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Conventional and Artificial Intelligence (Ai) Based Optimization Techniques For Reactive Power Management – A Review

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Abstract

This paper reviews conventional and artificial intelligence techniques for reactive power optimization. Reactive power optimization is an important function both in planning for the future and day-to-day operations of power systems. It uses all the reactive power sources judiciously, while planning suitable location and size of VAR compensation in a system. With increasing fuel costs and capital investments, economics of reactive power planning and scheduling have a tremendous effect on the profitable and reliable operation of a power system.

Keywords: Optimal power flow, optimization techniques, cost minimization, power grid.

I. INTRODUCTION

In the present scenario, the load density of the system has increased abnormally and due to which the quality of power has decreased. The quality of power lacks due to the shortage of reactive power during the peak load periods which results in the reduction of overall voltage level [1]. So the Reactive Power Optimization (RPO) and voltage control are an essential topic of research. The reactive power and voltage control improves the economy and security of the power system [2-4]. The load bus voltages can be maintained within the permissible limits by reallocating reactive power generation in the system which is achieved by adjusting the transformer taps, generator voltages and switchable VARs [3]. The real power losses in the system are minimized by the redistribution of the reactive power. So the RPO problem deals with the minimization of the real power loss in the system and improvement of the voltage profile of the system. Mathematically, RPO problem is a complicated non-linear programming problem with non-linear objective functions, nonlinear equality and inequality constraints [4-5].

Optimization deals with the problem of seeking solution over a set of possible choices to optimal criteria. If the criterion considered is one, it is a single objective optimization problem. If the number of criteria is more than one and if they are treated simultaneously, the problem is a Multi-Objective Optimization (MOO) problem. The MOO problem arises in the modelling and planning of many complex real systems. The MOO problem is of interest to researches from early 1960s [6-8]. The conventional RPO takes minimum power loss or voltage quality as major objectives and concerns little over the voltage stability and investment cost of the VAR sources. So RPO problem is a single objective optimization problem. The conventional RPO problem is solved using the non-linear programming technique, sensitive and gradient based techniques and heuristic techniques [9]. The non-linear programming has various drawbacks like insecure convergence, more execution time and complexity.

The sensitive and gradient based techniques get trapped in the local minima which lead to the attainment of a solution which is not optimal. The heuristic technique which is a search based technique has attained great success in solving the RPO problem [10-11].

In recent researches in order to improve the system stability and to minimize investment cost over the VAR sources the RPO is formulated with multiple objectives like average voltage deviation, voltage stability index, voltage stability margin and minimization of investment cost in addition with the minimization of active power loss. The RPO formulated with multiple objectives is called as the Multi-Objective Reactive Power Optimization problem (MORPO) [12-14].

In traditional methods, the MORPO is initially converted into a single objective and then solved using a traditional technique. The major drawback of the traditional technique is the requirement of multiple runs to reach the optimal solution. Further as there are many uncertainties in power system problems because power systems are large, complex, highly non-linear and computationally difficult environments the traditional algorithms generate weak non-dominated solution. The major difficulties of the traditional methods are the algorithm has to be implemented many times to obtain the pareto optimal front, sensitivity to the pareto optimal front and need of some knowledge of the problem to be solved [15-18]. On the contrary, the heuristic techniques or the intelligent techniques have proved that they are efficient to eliminate the difficulties of traditional methods. The heuristic methods use a population of solution in the search, so multiple optimal solutions can be obtained in a single run by simultaneously optimizing all the objectives. The various intelligent techniques used to solve the MOO problem include Multi-objective Genetic Algorithm (MOGA), Non-dominated Sorting Genetic Algorithm (NSGA), Niched Pareto Genetic Algorithm (NPGA), Non-dominated Sorting Genetic Algorithm II (NSGA-II), Strength Pareto Evolutionary Algorithm (SPEA). Further Multi-Objective Evolutionary Programming (MOEP), Multi-Objective Tabu Search (MOTS) and Multi-Objective Particle Swarm Optimization (MOPSO) algorithms have also been used to solve the MOO problem [19-23].

In this paper MORPO problem is considered using EP, TS and PSO based algorithm. The results revealed that the performance of these algorithms has to be improved. So in order to improve the performance of the algorithms, fuzzy logic has to been incorporated in the EP, TS and PSO based algorithms. Incorporation of the fuzzy logic in the search techniques avoids premature convergence and also reduces the time of computation. The incorporation of the fuzzy logic leads to the Fuzzy Mutated Evolutionary Programming (FMEP), Fuzzy Guided Tabu Search (FGTS) and Fuzzified Particle Swarm Optimization (FPSO). The MORPO is solved using the FMEP, FGTS and FPSO based algorithms [24-27].

To accelerate the convergence speed and to improve solution quality quasi-opposition based learning (QOBL) concept is incorporated in original TLBO algorithm. The proposed TLBO and quasi-oppositional TLBO (QOTLBO) approaches are implemented on standard IEEE 30-bus and IEEE 118-bus test systems. Results demonstrate superiority in terms of solution quality of the proposed QOTLBO approach over original TLBO and other optimization techniques and confirm its potential to solve the ORPD problem [28].

Reactive Power reduces power system losses by adjusting the reactive power control variables such as transformer tap - settings, generator voltages and other sources of reactive power such as capacitor banks. Reactive Power provides better system voltage control resulting in improved voltage profiles, system security, power transfer capability and overall system operation. Also Differential Evolution (DE) Algorithm has been studied, and the technique based on improved DE Algorithm for reactive power is going to be taken in this paper Optimization for the IEEE 14 - bus and IEEE 57 bus system proves that the improved DE algorithm used for reactive power optimization is valuable. The algorithm is simple, convergent and of high quality for optimization, and thus appropriate for solving reactive power optimization problems, with some application point of view [29].

A power system needs to be with sufficient reactive power capability to maintain system voltage stability and system reliability. Reactive power reserve can be ensured by installing var sources or optimizing the reactive power generation from the existing var sources [30].

Reactive power optimization (RPO) is an important issue in the operation and control of power system. To reduce the real power losses along the transmission lines and to improve the voltage profile under various operating conditions, power system operator can select a number of control variables such as generator voltage setting, transformer tap positions and switchable VAR sources [31].

Artificial Bee Colony (ABC) algorithm is an optimization algorithm based on the intelligent foraging behaviour of honey bee swarm. In this algorithm, the colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts. ABC optimization technique is easy to implement and capable of finding out near global optimum solution with fast convergence and efficiency. The proposed approach is analyzed and demonstrated on the standard IEEE-30 bus test system and simulation results show that there is a great potential in the proposed approach to solve the multi-objective reactive power optimization (RPO) problem [32].

II. REACTIVE POWER OPTIMIZATION TECHNIQUES

From the view of optimization, the various techniques including traditional and modern optimization methods, which have been developed to solve power system operation problems, are classified into three groups:

(1) Conventional optimization methods including
- Unconstrained optimization approaches
- Nonlinear programming (NLP)
- Linear programming (LP)
- Quadratic programming (QP)
- Generalized reduced gradient method
- Newton method
- Network flow programming (NFP)
- Mixed-integer programming (MIP)
- Interior point (IP) methods

(2) Intelligence search methods such as
- Neural network (NN)
- Evolutionary algorithms (EAs)
- Tabu search (TS)
- Particle swarm optimization (PSO)

(3) Non-quantity approaches to address uncertainties in objectives and constraints
- Probabilistic optimization
- Fuzzy set applications
- Analytic hierarchical process (AHP)

1. CONVENTIONAL METHODS

1.1 Unconstrained Optimization Approaches

Unconstrained optimization approaches are the basis of the constrained optimization algorithms. In particular, most of the constrained optimization problems in power system operation can be converted into unconstrained optimization problems. The major unconstrained optimization approaches that are used in power system operation are gradient method, line search, Lagrange multiplier method, Newton–Raphson optimization, trust-region optimization, quasi–Newton method, double dogleg optimization, and conjugate gradient optimization, etc.

1.2 Linear Programming

The linear programming (LP) based technique is used to linearize the nonlinear power system optimization problem, so that objective functions and constraints of power system optimization have linear forms. The simplex method is known to be quite effective for solving LP problems. The LP approach has several advantages. First, it is reliable, especially regarding convergence properties. Second, it can quickly identify infeasibility. Third, it accommodates a large variety of power system operating limits, including the very important contingency constraints. The disadvantages of LP-based techniques are inaccurate evaluation of system losses and insufficient ability to find an exact solution compared with an accurate nonlinear power system model. However, a great deal of practical applications show that LP-based solutions generally meet the requirements of engineering precision. Thus LP is widely used to solve power system operation problems such as security-constrained economic dispatch, optimal power flow, steady-state security regions, reactive power optimization, etc.

1.3 Nonlinear Programming

Power system operation problems are nonlinear. Thus nonlinear programming (NLP) based techniques can easily handle power system operation problems such as the OPF problems with nonlinear objective and constraint functions. To solve a nonlinear programming problem, the first step in this method is to choose a search direction in the iterative procedure, which is determined by the first partial derivatives of the equations (the reduced gradient). Therefore, these methods are referred to as first-order methods, such as the generalized reduced gradient (GRG) method. NLP-based methods have higher accuracy than LP-based approaches, and also have global convergence, which means that the convergence can be guaranteed independent of the starting point, but a slow convergent rate may occur because of zigzagging in the search direction.

1.4 Quadratic Programming

Quadratic programming (QP) is a special form of nonlinear programming. The objective function of QP optimization model is quadratic, and the constraints are in linear form. Quadratic programming has higher accuracy than LP-based approaches. Especially, the most often-used objective function in power system optimization is the generator cost function, which generally is a quadratic. Thus there is no simplification for such objective function for a power system optimization problem solved by QP.

1.5 Newton's Method

Newton's method requires the computation of the second-order partial derivatives of the power flow equations and other constraints (the Hessian) and is therefore called a second-order method. The necessary conditions of optimality commonly are the Kuhn–Tucker conditions. Newton's method is favored for its quadratic convergence properties.

1.6 Interior Point Methods

The interior point (IP) method is originally used to solve linear programming. It is faster and perhaps better than the conventional simplex algorithm in linear programming. IP methods were first applied to solve OPF problems in the 1990s, and recently, the IP method has been extended and improved to solve OPF with QP and NLP forms.

1.7 Mixed-Integer Programming

The power system problem can also be formulated as a mixed-integer programming (MIP) optimization problem with integer variables such as trans- former tap ratio, phase shifter angle, and unit on or off status. MIP is extremely demanding of computer resources, and the number of discrete variables is an important indicator of how difficult an MIP will be to solve. MIP methods that are used to solve OPF problems are the recursive mixed-integer programming technique using an approximation method and the branch and bound (B&B) method, which is a typical method for integer programming. A decomposition technique is generally adopted to decompose the MIP problem into a continuous problem and an integer problem. Decomposition methods such as Benders' decomposition method (BDM) can greatly improve efficiency in solving a large-scale network by reducing the dimensions of the individual sub problems. The results show a significant reduction of the number of iterations, required computation time, and memory space. Also, decomposition allows the application of a separate method for the solution of each sub problem, which makes the approach very attractive. Mixed-integer programming can be used to solve the unit commitment, OPF, as well as the optimal reconfiguration of electric distribution network.

1.8 Network Flow Programming

Network flow programming (NFP) is special linear programming. NFP was first applied to solve optimization problems in power systems in 1980s. The early applications of NFP were mainly on a linear model. Recently, nonlinear convex network flow programming has been used in power systems optimization problems. NFP-based algorithms have the features of fast speed and simple calculation. These methods are efficient for solving simplified OPF problems such as security-constrained economic dispatch, multi-area systems economic dispatch, and optimal reconfiguration of an electric distribution network.

2. INTELLIGENT SEARCH METHODS

2.1 Optimization Neural Network

Optimization neural network (ONN) was first used to solve linear programming problems in 1986. Recently, ONN was extended to solve nonlinear programming problems. ONN is completely different from traditional optimization methods. It changes the solution of an optimization problem into an equilibrium point (or equilibrium state) of nonlinear dynamic system, and changes the optimal criterion into energy functions for dynamic systems. Because of its parallel computational structure and the evolution of dynamics, the ONN approach appears superior to traditional optimization methods. The ONN approach is applied to solve the classic economic dispatch, multi-area systems economic dispatch, and reactive power optimization.

2.2 Evolutionary Algorithms

Natural evolution is a population-based optimization process. The evolutionary algorithms (EAs) are different from the conventional optimization methods, and they do not need to differentiate cost function and constraints. Theoretically, like simulated annealing, EAs converge to the global optimum solution. EAs, including evolutionary programming (EP), evolutionary strategy (ES), and GA are artificial intelligence methods for optimization based on the mechanics of natural selection, such as mutation, recombination, reproduction, crossover, selection, etc. Since, EAs require all information to be included in the fitness function; it is very difficult to consider all OPF constraints. Thus, EAs are generally used to solve a simplified OPF problem such as the classic economic dispatch, security-constrained economic power dispatch, and reactive optimization problem, as well as optimal reconfiguration of an electric distribution network.

2.3 Tabu Search

The tabu search (TS) algorithm is mainly used for solving combinatorial optimization problems. It is an iterative search algorithm, characterized by the use of a flexible memory. It is able to eliminate local minima and to search areas beyond a local minimum. The TS method is also mainly used to solve simplified OPF problems such as unit commitment and reactive optimization problems.

2.4 Particle Swarm Optimization

Particle swarm optimization (PSO) is a swarm intelligence algorithm, inspired by social dynamics and an emergent behavior that arises in socially organized colonies. The PSO algorithm exploits a population of individuals to probe promising regions of search space. In this context, the population is called a swarm and the individuals are called particles or agents. In recent years, various PSO algorithms have been successfully applied in many power engineering problems including OPF.

3. APPLICATION OF FUZZY SET THEORY

The data and parameters used in power system operation are usually derived from many sources, with a wide variance in their accuracy. For example, although the average load is typically applied in power system operation problems, the actual load should follow some uncertain variations. In addition, generator fuel cost, VAR compensators, and peak power savings may be subject to uncertainty to some degree.

Therefore, uncertainties due to insufficient information may generate an uncertain region of decisions. Consequently, the validity of the results from average values cannot represent the uncertainty level. To account for the uncertainties in information and goals related to multiple and usually conflicting objectives in power system optimization, the use of probability theory, fuzzy set theory, and analytic hierarchical process may play a significant role in decision-making.

The fuzzy sets may be assigned not only to objective functions, but also to constraints, especially the non probabilistic uncertainty associated with the reactive power demand in constraints. Generally speaking, the satisfaction parameters (fuzzy sets) for objectives and constraints represent the degree of closeness to the optimum and the degree of enforcement of constraints, respectively. With the maximization of these satisfaction parameters, the goal of optimization is achieved and simultaneously the uncertainties are considered. The analytic hierarchical process (AHP) is a simple and convenient method to analyze a complicated problem (or complex problem). It is especially suitable for problems that are very difficult to analyze wholly quantitatively, such as OPF with competitive objectives, or uncertain factors. AHP is employed to solve unit commitment, multi-area economic dispatch, OPF, VAR optimization, optimal load shedding, and uncertainty analysis in the power system.

III. LITERATURE REVIEW

Numerous techniques have been proposed in the literature to solve the reactive power optimization problem. They are categorized in to the following two groups:

1) Artificial intelligence techniques
2) Mathematical programming techniques

The following literature surveys have conducted for the proposed research work:

G. Mahalakshmi et al. (2014): In this paper reactive power flow problem is solved and Particle Swarm Optimization (PSO) technique is used for optimizing the values of generator voltage, transformer taps and switchable VAR sources. MATLAB is used for performing optimal power flow and formulating the algorithm for optimization of reactive power flow using PSO.

B. Mandal et al. (2013): This paper presents a newly developed teaching learning based optimization (TLBO) algorithm to solve multi-objective optimal reactive power dispatch (ORPD) problem by minimizing real power loss, voltage deviation and voltage stability index.

S. K Morya et al. (2013): In this research reactive power optimization is a nonlinear, multi - variable, multi - constrained programming problem, which makes the optimization process multifaceted. In this paper, based on the characteristics of reactive power opti mization, a mathematical model of reactive power optimization, including comprehensive concern of the practical constraints and reactive power regulation means for optimization, is established.

S. Sakthivel et al. (2013): This work aims to optimize the total reactive power generation by adjusting the power flow pattern in a system. Generator bus voltage magnitudes, transformer tap positions and static var conpensator (SVC) settings are taken as control parameters. Total reactive power generation is taken as the objective function value. An enhanced version of PSO algorithm, the improved PSO (IPSO) is suggested for the optimization task

B.S Prajapati et al. (2012): This paper presents Artificial Bee Colony (ABC) based optimization technique is to handle the RPO problem as a true multi-objective optimization problem with competing and non-commensurable objectives. The multi-objective of this paper is to allocate reactive power sources so that real power loss is to be reduced and voltage profile is to be improved, while satisfying certain system constraints.

S. Duman et al. (2012): In this paper, gravitational search algorithm (GSA) is proposed to find the optimal solution for optimal power flow (OPF) problem in a power system. The proposed approach is applied to determine the optimal settings of control variables of the OPF problem.

H. I Shaheen et al. (2011): This paper presents a new approach based on Differential Evolution (DE) technique to find out the optimal placement and parameter setting of Unified Power Flow Controller (UPFC) for enhancing power system security under single line contingencies.

R. Batham et al. (2011): This paper proposes an improved particle swarm optimization approach (IPSO) for solving non convex static and dynamic economic dispatch. The idea behind IPSO is i) to enhance the search capability of the CPSO by reinitializing the velocity vector whenever saturation sets in and ii) to use a parameter automation strategy to strike a proper balance between local and global search.

D. Faraji et al. (2011) assesses the management of reactive power generation to improve voltage stability margin (VSM) of power systems. The problem is formulated as a non-linear programming (NLP) optimization problem and is solved to obtain the optimal solution. The most important advantage of the proposed method is that, the VSM of system can be improved without adding new VAR compensation equipment and changing the active power dispatch of generators.

J Cai et al. (2010): This paper developed a multi-objective chaotic ant swarm optimization (MOCASO) method for solving the multi-objective EED problems of thermal generators in power systems.

AAA El Ela et al. (2009): This paper presents an efficient and reliable evolutionary-based approach to solve the optimal power flow (OPF) problem. The proposed approach employs differential evolution algorithm for optimal settings of OPF problem control variables.

Bo yang et al (2007) presented a survey of particle swarm optimization applications to solve power system optimization problems such as optimal power flow, economic dispatch, reactive power dispatch, unit commitment, generation and transmission planning, maintenance scheduling, state estimation, model identification, load forecasting, control and others.

Chettih et al (2007) presented a particle swarm optimization method to solve the optimal flow of reactive power problem with the application in the western Algerian transmission system.

Shanmuga latha et al (2007) presented a hybrid multi agent – based particle swarm optimization algorithm to solve optimal reactive power dispatch problem.

Al-Hamouz et al. (2007): This paper presents particle swarm optimization algorithm for solving the above problem. The important advantage of PSO approach is that it uses only the objective function information and hence is not restricted by the nature of the search space such as smoothness, convexity, uni-modality etc.

Yosionhikazu Fukuyama et al. (2005) has presented reactive power allocation problem as a mixed integer non linear programming problem dealing with both continuous and discrete variables. Four different particle swarm optimization techniques were presented to solve the reactive power allocation problem.

Gopalakrishnan et al. (2004) proposed a Hybrid Evolutionary programming method to solve RPP problem. The proposed hybrid technique was differing from the conventional EP solution by using the EP as a base level search towards the optimal region with limited computing time.

Chen et al. (2004) proposed the multi objective VAR planning problem that can be solved by the projection based two-layer simulated annealing algorithm for a large scale power system. The objective function for the reactive power planning problem includes active power loss, the investment cost of VAR sources and voltage deviation. The study presents minimizing each objective simultaneously while satisfying the constraints.

Ramos et al. (2004) presented Strength Pareto evolutionary algorithm (SPEA) to address reactive power compensation in power system as a multi objective problem. In this paper, Reactive compensation problem was treated as multi objective optimization problem with three conflicting objective functions. They are investment in reactive compensation devices, the active power loss and voltage security.

Pudijianto et al (2002) proposed a LP-based direct reactive OPF and a NLP-based direct reactive OPF using an interior-point algorithm which concurrently solves load flow and VAR allocation optimization problem.

Wen Zhang et al. (2002) has proposed the theory of decomposition and coordination with improved tabu search technique to reactive power planning in power systems. Based on theory of decomposition and coordination, the complex problem was decomposed into several sub problems under different load condition. Each sub problem was solved by tabu Search which is a heuristic optimal technique which was avoiding local optimal solution.

Dong et al. (2000) addresses the problem of achieving power system security, with emphasis on reactive power planning, within a competitive electricity market. Genetic algorithm has been used for solve the problem. The main outcome of the paper was planning the reactive power ancillary service market incorporating system security and minimizing the future risks.

Urdaneta et al. (1999) proposed a modified genetic algorithm at an upper stage and successive linear program at lower stage for the solution of optimal allocation of reactive power sources problem. The optimization level was divided into sub problems. In the first level the genetic algorithm was used to select the location of the new reactive power sources. This selection was passed on to the second level in order to select the amount of reactive power sources to be installed at each location by successive linear programming.

Venkatesh et al. (1999) has proposed non linear programming problem of ORPP solved in the successive multi objective fuzzy linear programming. ORPP problem has the objectives of optimally siting and sizing new capacitors at prospective location such that the transmission loss is minimal, acceptable voltage profile is obtained and the voltage stability is improved.

Chen et al. (1998) has proposed a weighted –norm approach based on simulated annealing to solve the multi objective VAR planning problem. First, the weak bus oriented criterion was used to determine the candidate buses for installing new VAR sources. Next a weighted norm approach based on simulated annealing was applied to solve general multi objective VAR planning problem.

Lee et al. (1998) has presented a comparative study of evolutionary programming, evolutionary strategy, Genetic algorithm and linear programming in solving the RPP problem. The ORPP problem is decomposed into P and Q optimization modules, and each module is optimized by the evolutionary algorithm in an iterative manner to obtain the global optimal solution.

Zhu et al. (1998) has presented a neural network approach to solve the reactive power optimization problem. The objective is to improve the system voltage profile.

Bahman et al. (1998) has presented a successive quadratic programming method for reactive power equipment operation and planning problem in the power system for providing maximum active power supply margin as viewed from static voltage stability and satisfying various system operation constraints.

Lai et al. (1997) proposed an evolutionary programming method to solve the reactive power planning problem and it is compared with Non linear programming method. The results obtained by using conventional gradient based optimization method and Broyden's method are presented to show that the EP method was better for power system planning.

Venkatramana et al. (1997) has proposed a systematic approach to decide the location, size and number of reactive power devices required in a power system. Parametric linear programming is applied to solve the reactive power allocation problem.

Chen et al. (1996) has proposed a simulated annealing method to solve the weak bus oriented reactive power planning for system security. The algorithm identifies the weak buses and selects those buses for installing new reactive power sources to enhance system security. The main idea behind this paper was that the voltage instability will occur at the weakest bus and needs new reactive power sources needs to be installed at those buses.

Mantovani et al. (1996) has proposed LP and MILP to solve the reactive power planning problem. The problem was sub divided as investment sub problem and operation sub problem.

Chattopadyay et al. (1995) proposed a method for simultaneously solving the reactive power planning and pricing. A two-part reactive power spot pricing scheme was formulated, by which the investment and operational costs can be recovered by the utility.

Thomos et al. (1995) approach consists of "If-then" based production rules. The National Grid Company of England has developed a computer program SCORPION, which was used to plan future investment in reactive compensation. This determines a near optimal pattern of new reactive sources required for voltage constraints to be satisfied in a number of system states.

Jwo et al. (1995) proposed hybrid expert system and simulated annealing (ESSA) approach to optimal reactive power planning problem. To achieve system maximum security and minimum cost in operation, reactive power planning is posed as a multi objective optimization problem. Fuzzy satisfying method is introduced in this paper for the development of ESSA algorithm.

Chen et al. (1995) presented a constraint method based on simulated annealing for solving a multi objective VAR planning problem. The objectives of the multi objective optimization problem were economical operating condition of the system, the system security margin and the voltage deviation of the system.

Lee et al. (1995) proposed a linear programming and simple genetic algorithm to solve the reactive power planning problem. The proposed VAR planning approach was in the form of a two level hierarchy. In the first level, the SGA is used to select the location and amount of reactive power sources to be installed in the system. This selection is passed on to the operation optimization sub problem in the second level in order to solve the operational planning problem.

Abdul Rahuman et al. (1994) presented a solution to the fuzzy security constrained optimal reactive power planning, taking into account the non probabilistic uncertainty associated with the reactive power demand. The objective is minimizing the real power loss and the allocation cost of new reactive power sources.

Venkatrama Ajjarapu et al. (1994) proposed a method of determining the minimum amount of shunt reactive power (VAR) support which indirectly maximizes the real power transfer before voltage collapse occur. Using a relaxation strategy that operates with a predictor-corrector/ optimization scheme, a voltage stability index that serves as an indirect measure to the closeness of reaching the steady state voltage stability limit was presented.

Iba et al. (1994) presented a new approach to the reactive power allocation planning. The GA based method utilizes unique intentional operators namely inter breeding and gene-recombination to solve the reactive power optimization problem.

Chen et al. (1994) proposed a multi objective optimization for reactive power planning. The objectives are active power loss cost reduction, minimization of the cost of the investment VAR sources, system security margin enhancement and reduction of the voltage deviation of the system. The goal-attainment method based on the simulated annealing (SA) approach to solve the problem by assuming that the decision maker has goals for each of the objective function was presented.

Hsiao et al. (1994) presented a simulated annealing based computer package for multi objective VAR planning in large scale power system. The formulation considers four different objective functions related to system investment, system operational efficiency, system security and system service quality. It also takes into consideration load, operation and contingency constraints.

Hsiao et al. (1993) has proposed an approach for contingency constrained VAR sources planning in large scale power system using simulated annealing method. The work based on simulated annealing determines the location to install VAR sources, the types and sizes of VAR sources to be installed and the settings of the VAR sources at different loading conditions.

Deeb et al. (1993) presented a novel decomposition based algorithm to solve RPP problem in large scale multi-area power system by the application of the Bender decomposition method.

Gomez et al. (1991) has proposed a two level decomposition technique for VAR source planning in electric power system. New VAR sources are modeled by discrete variables and the operating and investment costs were represented in detail in this paper.

Rafaey et al. (1990): A systematic procedure has been developed to locate and minimize the number of reactive power devices in power systems based on a set of indices and the sensitivity matrix.

Hong et al. (1990) presented an integrated methodology for long term VAR planning. The time (year) the location and amount of VAR compensation were determined by the integration of Newton-OPF with the generalized Bender decomposition.

Obadina et al. (1989) presented a method for identifying dispensed reactive power (VAR) supply that will enhance power systems pre and post contingency voltage security subject to technical and economical constraints. The problem is formulated in two stages. The first stage involves a non linear optimization problem which minimizes the amount of reactive supply. The second stage employs a mixed-integer linear program which optimizes the number of coordinate buses for VAR support.

Aoki et al (1988) have proposed a recursive mixed –integer programming technique by using an approximation method to solve reactive power planning problem. In this paper, the number of capacitors or reactor units is treated as discrete variable in solving large-scale VAR planning problem.

The methodology proposed in (Granville et al. 1988) represents multiple load levels, multiple contingencies calculate the trade off between investment cost and supply reliability and select the coordinate modes for VAR source planning.

Iba et al. (1988) proposed a successive linear programming method to solve reactive power planning problem. This method utilizes precisely calculated linear sensitivities including active power and voltage phase angle in the formulation.

IV. CONCLUSION

As the electricity supply industry all over the world is moving towards deregulation, the philosophy of reactive power management and power system operation is expected to change greatly, so that the significance of competition, coordination between market participants, and security requirements can be identified. The costs and contribution of a reactive power supply are not precisely evaluated. Real time pricing of generator real power and minimizing the system real power transmission losses are important consideration. To control frequency, stability, security and voltage profile of the system and to ensure the generation and transmission, ancillary services like frequency control, network control and system restart are needed. Reactive power and voltage control is one of the ancillary services to maintain voltage profile through injecting or absorbing reactive power in electricity market.Therfore, Diferrent types of optimization techniques for reactive power optimization in use are discussed in detail.

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