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Optimal Scheduling Of Generation Using ANFIS

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ABSTRACT
This paper proposes application of PSO trained Anfis for solving optimal scheduling of generation. Particle swarm optimization (PSO) is a population based stochastic optimization technique, inspired by social behaviour of bird flocking or fish schooling. The proposed approach has been examined and tested with the numerical results of optimal scheduling of generation with three and six generating units. The results of the proposed PSO-ANFIS algorithm are compared with that of other techniques such as Lambda-Iteration Method and PSO Method and compared to both cases; the proposed algorithm outperforms the solution.

Keywords – ANFIS, OSG, ELD, PSO, Lambda iteration.

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I. INTRODUCTION

Optimal scheduling of generation is an important task in the power generation plants operation which aims to allocate power generations to match load demand at minimizes cost while satisfying the power units and system constraints [1]. The optimal scheduling of generation is complexity due to the non smooth and nonlinear performances of the output-input curves of the generators, because of ramp rate limits, valve-point effect, and prohibited operating zones.

The mathematical programming based optimization methods such as base point participation method, lambda iteration, Newton's method and Gradient methods can solve the optimal scheduling problems successfully [2]. But these methods are unfortunately ineffective to handle the complex optimal scheduling problems with non-differentiable characteristics due to high complexity. Dynamic programming can solve such type of problem, but it suffers from curse of dimensionality, hence for optimal solution problem needs a accurate, robust and fast solution methodology. In present days heuristic evaluation methods such as simulated annealing[3] genetic algorithm [4],[5], evolutionary programming [6], particle swarm optimization [7-10], Bacteria foraging optimization [11], differential evolution [12] and chaotic ant swarm optimization [13] are employed to solve the optimal scheduling problems All the approaches have achieved success to a certain extent.

This paper presents the application of proposed PSO-ANFIS algorithm to optimal scheduling generation problem. The paper is organized as follows in Section 2 describes the mathematical modeling of optimal scheduling generation problem and in section 3 describes the existing PSO algorithm. The proposed PSO-ANFIS algorithm is described in section 4 and the description of test systems, results and comparisons of proposed algorithm with other methods are describes in section 5. Finally conclusion is given in section 6.

II. OPTIMAL SCHEDULING GENERATION PROBLEM

The optimal scheduling generation problem aim is to minimize the total operating cost of a power system while meeting the total load and transmission line losses with in the generator limits. Mathematically, the optimal scheduling generation problem is defined as to minimize equation (1) subjected to energy balance equation given by (2) and the inequality constraints given by equation (3).

$$F_i(P_i) = \sum_{i=1}^{NG}(a_i P_i^{\,2} + b_i P_i + c_i) \quad (1)$$

$$\sum_{i=1}^{NG} P_i = P_D + P_L \quad (2)$$

$$P_{imin} \le P_i \le P_{imax} \quad \text{(i=1, 2, 3... NG) (3)}$$

Where a_i, b_i and c_i are cost coefficients
P_D is load demand

P_i is real power generation
P_L is transmission loss
NG is number of generators

One of the most important approximate simple method of expressing transmission loss as a function of generator powers is through B-coefficients. Therefore the general loss formula for calculating B- coefficients is

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_i B_{ij} P_j \quad \text{MW} \quad (4)$$

Where P_i, P_j are real powers injections at the *i*th, *j*thbuses B_{ij} are loss coefficients

The above loss formula (4) is known as George's formula. In classical method of optimal scheduling generation problem the input – output characteristics of a generator using quadratic functions, under the assumption that the incremental cost curves of the units are monotonically increasing piecewise-linear functions.

$$F_i(P_i) = \sum_{i=1}^{NG} (a_i P_i^{\,2} + b_i P_i + c_i) \quad (5)$$

Where a_i, b_i, c_i are cost coefficients of *i*th unit.

Mathematically, optimal scheduling generation problem considering valve point loading is defined as minimizing operating cost. The minimizing operation cost is given by equation (5) and it is subjected to energy balance equation. The inequality constraints are given by equations (2) and (3) respectively.'

III. PSO ALGORITHM

Particle Swarm Optimization(PSO) is an approach to problems whose solutions can be represented as in n-dimensional solution space for a number of particles are randomly set into motion through this space an in each iteration, they can observe the "fitness" of each particles and their neighbors', and "emulate" successful neighbors by moving towards them. The Various schemes for grouping particles such as semi-independent flocks can belong to a single global flock. This extremely simple approach has been surprisingly effective across a variety of problem domains.

PSO was developed by Mr.Russel Eberhart and Mr. James Kennedy in 1995 after inspired by the Research of bird flocking behavior by biologist Mr.Frank Heppner. It is similar to evolution and solving problem techniques such as (GA) genetic algorithms.

As stated before, PSO simulates bird flocking behaviors. Let us assume a scenario where a group of birds are searching for food randomly in an area. There is only one piece of food particle in the area being searched but all the birds don't know where the food is, so what is the best way to find the food? The effective solution is to follow the bird which is nearest to the food.

PSO algorithm can learned from the above bird scenario, which is used to solve the optimization problems. In the PSO each single solution is a "bird" in the search space. We call it "a particle". All of particles have their fitness values which are solved by their fitness function to be optimized. They have their own velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

PSO is initialized with a group of random particles solutions and then searches for optima by updating generations, in each particle is in each iteration can be updated by following two "best" values. The first value is the "fitness" best solution it has achieved so far and fitness value is stored. Therefore this value is called "P best". The second "best" value that is tracked by the particle swarm optimizer is the best value and it is obtained so far by any particle in the population. Then this value is a global best and called it as "G best". When "a particle" takes a part of the population and its topological neighbors, the best value is a local best and is called "L best". After finding the two best values, the particle updates their velocity and positions with following equations (6) and (7).

V [] = V [] + C1 * Rand () * (P best [] – Present []) + C2 * Rand () * (G best[] - Present[]) (6)

Present [] = Present [] + v[] (7)

Where: V []-particle velocity

Present [] - current particle (solution)

Rand () -random number between (0,1).

C1, C2 are learning factors. (C1 = C2 = 2)

IV. ANFIS - (ADAPTIVE NEURO FUZZY INFERENCE SYSTEM)

An ANFIS (adaptive neuro fuzzy inference system) was a kind of artificial neural network which is based on Takagi–Sugeno fuzzy inference system. ANFIS technique was developed in 1990s. ANFIS having both fuzzy logic principles and neural network principles. The ANFIS has the potential to capture the both benefits in a single framework i.e neural networks and Fuzzy. Which inference system corresponds to a set of fuzzy "If-Then" rules that have learning capability to approximate nonlinear functions? Hence ANFIS is considered to be a universal estimator and uses a hybrid learning algorithm to tune the parameters of a Sugeno-type fuzzy inference system (FIS). This FIS (Sugeno-type fuzzy inference system) algorithm uses a combination of the least-squares and back-propagation gradient methods to model a training data set and this is also validates the models using to checking the data and set to test for over fitting of the training data. [14].

ANFIS is a type of Neuro-fuzzy system in which both neural networks and fuzzy systems are stand-alone systems, which increase the complexity of the process being modeled. The difficulty in development depends on fuzzy rules and their membership functions are increases, due to this to lead the development of another approach which is known as ANFIS (Adaptive neuro fuzzy inference).

The ANFIS have the benefits of both neural networks and fuzzy logic. Where the best advantages of fuzzy systems is that they describe fuzzy rules, which fit the description of real-world processes to a greater extent. The advantage of fuzzy systems is their interpretability by means that it is possible to explain why a particular value appeared at the output of a fuzzy system. In turn this have some of main disadvantages is that are expert's knowledge (or) rule based instructions are needed in order to define fuzzy system and the process of tuning parameters of the fuzzy system often requires a very long time. [15].

A completely opposite situation can be observed in the field of neural networks which is known that neural networks are trained, but it is extremely difficult to use a prior knowledge about the considered system and it is almost impossible to explain the behavior of the neural network system in a particular situation. In order to compensate the disadvantages of one system with the advantages of another system, therefore several researchers tried to combine fuzzy systems with neural networks. Finally they proposed a hybrid system which is named as ANFIS (adaptive neuro fuzzy inference system). In this system Fuzzy inference is realized with the aid of a training algorithm in which enables to tune the parameters of the fuzzy inference system.

V. RESULTS

The applicability and efficiency of PSO-ANFIS algorithm for practical applications has been tested on two test cases. The programs are developed using MATLAB 7.9. The Parameters for PSO algorithm considered here are: n=20, c1=2.0,c2=2.0, Wmax=0.9, Wmin=0.4.The proposed PSO algorithm stopping criteria is based on maximum-generation=500.

Test case 1:

The system consists of three thermal units [16]. The cost coefficients of all thermal generating units are listed in table (1). The economic load dispatch problem is solved to meet a load demand of 250 MW and 350 MW.

Table: 1 Cost coefficients for Three Generating units

Unit	Fuel cost coefficients			$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	a_i	b_i	c_i		
G1	0.00525	8.663	328.13	50	250
G2	0.00609	10.040	136.91	5	150
G3	0.00592	9.760	59.16	15	100

Table: 2 Comparison of results for test case 1

Load Demand	Parameter	Lambda-Iteration Method	PSO	PSO-ANFIS
250 MW	P1,MW	166.7576	177.6175	176.7296
	P2,MW	64.77573	60.08449	60.97661
	P3,MW	27.82649	19.51894	19.91045
	Total cost, Rs/h	**3066.886**	**3046.522**	**3024.913**
350MW	P1,MW	208.8003	228.0769	222.0719
	P2,MW	208.8003	102.6149	107.0234
	P3,MW	49.16101	33.80891	36.77991
	Total cost, Rs/h	**4252.906**	**4204.251**	**4202.18**

Table: 2 show the summarized result of all the existing algorithms along with proposed PSO-Anfis algorithm for test case 1. Form Table: 2, it is clear that proposed algorithm gives optimum result in terms of minimum fuel cost compared to other existing algorithms shown.

Test case 2:

The six unit test system chosen in this thesis is the IEEE 30 bus system [17] in which cost coefficients of the generating units, generating capacity of each are specified. The test system comprises of 6 generators, 41 transmission lines and 30 buses. The IEEE 30 bus system has a minimum generation capacity of 117 MW and a maximum generation capacity of 435 MW. The economic load dispatch problem is solved to meet a load demand of 250 MW and 350 MW.

Table: 3 Cost coefficients for Three Generating units

Unit	Fuel cost coefficients			$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	a_i	b_i	c_i		
G1	0.00375	2	0	50	200
G2	0.01750	1.75	0	20	80
G3	0.06250	1	0	15	50
G4	0.00834	3.25	0	10	35
G5	0.02500	3	0	10	30
G6	0.02500	3	0	12	40

Table: 4 Comparison of results for test case 2

Load Demand	Parameter	Lambda-Iteration Method	PSO	PSO - ANFIS
250 MW	P1, MW	154.4185	145.0891	152.8519
	P2, MW	43.07857	40.57219	42.1617
	P3, MW	19.08375	18.45729	18.1746
	P4,MW	18.23513	10	20.4484
	P5,MW	10	30	10.22818
	P6,MW	12	12	12.20023
	Total cost, Rs/h	682.1025	694.1102	679.7149
350MW	P1, MW	200	198.21	193.9732
	P2, MW	60.09514	52.59839	63.43082
	P3, MW	25.11083	25.29335	24.49742
	P4,MW	35	35	35.41954
	P5,MW	21.35671	30	18.84997
	P6,MW	20.08537	19.09262	24.27454
	Total cost, Rs/h	1052.668	1052.345	1049.334

Table: 4 show the summarized result of all the existing algorithms along with proposed PSO-Anfis algorithm for test case 2. Form Table: 4, it is clear that proposed algorithm gives optimum result in terms of minimum fuel cost compared to other algorithms shown.

VI. CONCLUSION

In this paper, a new PSO-ANFIS algorithm has been proposed. In order to prove the effectiveness of algorithm it is applied to economic load dispatch problem with three and six generating units. The results obtained by proposed method were compared to those obtained by conventional method and PSO. The comparison shows that PSO-ANFIS algorithm performs better than above mentioned methods. Therefore, this results shows that PSO-ANFIS optimization is a promising technique for solving complicated problems in power system.

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