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# A Detailed Investigation on Conventional and Meta-Heuristic Optimization Algorithms for Economic Power Scheduling Problems

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## ABSTRACT

This paper investigates the conventional and meta-heuristics optimization techniques in detail. In general, every living thing in this universe always looking for the optimized way in all the activities. This makes the inspiration to survey the optimization techniques. Optimization plays a key vital role in the field of all engineering fields. In this paper, the chief and complex power system optimization problem is considered for the investigations. The conventional optimization is an old and accurate model for optimizing the power system problems. The increase in dimensionality surges complexity in solving dynamic and complex problems. For solving these problems, a certain optimization algorithm is necessary. The intelligent Meta-heuristics optimization problems include nature-mimicking techniques that take the motivation in solving these problems. The optimization methods applied to the Economic Power Dispatch, Dynamic Economic Power Dispatch, Optimal Power Flow and Distributed Generation scheduling problems for better solving. In this regard, the studies are made with these optimization techniques for better indulgent. The conducted investigations may evoke some ideas to emerging investigators.

***Keywords*** **:-** Economic Power Dispatch, Dynamic Economic Power Dispatch, Optimal Power Flow and Distributed Generation scheduling Problems, Optimization Techniques.

## I. INTRODUCTION

Optimization is minimizing or maximizing the objective with satisfying the system constraints. Even in our home, breadwinners always want to spend their earnings in an optimized way with satisfying all other constrictions. Meanwhile the world's one and only chief industry i.e., electric power producing industry has to operate in optimized manner with maximum utilizing its resources. The economical operation of these power sectors made that nation wealthy and stimulates the technological development.

It is not astounding that the advancement of electric power consumption in the universe has been the lot nevertheless significant power systems is operated in a haughtier status of saving and reliability for enriched capability in the effort of restructuring. A country's wealth and its eminence are ascertained by the amount of electric power exploiting. Based on the power utilized, a country is aforementioned as technologically advanced or emerging one. These prosper for competition and challenges in developing countries like India. In this paper the economic proper scheduling using conventional and meta-heuristics optimization techniques are discussed further down.

## II. CONVENTIONAL OPTIMIZATION METHODS

Generally, the conventional method includes the Unconstrained Optimization methods, Linear Programming, Non Linear Programming, Quadratic Programming and Dynamic Programming, Newton's Method, Interior Point etc. For all these approaches the traditional methods power optimization problems such as Economic Power Dispatch (EPD), Dynamic Economic Power Dispatch (DPED), Optimal Power Flow (OPF) and Distributed generation scheduling etc., are reviewed below in detail.

### *A. Unconstrained Optimization*

Unconstrained optimization (UO) methods are the base of the constrained optimization procedures. Utmost all the constrained optimization problems in power system is transformed into unconstrained one. Initially the numerical methods were articulated [1]. The prime UO problems in the power system include Quasi Newton technique [2], conjugate gradient optimization methods [3], Newton Raphson technique [4], gradient technique [5], Lagrange multiplier technique for solving EPD [6] etc.,

### *B. Linear Programming*

Linear Programming (LP) is a traditional optimization technique valid for the problems in which the goal function and the limitations seem to linear purposes of the choice variables [7]. The limitations in LP problem might be in the kind of equalities or inequalities. However, numerous other approaches ought to establish throughout the days for elucidating LP problems. The LP methods has numerous benefits including reliability, superior convergence properties, rapidly recognize infeasibility and adapts hefty power systems operational limits comprising contingency limitations. The main hindrances of these methods are imprecise assessment of power structure losses and inadequate capability to discover precise result related through an exact nonlinear model. Accordingly LP is broadly used to crack the power system problems includes steady state security regions to OPF [8], EPD [9], Reactive power optimization problems [10], Dynamic EPD [11], EPD including losses [12], Security constrained EPD [13], Fast LP to OPF [14], Optimal scheduling of micro grid [15], Unit commitment problem [16] etc.,

### C. Non Linear Programming

In real world, the power system problems are nonlinear. Consequently, the Non Linear Programming constructed systems can effortlessly operate the power system operation problems [17] with nonlinear objective functions and limitation, Emission based EPD [18]. These problems include EPD with Valve Point Loading (EPDVPL) [19], Interior point NLP to OPF [20], mixed integer NLP [21], Optimal placement of DG [22] etc. For solving the NLP problem, the major step is to pick an exploration route in the iterative process, this is established by the first partial derivatives of the equations. Thus, these approaches are denoted as first-order approaches. NLP built approaches have superior precision than LP created methods and ensure global convergence, which signifies that the convergence is ensured unrelated to the initial stage. However, the sluggish convergent level could trail because of twist and turn in the exploration route.

### D. Quadratic programming

Quadratic programming (QP) [23] is a superior practice of NLP. The objective of QP technique is quadratic and limitations are in linear type. The frequently exercised goal function in power system optimization problem is the generator goal function; this is typically quadratic in nature. As a result, there is no simplification for this objective function resolved by QP. Conversely, the QP is employed to solve the power system optimization problems such as EPD [24], Large scale EPD [25], DPED [26] etc.

### E. Dynamic Programming

Dynamic programming (DP) is an arithmetical method extremely appropriate in lieu of the multistage optimization problems [27]. The DP process, while appropriate, signifies or indulges a multistage assessment problem as a succession of specific-stage assessment problems. The dissolution need be systematized in such a manner that optimum result of novel problem can be accomplished from ultimate solution of certain phase problems. DP technique is applied to EPD [28], Dynamic dispatch [29], Wind power Commitment and dispatch [30], Microgrid energy management [31], Coordinated control of DG [32], Multi objective distributed system [33], Renewable energy scheduling using adaptive DP [34], Reactive power optimization in wind farms [35] etc.,

### F. Newton's Method

Newton's Method (NM), entails the calculation of the second - order partial derivatives of the power flow equations with additional limitations thus known as a second - order scheme. The essential situations of optimality usually called as Kuhn -Tucker conditions. This method is preferred for the event of quadratic convergence properties. It is applied to power system problems such as voltage phase and frequency estimation [36], NM for radial distributed system [37], Nonlinear power flow equations [38], Three phase power flow for islanded operation using newton trust region method [39], Newton scheme for large power system [40], Three phase distribution network [41] etc.

### G. Interior Point Technique

The Interior Point (IP) technique is formerly used to crack the linear programming. It is quicker and feasibly superior than the traditional simplex procedure in LP. The IP techniques were foremost pertained to explain the optimal reactive power problems [42], EPD with ramp rate constraints [43], IP method for nonlinear OPF [44], Improved IPF for OPF [45], Security constraints energy markets [46], State estimation [47], Trust region IP for OPF [48] etc.

In recent times, metaheuristic technique has been introduced and encompassed to solve the problems in all the engineering fields. In this scope of work, the literature review is analyzed for the power system problems alone.

## III. METAHEURISTIC OPTIMIZATION METHODS

Utmost several metaheuristic optimization techniques are constructed on certain biological performances. The recent metaheuristic procedures for engineering optimization problems embrace the Genetic Algorithms (GA), Differential Evolution (DE), Simulated Annealing (SA), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Biogeography Based Optimization (BBO), Particle Swarm Optimization (PSO), Bacterial Foraging Optimization (BFO) and various others.

Each algorithm has its own advantages and shortcomings. Based on the power system real time problems, the optimization algorithms appropriate to solve the specific problems. Certain other fails to resolve distinctive problems. Thus, suitable selection of the algorithm for concerned problem is essential. The below discussion deals the advantages and inadequacies of some specific optimization techniques applied to field of power system.

### H. Genetic Algorithm

A genetic algorithm is an exploration heuristic technique that imitates the practice of natural progression [49]. This algorithm is consistently used to produce valuable results to exploration problems. GA appropriates to the superior development of Evolutionary Algorithms (EA), which produce results to problems using systems motivated by natural progression such as inheritance, mutation, selection and crossover. In addition, some benefits of GA include it reveal every problem that defined with the chromosome encoding. Meanwhile the GA implementation method is not reliant on the erroneousness surface, so that it can resolve multi-dimensional, non-differential, non-continuous and uniform non-parametric problems. This technique is extremely affluent to recognize and it virtually does not need the mathematical acquaintance. GA has certain drawbacks comprise the alternative problems may not be tattered. Since owing to incompetently recognized fitness functions that produce depraved chromosome blocks despite there simply worthy chromosome impedes the crossover operation. Around there is not at all entire guarantee that a GA will treasure a global optimum. It ensues repeatedly once the inhabitants have many issues.

The variants in GA includes Parallel GA for hypercube [50], Parallel GA [51], Niched pareto GA [52], Competitive GA [53], Non-dominated sorting GA [54], Fast and elitist GA [55], Atavistic GA [56], Improved GA [57], Hybrid Taguchi GA [58] etc.

In addition, the GA applied to power flow optimization problem such as engineering problem optimization by GA [59], Distribution systems loss configuration [60], Modified GA for optimal control problems [61], Economic dispatch with valve point effects [62], Reactive power optimization [63], Optimal selection of capacitors for DS [64], Refined GA for economic dispatch [65], Large-scale economic dispatch [66], Economic dispatch with prohibited operating zones [67], Unit commitment problem [68], Optimal reactive power dispatch by adaptive GA [69], Combined heat and power based EPD [70], Power EPD based hybrid GA [71], OPF by enhanced GA [72], Hybrid real coded GA for EPD [73], Network constrained EPD [74], Pareto GA for multi-objective EPD [75], improved GA for EPD with multiple fuels [76], Hybrid GA for EPD with valve point effect [77], Non-convex economic dispatch with AC constraints by real coded GA [78], Quantum GA for dynamic dispatch with valve point effect in wind plant [79], environmental economic dispatch of Smart Microgrid using chaotic quantum genetic algorithm [80], Hybrid GA and bacterial foraging to dynamic economic dispatch [81] etc.

### *I. Differential Evolution*

The differential evolution (DE) algorithm is an evolutionary technique [82] that aids a somewhat acquisitive and fewer stochastic method to unraveling the problem than traditional EA such as GA, Evolutionary Programming (EP) and Evolution Strategies (ES). It is a modest and prevailing population- constructed stochastic shortest exploration technique for resolving arithmetical optimization problems in continuous exploration interim. DE also encompasses an effective approach of self-adapting mutation by means of lesser inhabitants. The capabilities of DE are its modest construction, simple procedure, convergence property, superiority of results and heftiness. In DE, the unique trial generation approach is essential to be pre-quantified through its limitations remaining regulated by inefficient trial and error arrangement i.e. it takes superior computational attempt.

The variants in DE techniques incorporate the Self-adaptive DE [83], DE applied to practical problems [84], opposition-based DE [85], Improved Self-adaptive [86], DE with global and local neighborhoods [87], JADE [88], modified DE [89], DE with harmony search [90], DE with dynamic parameters [91] etc.

It is also applied to power system optimization problems such as DE – quadratic programming to EPD [92], Non-convex EPD by hybrid DE [93], economic load dispatch [94], Hybrid DE with BBO for EPD [95], Modified DE [96], Shuffled DE for EPD with valve point effects [97], Improved DE for EPD [98] etc.

### *J. Simulated Annealing*

Simulated annealing (SA) is an arbitrary hunt method for global optimization hindrances and it emulates the annealing progression in material treatment [99]. While the iron refrigerates and embargoes into the glassy condition through the least strength and bigger crystal proportions in order to diminish the flaws in metal arrangements. The strengthening progression comprises the suspicious constraint of heat and freezing level, repeatedly termed annealing plan. Contrasting the gradient-based approaches and additional deterministic exploration approaches, it has the drawback of subsisting stuck into local minima. Actually, it has remained verified that the simulated annealing will converge to its global optimality if adequate arbitrariness is used in the amalgamation through precise gradual cooling. This technique utilizes a Markov chain that convergence in suitable circumstances regarding its conversion probability. SA technique typically converges in the more simulation time than other search methods, i.e., it takes much iteration for convergence.

The variants are briefed as follows very fast simulated re-annealing [100], Parallel SA [101], SA with EPD based algorithm [102], Adaptive GA [103], SA based multi-objective optimization algorithm [104] etc.,

The application of SA to power problems such as Unit commitment [105], GA-SA for EPD [106], SA based goal-attainment method for EPD [107], Chaotic SA neural network model for EPD [108], SA approach to EPD with valve point loading [109], Hybrid Ant Colony Optimization - SA to emission EPD [110], Hydrothermal scheduling with emission EPD using cultural DE [111] etc.,

### *K. Ant Colony Optimization*

The Ant Colony Optimization (ACO) is stimulated by the factual ants for problems that can be condensed to locating the optimal paths in the examination area [112]. ACO is constructed on the representation of ants in search of food grains, so that makes sure that, an ant desires to exit the peak (mountain in optimization field) and initiate to roam into an arbitrary path. Although the slight pest bounces nearby, it leaves a trajectory of pheromone. Consequently, the ant has discovered somewhat foodstuff, it can trail its arrangement behind. By accomplishing, it dispenses additional coating of pheromone on the track. An ant that drifts the pheromone will trail its path through assured possibility. Every ant that treasures the foodstuff will evacuate particular pheromone on the trail. In this instance, the pheromone concentration of the trail will surge and additional ants will track it toward the food and return. Greater the pheromone concentrations, more amount of ants deferment on the trajectory. Conversely, the pheromones disappear in particular time. Uncertainly when the entire food is treasured, they will not at all rehabilitate and the trail will evaporate later. Now, the ants will precede to different indiscriminate positions. The pros of the ACO are intrinsic parallelism. In this algorithm, the constructive response reports for speedy finding of worthy results. In addition, it is effective for travelling salesman and analogous problems. It may be exercised in dynamic attentions i.e., this algorithm adjusts to variations include new distances, etc. Lastly the hindrances of the ACO are theoretic examination is challenging. Mainly the probability dissemination deviates by iteration and computational interval to convergence is unreliable.

The advancement in ACO comprises of immunity based ACO [113], Pareto ACO [114], Hybrid neural-ACO [115], Parallel ACO [116], Improved ACO [117] etc.

ACO is applied to power system optimization problems such as EPD [118], multiobjective ACO to EPD with pollution control [119], microgrid power management [120], EPD with non-smooth cost function [121], chaotic ACO electric load forecasting [122], Differential Evolution based ACO to EPD [123], DPED with valve point loading [124], Enhanced ACO [125], Hybrid ACO–ABC–HS to EPD [126] etc.

### *L. Tabu Search*

The Tabu Search (TS) technique is generally exercised for cracking combinatorial optimization glitches [127]. It is an iterative exploration procedure, categorized by the rehearsal of an amenable memory. This technique is capable to expel local minima and to hunt zones outside an indigenous least possible. The TS scheme is predominantly manipulated to elucidate power system problems. It is tough in describing operative reminiscence organizations and tactics that are problem reliant.

The variants in TS algorithm includes fast TS algorithm [128], parallel TS [129], hybrid TS [130], advanced TS [131], parallel TS [132], multi-objective TS [133] and so on.

It also applied to power optimization problems such as OPF [134], Improved TS for EPD [135], Genetic–based TS for optimal Distribution Generation (DG) allocation [136], DPED [137], Modified TS for DG reconfiguration [138], Maintenance scheduling for generating units [139], Hybrid TS for Solving EPD [140] etc.

### *M. Biogeography Based Optimization*

In the Biogeography Based Optimization (BBO) algorithm [141], biogeography is defined as nature's approach of allocating species (plant, or living organism). At BBO, the island (land mass) of habitat through a high Habitat Suitability Index (HSI) is compared to the good (best optimal) solution and the landmass by means of a low HSI solution as a poor (worst) solution. The High HSI solutions fight to convert better than low HSI solutions. The Low HSI solutions motivated to counterfeit worthy characters from high HSI solutions. Collective characters persist in the high HSI solutions, even though simultaneously acts as innovative characters in the low HSI solutions. This occurs when particular representatives (agents) of a species specified towards an environment, whereas other representatives persist in their indigenous habitat. The solutions with poor characteristics approve many innovative features from the worthy solutions. These accumulations of innovative characters on low HSI solutions could promote the superiority of the optimal results. Further, the BBO technique has assured some distinctive qualities astounded numerous drawbacks of the typical approaches as revealed as follows. In the GA owing to the crossover process the worthy solution attains initially, occasionally the solution may fail to attain the fitness in later iterations. Similarly, in BBO has not any crossover technique and due to migration process the solution modified progressively. The most important process of this algorithm is Elitism. This process retains the best solution and made the proposed BBO technique more competent with the other techniques. Considering the PSO algorithm, the solutions are further probable to group together in analogous groups to search the optimal solution, though in BBO algorithm the solutions does not group owing to its mutation operation. Simultaneously, the limitations handling is considerably accessible when compared to BFO technique. Although the conventional BBO has an edge over other algorithms, it suffers from poor convergence characteristics when considering complex problems. In the BBO algorithm, the deprived solution admits some new features from worthy ones, this progresses the superiority of problem solutions. Comparably this is another distinctive component of BBO technique, when associated with alternative methods.

The variants in BBO include Blended BBO [142], Oppositional BBO [143], Markov models for BBO [144], real-coded BBO with mutation [145], BBO based differential evolution algorithm [146], krill herd algorithm migration in BBO [147] etc.,

BBO is also applied to power system problems include EPD [148], Hybrid DE-BBO for emission dispatch [149], multi constraint OPF [150], BBO for optimal phasor measurement unit placement [151], economic emission dispatch [152], Neighborhood search-driven BBO for optimal load dispatch [153], power management of a small autonomous hybrid power system [154], Polyphyletic migration operator and orthogonal learning aided dynamic EPD [155], Enriched BBO [156], dynamic EPD of integrated multiple-fuel and wind power plants [157] etc.

### *N. Artificial Bee Colony algorithm*

Artificial Bee Colony algorithm (ABC) is stimulated by the scavenging activities of honeybees [158]. Bees bring nectar together after massive ranges round their hive. The bee clusters have been perceived to direct bees to accumulate nectar from flower spots compared to the quantity of honey accessible on every area. Bees converse through everyone at the hive by means of a wiggle jazz that appraises new bees available in the hive by way of the path, space as well as superiority assessment of honey traces. The dominant advantage of ABC process is that it ensures not entail exterior limitations include crossover and mutation rate, like in the instance of GA, DE and other EAs besides these are difficult to regulate erstwhile. The additional benefit is that the global exploration capability in the procedure is executed by commencing vicinity trace making apparatus that is analogous to mutation procedure.

The selected variants of ABC includes hybrid simplex ABC [159], Gbest-guided ABC [160], Modified ABC [161], Rosenbrock's ABC [162], Efficient ABC [163], Dynamic clustering with improved ABC [164], Levy flight ABC [165] etc.

The problems solved in power system using ABC technique includes EPD with non-smooth cost functions [166], Dynamic EPD [167], Optimal DG allocation and sizing [168], Optimal reactive power flow [169], unit commitment [170], Optimal hybrid PV/WT sizing and distribution system reconfiguration using multi-objective ABC [171], Multi-objective OPF [172], Non-convex EPD with valve point loading [173], Multi area EPD [174], Economic and emission dispatch [175], Chaotic bee colony optimization for dynamic EPD with valve point loading [176], New modified ABC for EPD [177] etc.

### *O. Particle Swarm Optimization*

Particle Swarm Optimization is a method of group intellects in which the behaviour of a living social arrangement like the flock of birds or schools of fishes are replicated [178]. Once the group stares for food, its beings will smear in the atmosphere and travel round autonomously. Every creature has a grade of choice or randomness in its actions that permits it to treasure food deposits. The central advantages of PSO is as follows when associated with all other evolutionary computation algorithms, all the particles incline to congregate to the finest result rapidly. PSO is affluent to execute and there are limited factors to regulate. It is computationally economical subsequently it consumes little memory and central processing unit speed necessities. Shortcomings of PSO embrace slow convergence in sophisticated exploration phase, i.e., an inadequate local search capability.

The variants in PSO comprises of dynamic neighborhood PSO [179], Fitness-distance-ratio based PSO [180], Discrete PSO [181], Improved PSO [182], effective co-evolutionary PSO [183], Adaptive PSO [184], Chaos-enhanced accelerated PSO [185], improved accelerated PSO [186] etc.

The optimization problems in power system includes OPF [187], EPD with generator constraints [188], Multiple objective PSO for EPD [189], Hybrid PSO for unit commitment [190], New PSO to non-convex EPD [191], Chaotic PSO EPD with generator constraints [192], Anti-predatory PSO non-convex EPD [193], Adaptive PSO for DPED [194], PSO with time varying acceleration coefficients for non-convex EPD [195], Reserve-constrained multi area environmental EPD [196], Quantum-inspired PSO for valve point EPD [197], Improved PSO for non-convex EPD [198], Improved chaotic PSO for DPED [199], Hybrid multi-agent based PSO for EPD [200], Iteration PSO for EPD with generator constraints [201], GA-PSO for optimal DG location and sizing [202], Hybrid PSO optimum simultaneous multi-DG distributed generation Units placement and sizing [203], multi-objective function in reconfigured system for optimal placement of distributed generation [204], Optimal location and sizing determination of Distributed Generation and DSTATCOM [205] etc.,

### *P. Bacterial Foraging Optimization*

Bacterial Foraging Optimization (BFO) employs biochemical-identifying tissues to sense the intensity of nutritious affluences in its surroundings [206]. The bacteria travels across the surroundings by the sequences of tumbling and trailing, evading the toxic ingredients and reaching nearer to nutrition spot ranges in the practice named chemotaxis. In addition, the bacteria can emit a biochemical mediator that fascinates its mates, ensuing in an ancillary practice of interaction. Stimulated through the E.Coli scavenging scheme it is used to apply for various optimization problems. In the conventional BFO, the foraging behaviour of bacteria explores the global optimum solution, which is administered by inertial, cognitive and collective behaviour. The memory and collective behaviour are the main apparatuses of the scavenging behaviour, which supports the swarm of bacteria to find nutrient gradients in optimal path. BFO is superior to PSO in provisions of convergence, sturdiness and accuracy.

The application of BFO in electric power system problem include BFO-Nelder-Mead algorithm for EPD [207], Fuzzy based BFO for emission EPD [208], Dynamic adaptive BFO for EPD with valve point effects [209], Multiobjective fuzzy dominance based BFO for economic emission dispatch [210], Multiobjective BFO for EPD [211], Intelligent BFO to EPD [212], Improved BFO for combined static/dynamic environmental economic dispatch [213], DPED with security constraints using BF PSO-DE [214], Emission, Reserve and EPD with non-smooth and non-convex cost functions using hybrid BFO-Nelder-Mead algorithm [215], EPD using PSO-BFO [216], Hybrid bacterial foraging – simplified swarm optimization for practical optimal dynamic load dispatch [217], Multiobjective BFO to solve environmental EPD [218], Optimal size and siting of multiple DG in distributed system using BFO [219], Modified BFO for optimal placement and sizing of DG [220], Hybrid multi-objective improved BFO for EPD considering emission [221] etc.

## IV. CONCLUSIONS

This paper precisely inclines certain attentions of conventional and meta-heuristics nature oriented swarm intelligence optimization algorithms in the field of power system. Among them the nature inspired optimization relinquishes the special considerations. The considered optimization techniques with certain variants applied to general engineering and in the power-scheduling problem is presented. The power dispatching problems such as Economic Power Dispatch, Dynamic Power Economic Dispatch and Optimal Power Flow problem are surveyed briefly. Each algorithms advantages and shortcoming are discussed. The conducted investigations are affluent indulgence and helpful to enlightening researchers.

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