SHORT TERM HYDROTHERMAL SCHEDULING IN POWER SYSTEM USING IMPROVED PARTICLE SWARM OPTIMIZATION

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ABSTRACT
The problem of determining the optimal hourly generation in hydrothermal power plants and total thermal generation is studied. A multi reservoir cascaded hydro-electric system with a non-linear relationship between water discharge rate, net head and power generation is considered. PSO technique has been motivated by the behavior of the organisms such as fish schooling and bird flocking. The individual particles are drawn stochastically towards the position of their own previous best performances and the best previous performances of the neighbors. The improved PSO technique is applied in this problem and the results are obtained. The simulation results reveal that the features of are easy to implement, with an acceptable execution time for scheduling the hydrothermal system can be active.

KEYWORDS— Particle Swarm Optimization, Hydro Thermal Scheduling, Economic Operation, Problem Formulation, Objective Function.

INTRODUCTION
Economic operation and control of interconnected power systems involves the solution of difficult optimization problems that require good computational algorithm. Evolution is an optimization proves that can be simulated on a computer and for good engineering purpose.

The objective of hydrothermal scheduling is to optimize thermal generation thereby reducing the total fuel cost. The computation time of the hydro sub problem forms the main constraint, where the earlier water flow affects the discharge capability, the varying system load demand, the cascade nature of the hydraulic network and the loading limits. In this work particle swarm optimization is applied to the hydrothermal scheduling. Improved PSO is more efficient in terms of number of functional evaluations and therefore computation time.

The hydro scheduling problem is solved in two stages. This paper presents a method to determine the hourly schedule using Improved PSO technique. The Improved PSO has attractive futures such as its simplicity of the algorithm, the ability to handle all sorts of functional representations of problems, its robustness etc. The earlier methods are limited for particular program domain and those are not so robust.

The systematic co-ordination of the operation of a system of hydrothermal generation plants are usually more complex than the scheduling of an all thermal generation system. The co-ordination of the operation of the hydroelectric plants involves the scheduling of water releases. The long range hydro scheduling involves the long range forecasting of water availability and the scheduling of reservoir water releases for an interval of one week to one year.

The short range hydro scheduling involves the hour by hour scheduling of all generation on a system to achieve minimum production cost for the given time period. Short range scheduling is considered in this work. In such a scheduling problem, the load, the hydraulic inflows and unit availability are assumed to be known. A set of starting condition such as reservoir levels are given and the optimal hourly schedule that minimizes the desired objective while meeting the constraints is sought.

Hydraulic and thermal constraints may include generation, load power balance, operating capacity limits of the hydro and thermal units, water discharge rate, upper and lower bounds on reservoir volumes, water spillage, and hydraulic continuity restrictions. The optimal scheduling of hydrothermal plant is basically a non-linear programming problem involving objective function and a mixture of linear and nonlinear constraints.

IMPROVED PARTICLE SWARM OPTIMIZATION
A particle swarm optimization (PSO) based on the analogy of swarm of bird and school of fish. The PSO mimics the behavior of individuals in a swarm to maximize the survival of the species. In PSO, each individual makes his decision using his own experience together with other individual’s experiences. The algorithm, which is based on a metaphor of social interaction, searches a space by adjusting the trajectories of moving points in a multidimensional space. The individual particles are drawn stochastically toward the position of present velocity of each individual, their own previous best performance, and the best previous performance of their neighbors. The main advantages of the PSO algorithm are summarized as: simple concept, easy implementation, robustness to control parameters, and computational efficiency when compared with mathematical algorithm and other heuristic optimization techniques.

LITERATURE SURVEY
The problem is solved by using some conventional methods like Gradient Search [1]. In conventional methods simplifying assumptions are made to make the solution tractable. This is impractical. So, non-conventional methods are adopted for solving this non-linear problem. Methods like Genetic Algorithm [2,3,4], evolutionary programming [5, 6, 7] simulated annealing [8], neural network based techniques [9] are implemented. Simulated annealing requires more computational time and the tuning of its parameters is not an easy task. Most of the GA parameters are set after considerable experimentation, and it is the lack solid theoretical basis for their setting which is one of the main drawbacks of the GA methods. Theoretical research is continuing on the appropriate choice of GA parameters. Also the encoding and decoding schemes demand a higher computational time and computer memory. Among the existing methods EP seems to have given the best result. But the computational time is not negligible. To overcome these problems a novel approach of scheduling the hydro thermal generation using swarm optimization

algorithm is proposed [10, 11, and 12]. In this method the number of parameters to be tuned is less compared with other non-conventional method. PSO does not have genetic operators like crossover and mutation. Objective function is directly used as fitness function to guide the search in PSO, making it easy to handle non-linear and non-differentiable optimization problem. The complexity analysis of problem-dimension using PSO has been reported for three well known benchmark functions, DE Jong, Rosenbrock and Restringing in [13]. Hybrid differential Evolution [14] approach is a simple population based stochastic function method and has been extended from the original algorithm of differential evolution [15]. An evolutionary hybrid differential evolution for mixed-integer optimization problem which combines a local heuristic (acceleration) and a widespread heuristic (migration) to promote the search for a global optimum was proposed [16]. The application of a robust searching hybrid differential evolution method for optimal reactive power planning in large scale distribution system was presented[17]. A modified differential evolution(MDE) algorithm, for solving short term hydrothermal scheduling problem is presented [18]. This evolutionary computation algorithm has application not only in the area of power system but also in the area such as crypt analyzing block ciphers [19]. An efficient and reliable PSO based algorithm to solve combine economic-emission scheduling of hydrothermal power system with cascaded reservoir. PSO technique has been applied to solve hydrothermal scheduling by Mandal et al [20]. The conventional or classical optimization methods suffers from dimensionality difficulty, large memory requirement, large computation time, inability to handle non-linear plus non separable objective function, constrains and unable to handle global optimum etc. Beside this method during recent past, optimal hydrothermal scheduling problem have been solved by meta-heuristic approaches such as genetic algorithm and particles swarm optimization. Several PSO versions have been reported the recent past to enhance the computational of the PSO. The constrained factor approach was suggested in the velocity updating equations to assure convergence of PSO [21, 22].

To vary the cognitive and social behaviour of the swarm by dynamic control of acceleration coefficients within maximum and minimum bounds [23]. Conventional methods have failed to solve such problems as they are sensitive to initial estimates and converge into local optimal solution and computational complexity. Modern heuristic optimization techniques proposed by researchers based on operational research and artificial intelligence concepts, such as evolutionary programming, particle swarm optimization provide the better solution [24]. PSO is one of the modern heuristic algorithms developed by Kennedy and Eberhart. It has been developed through simulation of simplified social models. Compared to other evolutionary methods, the advantages of PSO are ease of implementation and only few parameters to adjust [25].

Similar to other evolutionary algorithms, PSO must also have a fitness function that takes agents position and assigns to it as a fitness value. For consistency, the fitness function is the same as for other evolutionary algorithms. The position with minimum fitness value in the entire run is called the global best. Each agent also keeps track of its minimum fitness value, called its local best. Each agent is initialized with a random position and random velocity. The velocity of the agent each of dimensions is accelerated toward the global best and its own personal best. In this article, PSO is used as the base level search method. Compared to other stochastic search methods, PSO has fast converging characteristics [26].

Conventional methods have failed to solve such problems as they are sensitive to initial estimates and converge into local optimal solution and computational complexity. Heuristic optimization techniques based on swarm optimization provide the better solution. PSO has gain popularity the best suitable solution algorithm for such problems. [27].

**SWARMS AND PARTICLE**

The particle swarm optimization concept and paradigm presented in this paper seem to adhere to following five principles.

i. Proximity principle: The population should be able to carry out simple space and time computations.
ii. Quality principle: The population should be able to respond to quality factors in the environment.
iii. Diverse principle: The population should not commit its activities along excessively narrow channels.
iv. Principle of stability: The population should not change its mode worth the computational price.

v. Stability principle: Particle should not commit its activity in extensively narrow channels.

Basic to the paradigm are n dimensional space calculations carried out over a series of time steps. The population is responding to the quality factors $P_{best}$ and $g_{best}$ ensure a diversity of response. The population changes its state only when $g_{best}$ changes, this adhering to the principle of stability. The population is adaptive because it does change when $g_{best}$ changes. The term particle was selected as a compromise while it could be argued that the population members are mass less and volume less and thus could be called points, it is felt that velocities and accelerations are more appropriate applied to particle, even if each is defined to have arbitrarily small mass and volume.

The hydraulic system network shown in figure

![Fig (1): Hydrothermal system with hydraulically coupled hydraulically coupled hydroelectric plants.](image)

**HYDROTHERMAL SCHEDULING PROBLEM**

**Problem Definition**

The section defines the objective function and constraints of hydrothermal scheduling problem. This problem is to find the optimal scheduling of hydro units, which minimizes the total cost while satisfying the constraints. The hydrothermal co-
ordination problems make a number of simplifying assumptions in order to make the optimization problem more tractable. The following assumptions are made here (i) The cost function of the generator can be represented by scheduling is done on an hourly basis (ii) Spillage of reservoir at time taken as zero.

**Problem Formulation**

The objective function is to minimize the operating cost of the plant. The composite fuel cost function is given as,

\[ F = \Sigma (a + (b * P_i(t)) + (c * P_i(t)^2)) \]  

Where a, b, c are co-efficient in cost equations of thermal plant

Objective function is

\[ \text{Min}F = \Sigma (a + (b * P_i(t)) + (c * P_i(t)^2)) \]  

Subject to a number of power system network equality and inequality constraints. These constraints are given below. System Active Power Balances

\[ \Sigma P_i(i,t) = \Sigma P_d(t) + P_l(t) \]  

where

- \( P_i \): System spinning reserve, MW
- \( P_h \): Generation of \( i \)th hydro unit at time \( t \), MW
- \( P_d(t) \): Power demand at time \( t \), MW
- \( P_l(t) \): Total transmission losses

Thermal Plant Generation Limits

\[ P_i(i)_{\text{min}} \leq P_i(i) \leq P_i(i)_{\text{max}} \]  

Hydro Plant Generation Limits

\[ P_h(i)_{\text{min}} \leq P_h(i) \leq P_h(i)_{\text{max}} \]  

Hydraulic Network Constraints

These constraints include Physical limitations on reservoir storage volumes and discharge rates.

\[ V_h(i,t)_{\text{min}} \leq V_h(i,t) \leq V_h(i,t)_{\text{max}} \]  

where

- \( V_h(i,t) \): Storage volume of \( i \)th reservoir at time \( t \)

\[ Q_h(i,t)_{\text{min}} \leq Q_h(i,t) \leq Q_h(i,t)_{\text{max}} \]  

Where

- \( Q_h(i,t) \): Water discharge rate of \( i \)th reservoir at time \( t \)

The desired volume of water to be discharged by each reservoir over the scheduling period.

**Table 1. Reservoir storage capacity limits, discharge limits, generation limits, and reservoir end conditions (10⁴, m³)**

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>( V_{\text{min}} )</th>
<th>( V_{\text{max}} )</th>
<th>( V_{\text{ini}} )</th>
<th>( V_{\text{end}} )</th>
<th>( Q_{\text{min}} )</th>
<th>( Q_{\text{max}} )</th>
<th>( P_{h,\text{min}} )</th>
<th>( P_{h,\text{max}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6000</td>
<td>18000</td>
<td>6000</td>
<td>16000</td>
<td>0</td>
<td>2000</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>6000</td>
<td>18000</td>
<td>18000</td>
<td>8000</td>
<td>0</td>
<td>2000</td>
<td>0</td>
<td>200</td>
</tr>
</tbody>
</table>

**Table 2. Data for hydro generation co-efficient**

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>( C )</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>260</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>260</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 3. Data for Reservoir inflow rates (acre-ft/h)**

<table>
<thead>
<tr>
<th>Hour</th>
<th>Reservoir 1</th>
<th>Reservoir 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10000</td>
<td>18000</td>
</tr>
<tr>
<td>2</td>
<td>6000</td>
<td>17000</td>
</tr>
<tr>
<td>3</td>
<td>10000</td>
<td>8000</td>
</tr>
<tr>
<td>4</td>
<td>14000</td>
<td>8000</td>
</tr>
<tr>
<td>5</td>
<td>18000</td>
<td>8000</td>
</tr>
<tr>
<td>6</td>
<td>16000</td>
<td>8000</td>
</tr>
</tbody>
</table>

**Table 4. Data for composite thermal plant**

<table>
<thead>
<tr>
<th>( a ) ($/MW²)</th>
<th>( b ) ($/MW)</th>
<th>( c ) ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00033803</td>
<td>1.9606</td>
<td>334.07</td>
</tr>
</tbody>
</table>

**Table 5. Load demand in 6 hours**

<table>
<thead>
<tr>
<th>Load Demand (MW)</th>
<th>Hour</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>700</td>
</tr>
</tbody>
</table>

\[ V_h(i,t) = 0 = V_h(i)_{\text{begin}} \]  

\[ V_h(i,t) = T = V_h(i)_{\text{end}} \]  

The continuity equation for the hydro reservoir network,

\[ V_h(i,t) = V_h(i,t-1) + I_h(i,t) - Q_h(i,t) - S_h(i,t) + \Sigma (Q_h(m,t-\tau(i,m)) + Q_h(m,t-\tau(i,m))) \]  

Where

- \( I_h(i,t) \): Inflow rate of \( i \)th reservoir at time \( t \)
In this work short term hydrothermal scheduling is carried out using conventional lambda iteration method and improved PSO technique. The test system comprises of two hydro and five thermal units. The scheduling of the thermal and hydro units for six hours is evaluated and the costs are determined. From the results the time consumed by improved PSO techniques is less (19.5 seconds) compared to conventional method (268 seconds) and the cost of generation also less in improved PSO technique.

**CONCLUSION**

In this paper short term hydrothermal scheduling is achieved by using improved PSO technique. The validity of the method is demonstrated with the help of a sample system and the results are compared with the conventional method results. The results reveal that improved PSO technique is better in terms of feasibility and the computation time is less. Thus the improved PSO technique is easy to implement and it can be extend to a system which has got large no of units.

**REFERENCES**


