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A Comprehensive Literature Survey on Power Loss Minimization Techniques and Methods in Electrical Distribution Networks

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***Abstract*—In recent years, electrical networks are operating under over loaded condition due to the exponential growth in the load. Due to poor voltage regulations, lack of up-gradation in the electrical infrastructure, load shedding and stochastic loads connected in the system causes instability in the network operations. Many researchers, policy makers, power suppliers, energy managers are actively participating to find the potential solutions to address these issues. In this paper, detailed literature review is carried out to list the optimization techniques and different methods used in the minimization of power loss. The DG placement, FACTS, DTC, line reconfiguration and re-conductring techniques are discussed in detail.**

***Index Terms*— Distributed Generation, Line Reconfiguration, Capacitor Placement, FACTS, Distributed transformer, Line Reconductoring, Voltage Stability, Optimization techniques, Power loss Minimization.**

***Nomenclature*—**

RES	Renewable Energy sources	AQIEA	Adaptive Quantum inspired Evolutionary Algorithm
DG	Distributed Generation	PSO	Particle Swarm Optimization
DTC	Distributed Transformer	AM	Analytical method
AVR	Automatic Voltage Regulator	MABC	Modified artificial bee Colony
FACTS	Flexible AC Transmission Systems	CS	Cuckoo Search
SVC	Static Var Compensator	GA	Genetic Algorithm
TCSC	Thyristor Controlled Series Compensator	TS	Tabu Search
UPFC	Unified Power Flow Controller	BSO	Binary swarm optimization
STATCOM	Static Synchronous Compensator	VPI	Voltage Performance Index
SSSC	Static Synchronous Series Compensator	SA	Simulated Annealing
IPFC	Interline Power Flow Controller	HSA	Harmony Search Method
TSR	Thyristor Switched Reactor	MCMF	Minimum Cost Maximum Flow
TCR	Thyristor Controlled Reactor	GT	Game theory
IWD	Intelligent Water drop	BA	Bat Algorithm
AIS	Artificial Immune System	ANN	Artificial Neural Network
BSOA	Backtracking search optimization algorithm	SFLA	Shuffled Frog Leaping Algorithm
GWO	Grey Wolf Optimizer	OPF	Optimal Power Flow
SOS	Symbiotic Organisms Search	ALO	Ant Lion Optimization
DEA	Differential Evolutionary Algorithms	IWO	Invasive Weed Optimization
ABC	Artificial Bee colony	NLP	Non Linear Programming

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HPSO	Hybrid Particle swarm optimization	DEA	Differential Evolutionary Algorithms
ACO	Ant Colony Optimization	HBMO	Honey bees Mating Optimization
NSG	Non-dominate sorting Genetic	EP	Evolutionary Programming
BFO	Bacterial Foraging Optimization	GSA	Gravitational Search Algorithm
FO	Firefly Optimization	FLO	Flower Pollination Optimization
EA	Evolutionary Algorithm	DER	Distributed Energy Resources

I. INTRODUCTION

The minimization of the T&D power loss is very much essential for all countries to enhance their electrical network reliability including financial benefits. In the present scenario, power utilities are showing more interest in reducing power loss in order to achieve enhanced quality of power supply in the deregulated market [1]. Improvising the stability and reliability with cut down in the electricity prices helps the electrical utilities to sustain in the competitive markets.

Many soft-computing techniques have been developed for solving complex electrical problems. Such as GA, FKBC, PSO, ANN, ABC, TS etc that are used for optimal placement of DG, PMU, capacitor, changing network topologies, DTC, FACTS placement etc.

This paper helps the researchers to understand the recent developments/ techniques deployed in the electrical network for overall enhancement of the network performance.

A. Dispersed/Distributed Power Generation

The distributed/ dispersed power generation is a controlled power generating units from few kW to MW at the load points to support the voltages profiles and reduce the burden on the electrical infrastructure to certain extent. The interconnection of millions of small DG's plays key role in enhancing the efficiency of the network. Use of grid computing, data mining and machine learning helps to predict the load and generation for few hours ahead so that economical scheduling and dispatching can be achieved. It also increases the individual power generating entity participation actively [2].

The interconnection of these small generating units to the grid is crucial which depends upon DG type, size and allocation in achieving reduction in power loss. The DG's are classified as type-I, II, III and IV depending on their power generation capacity [3]. The FKBC, PSO, GA, ABC, TS etc. are the optimization techniques that are used for optimal sizing and placement of DG which are tested on various networks. The Table. I shows the various DG sizing and placement using soft computing techniques on standard test systems.

TABLE I. DG PLACEMENT

Sl	Algorithm	Objective functions	Test system	DG Number	DG Power	Load type	DG variables	Ref
1	Fuzzy logic	Power loss minimization Enhancement of voltage profile	33 bus	Multiple	type-iv	constant	Size, Placement	4
2	Fuzzy logic	Reduction of power loss Enhancement of voltage	24 bus	single	type-iv	constant	Placement	5
3	GA-TS	Benefit/cost relation maximization	69	Multiple	type-iv	constant	Size, Placement	6
4	GA	Maximization of voltage profile Minimization of power loss	30	Multiple	type-iv	Stochastic	Size, Placement	7
5	PSO	Power loss minimization Improvement of voltage stability	69	Multiple	Wind and solar power	constant	Size and placement	8
6	PSO	Maximization of voltage profile Minimization of power loss	33 bus	Multiple	type -i	constant Industrial Commercia l residential	Size, Placement	9
7	EA &GT	Minimization of power loss Increase in the income	33 and 69	Multiple	type-iv	constant	Size and Placement	10
8	ABC	Enhancement of voltage Power loss reduction	69	Multiple	type -i	constant	Size and Placement	11
9	AQIEA	Minimization of power	33	Single	type-iv	constant	Placement	12

		loss						
10	EP	Minimize the power loss	33	Multiple	Wind power	constant	Placement	13
11	GSA	Power losses reduction Voltage profile improvement Environmental impact reduction	69	Multiple	type-iv	constant	Size and Placement	14
12	Fuzzy-PSO	Enhancement of voltage Power loss reduction	69	Multiple	type-iv	constant	Size and Placement	15
13	SOS	Minimization of power loss	33,69	Multiple	type-iv	constant	Size and Placement	16
14	BPSO	Enhancement of voltage Power loss reduction	69	Multiple	type-iv	constant	Size and Placement	17
15	HSA	Power loss reduction	33,69	multiple	type-iv	Variable load	Size and Placement	18

B. Network/Line reconfiguration

The line/ network reconfiguration deals with changing the network topology depending on the total load and power generation. The express feeders also come under network reconfiguration to reduce the burden on the network [19]. Around 40-70% of the networks are radial in the nature supplying power from centralized generation to loads which are located miles of distance away from the generating stations. This leads to over loading of electrical infrastructure causing poor voltage regulation and high power losses in the network [20].
The optimal line reconfiguration or change in the network topology can reduce over 20-60% power losses in the network. The HSA, PSO, AIS, DEA, ACO, ABC methods are used in the network reconfiguration. Table.II Enlists the soft computing techniques employed for network reconfiguration.

TABLE II. NETWORK/LINE RECONFIGURATION

Sl	Optimization Technique	Objective functions	Test system	Load type	Ref
1	ACO	Minimise the power loss Maximize the voltage profile	32,69	Constant	21
2	HSA	Reduction of total power loss	33,119	Constant	22
3	AIS	Minimise the power loss	14	Constant	23
4	HMS	Minimise the power loss Enhance the voltage profile	33	Constant	24
5	MCMF	Minimise the power loss	83,135,201,837	Constant	25
6	PSO	Minimise the power loss Improve the voltage profile	33,69	Variable	26
7	DLF	Reduce the energy loss Boost the voltage profile	33	Constant	27
8	ELA	Minimize the power loss	9	Constant	28
9	GA	Reduction of total power loss With improvement in the voltage profile	33,69	Constant	29
10	TS	Minimise the power loss Maximize the voltage profile	69	Constant	30
11	ANN	Minimise the power loss Enhancement of the voltage profile	33	Constant	31

C. Flexible AC transmission Systems(FACTs)

FACT devices are the rapid action power electronic devices which are used for congestion management. The optimal placement, capacity and type of FACT devices plays important role in ensuring reliable and stable operation of the electrical network [32]. Size of the network and selection of the FACT devices plays key role in ensuring the efficient operation of the network. The SVC, UPFC, STATCOM, TCSC SSSC, UPQC etc are main

FACT devices primarily used in the power system to enhance transfer capability of lines and reducing burden on network. Table-III shows the optimal placement of FACT and optimization techniques involved in allocation.

TABLE III. FLEXIBLE AC TRANSMISION SYSTEMS (FACTS)

Sl	Optimization Technique	Objective functions	Test system	Device	Ref
1	ELA	Minimize the power loss Enhancement of voltage profile	24	STATCOM	33
2	PLI	Minimize the power loss Maximize the voltage profile	10,33,69	D-STATCOM	34
3	SAF	Minimize the power loss	14,33	UPFC	35
4	VSI	Enhancement of the voltage profile	30	TCSC	36
5	GA	Minimize the power loss	33,69	UPQC	37
6	Fuzzy	Minimize the power loss Boost the voltage profile	14	UPFC	38
7	FPA	Minimize the power loss Enhancement of voltage profile	15,33,69	STATCOM	39
8	PSO	Minimize the power loss	68	SVC	40
9	GA	Minimize the power loss Maximize the voltage profile	5	SVC	41
10	FA	Minimize the power loss Improvement of the voltage profile	34,69	UPQC	42
11	GA	Minimize the power loss Enhancement of the voltage profile	30	STATCOM	43

D. Capacitor Placement

The capacitor placement technique is mainly used in the electrical network to compensate the part of the reactive power requirement. The soft computing techniques involving GA, PSO, ANN are employed to find the optimal allocation with their capacity to enhance the voltage profile. The optimal placement and sizing of capacitors are the key factors to improve the network operation. Table. IV shows the optimization techniques used in the single/ multiple capacitor placements.

E. DTC Placement and Line reconductoring

Most of the existing electrical infrastructure was built in 1980 to 1990. Every year 5-10 % increase in the demand causing poor voltage regulation increased the overloading of electrical infrastructure. The optimal placement of auto tap changing transformer boosts the voltage profile and reduces the I^2R losses in the network. The up-gradation of DTC capacity, interconnection of new DTC are the attracting solutions in the present days due to easy installment and less payback period with less investments.Table.6 shows the different optimization techniques used in DTC placement.

The line re-conductring is the up-gradation of transmission capacity of the transmission lines. Over the period of years increase in the load generation calls for up-gradation of transmission line capacity to reduces the I^2R losses rising frequent failures in the network. The up-gradation of transmission network majority depends on the connected load. Table.V shows the optimization techniques used in the DTC/ AVR placements.

Maintaining good voltage level is one of the core responsibilities of the electrical utility's. The high voltage drop in the network causes low voltage level at distribution side. This leads to poor power factor, more losses in the network and deteriorates the life of the equipments due to high I^2R loss. Hence electric utilities are targeting maintaining good voltage levels within the prescribed limits.

To achieve this AVR are widely used in large radial distribution networks. The placement and selection of size of the AVR many algorithms are used such as GA, SA, FKBC, PSO etc. are used.

Fig.1 shows the block diagram representation of different algorithms are involved in optimal placement of DG, capacitors, flexible AC transmission systems, automatic voltage regulators, network reconfiguration and distribution transformer placement. The optimal placement and sizing and selection of these devices benefits the economic and efficient operation of the large interconnected networks.

TABLE IV. CAPACITOR PLACEMENT

Sl	Optimization Technique	Objective functions	Test system	Load type	Ref
1	FKBC	Enhancement of voltage profile	33	Constant	44
2	GA	Minimize the power loss Maximize the voltage profile	118	Constant	45
3	PSO	Minimize the power loss	15,33	Constant	46
4	CS	Reduction of the power loss Maximize the voltage profile	33,69	Constant	47
5	ACO	Minimize the power loss	12,25,43	Constant	48
6	PSO	Reduce the power loss Enhancement of the voltage profile	84	Variable	49
7	ELFA	Minimize the power loss Enhancement of voltage profile	14	Constant	50
8	Fuzzy	Minimize the power loss	18	Constant	51
9	SWA	Enhancement of voltage profile	215	Constant	52
10	GA-PSO	Minimize the power loss Maximize the voltage profile	30	Constant	53
11	ANN	Minimize the power loss Enhancement of the voltage profile	30	Constant	54

TABLE V. DTC/ AVR PLACEMENT

Sl	Optimization Technique	Objective functions	Test system	Device	Ref
1	ELFA	Diminish the total power loss with Significant boost in the voltage profile	5	DTC	55
2	PGSA	Minimize the power loss Enhancement in the voltage profile	33,69	AVR	56
3	Fuzzy	Minimize the power loss	19	AVR	57
4	PSO	Minimize the power loss Improvement in the voltage profile	25	AVR	58
5	Fuzzy-PSO	Minimize the power loss	70	AVR	59
6	TLBO	Minimize the power loss Enhancement in the voltage profile	70	AVR	60
7	Observability	Minimize the power loss Enhancement of voltage profile	14	DTC	61
8	Fuzzy	Minimize the power loss	33	DTC	62
9	BTA	Minimize the power loss Improvement in the voltage profile	47,69	AVR	63
10	PSO	Minimize the power loss Maximize the voltage profile	15	AVR	64

Table.VI shows the comparison of different power loss reduction methods. The line reconfiguration mainly used for active power loss minimization with enhancement of load handling capacity of the network. In the same background DG and capacitor placements are used for diminishing the total power loss with significant enhancement in the voltages [65]. The main limitations of these methods are high investments with O&M costs. DTC placement is cost saving and immediate solution for voltage improvement and power loss minimization. FACTs placement is another solution for enhancement of the network stability, total power transfer capacity and maintaining all the parameters in the prescribed limits.

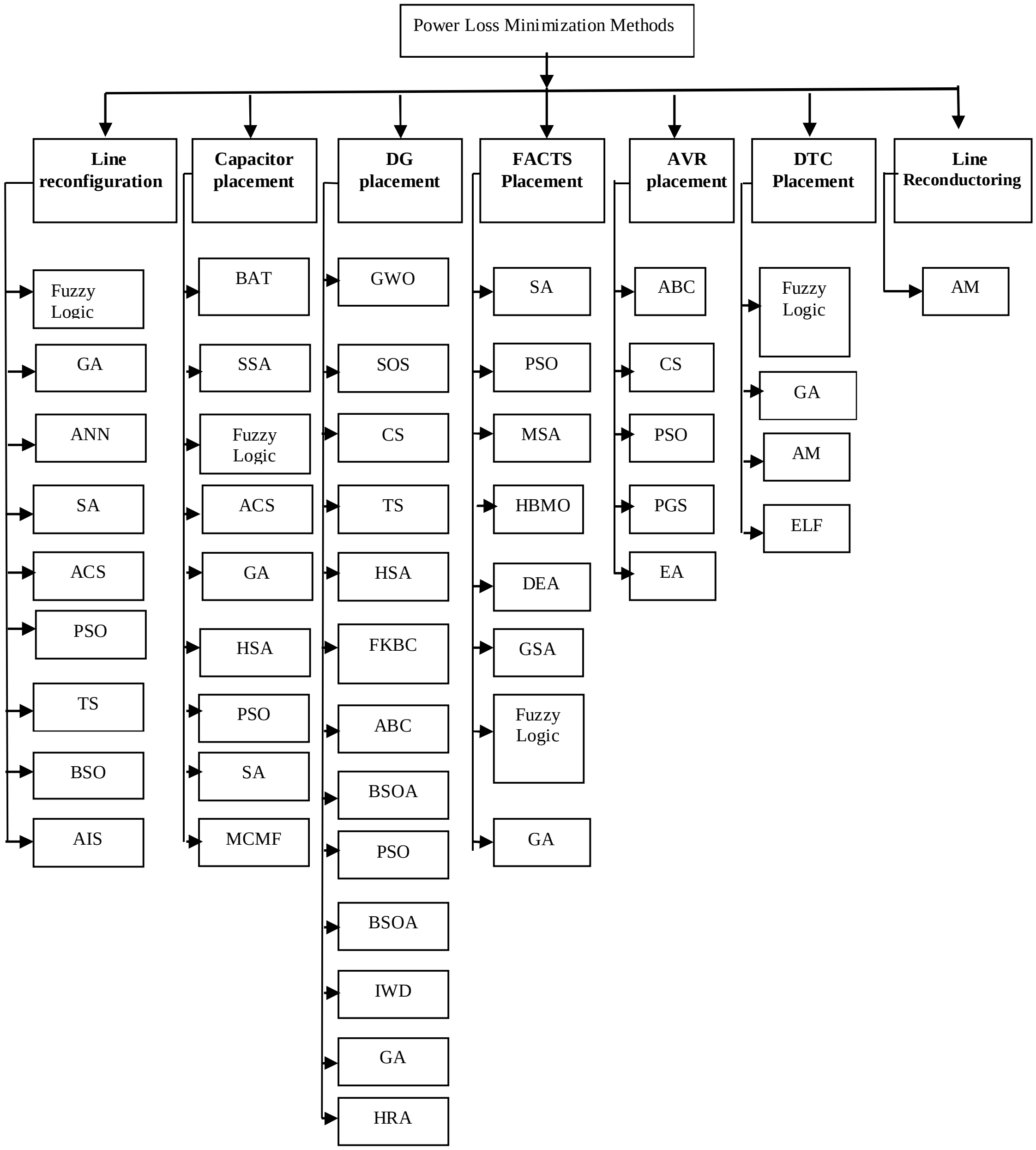

Fig.1 Block diagram representation of soft computing techniques and methods for power loss minimization

II. CONCLUSIONS

In this paper, a comprehensive literature survey is carried out on optimization techniques and methods involving the power loss minimization. The modern electrical network interconnected with number of loads, DG's, soft switching devices, integration of RES are increasing the complexity of network operation. This paper helps the researchers, energy managers and auditors to know the different optimization techniques, methods and work carried out so far to avoid the duplication of the work and up-gradation/ modification of the existing techniques to boost the network in terms of stability, better efficient and reliable operation of the system.

TABLE VI. POWER LOSS MINIMIZATION METHODS, OBEJECTIVES, ADVANTAGES AND DISADVANTAGES

Method	Objectives	Advantages	Disadvantages
Line reconfiguration	➢ Reduce the Power loss ➢ Reduce the cost ➢ Enhancement of voltage profile ➢ Minimize the switching	➢ Active power Loss reduction ➢ Increases the load handling capacity of the network ➢ Improvement in voltage profile.	➢ Additional Investment ➢ Installation of new transmission lines
DG Placement	➢ Efficient use of RES ➢ Minimization of power loss ➢ Maximise the voltage profile	➢ Enhancement of voltage stability ➢ Minimization of power loss ➢ Reduction of green house gases	➢ DG integration requires new protection scheme ➢ High investment
Capacitor placement	➢ Enhance of voltage stability ➢ Load balancing ➢ Active power loss reduction	➢ Maximize the voltage stability ➢ Reduction in power loss	➢ Additional Investment
FACTS placement	➢ Enhancement of voltage stability ➢ Power loss reduction ➢ Efficient power of system	➢ Enhancement of voltage stability ➢ Minimization of Power loss ➢ Increase the power handling capacity of the entire network ➢ Financial benefits	➢ High Investments ➢ Change in Protection scheme
DTC placement	➢ Cost saving ➢ Increase the voltage profile ➢ Minimise the total power loss	➢ Immediate solution for power loss minimization ➢ Investment is less ➢ Payback period is less	➢ The new technology is required for further improvement of system parameters ➢ The enhancement of the voltage stability is limited
Line reconductoring	➢ Power loss reduction ➢ Increase the transfer capability	➢ Minimization of active power loss ➢ Increases load handling capacity of the network	➢ Additional investment is required

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