An Enhanced Review on Power Loss Minimization in Power System

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***Abstract*— The enlarged load demand entails numerous challenges in DN. Inadequate reactive power in DN paves the way to increased bus voltage minimization and power losses. The recognition of the size, location, count, and kind of capacitors to be positioned is of huge importance, as it minimizes energy and power losses, raises the capacity and enhances the feeder voltage profile. Accordingly, this survey intends to review various topics to solve power loss minimization issues in the network. In addition, the algorithmic classification for the surveyed papers is analyzed and described. Also, the performance measures and the maximum performance achievements are analyzed and illustrated in this survey. Finally, the research issues of the suggested model are also discussed briefly.**

Keywords— ***Power loss minimization*; *Size; Location; Algorithms; Performance measures.***

Nomenclature:

Acronyms	Description
DG	Distributed generator
NRPF	Newton Raphson Power Flow
PV	Photovoltaic
BFA	Bacteria Foraging Algorithm
SCs	Switched shunt capacitors
ESs	Energy storages
LTCs	Load tap changers
RPL	Real Power Loss
GA	Genetic algorithm
FA	FireFly algorithm
MMG	Multi-MicroGrid
RCGA	Real coded genetic algorithm
SVRs	Step voltage regulators
IPSLP	Interior point successive linear programming
SDN	Smart distribution network
DR	Demand response
GU's	Generation units
HS-PABC	Heuristic search Algorithm
HSA	Harmony search algorithm
PABC	Particle artificial bee colony algorithm
APL	Active power loss
dFCM	Dynamic Fuzzy C-Means
DNs	Distribution Networks
RIN	Reduced islanded MG network
VSM	Voltage stability margin
IMGR	Islanded Microgrid Reconfiguration
EA	Evolutionary Algorithm
DE	Differential evolution
RPLM	Real power loss minimization
IPM	Interior point method
PSO	Particle Swarm Optimization
ORPD	Optimal Reactive Power Dispatch
TVR	Thyristor Voltage Regulator
DFR	Distributed feeder reconfiguration
PFC	Power factor correction
CSA	Cuckoo search algorithm
VLFQ	Variable Locations Fixed Capacitor banks
VLVQ	Variable Locations Variable sizing of Capacitors
HTSFGDPS	Hybrid Topology Scale-free Gaussian-Dynamic PSO
BA	Bat Algorithm

I. INTRODUCTION

In Power, system comprises of GU, transmission, and distribution. When the power is being transmitted from one location to another, there are possibilities of the problems on concerning the losses. The behavior of all the power system [1] [2] [3] could be accessed by carrying out load flow analysis that evaluates the flow of power via the lines of the system. There are diverse techniques to find out the flow of load namely, Newton Rap son, Gauss-Seidel process and the Fast Decoupled technique. From previous years, for determining solutions of digital computer, numerous improvements had been done for load flows in power system. Accordingly, electrical losses in DN [4] [5] systems are termed as, nontechnical losses and technical losses.

DG [6] [7] [8] is one of the major power producing stations that are gratifying the required increase in power. DG can be linked or disconnected from the network easily. This is the most important improvement in DG, and it has high reliability. In addition, most excellent operation and planning of DG [9] [10] include a lot of benefits such as economic savings, greater reliability, power losses reduction and high quality of power. Positioning DG at appropriate location acts a major role in DN system. Appropriate sizing and allocation of DG's are very essential for in attaining the greatest benefits. Suppose, if the DG is located at an inappropriate location in DN system there is a probability of raise in losses [11] [12].The optimization techniques are classified into numerical, analytical and fuzzy. Moreover, 2/3 rule is a logical technique, which was adopted for best possible installation of a single DG. Furthermore, several optimization techniques were introduced for determining the sizes and locations of various DGs to attain size and power loss minimization [13] [14] [15].

Accordingly, optimization techniques are very helpful for demonstrating the most excellent solution for a specified DN [16] [17], and it can be very constructive for the system developing engineer when managing with the rise of DG penetration, which is occurring these days. DG can be described as "an electrical power source connected directly to the consumer side meter. It may be simply stated as the small-scale electrical market". In the existence of DG [18] [19], the setting up of electrical system necessitates numerous parameters such as the most excellent technology to be modeled to function with numerous units and the capacity of the units, the optimal location, etc. Hence, the impact of DG [20] [21] on operating properties of the system namely, voltage profile, electric losses, reliability, and stability requires to be evaluated for reduced power loss in the DG system [22] [23].

This survey has reviewed various works related to the power loss minimization issues. Here, various algorithmic classifications, which are adopted in the surveyed papers, are demonstrated along with their performance measures. Along with it, the maximum performances achieved by the various works are also portrayed in this survey. The paper is organized as follows. Section II analyzes the various related works and reviews done under this topic. In addition, section III describes the reviews on various constraints, and section IV presents the research gaps and challenges. Finally, section V concludes the paper.

II. Literature Review

A. Related works

In 2018, Majid [1] has introduced a scheme, where the optimal synchronization of LTCs, SVRs, SC's and ESs with diffusion of PV energy resources for reducing the loss of energy and enhancing voltage profile simultaneously are accomplished by means of GA. The GA was introduced to determine the desired settings of the SCs, SVRs, and LTCs, together with the energy storage dispatch. In addition, the simulation outcomes obviously display that the close synchronization maintains voltage at consumer terminals in certain limits, underneath high penetration levels of solar-fuelled generation. Evaluation amongst adopted technique with EA and PSO were examined that displays the suggested procedure has improved outcomes than conventional methodologies.

In 2018, Bala *et al.* [2] have a technique to reduce the RPL of a power system by means of a novel procedure recognized as FA by enhancing the parameters for control namely, UPFC location and transformer taps. Accordingly, IPSLP method and RCGA were deliberated here to distinguish the outcomes and to demonstrate the effectiveness and authority of the suggested FA for the better optimization of RPL. Likewise here, BFA was implemented to authenticate the outcomes of the suggested algorithm.

In 2018, Farid *et al.* [3] have established a stochastic multi-layer approach for a MMG dependent SDN. Moreover, the entire network restraints have been considered to calculate the consequence of the RPL. In addition, DR schemes have been measured in the optimization procedure, which was one of the characteristics of the SDN. At last, executions were made to establish that how the suggested technique encourages every MG as their chief GU's. Furthermore, the performed outcomes demonstrate the variations in the schedules of the MGs regarding the power loss.

In 2017, Zongo and Anant [4] have introduced a solution to an issue of optimal distribution of DG for multi-objective minimization of RPL, voltage deviation, and reactive power generation. The issue was resolved by exploiting a method designed by an amalgamation of PSO and NRPF approaches. This hybrid approach exploits the better searching ability of PSO and the capability of NRPF technique to discover best solution when primary points were proficiently selected to arrive at a global optimum solution. The bus, which contributes the least value, was measured as the best runner for DG installation. Accordingly, here, DG exploited was from wind energy technology.

In 2017, Muthukumar and Jayalalitha [5] has adopted a technique based on the importance of effectual HS-PABC depending on HSA and PABC in the perspective of improving the performance of DG via network reconfiguration together with optimum distribution and sizing of shunt capacitors and DG. Finally, the outcomes attained on hybrid HS-PABC technique and the benchmark HSA exposes the effectiveness of the offered methodology that assures to accomplish best optimum solution along with reduced iteration.

In 2016, Hassan et al. [6] have adopted ANN for reconfiguring the power DG networks to attain the optimum alignment in which the APL was negligible. In addition, the offered ANN was minimized in size by changing the input space with kernels by means of an offered improved dFCM clustering procedure to attain a new model. The executed outcomes were distinguished to the outcomes attained by the conventional technique which was the switching process. The relative outcomes obviously confirm that by means of the offered framework for DG reconfiguration, an enhanced structure with increased accuracy was attained. Such characteristics display that the offered model can be efficiently exploited for power DG networks.

In 2016, Muthukumar and Jayalalitha [7] has adopted a technique to reduce the power losses in radial DG networks and enables an improvement by defining optimum locations, optimally sized DG by hybrid HSA methodology. To prevail over the disadvantage of slow and premature convergence of HSA over multi-model background, the PABC was exploited to improve the harmony memory vector. Finally, the simulation outcomes expose the effectiveness of the suggested hybrid procedure in attaining best solution for synchronized allocation of DG and shunt capacitors in DN's.

In 2016, Aggelos *et al.* [8] have introduced a new scheme concerning the penetration of DG in DNs for minimizing the loss. In addition, a Local PSO variant process was established so as to describe the best reactive and active power production and consumption necessities for the ideal amount of nodes, which attain loss minimization. Therefore, the suggested methodology offers the optimal sizing of DGs in a better way. The outcomes designate the best number, capability, and locations of DG units that were designed at the same time. At last, the influence of the predetermined quantity of allowable power flow to the best solution was also scrutinized and better outcomes were attained.

In 2016, Hasan et al. [9]have established an enhanced indicator to approximate the VSM of a two-bus system. Accordingly, a novel conception called RIN, was deployed for simplification of the suggested index to n-bus islanded MGs and an enhanced power flow process was also adopted for splitting these networks. In addition, IMGR was suggested as an functioning tool for enhancing loading ability in addition to reducing power losses by means of HSA model. Finally, the performance and efficiency of the recommended technique were established, and better outcomes were attained.

In 2015, Youcef et al. [10] have introduced a DE method with numerous trial vector generation policies for RPLM in power system. Here, the suggested method identifies control variable to be switched, for RPLM in the transmitting systems. In addition, the DE technique was scrutinized, and the attained outcomes were distinguished with two other approaches, that is, IPM, PSO and other approaches. Finally, the evaluation establishes the prospective of the recommended scheme and demonstrates its efficiency for resolving the ORPD problem.

In 2015, Gian et al. [11] have analyzed a control system depending on GA on a part of the actual electric DN. The combined optimization of both PFC and DFR was also determined using this model. The PFC was accomplished by regulating the phases of the DGs and the output voltage of the TVR. The DFR was implemented depending on a graph-based process, which was capable to discover all the probable radial alignments of the DN. Finally, the attained outcomes encourage the usage of derivative-free approaches, presenting that the performances attained by the optimization measures were very adjacent with respect to the objective function values when compared with other conventional schemes

In 2015, Thuan et al. [12] have adopted a reconfiguration approach depending on a CSA for reducing APL and the increasing the voltage magnitude. Related to conventional approaches, CSA technique includes lesser control factors and was more efficient in solving the issues. In addition, the efficiency of the suggested CSA was established on three diverse DN systems and the attained outcomes was distinguished with other techniques and finally, the execution outcomes display that the recommended CSA was an effectual and capable for DN reconfiguration issues.

In 2015, Satish et al. [13] have suggested two novel processes to resolve optimal allocation of capacitors in radial DN systems using techniques, namely, i.e., VLFQ and VLVQ for RPL minimization and network savings expansion. In addition, the suggested methodologies were found to be proficient of generating high-quality solutions with improved convergence performance. Thus, the adopted technique was found to offer better outcomes when compared with other schemes.

In 2014, Imran et al. [14] have established a novel effectual technique to resolve the network reconfiguration with an intention of enhancing voltage profile and power loss minimization of the DN system. In addition, the executed outcomes were distinguished with other conventional approaches. It was noticed that the performance of suggested technique was improved than the other approaches with respect to the quality of solutions. Moreover, various abnormal cases were also measured throughout reconfiguration of DN to analyze the efficiency of the established technique and the outcomes attained were found to be promising.

In 2014, Wang et al. [15] have adopted a HTSFGDPS process for APL minimization issue of power system. In addition, it facilitates the scheme to include the robust searching ability and rapid rate of convergence at the similar time. Accordingly, the implemented topology reveals disassortative collaborating property that could develop the swarm population variety. In addition, the adopted scheme concerns on a novel amalgamation of complex network theory in addition to its application in electric power system. Finally, the accessible technique was confirmed and the arithmetical results, distinguished with conventional schemes, display that HTSFGDPS could discover superior results with advanced probability and convergence rate.

III. Review on Various Constraints and Algorithms

A. Algorithmic Classification

The various algorithms adopted in each reviewed paper includes GA, FF algorithm, LS algorithm, PSO algorithm, HSA algorithm, dFCM algorithm, PABC algorithm, DE algorithm, CS algorithm, BA & CS algorithm, FWA algorithm, HTSFGDP algorithm. Accordingly, GA algorithm was adopted in [1] and [11]. FF algorithm was exploited in [2], and LS approach was implemented in [3]. In addition, PSO algorithm was presented in [4] and [8], and HSA was adopted in [5] and [9]. dFCM algorithm was implemented in [6], PABC algorithm was exploited in [7]. Moreover, DE algorithm was adopted in [10], and CS scheme was presented in [12]. Also, BA&CS was implemented in [13], FWA algorithm was implemented in [14], and HTSFGDP algorithm was implemented in [15]. The brief description of the reviewed works is represented by Fig. 1.

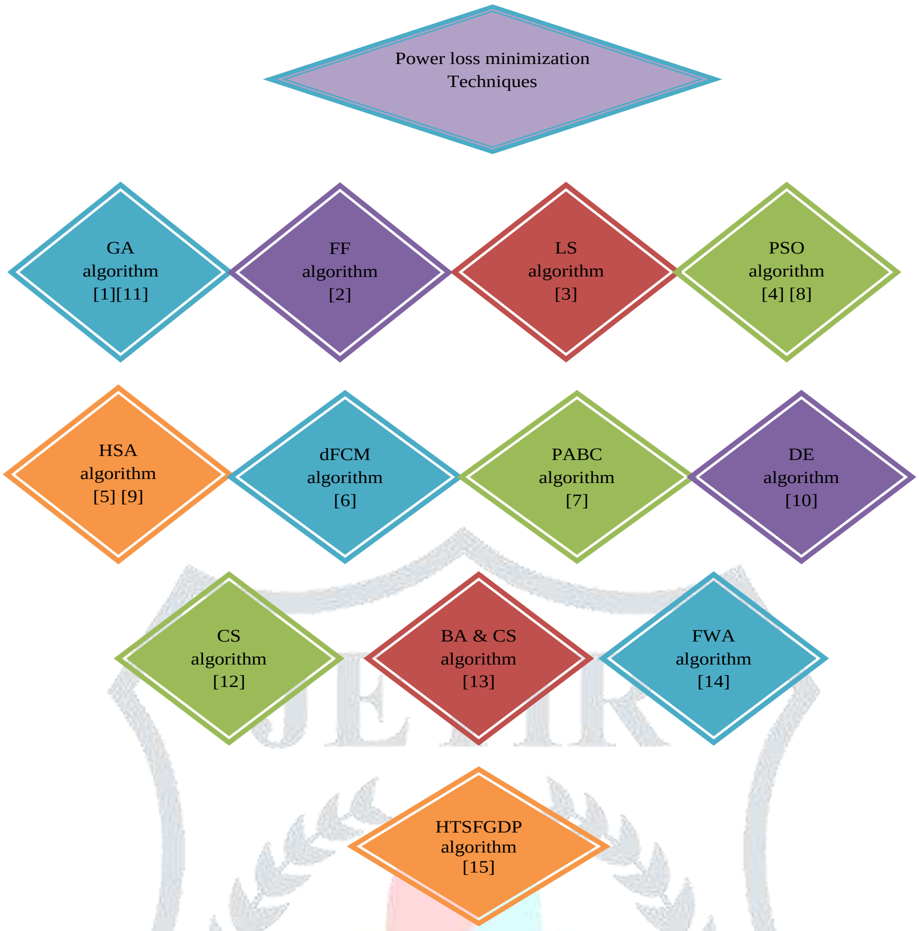

Fig. 1. Various schemes of the reviewed works

B. Maximum Performance Achieved

The maximum performance achieved by various performance measures is given by Table I. The power measure adopted in [10] has attained an optimal value of 300.96MW. In addition, voltage adopted in [1] has attained a higher percentage of 21.98V. Current implemented in [1] has attained a higher value of 5.3A and RPL implemented in [7] has attained a higher value of 14.21KW and cost implemented in [3] has attained a higher value of 765.96$. Accordingly, APL and time have attained a higher value of 11.71KW and 0.51Sec respectively. Also, Penalty factor and VSI has presented increased values of 10 and 0.99, which were determined in [8] and [9]. Likewise, Frequency, Fitness, Transformer tap setting and population size was measured in [9] [12] [4] and [2], and it has adopted a value of 59.926Hz, 0.728, 1.1 and 30. Similarly, Load level was deployed in [5], and they have attained optimal values of 100%. DG size and Capacitor size was deployed in [7], and they have attained optimal values of 1245KW and 700kVAR. Also, Convergence tolerance and Inertia lower limit were measured in [8], and it has adopted a value of $10^{-7}$and 0.4. In addition, Crossover fraction was deployed in [11], and it has an attained optimal value of 0.8.

TABLE I. MAXIMUM PERFORMANCE ACHIEVED BY THE REVIEWED WORKS

Measures	**Maximum value**	**Citation**
Power	300.96MW	[10]
Voltage	21.98V	[1]
Current	5.3A	[1]
RPL	14.21KW	[7]
Cost	765.96$	[3]
APL	11.71KW	[9]
Time	0.51Sec	[6]
Penalty factor	10	[8]
VSI	0.99	[9]
Frequency	59.926Hz	[9]
Fitness	0.728	[12]
Transformer tap setting	1.1	[4]
population size	30	[2]
Load level	100%	[5]
DG size	1245KW	[7]
Capacitor size	700kVAR	[7]
Convergence tolerance	10^{-7}	[8]
Inertia lower limit	0.4	[8]
Crossover fraction	0.8	[11]

C. Performance Measures

The performance measures contributed in each paper are described in this section. The performance measures such as cost of congestion, power, voltage, current, RPL, cost, APL, time, penalty factor, VSI, frequency, fitness, transformer tap setting were analyzed in the surveyed works. Accordingly, power was exploited in [1] [3] [4] [5] [10] [12] [15] that offer about 46.67% of the total contribution. In addition, voltage was adopted in [1] [4] [12] [14], which provide about 26.67% of the total contribution. Current was measured in [1], which provides about 6.67% of the total contribution. RPL was exploited in [2] and [7] that offer about 13.33% of the total contribution. Likewise, cost was measured in [3], which provides about 6.67% of the total contribution. Also, APL was deployed in [5] [9] [10] [11] [12] [13] and [14] that offer about 46.67% of the entire contribution. Time was adopted in [6] [10] [14], which provide about 20% of the total contribution. Penalty factor, VSI, fitness was measured in [8] [9] and [12], which provides about 6.67% of the total contribution respectively. Similarly, frequency was adopted in [9] and [13], and transformer tap setting was determined in [4] and [15] respectively. Other contributions such as population size, load level, DG size, capacitor size, convergence tolerance, inertia lower limit and crossover fraction were analyzed in [2] [5] [7] [7] [8] [8] and [11]. The various performance measures adopted in the reviewed papers is given by Fig. 2.

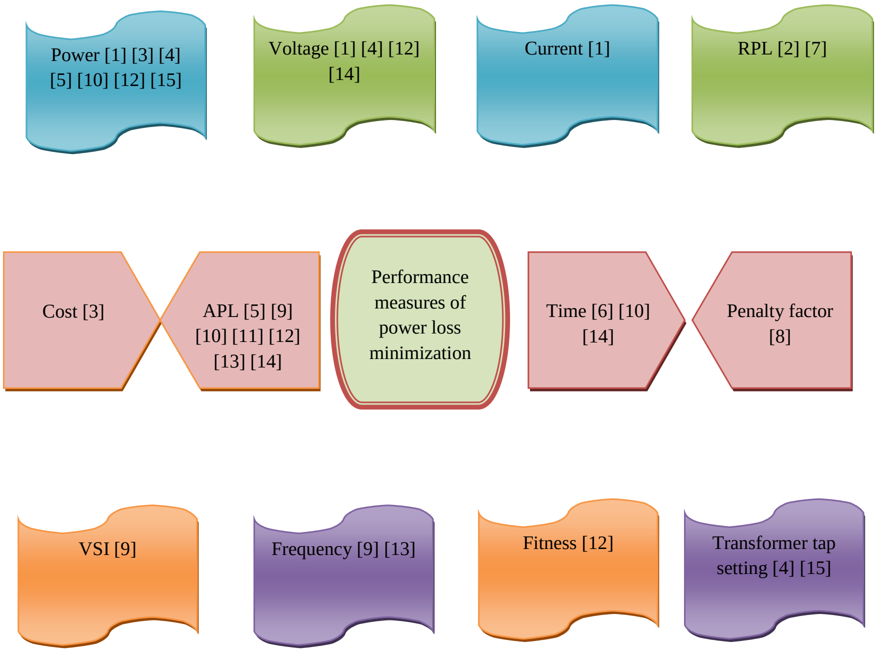

Fig. 2. Various performance measures of the reviewed works

D. Analysis on Test Bus Systems

The test bus systems that were contributed in each paper are described by Fig. 3. Accordingly, IEEE 14 was adopted in four works, i.e. 26.67% of the entire contribution. Also, IEEE 33 was adopted in four works, which offers about 26.67% of the entire contribution. IEEE 119 and IEEE 69 bus systems are implemented by two works, and it has offered about 13.33% of the total contribution. IEEE 30 was adopted by three works, which offers about 20% of the entire contribution. Also, IEEE 123, IEEE 39, IEEE 34 and IEEE 85 were implemented in each paper, and they offer about 6.67% of the entire contribution.

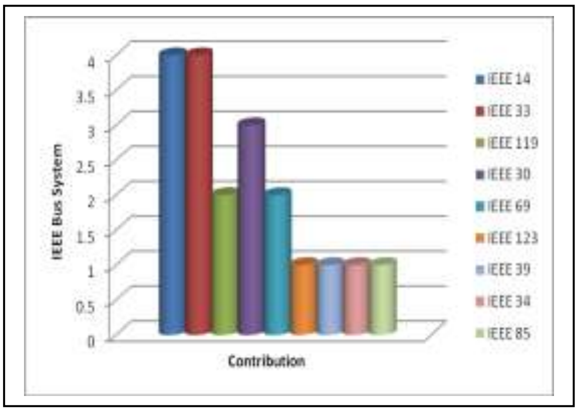

Fig. 3. Various IEEE bus systems adopted in the reviewed works

IV. Research Gaps and Challenges

Growing demand for electrical power owing to the modern developments has entailed several challenges namely, transmission loss, voltage instability, and power factor variations on power systems. The recent evolution has resulted in rising demand for electrical power in each sector of life continuously [1]. The requirement has imposed numerous challenges on the power production owing to the major variations in the energy market as power demand is increased than the accessibility [2]. The challenges comprise of overloading of distribution and transmission lines, voltage stability loss and high APL [3]. These challenges have subsequently exaggerated the performance of functioning loads and resulted in power failures. The determination of location, size, type, and count of capacitors to be positioned is of huge importance, since it minimizes energy and power losses, raises the potential capacity of the feeders and enhances the voltage profile.

Several techniques for resolving the APL problem in terms of loss minimization have been suggested in many of the conventional works. Permitting for, numerous capacitors at inappropriate position will further raise the losses. Anyhow, the reduction of losses does not provide any guarantee of increasing the benefits unless the issue is defined well. In addition, fortification of a DN turns out to be more complex and challenging once numerous DGs are linked in RDN. The difficulties in system security are growing owing to the correlation of DGs, as there are variations in power flow. In addition, challenges like alteration of relay reach, bi-directional power flow, islanding, reclosing, security in the existence of current restricted converters and temporary arc faults require to be dealt in the future.

V. Conclusion

Power loss reduction was a significant characteristic in DN system in which the load deviation was more distinguished with other systems. There were various techniques to reduce the power loss like capacitor placement, DG placement, and load balancing and so on. Among such techniques, DG placement was found to be more advantageous since it was related directly to RPL. Accordingly, in this survey, numerous papers were analyzed, and the related techniques adopted in each surveyed paper were described. In addition, the performance measures focused in each paper were illustrated, and along with it, the maximum performance measures attained were also illustrated. Thus the survey provides the detailed analysis of the power loss minimization from the reviewed papers.

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