Generation Expansion Planning Using WASP-IV Program (Case Study: Khuzestan Power Grid in Iran)

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Abstract- **Generating expansion planning is one of the most significant parts in grid expansion planning. The generating expansion planning extends from 10 to 30 years; reliability is one of the most important constraints in power stations. In generating expansion planning, the Loss of Load Probability index is one of the most vigorous indices for reliability system. This paper tends to represent primarily generating expansion evaluation with the help of WASP-IV program for Khuzestan power grid in Iran within a time period of 10 years.**

Keywords: **Generating Expansion Planning, Reliability, Loss of Load Probability, WASP-IV program.**

I. Introduction

Generation expansion planning is one of the most important parts in grid expansion planning. The purpose of Generation expansion planning is to find a combination of power plants to obtain consumers needed load effectively and oppose the minimum cost on system for load supply. To accomplish this goal, some considerations should be taken in to account, such as the type of power plant, its capacity, and its time and location settlement. This type of planning is usually carried out for duration between 10 to 30 years [1]. The barrier that hinders from representing a comprehensive solution for optimization problem is the vast dimensions of the problem caused by a large number of decision-making variables, the existence of constraints, and non linear behavior; however, the proposed methods benefit of simplification for reducing its diminutions [1]. WASP program is one of the most powerful instruments for generation expansion planning. The implied assumption in this program is that the total amount of load and all power plants generation are centralized in one bus. This presupposition has brought the reduction of problem dimensions and makes the problem easy to solve [1]. If the consumers load distribution for intended geographical area or the fuel supply cost is uniform, it will be expected to have the maximum optimization with the help of wasp program. Unfortunately, these assumptions are not always accurate. If modern power plants are located in centers much further away from loads, it will be expected to oppose so much cost to set transmission lines. On the other hand, if these power plants are centralized very closely to load and further from fuel supply, it may lead to enhance fuel cost [1-2]. So generation expansion planning will not obtain optimal response, otherwise, it regards several considerations including load geographical distribution, constraints on fuel supply, electrical power transmission by transmission lines, and other constraints resulted from geographical limitations, land cost and go forth. It also should be noted that covering electrical load changes (both time and place) without having auxiliary storage with high capacity seems to be impossible. In similar vein, having intermittent system with long distance is impossible some load changes occur mildly along 24 hours called middle load produced by average load power plants such as hydro-power plants and gas-power plants (power-plants with constant average generation and low variable cost). Some other loads called peak load characterizes with high change that occurs four hours in day. To cover these loads the above mentioned power plants cannot be applied. Among the abundant proposed and used solutions are spinning reserve, using big system with various horizons (extended in geographical altitude), using diesel generators, small .hydro-power plants, small gas-power plants, steam power plants with high speed in generation level change, pumped-storage power plants, and so on. Among the electrical storage systems we can refer to super conductive storage system, batteries, dense-air storage system, dense-air storage system inherent in pipes, and pumped-storage power plans [3-8]. One of the most prominent constraints in generating expansion planning is validity constraint that is introduced by loss of load probability (LOLP). The present study tends primarily to offer generation expansion evaluation for Khuzestan power grid in Iran within a time period of 10 years (2014-2024) by using WASP-IV program.

II. Mathematical Modeling for Generation Expansion Planning Using WASP-IV

WASP program is used for generation expansion planning, and it utilizes minimum cost method for economical evaluation by means of dynamic program. In this program the objective function pertains to minimizing the sum of maintenance cost, fuel, and outage and … in power plants and constraints are characterized by the balance between generation and load, reliability and so on.

A. Objective Function

Objective function in wasp programming is minimizing of below relation:

$$Objective\ \ function=\sum_{t=1}^{T}\sum_{j}\left(I_{jt}+F_{jt}+M_{jt}+O_{jt}-S_{jt}\right) \qquad (1)$$

In above formulation j, and T represent type of power plants and time period related to case study, and total duration respectively. I_{jt} shows power plant cost of J type for tth period, M_{jt} refers to maintenance cost of power plant type j for tth period, F_{jt} is fuel cost for power plant type j for tth period, O_{jt} outage cost for power plant type j in tth period, and S_{jt} indicates remained capital cost for power plant type j in tth period. WASP program employs ongoing dynamic method to solve expansion problem. In this method the state of the problem in k+1 is determined based on its state in Kth stage in such a manner that the resulting cost of transmission from K stage to k+1 stage and it's to be minimized.

B. Constraints

Several considerations such as hydro power plant effect, thermo-power plant maintenance planning, and constraints for fuel supply in different seasons have been taken in to account in WASP via dividing one year to several equal periods and studying each period individually. In each year (tth period), the critical period $k_{t,p}$ is the period in which the difference between available generating capacity with one load in a period is maximized. If the peak load in critical period is shown with $D_{t,p}$, the following formulation will be the first constraint considered in WASP as follow.

$$(1+a_t)D_{t,p} \le P(k_{t,p}) \le (1+b_t)D_{t,p} \qquad (2)$$

In this equation $P(k_{t,p})$ represents generation ratio in critical period of tth, that shows the minimum storage, and b_t shows the maximum amount of system storage. In WASP, reliability is evaluated by LOLP index that leads to following formulation.

$$LOLP(k_{t,p}) \le C_{t,p} \qquad (3)$$

$$LOLP(k_{t,a}) \approx C_{t,a} \qquad (4)$$

$C_{t,p}$ and $C_{t,a}$ are defined as standard amount or acceptable for this index in tth critical period. In each duration, all the components that may meet problem constraints are determined and then the optimal combination is selected based on minimum cost compared with previous period. The following formulation figures out other constraints in WASP.

$$U_t^0 \le U_{jt} \le U^0 + \Delta V_t \qquad (5)$$

U_t^0 represents the minimum permitted amount of system arrangement in year the tth. ΔV_t is a constraint in this index for critical period of the tth. Suppose k_{jt} represents the number of different stages of generating units in implementation of J program in the tth year. So:

$$K_{jt} = k_{j,t-1} + A_{jt} - R_{jt} + U_{jt} \qquad (6)$$

Where Ajt is vector of generated unit number j that has been developed in t year, Rjt is vector of generated unit number j that has been retired in t year, and Ujt is vector of generated unit number j that has been optimized in t year.

WASP program is characterized with having 12 choices of power plant types. These studies have usually done for duration of several years (up to 30 years). To see the effect of hydro-power plants without constant production that their production is changed seasonally, the studied period, must be less than one year. WASP enables you to divide one year to different unequally periods. In this case, the program attempts to balance load and generating within different periods of time. Considering the total consumption and the way of curve change (LDC curve) different features of power plants including maximum production, production cost, and a combination of new and old power plant are introduced in such a manner that provides not only the balance load and its generation but also the needed cost ratio for setting new power plants, power generation, and maintenance are minimized.

III. Case Study, Khuzestan Power Grid in Iran

The present paper is a survey on Khuzestan power grid in Iran that its planning procedure has been carried out by the WASP-IV program. The input information of WASP-IV planning has been identified in three modules including loadsys, fixsys, and varsys.

1. Loadsys: relates to load data in which peak load during the period and curve points in each period have been considered as input data. Four periods (spring, summer, fall, winter), in each period the inherent points in load duration curve have been brought one by one.

2- Fixsys**:** It identifies information related to existent power plants. The power plants have been classified based on their types, capacity, and number. The maximum types of fuel in WASP are 10 cases. This study considers five types of fuels represented in Table I.

Table I
Fuel Type

Fuel	Name	Short Description	Type
0	NUCL	NUCLEAR	Nuclear
1	HFO	HEAVY FUEL OIL	Mazut Oil
2	GASO	GAS OIL	Diesel
3	1 × mI	NG/HFO	Natural Gas, Mazut
4	2 × mI	NG/GO	Diesel, Natural Gas (Combined)

Most existent huge units in Khuzestan power grid in Iran are characterized as thermal power plants. The most important features of thermal power plants that might be mentioned are forced out put ratio and maintenance program. Moreover, the number of units that should be added or subtracted during this course is also determined. The available number of hydro-power plants has been estimated to 26 divided into two major types including big reservoir and small reservoir. In hydro-power plants properties such as productivity year, settlement capacity (Mw), and storage capacity (Gwh) are identified. Furthermore, the average capacity (Mw) and energy (Gwh) in each period are defined.

3-Varsys**:** This term represents information relevant to candidate power plants. They are categorized based on type and capacity. Four candidate power plants are employed in this study; their features resemble inherent thermal power plants that show in Table II.

Table II
Input Data WASP Relevant to Candidate Power Plants

Power plant type	Small gas (G13S)	Big gas (G13B)	Steam (S325)	Combine cycle (CC40)
Generating power (Mw)	130	130	325	400
Construction time (year)	1	2	5	5
Power plan life (year)	20	15	30	30
Forced outage rated (percent)	9.8	10.2	12.9	13.67
Maintenance time annual average (day)	35	40	56	43
Domestic consumption (percent)	0.8	0.6	6.4	1.6
Efficiency (percent)	25	33.4	38.5	50
Installed cost ($/Kw)	620	1000	1733	1793
Maintenance cost ($/Kw)	19	11	34	12
Fuel cost (c/million kcals)	683	683	569	683
Fuel type	4	4	3	4

Three major modules of WASP are CONGEN, MERSIM, and DYNPRO that under take the task of calculations. To sum, CONGEN refers to the number of acceptable components in each period, MERSIM is used for simulation of generating probability, and DYNPRO is associated with optimizing by using dynamic planning. In DYNPRO the optimization is done according to cost. Table III is showed the optimum solution WASP implementation.

Table III
Optimum Solution of WASP Implementation

OPTIMUM SOLUTION
ANNUAL ADDITIONS: CAPACITY(MW) AND NUMBER OF UNITS OR PROJECTS
FOR DETAILS OF INDIVIDUAL UNITS OR PROJECTS SEE VARIABLE SYSTEM REPORT
SEE ALSO FIXED SYSTEM REPORT FOR OTHER ADDITIONS OR RETIREMENTS

NAME			S325	G13S	CC40	G13B
Size(MW)			325	130	400	130
YEAR	LOLP	CAP				
2014	0.1173	0.				
2015	0.1102	325.	1			
2016	0.1035	130.		1		
2017	0.1014	130.				1
2018	0.1010	0.				
2019	0.0938	800.			2	
2020	0.0912	0				
2021	0.0810	260.		2		
2022	0.0542	0				
2023	0.0091	650.	2			
2024	0.0017	0				
TOTALS		2295.	3	3	2	1

As indicated in Table 3, S325 (steam), G135 (small gas), CC40 (combined cycle), and G13b (big gas) are all candidate power plants. The justified number for power plants S32s, G13P, CC40, and G13B are 3, 3, 2, and 1, respectively.

IV. Conclusion

Generation Expansion planning is a subdivision derived from general problem for power network expansion planning. In this planning, the efficiency or qualification of power plant for Khuzestan power grid in Iran in order to supply consumers load has been studied according to reliability constraint. In the case of power plant being in efficient, the generation expansion planning identifies the appropriate types of power plants, their capacity, and time duration to meet designed Efficiency, along with, the minimum cost for operating new power plants. This study primarily represents an evaluation for generation expansion by means of WASP-IV program in Khuzestan power grid in Iran within a time period of 10 years.

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