Short Term Optimal Generation Scheduling of NCHES: A Review

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***Abstract:* - In cascaded hydroelectric systems, the water deliverance from upstream power plants increases the tail race stratum of the same plant and reservoir stratum of its imminent downstream plant, as well with a delay of water traveling time. This detract the effective head of the upstream power project which results in sparing power generation. Generally in the cascaded systems, the available water at any time in the reservoir is determined with the water continuity equation. This equation provides the available water volume in any reservoir at time t+1 considering available water in that reservoir at time t, natural inflows with proper time delay and outflows. In the available literature, the traveling time between consecutive reservoirs has been considered as constant, however, this time varies as per the discharge of water. The optimal generation scheduling of NHECS considering varying water traveling time in water continuity equation of consecutive reservoir is addressed in three phases namely structuring of problem, problem decision and implementation or computational phase.**

Keywords:- Narmada Cascade Hydro Electric System (NCHES), Particle Swarm Optimization (PSO), Economical Load Dispatch (ELD), Problem Formulation.

INTRODUCTION

Diminution of fossil fuels, unremitting increase of power and environmental concerns have forced the power system engineers to adopt alternative sources of energy, energy conservation and use of efficient technologies. In India, the percentage of power generation through thermal power plants is higher than the hydro power plants generation and it is not surpassing seeing the global warming issues and shortage of energy sources. In such circumstance, it is a must that hydro potential should be properly harnessed and optimally utilized as they are the spotless sources of power generation.

In current scenario, most of the electrical power is generated by the fossil fuels i.e. coal, oil, gas, nuclear etc. which influence the atmosphere directly or indirectly. So it is must to use spotless sources of energy i.e. hydro and renewable sources. But contradictory to that seeing to the generation profile it is thermal dominated .The optimal generation scheduling of NHECS considering varying water traveling time in water continuity equation of consecutive reservoir is addressed in three phases namely structuring of problem, problem decision and implementation or computational phase.

Initially, Economical Dispatch (ED) problem was formulated as economic cost dispatch (ECD), but further due to the amendment of clean air act in 1990s, existence of emission dispatch (EMD) leads to the formulation of combined emission economic dispatch (CEED) (89) and emission controlled economic dispatch (ECED) problem formulation, as individual optimization of these two contradictory objectives will not serve the purpose. Various conventional methods like nonlinear optimization (31,45,48,58), Metaheuristic approaches (2), Lagrange relaxation (22,78), Bundle method (71), TVAC_PSO(33,41,82), Two Phase Neural Network(77), Dynamic Programming(76), Optimal based algorithm(79), Linear programming(86), Firefly Algorithm(18), Particle Swarm Optimization (PSO) (10,13,25,27,38,54,60,75), HPSO (1,49,56), IPSO (3,6,23,28,34,44,65,73), CPSO(4,5,63), APSO (57), MPSO (35), CFPSO (11,12,42), DCPSO (7), IAGA (14), NEIW_PSO (17,30) reported in the literature are used to solve such problems. Each method has its own advantages and disadvantages; however PSO has gained popularity as the best suitable solution algorithm for such problems. This paper is a response note on previous work of application of population based PSO algorithm to solve the various ED problems.

PROBLEM FORMULATION

Optimal generation scheduling of cascaded hydroelectric system requires the judicious optimization problem formulation which includes the objective function and various constraints as well. This problem is nonlinear and un-predicting in nature due to the relation of power generation with effective head and Discharge from individual hydro power plants and unexpected load profile. It is having dynamic behavior due to the water continuity equation which considered as one of the important equality constraints in this scheduling problem. Economic dispatch requires a judicious formulation of practical ED problem. It can be formulated as single objective and multi objective problem which are nonlinear and non convex in nature. The primary of any ED problem is to reduce the operational cost of the system fulfilling the load demand within the limit of constraints. In present work problem will be formulated as multi objective function which needs the judicious mathematical modeling of all hydro power plants in cascade fashion involved in the test system.

OBJECTIVE FUNCTION

An objective function expresses the main aim of the model which is either to be minimized or maximized. In a cascade system satisfying all physical and operational constrains. These are in form of demand supply balance, flow balance or continuity equation, bounds on reservoir storage, bound on water release or discharge, limit on spillage and coupling constraints that put a boundary condition on the initial and final reservoir level. The objective is to minimize the summation of the production cost of energy import or export over the scheduling period. The objective of this research is to increase the operational efficiency and output of this Narmada Cascade Hydro Electric System (NCHES), by economical and technical parameters optimization. In cascaded hydroelectric system the water release from upstream power plants increases the tail race level of the same plant and reservoir level of its immediate downstream plant as well with a delay of water traveling time.

$$E = Min\sum_{t=1}^{T}[(1/2)*(p_D^t - \sum_{j=1}^{n} p_j^t)^2] \qquad 1$$

Where P_D^t and P_j^t represented load demand power generated through jth hydro power plant of hydroelectric system at time t respectively. The various kinds of objective function formulation are given below.

a) Simplified economic cost function: - The Let Fi mean the cost, expressed for example in dollars per hour, of producing energy in the generator unit i. The total controllable system production cost such an approach will not be workable for nonlinear functions in practical systems. Therefore will be

$$FT = \sum_{i=1}^{N} F_i(P_i) \qquad 2$$

The fuel input-power output cost function of the ith unit is given as

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \qquad 3$$

Where FT : total generating cost; F_i cost function of ith generating unit; $a_{i,} b_{i,} c_i$; cost coefficients of generator; P_i power of generator I,n; number of generator.

b) Water dynamic balance equation with travel time: - The initial water level trajectory of each hydropower station is determined. It can be the dead water level or the normal water level. The respective equation in below,

$$V_{i+1} = V_i + q_i - Q_{xi} - \Delta q_i \qquad 4$$

Where $V_{i,} V_{i+1}$ represent separately the amount of water in the reservoir at the starting point and ending point of period i, q_i represent the average amount of natural water flowing into the reservoir in period i. Q_{xi} represent the amount of water flowing downward of the station and Δq_i represents the loss of water.

System Constrains: - The optimal value of the objective function as shown in equation is computed subjected to constraints of two kinds of equality constraints and inequality constraints or simple variable bounds as given below. The decision is discretized into one hour periods.

EQUALITY CONSTRAINTS

This equation relates the previous interval water storage in reservoirs with current storage including delay in water transportation between reservoirs and expressed as:

$$X_j^{t+1} = X_j^t + Y_j^t + U_{up}^{t-\delta} + S_{up}^{t-\delta} - U_j^t - S_j^t - IR_j^t - EL_j^t \qquad 5$$

Where X_j^t :reservoir storage of the jth plant at time t, Y_j^t :Natural inflow in the jth plant at time t, U_j^t : Discharge through jth plant at time t, S_j^t : spill from the jth plant at time, δ : time delay for water flow from upstream to downstream plant. X_j^{t+1}= Reservoir storage of the j^{th} plant at t+1.

WATER BALANCE EQUATION

Generation associated discharge various with time and there environmental and weather factor which also contribute directly to change in water level. This water continuity equation relates the previous interval water storage in reservoirs with current storage including delay in water transportation between successive reservoirs water continuity has been expressed as,

$$X_j^{t+1} = X_j^t + U_{up}^{t-\delta} + S_{up}^{t-\delta} - U_j^t - S_j^t \qquad 6$$

ACTIVE POWER BALANCE EQUATION:-

For power balance equation, equality constraints should be satisfied. The total generated power should be the same as total load demand plus the total line loss,

$$\sum_{i=1}^{N} P_i = P_D + P_{loss} \qquad 7$$

Where P_D is the total system demand and P_{loss} is the total line loss. P_i is power generation.

Minimum and maximum power limits: Generator output of each generator should be laid between maximum and minimum limits. The corresponding inequality constraints for each generator are

$$P_i^{min} \le P_i \le P_i^{max} \qquad 8$$

Where P_i^{min} and P_i^{max} are the minimum and maximum output of generator i.

DESCRIPTION OF NCHES:-

Narmada is the fifth largest river in India and largest west flowing river of Indian peninsula originating from Maikala ranges at Amarkantak (in Madhya Pradesh) at an elevation of 900 m. It flows westwards over a length of 1,312 Km before draining into the Gulf of Cambay, 50 Km west of Bharuch city. The basin lies between the East longitude 72 32' and 81 45', and the North latitudes 21 20' and 23 45'. The Vindhya range in the North, the Satpura range in the South, the Maikala range in the East and the Arabian Sea in the West forms the boundaries of the basin. In the first 1,077 Km reach, the river flows in Madhya Pradesh. The next 35 Km stretch of the river forms the boundary between the States of Madhya Pradesh and

Maharashtra. Again for the next 39 Km, it forms the boundary between Maharashtra and Gujarat. The last stretch of 161 Km lies in Gujarat. The annual utilizable quantity of water of Narmada at Navagam in Gujarat has been assessed as 34,537 Million Cubic Metre (MCM) i.e. 28 Million Acre Feet (MAF) at 75% dependability by NWDT. On full development, the Narmada has a potential of irrigating over 6 million ha (15 Million Acres) of land along with a capacity to generate about 3,460 Mega Watt hydro electric power. Out of the total catchment area of 98,796 sq. km., 85,115 sq. km. (86.15%) lies in Madhya Pradesh, 744 sq. km. (0.75%) in Chhatishgarh, 1,538 sq. km. (1.56%) in Maharashtra and 11, 399 sq. km. (11.54%) in Gujarat. It is also called the life line of Madhya Pradesh and Gujarat. The share of states in power generation and water are shown in table. In Madhya Pradesh share are very large in the other because of the area of the river is large.

Table:- Share of States in Power Generation & Water

Party States	Share of Party States	
	Power from SSP(%age)	Narmada Water at SSP(MAF)
Madhya Pradesh	57	18.25
Gujarat	16	9.00
Maharashtra	27	0.25
Rajasthan	-	0.50
Total	100	28.00

REVIEWS FOR PSO IN ECONOMIC DISPATCH PROBLEM:-

Prabakaran et al. [1] proposed a new Hybrid Particle Hybrid Optimization (HPSO) approach to solve the problem of the Economic Dispatch (ED) considering the forbidden operating zone, the increase rate limits, the capacity limits and the power balance restrictions. This method integrates evolutionary programming (EP) techniques and optimization of wake particles (PSO) to exploit the qualities of the optimization method and determine the quality solution. The result shows that the previous method is able to produce the best solutions to reduce the fuel cost of generating units with faster convergence characteristics.

Hidalgo et al. [2] formulated the short-term generation scheduling problem of the two cascaded Brazilian hydroelectric plants, which are Jupi´a and Porto Primavera plants, that belong to the national interconnected system. This problem has been solved using two metaheuristic approaches, that is the hybridization of the genetic algorithm with the Pareto evolutionary force algorithm and the optimization of the ant colony.

Khan et al. [3] introduced to the optimization of the swarm of inertial particles of natural exponent weight to solve the problem of the expenditure of economic load. The inertial weight strategy optimizes the swarm of particles to achieve optimal energy expenditure with satisfaction of restrictions and minimization of operating costs. The results are compared between the classical methods of optimization of the Swarm particle (CPSO), e1PSO, e2PSO.

Mistry et al. [4] adopted the particle swarm optimization (PSO) algorithm to solve the economic dispatch (ED) problem. Here the objective is to minimize the total operating cost of the committed generating units considering various equality and inequality constraints. For the results opting compare the conventional method and PSO method for minimize the fuel cost.

Jadoun et al.[5] optimized a Non convex Economic Dispatch Using Particle Swarm Optimization with Time Varying Operators. Particle swarm optimization (PSO) is used to solve difficult combinatorial optimization problems, such as the problem of non-convex and discontinuous economic dispatching (ED) of large thermoelectric power plants.

Yadav et al. [6] presented a improved particle swarm optimization (IPSO) algorithm for solving the system short term hydrothermal scheduling (STHTS) problem considering valve point loading for fixed head hydro-thermal system. short term hydrothermal scheduling (STHTS) problem which is a complicated nonlinear dynamic constrained optimization problem.

Jaodun et al. [7] developed a dynamically controlled swarm particle optimization method (DCPSO) to solve the short-term energy system (EESTHS) problem with a variety of operational and network limits. This method is studied in two different test systems that have different operational and network constraints.

Awasthi et al. [8] presented a concept to regulate the release of water in order to obtain optimal performance of the units in a hydroelectric plant while satisfying the load demand. This concept is used in hydraulic and electrical losses in a hydroelectric plant and satisfies the load demand with a minimum amount of water.

Ramya et al. [9] proposed a stochastic economic dispatching model (SED) that incorporates wind energy storage generators as well as thermal generators. Compare the optimal result for the model mentioned above with the two adoptive methods, namely the modified PSO algorithm (MPSO).

Ghani et al. [10] illustrated the application of PSO in ED problems, which is the most complex optimization problems. The practical problems of economic transmission (ED) are an objective function of the non-linear, non-convex type, and have restrictions of intense equality and inequality.

Salma et al. [11] solved the short term fixed head hydrothermal scheduling problem with transmission line losses. Genetic algorithm (GA) and constriction factor based particle swarm optimization (CFPSO) technique are improved the performance efficiency of the hydrothermal test system comprising of three thermal units and one hydro power plant.

SALAMA et al. [12] solved short term multi chain hydrothermal scheduling problem with non smooth fuel cost objective functions. This algorithm is demonstrated on hydrothermal test system comprising of three thermal units and four hydro power plants are in cascade system.

Tiwari et al. [13] presented an overview of the basic PSO to provide a complete survey on the problem of economic freight transport as an optimization problem. Dispatching the economic load is a non-linear optimization problem that is of great importance in power systems. Optimization of the swarm of classical particles (CPSO) as optimization to solve the quadratic cost function based on constraints with generator constraints and power loss.

Zheng et al. [14] improved Adaptive Genetic Algorithm (AGA) and its application in the optimal functioning of the short-term set of Qing. Hydroelectric stations of the river cascade. a new selection operator is adopted to maintain the diversity of the population in the selection process by performing a non-line conversion to the fitness function.

Sharma et al. [15] reviewed that Economic Load Dispatch (ELD) for valve point loading. Particle swarm optimization (PSO) with chaotic sequence can be applied. Particle swarm optimization is an effective & reliable evolutionary based approach.

RAHMANI et al. [16] proposed a developmentally modified PSO (Particle Swarm Optimization) is used to find fast and efficient solutions for different energy systems with different numbers of generating units. This algorithm minimizes the total cost function of the generating units.

Kishore et al. [17] presented an Optimum Swarm Optimization approach to the weight of natural exponential inertia (NEIW_PSO) to determine the optimal generation program of hydropower plants in the cascade hydroelectric test system.

Yang et al. [18] presented a new approach to determine the optimal and feasible solution of erectile dysfunction problems using the recently developed Firefly (FA) algorithm. This method can find cheaper rates than those determined by other methods.

Li et al. [19] proposed optimal programming of the cascade hydroelectric system using the grouping differential evolution algorithm. The algorithm is applied to a medium and long-term cascade hydroelectric system case. Its algorithm is a complex problem of the optimal programming of the cascade hydroelectric system, a new algorithm of differential development of the grouping (GDE).

Luo et al. [20] presented Long-term optimal scheduling of cascade hydropower stations using fuzzy multi-objective dynamic programming approach. A multi-objective fuzzy dynamic programming model for used on three Gorges cascaded hydropower plant.

XIE et al. [21] analyzed optimal scheduling processes for short term power generation rules for cascade hydropower stations based on hybrid algorithm. A mathematical model was established based on the principle of reservoir operation.

Rodrigues et al.[22] implemented problem of short-term programming of hydrothermal energy systems through the relaxation of Lagrange and the increase of Lagrangiana, which translates into a problem of non-linear programming of large-scale mixed whole. A Lagrangian relaxation (LR) is designed according to the variable division in which the resulting two-fold problem is solved by a Bundle method.

Mandal et al. [23] presented a new technique of improved particle swarm optimization called self-organized hierarchical swarm optimization technique with variable acceleration coefficients over time (SOHPSO_TVAC) to solve the short-term economic generation program of hydrothermal systems to avoid premature convergence.

Mahor et al. [24] suggested. Practical economic dispatch (ED) problems have nonlinear, non-convex type objective function with intense equality and inequality constraints. Metaheuristic optimization techniques especially particle swarm optimization (PSO) has gained an incredible recognition as the solution algorithm for such type of ED problems.

Rugthaicharoencheep et al. [25] developed based particle swarm optimization (PSO) algorithm, is applied to search for the optimal schedule of all generations units that can supply the required load demand at minimum fuel cost while satisfying all unit and system operational constraints.

PENG et al. [26]proposed to improved artificial fish swarm algorithm (IAFSA) is used to solve the problem of optimal operation of cascade reservoirs. Artificial fish swarm algorithm (AFSA) is a novel method for searching the global optimum.

Sreenivasan et al. [27] presented Short-term hydrothermal programming based on OSPs with prohibited discharge areas. A new approach is to determine the optimal time schedule for generating energy in a hydrothermal energy system using the PSO technique.

Dieu et al. [28] proposed a newly improved particle swarm optimization (NIPSO) is based on the particle swarm optimization with time-varying acceleration coefficients (PSO-TVAC) with more improvements including the use of sigmoid function with random variation for inertia weight factor, pseudo-gradient for guidance of particles, and quadratic programming for obtaining initial condition.

Saber et al. [29] proposed economic load dispatch using particle swarm differential evolution optimization (PSDEO) algorithm. A new hybrid algorithm combining the conventional Particle Swarm Optimization (PSO) algorithm with Differential Evolution (DE) has been suggested wherein PSO is used for exploitation, DE is used for exploration and the hybrid PSDEO has a good balance between local and global search abilities for ELD.

Kishore et al. [30] presented a natural approach to optimize the exponential inertial particle swarms (NEIW_PSO) to determine the optimal generation program of hydroelectric power plants in the cascade hydroelectric test system.

Díaz et al. [31] proposed a non-linear programming model based on a programming that determines both the optimal engagement of the unit and the sending of the generation of the units involved. The power generated by each hydraulic unit is considered a non-linear function of the water discharge and the volume of the associated tank.

Tu Vu et al. [32] adopted the optimization problems of optimal power flow (OPF) and the economic load dispatch (ELD) with valve-point effects in power systems are recently solved by some types of artificial intelligent (AI) algorithms. In this paper, based on improving the function of weight parameters.

Mahor et al. [33] adopted a Hydro-logically efficient operation of power plants in such cascaded system requires that water resources should be managed efficiently, so that it can dispatched to predicted demand considering all physical and operational constraints. Time Varying Acceleration coefficients PSO (TVAC_PSO) has been used to determine the optimal generation schedule of real operated cascaded hydroelectric system located at Narmada River in state Madhya Pradesh, India.

Park et al. [34] presented an improved particle swarm optimization (IPSO) efficient approach for solving economic dispatch (ED) problems with non-convex cost functions. It is applied to large scale power system of Korea.

Bhattacharya et al. [35] presented optimization of swarms of modified particles (MPSO) to solve the non-convex economic dispatch. A new swarm particle optimizer combined with the roulette selection operator to solve the problem of sending economic load (ELD) of the thermal generators of a power system. Compared to the MPSO and PSO method.

Khamsawang et al. [36] proposed to solve the economic dispatch problem using Novel Particle Swarm Optimization (NPSO). An improved approach based on Conventional Particle Swarm Optimization (CPSO) for solving an economic dispatch(ED) problem with considering the generator constraints.

Stojanovic et al. [37] introduced a short term and long term management for hydropower plant in a cascade system. This modes is management used in a “Vlasinske HPPs” that is a cascade that consists of 4 hydropower plants. It solves the water level in the storage the discharge through the power house and the power and electricity generation realized by hydropower plant.

Chen et al. [38] present a new methodology based on a PSO for solving the hydro units scheduling problem in the daily hydro-thermal coordination. New solution methods and results based on a particle swarm optimization (PSO) for solving the hydro generation scheduling problem.

Catalao et al. [39] proposed a Novel Mixed-Integer Quadratic Programming Approach (NMIQPA). It has short term hydro scheduling (STHS) in head dependant cascade hydro system. This method approach allows an efficient consideration of the nonlinear dependence power generation, water discharge and head.

Wang et al. [40] investigated multi area environmental/economic dispatch (MAEED) is addressing the environmental issue during the economic dispatch (ED). An improved multi objective particle swarm optimization (MOPSO) algorithm is developed to derive a set of Pareto-optimal solutions.

Khokhar et al. [41] proposed a efficient particle swarm optimization (EPSO) approach with time varying acceleration coefficients (TVAC_PSO) for an extensive study of the economic dispatch problem with valve point loading (EDVPL).It is minimize transmission losses and valve-point loading (VPL) have been considered.

Salama et al. [42] proposed optimal generation scheduling of cascade hydrothermal system using genetic algorithm (GA) and particle swarm optimization with constriction factor (CFPSO).

Abido et al. [43] proposed a new technique of optimization of multi-objective particle swarms (MOPSO) for the problem of environmental / economic dispatching (EED). The MOPSO technique develops a multi-objective version of PSO proposing the redefinition of the best and best local people in the field of multi-objective optimization.

Hota et al. [44] presented a new approach to the optimal energy generation solution for the problem of short term hydrothermal programming, using the improved technique of particle sweep optimization (IPSO). , the delay in water transport and the connection of programming times that make it difficult to find the global optimum using standard optimization methods.

Catalao et al. [45] proposed nonlinear optimization approach for short term hydro scheduling considering head dependent reservoirs under competitive environment. This method used in hydroelectric power generation as well as water discharge and of the head, but also that the maximum water discharge, giving the maximum power generation, is a function of the head.

Vlachogiannis et al. [46] introduced An improved algorithm for particle-based swarm optimization based on aggregation (ICA-PSO) serves to solve the optimal problem of dispatching the economic load (ELD) in energy systems. The ICA-PSO algorithm is tested in a series of power systems.

Moradi et al. [47] introduced to evaluate the Particle Swarm Optimization (PSO) algorithms for solving complex problems of water resources management. The standard particle swarm optimization algorithm and the modified method named Elitist-Mutation Particle Swarm Optimization (EMPSO) are used to determine optimal operating of a single reservoir system.

Catalao et al. [48] proposed a new non-linear approach to solve the problem of short-term hydraulic planning in deregulation, considering the dependence on the head. The hydraulic coupling of hydroelectric systems in cascade and the complexity associated with the generation of head-sensitive hydroelectric energy still represent a real challenge for modelers.

Jiekang et al. [49] proposed a model for short-term scheduling optimization of cascaded hydro plants, which includes uncertainties, spatial-temporal constraints among cascaded reservoirs. A hybrid particle swarm optimization (HPSO), which is embedded with evolutionary algorithms, is to use for the solution of global optimization problems.

Sugsakarn et al. [50] presented an effective method for solving economic dispatch problem (EDP) with non smooth cost function using a hybrid method that integrates particle swarm optimization (PSO) with sequential quadratic programming (SQP).A hybrid PSO-SQP method is applied to solve EDP of a test system with ten generator units.

Sriyanyong et al. [51] proposed a method of combining the conventional PSO algorithm with Gaussian mutation (GM) operator to enhance the global search capability and investigate the performance of the proposed hybrid PSO-GM algorithm, while solving the Economic Dispatch (ED) problem considering non-smooth cost functions.

Diniz et al. [52] suggested the self-scheduling of a hydro plant a precise integer modeling of the hydro power production function (HPF) is convenient, in the security constrained short-term hydrothermal dispatch problem for large-scale systems a strategy which best balances an accurate representation with an acceptable computational burden is required.

Chaturvedi et al. [53] applied a new optimization of wake of self-organized hierarchical particles (SOH_PSO) for the non-convex economic expedition (NCED). Performance is further improved when variable acceleration coefficients are included over time.

Samudi et al. [54] presented a new approach of particle swarm optimization (PSO) algorithm for short term Hydro Thermal Scheduling (HTS) problems.

Zhu et al. [55] presented the particle swarm optimizer (PSO) is a stochastic, population based optimization technique that can be applied to a wide range of applications.

Sriyanyong et al. [56] presented the application of Optimization Sweat Optimization (EPSO) combined with the Gauss Mutation (GM) to solve the problem of the Dynamic Economic Dispatch (DED) taking into account the operating limits of the generators. EPSO consists of a standard PSO and a modified heuristic search approach.

Panigrahi et al. [57] presented adaptive particle swarm optimization (APSO) approach for static and dynamic economic load dispatch problem a novel heuristic optimization approach to constrained economic load dispatch (ELD) problems using the adaptive variable population PSO technique.

Catalão et al. [58] proposed a new non-linear optimization method to consider the generation of hydroelectric energy as a function of water discharge and also of the head. Head dependence is considered in short-term hydropower programming to achieve more realistic and feasible results.

Yuan et al. [59] proposed an optimized algorithm for particle swarm optimization (EPSO) to solve the optimal daily problem of hydropower generation programming. Improvements mainly include three aspects. Firstly, the concept of repellent that acts in a complementary way to the concept of attractor is introduced in PSO, in second place, chaotic sequences based on the logistic map are adopted in place of random sequences in PSO; thirdly, a selection comparison technique based on feasibility and a heuristic rule is designed to effectively manage the constraints in PSO.

Mandal et al. [60] presented Particle swarm optimization is applied to determine the optimal time schedule of power generation in a hydrothermal energy system. It is considered a cascade hydroelectric system of multiple deposits with a non-linear relationship between water discharge, net head and energy generation.

Ling et al. [61] suggested a new hybrid particle swarm optimization (HPSO) that incorporates a wavelet theory based mutation operation for solving economic load dispatch. Economic load dispatch, that optimizes the operation cost with respect to the load demands of customers, is one of the most important problems in power systems.

Coelho et al. [62] suggested solve the problem of the shipment of the economic load in the power system through the chaotic and Gaussian particle swarm optimization (GPSO). The objective of the Economic Dispatch Problems (EDP) problems of the generation of electricity is to program the results of the production units engaged in order to satisfy the requested load request at a minimum operating cost while satisfying all the units and the equality of the system and inequality constraints of the system.

Jiejin et al. [63] proposed a Chaotic particle swarm optimization (CPSO) methods are optimization approaches based on particle swarm optimization (PSO) with adaptive inertia weight factor (AIWF) and chaotic local search (CLS). Two CPSO methods based on the logistic equation.

Yu et al. [64] introduced the approaches based on different particle swarm optimization (PSO) techniques are applied to solve the short-term hydro-thermal scheduling problem. This algorithm is demonstrated through an example system.

Titus et al. [65] presented a solution procedure using particle swarm optimization to solve the hydrothermal coordination problem for power generation considering prohibited operating zones (POZ). Prohibited operating zones (POZ) induce nonlinear characteristics into the problem. A PSO based algorithm to solve the HTC problem.

Selvakumar et al. [66] proposed a new version of the classical particle swarm optimization (CPSO), new PSO (NPSO), to solve non convex economic dispatch problems. In the classical PSO, the movement of a particle is governed by three behaviors, inertial, cognitive, and social. A simple local random search (LRS) procedure is integrated with NPSO.

Selvakumar et al [67] proposed a new particle swarm optimization (PSO) anti-predatory particle swarm optimization (APSO) to solve non convex economic dispatch problems. The anti-predatory activity is modeled and embedded in the classical PSO to form APSO.

Marques et al. [68] concerned to estimate the benefits of coordination in the operation of hydroelectric power system by optimization model representing the detail operating characteristics of hydro plants. The benefits of coordination have been estimated through the application of the optimization model in two different approaches.

Glanzmann et al. [69] presented a supervisory controller for cascade river power plants, which is based on model predictive control. In the power plant cascade is derived from the Saint Venant equation by the requirement of linear discrete time model.

Eusébio et al. [70] proposed a practical deterministic approach for computing the short-term economic value of the water stored in a power system reservoir, emphasizing the need to considerer water stored as a scarce resource with a short-term economic value. Mezger et al. [71] presented a dual approach to solve the short term hydrothermal scheduling (STHS) problem for systems under pool–bilateral markets. The sub problems are solved analytically or by a primal-dual interior point method, whereas the dual problem is solved via bundle method.

Chuanwen et al. [72] proposed a novel self-adaptive chaotic particle swarm optimization (SAC_PSO) algorithm to solve the short term generation scheduling of a hydro-system better in a deregulated environment. Since chaotic mapping enjoys certainty, ergodicity and the stochastic property, the approach introduces chaos mapping and an adaptive scaling term into the particle swarm optimization algorithm, which increases its convergence rate and resulting precision.

S. He et al. [73] improved particle swam optimization (PSO) to solve optimal power flow (OPF) problems. The standard PSO algorithm is extended by incorporating a biology concept "passive congregation" to prevent premature convergence and refine the convergence performance.

Basu et al. [74] presented a method for achieving objectives based on simulated annealing for the shipment of the economic emissions load of the fixed-head hydrothermal energy system. A new multi-objective optimization method for sending economic emission costs of fixed-head hydroelectric plants and thermal plants with non-uniform fuel cost and emissions functions.

Gaing et al. [75] proposed a particle swarm optimization (PSO) method for solving the economic dispatch (ED) problem in power systems. The PSO algorithm has been demonstrated to have superior features including high quality solution, stable convergence characteristic and good computation efficiency.

Arce et al. [76] adopted a dynamic programming model has been developed to optimize the number of generating units in operation at each hour of the day in order to attain the total generation scheduling of the plant in the most economic way. The optimal dispatch of generating units of Itaipu, the world's largest hydroelectric plant is in operation.

Naresh et al. [77] presented a solution technique based on two-phase neural network for short term scheduling of hydropower generation. It is based in solution of a set of differential equation realized from transformation of an augmented Lagrangian energy function.

CONCLUSIONS

Due to deregulation of the power industry and drastic environment regulations, highly non-linear constraints, multi objective problem with inconsistent objective functions are besmeared in ELD problem. In practical ELD problem it is essential to ponder valve point loading, prohibited zones with ramp rate limit as well as transmission network losses and multi-fuels with valve point effects. The insolubility further increases when dimensionality of power system increases. The basic PSO is insufficient to address the problem of practical ELD. The universal optimal solution and universal search ability, premature convergence and convergence speed, and stuck in local optima are certain major issues for PSO. In this review, it is shown that many new algorithms are developed to resolve this problem of PSO. If PSO is applied with another evolutionary programming technique it can provide much better results.

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