USE OF INTELLIGENT OPTIMIZATION IN POWER SYSTEMS

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Abstract: Optimization methods have been applied in power systems for the last hundred years. They have been applied across a broad region spanning from power system design to power system planning and economic power dispatch to protection. This work presents an overview of the metaheuristic optimization techniques and their applications to power systems.

Keywords: Power systems, optimization methods, evolutionary methods.

1. Introduction:

The electrical power systems have become highly complicated structures. Their planning, with generation and the after expansion has made designing and operating them optimally, a formidable problem. Maintaining the quality of power is equally important. Also the multiple objectives desired imply that the simple analytical methods of optimization cannot be used beyond a certain point. Advances in intelligent control, have changed the scenario. This paper presents a birds eye view of intelligent approaches in optimization and their applications to power systems.

In the paper Section 2. describes the classical optimization methods. Section 3. discusses the power system applications of the metaheuristic approaches. Section 4 deals with fuzzy logic and neural networks, their relation with optimization and some of their applications. Conclusions are drawn in section 5.

2. Classical optimization:

Optimization means obtaining the best results under given conditions. Optimization can be traced to the days of Newton, Lagrange and Cauchy. The ‘Calculus of Variations’ was developed. In so far as electrical engineering is concerned, the theory of Optimal control was developed. The Kuhn – Tucker algorithm has still been used for optimal control for combined heat and Power systems [1].

An optimization problem can be categorized into two classes: Linear Programming (LP) and Non Linear Programming (NLP). Linear programming is applicable for solving problems in which the objective functions and the constraints appear as linear functions of the decision variables. Linear programming is used for optimization of electrical generation power schemes. They have also been used for online relay coordination for adaptive protection [2].

If the cost function and the constraints are not linear functions of the decision variables, then it is termed as a non linear programming problem. The same problem can change from a non-linear one to a linear one if some constraints are relaxed or some assumptions made. In many situations, decisions have to be made sequentially at different points in space and at different levels. Such problems are called sequential decision problems. Dynamic programming, a method first developed by Bellman can be applied for solving these class of problems. In power systems the operation of hydro electric-thermal power systems is a sequential process as such and dynamic programming has been applied [3].

There are cases where all variables are constrained to take only integer values in an optimization problem. For example the number of electrical generators cannot be taken as say 1.7. Such a constraint makes it an Integer programming problem (IP). When restrictions are placed only on some variables to have integer values it is called a Mixed Integer programming problem (MIP). Stochastic optimization deals with optimization of random variables.

However, the classical methods are analytical and use techniques of differential calculus in finding optimal solutions. As realistic problems entail cost functions that are
discontinuous and/or differentiable analytical optimization techniques have limited scope in practical applications.

3. Metaheuristic methods:

Heuristic search methods are mostly intuitive and do not have much theoretical support. They can get stuck in local optima. Metaheuristic methods can overcome this limitation. Most metaheuristic methods are founded on some biological behaviour of animals. Metaheuristic methods make little assumptions about the problem being optimized and explore large spaces of candidate solutions. However, they do not ensure that an optimal solution will always be possible. They usually begin from a set of points and approach towards an improved solution, guided by heuristic and empirical rules.

Evolutionary Algorithms are stochastic search methods. The initial solutions undergo probabilistic operations like mutation, selection etc. and evolve better solutions.

Genetic algorithms which belong to the evolutionary class have been used to estimate faulted sections accurately in the power system distribution network and restore power quickly [4]. A protection system contains many relays. GA's have also been used for co-ordination of directional overcurrent relays [5]. The time coordination of these relays is important. Relay coordination avoids maloperation and outage. But in addition if the relays are coordinated optimally it results in an increase in speed of operation. A hybrid GA-NLP approach has been made for determining optimum values of Time Multiplier setting(TMS) and Plug Setting(PS) of overcurrent relays[6].

An Evolutionary algorithm which uses a stochastic parallel method for variables has also been used to this end, [7]. It can find out the optimum relay settings with maximum satisfaction of coordination constraints. The authors claim that the algorithm optimizes the relay operating times.

The Strength Pareto Evolutionary algorithm(SPEA) and the Non-dominated Sorting Genetic Algorithm II(NSGA-II) are applied to resolve an optimal multi-objective dispatch of hydroelectric generating units problem. The aims are maximization of the system efficiency and minimization of the startup/shutdown price of generating units. Investigational results show that these algorithms can to present several alternative plans to the executioner [8].

Power System stabilizers control the excitation system of generators and improve the dynamic performance by damping system oscillations. The Population Based Incremental Learning(PBIL) and the Breeder Genetic Algorithm(BGA) have been used for Design and Implementation of Power System Stabilizers [9]. The authors found that their performance was better than the conventional Power system Stabilizers.

A constrained Genetic algorithm based load flow has been developed for Load flow of systems containing Unified Power flow controllers(UPFC)[10].The performance of the program on the standard IEEE 30 node system with UPFC's was studied. The performance of the algorithm was found to be superior to the Newton - Raphson method and convergence was fast.Genetic algorithms have been used for optimum placement of phasor measurement units, such that they can give complete observability of the system, [11].

That assessment of frequency, phase and amplitude of voltage can be done with a continuous Genetic Algorithm (CGA) has been shown by [12]. The authors have compared the continuous genetic algorithm with a binary genetic algorithm (BGA) and found that the CGA requires less storage and is quicker than binary GA.

The Particle Swarm Optimization (PSO) algorithm is, computationally inexpensive in terms of memory and speed, simple, easy to implement, speedy and robust. It has found wide applications. PSO's have been applied for tuning the controller gains ($K_p$ and $K_i$) of the automatic generation control System [13].

Ant colony optimization algorithm solves problems which reduce to finding excellent paths through graphs. It mimics the behaviour of ants. Hybrid ant colony technique has found application for reactive power tracing in deregulated power systems, [14]. The authors propose, optimization supported reactive power tracing via hybrid ant colony technique. The Blended Crossover continuous Ant colony optimization (BX-CACO) technique was used. It was experimented on the IEEE 14 bus system and results have shown its performance to be better, compared to the Proportional sharing principle and circuit theory.

Cuckoo search algorithm is motivated by the obligate brood parasitism of the Cuckoo bird. In the Cuckoo search optimization method an egg in a nest represents a answer and a cuckoo egg corresponds to a new answer. The aim is to use the new and potentially improved solution (cuckoos
egg) which replaces the not so superior answer (other bird’s egg).

For exploiting the potential of distributed generation, the optimal allocation and sizing of distributed generation are necessary. The Cuckoo search algorithm has been implemented for optimal location and sizing of a radial distributed generation system [15]. The objective was to decrease the total real power losses and improve voltage stability in the system and simultaneously improve voltage profile in the voltage constraints. Two case studies were carried out on the 69 bus radial system and the results were compared to the Standard Genetic Algorithm and Particle Swarm Optimization. The authors claim that the Cuckoo search outperformed so far as solution quality and standard deviation. Cuckoo search has been applied for optimal capacitor placement in distribution networks [16]. The system is a mixed non-linear integer optimization problem where the aim is to minimize losses in distribution systems. The algorithm was estimated on the IEEE 16-bus, IEEE 33-bus and IEEE 69-bus distribution networks and found to be effective.

Simulated annealing is a stochastic relaxation technique derived from the annealing process used in metallurgy where, we start the process at a higher temperature and then lower the temperature slowly while maintaining thermal equilibrium. It is a powerful tool for solving non-convex optimization problems. Simulated annealing technique has been applied to Transmission System Expansion Planning [17].

Tabu search algorithm is similar to simulated annealing and is applied to combinatorial planning problems. Meter placement executes a vital task in transmission security control. To enhance the topological observability in the network the meter should be placed at the optimal location for power system state estimation. Mathematically this gives rise to complicated combinatorial optimization that it is difficult to solve for large systems. Tabu search has been used effectively for solving this problem [18]. The author has demonstrated the effectiveness of this method on the IEEE 57 and 118 node systems.

Long term Transmission Network Expansion Planning has been approached by using the Tabu search algorithm. The authors have tested it with two cases and found that Tabu Search is a robust technique [19].

Among other algorithms, the artificial Bee colony algorithm (ABC) is founded on the intelligent foraging activities of honey bee swarms. A modified honey bee optimization algorithm has been used to analyze dynamical optimal power flow taking into consideration generator constraints [20].

4. Fuzzy logic and Neural networks:

Fuzzy and neural approaches viewed as branches of Artificial Intelligence have now become disciplines of their own. They are used to design optimal controllers. Fuzzy logic controllers have been designed for power system stabilizers, excitation control of generators [21]. Genetically optimized neuro-fuzzy power system stabilizers for damping modal oscillations of power systems have been devised [22]. It has also found applications in optimal sizing of hybrid solar wind power systems. Fuzzy Controllers for Flexible AC transmission devices have been developed. Fuzzy theory has also been applied for detection and classification of partial discharges, [23].

Supervised training of a multilayered perceptron can be analyzed as an optimization problem, [24]. Adjusting the synaptic weights is related to optimizing the cost function. To calculate the output layer connection weights (Train NN), Evolutionary algorithms like Genetic Algorithms, Firefly algorithm and Bacterial foraging optimization have been used. Cuckoo search has been applied to train neural networks with improved performance. It has also been successfully applied to train spiking neural models.

Neural networks have found application for online neural training of power system stabilizers. Numerous uses of fuzzy logic and neural networks are developed.

5. Conclusion:

Apart from the above mentioned applications, the metaheuristic algorithms have found wide range of applications in; Maintenance Planning, Network reconfiguration for loss minimization, Pollution dispatch of Thermal Power plants, Power system Planning to name a few [25]. This leads one to conclude that evolutionary algorithms show quite a promise and will be undoubtedly useful to a number of predicaments in power schemes in the future.

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