Experimental Study on Single Area Unit Commitment Problem using hybrid optimization

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ABSTRACT

This paper addresses the Unit Commitment (UC) problem, which is a well-known combinatorial optimization problem arising in operation planning of power systems. In the UC problem, the mathematical formulation of Unit Commitment Problem has been developed. The algorithm for Unit commitment problem has been developed using Dynamic Programming Approach and Quadratic Programming based Particle Swarm Optimization (QP-PSO) Approach. The outcome of QP-PSO algorithm is an appreciable outcome of the work. The results of various IEEE Bus systems have been shown. Also, the performance of proposed algorithm is compared with Heuristic PSO Algorithm, Dynamic programming Algorithm and Genetic Algorithm.

Keywords: unit commitment, scheduling, generation, genetic algorithm, quadratic programming.

I. INTRODUCTION

Electrical power plays a pivotal role in the modern world to satisfy various needs. It is therefore very important that the electrical power generated is transmitted and distributed efficiently in order to satisfy the power requirement. The Economic Load Dispatch (ELD) problem is the most significant problem of optimization in forecasting the generation amongst thermal generating units in power system. The ELD problem is to plan the output power for each devoted generating unit such that the cost of operation is minimized along with matching power operating limits, load demand and fulfilling diverse system limitations. The ELD problem is a significant problem in the operation of thermal/hydro generating station. It is considered an optimization problem, and is defined for minimized total generation cost, subject to various non-linear and linear constraints, in order to meet the power demand.

The ELD problem is classified in two different ways, as convex ELD problem and non-convex ELD problem. The convex ELD problem is modeled by considering the objective function as minimizing the generator cost functions considering linear limitations/constraints. In the nonconvex ELD problem the non-linear limitations/constraints are considered beside linear limitations while reducing cost function. The linear constraints, that is the generation capacity and power balance leads the ELD problem as approximate, simplified problem and the characteristics curve is assumed to be piecewise linear. A more precise and accurate problem is modeled by having the non-linear constraints such as prohibited operating zones, valve point effects and ramp rate limits. The problem of ELD is usually multimodal, discontinuous and highly nonlinear.

Although the cost curve of thermal generating units are generally modeled as a smooth curve, the inputoutput characteristics are nonlinear by nature because of valve-point loading effects, Prohibited Operating Zones (POZ), ramp rate limits and so on. Large steam turbine generators normally have multiple valves in steam turbines. These valves are opened and closed to keep the real power balance. However, this effect produces the ripples in the cost function. This effect is known as valve-point loading effect. Ignoring of valve-point effects leads to inaccurate generation dispatch. Besides this, the generating units may have definite range where operation is abandoned due to the physical limitations of mechanical components. Such restricted regions of loading arecommonly known as POZ.

When a generating unit has POZ, its operating region breaks into remote sub-regions, thus forming a non-convex decision space. Furthermore, the operating range for online units is restricted by their ramp rate limits. To keep thermal changes in the turbine inside safe limits and to avoid shortening of life, the rate of increase or decrease of power output of generating units is limited within a range. Such ramp rate constraint makes the conventional ED problem as a Dynamic Economic Dispatch (DED) problem. The presence of these nonlinearities in practical generator operation makes solving the ED problem more challenging.

II. PROBLEM FORMULATION

Single Area Unit Commitment Problem

The main objective of unit commitment is to find the optimal schedule for operating the available generating units in order to minimize the total operating cost of the power generation. Total operating cost of power generation includes fuel cost, start up and shut down costs. The fuel costs are calculated using the data of unit heat rate & fuel price information which is normally a quadratic equation of power output of each generator at each hour determined by Economic Dispatch(ED).

$$F_c(P_i) = a_i + b_i P_i + c_i P_i^2$$

where, a_i, b_i, c_i are the cost coefficients.

The total fuel cost over the given time period „T"is

$$TFC = \sum_{t-1}^{T} \sum_{i=1}^{N} F_c P_i * X_i(t)$$

where, X_i (t) is the position or status of i^{th} unit at t^{th} hour.

Start up cost is that cost which occurs while bringing the thermal generating unit online. It is expressed in terms of the time (in hours) for which the units have been shut down. On the other hand, shut down cost is a fixed amount for each unit which is shut down. A start up cost can be expressed as :

$$SUC_i = \begin{cases} HSC_i, if MDT_i \le DT_i < MDT_i + CSH_i \\ CSC_i, if DT_i > MDT_i + CSH_i \end{cases}$$

where,

DT_i- shut down time,

MDT_i- Minimum down time,

HSC_i- Hot start up cost,

CSC_i- Cold start up cost,

CSH_i- Cold start hour of i^{th} unit.

Algorithm of Proposed Hybrid Particle Swarm Optimization :

The Proposed Algorithm consists of Hybrid combination of Quadratic Programming and Particle Swarm optimization (QP-PSO). The procedure of the proposed hybrid algorithm is as follows:

Step-1: Initialize the Generating Units parameters i.e. Pmin, Pmax, MDT, MUT, a, b,c, SUC, SUH, Tcold, Init State, NG,T, Pload etc.

Step-2: Initialize the PSO parameters i.e**.** NP, ITERmax, Zmax, Zmin etc.

Step-3: Initialize the swarm. and sort Pmax in decending order w.r.t. time.

Step-4: Satisfy the load demand constraints and Reserve constraints using the equation () and () respectively. The Pseudo Code for constraints is mentioned below.

Step-5: Satisfy Minimum Up Time and Down Time constraints using the equation () and () respectively.

Step-6: Again Check the load demand constraints and Reserve constraints for updated population using the equation () and () respectively.

Step-7. Solve the Economic load Dispatch Problem without considering valve-point effects incorporating wind power using Quadratic Programming.

Step-8: Update the Swarm Position and Velocity using equation () and () respectively.

Step-9: Calculate the updated constraints using ( ) and randomly generate initial population around the solution obtained from **Quadratic Programming** for PSO.

Step-10. Again Solve the Economic Load Dispatch problem with valve-point effects and calculate Gfitness using Particle Swarm optimization. The Pseudo code for updating the status of swarm is mentioned below.

Step-12: Display the final status of the Generating units and Minimum Cost.

Step-13: Save the final results.

III. RESULTS AND DISCUSSIONS

Modern Soft Computing Technique: QP-PSO Algorithm

The Hybrid QP-PSO algorithm has been developed as Modern optimization algorithm to solve the Single Area Unit Commitment problem. The corresponding results of above mentioned IEEE Bus systems using Hybrid QP-PSO algorithm are shown below:

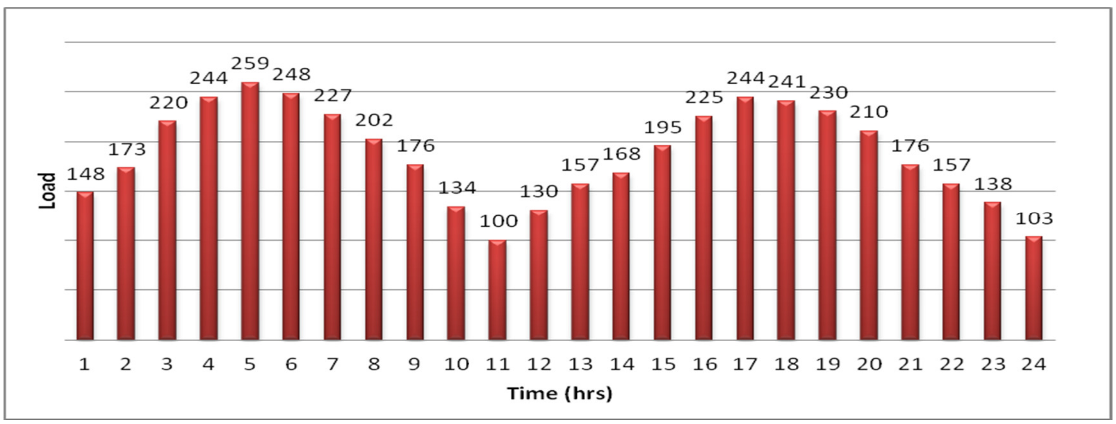

Fig. 1: Load Demand pattern for 24-hours for 14-Bus System

Table 1: Results for 14-Bus System Using QP-PSO

Time	1	2	3	4	5	6	7	8	9	10	11	12
G1	148	173	220	144	159	148	227	202	176	134	100	130
G2	0	0	0	0	0	0	0	0	0	0	0	0
G3	0	0	0	100	100	100	0	0	0	0	0	0
G4	0	0	0	0	0	0	0	0	0	0	0	0
G5	0	0	0	0	0	0	0	0	0	0	0	0
Time	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
G1	157	168	195	225	234	121	220	210	176	157	0	0
G2	0	0	0	0	0	0	0	0	0	0	38	103
G3	0	0	0	0	0	0	0	0	0	0	100	0
G4	0	0	0	0	0	120	10	0	0	0	0	0
G5	0	0	0	0	10	0	0	0	0	0	0	0
TOTAL COST=12886												

Table 2: Results of 30-Bus System Using QP-PSO

Time (hrs)	1	2	3	4	5	6	7	8	9	10	11	12
G1	166	116	149	200	200	142	166	133	112	81	147	160
G2	0	80	80	37	38	80	0	0	80	80	0	0
G3	0	0	0	0	15	50	50	50	0	0	0	0
G4	0	0	0	0	0	0	0	0	0	0	0	0
G5	0	0	0	30	30	0	30	30	0	0	0	0
G6	0	0	0	0	0	0	0	0	0	0	0	0
Time (hrs)	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
G1	170	105	128	152	166	161	156	145	124	102	161	131
G2	0	80	80	80	80	80	80	80	80	80	0	0
G3	0	0	0	0	0	0	0	0	0	0	0	0
G4	0	0	0	0	0	0	0	0	0	0	0	0
G5	0	0	0	0	0	0	0	0	0	0	0	0
G6	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL COST=13733												

Table 3: Compared Results

Optimization Algorithm	No. of Generating Units	Total Operating Cost
Heuristic PSO Algorithm	10	557183
Shuffled Frog Leaping Algorithm	10	564769
Dynamic Programming Algorithm	10	**553837**
Hybrid QP-PSO Algorithm [Proposed Algorithm]	10	**566960**

CONCLUSIONS

In this work, the formulation and implementation of solutions methods to obtain the optimum solution of Single Area unit Commitment Problem using Dynamic Programming Approach and Hybrid QP-PSO algorithm is carried out. The following important points have been observed throughout the work:

1. Particle Swarm optimization algorithm can be used to solve many of the same kinds of problems as Genetic Algorithms.
2. Particle Swarm system has memory which the Dynamic Programming algorithm and Lagrangian Relaxation Algorithm does not have.
3. In particle Swarm optimization, individual that fly past optima are tugged to return toward them, knowledge of good solutions is retained by all particles.
4. Particle Swarm Optimization has also been demonstrated to perform well on Heuristics PSO algorithm test functions and it appears to be a promising approach for robot task learning.

The effectiveness of the developed algorithm is tested for IEEE-14 Bus System, IEEE-30 System, IEEE-56 Bus System and IEEE Bus system consisting of 10 Generating Units. The results obtained by QP-PSO algorithm is also compared with Dynamic Programming algorithm, Heuristics PSO algorithm and Shuffled Frog Leaping Algorithm. It is found that QP-PSO is giving better results as compared to Heuristics PSO algorithm. Operating Cost using Dynamic Programming algorithm is better than Classical PSO algorithm.

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