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Optimal Power Flow Using Hybrid PSO-LRS Technique

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Abstract

Now a days, several methods are discovered for providing an efficient and an undisturbed power supply to the customers. This paper presents a hybrid particle swarm optimization (PSO) approach for solving the optimal power flow (OPF) problem with uncertainties. Optimal power flow is an optimization problem which minimizes the fuel cost, emission, and real power loss while satisfying physical and technical constraints on the network. The OPF method is an important method used to increase the power flow in buses in the power system. The goal of OPF is to find out the optimal settings of a power system network that optimizes a certain objective function while satisfying its power flow equations, system security, and equipment operating limits. The proposed hybrid technique combines both the PSO and LRS algorithm. The proposed OPF technique tested with IEEE30 bus systems with power flow analysis

Keywords: OPF, FACTs, UPFC, Hybrid Technique, PSO and LRS.

I. Introduction

The optimal power flow (OPF) problem has been one of the most widely studied subjects in the power system community [1]. In power system operation, OPF is an extended problem of economic dispatch (ED) to include several parameters such as generator voltage, transformer tap change, SVC, and also include constraints such as transmission line, transformer loading limits, bus voltage limit, and stability margin limit [15]. The main purpose of OPF is to determine the optimal operation state of a power system while meeting some specified constraints [4] [12]. OPF study plays an important role in the Energy Management System (EMS), where the whole operation of the system is supervised in each conceivable real time intervals [3].

OPF problem may be defined as determining the optimal settings of a given power system network that optimizes a certain objective function while satisfying power flow equations and inequality constraints like system security and equipments operating limits [11]. OPF problem is the perfect incorporation of the contradictory doctrines of maximum economy, safer operation and augmented security [14]. The OPF is usually considered as the minimization of an objective function representing the generation cost and/or the transmission loss [5] [8]. The solution for OPF problem aims reduce fuel cost via optimal adjustment of the power System control variables, and also it satisfies various equality and inequality constraints [7].

The equality constraints are similar to that of the nodal power balance equations, while the inequality constraints are as the limits of all control or state variables [2]. The constraints involved are the physical laws governing the power generation-transmission systems and the operating limitations of the equipment [6]. OPF is assessing the finest settings of the control variables viz, the active power and voltages of generators, discrete variables like transformer taps, continuous variables like the shunt reactors, capacitors, other continuous and discrete variables so as to attain a common objectives such as minimization of operating cost or social welfare while respecting all the system limits for safe operation [3].

The possibility of operating power systems at the minimal cost while satisfying specified transmission and security constraints is one of the current issues in stretching transmission capacity by the use of FACTS devices [16]. FACTS devices can regulate the active and reactive power control as well as are easily adaptive to voltage-magnitude control simultaneously, because of their flexibility and fast control characteristics [17]. With the use of FACTS technology, such as Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) etc., bus voltages, line impedances and phase angles in the power system can be regulated rapidly and flexibly [18]. The solution techniques for the OPF problem include linear programming, quadratic programming, gradient methods, interior point techniques and stochastic optimization models [9]. These methods rely on convexity to obtain the global optimum solution, and are forced to simplify the relationships to ensure convexity [13].

Many heuristic algorithms such as evolutionary programming (EP), Tabu Search (TS), hybrid tabu search and simulated annealing (TS/SA), improved tabu search (ITS) and improved evolutionary programming (IEP) have been proposed to solve the OPF problems [10]. In the present paper the OPF problem is formulated as a optimization problem, where optimal control settings for simultaneous minimization of fuel cost and loss. In this paper, PSO-LRS algorithm is used to solve the OPF problem. The description of proposed OPF technique is described in Section 3. Before that, the resent OPF research works are presented in Section 2.In Section 4, the results and discussion are illustrated. The paper is concluded in Section 5.

II. Recent Research Works: A Brief Review

In literature various research works are available on optimal power flow of power system by different techniques. Some of them are reviewed here.

Syaiin et al. [19] have proposed an OPF based on Improved Particle Swarm Optimization (OPF-IPSO) with generator capability curve constraint, which is used by NN-OPF as a reference to obtain the pattern of generator scheduling. There are three stages in designing NN-OPF. The first stage is design of OPF-IPSO with generator capability curve constraint. The second stage is clustering load to specific range and calculating its index. The third stage is training NN-OPF using constructive back propagation method. In training process, total load and load index were used as input, and pattern of generator scheduling was used as output.

Devaraj et al. [20] have proposed an approach based on Enhanced Genetic Algorithm (EGA) to solve the OPF with FACTS devices in order to eradicate line over loads in the system following single line outages. The optimizations are performed on two parameters: the location of the devices, and their values. Two different kinds of FACTS controllers have been used for steady state studies: TCSC and Thyristor controlled Phase shifting Transformers (TCPSTs). An index called the single contingency sensitivity (SCS) has been used by the proposed approach to rank the system branches according to their suitability for installing TCSC and TCPST. Once the locations are identified, the problem of determining the optimal TCSC and TCPST parameters is formulated as an optimization problem and a GA based approach has been applied to solve the OPF problem.

Krishnasamy [21] have proposed a genetic algorithm based OPF to determine the optimal location and rating of the UPFC in power systems and also to simultaneously determine the active power generation for different loading condition. The overall system cost function which includes generation cost of power plants and the investment costs of UPFC have been utilized to evaluate the power system performance. They have confirmed that the power flow in transmission lines are improved, the voltage magnitudes are increased and also the real power losses in the system are minimized by using their proposed approach.

Sinsuphun et al. [22] have described the OPF based on swarm intelligences, in which the power transmission loss function is used as the problem objective. Although most of optimal power flow problems involve the total production cost of the entire power system, in some cases some different objective may be chosen. Four decision variables have been participated to minimize the overall power transmission losses. They are 1) power generated from generating plants, 2) specified voltage magnitude at control substations, 3) tap position of tap changing transformers and 4) reactive power injection from reactive power compensators. Swarm intelligences are popular and widely accepted as potential intelligent search methods for solving such a problem.

Vijayakumar Krishnasamy [23] has concerned the OPF in multi machine Power System with UPFC using Genetic Algorithm (GA). The objective was to minimize the cost of the power system, to enhance the power flow in transmission lines and to maintain the voltages at the buses using UPFC. Using the proposed method, the optimal cost and real power losses of the power system with UPFC was achieved by developing a simple GA and the location and rating of UPFC was also achieved by Newton Raphson’s load flow method.

Nireekshana et al. [24] have developed a Newton-based OPF for power system simulation environment. The OPF performs all system control while maintaining system security. System controls include generator megawatt outputs, transformer taps, and transformer phase shifts, while maintenance of system security ensures that no power system component's limits are violated. Special attention is paid to the heuristics important to creating an OPF which achieves solution in a rapid manner.

Prakash Burade et al. [25] have discussed Unified Power Flow Controller (UPFC) a FACTS device that could be control the power flow in transmission line by injecting active and reactive in voltage components in series with the lines. The proposed methodologies were based on the use of line loading security performance index sensitivity factors have been suggested for optimal placement of UPFC. These methods were computationally efficient PI sensitivity factors have been obtained with respect to change in two of the UPFC parameters viz., magnitude and phase angle of the injected voltage in the lines. The proposed methodologies were tested validated for locating UPFC in IEEE 30-bus system.

A. V. Naresh Babu et al. [26] have proposed intelligent search evolution algorithm (ISEA) to minimize the generator fuel cost in optimal power flow (OPF) control with multi-line flexible alternating current transmission systems (FACTS) device which was interline power flow controller (IPFC). Unlike the OPF solution methods existing in the literature, in the proposed algorithm, a two step initialization process have been adopted which was eliminated the mutation operation and also it gives optimal solution with less number of generations. The proposed algorithm has been examined and tested on a standard IEEE-30 bus system without and with IPFC.

Easwara Moorthy Nanda Kumar et al. [27] have presented an efficient and reliable evolutionary-based approach to solve the optimal power flow (OPF) problem. The proposed approach employs hybrid particle swarm optimization (HPSO) algorithm for optimal settings of OPF problem control variables. The problem was decompressed into the optimal setting of TCSC parameter sub problem that was searched by the hybrid PSO approach and the OPF with fixed FACTS parameters sub problem that was solved by the Modified Interior Point programming method. The proposed approach was examined and tested on the standard IEEE 30-bus test system with different objectives that reflect fuel cost minimization, voltage profile improvement, and enhancement.

From the review of the recent research work shows that, the OPF problem solved by utilizing different types of optimization techniques. In most of the recent works optimization process is done by considering loss and total fuel cost and in some works the environmental pollution that occurs during generation is also considered. The FACTS controllers are connected in the bus to improve the active and reactive power flow in the bus in which they are connected. After connecting the FACTS controller, the power flow in the system will change. Then based on the load, the amount of power to be generated by each generator is calculated using various algorithms. Some of the heuristic algorithms for calculating optimal power flow in power system are genetic algorithm, neural network, fuzzy logic, particle swarm optimization, Bees algorithm, Biogeography Based Optimization etc. In those algorithms, the computational time is relatively high in the current computing environment. Hence, there is a need for better optimization algorithm which reduces the computational time, cost and losses in the system. This necessity has motivated to do the research in this area.

III. Problem Formulation

The Optimal Power Flow (OPF) problem is to optimize the settings of control variables in terms of one or more objective functions while satisfying several equality and inequality constraints.

The problem can be formulated as:
minimize

$$J_i\,(x,u) \quad i=1,\ldots\ldots,N_{obj} \tag{1}$$

$$\text{Subjected to: } g(x,u) = 0 \tag{2}$$

$$h(x,u) \leq 0 \tag{3}$$

wherej $_i$ is the ith objective function, and N_{obj} is the number of objectives is the equality constraints, represent the nonlinear power flow equations. h is the system operating constraints that included functional operating constraints and limits on control variables. 'x' is the vector of dependent variables consisting of load bus voltage magnitude limits, reactive capabilities of generators, slack bus active power and branch flow limits

$$X^T = [V_{L1}...V_{LNL}, Q_{G1}...Q_{GNG}, P_{GSLACK,} S_{L1}...S_{LN1}] \tag{4}$$

where NL, NG and nl are number of load buses, number of generator buses and number of transmission lines, respectively.

U is the vector of control or independent variables consisting of generator-bus voltage magnitudes, active power generations,
transformer-tap settings and reactive shunt compensators.

$$U^T = [V_{G1}...V_{GNG}, P_{G2}...P_{GNG}, T_{1,}...T_{NT}, Q_{C1}...Q_{CNC}] \tag{5}$$

A. Objective functions

Case 1: generation cost or fuel cost (FC)

$$J = \sum_{i=1}^{NG} F_i \tag{6}$$

$$F_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2 \tag{7}$$

whereai, bi, ci are cost coefficients of unit 'i', P_{Gi} is real power generation of unit 'i'.

Case 2: real power losses (PLoss)

$$J = \sum_{i=1}^{nl} Loss_i \tag{8}$$

where nl is the number of branches, $Loss_i$ is the power loss in branch i. Power loss in each branch is calculated from the power flow solution using the active power flow through the line.

B. Problem constraints

Case 1: Equality constraints

These constraints are typical load flow equations

$$0 = P_{Gi} - P_{Di} - V_i \sum_{j=1}^{n} V_j (G_{ij} \cos \partial_{ij} + B_{ij} \sin \partial_{ij}) \tag{9}$$

$$0 = Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{n} V_j (G_{ij} \sin \partial_{ij} + B_{ij} \cos \partial_{ij}) \tag{10}$$

i=1.. .n. where nis the number of buses in the system. P_{Gi} and Q_{Gi} are active and reactive power generations at busi, PDiandQDiare

Corresponding active and reactive load demands.

Case 2: Inequality constraints

These constraints represent system operating limits.

(a)Generator constraints: generator voltage magnitudes V_G, Generator active power P_G and reactive power Q_G are restricted by their

lower and upper limits

$$V_{Gi}^{\min} \le V_G \le V_{Gi}^{\max}, i = 1,....,NG \tag{11}$$

$$Q_{Gi}^{\min} \le Q_G \le Q_{Gi}^{\max}, i = 1,....,NG \tag{12}$$

$$P_{Gi}^{\min} \le P_G \le P_{Gi}^{\max}, i = 1,....,NG \tag{13}$$

(b) Transformer constraints: transformer taps have minimum and maximum setting limits.

$$T_i^{\min} \le T_i \le T_i^{\max}, i = 1,....,NT \tag{14}$$

(c)Switchable VAR sources: the switchable VAR sources have restrictions as follows

$$Q_{ci}^{\min} \le Q_{ci} \le Q_{ci}^{\max}, i = 1,....,NC \tag{15}$$

(d)Security constraints: these include the limits on the load bus volt-age magnitudes and line flow limits.

$$V_{Li}^{\min} \le V_{Li} \le V_{Li}^{\max}, i = 1,....,NL \tag{16}$$

$$S_{Li} \le S_{Li}^{\max}, i = 1,....nl \tag{17}$$

IV. Development of Proposed Hybrid Particle Swarm Optimization

A. Particle Swarm Optimization

PSO is basically developed through simulation of bird flocking in two-dimension space. Bird flocking optimizes a certain objective function. It updates the population of individuals according to the fitness information, so that the individuals of population can be expected to move towards better solution areas. The position of each agent is represented by XY axis position and also the velocity is expressed by VX (the velocity along X axis) and VY (the velocity along Y axis). Modification of the agent position is realized by the position and velocity information.

Each agent knows its best value so far (pbest) and its XY position. This information is analogy of personal experiences of each agent. Moreover, each agent knows the best value so far in the group (gbest) among pbests. This information is analogy of knowledge of how other agents around them have performed. Namely, each agent tries to modify its position using the following information:

The current positions (x,y); the current velocities (vx, vy); the distance between the current position and pbest; the distance between the current position and gbest. This modification of positions can be represented by the concept of velocity. the detailed PSO parameters used in this algorithm are reported. Velocity of each agent can be modified by the following equation

$$V_i^{k+1} = WV_i^k + C_1 rand_1 X(P_{best} - X_i^k) + C_2 rand_2 X(g_{best} - X_i^k) \tag{18}$$

Where, V_i^k : velocity of particle i at iteration k; w = weighting function; *C1, C2* = acceleration constants; rand = random number between 0 and 1; Xki = current position of agent *i* at iteration *k; pbesti = pbest of agent i; gbest = gbest* of the group. The following weighting function is usually utilized in (9):

$$W = W_{\max} - \frac{W_{\max} - W_{mIN}}{iter_{\max}} \times iter \tag{19}$$

Where

Wmax = initial weight; Wmin = final weight;

iter max= maximum iteration number,

Iter = current iteration number.

Using (18) and (19), a certain velocity, which gradually gets close to pbest and gbest, can be calculated. The current position (searching point in the solution space) can be modified by the following equation:

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (20)$$

B. Local random search (LRS)

To enhance further efficiency of the PSO, a technique based on LRS is proposed to improve the PSO, i.e. a simple LRS procedure is added to the PSO. The hybrid PSO (PSO-LRS) can generate better solution within shorter execution time than the pure PSO. The LRS procedure is stated as follows. The initial search solution is taken as Yi, having fitness function value F_i .

Step 1: Set the maximum number of local search iterations Iter $_{LRS}$ and specify the neighborhood function G.

Step 2: Randomly generate neighboring solution $Y_j \in G(Y_i)$, while satisfying constraints and then calculate the change in fitness function value. $\Delta_{ij} = F_j - F_i$

Step 3: Accept solution $Y_j (Y_i \leftarrow Y_j) if \Delta_{ij} > 0$

Step 4: If maximum iteration for local search is not reached, the iteration count is incremented by one and the above procedure is repeated from step 2. Otherwise, return Y_i and F_i as the optimum results found by the LRS algorithm.

C. Hybrid PSO Algorithm for OPF

In phase -1 of the hybrid algorithm, PSO is employed to explore the whole search space and in phase-2, the LRS is applied.

Phase-1 algorithm

Step 1: Initialization: Initial searching vectors and velocities are generated randomly.

Step 2: The objective function for each particle in the initial population is evaluated using load flow calculation. Pbest is set to each initial searching point. The initial best-evaluated value among Pbests is set to gbest.

Step 3: Velocity updating: Using the global best and individual best of each particle, particle velocity is updated according to (5)

Step 4: Position Updating: Based on the updated velocities, each particle changes its position according to the (6).

Step 5: The objective function to the new searching points and the evaluation values are calculated. If the evaluation value of each agent is better than the previous Pbest value, the value is set to Pbest. If the best Pbest is better than gbest , the value is set to gbest. All of gbests are stored as candidates for the final control strategy.

Step 6: If the stopping criterion is met, then go to Step 7. Otherwise, go to Step 3.

Phase-2 algorithm

Step 7: If F_k G_{best} is better than F_{k-1} G_{best} , the LRS procedure is executed. The Y_i and F_i for the LRS are taken as G_{bestk} and Fk G_{best} , respectively. The PSO-LRS presents the best particle to the local search procedure for the purpose of improving its fitness function value. Our testing results demonstrated the effectiveness of the PSO-LRS approach when compared with pure PSO (i.e. without the local search phase), and we are sure that the LRS is a key step in the algorithm.

Step 8: Stop criterion

The stop criterion is that the difference ΔFk is smaller than the given tolerance in several iteration numbers. The percentage of the difference ΔFk is expressed as follows.

$$\frac{F_{Gbest}^{k} - F_{Gbest}^{k-1}}{F_{Gbest}^{k-1}} * 100\%$$

The optimization update procedure stops when the stop criterion is reached. Otherwise the process returns to step 2.

V. Result and Discussions

The proposed approach presents the results of simulation on IEEE 30 bus test system to evaluate the performance of the proposed method also present a comparison of these results PSO–Fuzzy, SPEA using EGA-DQLF approaches. In this case, hybrid PSO algorithm is implemented on theIEEE30 bus test system with bus voltage, real /reactive power and line flow constraints. The upper and lower voltage limits at all buses expect slack bus were taken 1.10 and 0.95., respectively. Line loading limits of 120% of base case was considered. For implementing the HPSO techniques, population size of 15 was taken and the maximum number of generation (iterations) was taken as 100.Software has been developed in matlab to solve optimal power flow using hybrid technique. Table 1 shows the control settings and objective function values for base case (without any optimization objective) and with single objective optimization using PSO–LRS.

Case 1: Minimization of fuel cost causes the system losses to increase to its maximum. The control settings corresponding to cost based OPF result in a reduction of 10.25% in fuel costs but cause the system losses to increase by 38.07% of base case values.

Case 2: Minimization of loss as objective in OPF results in reduction of 46.19% in losses, but the generation cost increased by 6.98% over the base case.

Case 3: Control settings based on Stability enhancement as objective in OPF results in a loss reduction of only 1.49%. The fuel costs experience slight variation. Therefore, cost based OPF solutions are not attractive solutions from system stability or loss minimization point of view. Therefore such optimization objectives cannot be treated independently. Optimizing the network for costs alone will result in in-creased system losses. Because all the optimization objectives are inter related, system controls cannot be recommended based on individual optimizations alone. Table 2 provides comparison between the results obtained with PSO-LSR and PSO–Fuzzy, SPEA using EGA-DQLF approaches

Table 1: Comparison of OPF control variables using Hybrid PSO techniques

Variables	**Base**	**Case-1**	**Case-2**	**Case-3**
PG_2(MW)	80.0	49.609	78.60	53.0
PG_5(MW)	50.0	23.12	49.8	38.789
PG_8(MW)	20.0	22.39	37	30.02
PG_{11}(MW)	20.0	12.1	29.35	20.58
PG_{13}(MW)	20.0	12.23	36.431	15.89
V_{G1}(p.u)	1.0	1.0	1.0	1.0
V_{G2}(p.u)	1.0	.988	.99	1.024
V_{G5}(p.u)	1.0	.976	.98	1.03
V_{G8}(p.u)	1.0	.973	.978	1.032
V_{G11}(p.u)	1.0	1.023	1.041	1.023
V_{G13}(p.u)	1.0	1.035	1.023	1.011
$T_{6,9}$(p.u)	1.0	0.9	0.9	0.9
$T_{6,10}$(p.u)	1.0	0.95	1.0	0.95
$T_{4,12}$(p.u)	1.0	.95	.9652	0.92
$T_{28,27}$(p.u)	1.0	.9	.9652	0.92
S_{10}(p.u)	0.0	0.04	0.5	0.4
S_{12} (p.u)	0.0	0.04	0.5	0.4
S_{15}(p.u)	0.0	0.04	0.4	0.3
S_{17}(p.u)	0.0	0.03	0.3	0.4
S_{20}(p.u)	0.0	0.04	0.5	0.2
S_{21}(p.u)	0.0	0.02	0.3	0.4
S_{23}(p.u)	0.0	0.03	0.3	0.3
S_{24}(p.u)	0.0	0.05	0.5	0.3
S_{29}(p.u)	0.0	0.03	0.4	0.2
Fuel cost($/h)	902.923	801.89	946.78	821.06
Loss (MW)	6.178	9.8209	3.994	5.582

Table 2: Comparison of best compromise solution obtained using PSO-LRS approaches

TECHNIQUE	**FUEL COST ($/h)**	**Loss (MW)**
PSO-LRS	821.06	5.582
SPEA using EGA–DQL	822.9	5.613
PSO–Fuzzy	847.01	5.666

VI. Conclusion

In this paper, we proposed Hybrid Particle Swarm Optimization Technique for Optimal Power Flow. The proposed hybrid technique would be combined with PSO and LSR. The Hybrid PSO algorithm is to calculate recommended set points for power system controls that are a tradeoff between security and economy. In this research the researcher has attempted made to simultaneously optimize all the conflicting objectives, and suggest the power system operator a set of controls which are the best compromise controls with respect to all the objectives. PSO-LRS provides a better optimal solution when compared to PSO–Fuzzy satisfaction maximization approach. The proposed algorithm can act as decision supporting tool for power system operators. Though the paper concentrated on the steady state network cost and loss minimization, the proposed OPF technique was evaluated with IEEE 30 bus system. The fuel cost and power loss of proposed Hybrid OPF method is highly promising

VII. Refrences

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