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PSO Based Generation Resources Planning Considering Reliability

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Abstract

Reliability is a major factor in power system planning such as generation expansion planning (GEP). GEP is a programming, which denotes place, capacity, time, and technology of new installed generation units. In this paper, generation expansion planning is carried out subject to reliability satisfaction. In the proposed method, the system reliability is incorporated as a constraint in the planning. The planning is formulated as a constrained optimization programming and solved by using particle swarm optimization (PSO) technique.

Keywords: Reliability; particle swarm optimization, generation resources planning, power system planning.

Introduction

Power system expansion is a necessary action to cope with demand increasing in the future[1,2]. Generation expansion planning (GEP) is an important expansion planning in power systems. The main purpose of GEP is to denote the type on new generation units, place of new units and time of installing the new units, in order to minimize the total cost of planning subject to satisfying the constraints and reliable feed of demand over the horizon planning. In this regard, reliability is a inseparable part of generation expansion planning and it should be included in the planning. Many researchers have been carried out to show the effect of reliability in generation expansion planning[3-14]. Demand and electricity price are also very important in deregulated electricity market[15].

Al-Shallan A.M.[14] presents methodologies and techniques that can be adopted and used in the quantitative assessment of power system reliability and its application to cost/benefit evaluation in system generation expansion planning. A practical approach that can be used to estimate reliability worth is focused on the evaluation of the expected energy not served (EENS) to the consumers resulting from power outages and service interruptions. The EENS cost can then be compared with system cost (fixed and variable) in order to arrive at the most appropriate reliability level that can insure both acceptable service quality and reasonable cost. A reliability constrained generation expansion planning (GEP) in the presence of wind farm uncertainty in deregulated electricity market has been presented Hemmati R. et.al.[7]. In this paper, the expected profit of all GENCOs is maximized subject to security and reliability constraints and wind farm uncertainties are also included in the planning. The uncertainty is modeled by probability distribution function and Monte-Carlo simulation is used to deal with such a situation. The proposed GEP is solved by using particle swarm optimization (PSO) method. Moghaddas Tafreshi s. et.al.[11] discusses that one of the main challenges of restructured power systems is to maintain sufficient installed generation capacity to meet system demand in different load points of transmission network both for present and future time. Therefore, paper[11] address a GEP methodology in pool market and in this methodology, the paper aims at ensuring reliable and secure operation of system under different loading conditions. This planning is performed at two levels as master and slave. At master stage, Game Theory is used to assess the contrast of GENCOs and reliability of all load points is optimized. At slave stage, the GENCOs planning is solved by using dynamic programming method. Tafreshi s. et.al.[11] presents a mathematical model based on the stochastic programming for simultaneous generation expansion and retirement planning, where, retirement planning deals with aging phenomena. This paper aims at minimizing the expected total cost consisting of the investment required for commissioning new units, operation and maintenance costs, the retirement salvage cost, and the system risk cost. Energy limitation is modeled by a probabilistic method and Monte Carlo simulation is used to deal with it. Pereira A.J.C. et.al.[16] addresses a new GEP methodology to help GENCOs to invest on new generation units and power plants. This problem performed in deregulated electricity market and therefore the problem is more risky than conventional power systems. The GEP aims at maximizing the expected revenues of each GENCO subject to safe operation of system in the presence of uncertainties related with price, reliability, demand, and costs. Probability distribution function is used to model the uncertainties and genetic algorithms are used to solve the problem.

In this paper a generation expansion planning is presented considering reliability constraint. In the proposed planning, several generation types such as hydro, nuclear, coal, oil, and combustion turbine are included and each generation type contains several units. The proposed planning is managed as a constrained mathematical programming and solved by using PSO. Simulation results demonstrate that the proposed methodology can successfully minimize the total cost of the planning and satisfy the constraint.

Methodology

Mathematical Formulation: From view of mathematical modeling, generation expansion planning is a constrained optimization programming and can be formulated as follows:

$$\text{Min}\left[\sum_{t=1}^{T}\sum_{j=1}^{C}\left(IC_t^j \times XT_t^j + OC_t^j \times XT_t^j\right)\right] \quad (1)$$

Subject to

$$LOLE \le LOLE^{\max} \quad (2)$$

$$XT_t^j \le Max\_XT_t^j \qquad t = 1,2,3,...,T; \quad (3)$$

$$\sum_{j=1}^{C} XT_t^j \le XC_t \qquad t = 1,2,3,...,T; \quad (4)$$

$$RM^{\min} \le RM \le RM^{\max} \quad (5)$$

$$t = 1,2,...,T; \quad (6)$$

$$j = 1,2,...,M; \quad (7)$$

The proposed set of equations provides a constrained optimization programming. In this programming, equation-1 shows the objective function and equation 2 to 7 indicate the constraints. The objective function-1 minimizes the planning cost at all stages. Where, the investment and operation costs are minimized. The first term shows the investment cost (IC) of the installed technology *j* at stage *t* of the horizon planning *T*. The second term shows the operation cost (OC) of the installed technology *j* at stage *t* (XT^j_t) of the horizon planning *T*. The reliability constraint is presented in 2, where, the LOLE index should be smaller than $LOLE^{max}$ at all stages of the horizon planning. Constraint-3 demonstrates that the installed technology *j* at stage *t* should be smaller than a specified value at all stages. Constraint-4 denotes the total installed capacity at stage *t* should be smaller than a specified value at all stages. Constraint-5 shows the reserve margin criteria. Relationship 6 indicates the stages of the horizon planning and constraint-7 shows the number of included technologies in the planning.

Particle swarm optimization: Optimization algorithms have been developed to deal with the mathematical problems based on a new procedure[17,18]. Particle swarm optimization (PSO) is an iterative optimization approach that optimizes the optimization problems based on the computational and iterative procedure. PSO optimizes the optimization problems by using the candidates which are called particles. PSO mainly starts with a population, which is formed as a matrix, and each row of this matrix is called particle. PSO moves the particles toward the best solution in the search space based on the mathematical formulation over the particle's position and velocity. The movement of each particle is mainly influenced by two factors as the best position of current particle (local optimal) and the best solution of all particles (global optimal) which have been found so far. By using these two facts, it is expected to move the population toward the best solutions. PSO can search very large space problem and has been successfully used to solve different optimization problems. In the PSO method, it is not require that the problem be differentiable, while it is required at the classic optimization methods such as quasi-Newton and gradient descent.

Algorithm: The PSO mainly starts with a population and each row of this population is called particle. The particles are the candidate solutions. The particles move toward the best solution around the search-space based on the mathematical formulation. The particles' movements are directed by their own best known position in the search-space as well as the entire swarm's best known position. Then, the improved positions are used to direct the movements of the swarm. The process is iterated until the convergence of algorithm.

Parameter selection: PSO method has several parameters, which should be selected by the designer. The parameter selection has a significant impact on the optimization process and performance. Many studies have tried to find the process of finding PSO parameters in order to yield good performance. The PSO parameters may also be adjusted by using the other optimization methods.

Convergence: This optimization process is iterated until a convergence condition is reached. Common convergence conditions are: satisfying minimum criteria; fixed number of iterations; computation time is reached, manual inspection and so forth.

Biases: The conventional PSO works dimension by dimension and it is very clear that the solution point is easier found when it is placed on an axis of the search space or on a diagonal. Many approaches have been proposed to avoid this bias. For instance, using the non-biased rotated benchmark problems, or modifying the algorithm.

Test System: In order to evaluate the proposed method, a test system is considered and data are provided in table-1[19]. The proposed test system comprises five generation types as hydro, nuclear, coal, oil and combustion turbine and each generation type contains several units. The total capacity before planning is 4100 MW and peak demand is 3550 MW. The load levels over the horizon planning are presented in table-2[19]. Where, three stages are considered for expansion. The other necessary data for planning are provided in table-3[19].

Results and Discussion

The mathematical planning in section 2 is solved by using PSO method and results are depicted in figure-1. In first stage, hydro and nuclear units are installed, in the second stage, coal and oil units are installed and eventually, the combustion units are installed at end stage. The units with high investment cost are installed in initial stage and on the other hand, the units with low investment cost and high operation cost are installed in last stage. This procedure minimizes the total cost of the planning. In addition, the system constraints are satisfied at all stages of the horizon planning.

Table-1
The data for generation units

Unit Type	Number of Units	Capacity (MW)	Fuel Cost ($/kWh)	Operation Cost ($/MW)	FOR
Hydro	4	200	0	235	0.12
Nuclear	2	650	2.41	113.75	0.055
Coal	2	400	4.21	450	0.09
Oil	2	300	11.3	195	0.36
Combustion Turbine	2	50	12.16	235	0.015

Table-2
Forecasted peak demand

Stage	0	1	2	3
Peak Demand (MW)	3550	5500	6800	8200

Table-3
The technical and economical data of generation units

Unit Type	Capacity (MW)	Capital Cost ($/kW)	Fuel cost ($/kWh)	Operation Cost ($/MW)	Life time (year)
Nuclear	650	625.5	2.41	113.75	30
Coal	400	635	4.21	450	25
Oil	300	255.75	11.3	195	25
Combustion Turbine	50	152	12.16	235	5

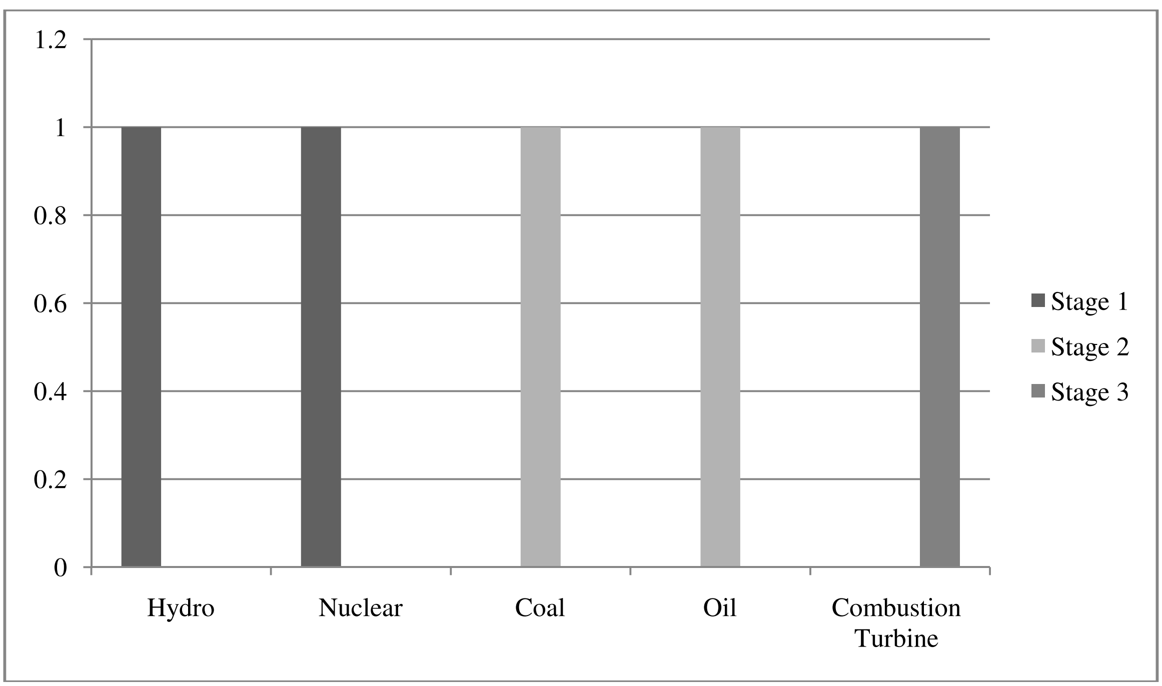

Figure-1
The installed units in each stage

Conclusion

A reliability constrained generation expansion planning was addressed in this paper. Loss of load expectation was assumed as a reliability constraint for the planning. Several generation types such as hydro, nuclear, coal, oil, and combustion turbine were included in the planning. The planning was formulated as a constrained optimization programming and solved by using PSO method. The effectiveness and viability of the planning was assessed based on the simulation results.

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