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Modelling base electricity tariff under the Malaysia incentive-based regulation framework using system dynamics

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ABSTRACT

In the context of a single buyer (SB) electricity market, this study provides an electricity tariff model developed using system dynamics (SD). Using data from the Malaysian electricity supply industry (MESI), the model was developed with the intent of evaluating the influence of load variation on Malaysia's base electricity tariff. Given that Malaysia's electricity demand has increased significantly over the past few years in unison with the country's economic growth and modernization, this model is developed to investigate the relationship between the two. Moreover, the lack of a comprehensive MESI upstream market model that can monitor this issue was the impetus for this research. This study employed an SD approach, as it is a well-known technique for simulating complex systems and analyzing the existing dynamism between each variable and each system. This model can be a valuable tool for developing an electrical tariff model. Findings revealed that the base electricity pricing on the MESI upstream market is affected by load growth variation during the 30-year time. Since new power sources are needed to meet demand, the tariff becomes more expensive as the load increases. This model may benefit the utility or generating company plan for future generation.

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1. INTRODUCTION

In recent decades, Malaysia's electricity demand has increased considerably due to the country's strong economic expansion and modernization. Chandran et al. have confirmed this tendency in [1] that illustrates the relationship between power consumption, gross domestic product (GDP), and price through time. As per record, between the year of 2007 and 2017, electricity consumption increased from 81,710 GWh to 116,273 GWh; GDP (current price) from MYR562,222 million to MYR1,125,017 million, and installed capacity from 30,441.58 MW in 2015 to 34,182.9 MW in 2017 [2]. Generation mixes in 2017 was chronicled as 44.3% coal, 37.4% natural gas, 17.3% comes from hydropower, 0.5% from oil, and remaining of 0.4% of renewable energy. While Malaysia's economy is predicted to grow significantly in the next years, electricity demand is also expected to rise. This growth may lead to the increase in energy consumption as well as the challenges due to limitation in energy supply and resulting competition for resources [3]. With economic growth driving the need for more energy, Malaysia has set out plans to meet this demand while at the same time changing the way it generates and delivers electricity. However, electricity has distinct characteristics in which it cannot be stored economically, once produce it has to be supplied and the demand curve are inelastic [4]. A proper plan needs to be ruled out. Malaysia's average GDP growth over the past four years has been approximately 6%, allowing experts to stay hopeful about the country's freshly industrialized market economy. Strong economic growth is driving demand for electricity, which, according to the national power utility company Tenaga Nasional Berhad (TNB), is projected to increase at a pace of 3% per annum until 2030, when per capita demand should reach the Organization for Economic Cooperation and Development (OECD) average. Malaysia has usually considered its electricity sector as a strategic asset and a crucial economic contribution.

Energy commission has set up the percentage of each component to calculate the base electricity tariff for the current regulatory period 2 (2018 to 2020) [5] which includes 68.6% that comes from the generation cost, 10.2% from the transmission, distribution and network carries 18.1%. Meanwhile, customer services, single buyer operation, and grid system operation, contribute 2.4%, 0.5%, and 0.2% respectively. Hence, on September 2018, energy commission has fixed the base electricity tariff at 39.45 sen per kWh with the assumption that international coal prices are USD 75 per tonne and gas price at MYR 27.20 per mmBtu. This tariff would not be reduced for the time being regardless growing calls for a reduction due to falling prices of fuel used in power generation. In July 2018, coal price fell by more than 30% from MYR 479 per tonne to MYR 322.50 per tonne. In the recent scenario of Malaysia electricity supply industry (MESI), new wave of market reformation has been one of the talks of the town after going through various stages of it [6], [7]. In this new wave of market reform, the implementation of incentive-based regulation (IBR) as an economic regulation mechanism to replace the conventional rate-of-return based regulation (RORB) seems doable. The IBR framework consists of tariff setting principles, an incentive mechanism for promoting efficiency and service standards, and a tariff review procedure [5]. Under the IBR framework, TNB is organized into several regulated business entity (RBE) which later involves in calculating the electricity tariff. RBE comprises of single buyer (SB), transmission, grid system operator, distribution, and customer service. Among the five entities in RBE, SB plays a big role to procure the electricity from the independent power producers (IPPs) and TNB generation (TNBG) based on their power purchase agreement (PPA) and service level agreement (SLAs). The generations from these IPPs and TNBGs are then dispatch by SB based on merit order. SB also involves in producing the day-ahead dispatch planning. Therefore, this study is adapting SB model to resonate the current market in MESI using the approach of system dynamics (SD).

In the field of electricity sector research, SD has been utilized for many years to build a forecasting, strategic planning, assessing policy, assessing risk management, introducing new technology, and many more models [8]–[13]. Besides that, numerous researchers have utilized SD to construct a model that may be utilized by the utility; for instance, to take a system-wide perspective [11], [13]–[15]. A few objectives have been discussed under the IBR framework and one of it is to design an electricity tariff structure for a better efficiency in supply and consumption [16], [17]. Therefore, implementing the objective of IBR framework into a model using SD approach has been the drive of this research. This is one of the studies that statistically quantifies the IBR framework and explicitly models the variables that affects the tariffs in the model over the time. Undefined electricity tariff strategies in regulated markets such as the MESI environment will continue to reduce profit margin [18]. Hence, a proper strategy needs to be planned out. Besides that, the motivation of this research is to emphasize SD contribution to electricity tariff modelling in Malaysia electricity scenario. The objectives of this research include: i) to establish electricity tariff modelling based on IBR framework using SD, and ii) to observe the effects of load growth towards electricity tariff via constructed SD models. In order to see the relationship, the model is set between time interval starting from 2015-2045. Due to a significant number of time-sensitive variables, the thirty-year interval has been selected.

2. METHOD

The purpose of the first SD model created by Forrester [19] was to establish how the structure of a system impacts its behaviors. It is designed as a decision-making aid for a specific purpose in order to comprehend the causal effects in a system's structure that lead to the system's outcome. To make this SD model unique, the model's structure can be modified if the system requires any form of enhancement. The use of causal loop diagram (CLD) and stock flow diagram (SFD) in SD design is becoming increasing prevalent. The structure of a system and the correlation between its volatility produce dynamic patterns to the behavior for the system's volatility over time. Another context is used to explicitly summarize the modifications to the system that resulted from the modelling approach [20]. Figure 1 picturized the steps in order to design MESI market model with the approach of SD with the following steps below are being commenced: i) comprehend the market scenarios in MESI, ii) investigate the structure and operation of the market model; iii) obtain the exogenous and endogenous factors that are significant and connected to the generation mix of a market model, iv) construct the market model with the distinguished components in generation mix using SD, and v) perform comparative analysis on the model with the real-world execution.

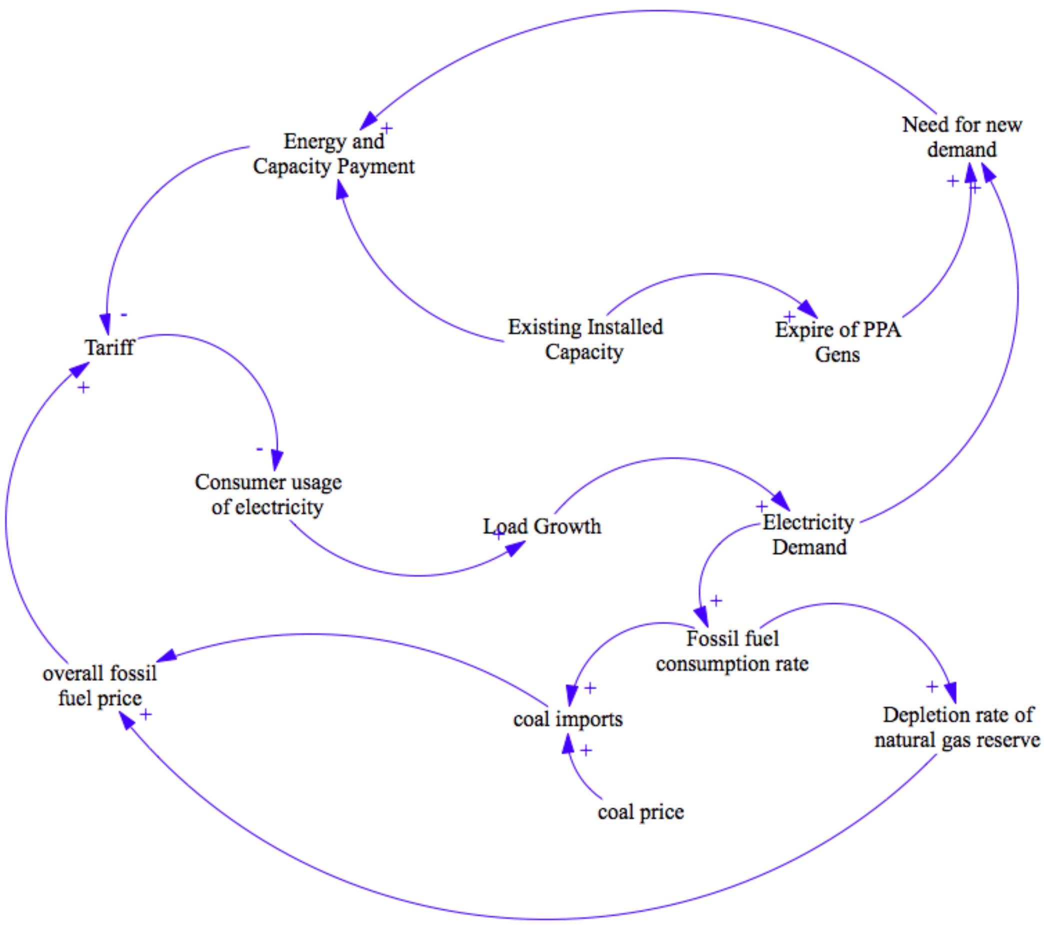

Figure 1. Causal loop diagram for the electricity tariff model based on IBR

2.1. System dynamics modelling

In this section, the proposed models using SD is presented. The research started with constructing a CLD for the load growth as well as the electricity tariff in Malaysia scenario. The purpose of having CLD is to outline the relationship between each variable as well as to expand the interaction. The research then proceeds with developing the stock and flow diagram (SFD) of the system since CLD has made the system structure and behavior are much simpler to visualize.

2.1.1. Load growth model

There are two types of load growth prediction methods, named as analytical and global prediction methods [21]. Global method is achieved by making assumptions that future growth will be unchanged as the growth in the past. The principal of load growth is resolved by analyzing the statistical data on the past load growth. Along with global method, another method used is analytical load growth prediction method. This method is based on the several separate analyses and on investigation of the needs of different types of consumers. In this research, two variables that seems to be related to each other has been taken into consideration in order to predict the load growth pattern in Malaysia. The two variables used are the GDP and population. Table 1 shows the data used to find the load growth prediction in Malaysia [2]. From the data, a regression analysis has been made and it shows that the GDP and population have a strong relationship and reliable with 98% of multiple R and 97% of R-squared. From this relationship, a load growth prediction has been made and the regression equation is shown in (1).

$$Load\ growth = 8779.12 + (0.512 \times pop) + (0.097 \times GDP) \quad (1)$$

Table 1. Population and GDP data from 1991 until 2016 used for the regression analysis

Year	Population ('000 people)	GDP (RM Million)	Year	Population ('000 people)	GDP (RM Million)
1991	18,547	145,991	2004	25,542	493,223
1992	19,068	162,800	2005	26,046	543,578
1993	19,602	186,042	2006	26,550	596,784
1994	20,142	211,181	2007	27,058	665,340
1995	20,682	240,365	2008	27,568	769,949
1996	21,122	274,138	2009	28,082	712,857
1997	21,769	304,458	2010	28,589	821,434
1998	22,334	306,022	2011	29,062	911,733
1999	22,910	324,952	2012	29,510	971,252
2000	23,495	370,817	2013	30,214	1,018,614
2001	24,031	366,841	2014	30,709	1,106,443
2002	24,543	398,714	2015	31,186	1,157,723
2003	25,038	435,708	2016	31,661	1,230,120

2.1.2. Causal loop diagram for the electricity tariff model

Figure 1 shows the causal loop diagram (CLD) for the electricity tariff model based on IBR. The purpose of CLD as discussed in [22] is to demonstrate the relationship between each variable exist in the model. The positive link indicates that the variable is directly proportional to each other. For example, the load growth gives positive feedback towards electricity demand, which means that the higher the load growth, the higher the electricity demand is. Meanwhile, the negative link indicates otherwise [23]. Referring to the CLD, tariff and consumer usage of electricity has a negative link. It signifies the higher the tariff, the lower the usage of electricity by the consumer. All variables in this CLD model are chosen based on their relationship to the electricity tariff. They are related in that they both play a significant role in directly influencing the tariff. For instance, the fossil fuel price is one of the biggest influences in determining the tariff's calculation. Following the CLD model, Figures 2 and 3 show the cause tree diagrams that are more straightforward and easier to understand. The tree represents the cause and effect where the findings is located at the tail of the arrow and the head of the arrow is where the variable that will display the effect over the time. Figure 2 shows the causes that affect the electricity tariff. By referring to [24], the model of this electricity tariff cost is considering the components under the IBR framework.

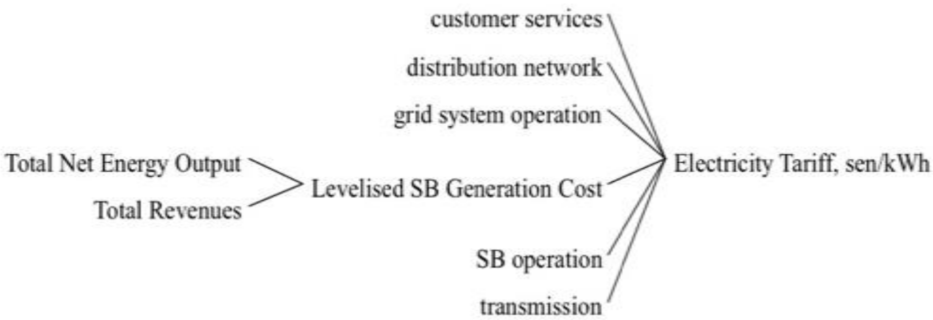

Figure 2. Cause tree for the electricity tariff

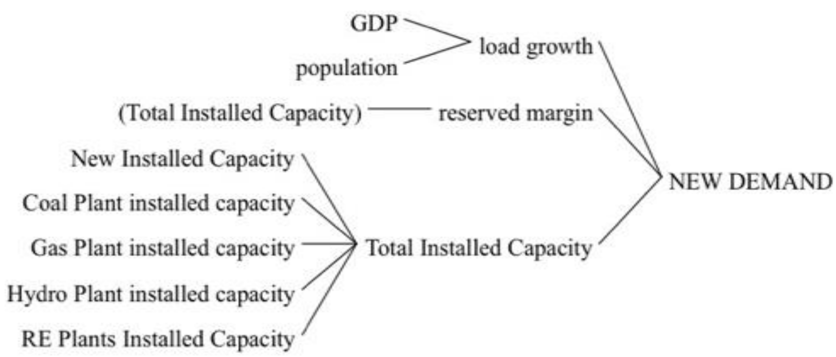

Figure 3. Cause tree of the variables exists in the new demand

Figure 3 shows the causes that affect the decision of a new demand. In this cause tree diagram, load growth is seen to be one of the causes together with reserved margin and total installed capacity. The reserved margin of the system is set at average of 20% out of the total installed capacity. In this system, the decision of making a new power plant is based on the generation mix in [24]. The new demand will be established after considering the total amount of the load growth and reserved margin. If the total amount is greater than the total installed capacity, new demand is necessitated. Otherwise, new demand will remain zero.

2.1.3. Stock and flow diagram for load growth and base electricity tariff model

Figures 4 and 5 shows the stock and flow diagram (SFD) of load growth and electricity tariff. These two are part of the model of MESI developed in this study. For Figure 4, the load growth model is developed based on the correlation that has been discussed in section 2.1. Using the correlation analysis in (1), value of the load growth become the input for decision (capacity check) whether new capacity is need in the system. The new demand is the additional capacity needed to cater the total installed capacity that might be lacking due to the increased load growth. From the new demand capacity, it will then distribute to the four technology-coal, hydro, gas, and renewable energy power plants-according to the pre-defined power generation mix.

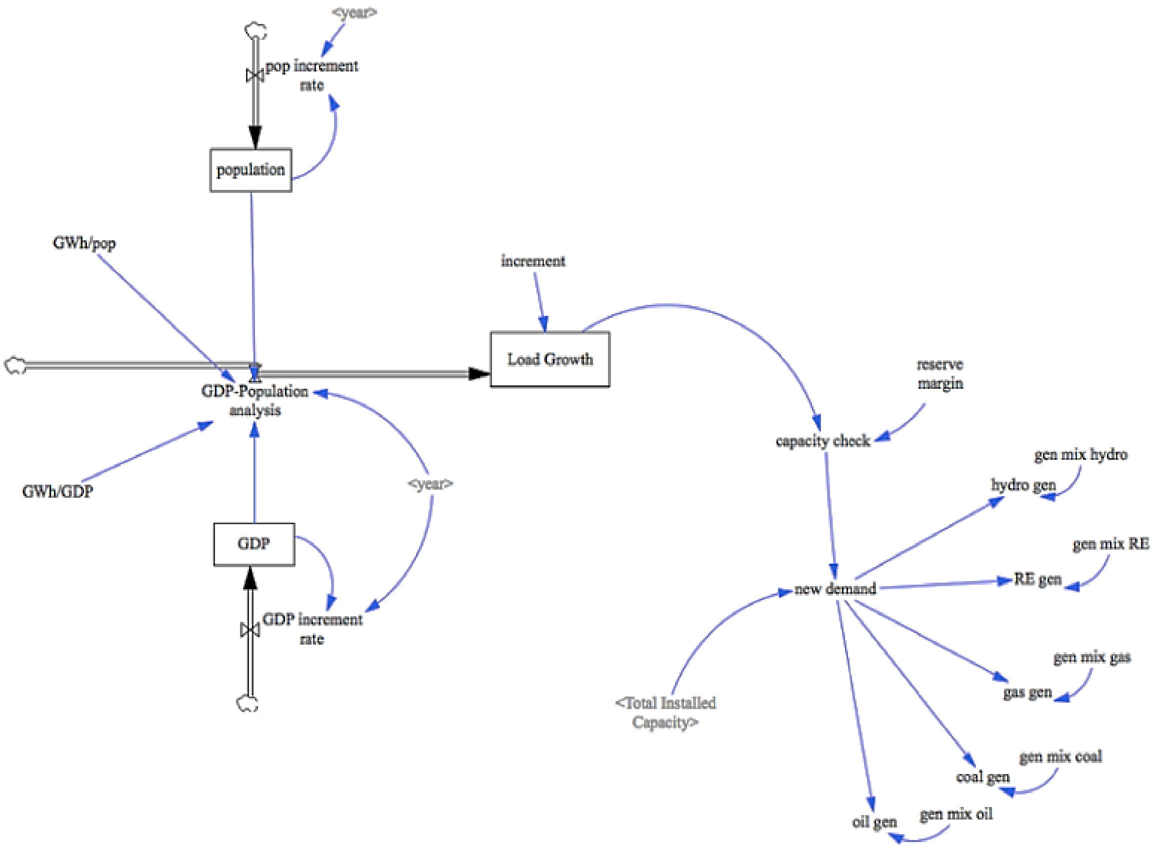

Figure 4. Stock and flow diagram of the load growth model

Meanwhile, Figure 5 shows the SFD for the electricity tariff. The electricity tariff is calculated based on (2). The levelized SB cost is calculated based on the total revenue as well as the net energy output of the operating generation plants. Meanwhile the cost of transmission, distribution network, grid operating system (GSO), single buyer operation (SBO), and the customer service (CS) are set at fixed value. All the data utilized in this study is taken from Energy Commission 2017 annual report [25].

$$Electricity\ tariff = Levelised\ SB\ Gen\ Cost + Transmission + Dist.Network + GSO + SBO + GS \quad (2)$$

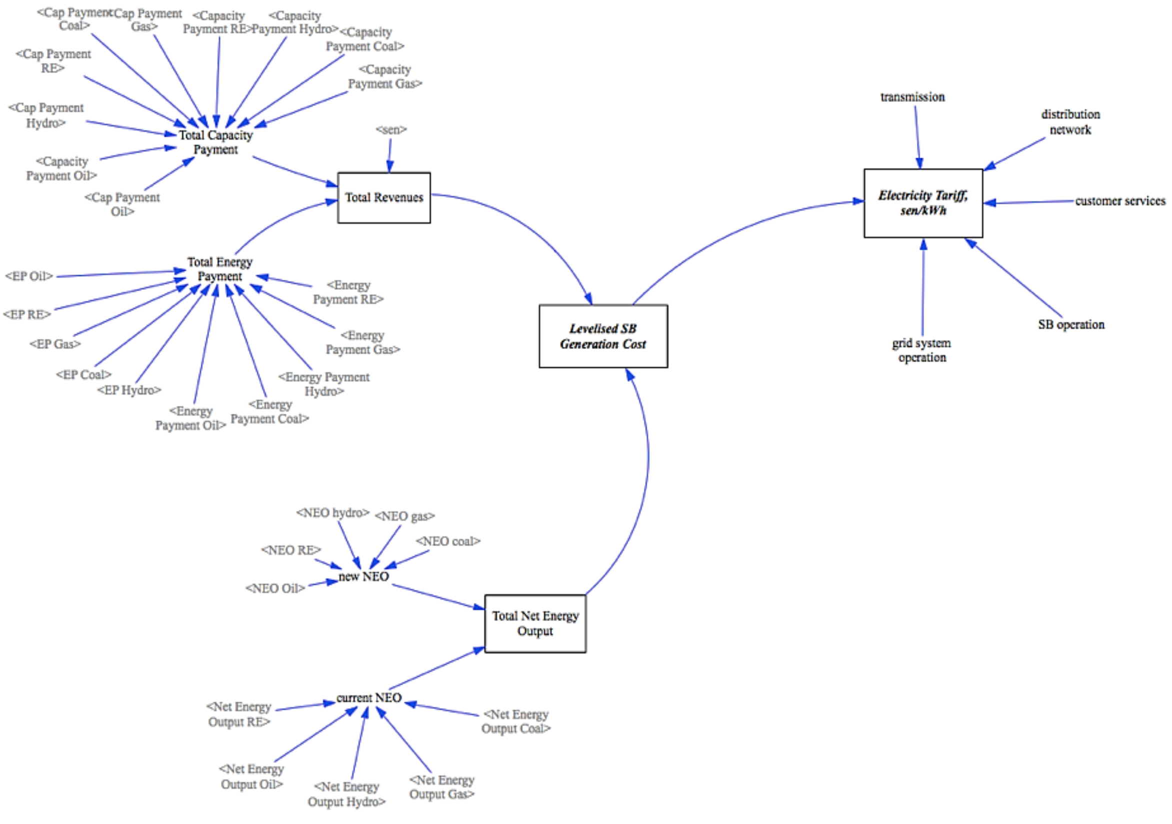

Figure 5. Stock and flow diagram for the electricity tariff

3. RESULTS AND DISCUSSION

Given that this model is looking at the electricity tariff and load growth over a 30-year span of time, the expiry date of each plant is essential to decide on the new capacity needed over the time. This simulation is made under five conditions which are i) base case, ii) 20% load growth drop off, iii) 30% increase in load growth, iv) 50% increase in load growth, and v) 80% increased of load growth. Figure 6 shows the changes in load growth according to the five conditions of simulation that has been made. Referring to the explanation made in section 2.1, the load growth is simulated based on the regression analysis between the GDP and population. Based on the date used in Table 1, it is expected that the load growth is directly proportional to the time frame and has a steady increment since the beginning regardless the condition given. The increment of the load growth is predicted to gives impact to the total installed capacity, the new demand, as well as the electricity tariff. Meanwhile, Figure 7 shows the output graph of the simulation for the total installed capacity of the system. The output shows the same characteristic for all five conditions. The total installed capacity shown in the graph is the accumulation of the existing installed capacity and the new installed capacity in the system. Since this model is taking the PPA expiry into consideration, it can be seen from the graph that the total installed capacity started to increase from year 4. This is due to the expiry of few plants.

It can be seen in Figure 8 where the new installed capacity started to take place to cater the demand capacity needed in the system from year 4 onwards. The existing installed capacity can only cater the demand from year 1 until year 3 before a new capacity need to be installed. From these two graphs, it is clearly seen that the increment of load growth directly affects the installed capacity of the system.

Moving to the second objective of this paper which is observing the effect of load growth to the electricity tariff. The simulation output is shown in Figure 9. The graph shows that there is variation of electricity tariff under the five conditions tested on the model. The lowest tariff is observed during the decrement of the load growth, followed by the normal case condition. The electricity tariff is recorded at its highest value during the condition where load growth is increase at 80%. Even though the demand is steadily increased; the tariff gives a bit of fluctuation output due to some variables occurs in the system such as the changes of technology, thus it affects the generation cost of the system. In year 4, for example, there was a significant increment of tariff recorded. This happened due to the new plant constructed to cater the load demand that can no longer be catered by the existing generators.

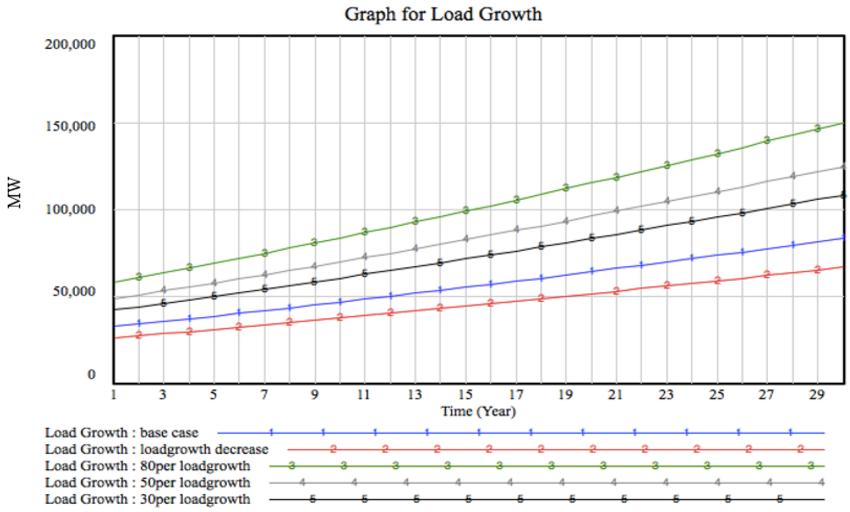

Figure 6. Changes of load growth for all five settings of the simulation

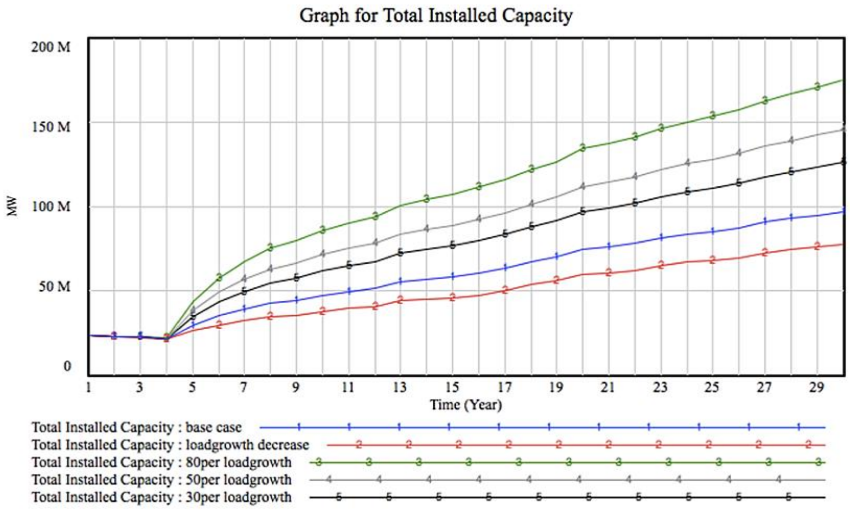

Figure 7. Total installed capacity with regards of changes in load growth

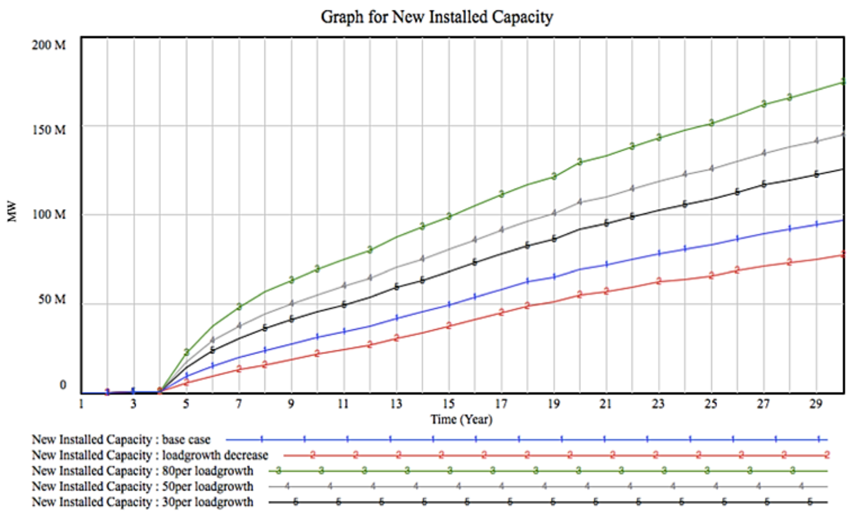

Figure 8. New installed capacity of the system

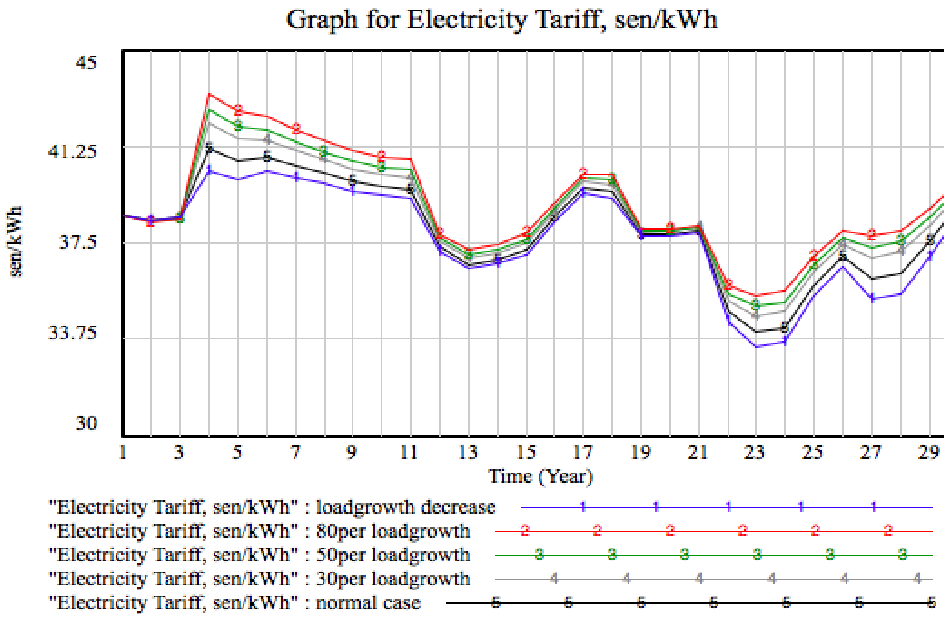

Figure 9. Electricity tariff with regards of changes in load growth

4. CONCLUSION

In conclusion, this paper has developed a Malaysian electricity supply industry (MESI) upstream market model resonating the SB market framework that investigates the effect of load growth to the electricity tariff in Malaysia. Simulation highlighted the dependence and interaction of each variable on electricity tariff calculation. It is clearly shown that those variables exist in the system are interacting to one another that in a way gives effect to the system. The regression analysis executed during the simulation shows that load growth in Malaysia is affected by the population and the GDP. Even though the increment is only 10% as in percentage, but the value is still significant since the electricity tariff is in the unit of sen/kWh. Thus, every difference in sen gives effects on the tariff. For the future direction, the model can be enhanced by focusing on the new reform market of MESI that seems to be having merchant generators to join in as the generation company together with the existing generation companies that are already bound by the power purchase agreement (PPA).

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REFERENCES

[1] V. G. R. Chandran, S. Sharma, and K. Madhavan, “Electricity consumption-growth nexus: The case of Malaysia,” *Energy Policy*, vol. 38, no. 1, pp. 606–612, Jan. 2010, doi: 10.1016/j.enpol.2009.10.013.
[2] Suruhanjaya Tenaga Energy Commission, “National energy balance 2017,” *Suruhanjaya Tenaga (Energy Commission)*, 2019. Accessed: Feb. 14, 2018. [Online], Available: https://tinyurl.com/2p98ezty
[3] T. H. Oh, M. Hasanuzzaman, J. Selvaraj, S. C. Teo, and S. C. Chua, “Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth-An update,” *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 3021–3031, Jan. 2018, doi: 10.1016/j.rser.2017.06.112.
[4] M. I. K. M. Safari, N. Y. Dahlan, N. S. Razali, and T. K. A. Rahman, “Electricity prices forecasting using ANN hybrid with invasive weed optimization (IWO),” in *2013 IEEE 3rd International Conference on System Engineering and Technology*, Aug. 2013, pp. 275–280, doi: 10.1109/ICSEngT.2013.6650184.
[5] Suruhanjaya Tenaga Energy Commission, “Electricity tariff review in peninsular Malaysia for regulatory period 2 (RP2: 2018-2020) under Incentive-based regulation (IBR) mechanism,” *Suruhanjaya Tenaga (Energy Commission)*, 2018. Accessed: Apr. 25, 2020. [Online], Available: https://tinyurl.com/5ehcru6p
[6] H. F. Mohamad and S. N. M. E. Amran, “Electricity industry to undergo transformation with MESI 2.0,” *New Straits Time*, 2018. https://www.nst.com.my/business/2018/09/412549/electricity-industry-undergo-transformation-mesi-20 (accessed Feb. 14, 2019).
[7] Suruhanjaya Tenaga Energy Commission, “Report on peninsular generation development plan 2019,” *Energy Commission Malaysia*, 2020. Accessed: Aug. 28, 2021. [Online], Available: https://tinyurl.com/2p8jtdey

[8] J. Wang, J. Wu, and Y. Che, "Agent and system dynamics-based hybrid modeling and simulation for multilateral bidding in electricity market," *Energy*, vol. 180, pp. 444–456, Aug. 2019, doi: 10.1016/j.energy.2019.04.180.
[9] Z. Wu and J. Xu, "Predicting and optimization of energy consumption using system dynamics-fuzzy multiple objective programming in world heritage areas," *Energy*, vol. 49, pp. 19–31, Jan. 2013, doi: 10.1016/j.energy.2012.10.030.
[10] A. J. C. Pereira and J. T. Saraiva, "A long term generation expansion planning model using system dynamics-Case study using data from the Portuguese/Spanish generation system," *Electric Power Systems Research*, vol. 97, pp. 41–50, Apr. 2013, doi: 10.1016/j.epsr.2012.12.001.
[11] M. S. Owlia and H. Dastkhan, "An application of system dynamics in electricity supply systems: case of Yazd regional electricity company in Iran," in *The 30th International Conference of the System Dynamics Society. St. Gallen, Switzerland*, 2012, pp. 1–24.
[12] G. P. Kilanc and I. Or, "A system dynamics model for the decentralized electricity market," *International Journal of. Simulation. Systems, Science & Technology*, vol. 7, no. 7, pp. 40–55, 2006.
[13] H. Qudrat-Ullah, "Understanding the dynamics of electricity generation capacity in Canada: A system dynamics approach," *Energy*, vol. 59, pp. 285–294, Sep. 2013, doi: 10.1016/j.energy.2013.07.029.
[14] T. S. Jalal and P. Bodger, "The development of a system dynamics model for electricity generation expansion In New Zealand," in *Christchurch, New Zealand: 2010 Electricity Engineers' Association (EEA) Conference*, 2012, pp. 1–10.
[15] S. W. Lim, K. F. Chen, and E. H. Yap, "System dynamics of electric cars (EC) usage and support infrastructure in Malaysia," *Applied Mechanics and Materials*, vol. 627, pp. 342–346, Sep. 2014, doi: 10.4028/www.scientific.net/AMM.627.342.
[16] N. Z. M. Zamin and J. B. Ibrahim, "Economic regulation of the single buyer: Enhancing efficiencies through an incentive based framework," *Tenaga National Berhad*, pp. 1–5, 2013.
[17] A. Bin Omar, "Guidelines on electricity tariff determination under incentive based regulation (IBR) for peninsular Malaysia," *Malaysia Energy Commission*, 2018. Accessed: Feb. 22, 2020. [Online], Available: https://tinyurl.com/t75jmned
[18] M. F. Sulaima, N. Y. Dahlan, M. H. Isa, M. N. Othman, Z. M. Yasin, and H. A. Kasdirin, "ETOU electricity tariff for manufacturing load shifting strategy using ACO algorithm," *Bulletin of Electrical Engineering and Informatics*, vol. 8, no. 1, pp. 21–29, Mar. 2019, doi: 10.11591/eei.v8i1.1438.
[19] J. W. Forrester, *Industrial dynamics*. M. I. T. Press, 1961.
[20] C. W. Kirkwood, "System dynamics methods: a quick introduction," Arizona State University, https://tinyurl.com/2cebf5a2 (accessed Apr. 25, 2020).
[21] I. Kuzle, D. Bosnjak, and H. Pandzic, "Comparison of load growth prediction methods in distribution network planning," in *IET Conference Publications*, 2009, doi: 10.1049/cp.2009.0969.
[22] J. W. Forrester, "System dynamics, systems thinking, and soft OR," *System Dynamics Review*, vol. 10, no. 2–3, pp. 245–256, 1994, doi: 10.1002/sdr.4260100211.
[23] J. Swanson, "Business dynamics-systems thinking and modeling for a complex world," *Journal of the Operational Research Society*, vol. 53, no. 4, pp. 472–473, Apr. 2002, doi: 10.1057/palgrave.jors.2601336.
[24] Suruhanjaya Tenaga Energy Commission, *Peninsular Malaysia electricity supply outlook 2017*. Suruhanjaya Tenaga (Energy Commission), 2017.
[25] Suruhanjaya Tenaga Energy Commission, "Energy industry in transition: annual report 2017," Suruhanjaya Tenaga Energy Commission, 2017. Accessed: Aug. 28, 2020. [Online], Available: https://tinyurl.com/2pzada5m

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