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Research Perspective on Congestion Management in Power System

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Abstract— Network congestion is defined as "the situation in which an increase in data transmissions results in a proportionately smaller (or even a reduction in) throughput". While there is congestion in the network, if one attempts to send huge data; only less data will be actually delivered effectively. CM is the action of controlling the power system to examine its transfer operations, which is perhaps the basic transmission management crisis nowadays. Accordingly, this survey intends to review various topics to solve CM issues in the network. In addition, the algorithmic classification for the surveyed papers are 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— Congestion Management; Transmission; Algorithms; Performance Measures.
Nomenclature:

Acronyms	Description
CM	Congestion Management
FACTS	Flexible AC Transmission System
MOPSO	multi-objective particle swarm optimization
TCM	transmission congestion management
DRPs	demand response programs
GSF	Generator Sensitivity Factor
BSF	Bus Sensitivity Factor
PSHU	pumped storage hydro unit
TLBO	teaching-learning-based optimization
PSO	Particle Swarm Optimization
PSO-ITVAC	PSO method with improved time-varying acceleration coefficients
PSO-TVAC	PSO with time-varying acceleration coefficients
DG	Distributed generation
FFA	firefly algorithm
ZIP	impedance, current, and power
GR	Generation Rescheduling
PBEM	Pool based electricity market
ELD	economic load dispatch
FPA	Flower Pollination Algorithm
GA	Genetic algorithm
ELD	Economic load dispatch
RPL	Real Power Losses
SBF	Simple Bacterial Foraging
MOCM	Multi-Objective Congestion Management
MMP	Mathematical Programming
GSA	Gravitational Search algorithm
MBD	modified Benders Decomposition
TEP	transmission expansion planning
EDNS	Expected Demand Not Served
EGNS	Expected Generation Not Served
EWL	Expected Wheeling Loss
MCS	Monte Carlo simulation

I. INTRODUCTION

In today's competitive electricity markets, generators contend to sell more power and customers attempt to purchase the majority of economical energy for increased profit. However, the transmission network [1], as a standard between utilization centres and power generation, has a limited capability in addition to its own security concerns [2] [3] [4]. Congestion in power markets takes place if the network for transmission is not capable of holding the entire desired transactions owing to certain contraventions in its functioning limits [5] [6]. Congestion in electricity markets, if not controlled, can pave the way to oligopoly and market power [2] [7]. CM, [8] [9] the action of controlling the power system to examine its transfer operations, is perhaps the basic transmission management crisis [10] [11]. For CM functions [12] [13], certain features such as FACTS [14] devices can be exploited to improve conventional transmission networks efficiently by rising power transfer capability as an efficient alternative to creating new transmission lines [15] [16]. TCSCs in CM is a design that exploits the real power performance index, reduces reactive power losses of the power system [17] [18]. Congestion could be improved through a variety of ways. Numerous experiments were conducted to solve the CM problems by means of load curtailment united with generation redispatch and security constrained optimal power flow [19] [20]. The problem of TCM is more prominent in competitive and deregulated markets, and it requires a unique treatment.

The CM techniques exploited today have reverse effects on energy markets, namely, monetary penalties and disruptions, under certain circumstances. For alleviating these concerns, a lot of CM [21] [22] techniques have been proposed, together with redispatch and curtailment of scheduled transmission. In the reconstructed electric energy field, novel CM [23] schemes are introduced, which attempts to attain the optimal degree of consistency while assisting the competitive power market [26]. In addition, the CM is more multifaceted in electrical markets, and it paves the way to numerous disputes [24] [25] [27].

This survey has reviewed various works related to the CM 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

In 2018,Kohan *et al.* [1] have introduced the MOPSO technique for TCM that regards GR and DRPs. The outcomes of the assessment for diverse conditions illustrate that DRPs minimize the congestion in electrical lines, permitting the exploitation of the power transmission with reduced loading capability. Moreover, in certain cases, devoid of consuming DRPs, resolving the TCM issue was not at all possible.

In 2016, Gope *et al.* [2] have established an optimization design for CM by integrating the evaluation of two aspects namely, GSF and BSF. Accordingly, the influence of PSHU was examined to cope up with TCM that further lessens the cost of congestion and develops system security. The established technique for CM regarding PSHU was verified, and the validity was attained by regarding the similar issue deprived of the existence of PSHU. The outcome of suggested scheme with appropriate exploitation of PSHU demonstrates the influence of PSHU and the examination of FF algorithm for reducing the TCM cost.

In 2016, Vermaand Saha [3] have presented a TLBO approach for CM in PBEM. The implemented TLBO model was modern population dependent schemes that do not necessitate any certain regulating constraints, unlike other schemes. It only necessitates common control constraints like count of generation and population size. The outcomes acquired were distinguished from those stated in the conventional schemes. The effectiveness of the TLBO process for attaining advanced solution was also recognized by the adopted model from the results.

In 2015, Sarwar and Anwar [4] had adopted a technique for CM in deregulated atmosphere by means of PSO-ITVAC. The price of rescheduling was reduced by means of PSO-ITVAC. The suggested method was verified for analyzing the efficiency of the offered algorithm. The outcomes acquired with suggested algorithm was distinguished with those attained by deploying PSO-TVAC.

In 2016, Verma and Mukherjee [5] have established an efficient and reliable meta-heuristic dependent technique to resolve congestion issue. The suggested procedure of the introduced work deploys FFA for improvement of TCM in a PBEM through active power rescheduling of generators. Numerous significant security parameters, namely, line loading and load bus voltage were taken into consideration while managing with congestion issue. In addition, the suggested procedure may support in eliminating the congestion with least cost of rescheduling. Finally, the arithmetical outcomes of the adopted model have been illustrated.

In 2014, Kumar and Ram [6] had suggested a scheme based on CM regarding the impact of stable ZIP load approach together with the load deviation pattern in the hybrid electricity market. The major contribution of the introduced scheme was optimal rescheduling, analysis on the effect of ZIP load design and load deviations, the effect of third generation FACTS, evaluation of outcomes attained for hybrid market prototype with and without ZIP load model. Finally, enhanced outcomes have been acquired by the proposed scheme when compared with other traditional schemes.

In 2013, Kumar and Charan [7] have introduced a significant problem of TCM in a PBEM with the contemplation of voltage stability. The base case ELD was attained for guaranteeing the loading limits and was considered as output data throughout CM to attain novel GR. Moreover, the influence of FACTS devices was calculated on the cost factors and optimal GR, and finally, the outcomes were attained from the simulation results.

In 2005, Talukdar *et al.* [8] have implemented a technique of CM by load shedding and GR. The novel load shedding and GR for such buses were further calculated depending on a technique that regards sensitivity and cost to line currents. The approach will support to produce the contingency plan rapidly for safe functioning of the TEP. In addition, the outcomes attained from the simulation outcomes display that load shedding, and GR plans can be attained to ease congestion of the power transmission by the implemented effectual technique.

In 2018,Peesapati *et al.* [9] have adopted a technique, where best capabilities of DG units were injected to eliminate congestion of huge power systems. Here, FPA was executed to attain the optimal capabilities of DGs, which were functioning at unity. In addition, the suggested FPA approach was compared with GA, and PSO techniques respect to RPL and line flows. Finally, outcomes have demonstrated that the suggested procedure includes greater perspectives, stable features of convergence and enhanced efficacy.

In 2011, Venkaiah and Vinod [10] had proposed a scheme, where generators were chosen on the basis of their sensitivity for exploiting the them proficiently and accordingly, optimal GR of contributing generators was endeavored by FABF. The FABF system was established, and the outcomes were distinguished with the PSO and SBF techniques for increasing the efficiency of CM. Moreover, from the outcomes, it was detected that FABF was efficiently reducing the generation cost in evaluation with PSO and SBF for better GR of producers to release congestion in power systems.

In 2016, Seyyed *et al.* [11] have introduced a scheme to solve MOCM problem along with MMP scheme for resolving the optimization issue of the CM, which could produce a well-distributed frontier. The introduced MMP solution and congestion management model scheme were executed, and the attained outcomes were distinguished with the outcomes of numerous other CM techniques. These evaluations validate the advantage of the introduced scheme.

In 2014, Masoud *et al.* [12] have established a method for congestion management in which three competing operations that comprise of total operating cost, transient stability margins and voltage were optimized at the same time. This paves the way to a cost-effective and robust functioning point where sufficient levels of transient security and voltage were comprised. The established technique optimally locates FACTS devices on the most congested branches. Individual sets, consequence from resolving MOCM for each location of FACTS devices. The outcomes of testing were described in detail, and it substantiates the effectiveness of the established scheme.

In 2017, Akanksha *et al.* [13] have introduced GSA to avoid congestion in transmission lines. Moreover, optimal sizing of IPFC was performed by deploying GSA. A MOCM function has been selected for adjusting the constraints of the IPFC. Further, the adopted scheme was validated under varied conditions, and the efficiency of the introduced scheme was exposed in the suggested model via the minimization of values in optimal operations.

In 2013, Masoud *et al.* [14] have introduced a two-stage technique by means of MBD for CM in hybrid power markets together with bilateral transactions. In addition, a novel convergence measure and a novel form of sub-problem were adopted by means of MBD in CM. The introduced scheme not only provides the effective solution, but it also offers sufficient transparency regarding the congestion cost. Finally, the outcomes of the presented work substantiate the effectiveness of the adopted CM technique.

In 2012, Neeraj *et al.* [15] has suggested a TEP method that involves multi-objective functions such as, minimization of the investment cost, EGNS, EWL and EDNS costs to compute consistency and economic examination by means of MCS to reduce functioning cost of generators, load flow examination to compute EDNS, EWL and EGNS, a new CM to determine optimal transmission line capacity, and GA optimization scheme. Finally, the proposed model was simulated, and from the results, the enhanced performance of the adopted scheme was known.

III. CATEGORIZATION OF ALGORITHMS AND ITS PERFORMANCE MEASURES

A. Algorithmic Classification

The various algorithms adopted in each reviewed paper includes PSO algorithm, FF algorithm, TLBO approach, GSA algorithm, Block bid function, LSA algorithm, FPA algorithm, FABF algorithm, NNC Scheme, Fuzzy decision maker, MBD algorithm and MCS algorithm. Accordingly, PSO algorithm was adopted in [1] and [4]. FF algorithm was exploited in [2] and [5], and TLBO approach was implemented in [2] and [5]. In addition, GSA algorithm was presented in [13], and Block bid function was adopted in [6] and [7]. LSA algorithm was implemented in [8], FPA algorithm was exploited in [9]. Moreover, FABF algorithm was adopted in [10], and NNC Scheme was presented in [11]. Also, Fuzzy decision maker was implemented in [12] , MBD algorithm was implemented in [14], and MCS algorithm was implemented in [15]. The brief description of the reviewed works is represented by Fig. 1.

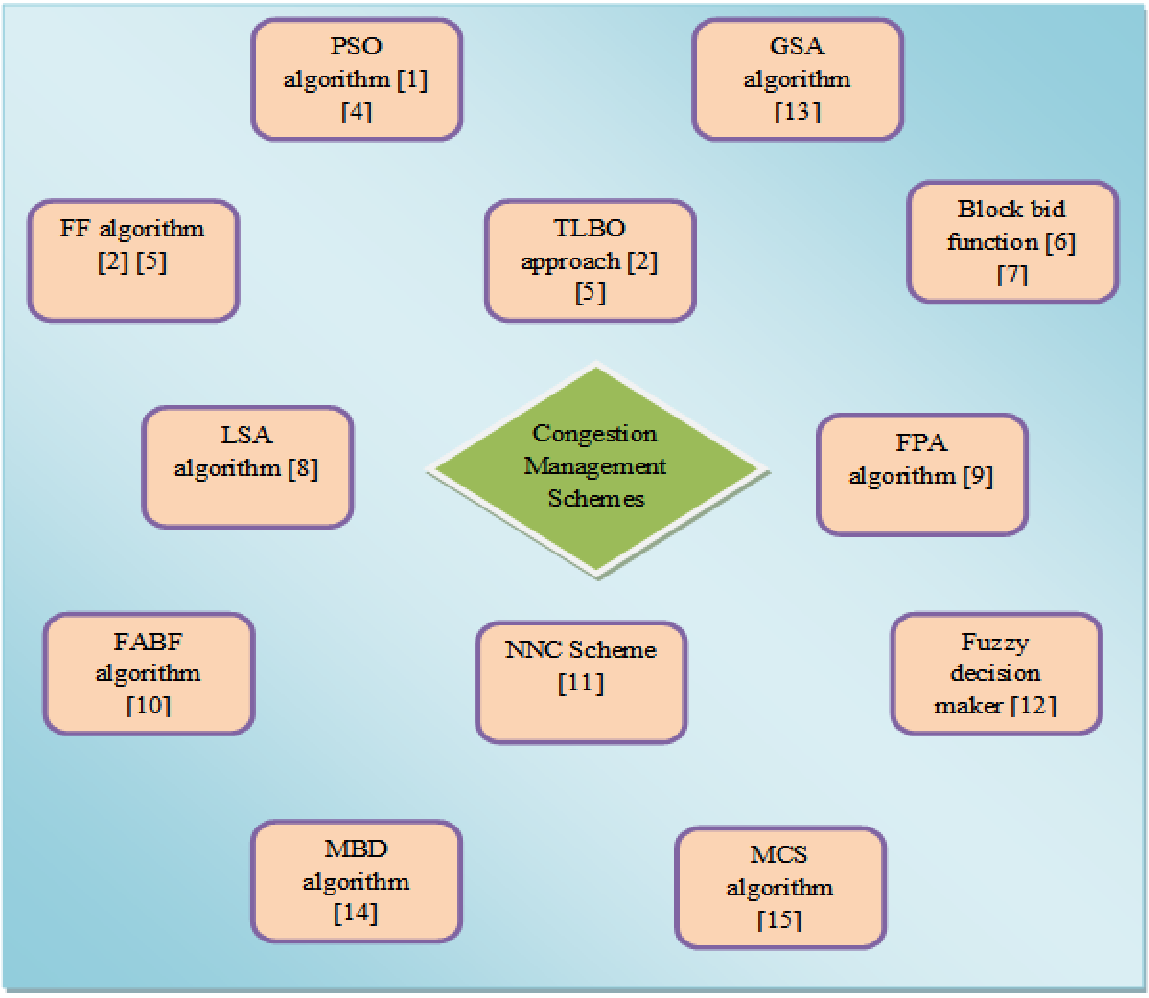

Fig. 1: Various schemes of the reviewed works

B. ***Maximum Performance Achieved***

The maximum performance achieved by various performance measures is given by Table I. The cost of congestion adopted in [1] has attained an optimal value of 574.87$/h. In addition, VSM adopted in [11] has attained a higher percentage of 40.2%. CTEM implemented in [11] has attained a higher value of 38.26p.u and line limit implemented in [5] has attained a higher value of 130MW and power flow implemented in [2] has attained a higher value of 500MW. Accordingly, sensitivity and population size have attained a higher value of 2.8,149.96Rs/MWh and 200 respectively. Also, emission and fitness function has presented increased values of 393.38$/h and 500$/h, which were determined in [1] and [3]. Likewise, number of agents was measured in [13], and it has adopted a value of 50. Similarly, reduction of EDNS and reduction of EWL was deployed in [15], and they have attained optimal values of 20.7 MW and 69%.

TABLE I. MAXIMUM PERFORMANCE ACHIEVED BY THE REVIEWED WORKS

Measures	Maximum value	Citation
Cost of congestion	574.87$/h	[1]
VSM	40.2%	[11]
CTEM	38.26p.u	[11]
Line limit	130MW	[5]
Power flow	500MW	[2]

Sensitivity	2.8,149.96Rs/MWh	[10]
Population size	200	[1]
Emission	393.38$/h	[1]
Fitness function	500$/h	[3]
Number of agents	50	[13]
Reduction of EDNS	20.7 MW	[15]
Reduction of EWL	69%	[15]

C. Performance Measures

The performance measures contributed in each paper are described in this section. The performance measures such as cost of congestion, VSM, CTEM, line limit, power flow, sensitivity, population size, emission, fitness function, and number of agents, reduction of EDNS, and reduction of EWL were analyzed in the surveyed works. Accordingly, cost of congestion is exploited in [1] that offers about 80% of the total contribution. In addition, VSM was adopted in [11] and [12], which provides about 13.33% of the total contribution. CTEM was measured in [11] and [12], which provides about 13.33% of the total contribution. Line limit was exploited in [4] and [5] that offer about 13.33% of the total contribution. Likewise, power flow was measured in [2] [3] [5] [6] and [10], which provides about 33.33% of the total contribution. Also, sensitivity was deployed in [4], [10] and [14] that offer about 20% of the entire contribution. Other contributions such as population size, emission, fitness function, number of agents, reduction of EDNS, and reduction of EWL were analyzed in [1] [3] [4] [5] [7] [8] [9] [13] and [15]. The various performance measures adopted in the reviewed papers is given by Table II.

TABLE II. PERFORMANCE MEASURES OF DIFFERENT CONTRIBUTIONS

Citation	Cost of congestion	VSM	CTEM	Line limit	Power flow	Sensitivity	Others
[1]	✓						✓
[2]	✓				✓		
[3]	✓				✓		✓
[4]	✓			✓		✓	✓
[5]	✓			✓	✓		✓
[6]	✓				✓		
[7]	✓						✓
[8]							✓
[9]							✓
[10]	✓				✓	✓	
[11]	✓	✓	✓				
[12]	✓	✓	✓				
[13]	✓						✓
[14]	✓					✓	
[15]							✓

D. Additional Constraints

The various constraints adopted in each review is given by Table III. It includes transient stability, rescheduling cost, GR, congestion cost, generation cost, operating cost, ELD, installation cost, investment cost and voltage deviation. Transient stability was adopted in [11] and [12], and rescheduling cost was determined in [4] [5] [6] and [8]. In addition, GR was analysed in [1] and congestion cost was determined in [1] [2] [3] [7] [11] and [14]. Accordingly, generation cost was adopted in [10], and operating cost was analyzed in [12] and [15]. Also, ELD and installation cost were determined in [7] and [15] respectively. Furthermore, investment cost was adopted in [9] and [15] and voltage deviation was proposed in [9] [11] [12] [13] and [14].

TABLE III. ADDITIONAL CONSTRAINTS OF THE REVIEWED WORKS

Sl.No	Transient stability	Rescheduling cost	GR	Congestion cost	Generation cost	Operating cost	ELD	Installation cost	Investment cost	Voltage deviation
[1]			✓	✓						
[2]				✓						
[3]				✓						
[4]		✓								
[5]		✓								
[6]		✓								
[7]				✓			✓			
[8]		✓								
[9]									✓	✓
[10]					✓					
[11]	✓			✓						✓
[12]	✓					✓				✓
[13]								✓		✓
[14]				✓						✓
[15]						✓			✓	

IV. RESEARCH GAPS AND CHALLENGES

CM has turn out to be one of the major considerations in power productions. Electricity has to be passed from a generating station to a customer through numerous substations via distribution and transmission lines. When requirement is higher than the power transfer capabilities of transmission lines, congestion occurs, and henceforth a management is necessary. Therefore, CM is about handling the power distribution and transmission among the valued consumers based on priority. Issues take place in electric lines owing to congestion in transmission lines. It happens due to higher power demand, and in addition, varied kinds of load might cause the subsequent issues.

- The customers are enforced to minimize the utilization of power, as the electricity expenses rises.
- Security of the system may be exaggerated.
- The system is enforced to function at minimum stability margins.
- The system might collapse owing to instigation of cascade tripping.
- Congestion prevents the system operator from conveying further power from a specific generator.
- The excess congestion prices are raised.

In addition, congestion may ruin the systems equipment. Congestion in a transmission system could not be endured, as this may cause several damages such as load losses. The cost related with required corrective processes to get rid of congestion could rise to a stage, which offers an obstacle in electricity transaction. Thus, CM was considered as a significant issue in the electricity market. With complications in constructing novel transmission lines owing to issue of economic crisis and substantial rise in the power transmissions related with the economical PBEM, sustaining the security of the system had turned out to be one of the chief issues for operating the systems. Moreover, transmission congestion may avoid the execution of innovative agreements, and it could cause extra outage, raise the charges of electricity in certain areas and endanger the system reliability and security.

V. CONCLUSION

Congestion can take place owing to numerous causes. For instance, if a stream of packets arrives unexpectedly on a number of input lines and requires being out on the similar output line, then a long queue has to be constructed for that output. If there is no sufficient memory to hold these packets, they may get dropped. Addition of excessive memory also may not support in specific situations. 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 CM problems from the reviewed papers.

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