variability and Complexity Trade-Off”, Journal of Theoretical and Applied Information Technology, vol. 86, issue 2, 2016.