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Impact of distributed generation on nodal prices in hybrid electricity market

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Abstract

Wind power integration in electrical utilities all over the world is increasing manifold due to environmental degradation concerns, technological innovations in turbine technology, smart grid initiatives, and competitive electricity market operation. In this paper, impact of distributed generation is presented on fuel cost and nodal prices in mix of pool and bilateral electricity market. In this paper, the main contributions are: (i) Mixed integer nonlinear programming (MINLP) approach for determining optimal location and number of distributed generators (ii) impact of wind power output on nodal prices of real and reactive power with wind power variation during 24 hours. The proposed MINLP based optimization approach has been applied for IEEE 24 bus reliability test system.

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Keywords: Distributed generation ; electricity market; nodal prices; real and reactive power prices

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1. Introduction

Many different techniques were developed and reported in the literature for problem of optimum size and location of DG units. Minimizing the power losses and improving the voltage profile are main objective function for the problem of DG integration [1-6]. Lagrangian based approach, Tabu search, Genetic algorithm, was proposed for optimal location of DGs considering loss reduction, voltage profile improvement, economic as well as stability limit criteria in [7-10]. A combined method based on improved PSO and Monte Cario simulation for optimal allocation of DG units in order to minimize the cost of power losses and improve the voltage profile and reliability was proposed in [11]. A combined solution based GA and PSO, OPF and discrete form of PSO for DRG allocation in order to

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minimize power losses, improve voltage stability, and enhance voltage regulation that considering security constraints was proposed in [12,13]. A multi-objective optimization approach using evolutionary algorithm for sizing and siting of distribution generation in distribution system has been presented in [14-16]. A dynamic programming for multi-objective DG allocation for power losses minimization, voltage profile improvement and reliability enhancement has been proposed [17]. A theoretical in sigh to a competitive market integration mechanism for DG in a pool based system and multi-objective optimization for DG allocation for loss reduction and voltage improvement was proposed in [18, 19]. A mixed integer nonlinear programming (MINLP) approach for determining optimal location and number of distributed generator considering minimization of transmission loss with the presence of DFIG [20, 21]. The impact of wind speed variation has also been incorporated in the optimization model for obtaining the impact of DFIG output on the transmission loss. Large scale wind farm integration issues with dynamic model and optimal generation control aspects were presented in [22-24]. With competitive electricity market evolution and different ways of trading power, it is essential to consider impact of wind source integration on losses, voltage profile and nodal prices of both real and reactive power.

In this paper, the main contributions are: (i) Mixed integer nonlinear programming (MINLP) approach for determining optimal location and number of distributed generators considering minimization of fuel cost of conventional generator and cost of distributed generators in bilateral electricity market, (ii) impact of wind power output on nodal prices of real and reactive power with wind power variation during 24 hours. The proposed MINLP based optimization approach has been applied for IEEE 24 bus reliability test system. The optimization problems have been solved using MTLAB and GAMS interfacing with DICOPT solver in GAMS.

2. Mathematical model formulation

The power output of the DG is taken for 24 hours and impact of DG has been determined on scheduling of conventional generators in hybrid electricity market.

The objective function is Min $F\left(x,u,\xi^{\text{int}}\right)$ (1)

Subject to equality and inequality constraints defined as

$$h\left(x,u,\xi^{\text{int}}\right)=0 \tag{2}$$

$$g\left(x,u,\xi^{\text{int}}\right)\leq 0 \tag{3}$$

where,

x is state vector of variables V, δ;

u are the control parameters, P_{gi},Q_{gi}, P_{DGi}, $Q_{DGi,}$ P_{gpi}, *and* P_{gbi};

ξ^{int} is an integer variable with values {0,1}. The zero value represents absence and one value represents presence of distributed generator in the network.

The objective function taking variation of power for 24 hour is

Min

$$F\left(x,u,p,\xi^{\text{int}}\right)=\left\{\sum_{i\in N_g}\left(a_{gi,k}+b_{gi,k}P_{gi,k}+c_{gi,k}P_{gi,k}^{2}\right)+\xi_{i,k}^{\text{int}}*\sum_{i\in N_{DG}}\left(a_{DGi,k}+b_{DGi,k}P_{DGi,k}+c_{DGi,k}P_{DGi,k}^{2}\right)\right\}\forall i=1,2..N_b, k=1,2..24 \tag{4}$$

2.1. Equality constraints

Power flow equations corresponding to both real and reactive power balance equations are equality constraints that can be modified in the presence of distributed generation for all the buses as:

$$P_{i,k}=P_{gi,k}+\xi_{i,k}^{\text{int}}*P_{DGi,k}-P_{di,k}\ \forall i=1,2,\ldots N_b, k=1,2,...24 \tag{5}$$

$$Q_{i,k} = Q_{gi,k} + \xi_{i.k}^{\text{int}} * Q_{DGi,k} - Q_{di,k} \forall i = 1,2,\ldots N_b, k = 1,2,\ldots 24 \tag{6}$$

$$P_{i,k} = \sum_{j=1}^{N_b} V_{i,k} V_{j,k} \left[G_{ij} \cos\left(\delta_{i,k} - \delta_{j,k}\right) + B_{ij} \sin\left(\delta_{i,k} - \delta_{j,k}\right) \right] \quad \forall i = 1,2,\ldots N_b, k = 1,2,\ldots 24 \tag{7}$$

$$Q_{i,k} = \sum_{j=1}^{N_b} V_{i,k} V_{j,k} \left[G_{ij} \sin\left(\delta_{i,k} - \delta_{j,k}\right) - B_{ij} \cos\left(\delta_{i,k} - \delta_{j,k}\right) \right] \quad \forall i = 1,2,\ldots N_b, k = 1,2,\ldots 24 \tag{8}$$

2.2. Inequality constraints

(a) *Real power generation limit*: This includes the upper and lower real power generation limit of generators at bus-i

$$P_{gi,k}^{\min} \le P_{gi,k} \le P_{gi,k}^{\max}, i = 1,2,\ldots N_g, k = 1,2,\ldots 24 \tag{9}$$

(b) *Reactive power generation limit*: This includes the upper and lower reactive power generation limit of generators and other reactive sources at bus-*i*

$$Q_{gi,k}^{\min} \le Q_{gi,k} \le Q_{gi,k}^{\max}, i = 1,2,\ldots N_q, k = 1,2,\ldots. 24 \tag{10}$$

(c) *Voltage limit*: This includes the upper and lower voltage magnitude limit $V_i^{\min}, V_i^{\max}$ at bus-*i*

$$V_{i,k}^{\min} \le V_{i,k} \le V_{i,k}^{\max}, i = 1,2,\ldots N_b, k = 1,2,\ldots 24 \tag{11}$$

(d) *Phase angle limit*:This includes the upper and lower angle limit $\delta_i^{\min}, \delta_i^{\max}$ at bus-*i*

$$\delta_{i,k}^{\min} \le \delta_{i,k} \le \delta_{i,k}^{\max}, i = 1,2,\ldots N_b, k = 1,2,\ldots 24 \tag{12}$$

(e) *Line flow limits*: These constraints represent maximum power flow in a transmission line and are based on thermal and stability considerations. The line flow limit can be written as:

$$\left| S_{ij,k} \right| \le S_{ij,k}^{\max} \tag{13}$$

(f) Two inequality constraints have to be added in an OPF model with distributed generation.

2.3. Power generation limit

This includes the upper and lower real power generation limit of generators at bus-*i*

a) Real power generation limit

$$P_{DGi,k}^{\min} \le P_{DGi,k} \le P_{DGi,k}^{\max}, i = 1,2,\ldots N_{DG}, k = 1,2,\ldots 24 \tag{14}$$

where, $P_{DGi,k}^{\min}, P_{DGi,k}^{\max}$ are the minimum and maximum generation limit.

b) Reactive power generation limit: This includes the upper and lower reactive power generation limit of distributed generators at bus-*i*

$$Q_{DGi,k}^{\min} \le Q_{DGi,k} \le Q_{DGi,k}^{\max}, i = 1,2,\ldots N_{DG}, k = 1,2,\ldots 24 \tag{15}$$

where, $Q_{DGi,k}^{\min}, Q_{DGi,k}^{\max}$ are the minimum and maximum generation limit.

c) Optimal number of distributed generators: This includes the limit on number of maximum distributed generators in the network.

$$N_{DG} = \sum_{i=1}^{N_{DG}} \xi_{i,k}^{\text{int}} \le N_{DG}^{\max} \tag{16}$$

Additional constraints for hybrid market model are:

$$P_{di,k} = \mathrm{P}_{dbi,k} + \mathrm{P}_{\mathrm{dpi,k}} \quad \forall i = 1,2,\ldots N_b, k = 1,2,...24 \tag{17}$$

$$P_{gi,k} = \mathrm{P}_{gbi,k} + \mathrm{P}_{\mathrm{gpi,k}} \quad \forall i = 1,2,\ldots N_b, k = 1,2,...24 \tag{18}$$

Where Pdbi,k and Pdpi,k are the bilateral and pool demand

Pgbi,k and Pgpi,k are the bilateral and pool conventional generation

$$P_{dbi,k} = \sum\nolimits_{\mathrm{i}} \mathrm{GD(i, j, k)} \quad \forall i = 1,2,\ldots N_b, j = 1,2,\ldots N_b, k = 1,2,...24 \tag{19}$$

$$P_{gbi,k} = \sum\nolimits_{\mathrm{j}} \mathrm{GD(i, j, k)} \quad \forall i = 1,2,\ldots N_b, j = 1,2,\ldots N_b, k = 1,2,...24 \tag{20}$$

Where, GD is the bilateral transaction matrix. The GD matrix is obtained and is explained well in [20].

Inequality constraints considering the bilateral contracts is bilateral contracts between buses i and j during hr k must fulfil the following criterion:

$$GD(i, j, k) \le GD_{\max}(i, j, k) \forall i = 1,2,\ldots N_b, k = 1,2,...24 \tag{21}$$

3. Results and discussions

The results obtained with maximum number of 4 DGs are given in Table 1. The results given in table are fuel cost of conventional generators, DG cost, total real and reactive power loss, DG size and optimal location at the buses. The highlighted elements shows the maximum output from DGs and their corresponding location at the buses, there is need of only three DGs to obtain the minimum fuel cost at these outputs.

Table 1. Result for minimization of fuel cost with four DG

Hrs	Fuel cost including DG cost ($/h)	DG Cost ($/h)	PLT (p.u.MW)	QLT (p.u.MVar)	DG size (p.u.MW)	DG size (p.u.MVar)	Optimal DG Location
1	14622.84	3.1966	0.472289	-1.27935	0.1368	0.06616	3,4,5,6
2	14617.85	10.8133	0.470129	-1.29419	0.4644	0.22484	3,4,5,6
3	14600.68	38.9923	0.473129	-1.45278	1.6764	0.81192	3,4,5,10
4	14610.23	22.7359	0.470643	-1.29345	0.9772	0.47336	3,4,5,6
5	14617.85	10.8133	0.470129	-1.29419	0.4644	0.22484	3,4,5,6
6	14622.84	3.1966	0.472289	-1.27935	0.1368	0.06616	3,4,5,6
7	14581.93	82.7023	0.436436	-1.80981	2.6673	1.29183	3,4,5,10
8	14577.78	136.2517	0.389112	-2.24801	4.3947	2.12853	3,4,5
9	14600.68	38.9923	0.473129	-1.45278	1.6764	0.81192	3,4,5,10
10	14610.23	22.7359	0.470643	-1.29345	0.9772	0.47336	3,4,5,6
11	14622.84	3.1966	0.472289	-1.27935	0.1368	0.06616	3,4,5,6
12	14617.85	10.8133	0.470129	-1.29419	0.4644	0.22484	3,4,5,6
13	14600.68	38.9923	0.473129	-1.45278	1.6764	0.81192	3,4,5,10

14	14581.93	82.7023	0.436436	-1.80981	2.6673	1.29183	3,4,5,10
15	14577.78	136.2517	0.389112	-2.24801	4.3947	2.12853	3,4,5
16	14610.23	22.7359	0.470643	-1.29345	0.9772	0.47336	3,4,5,6
17	14591.18	59.1919	0.457397	-1.59046	2.5452	1.2328	3,4,5,10
18	14580.24	108.6865	0.412307	-2.04203	3.5055	1.69782	3,4,5
19	14581.93	82.7023	0.436436	-1.80981	2.6673	1.29183	3,4,5,10
20	14577.78	136.2517	0.389112	-2.24801	4.3947	2.12853	3,4,5
21	14610.23	22.7359	0.470643	-1.29345	0.9772	0.47336	3,4,5,10
22	14600.68	38.9923	0.473129	-1.45278	1.6764	0.81192	3,4,510
23	14591.18	59.1919	0.457397	-1.59046	2.5452	1.2328	3,4,5,10
24	14581.93	82.7023	0.436436	-1.80981	2.6673	1.29183	3,4,5,10

From Table 1, it is observed that for minimization of fuel cost, the optimal bus locations of DG buses 3, 4, 5 and 10 in each hour, except 8, 15, 20th hours. At cut in speed of wind the DG output power is 0.0342p.u.MW and 0.01654p.u.MVar (i.e. in 1st hour). The fuel cost of conventional generator in 1st hour is 14622.84$/hr. This is the maximum fuel cost obtained with four DG. At the rated wind speed 12m/s the DG output power is 1.4649p.u.MW and 0.70951p.u.MVar (i.e. in 8th hour). The fuel cost in 8th hour is 14577.78$/hr. This is the minimum fuel cost obtaine4d with four DGs. The minimum fuel cost is obtained at the rated speed during 8, 15 and 20th hours. From Table 1, it is observed that the optimal number of DG's is three, wherever the output of DGs is maximum. It is because at this output power of DG is only three DG are sufficient to minimize the fuel cost of conventional generator in 8, 15, 18 and 20th hour. These locations are also highlighted in Table 1.

The optimal conventional generation schedule is given in Fig 1(a) and 1(b). It is observed from Fig. 14(a) that at bus 1 in 1st hour the active generation is 1.402p.u.MW and reduced to its minimum value (i.e. 0.15p.u.MW) in 8th hour. From 1 to 8 hours the reduction occurs continuously in active generation of the generator at bus 1 as the output of DG increases with wind speed. At bus 2 the generator is scheduled at its minimum generation (i.e. 0.15p.u.MW) in each hour. At bus 16, 22, and 23 the conventional generators are scheduled at its maximum generation limit in each hour. At bus 7, 13 and 15 when DG output is minimum the conventional generation is at its maximum limit and When DG out increases to its rated value, the conventional active generation at bus 15 reduces to the minimum limits. At bus 21, the active generation is reduced with increment in DG output and it is minimum limit of active generation whenever the DG output is at its rated value. It is observed that more reduction occurs in generator at bus 1, 15 and 21. It is because of the fuel cost is higher at these buses as compared to other buses. In Fig 1(b), the reactive power generation of conventional generator is shown. It is observed that the reactive power output of generators at bus 2 and 22 is negative and the rest generators are scheduled at positive reactive power output. It means these generators are absorbing reactive power, whereas the rest generators are supplying reactive power. At bus 1, the reactive generation is 0.612p.u.MVar in 1st hour which reduced to -0.1947p.u.MVar with increment in output in 8th hour. At bus 2, the conventional generator is scheduled at its minimum reactive generation (i.e. -0.5p.u.MVar). At bus 7, the reactive generation is 0.5142p.u.MVar in 1st hour which reduced to 0.346p.u.MVar with increment in output in 8th hour. At bus 13, the reactive generation is 0.2516p.u.MVar in 1st hour which reduced to 0.00p.u.MVar with increment in output in 8th hour. At bus 15, the reactive generation is 1.1p.u.MVar in each hour except 8, 15 and 20th hours, when the DG output is at its rated value. In these periods the reactive generation at bus 15 reduced considerably. At bus 18, the reactive generation is 0.699p.u.MVar in 1st hour which reduced to 0.6509p.u.MVar with increment in output in 8th hour. At bus 21, the reactive generation is 0.332p.u.MVar in 1st hour which reduced to 0.1519p.u.MVar with increment in output in 8th hour. At bus 23, the reactive generation is 0.6328p.u.MVar in 1st hour which reduced to 0.1527p.u.MVar with increment in output in 8th hour. It is observed from this discussion that reactive power of conventional generator is reduced considerably with the increment in DG output. The DG active and reactive power output in each hour is shown in Fig. 2(a) and (b) respectively. It is observed from Figs. that the optimal location is at bus 3, 4, 5 in 8, 15, 18 and 20th hour which is also mentioned in Table 1. Fig. 3(a) and 3(b) shows pool and bilateral generation respectively.

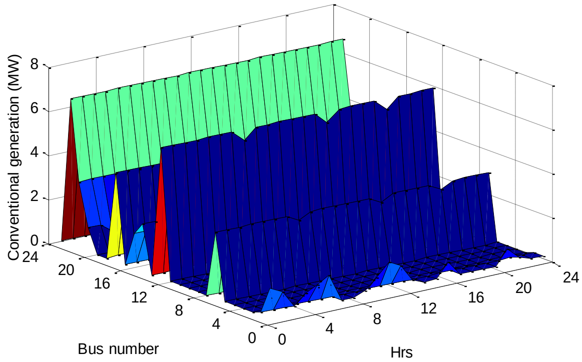

Fig. 1 (a) Real power generation (p.u.MW)

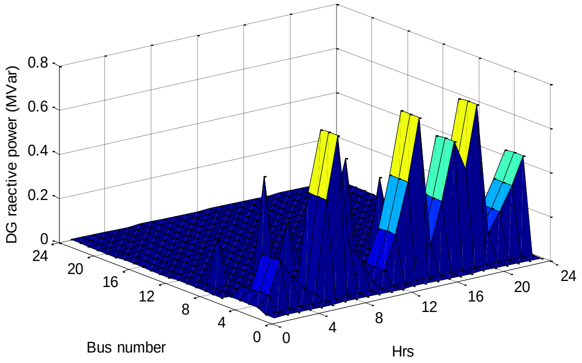

Fig 2(b) DG reactive power output (p.u.MVar) at 0.9 power factor lagging

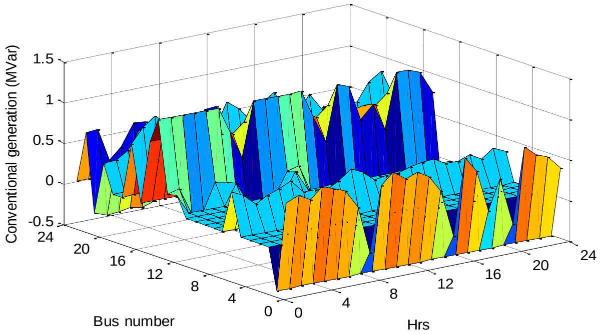

Fig. 1 (b) Reactive power generation (p.u.MVar)

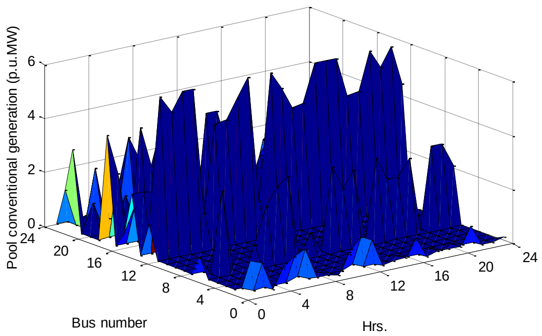

Fig. 3(a) Generation for pool demand Pgp (p.u.MW)

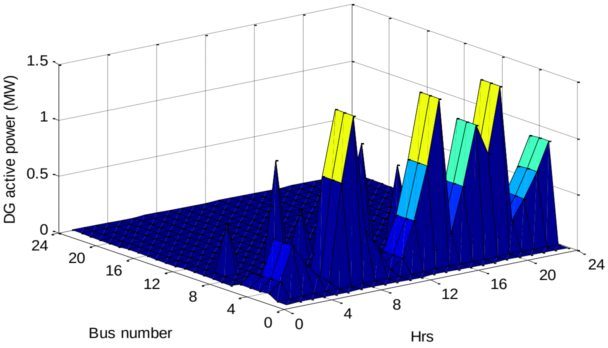

Fig. 2 (a) DG active power output (p.u.MW)

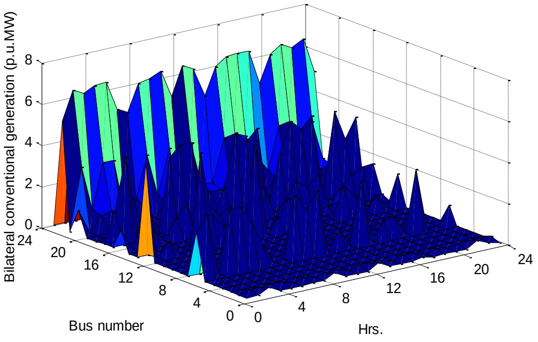

Fig. 3(b) Generation for bilateral demand Pgb (p.u.MW)

In Figs. 4(a) and 4(b), the active and reactive power nodal price at each bus is shown respectively. From Fig. 4(a) it is observed that the maximum active power nodal price is observed at bus 1. In 1st hou when the DG generation is minimum at 0.0342p.u.MW the real power nodal price at this bus is 35.88437$/p.u.MWh and when the DG output is near to the rated value the real power nodal price at this bus reduced considerably (i.e. at DG output 1.46 MW the real power nodal price at bus 1 is 20.81814$/p.u.MWh). As the DG output increases from its minimum value to its rated value the real power nodal price at each bus reduces.

It is observed that the reactive power nodal price at bus 6 in each hour is maximum. The Lagrangian multiplier for reactive power can be both positive and negative. The reactive power price negative sign indicates the negative sign associated with Lagrange multiplier corresponding to reactive power balance equation, however, the price has to be paid for reactive power absorption as well as for injecting reactive power in the network. The voltage profile is shown in Fig. 5. The overall fuel cost without and with DG is shown in Fig. 6. In case 4, the maximum number of DG is four. In hour 8, 15, 18 and 20, the maximum number of three DG's are utilised for the minimization of fuel cost. In these periods, the wind speeds are greater than 10m/sec and the output of DGs is maximum. Three DG's are sufficient to minimize the fuel cost of conventional generator. It is observed that the minimum fuel cost is obtained for case 4. There is a considerable impact of DGs in the system for overall fuel cost reduction and improvement in the voltage profile.

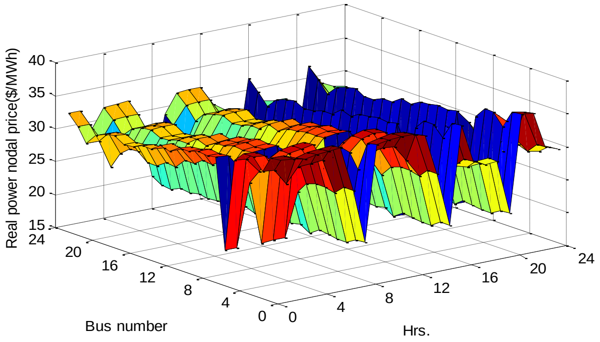

Fig. 4(a) Real power nodal price ($/p.u.MWh)

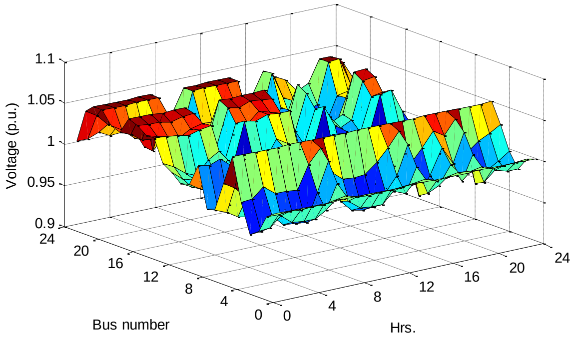

Fig.5. Voltage profile

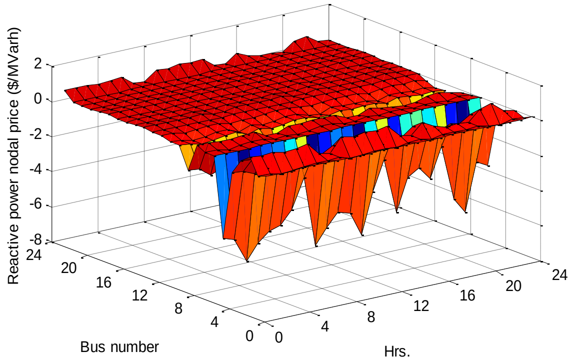

Fig. 4(b) Reactive power nodal price ($/p.u.MVarh)

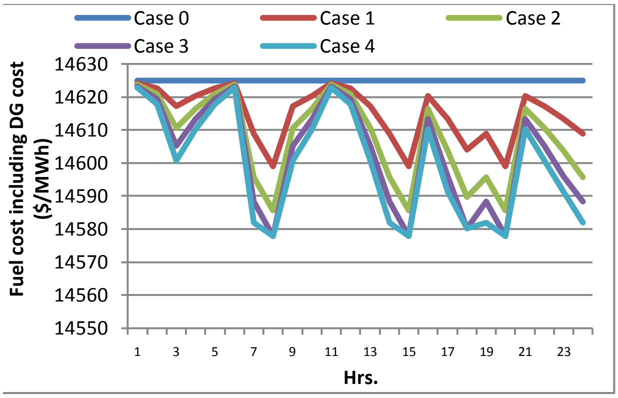

Fig.6. Fuel cost including DG cost ($/hr) with and without DG

4. Conclusions

In this paper, an optimization based approach using mixed integer non-linear programming has been proposed for DFIG location. The impact on the nodal prices has been obtained with DGs presence. It is observed that the nodal prices are observed lower at each buses with DFIG. At few hrs in a day when wind power is at its maximum value, the maximum numbers of DGs are three. In such hrs, the wind power output is at its rated capacity. At other hrs when wind power is lower than its rated capacity, the maximum numbers of DGs obtained are four except at hrs when wind power output is at its rated capacity. With DG integration, there is considerable improvement in voltage profile, loss reduction and over all fuel cost reduces. The nodal prices at each bus are observed lower for both real and reactive power. This is the economical advantage in terms of societal benefit to consumers as well as suppliers. The power of wind source can be dispatched at competitive price for its sustainability and economic viability based on the nodal prices reduction and consumers pay as per the price at the node they are connected.

References

[1] Ugranli F, Karatepe E, Long –term performance comparison of multiple distributed generation allocations using a clustering-based method, Electric Power Compon Syst, 2012;40(2), pp.195-218.

[2] Arya LD, Koshti A, Chounbe SC, Distributed generation planning using differential evolution accounting voltage stability consideration, Int J Electr Power Energy Syst,2012,42(1) pp.196-207.

[3] Kumar A, Gao W, Voltage profile improvement and line loss reduction with distributed generation in deregulated electrical market, In: Proceeding of the IEEE region Conference TENCON, 2008, pp.1-6.

[4] Qian K, Zhou C, Allan M, Yuan Y, Effect of load models on assessment of energy losses in distributed generation planning, Int J Electr Power Energy Syts,2011,33(6), pp.1243-1250.

[5] Ghosh S, Ghoshal SP, Ghosh S, Optimal sizing and placement of distributed generation in a network system, Int J Electr Power Energy Syts, 2010,32(8), pp.849-856.

[6] Singh RK, Goswami SK, Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage improvement including voltage rise issue, Int J Electr Power Energy Syst,2010,32(6), pp.637-644.

[7] N. Mithulananthan, T. Oo, and L. V. Phu, Distributed generator placement in power distribution system using genetic algorithm to reduce losses, Thammasat International Journal of Science and Technology2004, 9, pp. 55–62.

[8] M. Mohammadi, Mehdi Nafar, Optimal placement of multi types DG as independent private sector under pool/hybrid power market using GA-based Tabu Search method, International Journal of Electrical Power & Energy Systems, 2013, 51, pp. 43-53.

[9] P. Aruna Jeyanthy& D. Devaraj, Multi objective genetic algorithm for reactive power optimization inclusing voltage stability, International Journal of Engineering Science and Technology,2010, 2(7), pp. 2715-2729.

[10] Abdi Sh. Afshar K, Application of IPSO-Monte Carlo for optimal distributed generation allocation and sizing, Int J Elect Power Syts,2013,44(1), pp.786-797.

[11] Gomez-Gonzalez M, Lopez A, Jurado F, Optimization of distributed generation system using a new discrete PSO and OPF, Elect Power Syts Res, 2012,84(1), pp.174-180.

[12] M.H. Moradi, M. Abedini, A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems, International Journal of Electrical Power & Energy Systems, 2012,34(1), pp.66-74.

[13] El-Zonkoly AM, Optimal placement of multi-distribution generation units including different loads models using particle swarm optimization, IET Gener, Transm Distrib,2013,5, pp.760-771.

[14] Celli G, Ghiani E, Mocci S, Pilo F, A multi-objective evolutionary algorithm for sizing and siting of distributed generation, IEEE Trans Power Syst ,2005,20(2), pp.750-757.

[15] Zhang X, Sharma R, Yanyi H, Optimal energy management of rural microgrid system using multi-objective optimization, In: Proceeding of IEEE PES innovative smart grid technologies(ISGT), 2012, pp.1-8.

[16] Khalesi N, Rezaei N, Haghifam MR, DG allocation with application of dyanamic programming for loss reduction and reliability improvement, Int J Electr Power Energy Syst,2011,33(2), pp.288-295.

[17] S. Porkar, A. Abbaspour-Tehrani Fard, S. Saadate, An approach to distribution system planning by implementing distributed generation in a deregulated electricity market, in Proc. Power System Large Engg. System Conf. 10-12, Oct. 2007, pp. 90-95.

[18] M. Sadighizadeh and A. Rezazadeh, Using genetic algorithm for distributed generation allocation to reduce losses and improve voltage profile, in Proc. World Academy of Science, Engineering, and Technology,2008, 27, pp. 251-256.

[19] Ashwani Kumar and Wen Zhong Gao, Optimal distributed generation location using mixed integer non-linear programming in hybrid electricity markets, IET Gener. Transm. Distrib2010,4(2), pp. 281-298.

[20] Ashwani Kumar, Manish Kumar and K. S. Sandhu, Optimal DFIG Location and Impact of Load Model in Pool Electricity Market, Proceedings of the *2014* International Conference on *Power* Systems, Energy, Environment (PSEE 2014), Interlaken, Switzerland,2014 pp.149-156.

[21] L.M. Fernandez, C.A.Garcia, J.R. Saenz, Aggregated dynamic model for wind farms with doubly fed induction generator with turbines, Renewable Energy, 2008,33(1),pp.129-140.

[22] R.G. de Almeida, E.D. Castronuovo, J.A.P.Lopes, Optimum generation control in wind farms when carrying out system operator requests, IEEE Transactions on Power System, 2006,21(2),pp.718-726.

[23] H.Lund, Large-scale integration of wind power into different energy system, Energy,2005,30(13), 2005, pp.2402-2412.

[24] Manish Kumar, K. S. Sandhu, and Ashwani Kumar, “Wind speed variation impact on transmission loss reduction in electricity markets”, Procedia computer Science,2015,70, pp. 526-537.