Dynamic Simulation of Electricity Supply and Demand for Industry Sector in East Java

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***Abstract*—Electricity is a main need for industrial sector to run it self. It is very important to know the quantity of electricity demand in the future. It could be managed to be as efficient as possible and obtain advantage from it. This research develops electricity model to estimates electricity demand growth on industrial sector in East Java using dynamic simulation approach. Dynamic simulation is employed to explore dynamic behavior of the existing and future electricity demand based on three scenarios. First scenario is normal GDP growth condition or most likely model, second scenario is increased 6% GDP growth per year or optimist model, and third scenario is decreased 6% GDP growth per year or pessimistic model. Dynamic simulation will be combined with econometric method to find the GDP and electricity demand relation in order to forecast electricity demand. The dynamic simulation forecast of electricity demand has a less error than DKL 3.2 method, since econometric method separates several types of industry GDP to forecast electricity demand per tariff whereas DKL 3.2 method only utilizes total GDP to forecast all tariff of electricity demand. The result of this research can be used as guidance for planning the industrial sector electricity supply in East Java. Furthermore, this research can be used to develop a flexible scenario for further electricity forecasting.**

Keywords—electricity; industry; dynamic simulation; forecasting; East Java

I. INTRODUCTION

Electricity is a main need for industries to run their processes. Electricity consumption in industries consist of small consumption such as lightning, computer, air conditioning, and big consumption such as heavy machine that used to manufacturing products of their own. Thus, based on this fact, a reliable plan for the electricity supply on industrial sector is needed, considering the electricity demand keeps growing bigger. East Java is one of province in Indonesia with industrial sector as a main gear for the economy. Industries in East Java experienced a significant growth compared to the other region. Industrial growth indirectly effects a much bigger electricity usage in result from a much bigger industrial activity, so the electricity demand grows as well. On the other hand, the electricity resource is starts to lose the capabilities to supply existing electricity demand. It is said that a sustainable plan for electricity resource development for the near future is necessary so the supply could meet electricity demand requirement. An efficient resource development can be planned if we can estimate the growth of electricity demand for industrial sector for the future. Dynamic simulation is an approach that creates a model of electricity supply and demand, then estimates the demand by combining dynamic simulation and other method that observe external factors in detail. In this case, the external factors are the factors that can affect electricity demand and the growth of the sector.

The result of this research is used to estimate electricity demand using dynamic simulation approach. It will be compared with the previous method to estimate the growth of electricity demand and determine which method is better in estimate electricity demand. Based on this research PT. PLN can make plan to build a new power plants and substations to fulfill the lack of electricity supply on industry sector [1]. A good planning can make PLN easier to determine where and when the new substations will be built [2].

II. LITERATURE REVIEW

A. *Electricity Supply and Demand for Industry Sector in East Java*

Electricity for Industry supplied from substation and distributed to industries in East Java. There are 16 APJ (Electricity Service Area) in East Java, every APJ has a different demand behavior. This research aggregates all electricity demand data from all 16 APJ in East Java. Whereas in tariff, East Java have four different tariff, which is I-1 for small industries, I-2 for industries with few electricity usage, I-3 for industries with a lot of electricity consumption, and I-4 for very huge industries.

B. *Dynamic Simulation*

Dynamic simulation approach can be used to make a decision in order to find policies and good decision to get profit that could be implemented in a period of time. We can use dynamic simulation as an analytical method to a system model and evaluate the behavior, graph, and forecasting data in system model [3]. 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

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data almost same as original data in base model. Credible model used to scenario decisions in order to make decisions in future.

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 quantitative correlation between variables in model [4]. 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 [5].

C. Econometric Method

Econometric Method is analytical method which calculates the growth of a problem in model combined with the actual economic changes based on a factual data [6]. Econometric method merges three different principal sciences such as economy, mathematics, and statistics. The relation between data from the model with secondary data like economic data turned into a mathematical equation and the data presented as a statistical data.

D. DKL 3.2 Model

DKL 3.2 Model is the old model used by National Electricity Company to estimate electricity demand in East Java [3]. DKL 3.2 Model calculates electricity demand in industry sector with the equation in (1):

$$E.I = E.I_{-1}\left(1 + eI \times \frac{gI}{100\%}\right) \qquad (1)$$

E.I in (1) represents electricity demand of industry in a time, on the other hand E.I-1 is electricity demand of industry in one time before E.I. While eI is elasticity of electrical industry and gI is GDP (Gross Domestic Product) growth of industry. The result of DKL 3.2 Model which is an old method to estimate electricity demand will be compared to dynamic simulation that used in this research.

III. Proposed Method

This research consists 4 steps; 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. Electricity and Industry Data

This research uses main electricity from national electricity 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 each tariff (I-1, I-2, I-3, I4) and connected power in VA unit in East Java [7]. On the other hand, distributed electricity power from all substation or in East Java in VA unit for electricity supply in industry sector [8]. 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 divided into several type of industry [9], such as:

a) Food industry

b) Farm industry

c) Textiles industry

d) Chemical industry

e) Paper and printing industry

f) metal processing industry

g) nonmetal processing industry

h) Mining industry

GDP data used on base model is data per three months from 2012 until 2014.

B. Econometric 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 [4]. This research uses econometric method to find equation in model of dynamic simulation. The connection between variables in electricity demand and GDP of industries must be design to find quantitative correlation that used in SFD. The result of mapping type of industry from BPS data to industry electricity tariff is given in Table 1. This mapping is expected to design demand conceptual model in CLD.

TABLE I. Mapping Tariff to Industry

Tariff	Type of Industry
I-1	All of very small industry
I-2	Food, Farm, Paper and Printing Industry
I-3	Textiles, Chemical, Mining, Metal Processing, Non Metal Processing Industry
I-4	All of very huge industry

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 industry. I-1 and I-4 is special case in econometric equation because there is no specific type of industry can be mapping on I-1 and I-4 tariff. Therefore, I-1 and I-4 use only electricity demand data from PLN to forecast electricity demand for industry sector in model [10]. On the other side, we can find econometric equation with regression from Table 1 mapping [11], (2) and (3) show the quantitative relationship between electricity industry tariff to GDP of the type of industries.

$$I - 2 = 0.013x_1 - 0.009x_2 + 0.09x_3 \quad (2)$$

I-2 in (2) refer to tariff I-2 electricity, x1 is paper and printing industry, x2 is farm industry, and x3 is food industry.

$$\begin{aligned} I - 3 &= 0.314x_4 + 0.342x_5 + 0.245x_6 \\ &+ 0.112x_7 + 0.185x_8 - 0.008 \end{aligned} \quad (3)$$

I-3 in (3) refer to tariff I-3 electricity, x4 is textiles industry, x5 is chemical industry, x6 is mining industry, x7 is nonmetal processing industry, x8 is metal processing industry.

Econometric equation in (2) and (3) is a quantitative relationship between growth of industries GDP and growth of industry electricity demand in model.

IV. Discussion

A. Models 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 [8]. Fig. 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.

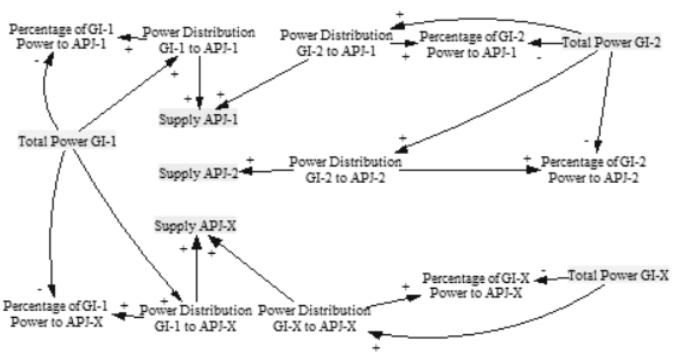

Fig. 1. Electricity Supply CLD.

Electricity demand CLD shown in Fig. 2 and Fig. 3. Fig 2 show conceptual model from mapping we get from Table 1 before. Fig. 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.

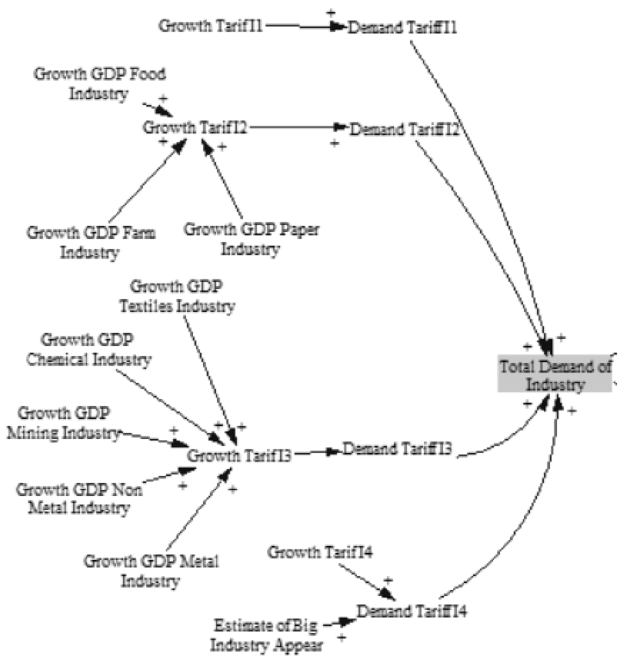

Fig. 2. Electricity Demand Mapping CLD.

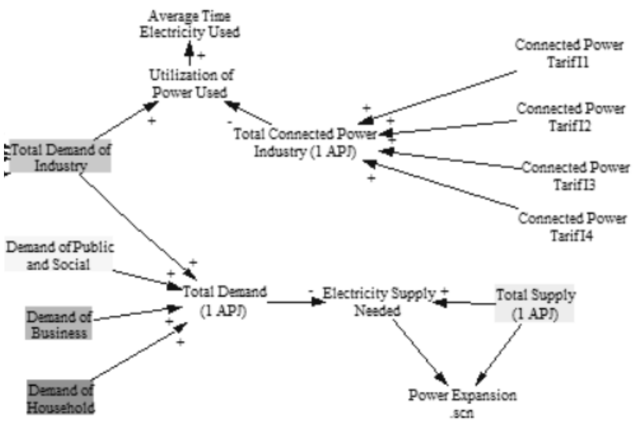

Fig. 3. Electricity Demand and Supply Relationship.

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. Fig. 4 shows the SFD model of electricity distribution from substations until electricity customer demand in one of APJ in East Java.

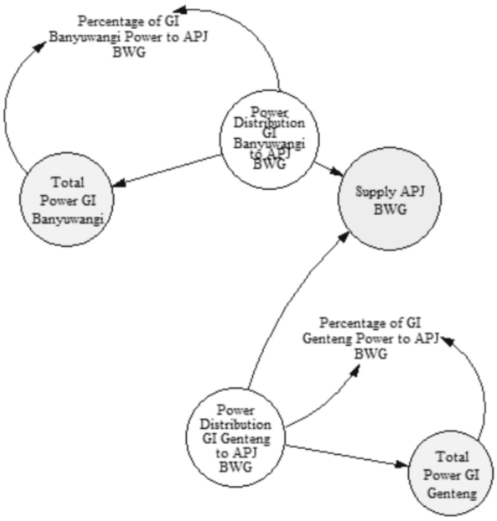

Fig. 4. Electricity Supply SFD.

Fig. 5 show the SFD model example mapping from food, farm, and paper industry to tariff I-2 [12]. Fig. 6 show the SFD model of quantitative relationship between electricity supply and demand.

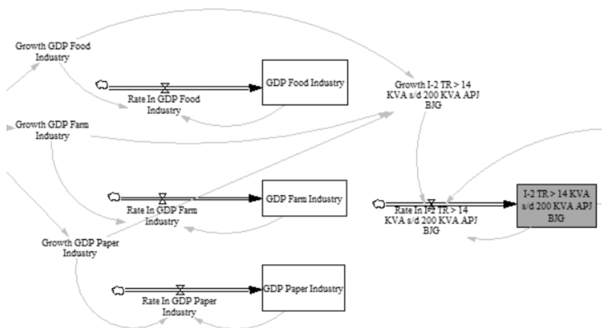

Fig. 5. Electricity Demand Mapping SFD.

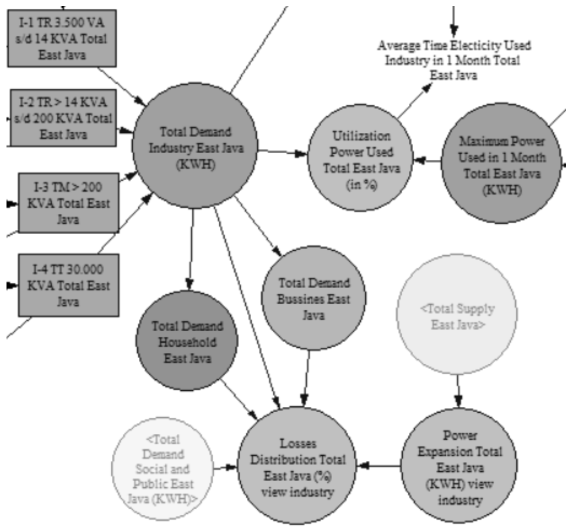

Fig. 6. Supply and Demand Relationship SFD.

SFD model can show growth of electricity demand graph. Fig. 7 show electricity growth graph. That graph not usual linier graph, but have oscilliation because electricity demand growth influenced by growth of industry GDP [13].

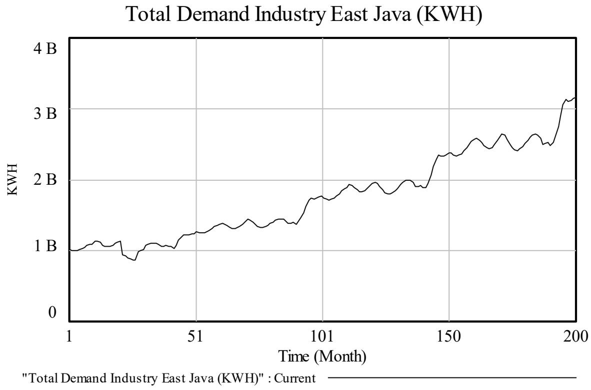

Fig. 7. Electricity Demand Growth in East Java.

B. Model Validation

Validation is a process to evaluate dynamic simulation to determine credibility of the system model as an acceptable dynamic model [14]. Historical data of electricity demand for industry 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%.

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

$$E1 = \frac{\left|\overline{S} - \overline{A}\right|}{\overline{A}} \tag{4}$$

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

The results of model validation error mean (*E1*) is 2.35% and error variance (*E2*) is 1.67%. It means that the model valid.

C. 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 [15]. This research modifies 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, which means in the future model not changing parameters value from base model.

Fig. 8, Fig. 9, Fig. 10, Fig. 11, and Fig. 12 comparing all tariff and total electricity demand of data model graphs from most-likely in middle graphs, optimistic scenario with increased growth 0.5% in upper graphs, and pessimistic scenario with decreased growth 0.5% in bottom graphs.

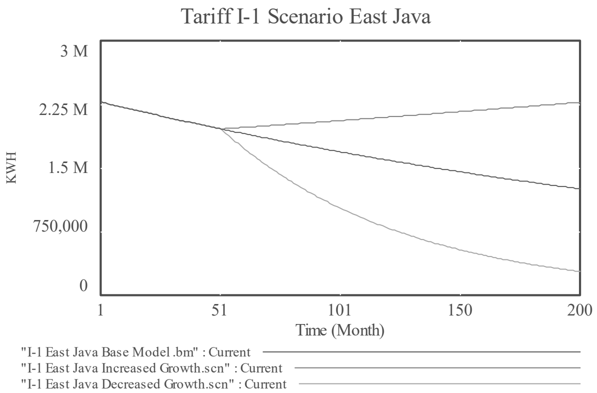

Fig. 8. Tariff I-1 Scenario.

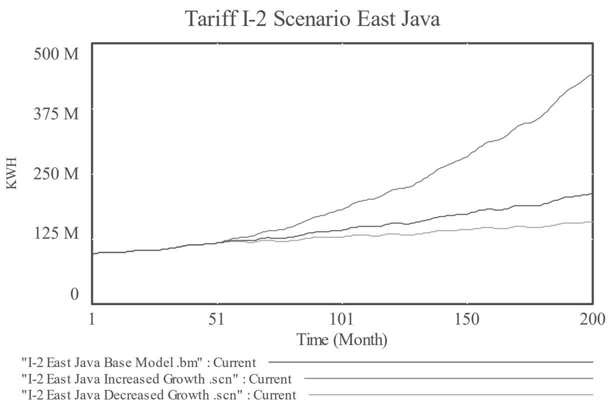

Fig. 9. Tariff I-2 Scenario.

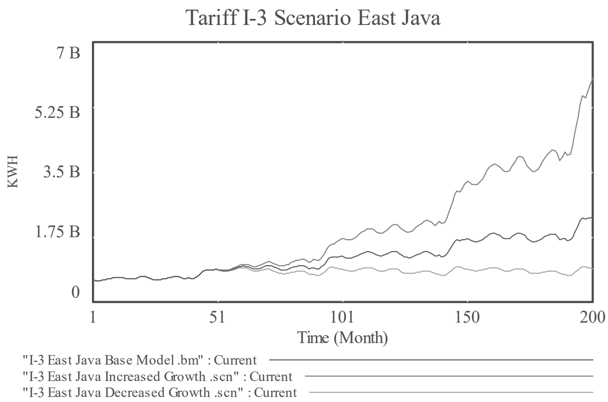

Fig. 10. Tariff I-3 Scenario.

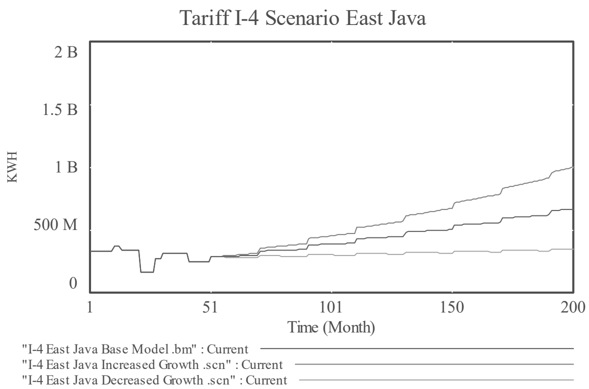

Fig. 11. Tariff I-4 Scenario.

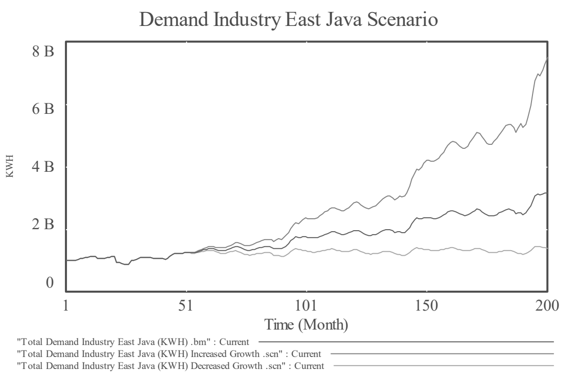

Fig. 12. Electricity Demand of Industry Scenario.

D. Comparison Dynamic Simulation and DKL 3.2 Method

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 II. DYNAMIC SIMULATION AND DKL 3.2 COMPARISON

E1	Dynamic simulation	2.35%
	DKL 3.2	13.87%
E2	Dynamic simulation	1.67%
	DKL 3.2	66.89%

V. CONCLUSION

Dynamics simulation approach is better way to forecast electricity demand model in the future than the old method, DKL 3.2. Comparison error mean (E1) and error variance (E2) between dynamic simulation and DKL 3.2 method on forecasting electricity demand in East Java define that dynamic simulation and econometric combined better than DKL 3.2 method. E1 of dynamic simulation has 2.35% error from actual data while DKL 3.2 has 13.87% and E2 of dynamic simulation has 1.67% error from actual data whereas DKL 3.2 has a 66.89% which is quiet big error. Dynamic simulation can experiment in scenario model at a period of time in future, which means dynamic simulation more flexible without having error in base model than the other method.

The result of electricity demand for industry sector can be used to make policies and power planning in the future. The result of this research also can be combined to find how many substation is needed in the future to fulfill electricity demand and Electricity Company can make a good planning for expansion, like where and when the possible expansion is can be implemented in the future.

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