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Generation cost optimisation of hydrothermal system using arithmetic optimisation algorithm considering transmission loss and valve point loading effect

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ABSTRACT

Hydrothermal scheduling is a crucial issue in the field of power system economics. The goal of short-term hydrothermal scheduling is to reduce the total cost of generation by optimising the hourly output of power generation for specific time intervals. This paper presents a new population-based approach called the arithmetic optimisation algorithm for solving the short-term hydrothermal scheduling problem. To verify the performance of the arithmetic optimisation approach, six different test systems with different cost functions were investigated. It has been observed that the proposed AOA reduced the generation cost by 3.41%. Furthermore, upon considering non-linearity in the fitness function by involving the valve-point effect, AOA diminished the generation cost by 8.54%. An appreciable 25.08% reduction in the algorithm execution time was also observed when the proposed AOA was used as the optimisation tool. Numerical results and non-parametric statistical analysis claim the superiority of the proposed approach.

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KEYWORDS
Arithmetic optimisation algorithm; statistical analysis; valve point loading effect; transmission loss; scheduling

Nomenclature

P_{Ti}	Output of thermal power generation in MW
N_s	Total number of thermal unit.
a_{si}, b_{si}, c_{si}, d_{si}, e_{si}	Fuel cost coefficient of i^{th} thermal plant
P_{Ti}^{min}, P_{Ti}^{max}	Minimum and maximum power generation limit of i^{th} thermal unit.
M	No of sub-interval
a_{0hj}, a_{1hj}, a_{hj}	Water discharge coefficients of hydro plant j
N_h	Total number of hydro unit.
P_{hj}	Output of hydro power generation in MW
M_Iter	Maximum number of iteration
α	sensitive parameter
P_{hj}^{min}, P_{hj}^{max}	Minimum and maximum power generation limit of j^{th} hydro unit.
P_{Lm}	Total transmission loss at time interval m.
W_{hj}	Volume of water available for generation by hydro unit j during the scheduling period.
B_{lr}	B-matrix coefficients for transmission power loss
D_{hj}	Discharge of j^{th} hydro unit at time interval of m (m^3).
t_m	Duration of sub-interval
P_{Dm}	Total demand at time interval m
C_Iter	Number of current iteration
Min, Max	minimum and maximum values of the accelerated function

1. Introduction

1.1. Motivation and incitement

In the field of power systems, the hydrothermal scheduling (HTS) problem is a significant issue. The problem involves a nonlinear objective function as well as a number of constants. As a result of these restrictions, traditional optimisation techniques are impossible to solve. Because they are not constrained by the complexity of system models, soft computing approaches have captured the attention of researchers and have been used to solve issues with power system optimisation. The utilisation of approaches like genetic algorithms (GA), particle swarm optimisation (PSO) and differential evolution (DE) for tackling HTS problems like the minimisation of generation costs is due to their impressive outcomes on a variety of benchmark functions. Nevertheless, GA, PSO and DE have their own lists of disadvantages too. Arithmetic optimisation algorithm (AOA) is a recently developed optimisation technique that has several advantages, like it requires minimum number of pivotal equations, a minimum number of tuning parameter and random numbers, and it is also capable of handling large dimensions problems in a shorter amount of computational time. All these advantages of AOA algorithm motivated the researcher to apply this algorithm towards the solution of the HTS problem.

1.2. Literature review

Thermal and hydroelectric power plants are the fundamental components of an electrical power system, which uses transmission lines to connect them in order to send electricity to loads like industrial areas, factories, etc. Thermal power stations use fossil fuels like gas, coal and oil for electrical generation, which are very expensive and will run out soon. In contrast, using water from natural rivers and discharging it through hydro turbines is thought to have negligible generation costs. Hydropower plants also have an edge over thermal plants when comparing the

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Application of henry gas solubility optimization algorithm for short-term hydrothermal scheduling considering variable water transportation delay and penstock head loss

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ARTICLE INFO

Keywords:
Water transportation delay
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ABSTRACT

This paper deals with the solution of short-term hydrothermal scheduling considering some practical scenario of hydro system like variable water time delay and penstock head loss along with other constraints related to hydro and thermal plant. The problem has been solved using Henry gas solubility optimization algorithm. This algorithm is basically works based on the principle of Henry's law. A test system consists of seven hydro units and eight thermal units have been adopted for study purpose. This test system is mainly inspired from Damodar valley corporation, India. The problem has been solved in MATLAB platform. The simulation results have been compared with symbiotic organism search algorithm, ion motion optimization algorithm, crow search algorithm and sine cosine algorithm. The results suggest that the proposed algorithm outperforms other algorithms in terms of quality solution and computation efficiency.

1. Introduction

It is a very challenging issue for power system engineers to meet the customer demand in a very economical way taking quality of power into consideration. So, cost-benefit analysis is an important factor in the power generation sector. Proper scheduling of power generation is a very vital issue and to tackle this situation researchers are trying to explore the possible solution. Actually, the limited energy storage capability of water reservoirs and the stochastic nature of availability of water make the solution more difficult for hydrothermal systems compared to pure thermal systems. In HTS problem the generation cost of the thermal unit gets minimized by using the hydro reservoir water in an optimum manner after satisfying different hydraulic constraints.

The present short-term hydrothermal scheduling (STHTS) problem deals with various constraints. With the presence of these constraints, the problem is become more complex. Different researchers across the globe have proposed different approach to deal with STHTS problem over the years. At the starting, several classical optimization techniques [1–6] have applied to solve STHTS problem. All these techniques facing some problems while solving HTS problem. For example, memory and simulation time rise exponentially in case of MIP method [3].

Afterward, evolutionary algorithms [7–11] have been broadly used and turn to be a popular approach due to their flexibility and robustness to find a global optimal solution. These techniques do not depend on the mathematical model of optimization technique like traditional mathematical approach. These techniques are very powerful to solve STHTS problem besides non-linear cost curve and linear and non-linear constraints. High quality solution can be achieved by using evolutionary algorithms in a reasonable time. Particle swarm optimization (PSO) [12], one of the most popular heuristic algorithms due to their easy implementation and computation efficiency has been widely used by the researchers. An improved particle swarm optimization (IPSO) [13] has been implemented to solve HTS problem and the results have confirmed its superiority compared to other techniques like DP, EP, NLP and DE techniques. IPSO is dealing with dynamic search-space squeezing strategy to accelerate the convergence process. Modified adaptive PSO (MAPSO) has been introduced by Amjady and Soleymanpour [14] to solve HTS problem. In MAPSO, time-varying acceleration coefficient, time-varying inertia weight and velocity limiter [14] have been employed to enhance the exploration ability as well as the convergence performance. Dynamic neighborhood learning scheme has been applied to PSO and collectively known as modified dynamic neighborhood learning particle swarm optimization (MDNLPSO) [15]. Bhattacharjee et al. proposed a real-coded chemical reaction based optimization (RCCRO) to solve STHTS problem [16]. A modified version of RCCRO named as, oppositional based RCCRO (ORCCRO) was implemented [17] to solve HTS problem and found to be a superior than RCCRO in results

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Fixed head short-term hydrothermal scheduling in presence of solar and wind power

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ARTICLE INFO

Keywords:
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ABSTRACT

A probabilistic short-term hydro-thermal-wind-photovoltaic scheduling based on point estimate method (PEM) is proposed in this article. To model the uncertainties associated with wind and solar power, point estimate method is used. The Weibull and Beta distributions are employed to handle the uncertain input variables. The mean generation cost of the system is optimized based on an optimization algorithm named crow search algorithm (CSA). Three test systems have been taken, the first test system contains only hydro and thermal plants, and rest of the two systems are based on wind and solar including hydro and thermal unit to investigate the effect of renewable energy sources in the selected test systems. Furthermore, underestimation and overestimation of available wind power has also been included in the problem. The simulation results show that when the penetration of renewable energy sources increases, the mean generation cost decreases. The results obtained by CSA have been compared with other well-known methods. Moreover, the accurate distribution of generation cost for the next day-ahead can be found out using Gram-Charlier series expansion.

1. Introduction

Being a large and complex network, power system has to deal with generation, transmission and distribution of power. The power system is expected to supply the changing load demand of the consumer at an economical way. Thus the importance of short-term hydrothermal scheduling (SHTS) problem has increased in recent years. The primary goal of SHTS problem is to minimize the generation cost of the thermal unit within a specific time interval by utilizing the available water of the hydro reservoir in an optimum manner. The reservoirs are basically connected in a cascaded way. The present SHTS problem has certain equality and inequality constraints which makes the problem complex and very interesting for power system engineers.

Nomenclature

Indices

i	Index of hydro power units.
j	Index of thermal power units.
L	Index of solar power units.
M	Index of wind power units.
T	Index of time periods.
U	Index of upstream reservoir.

Sets

N_h	

$P_D(t)$	Total demand at time interval t.
$P_{loss}(t)$	Total transmission loss at time interval t.
$OEC(m,t)$	Overestimation cost of m^{th} wind unit at time interval t
$UEC\ (m,t)$	Under estimation cost of m^{th} wind unit at time interval t.
C_{oe}, C_{ue}	Overestimation and under estimation cost coefficient
k, c	Shape (dimensionless) and scale factor (m/s) of wind turbine
C_w	Direct cost coefficient of wind unit.
v	The current wind speed (m/s).
w_r	Rated power of wind turbine (MW).
v_r, v_{in}, v_{out}	

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ORIGINAL ARTICLE

Quasi-reflected ions motion optimization algorithm for short-term hydrothermal scheduling

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Abstract This paper describes quasi-reflected ions motion optimization algorithm to solve the short-term hydrothermal scheduling problem. The aim of hydrothermal scheduling is to minimize the total cost of generation by optimizing power generation of several hydro and thermal units on an hourly basis. The algorithm mainly works on the principle that opposite charges attract each other and same charges repel each other. Two phases are employed in this algorithm, namely liquid phase and crystal phase, in order to perform exploration and exploitation. Furthermore, quasi-reflected-based learning scheme is incorporated to ions motion optimization algorithm, in order to increase the convergence speed as well as the quality of the solution. To investigate the performance of the ions motion optimization algorithm, the algorithm has been tested on seven test systems. The results obtained by the ions motion optimization algorithm have been compared with those obtained by many recently developed optimization techniques such as evolutionary programming, genetic algorithm, particle swarm optimization, differential evolution, artificial immune system, teaching–learning-based optimization, real-coded chemical-reaction-based optimization, cuckoo search algorithm and modified cuckoo search algorithm. Moreover, some statistical tests have been performed to evaluate the performance of ions motion optimization algorithm.

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Keywords Quasi-reflected ions motion optimization algorithm · Short-term hydrothermal scheduling · Statistical analysis · Valve-point loading effect

1 Introduction

Optimal scheduling of hydrothermal system is one of the important problems in power system operation that involves nonlinear objective function and a bunch of equality and inequality constraints. The basic aim behind hydrothermal coordination is to use thermal and hydropower generating stations optimally. In this problem, the optimal hourly release of water from the hydro reservoirs and output power of thermal units are determined in a schedule horizon to minimize the total operation cost. In the hydrothermal system, the hydro reservoirs are connected hydraulically with each other. For this reason, downstream reservoirs are always dependent on an upstream reservoir. The basic constraints related to hydrothermal scheduling (HTS) problem are power balance constraint, hydro discharge limits, generation limits and water availability constraint. These constraints along with valve-point loading effect on fuel cost function of thermal units make HTS problem a nonlinear non-convex optimization problem and that is hard to solve using classical optimization techniques.

Since the hydrothermal scheduling problem is very much important, in order to solve HTS problem several mathematical techniques have been employed so far, such as dynamic programming (DP) [1], nonlinear programming (NLP) [2], gradient search (GS) [3], network flow and linear programming (LP) [4–6], Newton's method [7], Lagrange relaxation (LR) [8], Lagrange multiplier method [9] and mixed integer programming (MIP) [10]. The DP method is more popular among these methods.

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RESEARCH ARTICLE - ELECTRICAL ENGINEERING

Solution of Short-Term Hydrothermal Scheduling Problem Using Quasi-Reflected Symbiotic Organisms Search Algorithm Considering Multi-fuel Cost Characteristics of Thermal Generator

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Abstract Hydrothermal scheduling is an important issue in the field of power system economics. The aim of the short-term hydrothermal scheduling is to optimize the hourly output of power generation for different hydrothermal units for certain intervals of time to minimize the total cost of generations. In this paper, quasi-reflected symbiotic organisms search is implemented for optimal scheduling of hydrothermal problems. In symbiotic organisms search, the word "symbiosis" defines the relationship between two different species. The relationships are mutualism, commensalism and parasitism, depending on which the algorithm works. Further, the quasi-reflected scheme is incorporated into symbiotic organisms search in order to improve the performance of the algorithm. To investigate the performance of quasi-reflected symbiotic organisms search algorithm, the algorithm is tested on three test systems. Along with this, some statistical tests have also been performed. The results obtained by the quasi-reflected symbiotic organisms search algorithm are compared with other recently proposed methods to establish its robustness.

Keywords Oppositional based learning · Prohibited discharge zone · Quasi-reflected symbiotic organisms search · Short-term hydrothermal scheduling · Statistical analysis

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1 Introduction

The hydrothermal scheduling (HTS) problem is an important issue in the field of power system. The problem deals with nonlinear objective function along with various constants. The main approach behind hydrothermal scheduling is to utilize the hydrothermal power plants in an economic way. In HTS problem, the hourly water released from the reservoirs and the power generated by the thermal unit is obtained in a scheduled time interval to reduce the total generation cost. There are several constraints related to HTS problem, such as water availability constraint, power balance constraint, hydro discharge limits, valve point loading effect and generation limits. In hydrothermal scheduling, the entire reservoir is connected in a cascaded system and should always maintain the water level in the reservoir for hydro power generation. Sudden alteration in the volume of water flow due to natural constraints and occurrence of flood, draught and other natural calamities also affect the hydro scheduling. So, initial and terminal reservoir volume constraints are very important factor. Navigational requirement of agricultural water may also govern the hydro scheduling. Another constraint is system load balance which is equally an important inequality constraint in HTS problem. Actually the main task of an electric power supply operator is to continuously match electricity generation with electricity demand. Continuous matching is needed since the supply system as such cannot store electrical energy. If electricity demand systematically exceeds the power delivered by the machines that drive the generators, the generating units will respond by decreasing their rotational speed. Consequently, the grid frequency will drop and the system will collapse in a matter of seconds, resulting in a blackout. Hydraulic continuity equation is another constraint. The volume of every reservoir mainly depends on the natural inflow, spillage and discharge from the upstream reservoir.

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METHODOLOGIES AND APPLICATION

Solution of short-term hydrothermal scheduling using sine cosine algorithm

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Abstract Hydrothermal scheduling is an important issue in the field of power system economics. The aim of the short-term hydrothermal scheduling is to optimize the hourly output of power generation for different hydrothermal units for certain intervals of time to minimize the total cost of generations. The purpose of this article is to propose a new population-based algorithm named sine cosine algorithm to solve short-term hydrothermal scheduling problem. Hydrothermal scheduling problem is considered as an optimization problem by formulating objective function taking different equality and inequality constraints. Along with valve point loading effect, transmission loss is also considered. Here six different test systems are considered with different cost functions to verify the performance of sine cosine algorithm. The results obtained by sine cosine algorithm are compared with the results obtained by other recently developed techniques, and it was observed that it provides superior results than others in terms of generation cost as well as simulation time. Sine cosine algorithm is still new and has not yet been applied by the researchers in the field of power system. Therefore, the researchers may apply this algorithm in a different power system-related problems.

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Keywords Convex and non-convex fuel cost function · Sine cosine algorithm · Short-term hydrothermal scheduling · Statistical analysis

1 Introduction

The hydrothermal scheduling (HTS) problem is an important issue in the field of power system. The problem deals with nonlinear objective function along with various constants. The main approach behind hydrothermal scheduling is to utilize the hydrothermal power plants in an economic way. In HTS problem, the hourly water released from the reservoirs and the power generated by the thermal unit are obtained in a scheduled time interval to reduce the total generation cost. There are several constraints related to HTS problem, such as water availability constraint, power balance constraint, hydro discharge limits, valve point loading effect and generation limits. Due to these constraints, HTS problems become nonlinear and solving them using classical optimization techniques is becoming difficult.

Several approaches have been applied so far to solve HTS problem, namely dynamic programming (DP) (Engles et al. 1976), nonlinear programming (NLP) (Saha and Khaparde 1978), progressive optimality algorithm (POA) (Turgeon 1981), mathematical decomposition (MD) (Habibollahzadeh and Bubenko 1986), gradient search (GS) (Wood and Wollenberg 1984), Newton's method (Zaghlool and Trutt 1988), network flow method (NFM) (Franco et al. 1994), Lagrange relaxation (LR) (Salam and Hamdan 1998) and mixed-integer programming (MIP) (Nilsson and Sjelvgren 1996). Although a popular method, DP method suffers from computational burden and dimensionality with the increase in system size. Meanwhile, the computational time and the memory required for storage increase. The Newton's method

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ELECTRICAL ENGINEERING

Symbiotic organisms search algorithm for short-term hydrothermal scheduling

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KEYWORDS

Prohibited discharge zone;
Short-term hydrothermal scheduling;
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Valve-point loading effect

Abstract Hydrothermal scheduling is an important issue in the field of power system economics. The aim of the short-term hydrothermal scheduling is to optimize the hourly output of power generation for different hydrothermal units for certain intervals of time in order to minimize the total cost of generations. In this paper, a new meta-heuristic technique, symbiotic organisms search is implemented to solve short-term hydrothermal scheduling problem. The word "symbiosis" defines the relationship between two different species. The relationships are mutualism, commensalism and parasitism, depending on which the algorithm works. To investigate its computational efficiency, symbiotic organisms search algorithm is employed to three test systems. The results obtained by the symbiotic organisms search algorithm are compared with those obtained by many recently developed optimization techniques such as evolutionary programming, genetic algorithm, differential evolution, teaching–learning based optimization, oppositional real coded chemical reaction based optimization and modified dynamic neighborhood learning based particle swarm optimization.

1. Introduction

Optimal scheduling of hydrothermal system is one of the important problems in power system operation which involves nonlinear objective function and a bunch of equality and inequality constraints. The important strategy behind hydrothermal coordination is to adopt an optimal plan to utilize hydro and thermal power plants economically. In this problem, optimal hourly release of water from the hydro reservoirs and output power of thermal units are determined in a schedule horizon in order to minimize the total operation cost. In hydrothermal system, the hydro reservoirs are connected hydraulically with each other. For this reason, downstream reservoirs are always dependent on upstream reservoir. The constraints those are related to hydrothermal scheduling (HTS) problem are power balance constraint, hydro discharge limits, generation limits, water availability constraint and prohibited discharge zones of hydro plants, etc. These constraints

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