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Review IJEPST

A Survey on Recent Progress in Transmission Congestion Management

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Abstract

After deregulating their electrical sectors recently, a number of nations, including Chile, Peru, the United States, the United Kingdom, the European Union, Canada, Colombia, New Zealand, Scandinavia, and Australia replaced their once-monolithic public utilities with competitive power markets. The electricity industry has been changing around the world over the last few decades, and as a result, network congestion is unavoidable. Market failure, transmission capacity limitations violations, and excessive energy prices, jeopardizing the reliability and security of power networks can be caused by congestion. Congestion may also result in unanticipated pricing discrepancies in electricity markets, resulting in market power. When the network is congested, the major concern of an independent system operator (ISO) in a deregulated power market (DPM) is to preserve the power market's stability and safety by increasing market efficiency. As a result, in DPM and the power system, congestion management (CM) is crucial. This study does a survey of CM approaches in order to compile every part of latest DPM papers. Its goal is to provide readers with a summary of advanced CM approaches, as well as classic CM methods which described already. We conducted a comparative study of the several famous CM approaches in this work.

Keywords: Available transfer capability, congestion management, demand response management, transmission system operator, zonal pricing method

INTRODUCTION

Several countries, like Peru, the European Union, Canada, Colombia, the United States, the United Kingdom, Chile, New Zealand, Scandinavia, and Australia have deregulated their electrical industries in recent years, replacing previously monolithic public utilities with competitive power markets. Vertical system turns into an unbundled system is referred to as restructuring. Liberalization, deregulation, and privatization all imply a reorganization of the economy. The independent system operator (ISO) in a deregulated power market (DPM) faces various challenges, including finding the appropriate auction mechanism to reduce market power and congestion while improving efficiency and system reliability. In Congestion Management (CM) crucial function such as rescheduling generation, calculating Available Transfer Capability (ATC), and reconfiguring network design, as well as load management and demand response management (DRM), will be performed by the ISO (DRM) [1–15].

Power transfer between two points on the network is limited due to transmission network limitations. We call a system crowded if one of

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those limitations is violated by the transmission network. Random power flows across the network due to line outage, system component malfunctions, and unplanned generator problems. Because numerous DPM transactions can generate congestion, transmission congestion is also caused by a deficient in power transmission line capacity for transactions. In this situation, a lack of attention results in extensive blackouts, causing damage to the system's electrical equipment as well as pricing disparities across the network. Because every transaction seeks maximum profit in an open-access electricity system, the risk of overcrowding is greater than in conventional monopolies. As a result, CM has become a hot topic in discussions about how to make the electricity business more competitive. CM is a strong weapon that does not go beyond the limits of transmission. To address this, academics from all around the globe have presented a variety of approaches for avoiding or reducing congestion and restoring rapid power delivery to consumers.

CM approaches are characterized as non-technical or technical in general. We can employ technical solutions on the transmission side like phase shifters and FACTS devices. Non-technical categories include zoning and nodal pricing, load curtailment, counter trading, redispatching, auctioning, and market splitting. On the generating side, non-technical options include rescheduling generation and optimal sitting of distribution generators (DGs). On the end-user side load curtailment, DRM, and other strategies are deployed. One of the issues in the electricity markets is how to give to congestion costs and profits. CM tackles economic difficulties and balances the system due to congestion. Conventional CM approaches include ATC based CM, nodal pricing, price area CM methods, and FACTS based CM. When compared to heuristic optimization approaches, conventional CM methods take longer to compute. Heuristic optimization methods include genetic algorithm (GA), firefly algorithm, particle swarm optimization (PSO), ant colony algorithm, and evolutionary algorithm. Congestion can be controlled for short, medium, and extended periods of time. To decrease congestion, Norway's DPM employs generator rescheduling (GR) with short, medium, and long-term intervals.

The numerous CM approaches were grouped into four broad groups by Kumar et al.: redispatch and willingness to pay methods, auction-based, sensitivity-based, and pricing-based strategies. Traditional CM and optimization methodologies such as GA and PSO were investigated by Anusha Pillay et al. Figure 1 depicts a high-level overview of CM approaches. As illustrated in Figure 2, Aishvarya Narain et al. divided CM approaches into three categories: end user, transmission, and generation [16–40].

The CM methods are integrally related to the market's overall design. The primary purpose of CM techniques is to efficiently sort out network capability surrounded by appropriate market players. This study explores a numeral of most important efforts of literature that has been suggested for CM. This survey looks at both conventional and unconventional optimization methodologies for reducing congestion.

ZONAL PRICING METHOD

In the zonal pricing method, buses by means of identical locational marginal prices (LMPs) are classified into zone. Firstly, there are no restrictions on the market. The two types of zonal CM methods are inter-zonal and intra-zonal CM. When a bottleneck occurs, the ISO receives more proposals to raise or decrease production. The ability to buy or sell power in the zone was up for grabs. Until the bid time ends, a system cost is set off grid by combining all sectors. If there are no restrictions based on the calculations, this pricing applies to all zones. The literature explored a zonal CM approach base on the LMPs [41–80].

ATC-BASED CM

The term "ATC" refers to the amount of physical transmission system transmit capacity that is available for additional operating actions beyond what has already been devoted. The network's ATC improvement can be used to achieve CM. ATC may also be used by ISO to book transmission facilities, arrange firm and non-firm transactions, also handle misfortune transfers among the supplier bus and purchaser bus. ATC and important transmission channels among areas have to be monitored, updated, and transmitted to an Open Access Same Time Information System on a regular basis (OASIS).

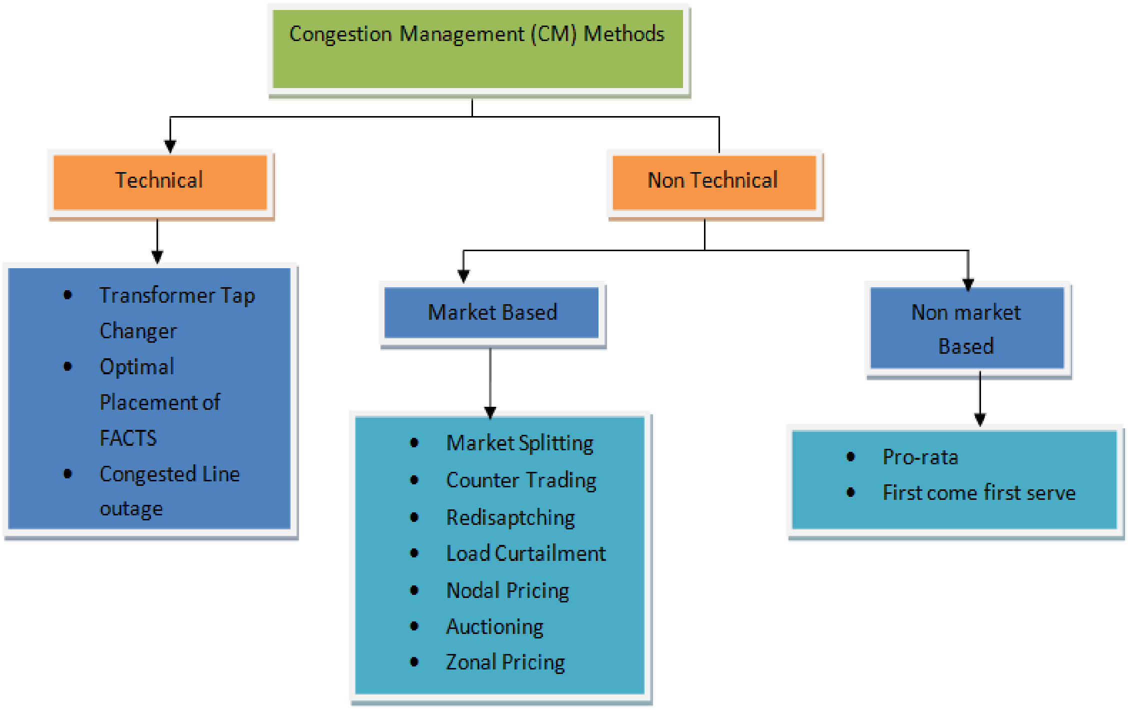

Figure 1. An overview of CM approaches.

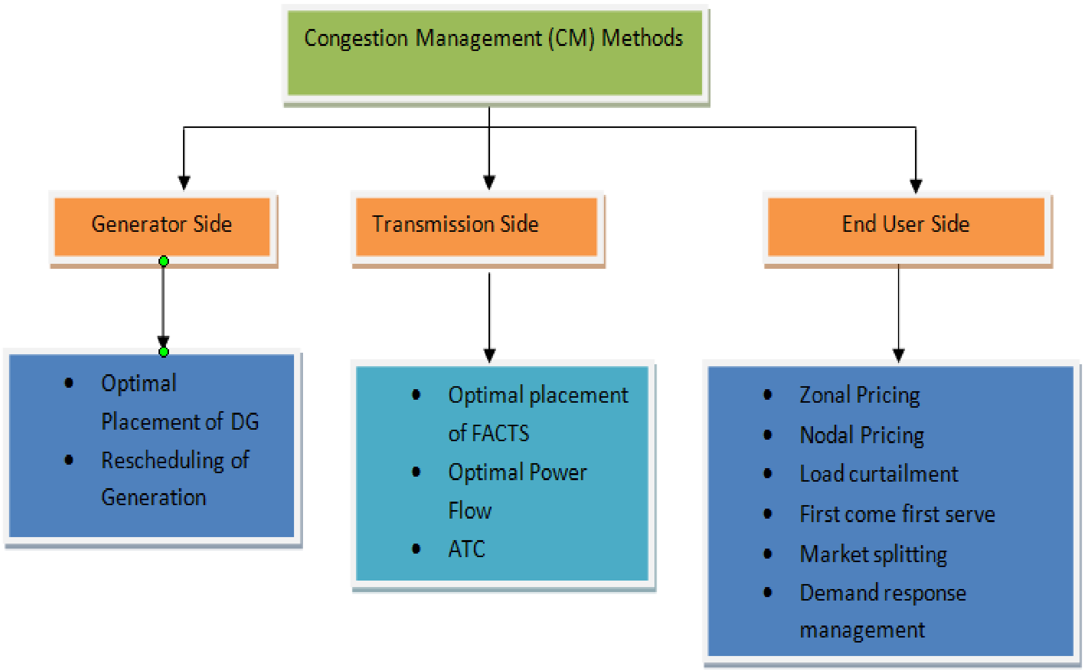

Figure 2. Based on application side summarized view of CM approaches.

Mathematically, ATC is defined as:

- ȺTC = ȾTC – ȾRM – (ɆTC + ȻBM)
- Where ATC :- ȺTC
- Total transfer capability :- ȾTC
- Transfer reliability margin :- ȾRM
- Existing transfer commitments :- ɆTC
- Capacity benefit margin :- ȻBM

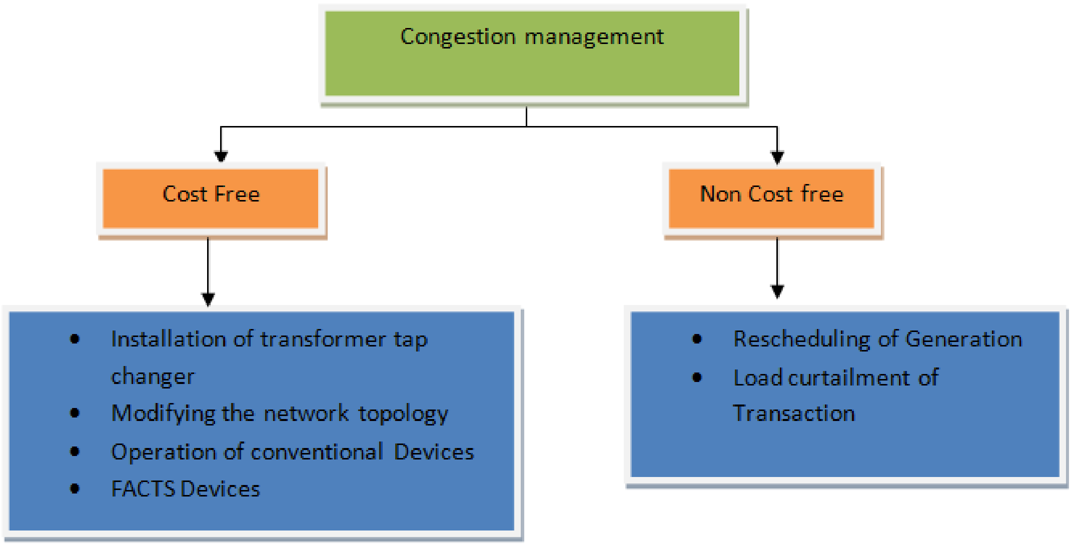

Figure 3. Cost-based CM methods.

The different techniques have been measured by ATC base on distribution parameter and uninterrupted power flow (UPF). The ATC have been expanded in literature by using FACT devices similar to the SVC and TCSC in the direction of boost power transactions within both emergency and non-emergency scenarios. A. Kumar presented an optimal power flow technique for calculating ATC in a multi-transaction context utilizing UPFC, and Sen Transformer in both devices were used on ATC to investigate the impact of the ZIP load model.

CM BY ELECTRIC VEHICLES

CM has become increasingly difficult due to the uncertainty of different energy resources in the power grid. The absorption of electric vehicles into the smart grid presents latest obstacles and gives new opportunity. ISO may leverage EVs prepared among Vehicle to Grid (V2G) technology to handle network overcrowding concerns in addition to restrictions, with the cargo space of RES surpluses. EVs' implications on the smart grid are discussed in literature from several perspectives, including network congestion, voltage dips, and power losses [81–96]. The use of the Lagrangian relaxation-based partial decomposition approach to regulate the charge of electric vehicles minimizes congestion in the transmission network [97].

DISTRIBUTED GENERATION

Renewable energy sources (RESs) are commonly deployed within DPM in favor of CM and are known as DGs. By injecting electricity into the network's critical nodes, distributed generation can improve transmission system efficiency. In this case, the operation has to be accepted to produce improved social benefit in favor of network having DG resources, regardless of the form of DG. CM can be done by reducing power flow on preferred transmission lines to enhance voltage profiles. Incorporation of distributed generation into power networks has several benefits, including improved power quality, enhanced voltage profile, loss drop, increased dependability, and overcrowding relief.

Due to its feasible benefits and open access transmission infrastructure. RES is often employed in the DPM to satisfy quickly expanding energy requirements instead of traditional power plants. The relevance of RES in favor of optimizing social benefit as well as CM within DPM was explained by Y. R. Sood et al. The suitable positions of DGs inside DPMs provide utmost system profit. A sensitivity analysis was utilized in the literature headed for find most favorable DGs along with GA in favor of DG's optimal capability calculation. To explore the impact of DGs within CM, the author of used a Fuzzy c-means clustering technique. Two innovative ways to detect significant congestion transmission lines have been used in literature to find the best DG size as well as location inside the DPM. With power transfer distribution factors, DGs as well as Energy Storage Systems (ESSs) be properly rescheduled headed for diminish predicted overcrowding. In order to ease congestion in competitive energy markets, a cost/worth analysis-based technique be employed to determine the most favorable position as well as DGs size. In the direction of diminish transmission bottleneck on the electricity market, uses an artificial neural network (ANN) to estimate DG's optimum placements and sizes.

Table 1 summarizes the many characteristics of the proposed CM approaches, including their use difficulty, scientific and financial profit, and probable risk as well as drawbacks.

Table 1. Judgment of different CM methods.

CM Method	**Methodology**	**Demerits**
ATC	Based on ATC data while dispatch, overcrowding was reduced here.	The ATC technique for CM is useless when line loading exceeds the line's maximum capacity.
Optimization techniques	Despite the fact that DPM systems are multi-objective or complicated, they have the potential to relieve congestion fast.	The most essential criteria in optimization techniques are non-linearity as well as the number of variables in the crisis. In a few examples, the calculation stage may be longer.
Distributed generation	The ideal integer of DG units within a favorable place to inject power at buses to decrease congestion base on alteration in the system power flow.	To ensure the system's security, dependability, and steadiness, the DPM must monitor market activities in a sophisticated and high-standard manner because to RES uncertainties.
Generation rescheduling	CM has been rescheduled for a sufficient amount of producing power outputs.	Any change in generator power outputs would outcome into a reorganization of GENCO financial support, as well as a loss of economic income.
DR	Participation of customers in power market operations has aided in the reduction of congestion. Load equipment rescheduling is possible with DR, including shifting loads from main hours toward non-critical hours along with modifying load patterns.	The operations of the market are becoming increasingly sophisticated. There is a rising demand in favor of extensive DR method in examining, communications, as well as accurate forecasting equipment.
FACTS devices	Congestion is alleviated in this situation by strategically positioning FACTS devices based on network power flow management	Due to load variations and RES unpredictability, the system has a low-cost burden and requires frequent monitoring.
Redispatch	Adjusting generating outputs in accordance with ISO rules has helped to alleviate congestion.	Influence other generators' profits. Many generators are becoming less efficient, while others are becoming more productive.

FLEXIBLE AC TRANSMISSION SYSTEMS DEVICES (FACTS)

FACTS devices could be a good way to reduce power flows on heavily laden lines. FACTS may lower production charge, minimize system loss, and manage networks power flow needs, as well as improve network efficiency and load ability. FACTS increase current transmission network capability with minimizing congestion charge with the help of managing reactive power, power stabilization, and controlling the voltage. Conventional compensation devices, transformer tap configuration, phase shifters, and FACTS device application are all covered by cost-free methods. These can be used by the transmission system operator (TSO) to change the network's topology. As shown in Figure 3, there are two sides of CM, one that is with free of cost and the second without free of cost. With free-of-cost methods are preferable since they eliminate any potential for economic disparities [81–85].

There are two types of methods for determining the optimal location of FACTS devices:- optimization-based methods and index-based methods. The employment of FACTS with optimization approaches is one of the major advancements in the current power situation. The influence of FACTS equipment on overcrowding and associated costs is discussed in the literature using various CM approaches. To optimize loading and decrease congestion, many ways for FACTS device most favorable location had been presented in the paper. Table 2 shows the results of the equivalent FACTS-based CM investigation [86–90].

Table 2. CM works with a variety of FACTS devices.

FACTS Devices	**Methodology**	**Remarks**	**Reference**
Unified power flow controller	Self-adaptive differential evolutionary (SADE) algorithm	Under practical security restrictions, SADE was employed to improve and manage the flow of power by utilizing UPFC.	[16]
Thyristor-controlled series capacitor (TCSC)	Sensitivity-based approach	The impact of TCSC on congestion was investigated using contingencies such as line disruptions.	[17]
TCSC, static VAR compensator	Non-dominated sorting PSO (NSPSO)	NSPSO applied to increase the static voltage stability margin, reduce deviation of load voltage, and minimize real power losses.	[18]
TCSC	Multi-objective optimization	Three goal functions were used in this optimization: in general, operating expenditure, transient stability limitations, along with voltage.	[19]
Unified power flow controller	Immune Algorithm (IA)	Using the IA, we were able to reduce the cost of generation.	[20], [21]
TCSC, thyristor-controlled phase angle regulator	Sensitivity-based approach	The author discovered the ideal placement for TCSC, and thyristor controlled phase angle regulator in order to reduce congestion.	[22]
Thyristor-controlled phase angle regulator	The mixed integer-based non-linear optimal power flow model	For CM, the ideal thyristor-controlled phase angle regulator position was discovered.	[23]
Interline power flow controller	Gravitational search algorithm (GSA)	GSA was utilized for the greatest enhancement of interline power flow controller for cm, whereas disparity line utilization factor was used for the optimum location.	[24]
Interline power flow controller	Multi-objective differential evolution	The disparity line usage factor (DLUF) was used to find the best IPFC location for removing transmission network congestion.	[25]
TCSC	Hybrid bacterial foraging and nelder-mead algorithm (BF-NM).	The cost of production, emissions, and TCSC has all been reduced.	[26]
TCSC	Improved Gray Wolf Optimization (IGWO)	The best location for TCSC was discovered to reduce active power losses, voltage variations, and generation overheads.	[27]
TCSC	LMP difference method and congestion rent contribution method.	Originate the convenient TCSC site with the least amount of congestion.	[28]
Unified power flow controller	Sensitivity-based approach and pricing based method.	The lowest cost for the generating rate was calculated using the interior-point approach.	[29]

NODAL PRICING METHOD

Both uniform and non-uniform pricing techniques are used by CM. LMPs are nodal prices that fluctuate geographically [71]. The LMPs will be subject to a non-uniform pricing system. Each bus in the network is seen as a node in the nodal pricing model. The LMP for each bus is calculated by the ISO by combining a cost-effective load dispatch with flow constraints [74, 75]. The precise position has been defined by the LMP as the lowest cost of adding another MW of power to the site not including jeopardizing the system's protection. In a market-based framework, the marginal price is replaced with a cost or bid. When the system through the less energy pricing is unable to reach all sites owing to congestion, more expensive generators will be assigned to match demand. LMPs readings might vary from any location to the other in this scenario. Participants in congested line transactions pay a congestion fees equivalent to the difference among the nodal marginal price on the spot of consumption and the nodal marginal price on the spot of injection. The LMPs-based CM process has been widely implemented across the world because of its intrinsic flexibility during assigning transmission power with no cause of network congestion.

LMPs = Marginal Loss Component (MLC) + Congestion Component (CC) + System Marginal Price (SMP)

Where, Marginal Loss Component (MLC) = Marginal Sensitivity Factor System Energy Price.

A corresponding CM strategy based on nodal pricing was presented in the literature [76] for overcrowding fall and most favorable energy stability. In the paper [71] outlines the key differences among CM and LMP and their collision on network operation base on redispatch. Y. R. Sood [73] suggested an easy DPM model with a pool and every sort of transactions, like multilateral, bilateral, firm, and non-firm interactions. In this paper, Location l marginal prices was designed for a number of buses in order to maximize the communal profit and calculate approximately the transaction's Short-Term Marginal Cost (SRMC). In the PJM market, the LMP approach is utilized to relieve transmission congestion [77, 78] demonstrated that the nodal price technique proposed for CM is a market-based price method wherein expenses are determined by a specified nodal price. The distributed LMP method proposed in [72] was designed to relieve congestion by introducing flexible needs toward a dispersed system.

OPTIMIZATION AND BIOINSPIRED COMPUTATIONAL INTELLIGENCE (CI) TECHNIQUES

In real meaning, CM is a multivariable non-linear issue that may be solved using optimization methods. Modern power systems have severe difficulties due to their construction, large-geographical variances, and unexpected factors. Metaheuristics optimization techniques have been continually improved in order to reduce the computing time of a given issue, improve the quality of solutions, and handle higher target instances. One of these strategies is hybridizing, which is particularly fascinating due to the vast range of challenges that may be adapted. Bioinspired algorithms among an extended the past of solving optimization issues include swarm intelligence and metaheuristics algorithms.

Bio-inspired optimization algorithms like PSO and GA contain behavioral factors so as to govern their presentation while optimizing a task. The efficiency of optimization is enhanced by a set of well-chosen parameters. Manually tweaking settings is a time-consuming process. In recent years, bioinspired optimization algorithms enclose demonstrating capability in the direction of create optimum scientific and engineering solutions to challenging computational challenges. Figure 4 depicts the bio-inspired CI techniques categorization [90–99].

To determine the appropriate location and organize of FACTS devices to minimize overcrowding, the literature [42–45] employed CI approaches in group and hybrid DPM models. Table 3 shows the various optimization approaches employed in DPM for congestion control.

Table 3. List of numerous CM optimization techniques.

Optimization Techniques	**Remark**	**Reference**
Fuzzy Adaptive Bacterial Foraging (FABF)	Based on generator sensitivity to the crowded line, the selected generators were ideally rescheduled for their active power.	[30]
PSO	By means of knowing the standard congestion sensitivity index, CM charge optimization may be achieved without the need of FACTS devices and without a load curtailment.	[31]
PSO	In market-based power systems, the most favorable location of UPFC has been discovered.	[32]
PSO	Enhancement within voltage stability as well as voltage profile are taken into account, with real and reactive power value for generators being kept as close to schedule as possible.	[33]
SPSO-TVAC	Costs of redispatch have been minimized.	[34]
Time-varying acceleration coefficients in the conventional PSO (PSO-TVAC)	By taking into account voltage stability as well as voltage profile, we were able to reduce fluctuations within the reactive as well as active power generator value from the listed value.	[35]
PSO	It minimizes operational expenses and the system's peak load via DR.	[36]
Hybrid mutation PSO (HMPSO)	Enhancement of ATC.	[37]
Twin extremity chaotic map adaptive PSO (TECMPSO)	Recognizing the participating generators reduced the cost of rescheduling.	[38]
Improved tent map embedded chaotic PSO (ITM-CPSO)	Estimation of participating generators was done using a power tracing algorithm. ITM-CPSO was utilized to reduce the cost of load shedding and rescheduling.	[39]
PSO technique with improved speed coefficients (PSO-ITVAC)	A few generators' real-time power outputs have been rescheduled.	[40]
Improved particle swarm optimization (IPSO)	STATCOM was placed in the best possible position.	[41]
Firefly algorithm (FA)	Active power is being rescheduled.	[42]
Growing radial basis function neural network (GRBFNN)	Nodal congestion cost in favor of CM is predicted.	[45]
Modified invasive optimization weed (MIWO)	Choosing redispatched generators based on the highest GS standards to reduce redispatched cost.	[46]
GAMES	To get low system overheads and real-time power redistribution.	[47]
Multi-objective strength pareto evolutionary algorithm (SPEA)	Realistic voltage dependent load modeling was employed for load shedding and rescheduling.	[48]
Black hole algorithm (BHA)	Reduce the cost of rescheduling actual power.	[49]
Chaos enhanced differential evolution (DE)	Sensitivity examination was utilized in the direction of locate the serious line loss, and DE was used to reschedule the generators that were involved.	[50]
GWO	The best possible position of several DG units within distribution network minimized reactive and active energy losses.	[51]
Metaheuristic satin bowerbird optimization (SBO)	Generators are being rescheduled.	[52]
Gray wolf optimizer (GWO)	DR program reduces congestion and CO_2 emissions.	[53]
Multi-objective glow-worm swarm optimization (MO-GSO)	Rearranging generation headed for decrease overall expenditure as well as transmission failure.	[54]
Artificial bee colony algorithm (ABC)	Overloads are alleviated by GR and load curtailments.	[55]
Metaheuristic TLBO	Generators are being rescheduled.	[56]
Teaching–learning-based optimization (TLBO)	Generators are being rescheduled.	[57]
Ant lion optimizer (ALO)	GR with real power	[58]
Evolutionary programming (EP) & DE	Pool power is delivered in a cost-effective manner.	[59]
Improved DE	To alleviate grid congestion, new wind farms will be installed in transmission lines, and generators will be rescheduled.	[60]

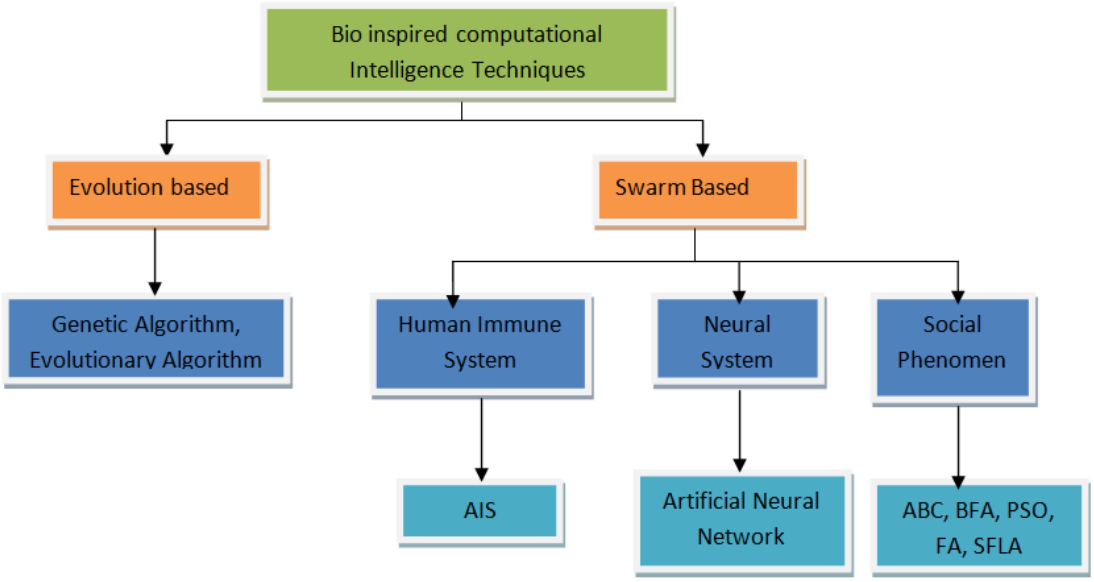

Figure 4. Types of bioinspired CI techniques.

DRM

Consumers can become active participants in the DPM using this DRM technique [89]. Customers will be rewarded if they adjust their needs during periods of congestion. During times of congestion, nodal costs may rise, prompting ISO to issue consumers orders to reschedule their energy usage. In contingency planning, Demand-side management (DSM) is critical. Figure 5 depicts many types of CM DR approaches.

The multi-objective particle swarm optimization (MOPSO) technique presented reschedules generation using DRPs in the literature [82]. When it comes to enlisting small customers in demand reduction, DRPs give the operator greater possibilities. This strategy attempted to cut operating expenditure, diminish emissions, and alleviate transmission line overcrowding. By taking into account DR and FACTS devices, A mixed-integer optimization strategy in favor of CM within DPM has been suggested by A. Yousefi et al. [85]. Jabir et al. [93] discuss many forms of DRM, as well as their consequences and current advances.

In favor of the pool based DPM model, A. Kumar et al. [81] proposed a demand-side-based CM strategy. By taking wind power unpredictability into account, J. Wu, B. Zhang, and colleagues [92] suggested a bilevel optimization approach to find the best DR buses for CM. A real time hybrid optimization (RTHO) approach in favor of adaptive instantaneous CM in smart power systems has been proposed by M. Mahmoudian Esfahani et al. [86].

REVIEW

This article gives an outline of the entire current developments in CM approaches. Researchers, utilities engineers, and academics will benefit greatly from the study. Periodic updates on this issue would be beneficial as the deregulated electricity sector continues to develop internationally. The authors have attempted to list all of the conceivable CM approaches that have been investigated thus far. The following are the findings of the literature review:

- FACTS devices are gradually put within the network to provide the most efficient network usage.
- The use of sophisticated optimization techniques within nonlinear overheads cuts overall reschedule overheads even supplementary with frees up time and effort for system operators.
- DRM is gaining popularity as a way to manage congestion charges while also improving system dependability and safety.

- In DPM, the utilization of distributed energy sources has risen. Because of the RES DGs, the DG base CM technique is a very proficient strategy.
- The use of optimization techniques to reschedule generations is a more efficient CM strategy.

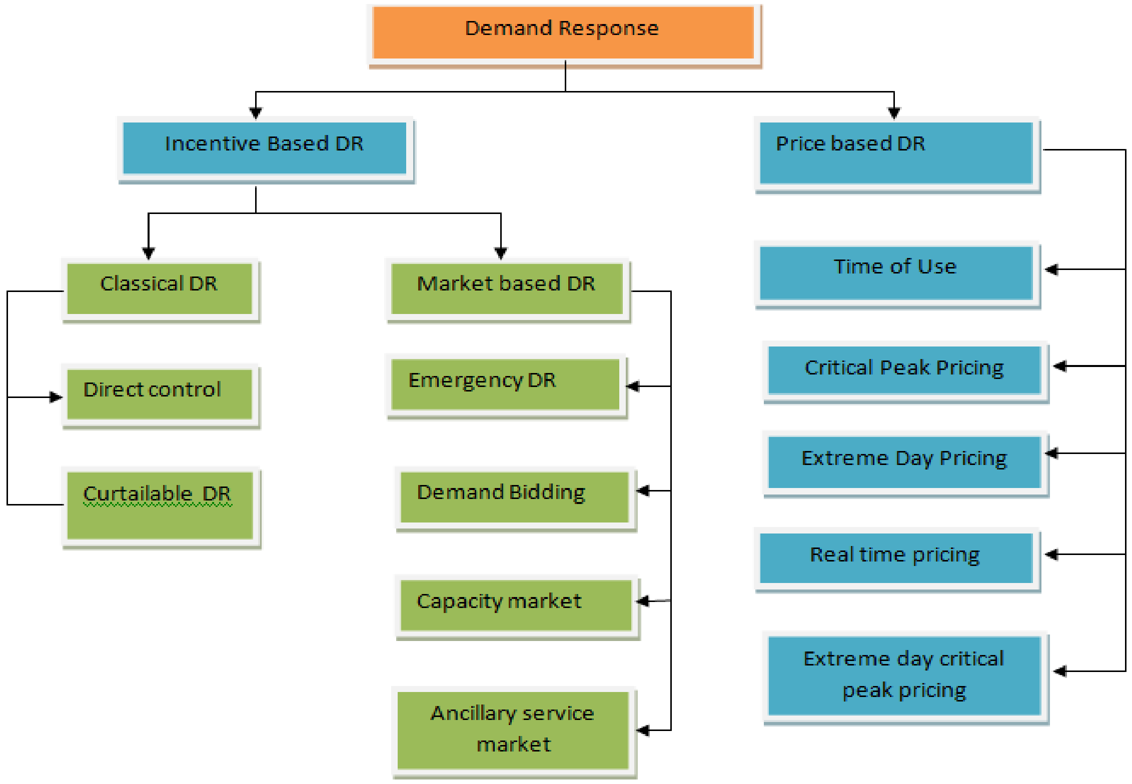

Figure 5. DR CM techniques [91].

CONCLUSION

Development of deregulated electricity transmission sector is happening continuously. Hence it is very important to perform the creative studies in this regards so that electricity transmission sector can take a fruitful turn for the betterment of human beings through proper use of natural resources. The comparative study with regards to CM approache ahead of analyzing the all the papers related to deregulated power market it has been observed that the classic approaches are not upto the mark to bring the innovation in transmission of electricity. Further work needs to be done by keeping in mind all the classical methods to improve the efficiency in electricity transmission sector.

Future Work

- The usage of CM is required in numerous domains, including vibrant CM for connected ramp rate constraints and probabilistic optimization of wind or PV systems.
- CM would require evaluating the optimal transmission switch approach within the equilibrium between closing and opening of the shunt condenser at the receiver end.
- When there is network congestion, it's critical toward explore the impact of EV aggregators on top of DPMs.
- Alternative computing load reduction technologies, such as machine learning and deep learning techniques, must identified.

REFERENCES

1. Kumar A, Srivastava SC, Singh SN. Congestion management in competitive power market: A bibliographical survey. Electr Power Syst Res. 2005;76(1–3): 153–164p. https://doi.org/10.1016/j.epsr.2005.05.001.

2. Fosso OB, Gjelsvik A, Haugstad A, Mo B, Wangensteen I. Generation scheduling in a deregulated system. The Norwegian case. IEEE Trans Power Syst. 1999;14(1): 75–81p. https://doi.org/10.1109/59.744487.
3. Rahman I, Mohamad-Saleh J. Hybrid bio-inspired computational intelligence techniques for solving power system optimization problems: A comprehensive survey. Appl Soft Comput J. 2018;69: 72–130p. https://doi.org/10.1016/j.asoc.2018.04. 051.
4. Manikandan BV, Charles RS, Venkatesh P, Mandala M. Comparative study of two congestion management methods for the restructured power systems. J Electr Eng Technol. 2011; 6(3): 302–310p. https://doi.org/10.5370/ JEET.2011.6.3.302.
5. Gumpu S, Pamulaparthy B, Sharma A. Review of congestion management methods from conventional to smart grid scenario. Int Emerging Electric Power Syst. 2019;20(3): 20180265p. https://doi.org/10.1515/ijeeps-2018-0265.
6. Narain A, Srivastava SK, Singh S.N. Congestion management approaches in restructured power system: Key issues and challenges. Electr J. 2020;33(3): 106715p. https://doi.org/10.1016/j.tej.2020.106715.
7. Prabhakar KS, Jacob RI, Kothari DP. Impact of FACTS devices on exercising market power in deregulated electricity market. Front Energy. 2013;7: 448–455p. https://doi.org/10.1007/s11708-013-0262-x.
8. Gumpu S, Pamulaparthy B, Sharma A. Review of congestion management methods from conventional to smart grid scenario. Int Emerging Electric Power Syst. 2019;20(3): 20180265p. https://doi.org/10.1515/ijeeps-2018-0265.
9. Yusoff NI, Zin AAM, Bin KA. Congestion management in power system: A review. 3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET). Johor Bahru, Malaysia. 2017. pp. 22–27, doi: 10.1109/PGSRET.2017.8251795. https://doi.org/10.1109/PGSRET.2017. 8251795.
10. Gupta M, Kumar V, Banerjee GK, Sharma NK. Mitigating congestion in a power system and role of FACTS devices. Adv Electr Eng. 2017;2017: 1–7p. https://doi.org/10.1155/ 2017/4862428.
11. Brosda, Handschin E. Congestion management methods with a special consideration of FACTS-devices. In: 2001 IEEE Porto Power Tech Proceedings. 2001. https://doi.org/10.1109/PTC. 2001.964593.
12. Rao RS, Rao VS. Electrical power and energy systems a generalized approach for determination of optimal location and performance analysis of FACTs devices. Int J Electr Power Energy Syst. 2015;73: 711–724p. https://doi.org/10.1016/j. ijepes.2015.06.004.
13. Kishore Y, Baleboina GM. Enhancement of voltage stability and transmission congestion management with UPFC. Int J Grid Distrib Comput. 2018;11(6):15–26p. https://doi.org/10.14257/ijgdc.2018.11.6.02.
14. Chong B, Zhang XP, Yao L, Godfrey KR, Bazargan M. Congestion management of electricity markets using FACTS controllers. In: IEEE Power Engineering Society General Meeting. 2007. 1–6p.
15. Pillay A, Prabhakar KS, Kothari DP. Congestion management in power systems: A review. Int J Electr Power Energy Syst. 2015;70: 83–90p. https://doi.org/10.1016/j. ijepes.2015.01.022.
16. Acharjee P. Optimal power flow with UPFC using security constrained self-adaptive differential evolutionary algorithm for restructured power system. Int J Electr Power Energy Syst. 2016;76: 69–81p. https://doi.org/10.1016/j.ijepes.2015.09.025.
17. Besharat H, Taher SA. Congestion management by determining optimal location of TCSC in deregulated power systems. Int J Electr Power Energy Syst. 2008;30(10): 563–568p. https://doi.org/10.1016/j.ijepes.2008.08.007.
18. Benabid R, Boudour M, Abido MA. Optimal location and setting of SVC and TCSC devices using non-dominated sorting particle swarm optimization. Electr Power Syst Res. 2009;79(12): 1668–1677p. https://doi.org/10.1016/j.epsr.2009.07.004.
19. Esmaili M, Shayanfar HA, Moslemi R. Locating series FACTS devices for multi-objective congestion management improving voltage and transient stability. Eur J Oper Res. 2014;236(2): 763–773p. https://doi.org/10.1016/j.ejor. 2014.01.017.

20. Taher SA, Karim AM. Optimal placement of UPFC in power systems using immune algorithm. Simul Model Pract Theory. 2011;19(5): 1399–1412p. https://doi.org/ 10.1016/j.simpat.2011.03.001.
21. Taher SA, Amooshahi MK. New approach for optimal UPFC placement using hybrid immune algorithm in electric power systems. Int J Electr Power Energy Syst. 43(1): 899–909p. https://doi.org/10.1016/j.ijepes.2012.05.064.
22. Singh SN, David AK. Optimal location of FACTS devices for congestion management. Electr Power Syst Res. 2017;58(2): 71–79p. https://doi.org/10.1016/j.jpba.2017.03.034.
23. Kumar A, Singh SN, Lai LL. Impact of TCPAR on congestion clusters and congestion management using mixed integer nonlinear programming approach. In: Power Engineering Society General Meeting. IEEE, 2006. https://doi.org/10. 1109/PES.2006.1709109.
24. Mishra A, Venkata NKG. Congestion management of deregulated power systems by optimal setting of Interline Power Flow Controller using Gravitational Search algorithm. J Electr Syst Inf Technol. 2017;4(1): 198–212p. https://doi.org/ 10.1016 j.jesit.2016.09.001.
25. Mishra A, Nagesh Kumar GV. Congestion management of power system with interline power flow controller using disparity line utilization factor and multi-objective differential evolution. CSEE J. Power Energy Syst. 2015;1(3): 76–85p. https:// doi.org /10.17775/CSEEJPES.2015.00038.
26. Hooshmand RA, Morshed MJ, Parastegari M. Congestion management by determining optimal location of series FACTS devices using hybrid bacterial foraging and Nelder-Mead algorithm. Appl Soft Comput J. 2015;28(C): 57–68p. https://doi.org /10. 1016/j.asoc.2014.11.032.
27. Behera SK, Mohanty NK. Congestion management using thyristor controlled series compensator employing Improved Grey Wolf Optimization technique. Int J Electr Eng Educ. 2019;58(2): 179–199p. https://doi.org/10.1177/0020720918822730.
28. Sharma A, Jain S. Locating series FACTS devices for man- aging transmission congestion in deregulated power market. India Int Conf Power Electron. IICPE, 2016. November, 2017. https://doi.org/10.1109/IICPE.2016.8079445.
29. Reddy KAK, Singh SP. Congestion mitigation using UPFC. IET Gener Transm Distrib. 2016; 10(10): 2433–2442p. https://doi.org/10.1049/iet-gtd.2015.1199.
30. Venkaiah C, Vinod KDM. Fuzzy adaptive bacterial foraging congestion management using sensitivity based optimal active power rescheduling of generators. Appl Soft Comput J. 2011; 11(8): 4921–4930p. https://doi.org/10.1016/j.asoc.2011.06.007.
31. Chanda, De A. Application of particle swarm optimization for relieving congestion in deregulated power system. In: 2011 IEEE Recent Advances in Intelligent Computational Systems., 2011. pp. 837–840. https://doi.org/10.1016/j.asoc.2011.06.007.
32. Hajforoosh S, Nabavi SMH, Masoum MAS. Coordinated aggregated-based particle swarm optimisation algorithm for congestion management in restructured power market by placement and sizing of unified power flow controller. IET Sci Meas Technol. 2012;6(4): 267p. https://doi.org/10.1049/ietsmt. 2011.0143.
33. Joshi SK, Pandya KS. Active and reactive power rescheduling for congestion management using particle swarm optimization. AUPEC 2011. 2011, pp. 1–6.
34. Shayanfar HA, Shayeghi H, Ghasemi A. SPSO-TVAC congestion management in a practical electricity market based generator sensitivity. In: Proceedings of the 2014 International Conference on Artificial Intelligence, ICAI 2014 – WORLDCOMP 2014, 2014.
35. Boonyaritdachochai P, Boonchuay C, Ongsakul W. Optimal congestion management in electricity market using particle swarm optimization with time varying acceleration coefficients. AIP Conf Proc. 2010;1239(4): 382–387p. https://doi.org/10.1063/1.3459776.
36. Kinhekar N, Padhy NP, Gupta HO. Particle swarm optimization based demand response for residential consumers. IEEE Power Energy Soc Gen Meet. 2015;1–5p. https://doi.org/10.1109/PESGM.2015.7286466.
37. Farahmand H, Rashidinejad M, Mousavi A, Gharaveisi AA, Irving MR, Taylor GA. Hybrid mutation particle swarm optimisation method for available transfer capability enhancement. Int J Electr Power Energy Syst. 2012;42(1): 240–249p. https://doi. org/10.1016/j.ijepes.2012.04.020.
38. Batra I, Ghosh S. A novel approach of congestion management in deregulated power system using

an advanced and intelligently trained twin extremity chaotic map adaptive particle swarm optimization algorithm. Arab J Sci Eng 2019;44: 6861–6886p. https://doi.org /10.1007/s13369-018-3675-3.
39. Batra I, Ghosh S. An improved tent map-adaptive chaotic particle swarm optimization (ITM-CPSO) – based novel approach toward security constraint optimal congestion management. Iran J Sci Technol Trans Electr Eng. 2018;42: 261–289p. https://doi.org/10.1007/s40998-018-0072-6.
40. Sarwar M, Siddiqui AS. An efficient particle swarm optimizer for congestion management in deregulated electricity market. J Electr Syst Inf Technol. 2015;2(3): 269–282p. https://doi.org/10.1016/j.jesit.2015.08.002.
41. Ravi K, Rajaram M. Electrical power and energy systems optimal location of FACTS devices using improved particle swarm optimization. Int J Electr Power Energy Syst. 2013;49: 333–338p. https://doi.org/10.1016/j.ijepes.2012.12.008.
42. Ahamed Jeelani Basha A, Anitha M, Elanchezhian EB. Application of firefly algorithm for congestion management problem in the deregulated electricity market. Int J Intell Eng Inform. 2018;6: 222–241p.
43. Bhattacharjee T, Chakraborty AK. Congestion management in a deregulated power system using NSGAII. In: 2012 IEEE 5th Power India Conference. PICONF. 2012. https: //doi.org/10.1109/PowerI.2012.6479529.
44. Ushasurendra S. Congestion management in deregulated power sector using fuzzy based optimal location technique for series flexible alternative current transmission system (FACTS) device. J Electr Electron Eng Res. 2012;4(1): 12–20p. https://doi.org/10.3317/jraas.2003.021.
45. Pandey SN, Tapaswi S, Tapaswi L. Growing RBFNN- based soft computing approach for congestion management. Neural Comput Applic. 2009;18: 945p. https://doi.org/10. 1007/s00521-008-0205-3.
46. Abedinia O, Amjady N, Naderi MS. Optimal congestion management in an electricity market using Modified Invasive Weed Optimization. In: 2012 11th International Conference on Environment and Electrical Engineering. EEEIC 2012 Conference Proceedings, 2012. https: //doi.org /10.1109/EEEIC.2012.6221423.
47. Mende D, Stock DS, Hennig T, Lower L, Hofmann L. Multiobjective optimization in congestion management considering technical and economic aspects. In: Asia-Pacific Power and Energy Engineering Conference. APPEEC, 2016. https://doi.org/10.1 109 /AP PE EC. 2016. 77 7 9 711.
48. Reddy SS. Multi-objective based congestion management using generation rescheduling and load shedding. IEEE Trans Power Syst. 2017;32(2): 852–863p. https://doi.org/10. 1109/ TPWRS.2016.2569603.
49. Ramachandran R, Arun M. Sensitivity based optimal real power rescheduling for congestion management using black hole algorithm. Aust J Basic Appl Sci. 2016;10(15): 183–193p.
50. Mandal S, Das G, Mandal KK, Tudu B. A new improved hybrid algorithm for congestion management in a deregulated electricity industry using chaos enhanced differential evolution. 3rd International Conference on Computational Intelligence & Communication Technology (CICT). Ghaziabad, India. 2017. pp. 1–5., https://doi.org/10.1109/CIACT.2017.7977386.
51. Sultana U, Khairuddin A, Mokhtar AS, Qazi SH, Sultana B. An optimization approach for minimizing energy losses of distribution systems based on distributed generation placement. J Teknol 2017;79(4): 87–96p. https://doi.org/10.11113/jt.v79.5574.
52. Chintam JR, Daniel M. Real-power rescheduling of generators for congestion management using a novel satin bowerbird optimization algorithm. Energies. 2018;11(1): 183p. https: //doi.org/10.3390/en11010183.
53. Salehi J, Abdolahi A. Optimal scheduling of active distribution networks with penetration of PHEV considering congestion and air pollution using DR program. Sustain. Cities Soc. 2019;51: 101709p. https://doi.org/10.1016/j.scs.2019.101709.
54. Salkuti SR, Kim SC. Congestion management using multiobjective glowworm swarm optimization algorithm. J Electr Eng Technol. 2019;14: 1565–1575p. https://doi.org /10.1007/s42835-019-00206-w
55. Saranya R, Balamurugan K, Karuppasamy M. Artificial bee colony algorithm based congestion management in restructured power system. Indian J Sci Technol. 2015;8(April): 171–178p.

https://doi.org/10.17485/ijst/2015/v8iS7/64298.
56. Basha AAJ. Transmission congestion management in restructured power system using firefly algorithm. Int J Comput Appl. 2014;85(January): 39–43p.
57. Verma S, Saha S, Mukherjee V. Optimal rescheduling of real power generation for congestion management using teaching learning-based optimization algorithm. J Electr Syst Inf Technol. 2016;5(3): 889–907p. https://doi.org/10.1016/j.jesit. 2016.12.008.
58. Mukherjee V, Verma S. Optimal real power rescheduling of generators for congestion management using a novel ant lion optimiser. IET Gener Transm Distrib. 2016;10(10): 2548–2561p. https://doi.org/10.1049/iet-gtd.2015.1555.
59. Balamurugan K, Muralisachithanandam R, Dharmalingam V. Electrical Power and Energy Systems Performance comparison of evolutionary programming and differential evolution approaches for social welfare maximization by placement of multi type FACTS devices in pool electricity market. Int J Electr Power Energy Syst. 2015;67: 517–528p. https://doi.org /10.1016/j.ijepes.2014.12.007.
60. Suganthi ST, Devaraj D, Ramar K, Hosimin Thilagar S. An Improved Differential Evolution algorithm for congestion management in the presence of wind turbine generators. Renew Sustain Energy Rev. 2018;81(June 2017): 635–642p. https:// doi.org /10. 1016 / j. rser. 2017.08.014.
61. Balaraman S, Kamaraj N. Application of differential evolution for congestion management in power system. Mod Appl Sci. 2010;4(8). https://doi.org/10.5539/mas.v4n8p33.
62. Nabavi SMH, Kazemi A, Masoum MAS. Congestion management using genetic algorithm in deregulated power environments. Int J Comput Appl. 2011;18(2): 19–23p. https://doi.org/10.5120/2257-2894.
63. Balaraman S. Congestion management in deregulated power system using real coded genetic. Int J Eng Sci Technol. 2010;2(11): 6681–6690p
64. Reddy SS, Kumari MS, Sydulu M. Congestion management in deregulated power system by optimal choice and allocation of FACTS controllers using multi-objective genetic algorithm. In: IEEE PES T&D. 2010, pp. 1–7. https://doi.org/10.1109/TDC.2010.5484520.
65. Pal S, Sen S, Sengupta S. Power network reconfiguration for congestion management and loss minimization using genetic algorithm. In: Michael Faraday IET International Summit. 2015, pp. 291–296. https://doi.org/10.1049/cp.2015.1646.
66. Peesapati R, Yadav VK, Kumar N. Flower Pollination Algorithm Based Multi-Objective Congestion Management Considering Optimal Capacities of Distributed Generations. Energy 2018;147: 980–994p.
67. Bhattacharyya B, Gupta VK. Fuzzy based evolutionary algorithm for reactive power optimization with FACTS devices. Int J Electr Power Energy Syst. 2014;61(1): 39–47p. https://doi.org/10.1016/j.ijepes.2014.03.008.
68. Pandey SN, Tapaswi S, Srivastava L. Integrated evolutionary neural network approach with distributed computing for congestion management. Appl Soft Comput J 2010;10(1): 251–260p. https://doi.org/10.1016/j.asoc.2009.07.008.
69. Panigrahi BK, Ravikumar Pandi V. Congestion management using adaptive bacterial foraging algorithm. Energy Convers Manag. 2009;50(5): 1202–1209p. https:// doi. Org / 10.1016/j.enconman.2009.01.029.
70. Ramesh Kumar A, Premalatha L. Security constrained multi-objective congestion management in transactional based restructured electrical network using bacterial foraging algorithm. In: International Conference on Circuits, Power and Computing Technologies (ICCPCT). 2013, pp. 63–67. https://doi.org/10.1109/ICCPCT.2013.6528913.
71. Mohanapriya T, Manikandan TR. Congestion management of deregulated electricity market using locational marginal pricing. IEEE International Conference on Computational Intelligence and Computing Research. Coimbatore, India. 2014, pp. 1–4.
72. Huang S, Wu Q, Oren SS, Li R, Liu Z. Distribution locational marginal pricing through quadratic programming for congestion management in distribution networks. IEEE Trans Power Syst. 2015;30(4): 2170–2178p. https://doi.org/10. 1109/TPWRS.2014.2359977.
73. Sood YR, Padhy NP, Gupta HO. Deregulated model and locational marginal pricing. Electr Power Syst Res. 2007;77: 574–582p.
74. Packiasudha M, Suja S, Jerome J. A new Cumulative Gravitational Search algorithm for optimal

placement of FACT device to minimize system loss in the deregulated electrical power environment. Int J Electr Power Energy Syst. 2017;84: 34–46p. https://doi.org/10.1016/j.ijepes.2016.04.049.
75. Kavitha K, Neela R. Optimal allocation of multi-type FACTS devices and its effect in enhancing system security using BBO, WIPSO & PSO. J Electr Syst Inf Technol. 2018;5(3): 777–793p. https://doi.org/10.1016/j.jesit.2017.01.008.
76. Yamin HY, Shahidehpour SM. Transmission congestion and voltage profile management coordination in competitive electricity markets. Int J Electr Power Energy Syst. 2003;25(10): 849–861p. https://doi.org/10.1016/S0142-0615(03)00070-X.
77. Ott A. PJM: a full service ISO market evolution (Panel on evolution of electricity market structures). IEEE Power Engineering Society Summer Meeting. Conference Proceedings (Cat. No.99CH36364). Edmonton, Canada. 1999, pp. 746–748. https://doi.org/10.1109/PESS.1999.787410.
78. Holmberg P, Lazarczyk E. Congestion management in electricity networks: Nodal, zonal and discriminatory pricing (March 27, 2012). IFN Working Paper, No. 915, SSRN: https://ssrn.com/abstract=2055655, http://dx.doi.org/10.2139/ssrn. 2055655iitiyiiy.
79. Sarwar M, Siddiqui AS. An approach to locational marginal price based zonal congestion management in deregulated electricity market. Front Energy. 2016;10: 240–248p. https://doi.org/10.1007/s11708-016-0404-z.
80. Muneender E, Kumar DMV. Optimal rescheduling of real and reactive powers of generators for zonal congestion management based on FDR PSO. Transmission & Distribution Conference & Exposition: Asia and Pacific. Seoul, South Korea. 2009, pp. 1–6. https:// doi.org/10.1109/TD-ASIA .2009.5356989.
81. Kumar A, Sekhar C. DSM based congestion management in pool electricity markets with FACTS devices. Energy Proced. 2012;14: 94–100p. https://doi.org /10.1016 /j egypro . 2011.12.901.
82. Zaeim-Kohan F, Razmi H, Doagou-Mojarrad H. Multiobjective transmission congestion management considering demand response programs and generation rescheduling. Appl Soft Comput J. 2018;70: 169–181p. https://doi.org/10.1016/j.asoc.2018.05.028.
83. Sood YR., Singh R. Optimal model of congestion management in deregulated environment of power sector with promotion of renewable energy sources. Renew. Energy. 2010;35(8): 1828–1836p. https://doi.org/10.1016/j.renene.2010.01.002.
84. Kumar A, Sekhar C. Comparison of Sen Transformer and UPFC for congestion management in hybrid electricity markets. Int J Electr Power Energy Syst. 2013;47(1): 295–304p. https://doi.org/10.1016/j.ijepes.2012.10.057.
85. Yousefi A., Nguyen T. T., Zareipour H., Malik O. P. Congestion management using demand response and FACTS devices. Int. J. Electr. Power Energy Syst. 2012; 37(1): 78–85p. https://doi.org/10.1016/j.ijepes.2011.12.008.
86. Mahmoudian Esfahani M, Sheikh A, Mohammed O. Adaptive real-time congestion management in smart power systems using a real-time hybrid optimization algorithm. Electr Power Syst Res. 2017;150: 118–128p. https://doi.org/10. 1016/j.epsr.2017.05.012.
87. Paqaleh MA, Tehrani Fard AA, Rashidinejad M, Lee KY. Optimal Placement and Sizing of Distributed Resources for Congestion Management considering Cost/benefit Analysis. IEEE PES, General Meeting, Minneapolis: MN, 2017, https://doi.org/10.1109/JPROC.2010.2066250.
88. Singh AK, Parida SK. Congestion management with distributed generation and its impact on electricity market. Int J Electr Power Energy Syst. 2013;48: 39–47p. https://doi.org/10.1016/j.ijepes.2012.11.025.
89. Tabandeh A, Abdollahi A, Rashidinejad M. Reliability constrained congestion management with uncertain negawatt demand response firms considering repairable advanced metering infrastructures. Energy. 2016; 104: 213–228p. https://doi.org/10.101 6/j.energy .2016.03.118.
90. Dehnavi E, Aminifar F. Congestion management through distributed generations and energy storage systems. Int Trans Electr Energy Syst. 2019;29(3): e12018p. https://doi.org / 10.1002/2050-7038.12018.

91. FERC, Assesement of Demand Response and Advanced Metering; 2006.
92. Wu J, Zhang B, Jiang Y. Optimal day-ahead demand response contract for congestion management in the deregulated powermarket considering wind power. IET Gener Transm Distrib 2018;12(4): 917–926p. https://doi.org/10.1049/iet-gtd.2017.1063.
93. Jabir HJ, Teh J, Ishak D, Abunima H. Impacts of demand-side management on electrical power systems: A review. Energies. 2018;11(5): 1050p. https://doi.org/10.3390/en11051050.
94. Nikoukar J, Haghifam MR. Transmission cost allocation based on the use of system and considering the congestion cost. Int J Electr Power Energy Syst. 2012;43(1): 961–968p. https://doi.org/10.1016/j.ijepes.2012.06.016.
95. Liu J, Salama MMA, Mansour RR. Identify the impact of distributed resources on congestion management. IEEE Trans Power Deliv 2005;20(3): 1998–2005p. https ://doi.org/10.1109/TPWRD.2004.843401.
96. Lopez MA, Martin S, Aguado JA, De La Torre S. V2G strategies for congestion management in microgrids with high penetration of electric vehicles. Electr Power Syst Res. 2013;104: 28–34p. https://doi.org/10.1016/j.epsr.2013.06.005.
97. Lopes JAP, Soares FJ, Almeida PMR. Integration of electric vehicles in the electric power system. Proc. IEEE. 2011;99(1): 168–183p. https://doi.org/10.1109 /J P ROC. 2010.2066250.
98. Hu J, Si C, Lind M, Yu R. Preventing distribution grid congestion by integrating indirect control in a hierarchical electric vehicles' management system. IEEE Trans Transp Electrif. 2016;2(3): 290–299p. https://doi.org/10.1109/TTE.2016.2554469.
99. Nireekshana T, Kesava Rao G, Sivanaga Raju S. Available transfer capability enhancement with FACTS using Cat Swarm Optimization. Ain Shams Eng J 2016;7(1): 159–167p. https://doi.org/10.1016/j.asej.2015.11.011.

