Calculating the Locational Marginal Price and Solving Optimal Power Flow Problem With Static VAR Compensator and Moth Flame Optimization

Trinadh Babu Kunapareddy[1], Sravana Kumar Bali[2]

[1]Research Scholar, GITAM Deemed to be University, Visakhapatnam, ktrinadhbabu.eee@gmail.com
[2]Assistant Professor, GITAM Deemed to be University, Visakhapatnam.

A production unit's efficiency and profitability can be evaluated using the locational marginal price (LMP), which considers both the capacity of transmission lines and the optimal power flow (OPF). If the cost of generators is decreased overall, electricity costs in the market can decline. Numerical and repetition-based approaches are more suited for solving power flow problems due to their nonlinear nature. To find the optimal power flow at a reasonable cost, this study employs a Moth Flame Optimization (MFO) to resolve the equations. Then, to make the MFO more efficient when used in tandem, to enhance its performance and to compute transmission line power. One method that has been employed to circumvent this problem in FACTS is the Static VAR Compensator (SVC). Finally, bus voltages, line losses, produced power, total generating costs, and generator profits would all be part of the final output of the proposed MFO algorithm. The proposed method improves upon previous attempts at fixing the OPF problem by testing it on the IEEE 57-bus network.

Keywords: Optimal Power Flow, Locational Marginal Price, SVC, Moth Optimisation, Cost Convergence, UMP.

1. INTRODUCTION

Electric power engineering has entered a new era, marked by competition between service-owned and sovereign authorities and long-standing power dynamics [1], [2]. Some licenses are close to each other. From countryside to countryside, and by growth a brief market where numerous consumers buy least client pricing power. This improved use of market pressures, new dealer support and confidence growing contemporary power model and finance system power deal corporation union has increased electric load organize transmission. The goal is to promote financial competence in the use of electric power organizations. Transmission of financial data from connected electric power facilities. Networks provide a typical discussion starter. Well-organized power markets. Besides description, financial send out maximize low Plant usability affects pay rates. With LMP's transmission limits, the next electric power spike at a bus can be provided at a minimal cost, considering both the generation of marginal cost and the physical elements of the transmission system.

Competitiveness among market actors facilitates power trade. It will boost industrial production and lower electricity costs for all consumers [3]. Market players like power producers, deregulated energy markets benefit customers and system operators. However, Energy market difficulties include generating loss, line outages, etc. [4-[5]. The Transmission systems are widely used due to electric market restructuring. for electricity trading. To integrate in a deregulated system, needs suitable formulation between regulatory entities like pool operators ‘system managers. This study emphasizes the latter of these difficulties. In this paper, we build mathematical models of pool, bilateral, and multilateral dispatch mechanisms. Concerning the operation of forward and real-time dispatch in the presence of all three modalities, it is addressed [6]. Producing and distributing companies' agreements cause transmission congestion in deregulated electricity systems globally. Transmission line congestion may be handled in deregulated energy networks for safe and economical operation. In overloaded lines, series connected UPFC devices are installed to ease system congestion [7]. Energy power flows must be estimated and improved in an electrical generating system. Locating FACTS devices and improving the power transmission line Available Transfer Capability (ATC) is crucial. It reduces system congestion and boosts power [8].

Calculating the LMP is crucial for evaluating generation unit performance and profit. This relies on transmission line capacity and OPF to minimize generator costs, alleviate transmission line congestion, and lower market electricity prices [9]. The RLMP is a novel power market clearing method developed in this study. The RLMP is produced by the risk-based security-constrained economic dispatch model, which models the risk to the system's security [10]. In order to reduce congestion in deregulated energy markets, this paper presents two ways for arranging series FACTS devices. Like the sensitivity factor-based strategy, the suggested strategies prioritize and narrow the solution space. The suggested methods use LMP differences and congestion rent, respectively [11]. Congestion in transmission lines might make it difficult to dispatch all planned power in a deregulated energy market. An interline power flow controller may enhance system stability and load ability by reducing system loss and power flow in severely laden lines. Management of transmission line congestion and optimal location can be achieved by combining the Gravitational Search approach with the Disparity Line Utilization Factor, according to the authors of this study [12].Using both single-objective and multi-objective optimization methods, the optimal selection, placement, and size of Static Var Compensators (SVC) and TCS) are addressed in deregulated power systems to decrease branch loads (congestion), voltage stability, and line losses [13].This research introduces an effective approach for optimizing FACTS device locations for congestion management by modifying device characteristics. Using FACTS devices for congestion control involves a two-step process.

To improve the network, first determine the ideal device placement and then optimize the control parameters[14].After defining irrigation efficiency equations, hierarchical analysis developed goal function coefficients for all irrigation efficiencies in SWDC model. All irrigation efficiency formulae depend on input discharge[15].Many recent research optimized furrow irrigation control settings. These experiments either optimized just complete irrigation status or not all infiltration parameters. The ideal equation for the soil water distribution curve was computed in this study using Microsoft Visual Basic (VB) programming [16].The 47-year period's monthly discharges are used for 42 years of training and 5 years of forecasting. A dynamic artificial neural network model was compared to a static one using the root-mean-squared error (RMSE) statistic. The best static and dynamic neural network topologies are found using data from 1960 to 2002 (October to September) [17]. Also, models with low coupling transformer impedances or controllers without a transformer are addressed by presenting an impedance compensation method, which helps with numerical instability or problems [18].

This study assesses power flow and uses generating scaling factor (GSF) to avoid congestion in limited local regions for each change in the control variables. When the line capacity is exceeded, the algorithm will leave this optimum spot and search for the best response. This approach makes power flow a reality, reduces convergence, and is less expensive. A 24-hour power flow test was conducted on a network with 30 to 57 nodes following the deployment of MFO. An analysis was conducted to determine the generator's profit by comparing the predicted power price using economic dispatching (ED), quadratic programming using Lagrangian coefficients, and UMP or LMP.

2. PROBLEM FORMULATION

Minimizing deviation from contract power transactions for market utilities is the goal of the optimal power dispatch model in the deregulated energy market. For transactions to go through without a hitch, both the equality and inequality criteria for operations must be satisfied at the same time.

2.1 Objective Function

OPF aims to reduce active power generation expenses. The active power-based cost function of each producing unit is shown by this quadratic curve. Add each generator's cost function to get the system's goal function.

$$F_c = \min\left(\sum_{i=1}^{ng} a_i P_{Gi}^2 + b_i P_{Gi} + c_i\right) \quad (1)$$

2.1.1 Equality constraints

Production should minimize cost while meeting power demand and transmission losses. So, power flow equations are equivalent limitations and which are given in (2) and (3).

$$\sum_{i=1}^{N} P_G = \sum_{i=1}^{N} P_{Di} + P_L \quad (2)$$

$$\sum_{i=1}^{N} Q_{Gi} = \sum_{i=1}^{N} Q_{Di} + Q_L \quad (3)$$

2.1.2 Inequality constraints

OPF limits vary according on power system equipment and dependability. Uneven constraints in buses connecting to power and producing units are usually high and low voltage. Generation restrictions include generator active power, transmission line capacity and phase shift. Limitations of unequal issue variables: Generator-powered buses have high and low active power. The voltage, Watt and wattles power and SVC limits are given from equations (4) to (7) respectively.

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max} \quad (4)$$

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad (5)$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \quad (6)$$

$$B_{svc}^{min} \leq B_{svc} \leq B_{svc}^{max} \quad (7)$$

3. ELECTRICITY MARKET PRICE CALCULATION

After calculating OPF and line power flow, we may compute electricity market price using two approaches. The first technique (UMP) uses power flow data without congestion, calculating electricity prices from the overall cost of functioning generators. Each node will have the equal power tariff. The next process (LMP) is used when one or more transmission lines are at capacity and the power cost for each node will vary based on generator output.

3.1 UMP price

Consider the IEEE 30-BUS network's generation units to determine the generators' ultimate cost for the minimal producing power:

$$MC_i\left(P_i^{min}\right) = \frac{dF_i(P_i^{min})}{dP_i^{min}}\left(\frac{\$}{MWh}\right), i = 1,2,3,6,8 \quad (8)$$

Power price (π) will be determined by the cost of the more expensive generator, since employing the cheaper generator would result in losses and be unfeasible. Electricity costs are based on generators' lowest power to keep prices low.

$$\pi = \max\left(MC_i\left(P_i^{min}\right)\right)\left(\frac{\$}{MWh}\right) \quad (9)$$

3.2 LMP price

The power price at network locations will be different if transmission line capacity hits its limit, since producers cannot employ their full generation capacity. This is termed locational marginal pricing. LMP implies adding a 1-MW excess load using the cheapest generators that can generate without exceeding transmission line limits. Therefore, LMP may be calculated by considering generators that are not at their limitations. Final generators are ones with some capacity left. Thus, LMP in buses with final generators equals their ultimate cost. LMP of nodes devoid of generators or whose generators have surpassed their maximum will also rely on buses with a final generator. Final-generator buses

$$\pi_i = LMP_i = MC_i(P_i), P_i^{min} < P_i < P_i^{max}, P_i \neq P_i^{min}, P_i \neq P_i^{max}, i \in \{1,2,3,6,8\} \quad (10)$$

Final generator buses are indicated by i. Finally, Fig. 1 displays the flowchart of all stated steps with green blocks representing algorithm outputs.

4. MOTH FLAME OPTIMIZATION

The optimisation strategy comes from nature. The programme was inspired by moth nocturnal navigation. Moths fly opposite the moon. Moths spiral around lights. Moths symbolise multi-objective function solutions. Problem criteria include moths' geographic dispersion. Moth behaviour mathematical models are summarised below: Given these limits, we may explain Fig. 1 shows MFO technique logarithmic spiral: S is the spiral function, M_i the i^{th} moth, and F_j the j^{th} flame.

$$M_i = S(M_i, F_I) \quad (11)$$

$$S(M_i, F_I) = D_i . e^{bt} . \cos(2\pi t) + F_j \quad (12)$$

The i^{th} moth's distance from the j^{th} flame is denoted as D_i, b is a logarithmic spiral constant, and t is a random value between -1 and 1.

$$D_i = |F_j - M_i| \quad (13)$$

In this case, D_i is the distance between the flames and the i^{th} moth, Mi is the i^{th} flame.

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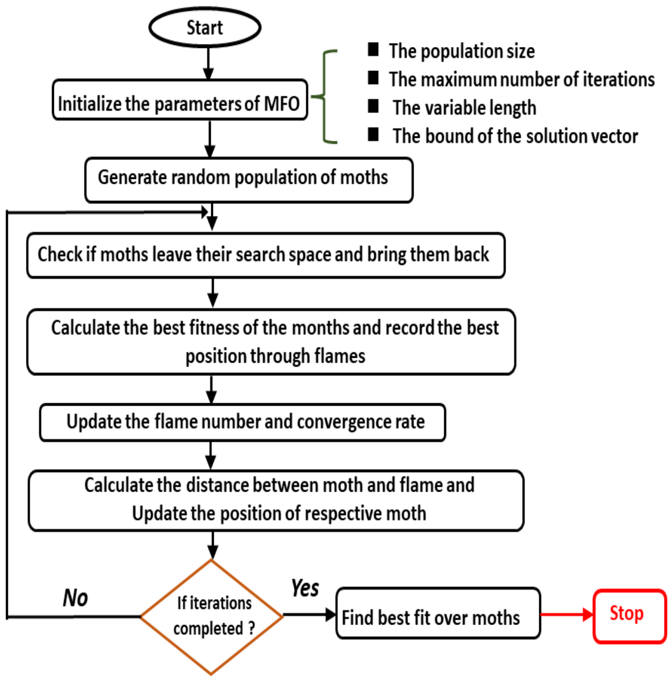

Figure 1. Flow Chart of Moth Flame Algorithm.

5. RESULTS AND DISCUSSION

Figure 2 shows IEEE- 57 node network with 80 lines of transmission, six PV nodes, one slack bus, and the remaining load nodes. Currently, SVCs are only being installed on load buses. Solar and wind power replace the final two remaining thermal generators at bus 9 and bus 12.

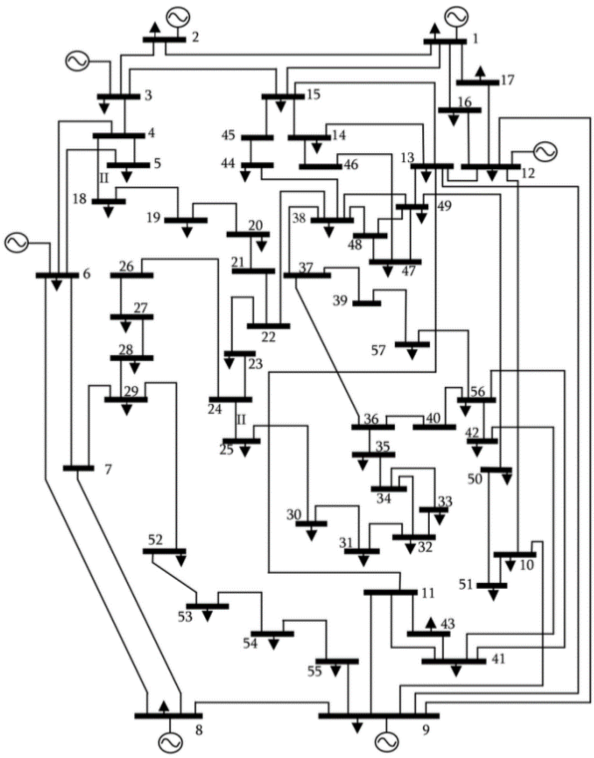

Figure 2. IEEE 57 Bus System

5.1 Results without SVC Device

In Figure 3, the hours to MW without the svc device are compared. At twelve minutes past the hour, demand for a given supply is at its peak. Supply and demand are influenced by the time of day.

The results of the proposed algorithm, including the injected power, production cost, network losses, and 24-hour electricity price are analysed. The data indicates that the network is limited by Line 2-3's 36 MW capacity, which reached its peak at 12 o'clock. The LMP values for various buses are shown in Table 6, which will determine the cost for this hour. The output power of generators and the current through lines were determined by these experiments. With MFO, we can connect line power injection to the bus with pinpoint accuracy. Negative power columns also invert the direction of power along that line. Taking lines 3–4 into account, the reduced power output of bus generator 2 is a result of electricity being transferred from bus 4 to bus 3. Table 2. Calculations for profits of generators in MFO method.

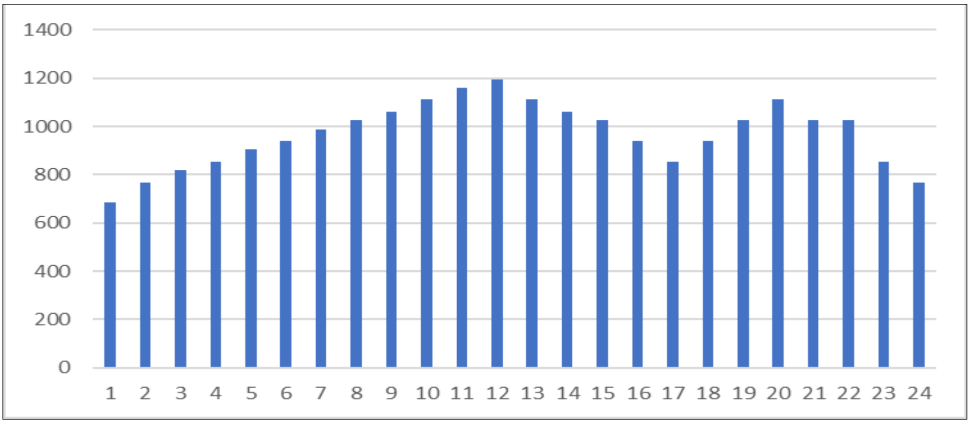

Figure 3. Network's power demand.

Table 1. LMP values for network buses

Bus No	LMP	Bus No	LMP	Bus No	LMP	Bus No	LMP
1	0.03	15	0.43	29	0.036	43	0.02
2	0.41	16	0.42	30	0.058	44	0
3	0	17	0.272	31	0.016	45	0
4	0.13	18	0.033	32	0.038	46	0.297
5	0.75	19	0.023	33	0	47	0
6	0	20	0	34	0.06	48	0.18
7	1.5	21	0	35	0	49	0.21
8	1.21	22	0.063	36	0	50	0.18
9	0.05	23	0	37	0.14	51	0.049
10	0	24	0.063	38	0	52	0.2
11	3.77	25	0	39	0	53	0.041
12	0.18	26	0.093	40	0.063	54	0.068
13	0.105	27	0.046	41	0.071	55	0.076
14	0.22	28	0.17	42	0.02	56	0.067

Table 2. Calculations for profits of generators in the MFO method

Hour	MFO									
	P1	P2	P3	P6	P8	P9	P12	Loss cost	Total profit of generators	pi
1	1922.25	0.0504	581.82	231	6547.71	0.05679	4773.04	312.39	13743.5	48
2	2361.98	529.2	554.3	231	6505.8	1.4524	4479.86	354.95	14308.6	48
3	1844.05	975	584.153	231	6573.5	0.0016	4673.84	355.05	14526.4	48
4	2271.42	2.447	705.94	231	7575.714	1.8082	5338	370.846	15755.4	48
5	2306.47	59.0293	712.7	231	7735.7	9.67652	5569.77	457.3255	16166.9	48
6	2488.73	268.09	740.64	231	7584.6	49.935	5426.3	508.38	16280.9	48
7	2212.92	975	694.032	231	7540.4	0.66393	5391.2	629.56	16415.6	48
8	2240.04	975	704.81	231	7666.64	34.188	5553.6	672.666	16732.6	48

9	2396.39	527.518	744.6	231	8041.46	348.57	5593.4	691.3254	17191.6	48
10	2307.8	975	720.44	231	7883.05	320.481	5696.26	751.43	17382.6	48
11	2307.8	975	722.778	231	7883.05	320.48	5696.26	758.46	17377.9	48
12	2307.8	975	722.77	234.6	7883.05	320.48	5696.26	770.16	17369.8.	LMP
13	2307.8	975	720.44	231	7883.05	320.481	5696.26	751.43	17382.6	48
14	2396.39	527.518	744.6	231	8041.46	348.57	5593.4	691.3254	17191.6	48
15	2240.04	975	704.81	231	7666.64	34.188	5553.6	672.666	16732.6	48
16	2488.73	268.09	740.64	231	7584.6	49.935	5426.3	508.38	16280.9	48
17	2271.42	2.447	705.94	231	7575.714	1.8082	5338	370.846	15755.4	48
18	2488.73	268.09	740.64	231	7584.6	49.935	5426.3	508.38	16280.9	48
19	2240.04	975	704.81	231	7666.64	34.188	5553.6	672.666	16732.6	48
20	2307.8	975	720.44	231	7883.05	320.481	5696.26	751.43	17382.6	48
21	2240.04	975	704.81	231	7666.64	34.188	5553.6	672.666	16732.6	48
22	2240.04	975	704.81	231	7666.64	34.188	5553.6	672.666	16732.6	48
23	2271.42	2.447	705.94	231	7575.714	1.8082	5338	370.846	15755.4	48
24	2361.98	529.2	554.3	231	6505.8	1.4524	4479.86	354.95	14308.6	48

5.2 Results with SVC

Table 3. Calculations for profits of generators in MFO method

Hour	MFO									
	P1	P2	P3	P6	P8	P9	P12	Loss cost	Total profit of generators	pi
1	1872.16	9.5879	161.44	14.3596	530.412	1500	13484.4	261.35	15309.6	48
2	888.22	0.5423	270.4	0.004	3111.07	1500	6057.43	262.0142	16701.2	48
3	1198.58	0.0424	368.24	0.0184	3784.9	1500	6057.43	264.66	17211.3	48
4	513.95	700	192.97	0	3237.71	1500	6057.43	312.088	17523.1	48
5	1644.08	0.94547	510.714	0.168	4908.056	1500	6057.43	323.006	17910.32	48
6	1131.67	700	385.197	0	4322.39	1500	6057.43	350.4	17316.52	48
7	1974.87	0.363	647.18	0.0464	5819.74	1500	6057.43	376.704	17523.21	48
8	2075.72	0.1208	646.92	0.04	6289.73	1500	6057.43	386.593	17621.32	48
9	2174.69	69.052	640.74	0.2722	6548.8	1500	6057.43	403.696	17421.61	48
10	2388.36	251.57	754.664	16.891	6355.92	1500	6057.43	405.1	17651.32	48
11	2355.61	108.48	747.8257	77.854	7289.19	1500	6057.43	450.16	17954.12	48
12	2277.15	358.72	757.61	62.86	7417.23	1500	6057.43	476.1554	1.81E+04	LMP
13	2388.36	251.57	754.664	16.891	6355.92	1500	6057.43	405.1	17954.12	48
14	2174.69	69.052	640.74	0.2722	6548.8	1500	6057.43	403.696	17421.61	48
15	2075.72	0.1208	646.92	0.04	6289.73	1500	6057.43	386.593	17621.32	48
16	1131.67	700	385.197	0	4322.39	1500	6057.43	350.4	17316.52	48
17	513.95	700	192.97	0	3237.71	1500	6057.43	312.088	17523.1	48
18	1131.67	700	385.197	0	4322.39	1500	6057.43	350.4	17316.52	48
19	2075.72	0.1208	646.92	0.04	6289.73	1500	6057.43	386.593	17621.32	48
20	2388.36	251.57	754.664	16.891	6355.92	1500	6057.43	405.1	17651.32	48
21	2075.72	0.1208	646.92	0.04	6289.73	1500	6057.43	386.593	17621.32	48
22	2075.72	0.1208	646.92	0.04	6289.73	1500	6057.43	386.593	17621.32	48
23	513.95	700	192.97	0	3237.71	1500	6057.43	312.088	17523.1	48
24	888.22	0.5423	270.4	0.004	3111.07	1500	6057.43	262.0142	16701.2	48

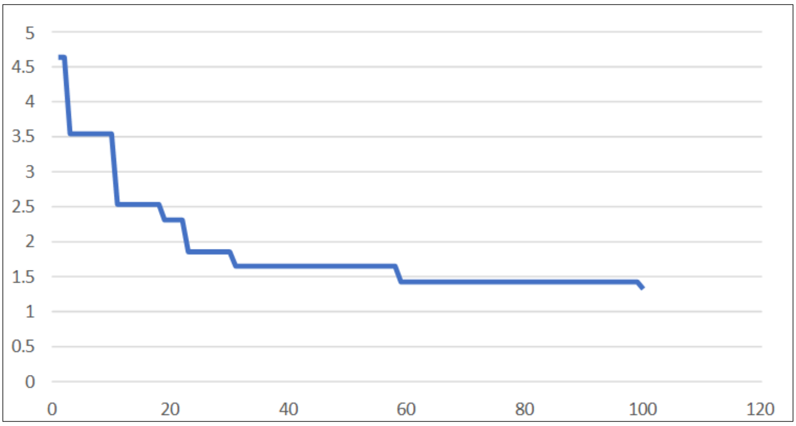

Figure 4. Cost convergence using MFO method

Table 3 shows FACTS device, SVC, and production losses and costs reducing when compared without SVC. MFO network losses are reduced by adding svc compared to Fig 5. 57-bus system voltage curve between voltage and supply demand is shown in Fig 9. Fig10 shows that svc system cost convergence lowers system cost over no facts devices. With the addition of svc, the profit of the system grew, as shown in red compared to the case without it. A comparison of the loss cost with and without svc, with the loss cost being lower with svc. Without svc, the loss cost is higher during peak hours. Since the loss cost is lower in svc, the system's overall profit will rise. You can see that the efficiency of the system is enhanced when the losses are reduced in the svc system compared to the without-svc system.

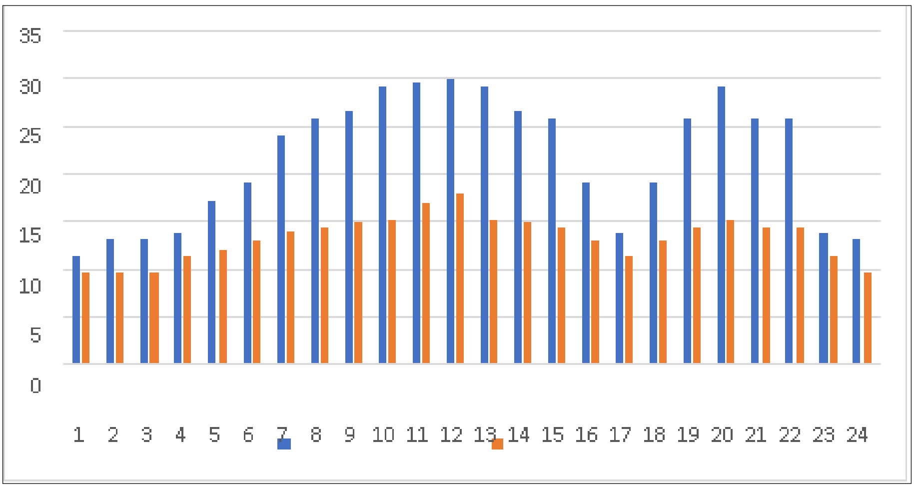

Figure 5. Generation losses between with and without SVC

6. CONCLUSION

The locational marginal price (LMP) is computed and the OPF problem is solved using the metaheuristic algorithm MFO in this work. If the network's flow power generation needs are not satisfied at the minimum point, the procedure will be repeated until the necessary conditions are satisfied. Power output from the generator, losses in the network, voltage across the bus, cost of generation, and line power are all outputs of the proposed method. By looking at line capacity, we may also find out how much power is sold for and how much generators make. Additionally, we can determine the revenue generated by generators. By reducing processing time, processing costs, and losses and enhancing the OPF to fit the real scenario, the simulation results demonstrate that the MFO method is effective. In the future, it will be feasible to study the proposed optimisation for different demand and source systems, producing systems that use different renewable energy sources, and for different cost and loss estimations. In this post, we figured out the locational marginal price (LMP) and solved the OPF problem using the metaheuristic algorithm MFO. We first implemented GSF in the MFO structure to enhance the evolutionary algorithm, which allows us to link changes in the power flowing over network lines to changes in generator power. simultaneously verify that all network flow power establishment conditions are met for each variable; if the obtained minimum point does not meet these conditions, the process is repeated. By verifying the line capacity, we can also determine the market price of power and the profit of generators; the final output of the suggested method will be the power going over lines, network losses, bus voltage, generating cost, and power of generation units. The absence of congestion on network lines is a significant concern in OPF. Reduced losses, short processing time, reduced generating cost, and reality-based OPF are some of the benefits observed in simulation results when comparing the MFO algorithm to approaches in literature.

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