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Distributed generation resources placement in power systems considering electricity markets

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ABSTRACT

In this paper, improvement and social welfare of present partners in energy and reserve markets in an annual time interval are presented using a new analytical method based on iteration and simultaneous optimizing net profit value in investment circulation for wind turbine developers at the presence of pumped-hydroelectricity energy storages (PHESS) in power systems. Obtained results of the proposed method are tested on a standard 14-bus IEEE system. And by using analysis and evaluation of the presented method it is determined that due to proving high flexibility in operation planning of system under the conditions of the pool-based market during the annual horizon, maximizing investment profit of these resources and other partners under the market conditions is achieved.

1. Introduction

Optimal placement of distributed generations (DGs) has a great importance. In a power system, optimal placement of wind turbines at the presence of PHESS is of high importance for improving objectives such as maximizing profits of owners and investors of wind turbines and turning into a market with perfect competitive conditions, loss reduction to a considerable extent, increasing reliability levels of network, improving voltage profiles of network, etc. Distributed generation units of wind turbines can participate in energy sale or reserve market independently, or they can act in an integrated way with a company that has PHESS or traditional thermal units or both of them. One of very common techniques is using optimal placement of DGs in sub-transmission or distribution networks. Application of wind turbines as a type of DGs for generating energy has a high capital cost, but its operation cost is very low. In PHESS, electrical energy is converted to potential energy and is stored in the upper reservoir in the form of water, and during the peak load times the stored water flows back through turbine path and like a usual hydroelectric system the energy is again converted to electricity. In this paper, in order to avoid problems in coding and decoding of problem parameters in intelligent methods and also due to nonlinear equations of power balance in constraints of optimal power flow (OPF) equations based on energy and reserve market conditions, mixed integer nonlinear programming (MINLP) analytic method is used for optimizing the problem of allocating optimal number, location and installation capacity of WTs from the viewpoint of the WTs investment owners and with regard to the presence of PHESS.

Literature review: compromise between incentives for DG developers and distribution network operators (DNOs) is evaluated by Atwa and El-Saadany (2011) using multi-objective OPF. Reconfiguration of the network is used by Albadi and El-Saadany (2010) in order to assess the maximum installed capacity of DGs in an optimal way. Zhang et al. (2011) proposed a hybrid optimization method for finding optimal locations and sizes of WTs, which reduces the annual loss amount to its minimum value. The proposed method combines genetic algorithm, gradient-based constrained nonlinear optimization and Monte-Carlo iterative simulations.

A Tabu search method is proposed by Caralis et al. (2012) for determining optimal location and size of DGs. For DG resources placement, mathematical formulation of the objective function of mentioned optimization problem should be defined in such a way that both owners of these resources with regard to installation-operation costs and the resulting income of circulating money in the market for investment and more active attendance in the electricity market are justified and in summary the profits of the other partners of reserve and pool-based markets such as thermal and PHESS units are determined in an optimal way.

2. Objective function

The first term of objective function, $NPV_{WindTurbins}$ index, will address the analysis of profitable investment for horizon of several years, which is carried out by owners and investors of WTs; owners net profit value (NPV) is defined as difference between obtained currents from electrical energy sale and investment cost of these DGs. The second term, $Socialwelfare_{TH-PSHPPs}$ index, is social welfare of remaining market partners, i.e. owners of PHESS and thermal units, which models the obtained profit of presence of these resources in pool-based energy market by simultaneous clearing of energy and reserve during an annual horizon.

$$\max(objective_{placement}) = NPV_{WindTurbins} + Socialwelfare_{TH-PSHPPs} \quad (1)$$

Net profit value of xi-th owner of WT in the several year planning horizon N_{yi} regarding optimal capacity allocation of this DG installed in an appropriate location in the network, is defined as Eq. 2:

$$NPV_{WT}(Bi, Xi) = \frac{FC(Bi, Xi)}{(1+r_{WT(Bi,Xi)})^{N_{yi}}} - IC(Bi, Xi) \quad (2)$$

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FC(Bi, Xi) index which is obtained by selling electrical energy to pool-based market under different levels of consumers load demands Li in yearly horizon, is calculated using Eq. 3:

$$\mathrm{FC(Bi,Xi)} = \sum_{\mathrm{Li}=1}^{\mathrm{N_{Li}}} (\mathrm{Time}_{\ \mathrm{Duration}}(\mathrm{Li}).\, \mathrm{E_{WT}(Bi,Xi,Li)}).\, \mathrm{MCP_{WT}(Li)} \quad (3)$$

where, $\mathrm{r_{WT}(Bi,Xi)}$ is investment profit rate and $\mathrm{IC_{WT}(Bi,Xi)}$ is capital cost of Xi-th owner of WT connected to bus Bi of power system, and $\mathrm{N_{yi}}$ index is the number of years accounted for optimal placement of WTs in the planning horizon. $\mathrm{E_{WT}(Bi,Xi,Li)}$ is wind energy sold by Xi-th owner of WT installed in bus Bi to pool-based market in electrical form in load demand level of Li. $\mathrm{Time}_{\ \mathrm{Duration}}(\mathrm{Li})$ is time and $\mathrm{MCP_{WTs}(Li)}$ is market clearing price corresponding to load demand level of Li at the presence of DGs such as WTs in addition to the other energy generation resources including thermal and PHESS units, and $\mathrm{N_{WTs}}$ is the total number of identified and candidate buses for WTs installation. Therefore, investment net profit value of all developers of DGs such as WTs at the presence of PHESS is calculated based on Eq. 4 as below:

$$\mathrm{NPV_{WindTurbins}} = \sum_{\mathrm{Bi}=1}^{\mathrm{N_{WTs}}} \sum_{\mathrm{xi}=1}^{\mathrm{WTs}} \mathrm{NPV_{WT}} \ \ \mathrm{(Bi,Xi)} \quad (4)$$

During the solving process of proposed analytic model, NPV of owners of WTs will be assessed considering the installation location and amount of electrical energy generation amount in different levels of load demands with regard to the predicted velocity-power scenarios based on statistical data of climate patterns during the several years planning horizon. Prediction of daily or monthly velocity-power curve of wind energy for WTs developers during the annual planning horizon in different places affects the market clearing price and obtained income from energy sale to electricity market, and finally has impacts on NPV of WTs developers in various buses of the network. As a result, acceptance or rejection of proposals of present generators (manufacturers) in supply section of energy market is determined by independent system operator (ISO) based on OPF and considering supply conditions and different levels of load demand in pool-based market during yearly planning horizon, as Eq. 5:

$$\mathrm{Socialwelfare}_{\ \mathrm{TH-PSHPPs}} = \sum_{\mathrm{Li}=1}^{\mathrm{N_{Li}}} \mathrm{time}_{\ \mathrm{Duration}}(\mathrm{Li}).\,(\mathrm{R_{TH}(Li)} + \mathrm{R_{PSHPPs}(Li)}) \quad (5)$$

Since consumers load demands in different buses of inelastic network are assumed to take the energy price, therefore, social welfare can be attributed to sum profit of generations including PHESS and thermal units, where indexes $\mathrm{R_{TH}(Li)}$ and $\mathrm{R_{PSHPPs}(Li)}$ are profits of thermal and PHESS units respectively, obtained from energy sale to pool-based market in load level of Li. In next sections, the accurate modeling of WTs owners' behaviors, PHESS and thermal units to attend the energy and reserve day-ahead pool-based market is presented assuming different load levels during an annual horizon.

3. The proposed algorithm

The algorithm procedure for optimal placement of WTs owners in power system is as follows in Fig. 1 (Hedegaard and Meibom, 2012): first, one of candidate places is selected randomly with regard to predetermined probabilistic scenarios for wind turbine installation.

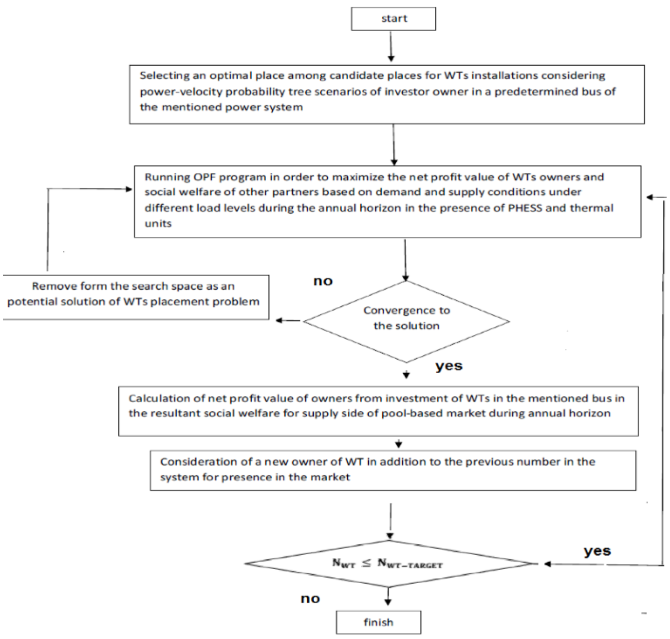

Fig. 1: Proposed algorithm.

4. Analysis

At last, in order to verify the effectiveness and validation of the proposed algorithm in finding optimal location and size of wind turbines in power systems, the algorithm is carried out on a 14-bus network (Connolly et al., 2011). Single-line diagram of this power system is shown in Fig. 2.

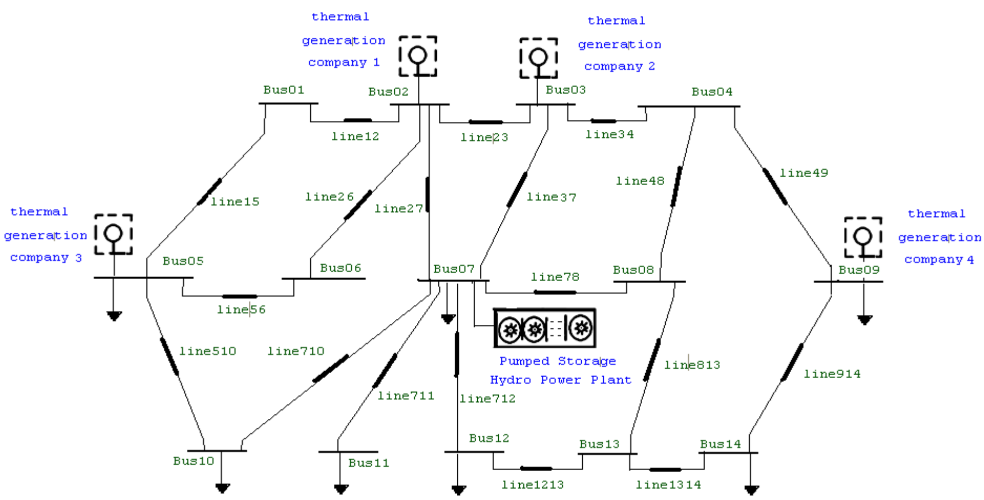

Fig. 2: single-line diagram of the studied 14-bus network.

As it is seen from the Fig. 2, generation part of the power system includes 4 thermal units respectively connected to Bus2, Bus3, Bus5 and Bus9, where all of them have permission of presence in energy and reserve market. Technical and economic data of the mentioned thermal units in terms of active and reactive power capacities and the way prices are proposed in the energy market and ancillary services are listed in Table 1 (Holttinen et al., 2011).

Table 1
Technical data of thermal units connected to different buses of 14-bus studied test system.

GENCOs	PG_{min}	QG_{min}	PG_{max}	QG_{max}	KGL_TH (L1-L4)	SGL_TH(L1-L3) $/MWh
					55	3.18
Genco1	15	-65	135	85	95	3.38
					135	3.57
					35	3.15
Genco2	15	-40	75	55	55	3.55
					75	3.87
					20	4.18
Genco3	10	-25	40	35	30	4.48
					40	4.67
					25	5.20
Genco4	5	-35	65	40	45	5.33
					65	5.42

One PHESS unit connected to Bus7 is available in the network, which has only permission of presence in the energy market from the operator. PHESS unit connected to Bus7 in the 14-bus network under study has 4 turbo units (Alishahi et al., 2011), which have both pump and generator modes of operations. In generator mode, maximum capacity for generating active and reactive powers are 100 MW and 85 MVar, respectively, and minimum active and reactive powers injected to the network are 10 MW and 5 MVar, respectively. For operation in pump mode, the maximum consumption level of active and reactive powers are 80 MW and 55 MVar and its minimum is 10 Mw and 5 MVar, respectively. All technical and economic data of these PHESS systems including initial energy and min/max stored energy behind the upper reservoir, efficiency and fixed cost of operation of power plant are given in Table 2.

Table 2
Technical and economic data of PHESS in 14-bus system under pool-based market conditions during yearly horizon.

PSHPPi	P_{gp-min}	P_{gp-max}	P_{pp-min}	P_{pp-max}	E_o	E_{min}	E_{max}	η
PSHPP1 (N=4) (C= 2$/MWh)	10	80	5	55	800	500	1200	%67

In addition, there will be the possibility of presence and investment of two owners of WTs on predetermined busesBus7, Bus12, Bus13 and Bus14, which are good choices to install these DG resources from the aspect of climate pattern studies. Owners and investors of WTs, considering possible scenarios of velocity-power and net profit value in circulation resulting from attending daily energy pool-based market during an annual horizon, are able to install a predetermined capacity and utilize it which in this study, these values for Bus7, Bus12, Bus13 and Bus14 are estimated 80, 100, 150 and 50 MW, respectively. Also, wind turbines as price taker resources for presence in power pool-based market during the annual horizon, benefit from incentive and penalty plans by ISO, respectively during excess and lower capacities of network requirements (Alishahi et al., 2012). As it can be seen from single-line diagram (SLD) of 14-bus studied power system, transmission network comprises 17 transmission lines: line12, line15, line23, line26, line27, line34, line37, line710, line78, line48, line49, line56, line510, line711, line712, line813 and line914. Data related to admittance of transmission lines, $G_{ij} - jB_{ij}$, and thermal limit capacity of transmission lines P_{line} of 14-bus studied power system are shown in Table 3.

Demand of network consumers that is assumed to be constant power loads are located on buses Bus5, Bus7, Bus9, Bus10, Bus11, Bus12 and Bus 14 in the network. These consumers are modeled as inelastic and are presented in a unipolar pool-based market that only thermal generation resources compete for energy sale and determining market clearing price (MCP). Active and reactive power demand of these network buses is listed in Table 4 for three load levels of low, average and peak loads during an annual time horizon.

Here, thermal units propose their no-load synchronous capacity by a price equal to 10% of marginal cost of energy generation by that unit in order to present spinning reserve to deal with the uncertainty of network such as utilization of wind turbines installed by private owners, random load changes and sudden loss of units and lines, so certain criterion equal to 10% of total load demand is met (Pierluigi and Mokryani, 2013). Then, the proposed analytic algorithm is used for wind turbine placement optimization problem at the presence of PHESS for a 14-bus power system.

Table 3
The data related to admittance and thermal limit capacity of transmission lines of 14-bus power system under study.

Transmission Lines	Gij(Bi , Bj , Lineij) P.U.	Bij(Bi , Bj , Lineij) P.U.	Pline. max(Bi , Bj , Lineij, ti) MW
line12	1.15	2.05	30
line15	1.02	2.10	25
line23	1.05	2.02	35
line26	1.08	2.06	25
line27	1.11	2.07	100
line34	1.14	2.09	40
line37	1.12	2.11	75
line710	1.45	2.27	35
line78	1.26	2.23	55
line48	1.20	2.14	45
line49	1.24	2.25	70
line56	1.30	2.35	25
line510	1.40	2.22	55
line711	1.32	2.12	25
line712	1.22	2.35	35
line813	1.42	2.17	65
line914	1.01	2.29	30

Table 4
Average active and reactive load demand of network buses for three low, average and peak loads during the annual time horizon for placement of wind turbines in a 14-bus power system.

14-Bus Test Power System		Load-level01	Load-level02	Load-level03
Pd (MW)	Bus05	10	15	20
	Bus07	30	55	80
	Bus09	30	35	45
	Bus10	35	45	55
	Bus11	10	15	20
	Bus12	15	20	30
	Bus14	10	15	25
Qd (Mvar)	Bus05	*5*	7	10
	Bus07	8	10	12
	Bus09	12	15	18
	Bus10	15	20	25
	Bus11	3	5	10
	Bus12	5	10	15
	Bus14	6	8	10

Based on network load demand situation at each level under pool-based market condition during the annual horizon, the proposed analytic algorithm chooses the whole cases of allocating size and placement capacity of these resources from the candidate places, iteratively, and carries out OPF on the transmission network by the aim of maximizing sum net profit value in circulation of market partners including thermal and PHESS and WTs owners. Among the whole studied cases, the only case where WT placement problem at the presence of PHESS converges to an optimal solution is when two WTs are installed on Bus7 and one bus is connected to Bus13. It has to be noted that these two resources are modeled in placement problem by using probability tree scenarios in Tables 5 and 6, respectively.

5. Results

Results of simulation studies for optimal placement of wind turbines during the annual horizon shows that for installation and investment, optimal capacity of WT1 and WT2 on Bus7 and Bus13 are obtained 80 MW and 66 MW respectively, which give net profit value in circulation equal to 38056.33$ and 23532.47$ for the owners. But dispatched active and reactive powers of thermal units according to the price-power proposals of piecewise linear curve and constant cost of PHESS are as follows. The generated active and reactive powers and the sold spinning reserve to energy market and ancillary services of thermal units connected to Bus2, Bus3, Bus5 and Bus9 during the annual horizon for three low, average and peak load levels are listed in Tables 7 and 8. It is worth noting, however, after solving the placement problem by the proposed analytic algorithm based on iteration of market clearing price for each of load levels, Load-level01, Load-level02 and Load-level03 are assessed as 5.20$, 5.33$ and 5.42$, respectively.

Table 5
Technical data of probabilistic generation capacity scenarios of owner of WT1 connected to Bus 7.

Wind Turbine 1 (Bus 7)		
Active Power Generation	$P_{wi\,min}$	$P_{wi\,max}$
	0 MW	80 MW
Scenarios	Probability	Generation
Scenario1	0.02	10
Scenario2	0.03	15
Scenario3	0.04	20
Scenario4	0.06	35
Scenario5	0.12	50
Scenario6	0.13	65
Scenario7	0.23	80
Scenario8	0.18	35
Scenario9	0.15	25
Scenario10	0.04	5

Table 6
Technical data of probabilistic generation capacity scenarios of owner of WT2 connected to Bus 13.

Wind Turbine 2 (Bus13)		
Power Generation	$P_{wi\,min}$	$P_{wi\,max}$
	0 MW	150 MW
Scenarios	Probability	Generation
Scenario1	0.2	10
Scenario2	0.3	35
Scenario3	0.6	85
Scenario4	0.8	115
Scenario5	0.12	125
Scenario6	0.18	150
Scenario7	0.33	100
Scenario8	0.18	50

Table 7
Dispatching active and reactive generation/spinning reserve by thermal units for three low, average and peak load levels during the annual time horizon in 14-bus power system.

14-Bus Test Power System		Load-level01	Load-level02	Load-level03
PG_TH (MW)	Bus02	135	63.21	123.99
	Bus03	75	15.98	15.98
	Bus05	40	10	11
	Bus09	6	6	6
QG_TH (Mvar)	Bus02	26.76	85	23.28-
	Bus03	32.14	-34.11	55
	Bus05	-25	2.69	24.49
	Bus09	40	40	40
SR	Bus02	0	71.7	11
	Bus03	0	59	59
	Bus05	0	30	29
	Bus09	59.01	59	59

Table 8
Consumption or generation amount of electrical energy by PHESS in studying placement of WTs for 14-bus studied power system.

LOAD LEVELS	Load-level1	Load-level2	Load-level3	GENCO
N	3	0	0	Bus7.PSHPP1
$P_{gp,t}(Bi, PSHPPi, ti)$	0	0	0	
$Q_{gp,t}(Bi, PSHPPi, ti)$	0	0	0	
$P_{pP,t}(Bi, PSHPPi, ti)$	237.45	0	0	
$Q_{pP,t}(Bi, PSHPPi, ti)$	15	0	0	
$E_{u,t}(Bi, PSHPPi, ti)$	959.09	959.09	959.09	

As it can be seen from the simulation results, the PHESS installed on Bus7 is used only for pump mode application with 3 units which has consumption equal to 375.45 MW. Under the assumed load demand conditions of pool-based market in different levels and configuration of remaining generation resources such as thermal units and wind turbines, considering the structure of transmission system it was expected that due to cheaper generation of these resources compared to PHESS, as long as capacity of these resources are not completely loaded, generation of hydroelectricity energy resource will not be used, and the numerical results are proofs for this claim. Based on optimal conditions of pool-based market's supply and demand during the annual time horizon, OPF of system is carried out in three load demand levels and its results for magnitude and phase angle of bus voltages, active and reactive powers flowing through the lines are presented as follows. Numerical results of simulation for voltage magnitude and phase angle of network buses are given as Table 9.

Table 9
Magnitude and phase angle of bus voltages for 14-bus power system for different load demand levels during the annual time horizon.

Bus voltages (magnitude)	Load-level1	Load-level2	Load-level3
Bus1	0.97	0.972	0.98
Bus2(slack)	1.00	1.00	1.00
Bus3	1.005	0.946	1.011
Bus4	0.994	0.952	0.977
Bus5	0.939	0.945	0.968
Bus6	0.968	0.971	0.983
Bus7	0.919	0.931	0.966
Bus8	0.985	0.977	0.995
Bus9	0.996	0.937	0.935
Bus10	0.901	0.903	0.925
Bus11	0.905	0.909	0.933
Bus12	0.900	0.900	0.920
Bus13	1.050	1.050	1.050
Bus14	0.980	0.914	0.90
Bus voltages (angles)	Load-level1	Load-level2	Load-level3
Bus1	-0.005	-0.010	-0.030
Bus2(slack)	0	0	0
Bus3	-0.046	-0.00001	-0.072
Bus4	-0.093	-0.050	-0.118
Bus5	-0.012	-0.023	-0.063
Bus6	-0.006	-0.012	-0.033
Bus7	-0.136	-0.006	-0.075
Bus8	-0.072	-0.016	-0.061
Bus9	-0.156	-0.132	-0.224
Bus10	-0.094	-0.038	-0.097
Bus11	-0.150	-0.025	-0.096
Bus12	-0.157	-0.029	-0.108
Bus13	0.00001	0.00002	0.00003
Bus14	-0.167	-0.152	-0.260

The obtained numerical results for OPF in 14-bus power system show the fact that voltage static range is also accurately satisfied. Similar to the previous studies, the positive direction for current flowing through the lines is assumed as from a bus with lower number toward a bus with higher number. Table 10 illustrates the active and reactive power flows in power system lines under a certain supply and demand condition for the day-ahead market during the annual time horizon.

Table 10
Active and reactive flows through the lines of 14-bus power system for different load demand levels.

Optimal power flow	Load-level1	Load-level2	Load-level3	Busi.Busj	Lineij
	-11.09	-13.11	-20.33	Bus01.(Bus02)	line12
	10.82	12.86	19.98	Bus01.(Bus05)	line15
	-22.41	-14.07	-34.30	Bus02.(Bus03)	line23
	11.98	14.09	21.63	Bus02.(Bus06)	line26
	89.50	21.94	47.72	Bus02.(Bus07)	line27
	-27.75	-22.53	-34.29	Bus03.(Bus04)	line34
	69.09	6.77	14.60	Bus03.(Bus07)	line37
	-8.25	-24.27	-34.93	Bus04.(Bus08)	line48
Active power (MW)	35.34	46.14	68.27	Bus04.(Bus09)	line49
	-11.41	-13.57	-20.92	Bus05.(Bus06)	line56
	51.99	21.20	31.57	Bus05.(Bus10)	line510
	-51.06	-8.46	-16.66	Bus07.(Bus08)	line78
	-13.83	25.07	25.16	Bus07.(Bus10)	line710
	10.11	15.25	20.48	Bus07.(Bus11)	line711
	15.21	20.43	30.92	Bus07.(Bus12)	line712
	-62.01	-33.99	-53.01	Bus08.(Bus13)	line813
	10.09	15.22	25.57	Bus09.(Bus14)	line914
Optimal power flow	Load-level1	Load-level2	Load-level3	Busi. Busj	Lineij
	-13.78	-10.99	0.117	Bus01.(Bus02)	line12
	13.78	10.99	-0.117	Bus01.(Bus05)	line15
	-14.04	27.07	-23.25	Bus02.(Bus03)	line23
	15.03	12.01	0.276	Bus02.(Bus06)	line26
	11.51	34.46	-0.800	Bus02.(Bus07)	line27
	-6.99	-14.99	5.682	Bus03.(Bus04)	line34
	24.00	6.50	23.38	Bus03.(Bus07)	line37
	11.35	-3.16	7.940	Bus04.(Bus08)	line48
Reactive power Mvar	-19.54	-13.03	-4.00	Bus04.(Bus09)	line49
	-13.99	-11.04	1.048	Bus05.(Bus06)	line56
	-2.731	17.27	12.69	Bus05.(Bus10)	line510
	-13.88	-27.22	-11.55	Bus07.(Bus08)	line78
	22.74	4.75	15.05	Bus07.(Bus10)	line710
	3.181	5.411	10.78	Bus07.(Bus11)	line711
	5.41	10.82	16.78	Bus07.(Bus12)	line712
	-7.31	-32.60	-6.126	Bus08.(Bus13)	line813
	6.207	8.506	11.30	Bus09.(Bus14)	line914

Numerical results of the study show that allocation of optimal size and location of wind turbines in the network can lead to better OPF, in addition to increasing competition, and as a result, both technical and economical improvements in power system operations. According to the simulation results, social welfare level, i.e. total profit of market partners is optimally obtained as 150900.64$.

6. Conclusions

In order to verify the effectiveness and application of the proposed iteration-based analytic algorithm for optimal placement of wind turbines at the presence of PHESS in addition to thermal units, simulation studies of 14-bus power system under pool-based power market with simultaneous clearing of energy and reserve during the annual time horizon, was performed. Behavior modeling of wind turbines based on generation capacity scenarios has been realized by applying probability tree structure. In addition, to study the loss values and active and reactive power flows through the lines for different load levels during a year, optimal power flow is used considering voltage constraints, thermal limit of lines and power plant constraints of generation resources present at the energy and reserve market under demand and supply conditions.

The obtained numerical results from simulation studies can be categorized as follows: the main result achieved from the placement study of wind turbines at the presence of PHESS with the aim of maximizing investment profit of these resources and other partners under market conditions is obvious and clear that always when solution is converging to an optimum, a fixed installation place for wind turbine is considered on a bus where PHESS is installed, and overall, with regard to remaining optimal installation places, maximizing net profit value in circulation of all investor owners happens on these resources in the electrical energy sale market.

The reason for this is providing high flexibility in system operation planning under pool-based market during the annual horizon; in such a way that PHESS by pumped operation in low load times of the network, will be able to prevent reduction of suboptimal load dispatching on some thermal units, or in some peak load times, working in its generation operation, avoid increase of suboptimal load dispatching on other resources present at pool-based market and in fact, it plays load adjustment role in the mentioned bus and network. For this purpose, analytic formulation of thermal and PHESS units considering the tree structure of power-velocity probabilistic scenarios under pool-based market conditions is included in this paper to accurately evaluate the effect of proposed model parameters on optimal placement of wind turbine and the required amount of spinning reserve. At last, simulation results show the fact that by allocating optimal number, place and capacity of wind turbines under pool-based conditions, in addition to maximizing the profit of investors on these resources and other present partners in the energy market during the annual horizon, simultaneously with modeling OPF with regard to demand side being inelastic, energy market will thrive more and as a result social welfare is increased and energy market will become closer to a perfect competitive market.

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