Vol.4 No.4 Oct 2021

Journal of Computational Mechanics, Power System and Control

Received 12 August, Revised 12 September, Accepted 08 October

A Novel World Horse Optimizer Algorithm for Rescheduling based Congestion Management

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Abstract: In a power system, Congestion Management is considered a demanding task because of maximizing the complexities of the system in a deregulated environment. The congestion reasons severe damage to modules of the power system if outages lead to take place additional regularly. Therefore, Congestion Management is a complicated task for an Independent System Operator (ISO) in the present case of the power system. This paper presents a proposal for a new optimization-based Congestion Management approach with a developed soft computing model. In this work, a novel hybrid approach is developed that clearly optimizes the power of the augmented generator with a bus system. Thus, the congestion is managed with a reduced cost of rescheduling. The adopted optimization approach is called Wild Horse Optimizer (WHO). Then, the simulation is performed on two test bus systems such as IEEE 14 as well as 30 bus systems. The adopted approach performance is evaluated with conventional techniques regarding the cost analysis.

Keywords: Congestion Management, ISO, IEEE bus System, Power System, Rescheduling Cost.

Nomenclature

Abbreviations	Descriptions
ADNs	Active Distribution Networks
DMO	Distribution-Level Market Operator
ISO	Independent System Operator
LSE	Load Served Error
DERs	Distributed Energy Resources
LSM	Load Served Maximization
SWM	Social Welfare Maximization
DCRs	Direct Control Resources
LV	Low-Voltage
GfG	gas-fired generation
ATC	Analytical Target Cascading
GLCM	Generation and Load shedding Cost Minimization
PtG	power-to-gas
DG	Distributed Generation
GWO	Grey Wolf Optimization
EV	Electric Vehicle
MDS	Mobile Distributed Storage
DTO	Data Traffic Operator
PshdM	Load Shedding Minimization
FF	Firefly
DSO	Distribution System Operator
SO	System Operator
PSO	Particle Swarm Optimization
FA-PSO	fuzzy adaptive-PSO
UC	Unit Commitment

https://doi.org/10.46253/jcmps.v4i4.a1

1. Introduction

The electricity deregulation sector has ensued in a huge alter in the viewpoint of electricity sector operation during the last two decades. In the market, the competition occurs due to the deregulation which reasons the cost-based electricity that occurs the price based market commodity as well as proposed the self-governing producing usefulness to put up for sale they are generated to the customers. Hence, the effort to enclose their generated power on a transmission line, as well as this, creates the transmission line congested. Generally, congestion is really a lack of capacity to provide waiting consumers. Additionally, congestion might reason a high issue to the power network's stability as well as it might use ineffectuality and price increase for the electricity in the market [1].

Basically, congestion is represented as a condition whilst a transmission network initiates operating furthermore to the particular permissible restricts like physical restrict, voltage restrict as well as line stability restrict [2]. Basically, congestion happens in deregulated market as buying and selling of energy might be established without really because of power system constraints. Inadequate reactive power aid, line outage, equipment failure, and weather diversity are a few of the reasons for congestion that causes a real danger to the security of the power system, and it might result in an electricity price increase. In order to alleviate the transmission networks' congestion, control measures or actions have been taken by the congestion management. Generally, the techniques used for the CM are generation rescheduling, load shedding, line switching as well as zonal pricing so on [3]. As congestion remnants as the main reason for the outages of the cascade by means of uncontrolled load loss, it cannot be acceptable. The congestion of transmission not only maximizes the prices of electricity by developing augmenting outages however a threat to the system reliability as well as security. In addition, the power system complexity will increase due to the deregulated environment with a large number of market players. It will create huge confronts for the ISO to coordinate with the market players to assure safe and dependable power flow. The market flows are taken into consideration as the most important units for transmission CM procedure [9].

In numerous studies, several techniques were developed to solve the CM issue [6]. The basic techniques used to alleviate the congestion which includes the generator power outcomes rescheduling, presenting reactive power aid as well as limiting load transactions/demands. The Optimal power flow-based Congestion Management approaches are extensively used in some works. Several CM techniques which are appropriate for diverse market structures were proposed. By exploiting Bender's decomposition was presented a coordinated technique among the SO as well as generation companies for CM. To ease the congestion because of the voltage instability as well as thermal overloads a novel technique was proposed. The electric transactions prioritization, as well as the associated limited model in the system wherein multilateral/bilateral and pool dispatches co-subsist, was explained. In a pool-based market, for CM a technique for exploiting the PSO [10] was presented. For the independent scheduling, a multi-utility interior point-based Optimal Power flow approach of each effectiveness for CM when attaining the multi-utility optimum was presented. Next, a two phase technique, by exploiting the enhanced Bender's decomposition technique was proposed for CM such as bilateral and centralized/pool-based transactions in the electricity markets. In numerous works, several kinds of PSO approaches were developed. To resolve the UC issue, an FA-PSO was exploited. A PSO that exploits the idea of binding fitness was employed for the optimum rescheduling of generator outputs to supervise the congestion in the system [7].

The major objective of this research is to work on rescheduling-based Congestion Management. A new Congestion Management approach with a developed soft computing approach is developed by exploiting a novel Wild Horse Optimizer (WHO) approach. The developed approach optimizes the generating power of the augmented generator by means of the bus system as well as therefore reduces congestion with a minimum cost of rescheduling. As mentioned before, the projected optimizer approach is created called WHO. At last, the adopted rescheduling-based Congestion Management approach was experiments on 2 IEEE test bus systems such as IEEE 14 as well as 30 bus systems to examine its analysis regarding the conventional techniques concerning cost analysis.

2. Literature Review

In 2020, ENBO LUO et al [1], worked on a two-phase hierarchical CM model for ADNs linked with multi-type DERs and microgrids. In the initial phase, the hierarchical optimization approach was modeled by taking into consideration of the dispatch of microgrids as well as DCRs. Concurrently, in order to optimize the microgrid autonomy approach as well as the ADN optimization approach an ATC approach was used. In order to tackle the scenario, a next phase optimization was modeled while the DCRs control, as well as microgrids, was not adequate to entirely eradicate the congestion. The method presented by the DER was set up for the CM approach to reduce the DSO operational cost.

In 2017, A.N.M.M. Haque et al [2], developed the direct as well as indirect approaches which were integrated into a combined method that make exploit the benefits of both techniques. An agent-based mode was developed with the intention that distributed as well as computational intelligence can be integrated to assure smooth coordination between actors. A sensitivity-based restriction model was exploited to integrate the unbalanced loading circumstance of LV networks.

In 2017, S. Surender Reddy [3] developed a novel CM model by load shedding as well as generation rescheduling, by realistic voltage-dependent load modeling. This research develops various objective models such as minimization of SWM including demand response offers GLCM, PshdM, LSM, as well as LSE. This work evidently performs the inaccurateness of conventional single objectives of CM like PshdM and GLCM/SWM by exploiting the voltage-dependent load approaches such as the minimization of a number of loads served.

In 2016, Arash Asrari et al [4], proposed a day-ahead market model for CM in smart distribution networks. The proposed approach develops a platform for cooperation between the DTO as well as DMO to improve congested feeders so that data transmission traffic among the market participants was competently managed in a smart grid. Additionally, by exploiting a decentralized model the EV aggregators were collaborated by means of general clients to use the benefits of EVs not merely as flexible loads but the MDS for congestion management. In addition, the developed model delineates an administrative action for DSO to aid the market while decentralized competitions between EV aggregators as well as DG aggregators do not completely alleviate severe congestion.

In 2017, Hadi Khani et al[5], investigated how the PtG and GfG amenities were augmented to the collection of existing resolutions while the enthusiasm was (partly) CM in power distribution systems. It also shows that GfG, as well as PtG units as merchant examines, can alter operation viewpoint from conventional protective to new accurate mode. Finally, a novel real-time optimal scheduling approach was presented to set up a PtG–GfG unit in order to optimally augment CM. A novel model was presented that the merchandise operator was financially compensated using the operator of the power system because of its involvement in the CM.

3. Mathematical Model

3.1 Congestion Management Problem Formulation

The bilateral contract and pool market features in the hybrid electricity market, the problem gets starts regarding the congestion is considered in this paper. The generators should be rescheduled so that overcome the problem in congestion management with a minimum cost of rescheduling. In [6], the congestion management with safe bilateral transactions requires to be attained regarding the inequality as well as equality operational constraints in the system. Hence, eq. (1) devises the complete issue which is considered as a constrained minimization function [14].

Consider $\Delta P_i : 0 \le i \le N_h$ be stated as power alter which requires to be rescheduled for the cost of $C(\Delta P_i)$ in \$ for i^{th} generation unit. Furthermore, on basis of Eq. (1), the minimization issue is mathematically stated that is subjected to the constraints which are stated as follows:

$$E^* = \arg\min_{\Delta P_i \forall i} \sum_{i=1}^{N_h} C(\Delta P_i) \tag{1}$$

a) Generation capacity constraint:

By exploiting the eq. (3) the generation quantity stated as P_i (in MW) is ascertained which is stated in eq. (3) and if ΩP_i is the previously generated power quantity.

$$P_i^{min} \le P_i \le P_i^{max} \tag{2}$$

$$P_i = \Omega P_i + \Delta P_i \tag{3}$$

b) Real Power balance constraint:

Based on eq. (4), the mathematical formulation of the constraint, where the transmission loss and the total power demand are stated as P_G and P_B correspondingly. Eq. (5) states the mathematical formulation of transmission loss in that the loss coefficients are stated as T_{ji}, T_{0i} and T_{00}.

$$\sum_{i=1}^{N_h} P_i - (P_B + P_G) = 0 \tag{4}$$

$$P_G = \sum_{i=1}^{N_h}\sum_{j=1}^{N_h}\left(P_j T_{ji} P_i\right) + \sum_{i=1}^{N_h}\left(T_{0i} P_i\right) + T_{00} \tag{5}$$

c) Stability Limits:

To define the congestion this is an important criterion and also to assure the alleviation of congestion. In eq. (6) to (8), the stability limits are mathematically formulated in that voltage limits and angle limits are denoted by exploiting the $\left(\partial_q^{min}, \partial_q^{max}\right)$ as well as $\left(V_q^{min}, V_q^{max}\right)$ correspondingly. From the generators to load busses the voltage stability is defined by both the limits such as voltage as well as angle limits. In addition, Eq. (8) ensure transmission lines are not overloaded as well as Z_{qd}^{max} indicates the utmost power flow limit in MVA.

$$V_q^{min} \le V_q \le V_q^{max} \tag{6}$$

$$\partial_q^{min} \le \partial_q \le \partial_q^{max} \tag{7}$$

$$P_{qd}^2 + Vd \le \left(Z_{qd}^{max}\right)^2 \tag{8}$$

d)Ramp up Limit:

The ramp-up limits define the lower as well as upper limits of the rescheduling quantity. Moreover, the equal down as well as up rescheduling cost is considered, and eq. (9) represents the ramp-up limit for this circumstance.

$$\Delta P_i^{min} \le \Delta P_i \le \Delta P_i^{min} \tag{9}$$

On the basis of the adopted model, the rescheduling scheme E^* of Eq. (9) is optimized using a novel hybrid approach that covers the method for minimizing congestion with reduced cost.

3.2 Congestion Cost

The congestion cost can be alleviated [6] by exploiting generator active power output can be rescheduled. Generally, rescheduling is attained by means of maximizing or minimizing the active power output in generators. However, this enhancement (maximize or minimize) in the active power outcome gives to the charge which is available as the price bids as well as aforesaid price bids do peek by the GENCOs generators. Therefore, as stated in Eq. (10), the congestion cost represents the rescheduling cost. By exploiting the C_{total} (\$/*i*), the complete cost of changing active power outcome is shown. Additionally, $C_d : d = 1,2,\ldots,N_h$ and T_d and indicates the price bides which are equivalents to rising or minimize of active power using d^{th} GENCO in \$/MWn. The increment, as well as the decrement of the active power of generator in MW, is indicated by exploiting the $\Delta P_i^+(d)$ and $\Delta P_i^-(d)$, correspondingly. Furthermore, the diversity among the submitted prices in a current hour (x) from the previous hour $(x-1)$ represents an alteration in the active power and it is indicated in Eq. (11). ΔP_i represents the change in active power, as well as $P_i(x-1)$ and $P_i(x)$ represents generated active power at $(x-1)$ as well as at present hour, correspondingly.

$$C_{total} = \sum_{d \in N_h}(C_d \Delta P_i^+(d) + T_d \Delta P_i^-(d))\$/n \tag{10}$$

$$\Delta P_i = |P_i(x-1) - P_i(x)| \tag{11}$$

3.3 Fitness Function

In \$ cost $C(\Delta P_i)$ for d^{th} generation, the unit is the sum of voltage level infringement as well as rescheduling cost of the relevant transmission line [7]. Eq. (12) represents the mathematical formulation of the total cost function in the rescheduling scheme. Here, $W_{profile}$ and W_{con} represents penalty cost forced on infringing voltage profile as well as constraints, correspondingly. Furthermore, Eq. (13) states the mathematical formulation of $C_{profile}$, here minimum, as well as maximum voltage of the generator, is shown by exploiting V_i^{min} and V_i^{max}, correspondingly.

$$C(\Delta P_i) = C_{total} + W_{profile} C_{profile} + W_{con} C_{con} \tag{12}$$

$$C_{profile} = |\min\left(V_i - V_i^{min}, 0\right)| + |\min\left(V_i^{max} - V_i, 0\right)| \quad (13)$$

4. Proposed World Horse Optimizer Model

In WHO [8], the social organization horses are separated into two groups such as non-territorial as well as territorial. Here, the main aim is to concentrate on non-terrestrial horses. In this paper, the behaviors of groups, mating, grazing, leadership as well as domination to model a WHO and carry out the optimization of several issues [8].

4.1 Initializing Population

If N is the count of members of the population, the count of groups is $G = \left[N \times PS\right]$. For the adopted model, PS represents stallions percentage in a total number of population and we set it as a control parameter. Therefore, on the basis of the count of groups leader G (stallion) is present, as well as the members of the remnant $N - G$ are separated equivalently amid these groups.

4.2 Grazing Behavior

As aforesaid, generally, the foals use a large number of their time for grazing on their group. In order to evaluate the grazing behavior, the stallion is considered in the grazing area center, and group search members around center (graze). Eq. (14) is exploited to imitate grazing behavior. Eq. (14) occurs the group members to travel as well as explore over leader with a diverse radius.

$$\vec{X}_{i,G}^{j} = 2Z\cos(2\pi RZ) \times \left(Stallion^{j} - X_{i,G}^{j}\right) + Stallion^{j} \quad (14)$$

wherein, $Stallion^{j}$ indicates the location of the stallion (group leader), $X_{i,G}^{j}$ indicates current group member (foal or mare) location Z indicates an adaptive model computed using Eq. (15), R represents a uniform arbitrary number in the range[-2, 2] that reasons the horses grazing at diverse angles (360 degrees) of group leader, The COS function by integrating the π as well as R occurs movement in inverse radius, as well as at last $\vec{X}_{i,G}^{j}$ indicates the new location of the group member while grazing.

$$P = \vec{R}_1 < TDR; IDX = (P == 0); \quad Z = R_2 \Theta IDX + \vec{R}_3 \Theta (\sim IDX) \quad (15)$$

wherein $\vec{R}_1$ and $\vec{R}_3$ represents arbitrary vectors with uniform distribution in the range [0, 1], P indicates a vector consisting of 0 and 1 equivalent to the problem dimensions, R_2 represents the arbitrary count with uniform distribution in the range [0, 1], IDX represents indexes of arbitrary vector, $\vec{R}_1$ 1 returns that assure circumstance $(P == 0)$. TDR indicates an adaptive parameter that initiates with a value of 1 as well as it reduces at the time of execution of the approach on the basis of the Eq. (16) and finally, the execution of the approach attains "zero".

$$TDR = 1 - itr \times \left(\frac{1}{\max itr}\right) \quad (16)$$

Wherein $\max itr$ represents a maximum number of iterations of the approach; itr represents current iteration.

4.3 Behavior of Horse Mating

In order to imitate, the mating as well as departure behavior of the horses, the eq. (17) is exploited that s similar to the cross-over operator of the man type is presented.

$$X_{G,K}^{p} = Crossover\left(X_{G,K}^{q}, X_{G,K}^{z}\right) \; i \neq j \neq k, p = q = end \quad (17)$$

wherein, $X_{G,K}^{p}$ represents horse p location from the group k as well as left the group as well as presents its location to a horse their parents are horses who be obliged to left group i and j as well as have attained teens. They have no family association as well as have mated and make a replica. $X_{G,K}^{q}$ The foal location q is from group and represents, a departure from the group, as well as subsequent to the attainment the teen's age, it mated with a horse z with the location $X_{G,K}^{z}$ that left the group j.

4. 4 Group Leadership

In the appropriate area, the group leader should lead the group. Towards the water hole, the group should be travel.

4. 5 Exchange and Leader's Selection

Initially, leaders arbitrarily were selected to protect the arbitrary nature of the approach. In further phases of the approach, leaders are chosen on the basis of fitness. If one of the group members is superior fitness to the group leader, leader location, as well as an equivalent member, will be altered on the basis of eq. (18).

$$Stallion_{G,i} = \begin{cases} X_{G,i} & \text{if } \cos t(X_{G,i}) < \cos t(Stallion_{G,i}) \\ Stallion_{G,i} & \text{f } \cos t(X_{G,i}) > \cos t(Stallion_{G,i}) \end{cases} \tag{18}$$

5. Experimental Procedure

In this section, an experimentation analysis of the developed rescheduling-based Congestion Management technique was performed. The adopted technique was simulated on IEEE 14 and 30 bus systems. Here, experimentation has experimented for the compensation cost as well as congestion cost, and it was compared with the conventional models such as FF [11], GWO [13], and PSO [12] algorithms.

Generally, the optimization approaches are stochastic and they aren't capable to present a precise outcome. Therefore, the statistical analysis is performed by evaluating the adopted and traditional techniques for 5-times and the equivalent performance metrics such as best, worst, mean, median as well as standard deviation are ascertained. One best way to confirm the effectiveness of the adopted model is to analyze the statistical tests on the attained outcomes. Here, the analysis is done for both the compensation as well as congestion cost, and it is exhibited in Fig 1 and 2. In Fig 1, the proposed model is 21% better than the PSO, 18% better than FF, and 28% better than GWO for best case. Moreover, the proposed model is 11% better than the PSO, 8% better than FF, and 10% better than GWO for the best case in fig 2. The overall analysis exhibits the performance of the adopted approach is superior to the traditional techniques.

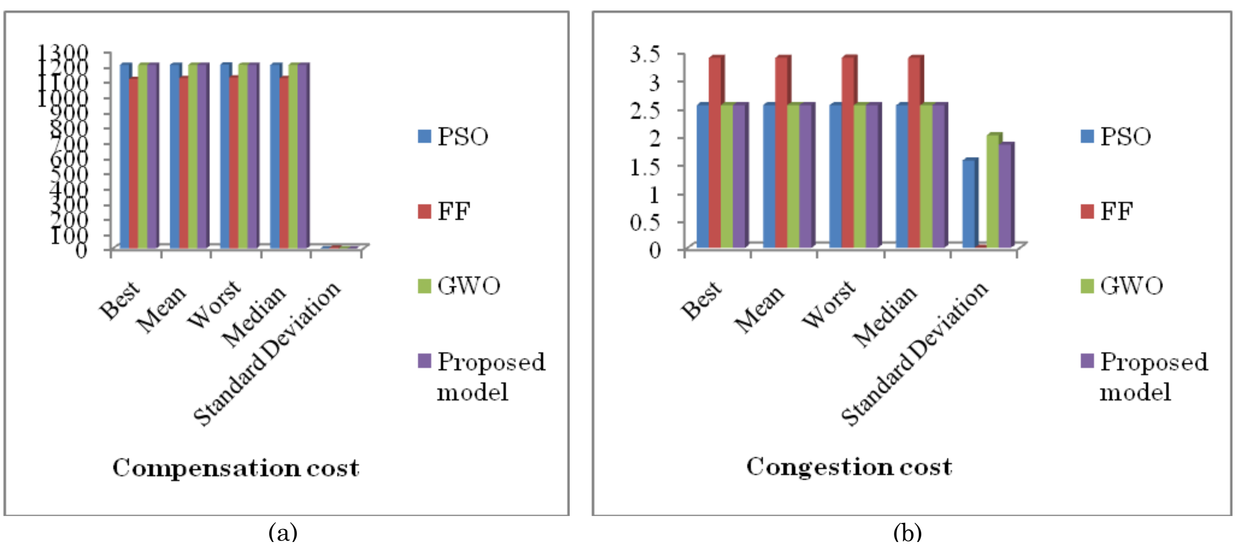
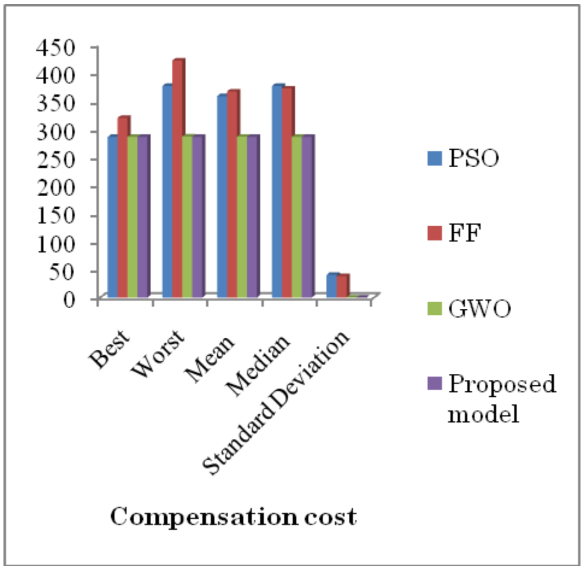
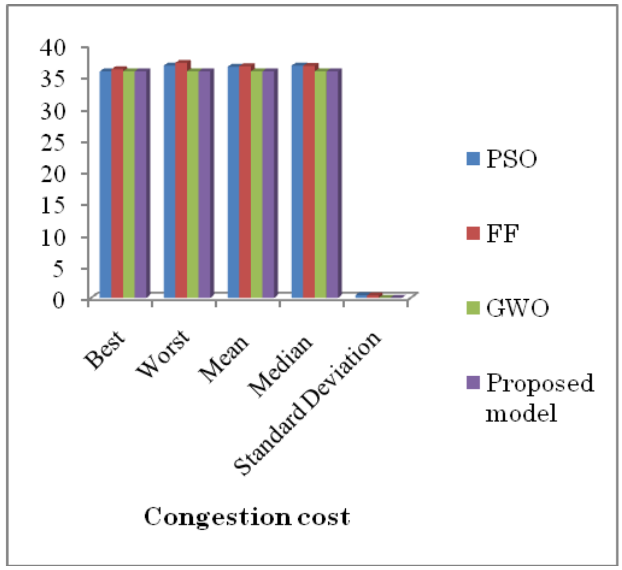


Fig.1. *Performance analysis of the adopted as well as traditional techniques for IEEE 14 bus system (a) Compensation cost (b) Congestion Cost*



(a)



(b)

Fig.2. *Performance analysis of the adopted as well as traditional techniques for IEEE 30 bus system (a) Compensation cost (b) Congestion Cost*

6. Conclusion

The main aim of the research was to model a new optimization-based Congestion Management approach with developed soft computing models. The adopted WHO optimization approach called WHO was formulated. The proposed optimization approach optimized the generated power of increased generators by means of the bus system. Therefore, the congestion management was reduced by means of minimum rescheduling costs. The adopted rescheduling-based Congestion management has experimented on IEEE 14 and 30 bus systems. Finally, the adopted model was validated with conventional approaches concerning cost analysis.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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