Generation and Transmission Planning for Yangon Region with the Consideration of Contingency Condition

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Abstract: This paper refers to generation and transmission planning for Yangon region with the consideration of load forecasting. The planning period is considered as long term planning with the period of 10 years. Yangon is now rapid urbanization according to its development plans of people's living standard, newly build townships and industrial zones with about 7.3 million people. It is obvious that, the electricity demand is under pressure to be sufficient energy for Yangon region. Therefore, consideration of power system planning becomes urgent issue. Wien Automatic System Planning Package (WASP-IV) is employed for generation planning with the result of five new projects in Yangon. Moreover, Newton-Raphson based load flow calculation is applied for making decision of new lines in the expansion of transmission planning. According to the transmission planning result, three lines are needed to upgrade the existing lines and four new lines are recommended are added.

Keywords: Long-term load forecasting, generation planning, transmission planning, WASP-IV, Newton-Raphson based load flow calculation.

1. INTRODUCTION:

Power system planning is one of the most important areas in power system research. The planning problems can be categorized into short–term, mid–term and long–term planning sub-problems, while in terms of planning objectives, the planning issues may also be classified into generation planning and transmission planning. Generation expansion aims to guarantee the adequate generation capacity to meet the load demand. The main task is to determine the optimal time, location, size as well as type of generating units with respect to operation constraints to achieve minimum cost as well as maximum stability, reliability and economic return. The case study is focused on Yangon power plants expansion. Yangon, the largest economic city in Myanmar, is now experiencing rapid urbanization. Currently, there are 7.3 million people in Yangon and 80% of population is electrified. In this paper, there are three main subjects which are load forecasting, generation planning and transmission planning. Currently, five combined cycle gas turbine power plants and four gas turbine power plants and rest of necessity supply from national grid which mainly depends on hydro power. 230 kV and 66 kV are taken as backbone of transmission system. There are twenty-three busses and twenty- three lines.

2. GENERATION PLANNING USING WIEN AUTOMATIC SYSTEM PLANNING PACKAGE (WASP-IV):

The Wien Automatic System Planning Package (WASP-IV) used for the generation expansion planning studies is designed to find the economically optimal generation expansion policy for an electric generating system, within user-specified constraints. The software was developed by International Atomic Energy Agency (IAEA) and runs a probabilistic estimation of system production costs, expected cost of un-served energy and reliability. The optimum generation mix to meet the demand for power and energy in a particular study period is evaluated using dynamic programming techniques for comparing the costs of alternative system expansion policies. The objective cost function (Bj) which is optimized in the study using the WASP methodology is:

$$B_j = \sum \left[I_{jt} - S_{jt} \right] + F_{jt} + M_{jt} + O_{jt} \qquad (1)$$

Where I = discounted capital investment costs, S= discounted salvage value of investments, F= discounted fuel costs, M= discounted operation and maintenance costs, O= discounted outage (un-served energy) costs, t= length of study period, j= total number of possible expansion plans. The optimal expansion plan is defined by the minimum [B_j] out of all possible configurations [2].

WASP-IV (Wien Automatic System Planning) model is a power generation expansion tool, used to model the power plants. WASP IV consists of the following seven modules as given below and each module determines different outputs with their respective inputs.

1. LOADSYS: A program that describes the load duration curves and forecast the peak loads for the system for the system.

2. FIXSYS: A program that describes the existing power system and all future additions and retirements which are to be firmly scheduled.
3. VARSYS: It's a program that describes the candidate plants (which are to be added in future) which might be used to expand the power system.
4. CONGEN : A program which is used to generate all possible year to year alternative combinations of expansion system, the alternative expansion configurations are combination of plants on economic and environmental basis.
5. MERSIM: It is used to determine whether a particular configuration has been simulated, if it's not simulated than it merges the system and calculates the production costs, ENS and system reliability denoted by LOLP for each configuration.
6. DYNPRO: It is a program to determine the optimum cost schedule by dynamic programming for adding new units to the system over the time period of interest.
7. REPROBAT: It's the last module that summarizes the input data and also the results of the study and the cash flow requirements of the optimum solution [3].

The present paper is focused on Yangon distribution network that its planning procedure has been carried out by the WASP-IV program. Twelve different types of power plant can be chosen in WASP program. The case study has usually done for duration of several years (up to 30 years). As the plants expansion planning starts from year 2016 to 2025, planning period takes 10 years. For the common case data of WASP-IV, the user can specify many periods (maximum number of periods is 5). In this model, it is divided into four periods of a year. Moreover, it can be applied up to five different hydro conditions; i.e. extremely dry year, dry year, normal year, wet year and very wet year, along with the probability of the whole 10 years. The sum of probabilities must be 1. In this model, three probabilities hydro conditions are considered as 0.2 represents to extremely dry year, 0.3 represents to dry year and 0.5 represents to normal year.

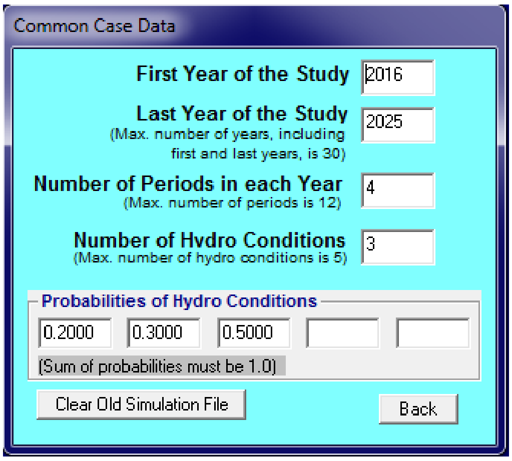

Fig.1 Input Data Assigned for Common Case Data

i. Input Programs of WASP-IV

The input programs of WASP-IV are load system program, fixed system program and variable system program. The required input data are assigned in that programs which are described in the following sections.

A. Load System Program

The LOADSYS program of WASP-IV describes forecast the peak loads, minimum load and energy demand of each period for the system. In this modular program, the required input data are predicted peak load demand for the whole case study years, peak load ratios and coefficients of load duration curves for each period. The input values of predicted peak load demand for that program are as follows:

Table I Predicted Peak Load Demand for 10 years

YEAR	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Peak Load (MW)	1178	1284	1426	1549	1672	1858	2024	2213	2424	2648

B. Fixed System Program

For the Fixed system (FIXSYSY) of WASP-IV program, the required input data for each generating station in the system include: number of identical units, minimum and maximum operating capacities, heat rates associated with these capacities, type of fuel, fuel cost, forced-outage rate, and maintenance requirements. Most of the installed capacity of Yangon relies on thermal plants and rest of necessity supply from national grid which mainly depends on hydro power. Now, almost 600MW of national grid is taken to meet the peak demand. There are nine thermal plants in Yangon. They are Ahlone(AHL), Hlawga(HLA), Tharketa(TKT), Ywarma(GT and NiDo), Toyothai, MyanShwePyi(MSP), E Gat(EGAT), Max power(MAX) and MCP. All of them are combined cycle plants and gas turbines. Table II represents the important parameters of Yangon's existing power plants.

Table II Input Parameters of Existing Government's Power Plants for Fixsys Program

For FIXSYS	AHL	HLA	TKT	YM (GT)	YM (ND)	TTPM	MSP	EGAT	MAX	MCP
No. of Units	1	1	1	2	1	1	13	2	16	26
Min. operating level (MW)	60	60	35	8	13	48	1.72	40	1.34	0.4
Max. generating capacity (MW)	125	125	92.4	15	26.7	108	3.84	100	3.014	0.9
Fuel Type	CC	CC	CC	GT	CC	CC	GT	GT	GT	GT
Heat rate at min. Operating level (kcal/kWh)	2737	2737	3108	3022	3022	1765	1750	2545	1750	1765
Avg. incremental heat rate (kcal/kWh)	2450	2450	2762	2719	2719	1589	1575	2290	1575	1587
Spinning reserve %	20	20	20	20	20	10	10	15	10	10
Forced outage rate %	4	4	4	3	3	4	3	4	3	3
Scheduled maintenance d/yr	45	45	45	30	45	45	30	30	30	30
Maintenance class size (MW)	154.2	154.2	115.6	18.45	33.4	120	4.3	120	3.349	1
Domestic fuel cost	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984
Foreign fuel cost (c/million kcals)	0	0	0	0	0	0	0	0	0	0
Fixed O & M cost ($/kW-mth)	1.25	1.25	1.25	1.25	1.25	1.25	1	1	1	1
Variable O & M cost ($/MWh)	1.3	1.3	1.3	1.3	1.3	1.3	2.5	2.5	2.5	2.5
Heat value of the fuel used (kCal/kg)	12105	12105	12105	12105	12105	12105	12105	12105	12105	12105
Pollutant I emission (SO2)	0	0	0	0.5	0	0	0.5	0.5	0.5	0.5
Pollutant II emission (NOx)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

C. Variable System Program

The Variable System Program defines the type of units that will be used to expand the system. Each particular unit whose type and capacity are defined becomes an expansion candidate plants. As in fixed system, Hydroelectric and projects is also be applied as energy supply from national grid. The data required to define a particular candidate are identical to those used in the Fixed System Program. Table III shows the required data of VARSYS program of WASP-IV. The required data is put into the VARSYS.

Table III Input Parameters of Expansion Power Plants for VARSYS Program

For VARSYS	Project 1	Project 2	Project 3	Project 4	Project 5
Min. operating level in each year (MW)	20	200	120	160	200
Max. generating capacity in each year (MW)	45	450	270	360	450
Fuel Type	GT	CC	CC	CC	CC
Heat rate at min. Operating level (kcal/kWh)	1765	1941	2023	1984	1941
Avg. incremental heat rate (kcal/kWh)	1575	1780	1830	1785	1780
Spinning reserve (%)	10	10	10	10	10
Forced outage rate (%)	3	6	6	6	6
Scheduled maintenance days/ year	30	42	42	42	42

Maintenance class size (MW)	50	500	300	400	500
Domestic fuel cost (c/million kcals)	1984	1984	1984	1984	1984
Foreign fuel cost (c/million kcals)	0	0	0	0	0
Fixed O & M cost ($/kW-month)	1	0.38	0.42	0.38	0.38
Variable O & M cost ($/MWh)	1.25	1.8	2	1.8	1.8
Heat value of the fuel used (kCal/kg)	12105	12105	12105	12105	12105
Pollutant I emission (SO2)	0.5	0	0	0	0
Pollutant II emission (NOx)	0.5	0.5	0.5	0.5	0.5

ii. Results of WASP-IV

Solution obtained by WASP-IV are economic loading data, the total full load generation cost, Capacity range, Committed capacity, operation cost, loss of load probability and energy not served for the planning period.

A. Configuration Generation Program

The main evaluated parameter in CONGEN is the configuration of the system during planning period. According to the records, the peak load of Yangon is 1070 MW in 2014. With the long-term planning, the peak demand at the end of study period is 2647.5MW. Thus, it's about 2.5 times to compare with 1070MW in 2015.According to the CONGEN program results, the expansion power plants are listed in the following which is satisfied the load growth year by year.

2016 Project 1- 2*50 MW of GT,
2018 Project 2- 500 MW of CC,
2020 Project 3- 300 MW of CC,
2022 Project 4- 400 MW of CC, and
2024 Project 5- 500 MW of CC.
Total 400 MW from nation grid (100 MW in 2017, 100 MW in 2019 and 200 MW in 2021).

According to the specified input data, evaluation of CONGEN system provide two data such as total full load unit generation costs (TOTAL FLD) and economic loading order which is defined in ascending order of total full load unit generation costs (ECON. L.O). The resulting economic loading data and the corresponding total full load generation cost for the permitted generation plants are shown in Table IV.

Table IV Economic Loading Data and Total Full Load Generation Cost for the Permitted Generation Plants.

No.	Plant Name by economic loading order	TOTAL FLD	Remark
1	Project 1	34.18	Variable System
2	TOYO THAI	35.24	Fixed System
3	MAX POWER	35.31	Fixed System
4	MYAN SHWE PYI	35.32	Fixed System
5	MCP	35.57	Fixed System
6	Project 2	38.53	Variable System
7	Project 5	38.53	Variable System
8	Project 4	40.30	Variable System
9	Project 3	40.30	Variable System
10	E GAT	49.96	Fixed System
11	AHLONE	52.65	Fixed System
12	HLAWGA	52.65	Fixed System
13	TAKATA	58.71	Fixed System
14	YAMA NEDO	58.18	Fixed System
15	YAMA GT	58.46	Fixed System

B. Merge and Simulation Program

After all input data are specified and CONGEN scheme is selected, the simulation for WASP-IV is carried out. The simulation results are obtained from MERSIM (Module5) output. MERSIM (Merge and Simulate), considers all configurations put forward by CONGEN and uses probabilistic simulation of system operation to calculate the associated production costs ($10^3$$), loss of load probability (%), energy not served (Days/ year), and system reliability for each configuration. During the simulation, the main output parameters of MERSIM for planning periods are obtained as shown in Table.

Table V Main Output Parameters of MERSIM for planning periods

YEAR	COST (10^3\$)	LOLP (%)	ENS (D/YR)
2016	264488	0.1935	0.706
2017	279275	0.3151	1.150
2018	292210	0.5550	2.026
2019	311846	0.8364	3.053
2020	340919	0.2482	0.906
2021	356509	0.2686	0.980
2022	399016	0.1182	0.431
2023	466469	0.6136	2.240
2024	518127	0.2719	0.993
2025	570484	0.6420	2.343

C. Dynamic Programming Optimization

According to the set cost and cost related data, the DYNPRO system simulate and provide the construction cost, salvage, operation cost and energy not serve cost for each year under planning. Based on the mentioned cost, the total cost for each year is calculated. The following table describes the simulation results of DYNPRO system. In this table, the objection function (OBJ. FUN.) is the total cost up to the recent year.

Table VI Simulation Results for DYNPRO System

YEAR	TOTAL	OBJ.FUN.(USD)
2016	320204	320204
2017	507785	827989
2018	378617	1206606
2019	513175	1719780
2020	333331	2053111
2021	383741	2436852
2022	277547	2714399
2023	395887	3110286
2024	320258	3430544
2025	349177	3779721

These values correspond to the cost of new constructed power plants. The next figure describes the objective function during planning period. The cost is linearly increased as the new plant construction. According to the result, the total cost for the new plants will be USD 3779721 thousand for 10 years planning.

3. TRANSMISSION PLANNING:

For 10 years transmission expansion planning, the power flow solution is based on Newton-Raphson method. If both the line flows and bus voltages are acceptable, the planning is carried out for next year. If the line flow is greater than the capacity of the existing line, the new line is added and it is again carried out with new line impedance data. This process is to be repeated until the line flow is less than the capacity of the new added line. After the line flow is inspected, the bus voltage magnitude is also checked. Based two output results i.e., the line flow and bus voltage are inspected, the planning is carried for year by year.

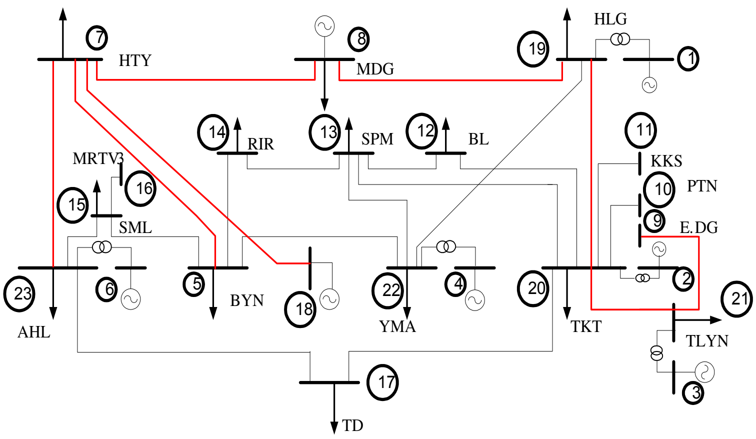

Fig.2 Single Line Diagram of Existing YESC Network

For the transmission expansion planning of Yangon Electricity Supply Corporation (YESC) network, the current transmission system is studied. The existing transmission system is primarily based on 230 kV network. Thus 230 kV network and 66kV are taken as the backbone of transmission system.

In YESC network, there are eight numbers of 230 kV buses and fourteen numbers of 66 kV buses. The remaining bus, i.e. Ywarma is added to YESC network whilst it is 33 kV bus currently since there is generation sources at this bus. There are twenty-three buses and twenty-three transmission lines in present transmission system. The loads are attached at all buses. The single line diagram of present YESC transmission network is shown in Figure 2. This figure is illustrated according data from YESC and Table VII represents the bus numbers and bus name.

Table VII. Name of Bus Number and Name

No	Bus No	Bus Name
1	19	Hlawga (HLG)
2	20	Tharketa (TKT)
3	21	Thanlyin (TLYN)
4	22	Ywarma (YMA)
5	5	Ba YintNaung (BYN)
6	23	Ahlone (AHL)
7	7	HlaingTharYar (HTY)
8	8	Moung Ta Ga (MTG)
9	9	E. Dagon (E.DG)
10	10	Pa Thane Nyunt (PTN)
11	11	KyiteKa San (KKS)
12	12	Bayli (BL)
13	13	Sein Pan Myine (SPM)
14	14	RIR (RIR)
15	15	Sin Ma lik (SML)
16	16	MRTV-3 (MRTV-3)
17	17	Thida (TD)

i. Data Preparation for Transmission Expansion Planning

As the maximum demand and generation growth, the capacity of the lines must also be increased. Presently, the lines with largest capacities of YESC network are 230 kV single circuit line and 230 kV double circuit line. The capacities of these lines are about 193 MW and 387 MW respectively. According to load forecast, the maximum demand of YESC network can be increased about 2.5 times within 10 years planning. Thus capacities of the lines must also be increased. In such condition, the use of higher voltage transmission lines is more preferable due to their larger Load-ability. Thus, for the capacity improvement of existing lines, High Voltage as well as Extra High Voltage transmission lines is considered in this thesis. Table IX illustrates the important parameters of transmission lines s' parameters which are considered in transmission expansion planning.

For transmission expansion planning, the yearly load and generation data for each bus is critical important. The line flow and hence the addition of line can be executed based on these data. Thus yearly maximum demand and generation data for each bus is evaluated and the resulting data are shown in Table X and Table XI respectively.

Table VIII. Existing Line Data Parameters

No	Line (from-to) name	Line no(from-to) number	Size	Length	R	X
1	HLG-TKT	19-20	795	22.3	0.0035	0.0217
2	HLG-YMA	19 - 22	$120mm^2$	14.58	0.0015	0.1055
3	HLG-MDG	19 -8	605	30.8	0.003	0.0224
4	TKT-TLYN	20-21	605	11.8	0.001	0.0058
5	TKT-PTN	20 - 10	397.5	3	0.01795	0.058
6	TKT-KKS	20 - 11	397.5	5.43	0.03249	0.0532
7	TKT-BL	20 - 12	795	0.8	0.0024	0.0125
8	TKT-SPM	20 - 13	795	10.26	0.0271	0.1375
9	TLYN- EDG	21-9	605	8.3	0.00353	0.02928

10	TKT-TD	20-17	795	6.84	0.01791	0.09137
11	YMA-BYN	22 - 5	605	0.25	0.0005	0.0029
12	YMA-HTY	18 -7	605	10.1	0.00207	0.00644
13	YM-SPM	22- 13	397.5	2.18	0.013	0.0346
14	BYN-HTY	5 -7	605	6.8	0.0011	0.0081
15	BYN-RIR	5-14	397.5	3.57	0.0214	0.0568
16	BYN-SML	5-15	605	2.9	0.006	0.0353
17	AHL-HTY	23 - 7	605	22.4	0.0022	0.0163
18	AHL- SML	23-15	605	4.21	0.0064	0.01423
19	TD-AHL	23-17	795	4.04	0.076	0.0168
20	HTY-MDG	7 - 8	605	36.04	0.0035	0.0263
21	BL-SPM	12-13	795	3.35	0.0102	0.0523
22	SPM-RIR	13-14	400mm^2	0.653	0.00199	0.0102
23	SML-MRTV3	15-16	605	1.56	0.0031	0.0182

Table IX. Transmission Line Parameters for Expansion Planning

No	Voltage (kV)	Loadability (MW)	Line Parameters			
			R(ohm/km)	X(ohm/km)	R (pu/km)	X(pu/km)
1	230 kV Single Circuit	193.77	0.102	0.8334	0.0001928	0.001575
2	230 kV Double Circuit	387.54	0.051	0.4167	0.000096	0.000787
3	345 kV Single Circuit	400	0.04	0.325	0.000034	0.000273
4	345 kV Double Circuit	800	0.02	0.1625	0.000017	0.000136
5	500 kV Line	900	0.026	0.2583	0.0000104	0.0001033

Table X. Generation Growth for 10 Years

Year	Generation Growth (MW)									
	Bus1	Bus2	Bus3	Bus4	Bus6	Bus8	Bus18	Bus19	Bus21	Total
2016	180	169	100	126	274	280	200	190	130	1649
2017	180	169	100	126	274	326	200	222	152	1749
2018	180	669	100	126	274	326	200	222	152	2249
2019	180	669	100	126	274	372	200	254	174	2349
2020	180	669	100	126	274	372	500	254	174	2649
2021	180	669	100	126	274	464	500	318	218	2849
2022	580	669	100	126	274	464	500	318	218	3249
2023	580	669	100	126	274	464	500	318	218	3249
2024	580	669	600	126	274	464	500	318	218	3749
2025	580	669	600	126	274	464	500	318	218	3749

Table XI. Load Growth for 10 Years

Year	Load Growth (MW)								
	Bus19	Bus 20	Bus 21	Bus22	Bus 5	Bus 23	Bus 7	Bus 8	Bus 9
2016	148.89	135.36	67.68	20.30	74.45	142.12	128.59	108.29	90.02
2017	162.36	147.60	73.80	22.14	81.18	154.98	140.22	118.08	98.16
2018	180.35	163.95	81.98	24.59	90.17	172.15	155.76	131.16	109.04
2019	195.85	178.05	89.02	26.71	97.93	186.95	169.14	142.44	118.41
2020	211.41	192.20	96.10	28.83	105.71	201.81	182.59	153.76	127.82
2021	234.97	213.61	106.80	32.04	117.49	224.29	202.93	170.89	142.06
2022	255.86	232.60	116.30	34.89	127.93	244.23	220.97	186.08	154.69
2023	279.79	254.36	127.18	38.15	139.90	267.07	241.64	203.49	169.16
2024	306.51	278.64	139.32	41.80	153.25	292.58	264.71	222.91	185.31
2025	334.74	304.31	152.16	45.65	167.37	319.53	289.09	243.45	202.38

Table XI. Continued

Year	Load Growth (MW)							
	Bus 10	Bus 11	Bus 12	Bus 13	Bus 14	Bus 15	Bus 16	Bus 17
2016	31.80	47.37	13.54	37.22	23.69	33.84	30.46	43.99
2017	34.67	51.66	14.76	40.59	25.83	36.90	33.21	47.97
2018	38.52	57.38	16.40	45.09	28.69	40.99	36.89	53.29
2019	41.83	62.32	17.80	48.96	31.16	44.51	40.06	57.86
2020	45.15	67.27	19.22	52.85	33.63	48.05	43.24	62.46
2021	50.18	74.76	21.36	58.74	37.38	53.40	48.06	69.42
2022	54.64	81.41	23.26	63.96	40.70	58.15	52.33	75.59
2023	59.75	89.02	25.44	69.95	44.51	63.59	57.23	82.67
2024	65.46	97.53	27.86	76.63	48.76	69.66	62.69	90.56
2025	71.49	106.51	30.43	83.69	53.25	76.08	68.47	98.90

As mentioned above, 230 kV single circuit and 230 kV double circuit transmission lines are currently employed in YESC network. For utilization of EHV level transmission lines for the future, also 230 kV single circuit and 230 kV double circuit transmission lines will be taken into account in transmission expansion planning.

ii. Simulation Results of Transmission Planning for Future 10 Years

As mentioned in earlier section, there are twenty- three numbers of transmission lines under YESC network. Among these lines, line 20-11, line 20-10 and line 15- 16 are needed to upgrade 66 single (66 s) to 66 double (66 d) line because of its load growth. And then, four new lines are recommended to install as new generation will be constructed and new lines should be considered. The results of line flow and bus voltage are described in Table XII and Table XIII in detail.

In 2020,
1. Line 20 - 11 66 s to 66 d (increasing Load)
2. Line 18 - 5 230 s New Line (increase 300MW Generation at Ywarma)

In 2022,
1. Line 20 - 10 66 s to 66 d (increasing Load)
2. Line 15 - 16 66 s to 66 d (increasing Load)
3. Line 19 - 7 230 d New Line (increase 400MW Generation at Hlawga)

In 2024,
1. Line 20 - 9 230 s New Line (increasing Load)
2. Line 23 – 21 230 d New Line (increase 500MW Generation at Thiliwa)

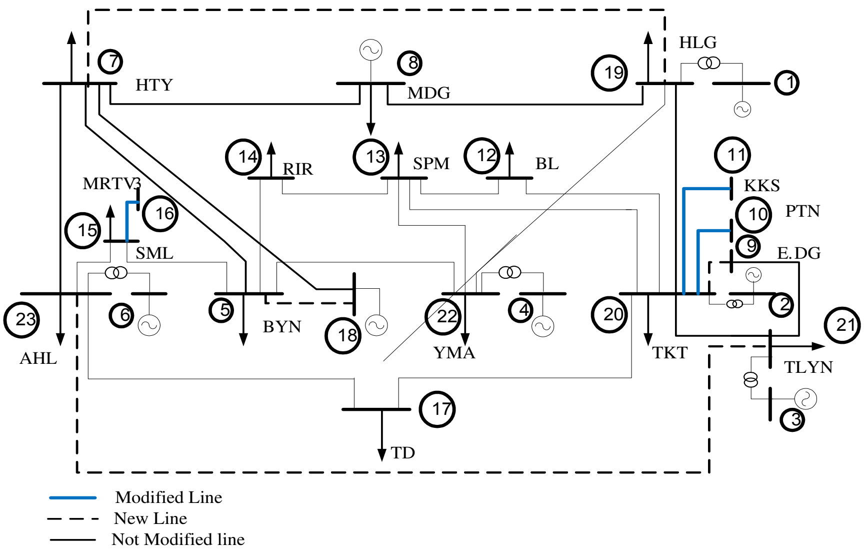

Fig.3 Single Line Diagram of Expanded YESC Network

To evaluate the performance of transmission expansion planning, two parameters are the most important as the bus voltage magnitude and the line flow. Under the acceptable planning, the magnitude of all bus voltages must be within the regulation limits and the power flow on each line must not exceed the capacity of the lines. Thus, the performance evaluation for 10 years planning of YESC network is executed based on these two parameters.

Table XII. Line Flow Results for 10 Years Planning

Year		Power flow (MW)								
		19-20	19-22	19-8	19-7	20-21	20-9	20-10	20-11	20-12
2016	Limit	286.8	51	193.8		193.8		68.6	68.6	82.3
	Flow	118.69	17.58	17.19		0.786		32.10	47.49	18.35
2017	Limit	286.8	51	193.8		193.8		68.6	68.6	82.3
	Flow	123.21	20.91	29.06		16.68		35.04	51.81	21.85
2018	Limit	286.8	51	193.8		193.8		68.6	68.6	82.3
	Flow	71.587	30.06	7.443		10.01		38.96	57.56	47.72
2019	Limit	286.8	51	193.8		193.8		68.6	68.6	82.3
	Flow	39.03	39.56	25.03		18.89		42.35	62.53	68.71
2020	Limit	286.8	51	193.8		193.8		68.6	137	82.3
	Flow	36.02	30.28	26.08		32.75		45.75	67.39	57.75
2021	Limit	286.8	51	193.8		193.8		68.6	137	82.3
	Flow	87.01	22.3	5.648		33.43		50.93	74.91	43.78
2022	Limit	286.8	51	193.8	193.8	193.8		137	137	82.3
	Flow	82.87	8.16	39.37	167.08	55.76		55.07	81.59	33.13
2023	Limit	286.8	51	193.8	387	193.8		137	137	82.3
	Flow	118.83	14.12	21.24	228.11	78.2		60.27	89.23	36.78
2024	Limit	286.8	51	193.8	387	193.8	194	137	137	82.3
	Flow	121.16	12.76	17.38	205.55	73.33	98.67	66.09	97.79	39.17
2025	Limit	286.8	51	193.8	387	193.8	194	137	137	82.3
	Flow	96.11	13.4	9.98	212.52	137.04	101.2	72.24	106.8	49.68

Table XII. Continued

Year		Power Flow (MW)								
		20-13	20-17	21-9	21-23	22-5	22-13	7-5	14-5	15-5
2016	Limit	82.3	165	194		88	68.6	193.8	82.3	111
	Flow	3.51	2.27	98.68		54.07	33.93	57.19	19.02	17.74
2017	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	4.686	5.02	98.52		57.919	35.341	63.97	19.75	20.89
2018	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	16.26	29.22	109.47		79.301	16.87	48.5	9.785	27.78
2019	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	25.63	48.56	118.92		86.33	2.09	47.05	2.28	33.1
2020	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	19.918	46.99	128.43		72.16	17.48	88.86	11.21	56.65
2021	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	12.51	39.31	142.84		38.25	37.67	127.7	24.245	78.493
2022	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	6.77	28.84	155.64		4.27	54.69	72.69	34.35	85.12
2023	Limit	82.3	165	193.8		88	68.6	193.8	82.3	111
	Flow	7.655	32.44	170.33		4.01	58.89	55.02	37.78	94.31
2024	Limit	82.3	165	193.8	387	88	68.6	193.8	82.3	111
	Flow	7.85	21.33	87.26	132.72	6.27	65.41	51.03	42.31	75.17
2025	Limit	82.3	165	194	387	88	68.6	193.8	82.3	111
	Flow	11.83	24.71	101.91	197.85	6.38	64.83	49.92	42.67	71.43

Table XII. Continued

Year		Power Flow (MW)								
		23-7	23-15	23-17	8-7	13-12	13-14	15-16	18-7	18-5
2016	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	
	Flow	33.66	46.87	41.93	76.12	4.79	4.78	30.51	144	
2017	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	
	Flow	42.32	49.58	43.22	97.36	7.07	6.23	33.27	150	
2018	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	
	Flow	49.82	50.53	24.36	110.99	31.23	18.96	36.96	144	
2019	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	
	Flow	59.80	51.97	9.86	139.24	50.76	28.93	40.14	138	
2020	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	387.5

	Flow	57.72	31.60	16.03	132.69	38.43	22.54	43.34	19.51	190.5
2021	Limit	193.8	110	165	193.8	82.3	82.3	55.6	387.5	387.5
	Flow	92.53	23.71	30.63	138.98	22.33	13.34	48.18	29.75	310.25
2022	Limit	193.8	110	165	193.8	82.3	82.3	110	387.5	387.5
	Flow	131.82	26.16	47.28	90.07	9.80	6.68	52.40	23.72	316.28
2023	Limit	193.8	110	165	193.8	82.3	82.3	110	387.5	387.5
	Flow	157.16	27.51	50.92	95.43	11.25	7.13	57.31	21.38	323.63
2024	Limit	193.8	110	165	193.8	82.3	82.3	110	387.5	387.5
	Flow	96.86	58.2	69.98	84.51	11.21	6.96	62.79	21.37	328.63
2025	Limit	193.8	110	165	193.8	82.3	82.3	110	387.5	387.5
	Flow	74.61	74.33	75.08	80.65	19.12	11.13	68.59	21.54	338.46

Table XIII. Bus Voltage Results According to Recommended Planning

Year	Bus Voltage Magnitude (pu)										
	BUS1	BUS2	BUS3	BUS4	BUS5	BUS6	BUS7	BUS8	BUS9	BUS10	BUS11	BUS12
2016	1	0.99	1	0.99	0.987	1	0.99	1	0.98	0.97	0.97	0.98
2017	1	0.98	0.99	0.99	0.985	1	0.99	1	0.98	0.96	0.96	0.98
2018	1	1	1	0.99	0.985	1	0.98	1	0.99	0.98	0.97	0.99
2019	1	1	1	0.98	0.976	0.99	0.98	1	0.99	0.97	0.97	0.99
2020	1	1	1	1	0.996	1	0.99	1	0.98	0.97	0.98	0.99
2021	1	1	1	0.99	0.992	0.99	0.99	1	0.98	0.97	0.98	0.99
2022	1	1	1	1	0.995	0.99	0.99	1	0.98	0.98	0.98	0.99
2023	1	1	1	0.99	0.991	0.98	0.99	1	0.97	0.98	0.98	0.99
2024	1	1	1	0.99	90.99	0.99	0.99	1	0.98	0.98	0.98	0.99
2025	1	1	1	0.99	0.991	0.99	0.99	1	0.98	0.98	0.97	0.99

Table XIII. Continued

Year	Bus Voltage Magnitude (pu)										
	BUS13	BUS14	BUS15	BUS16	BUS17	BUS18	BUS19	BUS20	BUS21	BUS22	BUS23
2016	0.978	0.977	0.982	0.977	0.982	1	0.996	0.988	0.991	0.988	0.99
2017	0.972	0.972	0.979	0.974	0.979	1	0.993	0.978	0.981	0.986	0.988
2018	0.979	0.977	0.978	0.972	0.981	1	0.997	0.998	0.998	0.987	0.988
2019	0.972	0.97	0.967	0.96	0.972	1	0.996	0.998	0.997	0.977	0.978
2020	0.984	0.982	0.981	0.973	0.98	1	0.996	0.998	0.996	0.996	0.988
2021	0.978	0.976	0.972	0.963	0.97	1	0.995	0.997	0.995	0.991	0.978
2022	0.979	0.977	0.972	0.967	1	1	0.997	0.997	0.994	0.995	0.979
2023	0.974	0.972	0.963	0.958	0.961	1	0.999	0.997	0.992	0.99	0.977
2024	0.972	0.97	0.97	0.964	0.969	1	0.999	0.996	0.994	0.99	0.981
2025	0.969	0.967	0.967	0.961	0.966	1	0.999	0.996	0.994	0.989	0.98

4. CONTINGENCY CONDITIONS FOR POWER SYSTEM OF YANGON:

After being implemented the generation and transmission planning of Yangon region for the period of 10 years, the proposed model is checked by n-1 condition. The proposed generation or transmission system may meet unexpected condition that is one of the generation units or transmission lines may be outage from the power system. And hence, it is checked for 2024 during the whole planning period. Removing one the transmission lines from the power system is considered as case I and then removing power from one of the generation units is considered as case II for 2024.

Case I: Removing One of the Transmission Lines

Once Line 23-7 (230 kV single circuit from HlaingTharYar to Ahlone), 96.8 MW flowing power in normal condition is considered as fault condition and remove it from the power system, the result of line flow and bus voltage magnitude are shown in the following figure and table.

Table XIV. Result of Bus Voltage Magnitude

Bus No	Voltage Magnitude	Bus No	Voltage Magnitude	Bus No	Voltage Magnitude
BUS 1	1	BUS 9	0.984	BUS 17	0.967
BUS 2	1	BUS 10	0.978	BUS 18	1
BUS 3	1	BUS 11	0.975	BUS 19	1
BUS 4	0.99	BUS 12	0.989	BUS 20	0.996
BUS 5	0.992	BUS 13	0.972	BUS 21	0.994
BUS 6	0.99	BUS 14	0.977	BUS 22	0.990
BUS 7	0.991	BUS 15	0.969	BUS 23	0.979
BUS 8	1	BUS 16	0.964		

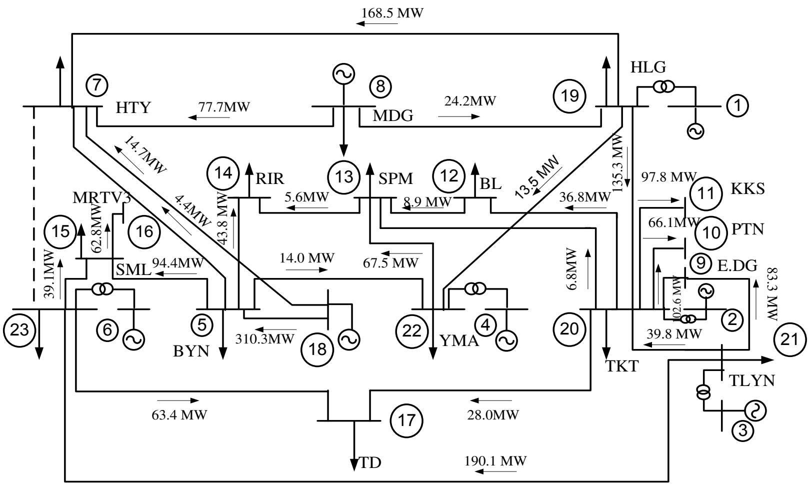

Fig.4 Single Line Diagram of Result of Flowing Line Power

According to the simulation result, both two parameters (Line flow and bus voltage) are under the acceptable and Losses is not much change (7.361 MW).

Case II: Removing Power of Generation Unit

In the outage of transmission line, 96.8 MW of flowing line has been chosen. And then, outage of 100 MW power from the Thilawa power station is considered as contingency condition. The result of line flow and bus voltage is shown in the following figure and table.

Table XV. Result of Bus Voltage Magnitude

Bus No	Voltage Magnitude	Bus No	Voltage Magnitude	Bus No	Voltage Magnitude
BUS 1	1	BUS 9	0.985	BUS 17	0.968
BUS 2	1	BUS 10	0.978	BUS 18	1
BUS 3	1	BUS 11	0.975	BUS 19	0.99
BUS 4	0.99	BUS 12	0.989	BUS 20	0.996
BUS 5	0.992	BUS 13	0.972	BUS 21	0.994
BUS 6	0.99	BUS 14	0.97	BUS 22	0.990
BUS 7	0.989	BUS 15	0.97	BUS 23	0.981
BUS 8	1	BUS 16	0.964		

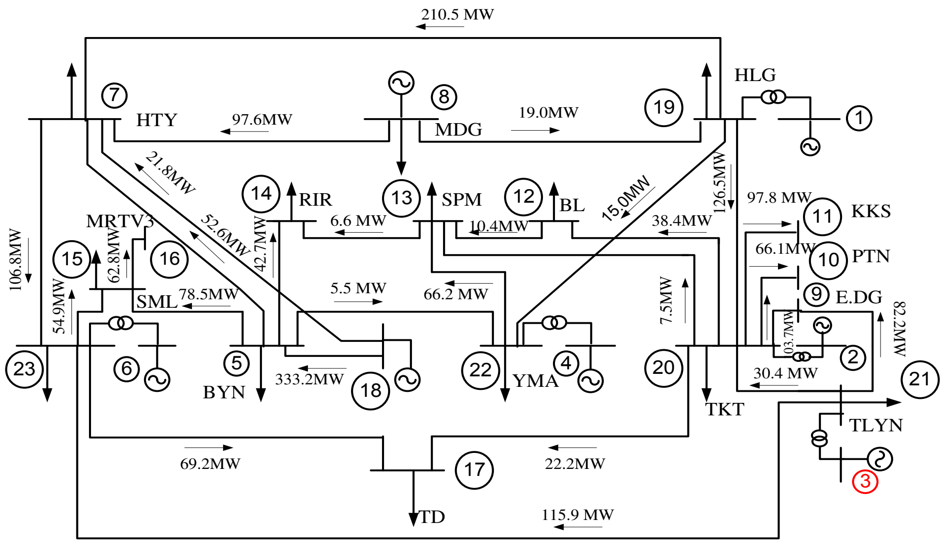

Figure 5 Single Line Diagram of Result of Flowing Line Power

According to the simulation result, both two parameters (Line flow and bus voltage) are under the acceptable and Losses is not much change (7.533 MW).

After being checked the power system using Newton-Raphson load flow solutions which are carried out with Matlab/Simulink software Version 7.10.0 based on n-1 condition at five times, line flows and bus voltages are acceptable with their limit. To be concluded, the proposed power system is said to be reliable.

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5. CONCLUSIONS:

As the generation planning results, the plant capacity of Yangon region are 600MW at Thilawa Project, 500 MW at Tharketa Project, 400MW at Hlawga Project and 300MW at Ywarma Project and 400 MW from national grid. All of the power plants are considered based on natural gas because of social, economical and political constraint of Yangon. Along with load and generation growth, three lines are upgraded the voltage level and four new lines are added after the transmission planning is completed. In order to acquire more reliable power system of Yangon, other contingency plan such as removing one line from the power system and then removing one of generation is considered by using contingency condition. After the simulation, the system remains in stable and consequently, the proposed model, power system planning for Yangon region is firmly assumed as a recommendation for the system. So this research helps to overcome the shortage of electricity in Yangon.

ACKNOWLEDGEMENTS:

The author expresses her deepest gratitude to his Excellency, Minister Dr. Ko Ko Oo, Ministry of Science and Technology and Dr. Wanna Swe, Associate Professor of Electrical Power Engineering Department, Yangon Technological University for continuous encouragement and academic guidance. The author is genuinely grateful to all the teachers, for their kindness, graceful, attitude and permission to do this paper.

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