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Research Article

Congestion Management in Deregulated Electricity Market with Generator Sensitivity Effects

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Abstract: This paper proposes a novel Modified Virus Colony Search (MVCS) algorithm to solve the Congestion Management (CM) problem in the deregulated electricity market, considering generator sensitivity and the rescheduling of active power. Thus, the generator output is determined using generator sensitivity index to manage transmission line limitation and achieve maximum efficiency in power transmission. The CM model is formulated with a single objective function to minimize the final cost by optimal planning of active power responses from generators. To develop the exploration and exploitation of VCS, several modifications are proposed in both the local and global parts, which improve the stability of the Virus Colony Search (VCS) structure. To evaluate the MVCS performance, it is tested on three well-known power systems, including Institute of Electrical and Electronics Engineers (IEEE) 30-bus and IEEE 118-bus. The numerical results show acceptable performance compared to other available methods.

***Keywords*:** congestion management, optimization, electricity market, virus search colony

1. Introduction

Power system during the recent years is moved from vertically and monopolistic model to restructured, independent and competitive model. In the vertical structure, the government has a monopoly role in controlling all sections e.g., Distribution Companies (DisCos), Transmission Companies (TransCos) and Generation Companies (GenCos) [1]. In the restructured model, the bilateral contracts between the power market participants under the Independent System Operator (ISO) managing raise new engineering fields in operation and planning [2]. According to the deregulation mechanism, this can be deduced that the ultimate goal is efficiency and social welfare increases in the programmed value based on the current and installed power system capacity. Also, the restructured power system prepares many ancillary services, wherein, congestion management is one of important service to control the transmission line and to contain the bilateral transactions [3]. Since the power system operator tries to transmit more power for consumers at the least planning cost, a result of a high-density user crossing point is that it makes a restricted access that bans the supply of energy to customers at an expensive cost [4]. This means that these customers should pay more for their requested power than they have if there was sufficient transfer capacity for the transfer of economic transactions. According to the review-knowledge, there are several congestion management methods which they try to present a new method solving these difficulties in a transmission line. Ghazvini et al. [5] proposed a market-based system to improve distribution system congestions throughout a centralized synchronized home energy management scheme. The power system operator employs dynamic

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and daily power based on distribution tariffs to handle congestions induced. Sumit et al. [6] suggested teaching-learning-based optimization algorithm for CM problem in the restructured electricity market. They consider security limitations such as load bus voltage and line loading. Rajagopal et al. [7] employed the capability of distributed generation to reduce the transmission line congestion in a power system. To reduce congestion, optimal power flow and accessible transfer ability-based approaches for giving out thyristor controlled series compensator by means of the congestion rent contribution method based on location marginal price is proposed in [8]. Also, the gravitational search algorithm is used to control congestion in a restructured electricity market. Panida et al. [9] employed particle swarm optimization with time-varying acceleration coefficients to solved optimal congestion management problem in a restructured electricity market. To the best review-knowledge of published papers based on congestion management problem with ancillary devices and optimal managing, there is yet a gap for more a powerful framework. Motivated by this note, the main idea of this paper is offering a useful and practical framework of congestion management in the restructured power system. In addition, to cover the previous optimization algorithm shortages, an improved algorithm based on virus colony search is proposed [10]. The proposed method is a new population-based method which has faster and better performance compare to other optimization methods. Therefore, the main contributions are:

i) Modeling of a practical model of congestion management problem.
ii) Consider generator sensitivity and optimal power flow simultaneously.
iii) Propose a modified VCS algorithm based on local and global searches.
iv) Evaluate the proposed model with three two well-known test systems.

2. Congestion management formulation

The objective is investigating of proposed VCS algorithm with generator sensitivity to manage congestion and congestion redispatch so as to minimize the final cost [9]. Hereby, it can express as follows:

$$\text{Min} \sum_{g=1}^{Ng} Ic_g\left(\Delta P_g\right) \cdot \Delta P_g. \tag{1}$$

Subject to:

$$\begin{gathered} \sum_{g=1}^{Ng}\left(GS_g^{ij} \cdot \Delta P_g\right) + F_l^0 \leq F_l^{\max} \\ \Delta P_g^{\min} \leq \Delta P_g \leq \Delta P_g^{\max};\ g = 1, 2, \ldots, Ng \\ \Delta P_g^{\min} = P_g^{\min} - P_g;\ \Delta P_g^{\min} = P_g^{\min} - P_g. \end{gathered} \tag{2}$$

where, IC_g is the incremental (decremental) cost of generator g. N_g and ΔP_g denote the number of participating generators and active power adjustment at bus g, respectively. $\Delta P_g^{\min}$ and $\Delta P_g^{\max}$ refer to the minimum and maximum boundary values of generator g. Furthermore, $P_g^{\min}$ and $P_g^{\max}$ dictate the minimum and maximum limitation to gth generator. The goal is to find the GS value of the g^{th} generator on the interconnected line between buses i and j, which can change as well as the active power flow. It can be calculated by:

$$GS_g^{ij} = \frac{\Delta P_{ij}}{\Delta P_{Gg}} = \frac{\partial P_{ij}}{\partial \theta_i} \cdot \frac{\partial \theta_i}{\partial P_{Gg}} + \frac{\partial P_{ji}}{\partial \theta_j} \cdot \frac{\partial \theta_j}{\partial P_{Gg}}. \tag{3}$$

where, θ_i and θ_j denotes the phase angle at buses i and j, ΔP_{ij} is active power change between buses i and j, and ΔP_{Gg} is changed value in active power of generator g. The power flow can be got by:

$$P_{ij} = -V_i^2 \cdot G_{ij} + V_i V_j \cdot G_{ij} \cdot \cos\left(\theta_i - \theta_j\right) + V_i V_j \cdot B_{ij} \cdot \sin\left(\theta_j - \theta_i\right). \tag{4}$$

3. Improved virus colony search

3.1 *Standard VCS*

The VCS is one method based on the population of viruses and host cells, founded on two behaviors of infecting the host cell and the dispersion or reproduction of the virus. Since the proposed developed model requires its mathematical basis, its mathematical formulation is fully described in this section. Refer to reference [10] for further study. For reader convenience and a short introduction of the standard VCS formulations, Figure 1 shows its procedures.

3.2 *Modified VCS algorithm*

Start

Set initial parameters such as population size (N), maximum iteration, ($Iter_{max}$), $\lambda = N/2$

Generate random-based population (V_{pop})

Calculate fitness value for each solution

while $iter < Iter_{max}$

    for $i = 1 : N$/Viruses diffusion/

        $V_{pop_i}' = \text{Gaussian}\left(G_{best}^g, \tau\right) + \left(r_1 \cdot G_{best}^g - r_2 V_{pop_i}\right).$

    end

    Check boundary conditions

    Calculate V_{pop}' fitness values and update V_{pop}

    for $i = 1 : N$/Host cells infection/

        $H_{pop_i^g} = X_{mean}^g + \sigma_i^g \times N_i\left(0, C^g\right)$

    end

    Check boundary conditions

    Calculate H_{pop} fitness values and update V_{pop}

    Set the best λ by $X_{mean}^{g+1} = \gamma^{-1} \sum_{i=1}^{\gamma} \omega_i V_{pop_i^{\gamma best}} \mid \omega_i = \ln(\gamma+1) / \sum_{j=1}^{\gamma} (\ln(\gamma+1) - \ln(j))$

    Compute P_r by $P_{rrank}(i) = (N - i + 1)/N$

    for $i = 1 : N$

        for $j = 1 : d$

            if $r > P_{ri}$

                $V_{popi,j}'' = V_{popk,j} - \text{rand}\ (V_{poph,j} - V_{popi,j});$

            else

                $V_{popi,j}'' = V_{popi,j}$

            end

        end

    end

    Calculate V_{pop}'' fitness values and update V_{pop}

end

Finish

Figure 1. Pseudo code for standard VCS, where, v_{pop} is population size, G_g^{best} is the best solution of the generation g, $N_i(0, C_g)$ is a normal distribution with mean 0 and $D \times D$ covariance matrix C_g, g is the current generation, D is the dimension of the problem and $\sigma g > 0$ is the step size, ω_i is the recombination weight and i denotes the index of i^{th} best individuals

The most important disadvantage of the standard VCS can be found in its rapid convergence. In this study, the following modifications are proposed. Based on VCS:

$$V_{pop_i}' = \text{Gaussian}\left(G_{best}^{g}, \tau\right) + \left(r_1 \cdot G_{best}^{g} - r_2 V_{pop_i}\right). \tag{5}$$

where r_1 and r_2 are two random parameters. Hereby they create weaknesses in searching process. To develop its performance, the following time-varying formulation is suggested:

$$V_{pop_i}' = \text{Gaussian}\left(G_{best}^{g}, \tau\right) + \left(\rho^{L} \beta_{t,i}^{L} G_{best}^{g} - \rho^{g} \beta_{t,i}^{g} V_{pop_i}\right). \tag{6}$$

$$\beta_{t,i}^{L} = -(t-i)^{-\vartheta} \sum_{i=1}^{t-1} (t-i)^{\vartheta} \tag{7}$$

$$\beta_{t,i}^{g} = (t-i)^{-\vartheta} \sum_{i=1}^{t-1} (t-i)^{-\vartheta}. \tag{8}$$

where $\beta_{t,i}^{L}$ and $\beta_{t,i}^{g}$ deote cognitive and social coefficients. ρ^{L} and ρ^{g} are two random variables in range (0, 1). ϑ and subscript t are positive value and iteration number, respectively.

4. Simulation results

The proposed method is evaluated on two well-known test systems, IEEE-30 bus and IEEE-118 bus. The obtained results with proposed MVCS compare to several version of particle swarm optimization, Classic Particle Swarm Optimization (CPSO) [9], Particle Swarm Optimization with Time-Varying Acceleration Coefficients (PSO-TVAC) [9], and Particle Swarm Optimization with Time-Varying Inertia Weight (PSO-TVIW) [9]. Also, they have performed on PC with Intel (R) Core (TM) Duo CPU @ 2.53GHz, 4GB of RAM using MATLAB 2011a.

4.1 *IEEE 30-bus system*

At first test system, the IEEE 30-bus power system with six generating units and forty one lines is employed. Its configuration is shown in Figure 2 and the system data can be found in [11]. This case, Bus 1 is considered as the reference bus or slack. A congested line between buses 1 and 2 exists as shown in Table 1. Table 2 present GS values of 6 generator units. Considering GS values, all generators are selected for redispatch. The obtained values for GS index in the IEEE 30-bus system are large; therefore, it dictates power system to use all of them in redispatch program to relieve the congested line. In this way, generator having large GS value considered to avoid the computation time.

Table 1. A congested line on the IEEE 30-bus system

Congested line	Active power flow (MW)	Line limit (MVA)	Overload (MW)
1 to 2	170	130	40

Table 2. Generation sensitivity of 6 units on the IEEE 30-bus system

Gen no	1	3	5	8	11	13
GS 1_2	0	-0.8908	-0.8527	-0.7394	-0.7258	-0.6869

Figure 3 shows the graphical results for convergence, it can be obvious that the proposed MVCS has fast performance as well. The average active power correction and GS values for all generators is shown in Figure 4. Regarding 30 trial simulation, the obtained statistical results with MVCS and other optimization algorithms tabulated in Table 3. According to this table, the proposed algorithm obtains the minimum redispatch cost solution of $ 212.4, whereas PSO-TVAC, CPSO, and PSO-TVIW obtained $ 237.9/h , $ 240.3/h, and $ 239.2/h, respectively. In addition, the proposed MVCS find this solution with lowest standard deviation 1.02, whereas PSO-TVAC, CPSO, and PSO-TVIW supply 1.6, 48.2, and 3.8, respectively [9]. To have a fair judgment, employed mismatch balance power index to compare the aforementioned algorithms:

$$\text{mismatch power } = \sum_{i=1}^{N_g} \Delta P_i\left(G_i\right) = 0. \tag{9}$$

The proposed index shows algorithm ability in solving complex mathematical problems and finding optimal solutions.

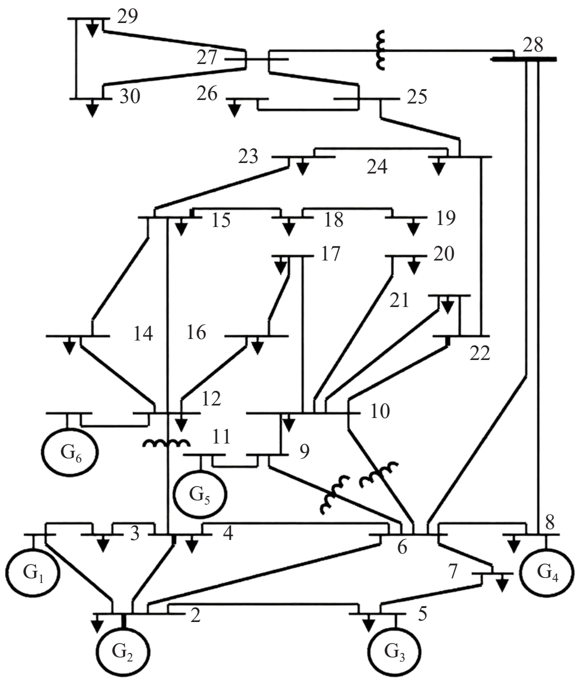

Figure 2. The IEEE 30-bus system configuration

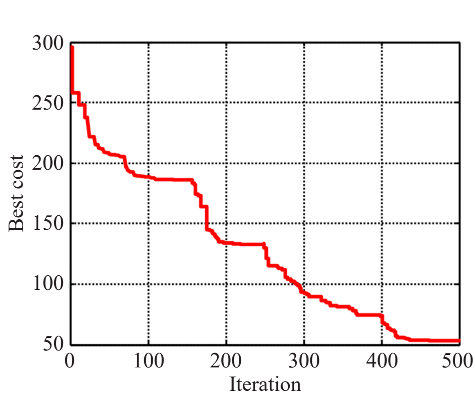

Figure 3. Evolution rate comparison CM problem in IEEE 30-bus test system

Table 3. Comparison of MVCS solutions on the IEEE 30-bus system

Method	MW	ΔP1	ΔP2	ΔP5	ΔP8	ΔP11	ΔP13	Total ΔP	Cost ($/h)	Mismatch power
CPSO	Max	-66.1	28.9	23.3	18.1	6.2	3.7	146.3	403.1	14.10
	Min	-47.9	18.6	16.5	11.3	2.8	0.1	97.2	240.3	1.40
	Mean	-55.9	22.6	16.2	10.5	5.6	2.6	113.2	287.1	1.60
	SD	8.3	7.6	3.5	3.3	3.2	3.3	15.9	48.2	-
PSO-TVIW	Max	-58.5	16.7	13.0	11.8	8.6	5.7	114.2	288.0	-2.70
	Min	-47.3	20.1	14.5	10.5	4.8	0.5	97.7	239.2	3.10
	Mean	-50.1	18.9	13.2	9.2	5.9	4.1	101.4	253.1	1.20
	SD	2.8	3.5	5.4	3.3	3.5	6.1	13.3	3.8	-
PSO-TVAC	Max	-51.1	22.0	14.7	8.8	6.2	1.0	103.8	254.9	1.60
	Min	-47.3	25.1	16.0	7.6	0.6	0.0	96.7	237.9	2.00
	Mean	-49.3	17.5	14.0	9.9	6.8	3.0	100.5	247.5	1.90
	SD	0.8	2.1	2.1	2.2	2.3	2.4	4.6	1.6	-
MVCS	Max	-45.6	20.5	17.1	8.56	3.6	1.02	96.4	243.2	0.75
	Min	-43.5	20.2	15.0	6.13	0.6	0.02	85.5	212.4	0.14
	Mean	-45.4	22.3	15.1	6.56	0.9	1.07	91.3	231.1	0.52
	SD	0.3	1.11	1.01	1.02	0.89	1.02	1.01	1.02	-

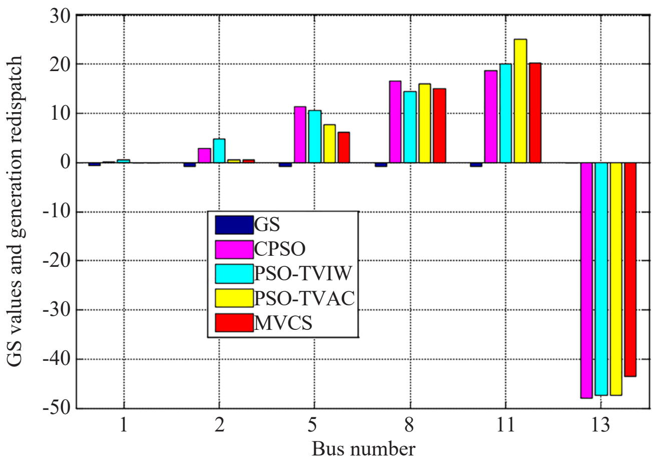

Figure 4. GS values and generation redispatch on the IEEE 30-bus system

4.2 *IEEE 118-bus system*

The configuration of the IEEE 118-bus system is shown in Figure 5 and data is available in [12]. Similar to the previous test system, slack bus is Bus 1. The congested line data is listed in Table 4.

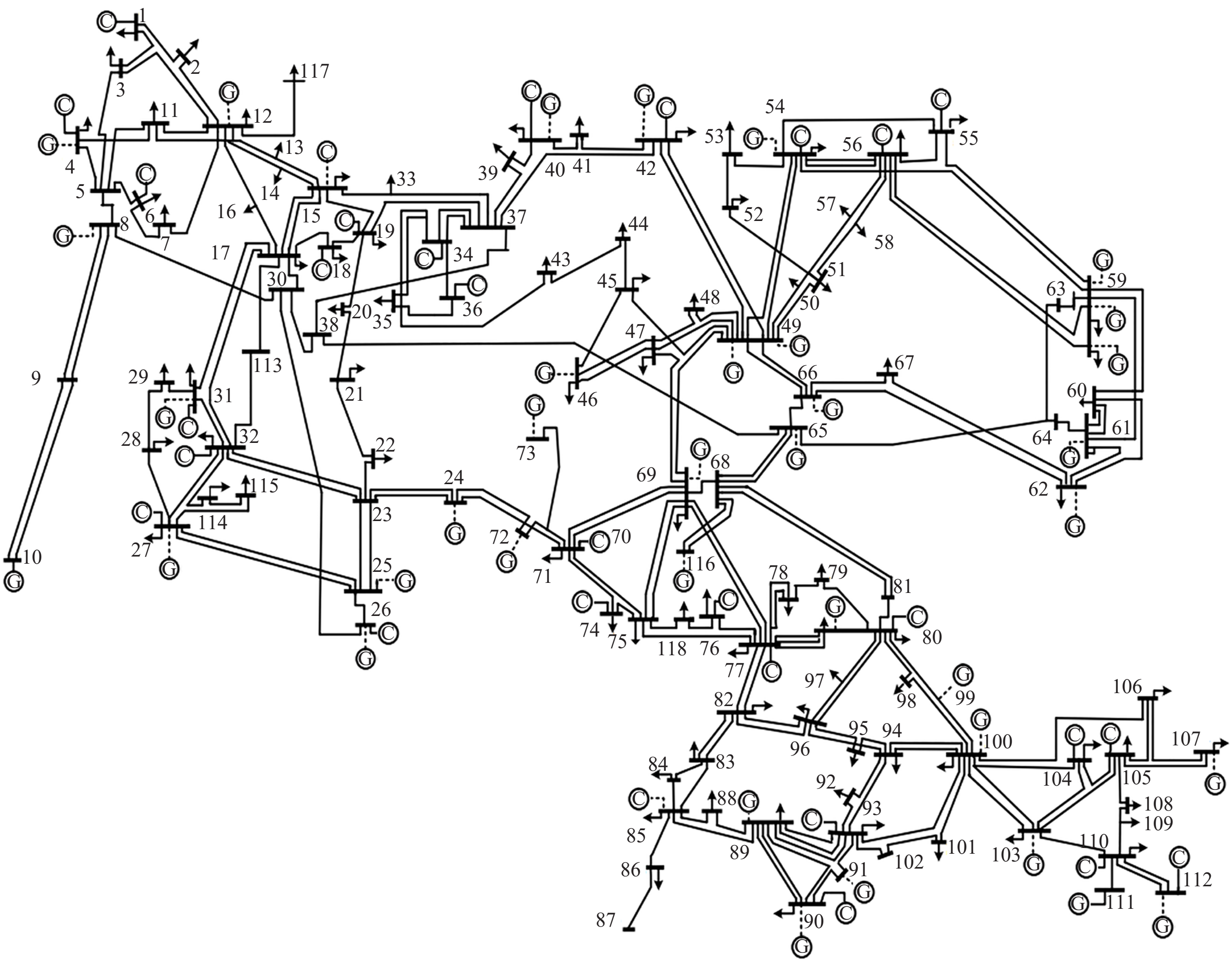

Figure 5. The IEEE 118-bus system configuration

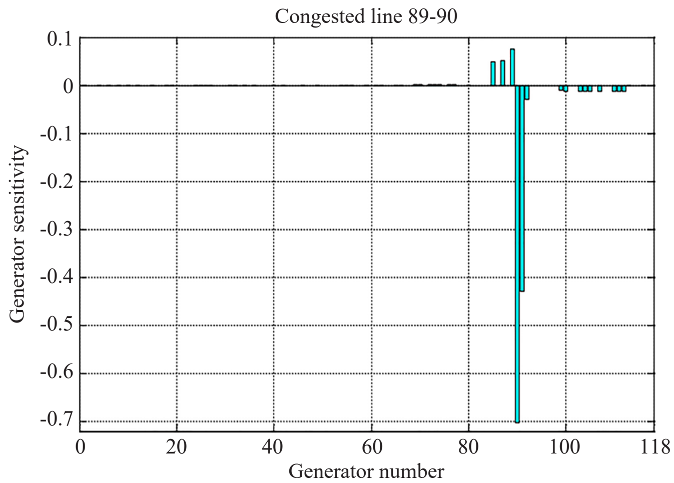

Figure 6. GS values of 54 units on the IEEE 118-bus system

Table 4. A congested line on the IEEE 118-bus system

Congested line	Active power flow (MW)	Line limit (MVA)	Overload (MW)
89 to 90	260	200	60

The calculated GS is shown in Figure 6, the obtained results of GS values for all generator buses are compared in Table 5. This results shown, the generator buses 85, 87, 89, 90, and 91 have most considerable magnitude of GS. This implies that these generators could considerably affect on the congested line. Consequently, they are selected in redispatched progress.

Table 5. GS values of 54 generators on the IEEE 118-bus system

Gen no.	GS (10^{-3})	Gen no.	GS (10^{-3})	Gen no.	GS (10^{-3})
1	0	42	-0.0375	80	-0.9250
4	-0.0005	46	-0.0242	85	50.068
6	-0.0001	49	-0.0460	87	50.654
8	-0.0014	54	-0.0838	89	74.455
10	-0.0014	55	-0.0871	90	-701.15
12	0.0004	56	-0.0854	91	-427.90
15	0.0021	59	-0.1100	92	-28.411
18	0.0051	61	-0.1160	99	-9.391
19	0.0046	62	-0.1130	100	-12.915
24	0.1350	65	-0.1350	103	-12.737
25	0.0484	66	-0.0983	104	-12.854
26	0.0337	69	0.2120	105	-12.772
27	0.0451	70	0.3690	107	-12.202
31	0.0339	72	0.2326	110	-12.274
32	0.0477	73	0.3400	111	-12.07
34	-0.0323	74	0.5410	112	-11.747
36	-0.0329	76	0.8650	113	0.0110
40	-0.0343	77	0.0012	116	-0.1750

Regarding 30 trial simulation, the obtained solutions from MVCS algorithm and other available method [9] are tabulated in Table 6. According to these results, MVCS algorithm gives the lowest redispatch cost of $ 822.4, whereas PSO-TVAC found 829.5/h and CPSO and PSO-TVIW obtained $ 819.7225/h and $ 853.8/h, respectively. According to the mean and SD indices, MVCS algorithm make 22.3, whereas PSO-TVAC is 94, CPSO and PSO-TVIW provide 196.4 and 165.8, respectively [9].

The association connecting of GS values and power redispatch is shown in Figure 7. Since the buses 85, 87, and 89 have positive values, the installed generators in these buses should reduce their output. In return, the installed units at buses 90 and 91 make the negative GS values; therefore their generating output should be increased. Furthermore, the GS magnitude affects the amount of active power correction. In addition, bus 1 employed to keep the power balance in a equilibrium point. Figure 8 shows the graphical results for convergence, it can be obvious that the proposed MVCS has fast performance as well.

Table 6. Comparison of MVCS solutions on the IEEE 118-bus system

Method	MW	ΔP1	ΔP2	ΔP5	ΔP8	ΔP11	ΔP13	Total ΔP	Cost ($/h)	Mismatch power
CPSO	Max	-5.1	-6.4	-8.6	-122.9	117.8	18.9	279.8	1,604.5	-6.30
	Min	-5.1	-27.3	-27.5	-28.9	68.1	25.9	182.7	875.0	5.20
	Mean	-5.9	-15.3	-31.5	-62.0	85.1	26.8	226.6	1,183.8	-2.80
	SD	4.4	8.4	11.4	17.5	23.2	14.6	30.5	196.4	-
PSO-TVIW	Max	-2.7	-13.8	-23.4	-97.7	121.4	10.4	269.4	1,497.8	-5.80
	Min	-6.8	-18.2	-28.2	-33.1	78.3	8.9	173.5	853.8	0.90
	Mean	-5.5	-12.1	-28.2	-59.8	76.4	29.8	211.7	1,088.4	0.60
	SD	4.3	6.7	10.7	16.9	21.1	13.5	26.3	165.8	-
PSO-TVAC	Max	-5.9	-6.2	-6.5	-96.2	80.1	30.5	225.5	1,229.6	-4.20
	Min	-0.8	-12.1	-13.9	-52.3	81.6	3.3	163.8	829.5	5.80
	Mean	-4.4	-10.3	-22.0	-58.5	69.4	24.7	189.3	970.7	-1.10
	SD	2.9	5.0	10.0	15.1	9.8	16.1	16.5	94.5	-
MVCS	Max	-4.8	-7.4	-6.8	-76.4	80.2	26.7	202.3	1,211.2	0.13
	Min	-1.1	-11.1	-14.1	-50.5	86.3	3.5	166.6	822.4	0.52
	Mean	-2.2	-12.2	-25.2	-52.3	70.1	13.1	175.1	965.13	1.04
	SD	1.0	2.2	6.4	11.1	5.1	13.1	12.5	22.3	-

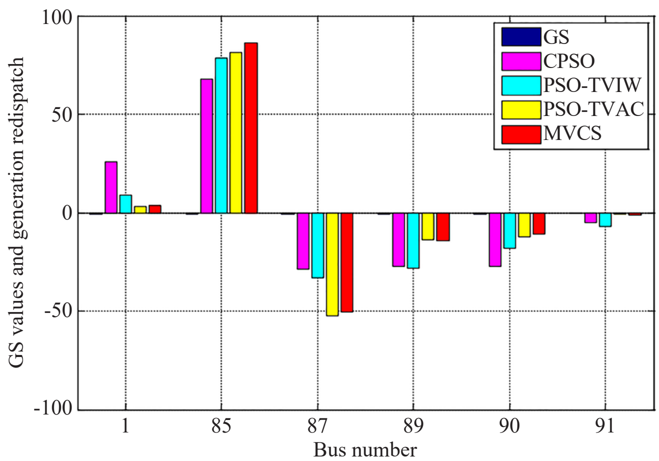

Figure 7. GS values and power redispatch on the IEEE 118-bus system

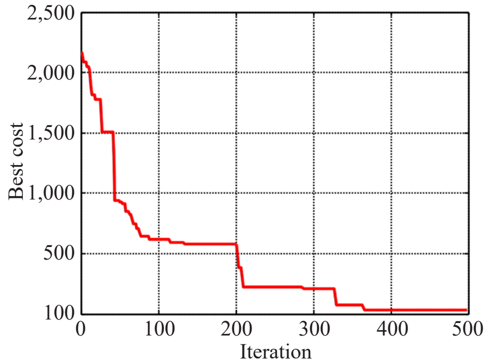

Figure 8. Evolution rate comparison CM problem in IEEE 118-bus test system

4.3 *Practical Indian 75-bus system*

As a real test system, the Indian 75-bus system including 15 generator buses and 60 load buses is selected while its data is available in [13]. Bus 12 has been assigned as the Slack bus. When the base case power flows in various branches were computed, Line 71 was already overloaded. The unconstrained scheduled power flow of 401.65 MW is recorded in line 71, whose power flow limit is 400.00 MW. Hence, congestion has to be relieved by rescheduling active power generation of the participating generators. In this case, only 10 generators have shown strong influence on the congested line; thus, these have been selected for CM. The optimization algorithms are employed to optimally reschedule the active power of the selected generators for relieving congestion in line 71. Table 7 gives the active power generation of the 10 participating generators before and after CM using MVCS, PSO [13], FPSO [13], and FDR-PSO [13].

Table 7. Active power generation before and after cm for the practical Indian 75-bus system

Gen No.	Active power generation (pu) before congestion management	Active power generation (pu) after congestion management			
		PSO [13]	FPSO [13]	FDR-PSO [13]	MVCS
3	1.9248	1.7731	1.8000	1.9310	1.9983
4	1.1653	0.9649	1.0000	0.9143	0.9823
5	1.7572	1.9576	1.8000	1.9776	1.8220
6	0.9680	1.0534	1.2000	1.0819	1.2113
7	0.7005	0.5693	0.6000	0.9220	0.6119
8	0.7469	0.9666	0.8000	0.8994	0.7726
10	1.0237	0.7376	0.8000	0.6925	0.7387
11	1.2258	1.2485	1.0900	1.0858	1.0222
14	1.3312	1.3950	1.5000	1.2989	1.2635
15	4.4229	4.5217	4.5400	4.4250	4.0198

The optimization algorithms have been executed over five times on the studied test system to find out the robustness and effectiveness of the MVCS. Table 8 tabulated the best, worst, and mean values after CM for optimal rescheduling of the active powers of the participating generators. It can be seen in Table 8 that the MVCS algorithm obtained the minimum cost in relieving congestion.

Table 8. Comparison of cm methods for the practical Indian 75-bus system

	PSO [14]	FPSO [14]	FDR-PSO [14]	MVCS
Best (Rs/MWh)	5,189.47	5,075.44	5,189.1	4,985.91
Worst (Rs/MWh)	5,243.81	5,133.08	5,213.77	5,122.42
Mean (Rs/MWh)	5,203.92	5,098.34	5,198.36	5,071.02
Time (Seconds)	2.1207	2.4600	1.9573	1.89
Losses (MW)	207.8246	205.1068	206.6673	204.012
Slack bus power (MW)	1,793.975	1,788.776	1,792.843	1,782.213

4.4 *Convergence analyze*

To evaluate and compare different methods such as PSO, MVCS and standard VCS in converge term; the Langermann's benchmark is consider in this regard [14]. In other words, it is a nonlinear and multimodal optimization problem with two variables x_1 and x_2. It can be formulated by:

$$f\left(x_1, x_2\right) = -\sum_{i=1}^{5} \frac{c_i \cos\left(\pi\left[\left(x_1-a_i\right)^2+\left(x_2-b_i\right)^2\right]\right)}{\frac{\left(x_1-a_i\right)^2+\left(x_2-b_i\right)^2}{e \qquad \pi}} \tag{10}$$

$$a=\begin{bmatrix}3 & 5 & 2 & 1 & 7\end{bmatrix}^T, b=\begin{bmatrix}5 & 2 & 1 & 4 & 9\end{bmatrix}^T, c=\begin{bmatrix}1 & 2 & 5 & 2 & 3\end{bmatrix}^T.$$

The simulation results are listed in Table 9. It can be seen, the MVCS convergence is more faster compare to other optimization algorithms.

Table 9. Frequencies of convergence during of 100 trials

Method	Range of iteration					
	0-50	50-100	100-200	200-500	500-1,000	> 1,000
MVCS	40	42	8	7	2	1
VCS	29	23	22	17	5	4
PSO	10	14	38	28	7	3

5. Conclusions

In this paper, a novel modified virus colony search based on time-varying coefficient is suggested to solve the congestion management problem with generator sensitivity in a restructured electricity market. The proposed congestion management is formulated based on minimizing redispatch cost. The proposed model is evaluated with two well-known power systems under different operating conditions. MVCS algorithm has the advantage of being easy to implement without additional computational complexity. In addition, the convergence speed of this algorithm is acceptable. According to simulation results, the proposed algorithm can solve CM problem more efficiency compare to several version of PSO in the proposed power system.

Conflict of interest

The author declares no conflict of interest.

References

[1] A. J. Conejo and R. Sioshansi, "Rethinking restructured electricity market design: Lessons learned and future needs," *International Journal of Electrical Power & Energy Systems*, vol. 98, pp. 520-530, 2018.

[2] D. P. Brown, "Capacity payment mechanisms and investment incentives in restructured electricity markets," *Energy Economics*, vol. 74, pp. 131-142, 2018.

[3] J. Wang, X. Pang, S. Gao, Y. Zhao, and S. Cui, "Assessment of automatic generation control performance of power generation units based on amplitude changes," *International Journal of Electrical Power & Energy Systems*, vol. 108, pp. 19-30, 2019.

[4] X. Yinliang, S. Hongbin, L. Houde, and F. Qing, "Distributed solution to DC optimal power flow with congestion management," *International Journal of Electrical Power & Energy Systems*, vol. 95, pp. 73-82, 2018.

[5] M. A. F. Ghazvini, G. Lipari, M. Pau, F. Ponci, A. Monti, J. Soares, R. Castro, and Z. Vale, "Congestion management in active distribution networks through demand response implementation," *Sustainable Energy, Grids and Networks*, vol. 17, pp. 1-13, 2019.

[6] V. Sumit, S. Subhodip, and V. Mukherjee, "Optimal rescheduling of real power generation for congestion management using teaching-learning-based optimization algorithm," *Journal of Electrical Systems and Information Technology*, vol. 5, no. 3, pp. 889-907, 2018.

[7] P. Rajagopal, K. Y. Vinod, and K. Niranjan, "Flower pollination algorithm based multi-objective congestion management considering optimal capacities of distributed generations," *Energy*, vol. 147, pp. 980-994, 2018.

[8] S. Akanksha and K. J. Sanjay, "Gravitational search assisted algorithm for TCSC placement for congestion control in deregulated power system," *Electric Power Systems Research*, vol. 174, pp. 105874, 2019.

[9] B. Panida, B. Chanwit, and O. Weerakorn, "Optimal congestion management in an electricity market using particle swarm optimization with time-varying acceleration coefficients," *Computers & Mathematics with Applications*, vol. 60, no. 4, pp. 1068-1077, 2010.

[10] M. D. Li, H. Zhao, X. W. Wenig, and T. Han, "A novel nature-inspired algorithm for optimization: Virus colony search," *Advances in Engineering Software*, vol. 92, pp. 65-88, 2016.

[11] O. Alsac and B. Stott, "Optimal load flow with steady-state security," *IEEE Transactions on Power Apparatus and Systems*, vol. 93, pp. 745-751, 1974.

[12] D. Devaraj and B. Yegnanarayana, "Genetic algorithm-based optimal power flow for security enhancement," *IEE Proceedings-Generation, Transmission and Distribution*, vol. 152, no. 6, pp. 899-905, 2005.

[13] Ch. Venkaiah and D. M. Vinod Kumar, "Fuzzy PSO congestion management using sensitivity-based optimal active power rescheduling of generators," *Journal of Electrical Engineering & Technology*, vol. 6, no. 1, pp. 32-41, 2011.

[14] A. Ghasemi, V. Khalil, and T. Akbar, "Multi objective optimal reactive power dispatch using a new multi objective strategy," *International Journal of Electrical Power & Energy Systems*, vol. 57, pp. 318-334, 2014.