Congestion Alleviation by Optimal Placing of Renewable Energy Generator in Power System Network using Stochastic Optimization Techniques

R.Ramaporselvi, G.Geetha, Mrunal Deshpande, J.Shri Saranyaa

Abstract—This paper peculiarly narrates about the optimal location of the renewable electrical generator along with minimizing the cost of generation. The aim of optimal congestion management is achieved by the suitable placement of the renewable electrical generator through PSO and VEPSO optimization technique. The renewable energy source boasts to be a vital and cost-free source for generating energy in the deregulated electricity network. Renewable energy generator (REG) location is identified on the minimum losses of the system thereby reducing the cost of generation. The approach is simulated and the results demonstrate the optimal location of REG and cost of generation in the 6 bus test system, IEEE-14-bus and IEEE-30 bus system.

Index Terms—Particle swarm optimization (PSO), Vector Evaluated Particle Swarm Optimization (VEPSO)

I. INTRODUCTION

In the deregulated electricity network, security and reliability play a paramount role. The outage in generation, failure of equipments, tripping of the transmission lines, sudden increment in demand, etc. scenarios affects the power system security and reliability. The transmission system is the heart of the electricity network that it has been operated at the near to peak capacity. The network’s power transfer capability may exceed beyond the scheduled transfer limit due to the sudden increasing power demand of the system. That’s the major reason for congestion occurring in the transmission sector. These congestion issues are mitigated by congestion management such as rescheduling the generation, curtailment of load, using FACTS devices, usage of renewable energy sources, etc. The sensitivity of the system loading factor based real and reactive power index scheme to determine the optimal location of FACTS device proposed [2]. Gravitational search algorithm for the optimal placement of IPFC for congestion management is proposed in [3]. In the developing countries, the global demand has seen a steady increase due to rising population, thereby making it necessary to meet the future demand by using new generator location in optimal places based on the minimum fuel cost, total emission and system loss [4].

Congestion management enacts to relieve the system congestion by non-cost free methods like re-dispatch of generation, load curtailment and built a new transmission line and cost-free methods are transformer taps, phase shifters, FACTS devices and renewable energy generation (REGs). Renewable energy generators pave a better solution for an economic electrical generation in electricity networks concerning the future power demand. Conventional energy sources are not adequate enough for generating the required energy and may lead to exploitation. It’s also environmentally harmful. A bio-inspired bee’s colony algorithm for placement of DG and size considering reliability and energy loss [6]. REG is one of the less cost-free methods because the operating cost is not included in the cost of generation. Locating the REG’s is based on the system’s minimum power loss.

II. PROPOSED METHODOLOGY

The global optimal location of REGs is resolved using stochastic optimization technique. The optimal location of REGs based on real power loss. The optimum location of REG gives the following benefits such as relieving congestion of system, minimizing the generation cost. The minimum objective generation cost is given by

\[ \text{Min } G.C = F(p_{gm}) + C(P_{REG}) \]  

Subjected to

i) Equality constraints

Power balance equation

\[ P_{GT} = P_L + P_D \]  

where,

\[ P_{GT} = \sum_{m=1}^{N} P_{gm} + P_{REG} \]

ii) Inequality constraints

Constraints (line flow, generating power of the unit, bus voltage, Complex power etc.) are operated within the operating limit.

\[ P_{lfk} \leq P_{lfk}^{\text{Max}} \]

\[ P_{gm(Min)} \leq P_{gm} \leq P_{gm(Max)} \]

\[ V_{bp(Min)} \leq V_{bp} \leq V_{bp(Max)} \]

Where \( p = 1, 2, \ldots, N \)

Fuel cost of existing system

\[ F(P_{gm}) = \sum_{m=1}^{N} \alpha_m p_g^2 + b_m p_g + c_m \]

Generation cost of Renewable energy generation system.

\[ C(P_{REG}) = 0.0001 P_{REG}^2 + 0.4 P_{REG} \]

Line loss of the system

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where \( k = 1, 2, \ldots \), \( P_{gm} \) is the generating power of the existing system, \( P_{PSO} \) is the generating power of renewable energy system, \( a_m, b_m \) and \( c_m \) are coefficients of fuel cost of the existing system, \( P_0 \) is the demand power of system, \( P_{Lk} \) is system loss of \( k \)-th line. \( P_{sl} \) is total generating power, \( P_{Lk} \) is power flow of \( k \)-th line, \( V_{pq} \) is voltage magnitude of \( p \)-th and \( q \)-th bus, \( G_k \) is conductance of \( k \)-th line between \( p \) and \( q \) bus, \( \delta_p \) and \( \delta_q \) are voltage angle of \( p \)-th and \( q \)-th bus, \( m \) is a number of existing generator, \( L \) is a number of lines and \( p \) is a number of buses.

In the solution suggested, the REG’s are connected at every bus to find the fuel cost and power losses of the system with assumption of constant power demand using the popular optimization algorithms PSO and VEPSO. The vital task of the PSO and VEPSO is to search the optimal value of generating cost and minimum real power losses of the system when REG is to be located on each bus through the various processes of iterations. The above process is then reiterated for all buses of the system until an optimal result is obtained. The lowest system losses give the optimal location for placing REGs. Thus by roping in the renewable sources at that particular location of bus helps in reducing all sorts of congestion challenges. Figure (1) shows the flowchart of the above proposed methodology.

**III. CASE STUDIES AND RESULTS**

The proposed framework is tested in a 6 bus system, IEEE-14 bus system and IEEE-30 bus system using the stated optimization techniques to solve the congestion management and determine the suitable location of REG based on the system losses and minimum generation cost.

### Six bus system

It has 11 lines, one slack bus considered as 1st bus and 2-generator bus and 3-load bus. The minimum system losses occur in the given system when the REG placed on 5-bus. Table (1) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique.

**Table 1: REG on different bus for six bus system**

| Bus No | Total Gen. (MW) | Total Gen. Cost ($/hr) | Total Loss (MW) | Total Gen. (MW) | Total Gen. Cost ($/hr) | Total Loss (MW) |
|--------|----------------|------------------------|----------------|----------------|------------------------|----------------|
| PSO    | VEPSO          | PSO                    | VEPSO          | PSO            | VEPSO                  | PSO            |
| Bus 1  | 211.815        | 3312.25                | 6.8148         | 211.895        | 3312.92                | 6.8954         |
| Bus 2  | 211.621        | 3309.75                | 6.6211         | 211.732        | 3310.04                | 6.7323         |
| Bus 3  | 211.587        | 3309.35                | 6.5871         | 211.613        | 3309.99                | 6.6136         |
| Bus 4  | 211.508        | 3308.55                | 6.5081         | 211.578        | 3308.69                | 6.5789         |
| Bus 5  | 211.442        | 3307.45                | 6.4423         | 211.448        | 3307.64                | 6.4483         |
| Bus 6  | 211.467        | 3307.55                | 6.4671         | 211.5          | 3307.8                 | 6.5007         |

**Table 2: Result of six bus system with and without REG**

| Status | Total Gen. (MW) | Total Gen. Cost ($/hr) | Total Loss (MW) | Total Gen. (MW) | Total Gen. Cost ($/hr) | Total Loss (MW) |
|--------|----------------|------------------------|----------------|----------------|------------------------|----------------|
| PSO    | VEPSO          | PSO                    | VEPSO          | PSO            | VEPSO                  | PSO            |
| With REG on Bus 5 | 211.442 | 3307.45 | 6.4423 | 211.448 | 3307.64 | 6.4483 |
| Without REG | 216.815 | 3375.9 | 6.8148 | 216.82 | 3376 | 6.8197 |

**Fig.1 Flow chart of proposed system**

**Fig.2 System losses of six bus system**
Table 3: REG on different bus of IEEE-14 bus system for PSO and VEPSO

| Bus No | Total Generation (MW) | Total Power Loss (MW) | Generation Cost ($/hr) |
|--------|-----------------------|-----------------------|-----------------------|
|        | PSO                   | VEPSO                 | PSO                   | VEPSO                 |
|        | Without REG           |                       |                       |                       |
| 272.653| 273.121               | 13.654                | 14.1217               | 12551                 | 12563.9 |
| 1      | 267.653               | 267.97                | 13.654                | 13.9707               | 12344   | 12352.7 |
| 2      | 267.389               | 267.826               | 13.3899               | 13.8266               | 12333   | 12345   |
| 3      | 266.973               | 266.979               | 12.9737               | 12.9798               | 12316   | 12316.2 |
| 4      | 267.101               | 267.231               | 13.1011               | 13.2316               | 12321   | 12324.6 |
| 5      | 267.19                | 267.059               | 13.1903               | 13.0597               | 12325   | 12321.4 |
| 6      | 267.184               | 267.569               | 13.1846               | 13.5696               | 12325   | 12335.6 |
| 7      | 267.101               | 267.289               | 13.1014               | 13.2896               | 12321   | 12326.2 |
| 8      | 267.101               | 267.962               | 13.1016               | 13.9626               | 12321   | 12344.7 |
| 9      | 267.101               | 267.364               | 13.1016               | 13.3646               | 12321   | 12328.2 |
| 10     | 267.088               | 267.163               | 13.0889               | 13.1636               | 12321   | 12323.1 |
| 11     | 267.125               | 267.968               | 13.1255               | 13.9686               | 12322   | 12345.2 |
| 12     | 267.117               | 267.002               | 13.1173               | 13.0026               | 12322   | 12318.9 |
| 13     | 267.074               | 267.562               | 13.0747               | 13.5626               | 12320   | 12333.4 |
| 14     | 266.983               | 267.361               | 12.9838               | 13.3616               | 12316   | 12326.4 |

IEEE 14-bus system

The minimum system losses occur in the given system when the REG placed on 3-bus. Table (3) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique. Fig (4) & Fig (5) illustrate the minimum cost of generation and system losses with respect to iteration respectively. Table (4) gives the information of line losses of each line.

IEEE 30- bus System

It has 41 lines, one slack bus considered as 1st bus and four generator bus. The minimum system losses occur in the given system when the REG placed on 5-bus. Table (5) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique.

Table 4: Line losses of IEEE-14 bus system with and without REG

| Line Number | Without REG | With REG |
|-------------|-------------|----------|
|             | On 3rd Bus  | On 14th Bus | On 13th Bus |
| 1 –Line(1-2) | 4.2532      | 4.0264    | 4.0631     |
| 2 –Line(1-5) | 2.8059      | 2.7035    | 2.6581     |
| 3 –Line(2-3) | 2.3874      | 2.2006    | 2.3436     |
| 4 –Line(2-4) | 1.6872      | 1.6435    | 1.6075     |
| 5 –Line(2-5) | 0.9203      | 0.9052    | 0.8646     |
| 6 –Line(3-4) | 0.4214      | 0.3433    | 0.4386     |
| 7 –Line(4-5) | 0.4917      | 0.4659    | 0.4911     |
| 8 –Line(4-7) | 0           | 0         | 0          |
| 9 –Line(4-9) | 0           | 0         | 0          |
| 10 –Line(5-6) | 0           | 0         | 0          |
| 11 –Line(6-11) | 0.1091      | 0.1084    | 0.1152     |
| 12 –Line(6-12) | 0.0805      | 0.0804    | 0.0734     |
| 13 –Line(6-13) | 0.2488      | 0.2482    | 0.2126     |
| 14 –Line(7-8) | 0           | 0         | 0          |
| 15 –Line(7-9) | 0           | 0         | 0          |
| 16 –Line(9-10) | 0.0063      | 0.0064    | 0.0046     |
| 17 –Line(9-14) | 0.0444      | 0.0452    | 0.0406     |
| 18 –Line(10-11) | 0.0422      | 0.0419    | 0.0398     |
| 19 –Line(12-13) | 0.0102      | 0.0102    | 0.0077     |
| 20 –Line(13-14) | 0.0954      | 0.0947    | 0.0597     |
| Total       | 13.654      | 12.9737   | 12.9838    |

Fig.4 System losses of IEEE-14 bus system

Fig.5 Cost of generation of IEEE-14 bus system

Fig (6) & Fig (7) illustrate the minimum cost of generation and system losses with respect to iteration. Table (6) gives the information of line losses of each line.
Table 5: REG on different bus of IEEE-30 bus system for PSO and VEPSO

| Bus No | Without REG | PSO | VEPSO | PSO | VEPSO | PSO | VEPSO |
|--------|-------------|-----|-------|-----|-------|-----|-------|
| 1      | 301.067     | 301.763 | 17.6714 | 18.3672 | 15234 | 15260.057 |
| 2      | 296.067     | 296.669 | 17.6714 | 18.2733 | 15010 | 15032.444 |
| 3      | 295.766     | 296.001 | 17.3699 | 17.605  | 15132 | 15140.764 |
| 4      | 295.589     | 295.782 | 17.2625 | 17.3859 | 15128 | 15132.6  |
| 5      | 295.536     | 295.814 | 17.1399 | 17.4174 | 15122 | 15132.345 |
| 6      | 295.29      | 295.298 | 16.9027 | 16.9111 | 15111 | 15131.31 |
| 7      | 295.442     | 295.967 | 17.0465 | 17.5721 | 15118 | 15137.598 |
| 8      | 295.35      | 296.119 | 16.9538 | 17.7232 | 15114 | 15142.694 |
| 9      | 295.41      | 295.654 | 17.0138 | 17.2578 | 15116 | 15125.096 |
| 10     | 295.44      | 295.444 | 17.044  | 17.4083 | 15118 | 15118.16  |
| 11     | 295.439     | 295.836 | 17.0435 | 17.4407 | 15118 | 15132.808 |
| 12     | 295.44      | 296.173 | 17.0441 | 17.7772 | 15118 | 15145.339 |
| 13     | 295.531     | 295.314 | 17.1358 | 16.9187 | 15122 | 15113.91  |
| 14     | 295.531     | 296.171 | 17.1358 | 17.7758 | 15122 | 15145.865 |
| 15     | 295.462     | 295.837 | 17.0656 | 17.441  | 15119 | 15132.995 |
| 16     | 295.417     | 296.624 | 17.0211 | 17.2279 | 15117 | 15124.709 |
| 17     | 295.469     | 295.653 | 17.0725 | 17.2567 | 15119 | 15125.866 |
| 18     | 295.428     | 295.4  | 17.032  | 17.0044 | 15117 | 15115.971 |
| 19     | 295.36      | 295.783 | 16.9641 | 17.3878 | 15114 | 15129.797 |
| 20     | 295.34      | 295.372 | 16.9444 | 16.9762 | 15113 | 15114.185 |
| 21     | 295.365     | 295.789 | 16.9673 | 17.3931 | 15114 | 15129.875 |
| 22     | 295.372     | 295.463 | 16.9765 | 17.0675 | 15115 | 15118.392 |
| 23     | 295.412     | 295.982 | 17.016  | 17.5863 | 15117 | 15138.265 |
| 24     | 295.371     | 295.418 | 16.9756 | 17.0229 | 15115 | 15116.763 |
| 25     | 295.347     | 296.102 | 16.9519 | 17.7066 | 15114 | 15142.145 |
| 26     | 295.384     | 295.821 | 16.9882 | 17.4252 | 15115 | 15131.293 |
| 27     | 295.354     | 295.3  | 16.9582 | 16.9037 | 15114 | 15111.969 |
| 28     | 295.43      | 295.843 | 17.0335 | 17.4465 | 15117 | 15132.398 |
| 29     | 295.411     | 295.298 | 17.0154 | 16.9025 | 15116 | 15111.793 |
| 30     | 295.319     | 296.002 | 16.9233 | 17.6063 | 15112 | 15137.47  |
| 31     | 295.324     | 295.562 | 16.9278 | 17.1662 | 15110 | 15118.89  |

Table 6: Line losses with and without REG

| Line Number | Without REG | On 30th Bus | On 5th Bus | On 29th Bus |
|-------------|-------------|-------------|------------|-------------|
| 1 –Line(1-2)| 5.1169      | 4.8961      | 4.8665     | 4.8996      |
| 2 –Line(1-3)| 3.161       | 3.0161      | 3.0581     | 3.0184      |
| 3 –Line(2-4)| 1.0243      | 0.9721      | 1.0107     | 0.973       |
| 4 –Line(3-4)| 0.8715      | 0.8306      | 0.8425     | 0.8313      |
| 5 –Line(2-5)| 3.0035      | 2.9478      | 2.7836     | 2.9488      |
| 6 –Line(2-6)| 1.9823      | 1.875       | 1.9395     | 1.8767      |
| 7 –Line(4-6)| 0.645       | 0.6056      | 0.6174     | 0.606       |
| 8 –Line(5-7)| 0.1641      | 0.1741      | 0.1275     | 0.1741      |
| 9 –Line(6-7)| 0.3889      | 0.4036      | 0.345      | 0.4033      |
| 10 –Line(6-8)| 0.1944    | 0.0989      | 0.1043     | 0.0999      |
| 11 –Line(6-9)| 0          | 0           | 0          | 0           |
| 12 –Line(6-10)| 0         | 0           | 0          | 0           |
| 13 –Line(9-11)| 0       | 0           | 0          | 0           |
| 14 –Line(9-10)| 0         | 0           | 0          | 0           |
| 15 –Line(4-12)| 0       | 0           | 0          | 0           |
| 16 –Line(12-13)| 0    | 0           | 0          | 0           |

Fig.6 System losses of IEEE-30 bus system

Fig.7 Cost of Generation of IEEE-30 bus system
IV. CONCLUSION

The techniques implemented in this paper exhibit that the congestion management can be rectified using PSO and VEPSEO optimization techniques to determine the optimal placing of REG based on the system losses. The work is demonstrated with the 6-bus system, IEEE-14 bus and IEEE-30 bus system to prove its effectiveness. It shows that power can be generated with minimum generating cost with the help of renewable energy generator, also by minimizing the system losses and alleviates the impact of congestion.

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