Indonesia's Electricity Dynamic Modelling toward Its National Policies

Joko Sulistio and Arifin Rosyadi

Abstract— **In the past five years, similar with the south east region's economic growth's, Indonesia's average is 5,1%. This growth leads an increase in energy consumptions, especially electricity. Indonesian government aware of this situation and create policies to address it. This article objective is to build a dynamic model of Indonesia's electricity demand. System dynamics proofed to show fruitful result for similar objective in other area. Therefor this article exercise system dynamics to build the model. Validation is essential to develop model credibility. For that reason, four techniques in system dynamics validations are applied. There were operational graphics, face validity, extreme condition test and historical data validation. The model shows that up to 2020, Indonesia will still be facing energy deficit. A surplus shown in 2021 and forward. Hence, Indonesian government's policies in energy will be a success.**

Index Terms— **Electricity supply, system dynamics, modeling, policy analysis.**

I. INTRODUCTION

There is a strong relation between economic growth and energy consumption. The energy consumption follows the rate of economic growth [1]. From 2012 up to 2017, Indonesia's economic growth is 5,1% in average. Hence, energy consumption including electricity increase in return. In electricity statistics report released by Statistics Indonesia, Indonesia's consumption per capita reach 0.766 MWh. To anticipate those demand, Indonesian government issued National Energy Policy through 2014 Government Ordinance No. 79 known as *Kebijakan Energi Nasional* (KEN). The ordinance targeted to build power plant to provide Indonesian people with 115 GWh electricity in 2025 and 430 GWh in 2050. This is unlikely to achieved, because statistics shows that electricity capacity improvement is not as optimist as the ordinance.

Fig. 1 shows gap of government expectation through KEN and forecast of power plant capacity improvement. Therefore, series of scenarios are design to meet the target. Firstly, achieve 85% electrification ration in 2015 and 100% in 2020. Secondly, determine the optimal primary energy mix. In 2025 Indonesia is expected to have at least 23% new and renewable energy, if all economic factors are in good shape, petroleum is less than 25%, coal minimum 30%, and natural gas minimum 22%. The numbers shifted in 2050, new and renewable energy percentage marked in 31%, petroleum is less than 20%, coal minimum 25%, and natural gas minimum 24%.

If the planned scenarios are running as it should, Indonesia will successfully provide the people with sufficient electrical energy. This paper's objective is to investigate those scenarios. A dynamic model based on system dynamics methodology applied to analyse Indonesia's electricity energy supply side.

II. METHODS

A brief literature review conducted as an attempt to recognize previous researches on electricity supply side model. A macroeconomic analysis and simulation of government policy over the long term. The method used is the IAR-CMM model developed by the research development institution Sanghai University. The IAR-CMM method considers several factors such as cycle and secular [2].

Another study estimates the growth in global energy demand, where there is climate change in Paris in 2015 that led to the demand so to keep it necessary to make a deal on the level of the United Nations in reducing global temperature rise of 1.5 ° C. The approach used in this study using dynamic econometric model validation to test some of the assumptions that generally make an increase in global energy demand [3]

Most of the methods used to study electricity supply side are optimization model. Selecting independent variables that effects it objective are essential. In many cases, the process involved excessive simplification. An alternate model which could provide broader perspective is needed due to the complexity of systems observed. Among vast range of possible methods, system dynamics offers view advantages. The use of dynamic systems model in the study has at least four advantages; (1) research can be conducted across sectors and broader scope; (2) modeler can perform experiments with the system; (3) the purpose of management activities and improvements to the system under study can be determined; and (4) predict behaviour and state of the system in the future [4].

In general, there are six steps to apply system dynamics. Firstly, formulate the problem along with the dynamic hypotheses. Secondly, develop a conceptual model with causal loop diagram. Thirdly, develop a flow diagram/ computer modelling. This phase requires specific computer program. Fourth, develop model credibility by performing series of validation steps. Fifth, design alternatives to address the problem. Finally, implement the best scenario. The general modelling process is shown in Fig. 1.

The object of this research is government policy through KEN 2025. The data taken is the consumption and production of electric energy in all regions in Indonesia. Systems

Manuscript received May 8, 2018; revised August 10, 2018.
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DOI: 10.7763/IJMO.2018.V8.670

dynamics performed to resolve dynamic issues that accommodate the interaction between variables that have reciprocal relationships. The steps undertaken in this stage are; (1) Identify both the dynamic variables involved and those that contribute to the system; (2) Identify the role of variables as well as the dynamic behavior in the system; (3) Determine the time unit; and (4) Setting objectives that are expected to contribute analysis and problem solving.

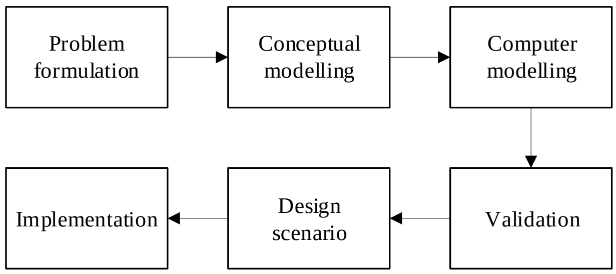

Fig. 1. System dynamics methods.

Knowing the needs of electricity to be one of the first stage done to see the existing trends. Electricity demand fulfillment calculated by the availability of existing supply. The final calculation of the need and availability of electricity will result in the availability of electricity stock around overstock or shortage.

Electricity distribution has several stages. This distribution path becomes one of the factors that need to be identified. Based data collected from the statistical center, there are several power plants along with the substation that conducts electricity distribution to the community. This identification aims to determine the process flow so that efficiency can be achieved. The design of a conceptual model is formed by the components or variables that affect the behavior of the system. In this stage, a hypothesis is developed that explains the underlying causes of dynamic problems.

The next stage of dynamic modeling is to develop a flow diagram (computer modeling). This is done by apply appropriate variable to describe specific behavior of the system. Then, connect according its relation and then determine the parameter value of each variable. Along the computer modeling, a verification is established to test whether the model is made in accordance with the initial hypothesis that has been designed previously. This is to ensure consistency of models made with hypotheses that have been built by researchers at and after the modeling system. After the computer modeling completed, a validation is required to ensure the model credibility. Afterwards, an analysis and further application of the dynamic model can be executed.

III. RESULT

A. The Model

Causal Loop Diagram (CLD) describes the pattern of relationships between variables that occur in the case of research. The creation of this conceptual model adapts the interrelated data in the electricity report, the use of electricity reports from the budget year 2014-2017. In accordance with the purpose of research is to see the national electrical resistance so that many variables that influence it from the electricity supply to the national scale electricity consumption.

Electricity supply is influenced by the net of electricity production. If the net output exceeds the total national electricity consumption, the surplus value will be distributed to another unit. The flow of the total variable of national electricity usage is influenced by the national electricity usage variable and other units. Those variables affect the net production of electricity and form the negative loop between them.

The net variable of electricity production is also directly affected by some variables that add value. Those variables are supply from PLN, Non-PLN and receive from other units. based on Electricity Statistics report from 2013-2016, national electricity consumption is influenced by National Electricity consumption and variable of energy losses of National Electric Substation. this study focuses on the Electric Surplus that occurs. The surplus value of electricity occurs when the Net Production value is greater than the public electricity consumption and the electricity needed to the other units. The value also adjusts to the supply of electricity, because surplus means value added for the country when it has been fully met the national electricity consumption.

Flow diagrams are formed from important variables that affect the objectives and represent the electrical statistics report. some of these variables are Variable Exogenous. That is, a parameter that affects the model but is assumed not influenced by other factors. There are 17 auxiliary variables that use the Interpolation formula based on previous data behaviour (Graph Lines). To design a flow diagram model, a predetermined variable is described by first inputting the modelling. This stage describes each variable and data used, calculations and formula / logic that corresponds to the real system.

Constant is a variable type which contains a fixed value that will be used in the calculation of auxiliary or flow variable. In this variable will explain how the use of field data entered into the dynamic system model. Constants in this study are power consumption of substations, percentage increase in electricity usage of substations, electricity usage distribution substation, percentage increase in electricity usage of distribution substation, annual distribution losses, percentage increase in distribution losses, annual transmission losses, and percentage increase in annual transmission losses. To define values in constant variable, the modeller simply calculates the average of series of data. For example, electricity usage in distribution substation is presented in Fig. 2. The graph was a presentation of the data collected from PLN yearly report. An assessment was made accordingly. The behaviour suggests that this data was a constant. Therefore, a constant assigned to represent this data.

Auxiliary is a variable type which contains basic calculations on other variables. In the case of this electrical supply auxiliary will contain historical data obtained from the Statistics of Electricity report, so that some variables resemble the level by using logic in it. All Auxiliary variable of power plant in this research use history data from electricity statistics report year 2013-2016, analysis result on variable of PLTU, PLTG, PLTGU and PLTMG in from graph illustrate that increasing its data increase every year. Thus, the formulas and logic are made to resemble the real system. For example, PLTG stands for Pembangkit Listrik Tenaga Gas or Gas Power Plant. The behaviour of this data is shown in Fig. 3.

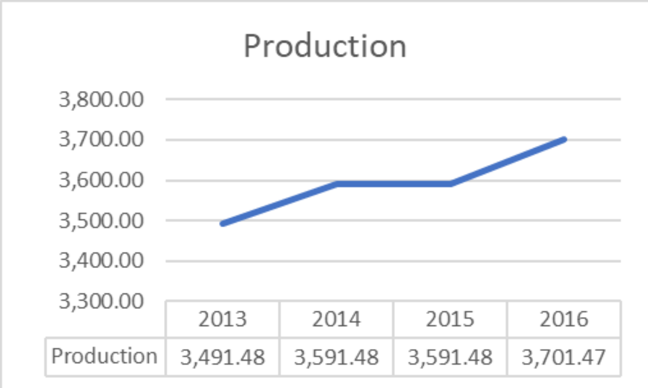

Fig. 2. PLTG production.

It suggests a combination of a trend and a constant. Therefore, the modeler decided to apply Graph function to capture such behaviour. The function is as follow: GRAPHLINAS(YEAR(),2013<<yr>>,1,{3491.48,3591.47,3591.47,3701.47//Min:3200;Max:4000//})*1<<mwh/yr>>.

In the input modelling, rate variable is a variable that will affect the level variable, in this case two levels are in-rate and out-rate. The rates in this study are electricity supply and electricity consumption. electricity supply. Level is a variable type which is the accumulation change. There is only one level in this study, it is electrical resilience. The complete flow diagram/ computer modelling is shown in Figure 4.

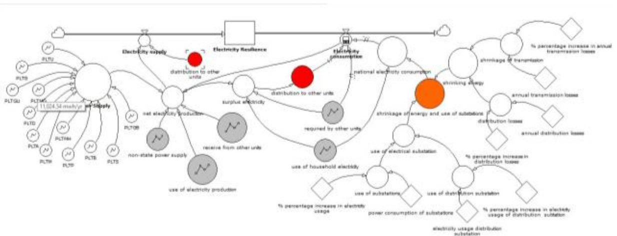

Fig. 3. Flow diagram/ computer modelling.

B. *Validation*

Validation is used to test the level of confidence of the built model and to know whether the simulation model has been able to represent the real system well or not. For that, it takes some testing of the simulation model. Not all variables will be validated, but only the variables that are important for the study alone. validation is done on the variable from Out-Rate side that is Total of National Electricity Usage, Energy Shutting and Electricity Usage, while on the In-Rate side is Net of Electricity Production with National Electricity.

Validation in system dynamic modelling performed in several ways including direct structure test without running model, structure-oriented behaviour test by operating model and comparison of model behaviour with real system (quantitative behaviour pattern comparison)[5]. Validation technique applied in this study are as follow:

Operational Graphics

The operational graphics technique is one of the validation methods that displays the simulation results by looking at the dynamic behaviour of the performance measures[6]. In this research, validation is done on the variable of National Electricity Supply and Total of National Electricity Usage as a benchmark of dynamic behaviour. The reason for choosing these variables is because they are influenced by some variables that change over time. Both variables show changes over time. the dynamic change in the model suggests that the model is Valid

Face Validity

Face validity technique is a validation technique by convincing the model that has been made to the expert who is very understanding the system in the model whether the system behaviour in the model and the variables used therein in accordance with the real system [7]. In this research, Face Validity helps model able to answer field fact which is happening, because the purpose of this research is to answer whether the need and the power supply will be the draw that will affect the variable of Electric Surplus. This stage has been done with consultation and adjustment to the actual system behaviour by the simulation experts and the electric power statistics year 2013-2016 which officially issued by the central statistics agency of the country.

Analysis Extreme Condition Test

This validation technique is done by changing the initial value of the variable to be tested, therefore the variable to be tested is the value of the variable of the Energy Loss and Electricity Usage of the substation by changing any exogenous variable on the out-rate side of electrical resistance to 0. This will reduce the value of national electricity usage. If there is no difference from the results of this test means that the model has not represented the real system.

Historical Data Validation

In general, Historical Data Validation test is done when there is data collected on a special system to build and test the model. Then part of the data used to build the model will determine the test results whether the model behaves like a system or not. There are 17 auxiliary variables in which using the Interpolation formula where the data is obtained from historical data from the electrical statistics report.

IV. Discussion

Research on supply and demand Electrical energy has been widely conducted but research with case study Indonesia is still minimal and has some limitations. A study on dynamic system model for hydroelectric power plant planning to fulfil supply and demand, a case study of Madura Island. The study investigated whether the built-up hydropower could reduce the burden of other power plants while potentially destroying natural resources [8].

Other studies discussed the analysis of demand and availability of electricity in the Industry sector using case study boundaries: East Java. Supply and Demand aspects of electricity with boundaries of specific areas. This results in limited area of analysis. the purpose of this study is to predict the demand for industrial electricity in the future [4]. Further research was conducted to analyse the extent to which projected electrical energy needs to know 2016-2025 in one of the provinces in Indonesia [9].

This research investigates the supply and demand of electricity in all sectors in Indonesia, the goal is to see whether

National power supply can offset National Electricity consumption. The advantage of this research lies in the method used and the scale of the investigation. In addition, the manufacture of causal loop diagrams in this study is in accordance with the results of statistical reports of electricity in 2013-2016.

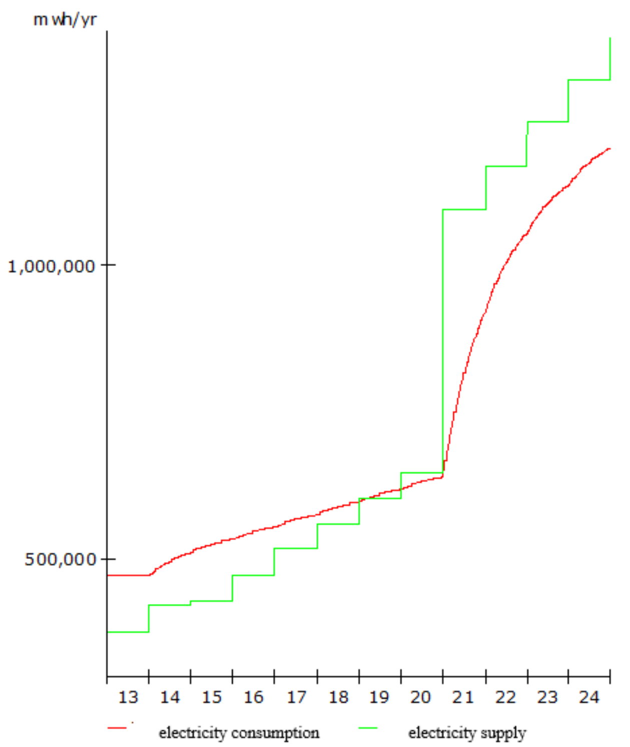

Fig. 4. Simulation results.

V. CONCLUDING REMARKS

The increasing demand for national electrical energy is an inevitable phenomenon. From the modelling results, there is a shortage of electricity supply from every PLN and non-PLN power plant. Until the year 2020 the country's electricity supply is still a deficit. But in 2021 there was an increase in electricity production. This causes the national electrical resistance to start normal. With massive production in each year, the exploited natural resources will also decrease. these side effects are often forgotten by the government in realizing sustainable energy development. The positive side is, it allows the government to successfully implement its plan on KEN 2025-2050.

ACKNOWLEDGMENT

This research was fully supported by Industrial Engineering Departement of Universitas Islam Indonesia. We would like to thank Delsim Laboratory who provided facilities to conduct the research. We would also like to show our gratitude to our colleagues who provided insight and expertise that greatly assisted the research.

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