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International Review of Applied Sciences and Engineering

13 (2022) 1, 29–41

DOI:


[10.1556/1848.2021.00286](https://doi.org/10.1556/1848.2021.00286)

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REVIEW PAPER



A survey on recent advances in transmission congestion management

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Received: April 6, 2021 • Accepted: June 11, 2021

Published online: August 31, 2021

ABSTRACT

For the last few decades, the power sector has been restructuring throughout the world, and because of this, congestion is bound to take place in the network. Congestion can lead to market failure, violate transmission capability limits and high electricity prices, and end up threatening the power systems' reliability and security. Increased congestion may also lead to unexpected price differences in power markets leading to market power. In a deregulated power market (DPM), the independent system operator (ISO)'s fundamental challenge is to preserve the power market's reliability and safety by improving market efficiency when the network is congested. Therefore, congestion management (CM) is essential in DPM and is the key to the power system. This paper carries out a congestion management methods survey to bring together all recent publications in the DPM. It aims to help readers summarize progressive CM methods, along with traditional CM methods that have been discussed so far. In this paper, we have carried out a comparative survey of the various well-known CM methods.

KEYWORDS

congestion management, deregulated power market, demand response, optimization techniques

1. INTRODUCTION

Despite increasing demand for electricity and technological development in recent years, the electrical industry in several nations, including Canada, the United Kingdom, the United States, New Zealand, Australia, Chile, Peru, Colombia, the European Union, and Scandinavia, have deregulated by substituting earlier monolithic public utilities with competitive power markets. Restructuring involves turning the vertical system into an unbundled system [1]. Liberalization, deregulation, and privatization mean restructuring itself [2]. The independent system operator (ISO) has a lot of challenges in a deregulated power market (DPM), including choosing a specific auction strategy to minimize market power and congestion to increase system reliability and efficiency [3]. The independent system operator ISO will take essential steps in congestion management (CM), such as available transfer capability (ATC) calculation, rescheduling of generation, and network topology reconfiguration, load management, and demand response management (DRM).

The constraints on the transmission network dictate the limited power transfer between two points on the network. If the transmission network violates one of those constraints, we say that system is congested [2]. The arbitrary power flows throughout the network due to unexpected generator faults, line outages, and system device malfunctions. Lack of power transmission line capacity for transactions is also a significant reason for transmission congestion because many DPM transactions can create congestion problems. In this case, the lack of attention leads to widespread blackouts, which damage the system's electrical equipment and price differences in various parts of the network [4]. In the open-access power system, the risk of congestion is more significant than in traditional monopolies because every transaction desires maximum profit. Therefore, CM has been the focus of discussion on facilitating competition in the power industry. CM is a powerful tool that does not breach transmission limitations. To solve this, researchers worldwide present various techniques to avoid or mitigate congestion and restore quick power transfer to consumers.

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In general, various CM methods are classified as non-technical and technical [1]. On the transmission side, we can use technical methods like FACTS devices and phase shifters. The methods like Zonal and nodal pricing, re-dispatching, market splitting, counter trading, load curtailment, and auctioning are coming under non-technical categories. Under non-technical approaches, rescheduling generation and optimum positioning of distribution generator (DG) are used on the generation side. Demand Response Management, load curtailment, and remaining techniques are used on the end-user side [5]. In the power markets, one of the problems is how to contribute to congestion costs and revenue. CM balances the system and resolves financial issues caused by congestion [6]. Nodal pricing, FACTS-based CM, ATC-based CM, and price area CM methods are coming under conventional CM methods. The computational time is more in Conventional CM methods compared to heuristic optimization methods. PSO, GA, BFA, ACO, FFA, FPA, ALO, and EA are examples of heuristic optimization methods. Congestion can also control for different periods in the short, medium, and long term [7]. Generator rescheduling (GR) with long-

medium and short-term durations is applied in Norway's DPM to control congestion [8].

Kumar et al. [9] divided the various CM techniques into four major categories: Sensitivity-based, auction-based, and pricing-based strategies, re-dispatch and willingness-to-pay methods. In [10], Anusha Pillay et al. have addressed the conventional CM and optimization techniques like particle swarm optimization (PSO) and genetic algorithm (GA). The general overview of CM methods is summarized in Fig. 1.

Aishvarya Narain et al. [5] outlined CM approaches by transmission side, generation side, and end-user side, as shown in Fig. 2.

The general design of the market is inextricably linked to the CM approaches. The basic goal of CM strategies is to redistribute network capacity among the relevant market participants as efficiently as possible. This paper critically examines a number of important works of literature that have been recommended for CM. Traditional strategies as well as alternative optimization strategies are studied in this survey for congestion alleviation.

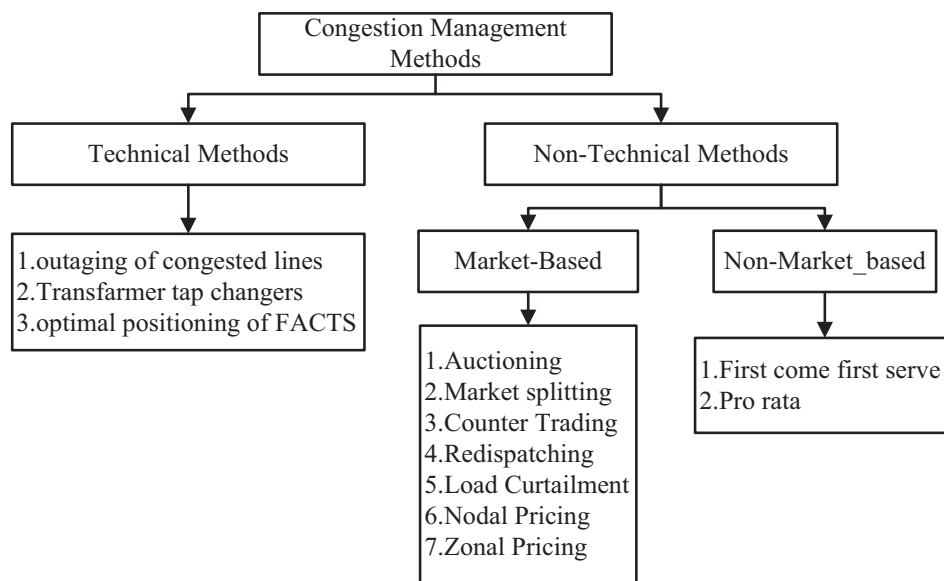


Fig. 1. General Overview of CM methods [1]

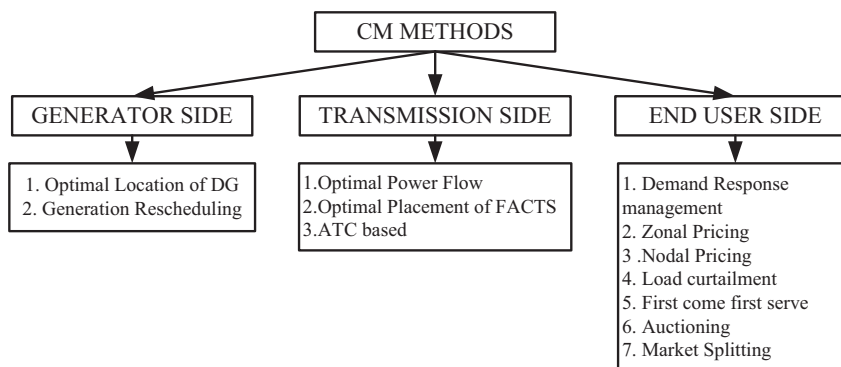


Fig. 2. CM approaches summarized view based on the application side [5]

2. FLEXIBLE AC TRANSMISSION SYSTEMS DEVICES (FACTS)

FACTS devices may be an alternative to minimizing power flows on highly loaded lines. FACTS can improve the loadability, and network efficiency, reduce system losses, reduce production costs, and handle the network's power flow requirements. FACTS devices improve existing transmission network capacity and reduce congestion costs by regulating the voltage, controlling reactive power, and power stabilization [11]. Activation of traditional compensation devices, phase shifters, the setting of transformer taps, and application of FACTS devices are coming under cost-free measures. These are available to the transmission system operator (TSO) for changing the topology of the network [12]. This CM has two aspects: Cost-free and the other one is non-cost-free, as illustrated in Fig. 3. Free cost measures are better because they avoid any economic discrepancies.

The approaches used for FACTS devices' optimum position are categorized in two ways: index-based methods and optimization-based methods. One of the leading developments in the current power scenario is to use FACTS with optimization methods [13, 14]. In different CM techniques, FACTS equipment's effect on congestion and its costs are addressed in the literature [15]. Various approaches for FACTS devices' optimal position have been proposed in the literature to improve loading and minimize congestion [16, 17]. The corresponding FACTS-based CM analysis is outlined in Table 1.

3. NODAL PRICING METHOD

CM has uniform and non-uniform pricing approaches. Nodal prices are geographically variable and referred to as "Locational Marginal Prices" (LMP) [30]. LMP is coming under a non-uniform pricing structure. Every bus in the network has been treated as a node in the nodal pricing scheme. By performing an economic load dispatch with the flow limits, the ISO calculates the LMP for each bus [31, 32]. The LMP has defined the particular position as the marginal cost to provide

a further MW power increase on the site without violating the system's security limitations. The marginal cost is substituted by a bid or price in a market-based structure. When the congestion in the system with the lowest energy costs cannot attain all areas, it will allocate more costly generators to meet the demand. In this case, LMP values can differ from one place to the next. A congestion fee equal to the difference between the nodal marginal price at the point of consumption and the point of injection is charged by participants participating in congested line transactions. Because of its inherent flexibility in allocating transmission power, the LMP-based CM method has been widely adopted worldwide without creating congestion in the network.

$$\begin{aligned} \text{LMP} = & \text{System Marginal Price (SMP)} \\ & + \text{Congestion Component (CC)} \\ & + \text{Marginal Loss Component (MLC)}. \end{aligned}$$

$$\text{MLC} = \text{system energy price} * \text{marginal sensitivity factor}.$$

In literature [33], a coordinated CM method was proposed for congestion reduction and optimum energy balance based on nodal prices. The literature [30] explains the fundamental differences between LMP and CM based on re-dispatch and evaluates its impact on grid operation. Y.R. Sood [34] suggested a simplified model for a DPM consisting of a pool and all forms of transactions, such as firm, non-firm, multilateral and bilateral. In this literature, LMP was calculated for different buses to optimize the social benefit and estimate the transaction's short-term marginal cost (SRMC). LMP method is used in the PJM market to ease transmission congestion [35]. In [36], the nodal price method proposed for CM proved that this strategy is a market-based pricing scheme in which system costs have been driven based on selected nodal price. In [37], the distributed LMP solution was intended to alleviate congestion by penetrating flexible demands to a distributed system.

4. ZONAL PRICING METHOD

Busess with identical LMPs have grouped into zones in the zonal pricing system. First of all, the market is free of

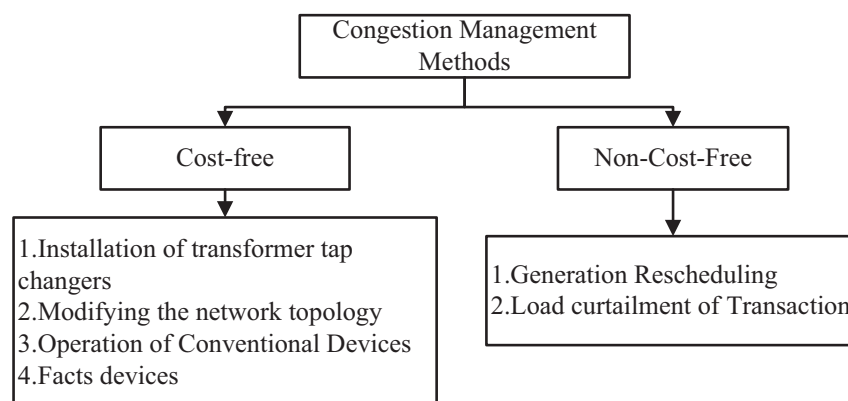


Fig. 3. CM methods based on cost

Table 1. Significant CM work using different FACTS devices

Reference	FACTS devise	Methodology	Remarks
Arun Kumar Reddy et al. [16]	UPFC	Sensitivity-based approach and pricing-based method	The interior-point method determined the minimum value for the generation rate.
Akanksha Sharma et al. [17]	TCSC	LMP difference method and congestion rent contribution method	Found the most acceptable location of TCSC for minimum congestion.
Behera and Mohanty [18]	TCSC	Improved Grey Wolf Optimization (IGWO)	The optimal place of TCSC was found to Curtail active power losses, voltage deviations & generation cost.
Rahmat- allah Hoosmand et al. [19]	TCSC	Hybrid Bacterial Foraging and Nelder-Mead algorithm (BF-NM).	Cost of generation, emission, and cost of TCSC minimized.
Akanksha mishra et al. [20]	IPFC	Multi-objective Differential Evolution	The optimal place of IPFC found using the Disparity line utilization factor (DLUF) to remove the transmission network congestion.
Akanksha mishra et al. [21]	IPFC	Gravitational search algorithm (GSA)	DLUF applied for best location & GSA used for most fine-tuning of IPFC for CM.
Ashwani Kumar et al. [22]	TCPAR	The mixed integer-based nonlinear optimal power flow model	The optimal location of TCPAR was found for CM.
S.N. Singh, A.K. David [23]	TCSC, TCPAR	Sensitivity-based approach	The author found the best location of TCPAR and TCSC to mitigate congestion.
S. A. Taher et al. [24], [25]	UPFC	Immune Algorithm (IA)	Minimized Generation cost by using IA.
M. Esmaili et al. [26]	TCSC	Multi-objective optimization	For optimization, three objective functions have been used here: overall operating expense, transient stability margins, and voltage.
R.Benabid et al. [27]	TCSC, SVC	Non-dominated sorting PSO (NSPSO)	NSPSO was used for maximizing static voltage stability margin (SVSM), load voltage deviation (LVD), and reduce real power losses (RPL).
Hadi Besharat et al. [28]	TCSC	Sensitivity-based approach	TCSC's effect on the congestion was studied by applying contingency like line outages.
P. Acharjee et al. [29]	UPFC	Self-Adaptive Differential Evolutionary (SADE) algorithm	SADE was used for enhancing and controlling the flow of power by using UPFC under practical security constraints.

limitations [36]. Zonal CM is split into two categories as inter-zonal and intra-zonal CM method [38]. In the case of congestion, the ISO receives additional bids to increase and decrease the generation. Participants bid to purchase or sell power in the zone. A system price is determined off-grid with all zones combined until the bid period has ended. If the calculation indicates that there are no limitations, this price applies to all zones. Zonal CM strategy based on the LMP was discussed in the literature [39].

5. OPTIMIZATION & BIO-INSPIRED COMPUTATIONAL INTELLIGENCE (CI) TECHNIQUES

In essence, CM is a nonlinear problem with many variables which can resolve through optimizing algorithms. Due to its

complexity of architecture, vast geographical differences, and unpredictable variables, modern power systems' problems are complicated. Reducing the computational time of the particular problem, improving the quality of solutions, and addressing higher target instances, particularly meta-heuristics optimization algorithms have been continuously enhanced. One of these techniques is hybridizing techniques that are especially interesting for the wide variety of issues to be adapted. Swarm intelligence and metaheuristics algorithms come under bio-inspired algorithms with a long history of solving optimization problems.

When optimizing a given problem, Bio-inspired optimization algorithms such as GA and PSO have some behavioural parameters that control their performance. A collection of carefully selected parameters is conducive to the efficiency of optimization. Manually tuning parameters is a laborious method. Bio-inspired optimization algorithms have shown the potential to generate optimal science and



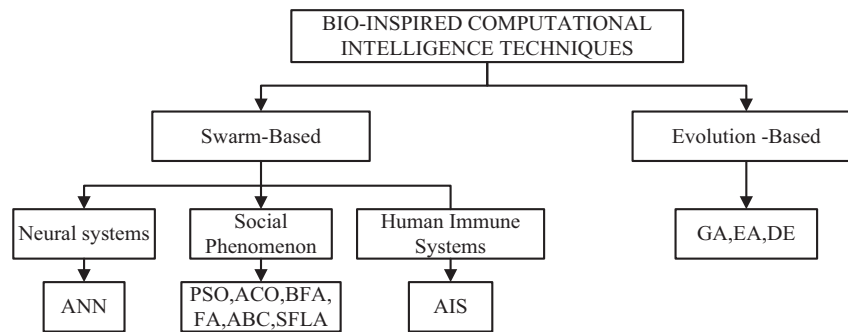


Fig. 4. Classification of Bio-Inspired CI techniques

engineering solutions to complex computational problems in recent years. The Bio-inspired CI Techniques classification is shown in Fig. 4.

The literature [40–43] used CI techniques in pool and hybrid models of DPM for finding the best position and control of FACTS devices to mitigate congestion. Table 2 provides different optimization techniques used for congestion management in DPM.

6. ATC BASED CM

ATC calculates the physical transmission network transfer capacity remaining for extra transaction activity over and above the uses previously committed. CM can be accomplished through the network's ATC enhancement. ISO can also use ATC to reserve transmission facilities, schedule non-firm and firm transactions, and coordinate emergency transfers between the seller bus and the buyer bus. ATC between interconnecting power system network areas and vital transmission paths between areas must be continuously measured, updated, and uploaded to the open access same-time information system (OASIS).

Mathematically, ATC is defined as:

$$ATC = TTC - TRM - (ETC + CBM)$$

Where

ATC available transfer capability
 TTC total transfer capability
 TRM transfer reliability margin
 ETC existing transfer commitments
 CBM capacity benefit margin

ATC has measured the various approaches based on distribution factors and the continuous power flow (CPF). Literature [81] has increased the ATC through FACTS devices like the SVC and TCSC to increase power transactions in contingency situations and without contingency. In [82], Aswin Kumar has provided an OPF strategy using UPFC and Sen Transformer to calculate ATC for a multi-transaction environment. The impact of the ZIP load model has been checked with both devices on ATC.

7. DEMAND RESPONSE MANAGEMENT (DRM)

This DRM method offers an opportunity for consumers to become active in the DPM [83]. If customers change their demands during congestion, they will get incentives. The nodal prices can increase during congestion hours, and, based on this, ISO may give customers instructions to rearrange their energy demands. Demand-side management (DSM) plays a significant role in contingency analysis. Different types of CM DR techniques are shown in Fig. 5.

In the literature [85], the Multi-Objective PSO (MOPSO) approach has proposed rescheduling generation with DRPs. The use of DRPs raises the operator's choice regarding small consumers' involvement in reducing demand. This approach aimed to lower operating costs, reduce emissions, and mitigate the congestion of transmission lines. A. Yousefi et al. [86] have proposed a mixed-integer optimization technique for CM in DPM by considering DR and FACTS devices. Jabir et al. [87] review different types of DRM, including effects and recent developments.

A. Kumar et al. [88] have given a demand-side-based CM approach for the pool-based DPM model. J. Wu, B. Zhang et al. [89] proposed a bi-level optimization model to find the optimum DR buses for CM by considering wind power uncertainty. M. Mahmoudian Esfahani et al. [90] have given a real-time hybrid optimization algorithm for adaptive real-time CM in smart power systems.

8. DISTRIBUTED GENERATION

Distributed generators (DGs) are generally renewable energy sources (RES) installed in DPM for CM. Distributed generation can enhance transmission system efficiency by injecting power into the essential nodes of the network. In this scenario, apart from the type of DG, the operation must be carried out to achieve higher social welfare for networks with DG resources. CM can be achieved through voltage profile improvements by power flow reductions on selected transmission lines.

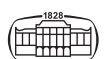


Table 2. List of various CM optimization techniques in the literature review

Reference	Optimization Technique	Remark
K. Ravi et al. [44]	Improved Particle Swarm Optimization (IPSO)	Found the optimal position of STATCOM
Md Sarvar et al. [45]	PSO Technique with Improved Speed Coefficients (PSO- ITVAC).	Rescheduled the real power outputs of selected generators.
Indu Batra and Smarajith Gosh [46]	Improved Tent Map Embedded Chaotic PSO (ITM-CPSO)	Power tracing algorithm applied for the estimation of participating generators. ITM-CPSO was used for mitigating load shedding and rescheduling cost.
Batra and Ghosh [47]	Twin Extremity Chaotic Map Adaptive PSO (TECMPSO)	Rescheduling cost minimized by recognizing the participating generators.
H. Farahmand et al. [48]	Hybrid Mutation PSO (HMPSO)	Available Transfer Capability enhancement.
N. Kinhekar [49]	PSO	Based on Demand Response (DR), it reduces operating costs and the system's peak load.
P. Boonyaritdachochai et al. [50]	Time-Varying Acceleration Coefficients in The Conventional PSO (PSO-TVAC)	Minimized variations in the reactive & active power generator value from the schedule values by considering the voltage stability and voltage profile.
Shayanfar et al. [51]	SPSO-TVAC	Redispatch costs reduced.
S.K Joshi et al. [52]	PSO	Minimizing variations in actual and reactive power values for generators from scheduled values, taking into account improvements in voltage stability and voltage profile.
S. Hajforoosh et al. [53]	PSO	The Optimal placement of UPFC Identified in market-based power systems.
Chanda et al. [54]	PSO	CM Charge Optimization with no FACTS device deployment and without curtailment of the load by recognizing the Standard Congestion Sensitivity Index.
C. Venkaiah et al. [55]	Fuzzy Adaptive Bacterial Foraging (FABF)	The selected generators optimally rescheduled for their active power based on generator sensitivity to the congested line.
Ramesh Kumar and Premalatha [56]	Bacterial Foraging Algorithm (BFA)	Generation Rescheduling was used to reduce congestion cost, power loss, and fuel cost.
B. K. Panigrahi and V. Ravikumar Pand [57]	Adaptive Bacterial Foraging Algorithm	Real-time CM
S. N. Pandey et al. [58]	Artificial Neural Networks (ANN)	
	Integrated Evolutionary Neural Network (ENN)	Forecasting of nodal congestion price (NCP) carried out on a competitive power market in real-time.
S. N. Pandey et al. [40]	Growing Radial Basis Function Neural Network (GRBFNN)	Prediction of Nodal Congestion Prices (NCPs) for CM.
Bhattacharyya and Gupta [59]	fuzzy logic	Found the optimal location of TCSC & SVC.
E. B. Elanchezhian et al. [43]	Firefly Algorithm (FA).	Reschedulling of active power
Vinod Kumar Yadav et al. [60]	Flower Pollination Algorithm (FPA)	Optimum capacity of DG units added to minimize the congestion in the transmission lines.
SanandanPal et al. [61]	Genetic Algorithm (GA)	To reduce the actual power loss of the power distribution network by appropriate reconfiguration and congestion reduction.

(continued)



Table 2. Continued

Reference	Optimization Technique	Remark
Surender Reddy et al. [62]	Genetic Algorithm (GA)	Found the optimal location and the size of FACTS units in the transmission line.
S. M. H. Nabavi et al. [63]	Genetic Algorithm (GA)	To found optimal generation levels.
Balaraman et al. [64]	Real-Coded Genetic Algorithm (RCGA)	To find the optimal generation
Balaraman et al. [65]	Differential Evolution(DE)	rescheduling.
S. T. Suganthi et al. [66]	Improved DE	Active Power rescheduling. To mitigate congestion through the installation of new wind farms in transmission lines and generator rescheduling.
K. Balamurugan, et al. [67]	Evolutionary Programming(EP) & Differential Evolution (DE)	Economic dispatch for pool electricity
V. Mukherjee et al. [68]	Ant Lion Optimizer (ALO)	Real power rescheduling of generators.
SumitVerma et al. [69]	Teaching- Learning-Based Optimization (TLBO)	Generation rescheduling.
Basha et al. [70]	Meta-Heuristic TLBO	Rescheduling of Generators.
R. Saranya et al. [71]	Artificial Bee Colony Algorithm (ABC)	Generator rescheduling and load curtailments are used to alleviate overloads.
Salkuti and Kim et al. [72]	Multi-Objective Glow-worm Swarm Optimization (MO-GSO)	Rescheduling generation to reduce the total cost and loss of transmission.
Salehi and Abdolahi et al. [73]	Grey Wolf Optimizer (GWO)	Congestion and emission of CO ₂ reduced in Demand Response Program.
Chintam and Daniel et al. [74]	Meta-Heuristic Satin Bowerbird Optimization (SBO)	Rescheduling of generators.
Peesapati et al. [60]	Flower Pollination Algorithm (FPA)	Investment costs, voltage differences, and active power losses minimized by optimal placement of DG
Sultana et al. [75]	GWO	The optimum allocation of multiple DG units reduced reactive and active energy losses in distribution networks.
Mandal et al. [76]	Chaos Enhanced Differential Evolution (DE)	Sensitivity analysis used to find Critical Line outage & DE used for rescheduling of participating generators.
Ramachandran R et al. [77]	Black Hole Algorithm (BHA)	Reduce the cost of real power rescheduling.
Reddy et al. [78]	Multi-objective Strength Pareto Evolutionary Algorithm (SPEA)2+	For load shedding and load rescheduling. Realistic voltage-dependent load modeling was used.
Mende et al. [79]	GAMES	To achieve minimum system costs and a re-dispatching real power.
Abedinia et al. [80]	Modified Invasive Weed Optimization (MIWO)	Based on the largest GS values choosing re-dispatched generators for minimizing re-dispatched cost.

Integration of distributed generations (DGs) into power systems brings advantages such as adequate power quality, improvement of voltage profile, loss reduction, promotion of reliability, and congestion alleviation. Instead of conventional power stations, the RES is commonly used in the DPM to meet the rapidly rising energy demand due to its viable advantages and open access transmission system (OATS). Y. R. Sood et al. in [91] explained the importance of RES for maximizing social welfare and CM in DPM. The right positioning of DGs in DPMs gives full system benefits. In literature [92], a Sensitivity analysis was used to find

optimal DGs and GA for DG's optimum capacity calculation. In [93], the author used a Fuzzy c-means clustering approach to analyze DGs' impact in CM. To find optimum DG size and position within the DPM, in literature [94], two new approaches have been implemented to detect critical congestion transmission lines. DGs and energy storage systems (ESS) were optimally rescheduled to reduce expected congestion with Power Transfer Distribution Factors (PTDF). A cost/worth analysis-based approach was used in DGs' optimum position and size to alleviate the congestion in competitive energy markets [95]. In [96], DG's

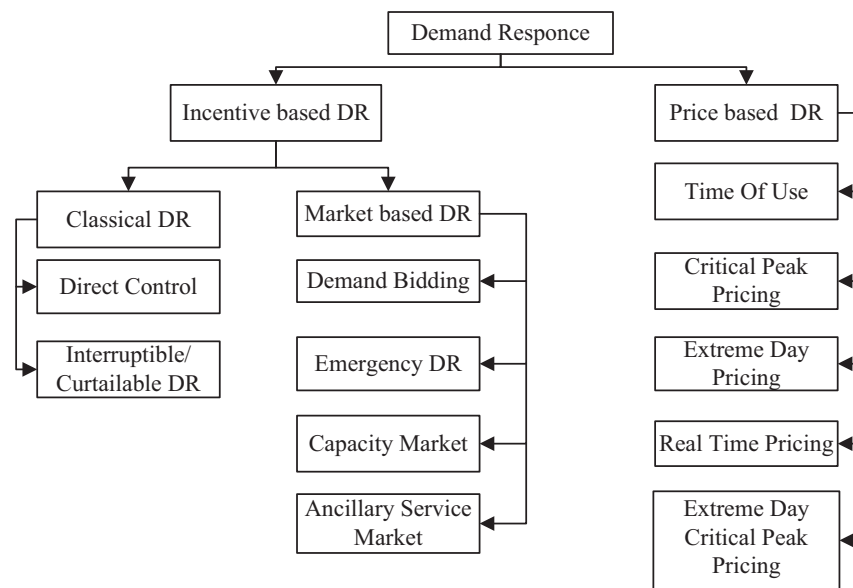


Fig. 5. Different demand response CM techniques [84]

Table 3. Comparison of different CM approaches

CM Method	Methodology	Demerits
Generation Rescheduling	For CM, an adequate number of generator power outputs have been rescheduled.	Any variation in generator power outputs would result in a restructuring of economic aids among GENCOs and economic income loss.
FACTS devices	Here, congestion is alleviated by positioning FACTS devices at appropriate sites based on power flow control in the network.	There is a little financial burden on the system, and frequent monitoring is needed because of load fluctuations and RES uncertainties.
Optimization techniques	Quickly mitigate congestion in DPM, although they are multi-objective or complex systems.	Optimization methods are mostly depending on non-linearity and the number of variables of the problem. In some cases, the computation time is more.
Re-dispatch	Congestion has been alleviated by controlling generator outputs up and down based on ISO instructions	Influence other generator's profits. Many generators reduce their level of efficiency while others increase their generation.
ATC	At the time of dispatch, congestion was relieved here based on ATC values.	Line loading exceeds the full capacity of the line, ATC technique not successful for CM.
Demand Response	Here, customer involvement in power market activities has eased congestion. DR supports the cycle of rescheduling load equipment, i.e., moving loads from vital hours to non-critical hours and adjusting load patterns.	The operations of the market are becoming complex. More needs for broad demand response techniques are needed for monitoring, communications, and exact forecasting technology.
Distributed generation	The optimum number of DG units is in a good position based on changes in the system's power flow and injects power at buses to minimize congestion.	To preserve the system's safety, reliability, and stability due to RES uncertainties, the DPM needs to monitor market activities complexly and with high standards.

appropriate positions and size are determined based on the artificial neural network (ANN) to eliminate transmission bottlenecks on the power market.

9. CM BY ELECTRIC VEHICLES

The uncertainties of alternate energy sources in the power system have made CM more challenging. The incorporation of EVs into the smart grid creates new challenges, but it also provides new opportunities. To manage network congestion issues and regulations and even the storage of surpluses of RES, ISO may take advantage of EVs equipped with the vehicle to grid (V2G) technologies. Literature [97] and [98] address EVs' impacts on the smart grid from different aspects, such as congestion of the network, voltage drops, and power losses. The control of EVs' charge using the Lagrangian relaxation-based, partial decomposition method reduces congestion of the transmitting network [99].

The conceptualized CM techniques are analyzed from different aspects, such as their application complexity, technical and economic benefits, and possible risks and demerits presented in Table 3.

10. SUMMARY

This paper provides an overview of all new trends in CM techniques in recent years. The survey will be very insightful and useful to researchers, utility engineers, and academics. As the deregulated electrical industry continues to grow globally, periodic updates on this topic would be useful. The authors have tried to include all possible CM methods that have been worked on so far. The outcomes from the reviewed literature are as follows.

- FACTS devices are progressively mounted in the network to allow the best possible use of networks.
- Generation rescheduling by using optimization techniques are more efficient CM methods.
- DRM is becoming popular to control congestion prices and improve system reliability and security.
- The application of distributed energy sources has grown in DPM. The DG-based CM approach is an efficient method, in particular, because of the RES DGs.
- The inclusion of advanced optimization algorithms in nonlinear costs reduces total rescheduling costs more significantly and relieves system operator computing time and effort.

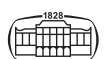
Future work:

- It is essential to examine the effect of EV aggregators on DPMs when there is network congestion.
- To identify alternative computational burden reduction methods, e. g. using machine learning & Deep Learning Techniques.
- In the balance between shutdown and turning on Shunt Condenser at the receiver end, CM would need to test the best transmission switching technique.

- CM needs to assess the complex real-world application of different fields, such as dynamic CM for interconnected ramp rate constraints and probabilistic optimization of wind or PV systems.

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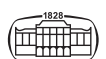
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