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Multi-Objective Sensitivity Analyses for Power Generation Mix: Malaysia Case Study

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***Abstract*— This paper presents an optimization framework to determine long-term optimal generation mix for Malaysia Power Sector using Dynamic Programming (DP) technique. Several new candidate units with a pre-defined MW capacity were included in the model for generation expansion planning from coal, natural gas, hydro and renewable energy (RE). Four objective cases were considered, 1) economic cost, 2) environmental, 3) reliability and 4) multi-objectives that combining the three cases. Results show that Malaysia optimum generation mix in 2030 for, 1) economic case is 48% from coal, 41% from gas, 3% from hydro and 8% from RE, 2) environmental case is 19% from coal, 58% from gas, 11% from hydro and 12% from RE, 3) for reliability case is 64% from coal, 32% from gas, 3% from hydro and 1% from RE and 4) multi-objective case is 49% from coal, 41% from gas, 7% from hydro and 3% from RE. The findings of this paper are the optimum generation mix for Malaysia from 2013 to 2030 which is less expensive, substantially reduce carbon emission and that less risky.**

***Keywords*— generation mix; dynamic programming (dp); single objective; multi-objective**

I. INTRODUCTION

The recent issues of generation mix in Malaysia are: 1) over-dependency on a certain fuel type (oil, natural gas, coal and hydro), which is not viable for a long-term option, 2) lack of availability for a competitive, sustainable and alternative commercial energy sources for the long-term. This becomes big challenges for Malaysia power sector as highlighted in the Energy Service Conference 2016. These have led Malaysia to find other alternative resources to generate electricity. Some possible options are: 1) coal, however, this leads to the dependency on imported coal and will increase gas carbon emission; 2) natural gas, however, its capacity has a contracted gas volume and depletion of gas reserves; 3) hydro, however, there is limited hydro potential in Peninsular since it is complex technology and high investment; and 4) renewable energy (RE), however, the resources are interruptible and expensive. It is critical for Malaysia power system to find an optimum future fuel mix strategy to ensure sustainability of supply. It is important and timely to determine the optimum future generation mix for Malaysia considering various fuels, economic and policy factors in ensuring cost effectiveness, sustainable and secure power generation.

Generation expansion problem can be expressed as a highly constrained, large scale, nonlinear, discrete optimization problem, mix-integer and stochastic optimization problem that typically aims at identifying the selection of the locations and technologies to use [1], [2], [3], [4]. There are numbers of computational optimization techniques that can be used for determining the optimal generation mix. The traditional approaches to solve the generation planning problem are based on mathematical programming methods such as Linear Programming (LP), mixed integer linear programming (MILP) model [3], [4], [5], [6] and Dynamic Programming (DP) [7]. The metaheuristic approach such as Genetic Algorithm (GA) [2][8] that is among popular AI-based techniques for generation mix optimization, Evolutionary Programming (EP) [9], [10], [11], Evolutionary Strategy (ES) [12] and Partial Swarm Optimization (PSO) [13], [14] are applied to solve expansion generation mix problem. A comparative study on the techniques used for generation expansion planning has been performed in [1], [15].

Generation mix problem is to determine what to build (choice of technology), how much to build (capacity of the plant), and when to build (suitable time for expansion). The choice of which technology to be included in the generation mix is essential, yet difficult because each technology has its own advantages and disadvantages [16].

The open literature is limited for studying the generation mix for Malaysia [10] using Evolutionary Programming (EP) to determine optimal generation mix planning at the least cost for 4,100MW additional capacity as announced by Malaysia Energy Commission. The combination of four technology options namely nuclear, coal, natural gas and renewable energy (RE), authors of [11] have extended the study to compare three objectives function that compared in term of economic cost, socio-environmental and power system reliability. However, both studies did not consider a long-term generation mix for Malaysia. On the other hand, [17] presents a long-term generation mix model to minimize the total cost of supplying electricity. After that, [7] proposes DP with efficiency multi-criteria decision technique in modelling multi-objective (i.e. to minimize the cost and to minimize CO_2 emission) of the long-term generation mix. They also conducted a sensitivity analysis to evaluate the impact of the inclusion of nuclear in the generation mix, increasing the gas price and the RE target policy. This paper did not consider a power system reliability as the objective function.

Section II presents the mathematical formulation of the DP-generation mix and display the test data. The optimization results and discussion described in section III. Section IV gives the conclusion and finding of the paper.

II. Material and Method

A. DP- based Generation Mix Model

DP is applied over a time horizon to find a set of optimal decision to minimize the objective function subjected to several constraints. The DP is an approach that transforms a complex problem into a simpler sub-problem. Its main characteristic lies in the way that optimization is solved in multi-stages. In the DP-based generation mix model, a state is defined as the existing units plus the new units. This model selects the generation options each year among the set of generation technologies until it reaches the optimization horizon.

The DP-based generation mix is tested using four cases of optimization objectives; 1) economic objective which is to minimize the total cost of generation expansion, 2) environmental objective which is to minimize the total carbon emission, 3) reliability objective which is to maximize the reliability of system by minimizing the loss of load expectation (LOLE) and 4) multi-objectives which is to minimize the normalized index.

The optimization model's objective function and constraints are presented below.

1) Least Cost Modelling

The DP-based generation mix is developed to minimize the total cost of generation expansion, including investment and operating costs. Some factors that contribute to the generation cost of the technologies are included in the generation mix model. These include investment cost, construction time, plant lifetime, fixed and variable O&M costs, fuel cost and fuels escalation rate. The total cost of future generation expansion, considering the generation cost profiles of different technologies, is given by the following equation:

$$TC = min \sum_{t=1}^{T} \{PC_{all}(X_t)_t + IC(U_t)_t + FOM_{all}(X_t)_t + \quad (1)$$

where TC is the total cost of generation mix over the simulation horizon, *PCall,t* is the total production cost of all the generating units in the system at year *t*, *ICt* is the total investment cost of the new investments at year *t*, *Xt* is the cumulative capacity (MW) vector in year *t*, *Ut* is the capacity addition vector in year t and T is the lifetime of the new plant. Multiplying the marginal cost by the energy produced gives the production cost of each unit. The energy produced each year is computed by performing economic dispatch for each segment of the load duration curve (LDC). *FOMall,t* is the total fixed O&M cost of all the generating units at year *t*, *VOMall,t* is the total variable O&M cost of all the generating units at year *t* and *CCt* is the total carbon emission cost of coal and combined cycle technologies at year *t*. Economic dispatch is modeled in the DP-based generation mix to calculate the power dispatch by the generating unit in the system and production cost of each unit [7].

2) Least Carbon Emission Modelling

The next model is developed to minimize the total carbon emission as an environmental objective function. It can be determined based on the carbon content of the different unit technologies. The total carbon emission for future expansion as the following equation:

$$TCO_2 = min \sum_{t=1}^{T} \{CI_t\} \quad (2)$$

where CI_t is the total carbon emission at year *t*.

3) Least Loss of Load Expectation (LOLE) Modelling

One of the main objective in generation mix optimization is for ensuring the long-term security of Malaysia power supply. In power supply section, generator outage can occur due to planned maintenance or mechanical failure that may leave the system with the insufficient generating capacity to meet load demand. The loss of load probability and loss of load expectation of the system is given by the following equation:

$$LOLP = \sum_{s=1}^{S} \sum_{i=1}^{n} Pi\left(\left(Ci - Ca(i)\right) < Pd\right) \quad (3)$$

$$LOLE = \sum_{t=1}^{T} d.LOLP \quad (4)$$

where Ci is actual capacity for state i, Ca is a capacity outage, Pd is load demand and d is duration for each segment in an hour. Equation (3) indicates that loss of load probability (LOLP) is probability loss of load occur when the system load exceeds the generating capacity available for use.

4) Least Normalized Index Modelling

The multi- objectives is a model combining the three cases of objective functions. Each individual case objective has different units and scales; therefore, the objective is formulated as the weighted sum of normalized values of these three cases of objectives. The objective function f_{norm} are scaled between 0 and 1. For each of the three case objectives, a minimum and maximum value are defined. The normalized index of multi-objectives function is given by the following equation:

$$f_{norm} = \frac{f - f_{min}}{f_{max} - f_{min}} \quad (5)$$

$$NI_{min} = w_1 TC_{norm} + w_2 TCo_{2norm} + w_3 LOLE_{norm} \quad (6)$$

$$w_1 = w_2 = w_3 = 1 \quad (7)$$

where f is the actual value, f_{min} and f_{max} is minimum and maximum value of objective function. Equation (6) indicates that the least normalized index is equal to summation of three normalized objective functions multiplied by weights. The weights of each objective in this study is set similar as shown in equation (7).

5) Constraints Modelling

- Generation capacity larger than demand capacity plus some reserve margin.

$$X_t = X_{t-1} + U_t - K_t, \forall t \in T \quad (8)$$

- Reserve margin lies between the minimum and maximum reserve.

$$R^{min} \leq R(X_t) \leq R^{max}, \forall t \in T \quad (9)$$

where *Kt* is the capacity retirement, *T* is the optimization horizon, *R* is the reserve margin resulting from the generation capacity *Xt*, and R^{min} and R^{max} are the minimum and maximum reserve requirement each year. Equation (8) indicates that the cumulative capacity at year *t* is equal to the capacity of the previous year, plus the new capacity built at year *t*, minus the capacity retirement happening at year t. Equation (9) constraints the installed capacity to be within the minimum and maximum reserve requirements allowed in the system.

B. Test Data

The proposed model has been implemented in Matlab programming. The analysis has been tested on Malaysia's Power System. The actual data was collected on 2012 from the Energy Commission (EC), Tenaga Nasional Berhad (TNB), U.S. Energy Information Administration (EIA) and International Energy Agency (IEA). The planning horizon consists of a period of seventeen years (2013-2030), and base year of 2012 with install generation capacity of 21,871MW. The system consists of one hundred thirty-two generating units from five different fuel technologies namely coal, gas, hydro, oil and RE as shown in Appendix. Three power plants as highlighted in bold in the Appendix are extending their expiry of the power purchase agreement's (PPA). Two power plants (Segari Energy venture and Genting Sanyen Power) will be granted a 10-year PPA extension and will be retired on 2027 and 2026 respectively. Meanwhile, SJ Sultan Iskandar (combined cycle) plant will extend its services for another 5 years and will be retired on 2022.

Fig. 1 shows a six-segment of discretised load duration curve (LDC) for Malaysia. The hourly load demand data is obtained from EC for the year 2012. Table 1 shows a demand and duration for each segment from LDC.

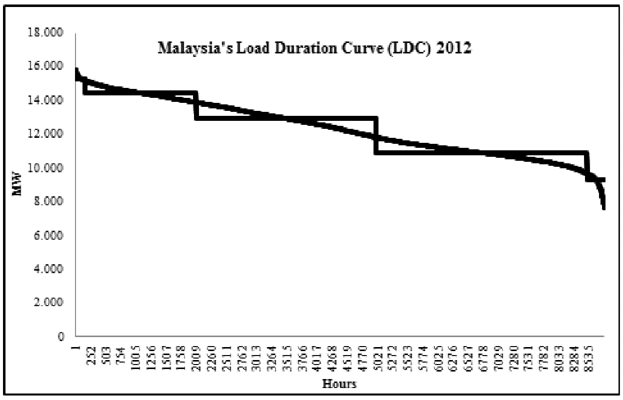

Fig. 1 Six-segment discretised Load Duration Curve (LDC) for Malaysia

Table 2 shows a long-term load growth forecast from the year 2013 to 2030. Average period growth rate forecast for the year 2013 to 2015 is 3.7%, the year 2016 to 2020 is 3.3% and year 2021 to 2030 is around 1.6%. This load growth is significant to be acquainted with the quality of load demand, reserve margin and total install capacity of the power plant.

TABLE I
DEMAND AND DURATION FOR SIX-SEGMENT

Segment	1	2	3	4	5	6
Demand (MW)	15,644	15,287	14,440	12,913	10,896	9,309
Duration (h)	16	144	1840	3000	3500	284

TABLE II
LOAD GROWTH FORECASTED 2013-2030

Year	2013	2014	2015	2016	2017	2018	2019
Growth (%)	4.5	3.6	3.2	3.8	3.2	3.3	3.0
Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Growth (%)	3.5	2.9	2.1	0.7	1.9	1.8	1.7
Year	**2027**	**2028**	**2029**	**2030**			
Growth (%)	1.7	1.6	1.5	1.4			

TABLE III
TECHNICAL OF MODELLING PARAMETERS

Parameter	Unit	Coal		Gas		Hydro	RE
Name	unit	PG 01	PG 02	PG 03	PG 04	PG 05	PG 06
Net capacity	MW	700	500	600	400	150	200
Heat rate	MBTU/MWh	8.13	8.13	9.37	9.37	5.77	4.31
Construction time	Years	4	4	5	5	5	2
Plant life time	Years	40	40	30	30	40	40

TABLE IV
COST AND FINANCING OF MODELLING PARAMETERS

Parameter	Unit	Coal	Gas	Hydro	RE	Oil
Carbon intensity	tc/MBTU	0.0258	0.0148	0	0	0
Fixed O&M	$/kW/yr	27.53	11.70	13.63	11.68	21.50
Variable O&M	$/MWh	4.59	2	2.43	0	3.17
fuel cost	$/MBTU	2.46	4.26	1	1	24.37
Fuel escalation rate	%	0.5	1.5	0	0	1.0
Force Outage rate (FOR)	-	0.06	0.04	0.05	0.08	0.10

This study considers four generation technologies i.e. coal, gas, hydro and RE that available to be selected by DP each year for future additional generation expansion. The technical and cost characteristics of the expansion plants are shown in Table 3 and Table 4. Similar costs data have been used for the existing system.

III. RESULTS AND DICUSSION

The DP-based generation mix model is analysed for four case studies. A case study has been carried out using the presented model to determine long-term optimum Malaysia generation mix with an 18-year planning period. It will be 64 possible options or also called states comes from 6 candidate units of technology for DP selection.

A. *Case 1: Economic Objective*

In this case, the generation mix is to minimize the total cost of power generation. The optimum generation mix for Malaysia at minimum cost objective in the year 2030 is 48% from coal, 41% from gas, 3% from hydro and 8% from RE with total install capacity is 29,439 MW, as shown in Fig. 2.

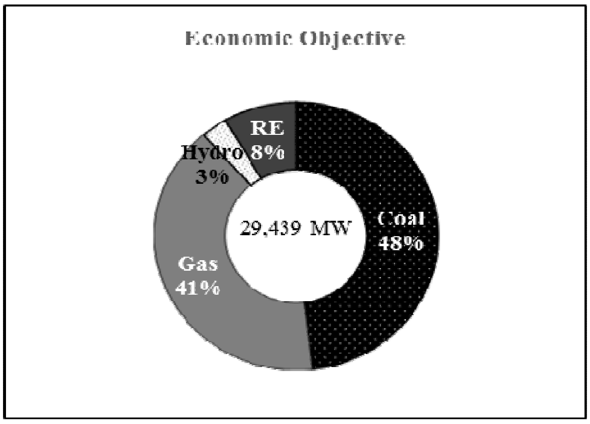

Fig. 2 Malaysia generation mix on 2030 with economic objective

Table 5 shows the result of optimum installed capacity for each type of technologies considering the economic objective. The optimum option is on option 54 from all 64 of possible options. The coal has the highest capacity of 14,201 MW followed by the gas with 11,911 MW the RE with 2,429 MW and hydro with 901 MW. The optimum total cost over the 18 years planning period considering economic objective is $96 billion. The carbon emission and LOLE for this least cost objective are 449 million tCO_2 and 1.71 days per year respectively.

TABLE V
OPTIMUM INSTALLED CAPACITY, TOTAL COST, TOTAL CO_2 AND LOLE FOR ECONOMIC OBJECTIVE

Option	Coal (MW)	Gas (MW)	Hydro (MW)	RE (MW)
54	14,201	11,911	901	2,429

Total Cost ($)	Total CO_2 (tc)	LOLE (days/year)
96,065,575,890.62	449,433,569.89	1.71

Fig. 3 shows the result of the expansion plants that are selected by the DP each year from 2013 until 2030 to meet the demand growth and to replace the retirement units. In the year 2015, there is no expansion of unit as the install capacity has met the demand and reserve requirement in that year. Throughout the years, gas technology has been shown as the favourite technology selected by DP.

B. *Case 2: Environmental Objective*

In the case of environmental objective, the optimum generation mix in the year 2030 is 19% from coal, 58% from gas, 11% from hydro and 12% from RE, with total install capacity is 29,839 MW as shown in Fig. 4. The coal technology in the generation mix reduces from 48% in the case of the economic objective to 19% in the case of the environmental objective. This is due to the coal technology that has the highest carbon content compared to the other technologies.

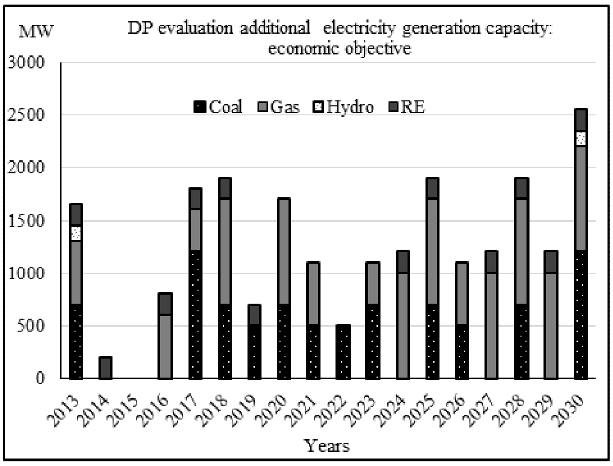

Fig. 3 DP evaluation additional electricity generation capacity for economic objective

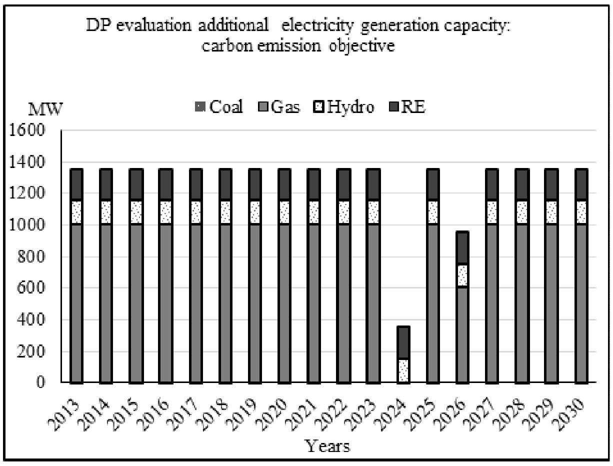

Fig. 5 DP evaluation additional electricity generation capacity for environmental objective

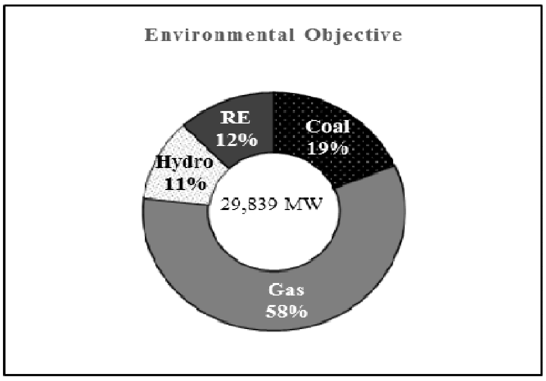

Fig. 4 Malaysia generation mix on 2030 with environmental objective

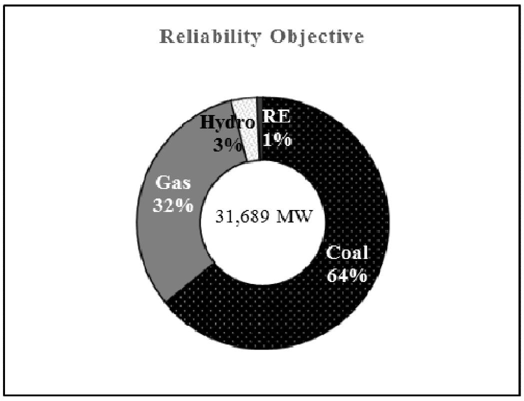

Fig. 6 Malaysia generation mix on 2030 with reliability objective

The optimal solution is option 61 with install capacity of 17,310 MW from the gas, 5,601 MW from the coal, 3,628 MW and 3,300 MW from the RE and hydro respectively. Table 6 shows that the total carbon emission considering environmental objective reduced by 18.72% as compared to total carbon emission in the case of the economic objective.

Fig. 5 shows that coal technology was not selected by DP due to higher carbon emission. In the year 2024 and 2026, technology selection was reduced since the installed capacity has met the demand and reserve requirement in that year.

C. Case 3: Reliability Objective

In the case of reliability objective, the optimum generation mix in the year 2030 is 64% from coal, 32% from gas, 3% from hydro and 1% from RE as shown in Fig. 6.

TABLE VI
OPTIMUM INSTALLED CAPACITY, TOTAL COST, TOTAL CO_2 AND LOLE FOR ENVIRONMENTAL OBJECTIVE

Option	Coal (MW)	Gas (MW)	Hydro (MW)	RE (MW)
61	5,601	17,310	3,300	3,628
Total Cost ($)	Total CO_2 (tc)	LOLE (days/year)		
110,250,420,884.15	365,297,466.89	0.57		

Table 7 shows that the optimum option is on option 30. The highest installed capacity in the generation mix is contributed by the coal with 20,300 MW. This is followed by gas with 10,109 MW, the hydro with 1,049 MW and the RE technology with 229 MW. The installed capacity of the coal and hydro technologies have significantly increased from the case of the economic objective. It is found that the LOLE considering reliability objective is more than 100% lower than the LOLE with the case of economic and environmental objectives. This indicates that by minimizing LOLE in power generation mix planning could maximize the power system reliability.

TABLE VII
OPTION, TOTAL COST, TOTAL CARBON EMISSION AND LOLE FOR RELIABILITY OBJECTIVE

Option	Coal (MW)	Gas (MW)	Hydro (MW)	RE (MW)
30	20,300	10,109	1,049	229
Total Cost ($)	Total CO_2 (tc)	LOLE (days/year)		
101,997,663,107.35	480,950,452.39	4.33E-6		

There are no technologies expansion in the year 2014 and 2015 as shown in result DP additional expansion at Fig. 7. Coal has been the most selected technology throughout the year because it is the most contributing technology in maximizing reliability. Less capacity of RE has been selected in this case as RE has a lower capacity factor hence availability in the system.

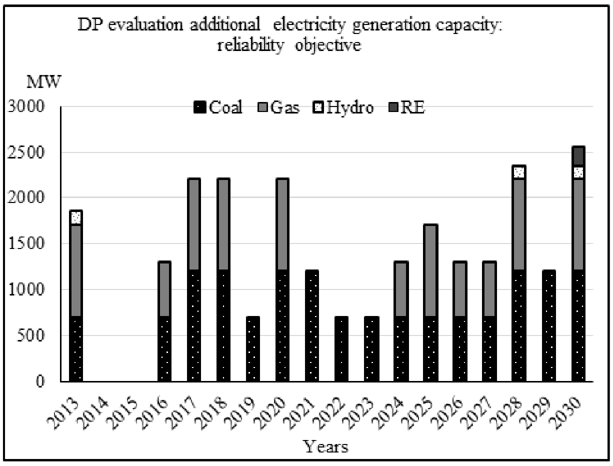

Fig. 7 DP evaluation additional electricity generation capacity for reliability objective

D. *Case 4: Multi-Objectives*

Case four presents generation mix considering simultaneous multi-objectives i.e. economic cost, environmental impact, and system reliability. The objective value for the three single objectives was normalized and the optimum generation mix depends on the minimum value of the normalized index. A weighted sum technique [3] was used in this case. The weighted value for each objective function is the same, where the total weight is equal to one. Fig. 8 shows the result of optimum generation mix for the multi-objectives case with 49% from coal, 41% from gas, 7% from hydro and 3% from RE technology.

Table 8 shows that coal has the highest installed capacity of 15,200 MW. This is followed by gas with 12,710 MW, hydro with 2,101 MW and RE with 1,030 MW. The total cost for this generation mix is $104 billion, total carbon emission is 447 million tCO_2 and LOLE is 2.24E-3 days per year. The result of LOLE achieved the reliability policy target that is less than 1day LOLE per year. The weighted sum approach gives the minimum multi-objectives index of 0.4171 with option 42.

TABLE VIII
OPTION, TOTAL COST, TOTAL CARBON EMISSION AND LOLE FOR MULTI-OBJECTIVES

Option	Coal (MW)	Gas (MW)	Hydro (MW)	RE (MW)
42	15,200	12,710	2,101	1,030
Total Cost ($)	Total CO_2 (tc)	LOLE (days/year)		
104,032,930,775.29	447,424,628.73	2.24E-3		
Normalize total cost	Normalize total CO_2	Normalize LOLE	Normalize Index	
0.2639	1	0	0.4171	

Fig. 9 shows that no expansion of power plant in the year 2014 and 2015 since the installed capacity has met the demand and reserve in that year.

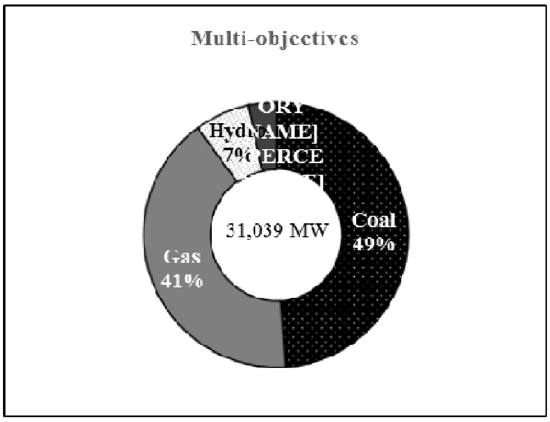

Fig. 8 Malaysia generation mix on 2030 with multi-objectives

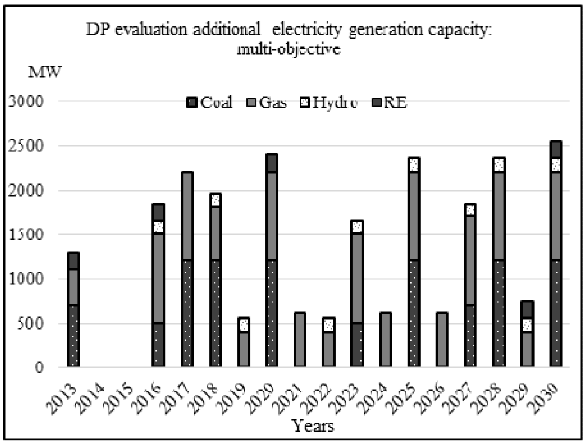

Fig. 9 DP evaluation additional electricity generation capacity for multi-objectives

Table 9 shows load capacity forecasted during the year 2013 until 2030 for six-segment. While Table 10 shows the install capacity of planning time horizon for four case studies.

TABLE IX
LOAD FORECASTED (MW) DURING 2013-2030

Year	**Segment**					
	1	2	3	4	5	6
2013	16,348	15,975	15,090	13,494	11,386	9,728
2014	16,937	16,550	15,633	13,980	11,796	10,078
2015	17,478	17,080	16,133	14,427	12,174	10,401
2016	18,143	17,729	16,746	14,975	12,636	10,796
2017	18,723	18,296	17,282	15,455	13,041	11,141
2018	19,341	18,900	17,853	15,965	13,471	11,509
2019	19,921	19,467	18,388	16,444	13,875	11,854
2020	20,619	20,148	19,032	17,019	14,361	12,269
2021	21,217	20,732	19,584	17,513	14,777	12,625
2022	21,662	21,168	19,995	17,880	15,088	12,890
2023	21,814	21,316	20,135	18,006	15,193	12,980
2024	22,228	21,721	20,517	18,348	15,482	13,227
2025	22,628	22,112	20,887	18,678	15,761	13,465
2026	23,013	22,488	21,242	18,996	16,028	13,694
2027	23,404	22,870	21,603	19,318	16,301	13,927
2028	23,779	23,236	21,949	19,628	16,562	14,150
2029	24,135	23,585	22,278	19,922	16,810	14,362
2030	24,473	23,915	22,590	20,201	17,046	14,563

TABLE X
INSTALL CAPACITY OF PLANNING TIME HORIZON FOR EACH CASE STUDY

Case Study / Year	Case 1 (MW)	Case 2 (MW)	Case 3 (MW)	Case 4 MW)
2013	23,280.5	22,980.5	23,480.5	22,930.5
2014	23,480.5	24,330.5	23,480.5	22,930.5
2015	22,643.5	24,843.5	22,643.5	22,093.5
2016	21,868.5	24,618.5	22,368.5	22,368.5
2017	22,481.5	24,781.5	23,381.5	23,381.5
2018	23,242.5	24,992.5	24,442.5	24,192.5
2019	23,942.5	26,342.5	25,142.5	24,742.5
2020	24,761.5	26,811.5	26,461.5	26,261.5
2021	25,531.5	27,831.5	27,331.5	26,531.5
2022	26,031.5	29,181.5	28,031.5	27,081.5
2023	26,222.5	29,622.5	27,822.5	27,822.5
2024	26,702.5	29,252.5	28,402.5	27,702.5
2025	27,272.5	29,272.5	28,772.5	28,722.5
2026	27,752.5	29,602.5	29,452.5	28,702.5
2027	28,277.5	30,277.5	30,077.5	29,877.5
2028	28,619	30,069	30,869	30,669
2029	29,089	30,689	31,339	30,689
2030	29,439	29,839	31,689	31,039

IV. CONCLUSIONS

In this paper, a DP-based model for four case studies has been developed to find the optimum generation mixes for Malaysia power sector. The model considers characteristics associated with different technologies, such as the investment cost, the O&M cost, the lifetime, the construction period, the fuel cost and the carbon intensity. The model has been tested on a generation portfolio based on Malaysia power system. The result shows that optimal Malaysia generation mix in 2030 for the economic objective is: 48% from coal, 41% from gas, 3% from hydro and 8% from RE. The optimum environmental objective is 19% from coal, 58% from gas, 11% from hydro and 12% from RE. Other than that, the optimum reliability objective is 64% from coal, 32% from gas, 3% from hydro and 1% from RE. While, the optimum multi-objectives are 49% from coal, 41% from gas, 7% from hydro and 3% from RE

Economic objective prefers coal technologies to minimize the total cost. On the other hand, environmental objective reduces coal technology in the generation mix, while the coal and hydro technologies are the most contributing technologies to the reliability objective. For multi-objective generation mix, the selection of all the four technologies is seen balance. The research will continue with optimizing under multi-objective decision technique.

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APPENDIX

Power Plant	Unit Name	Size (MW)	Unit Type	PPA Expiry
YTL Power Generation	001-009	9x130	gas	2015
Segari Energy Ventures Sdn. Bhd.	010-011	2x651.5	gas	2017 **2027**
Power Tek Sdn. Bhd.	012-015	4 x 110	gas	2015
Por t Dickson Sdn. Bhd.	016-019	4 x 110	gas	2015
Pahlawan Power Sdn. Bhd.	020-022	3 x 110	gas	2020
Genting Sanyen Power Sdn. Bhd.	23	1 x87	gas	2015
Genting Sanyen Power Sdn. Bhd. (GSP Extension)	024-026	3 x 225	gas	2016 **2026**
Teknologi Tenaga Perlis Consortium Sdn. Bhd.	027-030	3 x 145; 1x215	gas	2023
Panglima Power Sdn. Bhd.	031-033	2 x 230; 1x260	gas	2022
GB3 Sdn. Bhd.	034-037	1 x 205; 3x 145	gas	2022
Prai Power Sdn. Bhd.	038-039	1 x 225; 1x 125	gas	2024
KaparEnergy Ventures Sdn. Bhd. (KEV)	040-041	2x110	gas	2019
KaparEnergy Ventures Sdn. Bhd. (KEV)	042-047	4x300; 2x500	coal	2029
TNB JanamanjungSdn. Bhd.	048-050	3x700	coal	2031
Tanjung Bin Power Sdn. Bhd.	051-053	3x700	coal	2031
Jimah Energy Ventures Sdn. Bhd.	054-055	2x700	coal	2033
S.J. Sultan Ismail , Paka	056-067	3x100; 7x95; 2x87	gas	2017
S.J. Jambatan Connaught (CBPS)	068-074	4x130; 2x106; 1x105	gas	2014
S.J. Serdang (GT1 , GT2 & GT3)	075-077	3x135	gas	2015
S.J. Serdang (GT4 & 5)	078-079	2x110	gas	2025
S.J. Sultan Iskandar, PasirGudang (PGPS) (Thermal)	080-081	2x120	gas	2017
S.J. Sultan Iskandar, PasirGudang (PGPS) (Combined Cycle)	082-084	2x87; 1x95	gas	2017 **2022**
S.J. Sultan Iskandar, PasirGudang (PGPS) (Open Cycle)	085-086	2x110	gas	2016
S.J. TuankuJaafar, Por t Dickson (PD1)	087-089	2x236; 1x258	gas	2028
S.J. TuankuJaafar, Por t Dickson (PD2)	090-092	2x230; 1x250	gas	2030
S.J. Kenyir	093-096	4x100	hydro	2025
S.J. Pergau	097-100	4x150	hydro	2037
S.J. Temenggor	101-104	4x87	hydro	2022
S.J. Chenderoh	105-108	3x10.7; 1x8.4	hydro	2022
S.J Bersia	109-111	3x24	hydro	2022
S.J. Kenering	112-114	3x40	hydro	2022
S.J. Woh Sultan Idris II	115-117	3x50	hydro	2022
S.J. Cameron Highland	118-123	4x25; 2x2.75	hydro	2027
Sungai Piah Upper Power Station	124	1x14.6	hydro	2027
Sungai Piah Lower Power Station	125	1x54	hydro	2027
Odak Power Station	126	1x4.2	hydro	2027
Habu Power Station	127	1x5.5	hydro	2027
Kampong Raja Power Station	128	1x0.8	hydro	2027
Kampong Terla Power Station	129	1x0.5	hydro	2027
Robinson Falls Power Station	130	1x0.9	hydro	2027
S.J. Gelugor	131	1x330	oil	2024
BumibiopowerSdnBhd, Jana Landfill SdnBhd, Naluri Ventures SdnBhd& Recycle Energy SdnBhd	132	1x29	RE	2040