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An Effectual Literature on ORPD in terms of Various Parametric Measures

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Abstract— this paper presents a widespread review of recent researches that are performed in the area of ORPD. For enhancing the stability of the voltages in the power system, the ORPD is considered. By the appropriate dispatch of obtainable reactive power sources, the ORPD issue aspires to decide the reactive power necessitate of the system. Here, the related works comprise of a standard categorization of ORPD issue. Besides, this paper presents a survey on the research gaps in ORPD using different methods, which are proposed in the past. The ORPD objectives comprise of reactive compensations, and adjusting generator voltage set points, to minimize the power losses, enhancing the voltage profile. Moreover, various parameters are considered namely power losses, system load, voltage deviation, load demand, voltage magnitude, computational time and optimal installation cost of the devices. The ORPD is considered as a complex optimization issue, which involves continuous and discrete variables. Most of the metaheuristic optimization is applied to the solution because of nonconvex, no linear, as well as multi-modal nature of the ORPD.

Keywords—ORPD; power losses; load demand; voltage stability; voltage pro*file*

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Acronym	Description
TLBO	Teaching–Learning-Based Optimization
BBDE	Bare-Bones Differential Evolution
CPVEIHBMO	Chaotic Parallel Vector Evaluated Interactive Honey Bee Mating Optimization
TCSC	Thyristor Controlled Series Capacitor
CKHA	Chaotic Krill Herd Algorithm
ORPD	Optimal Reactive Power Dispatch
FACTS	Flexible AC Transmission Systems
SF	Superiority of Feasible solutions
TCPS	Thyristor Controlled Phase Shifter
BBPSO	Bare-Bones Particle Swarm Optimization
SP	Self-Adaptive Penalty
SR	Stochastic Ranking
EC	E-Constraint
ECHT	Ensemble of Constraint Handling Techniques
SD	Small Disturbance
TS	Transient Stability
CPF	Continuation Power Flow
VSI	Voltage Stability Index
DE	Differential Evolution
ABC	Artificial Bee Colony
U-DNs	Unbalanced Distribution Networks
RO	Regional Operator
QOBL	Quasi-Opposition Based Learning
GA	Genetic Algorithm
MVar	Mega Volt Ampere
OPF	Optimal Power Flow

I. INTRODUCTION

Almost all electrical power systems around the world are from vertically regulated as well as integrated environment in order to decentralized environment [17]. Before for the payment purpose, only the real power is considered. Nevertheless, the pricing of the reactive power plays a crucial role in the context of open access markets. Through injecting or absorbing the reactive power, it is considered as one of the auxiliary services, which exploit to maintain the voltage profile [18].

From the reactive power sources [20], the system operator should schedule the reactive power support to meet the demands of the reactive power requirements [31], in the transmission to recompense the loss of the reactive power and within specified limits to maintain the voltages of the bus and distribution networks [21] [23]. In order to develop the economics of the power system as well as the security, the appropriate scheduling of reactive power plays a crucial role [24]. On the basis of the economic and safe operation of the power system, the RPD issue has an important influence. In a power system, it is one of the most important complex issues because it needs the reduction of the real losses of power [25]. With a lot of uncertainties, the ORPD is contempleted as a non-linear optimization issue. On the basis of the voltage and load level, the requirement of reactive power changes incessantly. In a power system [32] [33] with the control of reactive power, the voltage control is associated [26]. In the power system, the RPD as well to the control of reactive power have such benefits in the distribution system as reduction of real- loss of power and augmentation of power factor. Moreover, in the power system, the best operation is attained by using the several tap changing transformers reactive compensation devices namely continuous variables (i.e., automatic voltage regulators), and discrete variables (i.e., shunt capacitors/reactors). The ORPD becomes a complex combinatorial optimization issue concerning the non-linear functions having multiple local minima because of the occurrence of continuous and discrete control variables [27].

It is a process, which assigns the reactive power generation in order to reduce the real losses of power transmission [28]. It occurs when fulfilling a number of inequality as well as equality limitations by keeping all the voltages within the restrictions [29].

However, without the production cost may influence the whole cost of the production in the reactive power generation using the loss of the transmission. The equality restraints comprise the power flow equations, as well as inequality restraints, comprise lower and upper limits of voltage as well as capacity constraints in several reactive power devices namely banks generators, shunt capacitor, as well as transformer taps. In nature, the transformer tap ratios and outputs of shunt capacitors are discrete. The continuous variables are represented as the reactive power outputs of the generators as well as the bus voltage magnitudes, static VAR compensators, and angles. With a combination of continuous and discrete variables, the RPD issue is considered as a nonlinear optimization issue, which is a sub-problem of OPF [30]. The RPD issue is considered as a global optimization issue that intrinsically has non-linear, multiple local minima solution and discontinuous restraints.

II. LITERATURE REVIEW

In 2015, Ghasemi *et al.* [1] presented the Gaussian bare-bones with TLBO named as GBTLBO approach with its modified version, which was termed as MGBTLBO. This modified method was exploited for the ORPD issue in the IEEE power systems with the continuous and discrete control variables for the minimization in the transmission of power loss. For standard IEEE 14-bus and 30 bus systems, the viability, as well as the performance of the aforementioned methods, were revealed. Finally, the experimental results exhibit the optimization efficiency of the proposed approach over the existing technique such as BBDE and BBPSO algorithm.

In 2014, Ghasemi *et al.* [2] developed an enhanced multi-objective approach in terms of the multi-objective ORPD. In addition, they have proposed a novel multi-objective CPVEIHBMO to discover the possible best solution of the multi-objective ORPD issue by in view of operational limitation of the generators. In power industry, the optimal RPD issue was a significant problem with non-linear structure, which comprises of the both the discrete and continuous control variables. In addition, Pareto dominance theory was exploited in a multi-objective optimization issue. This theory was used in order to produce as well as sort the dominated and non-dominated solutions to attain superior design with different solutions. Here, to extract the optimal compromise solution, the fuzzy theory was utilized.

In 2016, Mukherjee *et al.* [3] proposed a meta-heuristic method, which was termed as CKHA. This method was exploited for the solution of the ORPD issue of power system integrates FACTS devices. On the standard 30-bus test system, the performance of the proposed approach was tested and implemented. Here, the power system framework was prepared with dual kinds of FACTS controllers such as a TCSC and TCPS. Finally, the experimental outcomes show that the proposed approach obtains superior solution over other conventional approaches.

In 2012, Mallipeddi *et al.* [4] presented an effectual constraint handling ORPD issue. Here, they have validated the performance of the various constraint handling approaches namely SP, SR, SF, EC, and the ECHT on ORPD. On IEEE 30-bus, 57-bus, and 118-bus systems, the proposed method was tested. Finally, the simulation outcomes show the significance of using a competent constraint handling approach in order to resolve the ORPD issue efficiently.

In 2011, Ramirez *et al.* [5] proposed ORPD scheme by exploiting steady state voltage stability implications. Also, they have examined dual power systems of the open publications, and the analysis of power flow was performed. Here, the initial conditions such as SD, TS, and CPF were examined. To confirm the effect of the optimization scheme, the steady state voltage stability analysis was exploited. The eigenvalue analyses, PV curves, and time domain simulations were employed to reveal the proposed method.

In 2012, Huang *et al.* [6] presented a hybrid method to resolve the ORPD issue. Through controlling a number of control variables, the ORPD was stated as the reduction of active power transmission losses. With the aid of both the discrete and continues variables, it was developed as a nonlinear constrained optimization issue. To deal with the ORPD issue, the proposed method merges probabilistic state transition and variable scaling mutation rule on the basis of the original DE algorithm that exploited in the ant system.

In 2016, Aparajita Mukherjee and V. Mukherjee [7] proposed a CKHA to resolve the best VAR dispatch issue of power system. As an objective either considering reduction of real losses of power else the total value of absolute voltage deviation or enhancements of voltage profile when fulfilling all the inequality and the equality constraints of the power system network. Here, the comprehensive studies of various chaotic maps were demonstrated.

In 2017, Jianqiang Hu, *et al.* [8] proposed a new distributed optimal dispatch approach in a microgrid. It was integrated the distributed compromise method in multi-agent systems as well as in the economic dispatch the λ-iteration optimization method was applied for the power systems. Specially, by adding up a virtual pinner the proposed method contemplates the global active power constraint.

In 2017, Hao Xing *et al.* [9] worked on energy storage devices model, which were not integrates the inter-temporal energy arbitrage to minimize the overall production cost. To split generators' burden, it was also provides a spinning reserve. Here, they presume the communication networks were robustly linked directed graphs to resolve the issue and presented a fully distributed method on the basis of the ‘consensus-like’ iterative approach as well as the alternating direction approach of multipliers.

In 2018, Shijing Ma *et al.* [10] worked on a novel multi-objective global optimal ABC method to undertake multiobjective economic dispatch problems. The proposed method was exploited to create a new individual in order to speed up the convergence property. Subsequently, a crowding distance task method was utilized to develop the population. At last, a straightforward constraint checking process was exploited to undertake that different constraint of economic dispatch problem.

In 2017, Wenjin (Jason) Li *et al.* [11] studied the OPD issue for a two source centralized EV BCS. It aims to satisfy the FB demands and to discover the cost minimal power dispatch. Moreover, they have formulated the OPD method as a dual step stochastic optimization in order to resolve it exploiting SAA. The formulation was easy however competent of confines the basic physical restraints as well as the convergence were sensibly speedy on an average PC. Exploiting real price data, the numerical simulations was presented to confirm the proposed OPD framework as well as shown the efficiency of the method regarding a few affecting factors.

In 2017, Peishuai Li [12] presented and adaptive robust ORPD method for the U-DNs in view of uncertainty occurred by DGs. The main intention of the proposed approach was to minimize the losses of the power, as well as the voltage in the narrow restrictions, was maintained. To assure the reliable operation of U-DNs, the possible area of DGs was considered as well as calculated a novel constraint. Subsequently, as an adaptive robust optimisation issue, the ORPD issue was formulated on the basis of the semi-definite programming. To resolve the proposed adaptive robust RPD framework, the cutting plane approach was introduced competently.

In 2012, M. Granada *et al.* [13] address a decentralized method in multi-area power systems on the basis of the Lagrangian decomposition for the ORPD issue. This method permit allows a self-governing other than synchronized operation of each RO for the power system. Additionally, in each area it aspires to protect the privacy of the data in the network. Few disadvantages of the decentralized ORPD issues and convergence properties as well as the viability of the decomposition approach to ORPD issue were examined.

In 2012, Abbas Rabiee *et al.* [14] developed a novel method for the ORPD issue. Moreover, the proposed method was obtained on the basis of the local voltage stability index, named DSY, it has a sturdy connection with the VSM. The primary reason of ORPD was to create the objective function effectual for enhancing the VSM on the basis of the strong correlation.

In 2013, Barun Mandal and Provas Kumar Roy [15] proposed a novel TLBO method to resolve the multi-objective ORPD issue and it was done by minimizing the voltage deviation, real losses of power, as well as voltage stability index. In standard TLBO approach, to accelerate the speed of the convergence as well as to develop a quality of the solution, QOBL theory was integrated. On standard IEEE 30- bus and IEEE 118-bus test systems, the TLBO and QOTLBO methods were examined.

In 2010, Zechun Hua *et al.* [16] presented a chance-constrained programming approach for ORPD, which contemplates random branch outages and uncertain nodal power injections. To resolve the issue, a solution approach was proposed and verified, which combines both the GA and probabilistic load flow. Finally, the experimental analysis on various test systems demonstrates that the proposed approach can avert over-compensation of reactive power as well as enhance margins of the voltage security. These benefits were attained in the suitable expenditure of a miniature enhance in active losses of the power while comparing with the outcomes of traditional deterministic ORPD.

III. DETAIL REVIEW ON ORPD METRICS

A. Classification of Methods Exploited in ORPD

The taxonomy classification of different methods exploited in ORPD is shown in Fig. 1. Here, the classification is mostly done on the basis of the evolutionary approach. Numerous optimization algorithms are adopted such as TLBO [1] and [15], Two stage stochastic optimization [11], and evolutionary algorithms in [4] [5] [6] and [10]. Nevertheless, the other approaches used in ORPD are CKHA [7], CPVEIH BMO [2], and Distributed algorithm in [8] and [9], adaptive robust reactive power dispatch method [12], lagrangian decomposition method [13], DSY [14], and chance constrained programming formulation [16].

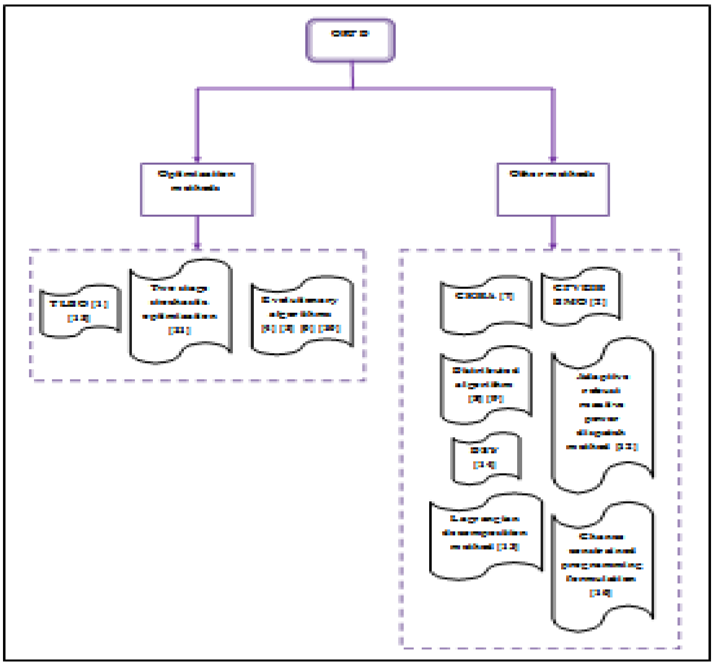

Fig.1: Taxonomy of different methods exploited in ORPD

B. Summary of Different Metrics Applied in ORPD

Table I shows the several performance metrics, which are reported in literature regarding the ORPD. Here, the metrics such as power loss, system loss, voltage deviation, load demand, voltage magnitude, computational time, optimal installation cost of the devices are exploited. Among the measures, the power loss is exploited by 66% of researchers. The voltage magnitude, optimal installation cost of devices, voltage deviation and computation time metrics are exploited by the 20% of researchers. However, the system load and load demand are exploited by 13% of researchers. The other metrics are exploited by 40% of researchers.

TABLE I. ARIOUS PERFORMANCE METRICES REPORTED IN THE LITERATURE WITH RESPECT TO THE ORPD

Citation	Power loss	System load	Voltage deviation	Load demand	Voltage magnitude	Computational time	Optimal installation cost	Others
[1]	√	√						
[2]	√		√					√
[3	√							√
[4]	√		√					
[5]	√	√						
[6]					√	√		
[7]	√			√		√		
[8]							√	

[9]								√
[10]								√
[11]								√
[12]	√				√			
[13]							√	
[14]	√			√				
[15]	√		√					
[16]	√					√		√

C. Maximum Performance Value for Different Metrics

The results for the maximum performance value for different metrics of ORPD are tabulated in Table II. Among the performance measures, the power loss is considered as most widely exploited metrics in ORPD. Here, the power loss exploited in [1] [2] [3] [4] [5] [7] [12] and [14] attained maximum value of 4.7802. The system load exploited in [1] and [5], which attained 3.15 maximum value. The voltage deviation used in [2] [4] and [5] attained 0.739736. The load demand exploited in [7] [14] obtained maximum value of 73.5. The voltage magnitude used in [6] and [12] attained the maximum value of 1.10. However, the computation time in [6] and [7] is 5.9. The optimal installation cost of devices [8] and [13] is 8.6431. The other metrics such as TVD [3], energy level [9], fuel cost [10], solution for emission [10] and conventional power sources [11] are 0.11724 p.u., 80 MW, 606.4028, 0.194267, and 317.86 kW.

TABLE 2 PERFORMANCE ANALYSIS OF THE DIFFERENT METRICES

Citation	Measures	Maximum value
[1] [2] [3] [4] [5] [7] [12] [14] [16]	Power loss	4.7802MW
[1] [5]	System load	3.15
[2] [4] [15]	Voltage deviation	0.739736
[7] [14]	Load demand	73.5 MVAr
[6] [12]	Voltage magnitude	1.10 p.u
[6] [7]	Computational time	5.9
[8] [13]	Optimal installation cost	8.6431
[3]	TVD	0.11724 p.u.
[9]	Energy level	80 MW
[10]	Fuel cost	606.4028
[10]	Solution for emission	0.194267
[11]	Conventional power source	317.86 kW
[11]	Renewable power source	300 kW

D. Categorization of Different Objectives in ORPD

This section states the categorization of objective function in ORPD. Fig 2 illustrates the categorization of objective functions, which is exploited in ORPD. The objective function such as power loss, network loss, power demand, generation cost, fuel cost, and reactive power injection are exploited. Here, the power loss is most commonly used objective function.

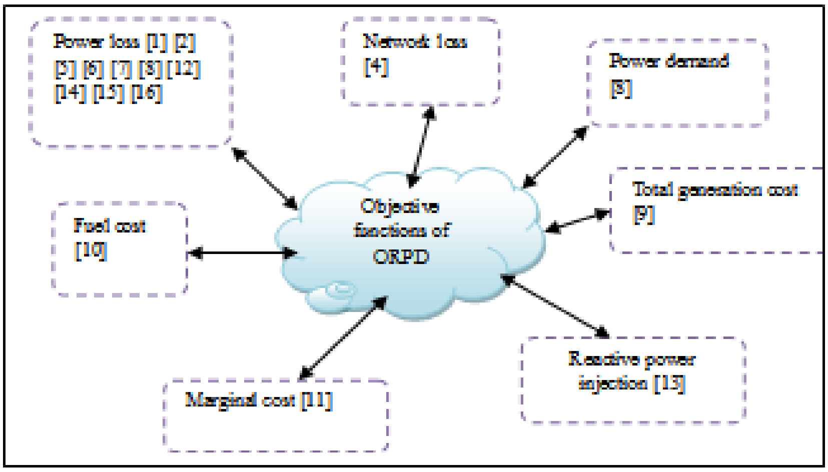

Fig. 2 Categorization of different objective function exploited in ORPD

IV. RESEARCH GAPS AND CHALLENGES

There are various factors, which makes the operating reactive power services with complexity in a competitive market model. However, the Reactive power wants to offers locally, therefore, the importance of single MVAr of reactive power, which is not similar ubiquitously the system. Therefore, if a reactive power market is developed as same as the real power market, ISO finish up with a stack of minimum-priced that presents from locations, which are disadvantageous from the system contemplations. Hence, the reactive power markets require a novel method that considers both offer such as the location and prices of the resources. As ancillary services, the Deregulated systems require to distinguish reactive power from sources except synchronous or generators condensors. The ancillary services are considered as the alterations at the policy level are, which are essential to comprise other reactive power sources for instance reactors, capacitors, FACTS devices, etc, The reactive power providers have the ability to determine the buses, which constantly need high reactive support. The provider positioned in such bus has the important chances to spoil in gaming as probable players in the system, which are inadequate. To decide the reactive power market price, if a consistent price sale is exploited, the providers have enticements to present their accurate opportunity and costs. As each provider obtains a price maximum than its available price, surrendering an offer price than its costs will interpret the provider to the risk, which the offer is not chosen with an ensuing revenue loss. Hence, provider's presents obvious enticements to offer prices that are equal to their costs as well as the quantities equal to their capability. In high demand areas, it can be disputed which nodal reactive power pricing approaches may inspire novel reactive power savings as well as. Thus, market power concerns are minimized. Nevertheless, the stated pricing methods will indicate a segment of the accurate cost of the reactive power service, which is related with costs of the fuels of the real power. The opportunity and capital cost components of reactive power are not considered. Hence, this kind of pricing will lead to highly unstable markets with the huge volatility of nodal prices. Thus, the design of a reactive power market is a significant problem, as well as the potential for market power and gaming require to be eradicated hence, the market functions resourcefully.

V. CONCLUSION

This paper has presented several concepts that were involved in the ORPD, which was performed by numerous researchers. The ORPD plays a vital role in attaining economic as well as secure operation in the power systems. In the operations and planning of power system, the RPD was considered as a fundamental task. In addition, the ORPD was supported to reduce the losses of the power, enhances stability of the voltage, and minimizes the cost. In addition, this paper presented a concise literature survey about the ORPD as well as this paper presents a comparative study on various optimization methods, which were utilized in ORPD. In addition, several parameters were represented in this paper namely power losses, system load, voltage deviation, load demand, voltage magnitude, computational time and optimal installation cost of the devices.

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