An Approach on Installation and Limitation of WPG in an EPS under System Steady Constrains

B. Kermanshahi, Z. Litifu, and C. H. Kelvin Chu

***Abstract*—Granted by Japan Society for Promotion Science (JSPS), this research deals with two vital problems in installation of Wind Power Generation (WPG) in an Existing Power System (EPS), one is determining the optimal installation bus and the other one is estimating the maximum limitation of WPG that can be safely introduced into EPS. Here, Domain-Link Method (DLM) is used for forming applicable domains based on the structural characteristic of EPS, consequently Maximizing Decision Method (MDM) is used for ensuring the best bus inside selected domain using operational indices of environment, economy, reliability and stability. The limitation of WPG is estimated after connecting WPG to the selected bus based on system steady constrains. The result is illustrated using the IEEE 30-Bus test system. Successive installation of WPG may be conducted with the same procedure satisfying new EPS constrains resulted from the previous installation. Other than complex computation process, this methodology shows its unique feasibility in application of WPG installation to EPS of different structure and capacity.**

***Index Terms*—DLM procedure, bus determination, MDM verification, WPG limitation.**

I. Introduction

THIS PAPER presents a technical procedure of installing WPG into an EPS aiming at reduction of transmission loss and track of load condition. However WPG influences stability of EPS so as to limit installable amount of WPG, influence degree depends obviously on the installation bus and WPG capacity. In actual application, appropriate bus is basic condition to guarantee efficient and economical operation of wind power turbines, and WPG limitation is vital reference to keep hybrid system operating within system constrains. Determining optimal bus and WPG limitation are therefore two important items in installation process. In this paper, DLM [1] is a developed computational method to select optimal buses; it may equivalently divide EPS into domains based on power flow direction and defined matrixes. Links are determined by connection characteristic of EPS. Since selected domain usually contains several buses; the best optimal buses can be produced from four system indices in the selected MDM. Stochastic particularity of WPG may affect EPS on reliability and stability [2], excessive WPG may cause EPS operating beyond system constrains, and there is hence a limitation on installing WPG. Here, it is necessary to indicate that WPG limitation should simultaneously meet steady and dynamic constrains of EPS, in some cases, dynamic constrains may provide more serious demand for WPG limitation. In this paper, WPG limitation under steady constrains is considered; dynamic particularity will be managed in next research referring to the result obtained from this paper. In order to verify other buses in EPS, a synthetic index is also derived. Main installation steps are denoted as follows:

Step1: Separate the EPS into domains by considering the power flow of network and the defined matrixes, and then select the most appropriate domain.

Step2: Determine the best optimal bus from the candidates inside the selected domain for WPG installation.

Step3: Determine the maximum limitation of WPG based on the EPS constrains under steady state.

II. Determination of Domain-Link

Supposing that EPS contains n generators, m buses and t transmission lines. As the first step, the calculation of power flow that responds to the maximum system generation and load demand is necessary. Along direction of power flow starting from top generators, all bus numbers need to be marked one by one in order of power flow direction, number “1” is therefore marked on the generator bus.

Three matrixes are established from the numbered structure of EPS, namely Generator Matrix $\mathbf{G}$, Bus Matrix B and Upside Matrix $\mathbf{U}$. Fig. 1 shows the basic principle to define the matrix elements.

- In forming Bus Matrix $\mathbf{B}$, regarding of the direction of power flow, if power flow is flowing from bus i to bus j (see bus i in Fig. 1(b)), then $b(i,j)=i$. As bus j receives power flow (see bus j in Fig. 1(b)), then $b(j,i)=0$. Here, $i=1,2,...,m$, $j=1,2,...,m$, then we have $m\times m$ matrix $\mathbf{B}$ as shown in (1).
- In forming Generator Matrix $\mathbf{G}$, without regarding to the direction of power flow, if bus i is connected to generator, then $g(i,k)=1$ (see bus i in Fig. 1(a)), otherwise, $g(i,k)=0$ (like bus j in Fig. 1(a)). Here, $i=1,2,...,m$, $k=1,2,...,n$ then we have $m\times n$ matrix $\mathbf{G}$ as shown in (2).
- In forming Upside Matrix $\mathbf{U}$, if bus i has no upside bus or we say there is no any bus in EPS to provide

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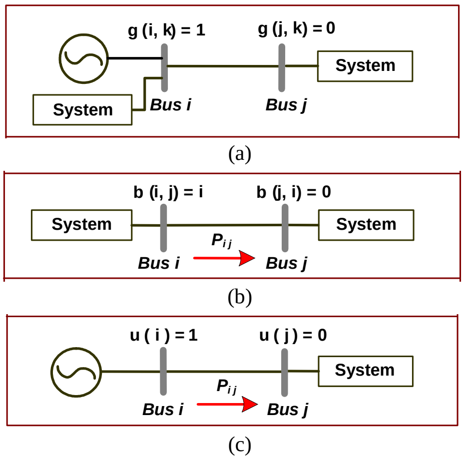

Fig. 1. Basic principle to define the matrix elements.

power flow for bus i, hence bus i is regarded as top bus, then $u(i)=1$ (see bus i in Fig. 1(c)), otherwise $u(i)=0$ (like bus j in Fig. 1(c)). Here, $i = 1, 2, ..., m$ then we have $m \times 1$ matrix $\mathbf{U}$ as shown in (3)

$$B = \begin{pmatrix} b_{11} & b_{12} & \cdots & \cdots & b_{1m} \\ b_{21} & b_{22} & & & \vdots \\ \vdots & & \ddots & & \vdots \\ b_{m1} & b_{m2} & \cdots & \cdots & b_{mm} \end{pmatrix} \quad (1)$$

$$G = \begin{pmatrix} g_{11} & g_{12} & \cdots & \cdots & g_{1n} \\ g_{21} & g_{22} & & & \vdots \\ \vdots & & \ddots & & \vdots \\ g_{m1} & g_{m2} & \cdots & \cdots & g_{mn} \end{pmatrix} \quad (2)$$

$$U^T = \left[u_{11}\, u_{21} \cdots \cdots u_{m1} \right] \quad (3)$$

Now, use formed matrixes to decompose EPS to domains.

1. Start from top line of all matrixes. Since supposed direction of power flow shows its function in elements of matrixes, usually we have $g_{11}=1$, $b_{11}=1$ and $u_{11}=1$.
2. Target of this step is to obtain improved matrix $\mathbf{G}$ by classifying generator contribution to each bus. Generally, supposing line j in matrix $\mathbf{B}$ is next-line neighbored to line i, If $b(j,i) = i$ and $u(i)=1$, then change $g(j,k)=0$ to $g(j,k)=1$ (if $g(j,k)=1$ is existing, then keep it), simultaneously change $b(j,i) = i$ to $b(j,i) = 0$ and give $u(j)=1$. Repeat with same way until all elements $b_{j1} \ldots b_{jm}$ in line j become 0, and then go to next line until all elements in $\mathbf{B}$ become 0 and all elements in $\mathbf{U}$ become 1. Along with this procedure the improved matrix $\mathbf{G}$ produced.
3. Target of this step is to form the domains. Equation used to classify domains is denoted as

$$Dec\,(j) = g\,(j,1) \times 2^{m-1} + \ldots + g\,(j,k) \times 2^{m-k} + \ldots = \sum_{k=1}^{m} g\,(j,k) \times 2^{m-k} \quad (4)$$

where, $j = 1,2,...,m$ and $k = 1,2,...,n$. $g(j,k)$ is element in improved matrix $\mathbf{G}$. As the results, for j line of matrix, one numeral result will be given, hence for m lines (represent m buses) m numeral results will be given. Combine the results of same value, one independent numeral result represent one domain. Buses have some numeral results indicate that those buses belong to the same domain.
4. Determine the links and the best domain for installation WPG. Link between two domains are obtained from the connecting structure of EPS by collecting lines upside domain (supply power for domain) and lines downside domain (absorb power flow from domain), one link therefore contains one or more transmission lines. The domain with the most upside links and supported by the most generators are regarded as the best domain for installing WPG. Anyway, the final selection will be made by verifying system indices.

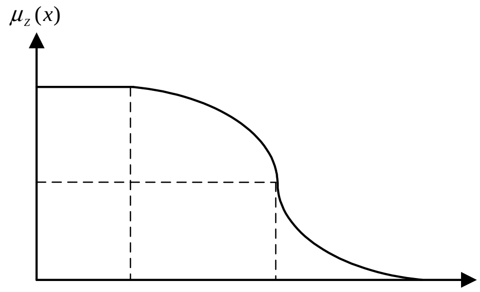

Fig. 2. The curve responding to tangent hyperbolic membership function.

III. Determination of Optimal Bus

The selected best domain usually contains several buses inside it. It is necessary to know which one is the best one for installing WPG. In this section, this problem is considered based on the four operational indices that respond the system operational characteristics in economy and stability [3]. Tangent Hyperbolic Membership Function being used for determining the value of indices is expressed by (5)

$$\begin{cases} \mu_z(x)=1 & (x \le a) \\ \mu_z(x)=1-2\left[(x-a)/(b-a)\right]^2 & [a < x \le (a+b)/2] \\ \mu_z(x)=2\left[(x-b)/(b-a)\right]^2 & [(a+b)/2 < x \le b] \\ \mu_z(x)=0 & (b < x) \end{cases} \quad (5)$$

Equation (5) forms a suitable selectivity function for the system evaluated indices, appropriate thresholds can be determined based on the system operational condition. Fig. 2 shows the particularity of the target index $\mu_z(x)$ related to values of a, b and x.

The system indices used in this study are denoted as follows:

Load index μ_L is obtained from the load condition of each line in EPS, this index shows if the power flow of transmission line is within the thermal limit or not. n-1 security index μ_S indicates the range of power flow after one of transmission line is cut; this index hence represents the overload ability of each line in EPS. Environmental index the overload ability of each line in EPS. Environmental index μ_E is obtained from the amount of waste gas F_{CO_2} (ton/hr) discharged from the system in

TABLE I
THE RELATED PARAMETERS OF GENERATOR

Bus No	Fuel type	Max. output [MW]	Eco. Index [JPY/kWh]	Env. Index [g/kWh]
1	Oil	60	10.2	200
2	Coal	60	6.5	270
13	LNG	40	6.4	178
22	Oil	40	10.2	200
23	LNG	30	6.4	178
27	Coal	45	6.5	270

TABLE II
NON-NULL ELEMENTS IN MATRICES

Matrix	Results of non-null elements in the matrixes
$g(i,k)$	(1, 1)=(2, 2)=(13, 2)=(22, 4)=(23, 5)=(27, 6)=1
$u(i,j)$	(2, 1)=(3, 1)=1. (4, 2)=(5, 2)= (6, 2)= 2. (4, 3) = 3. (6,4)=4. (7,5)=5. (7,6)=(8, 6)=6. (6, 9)=(11, 9)=9. (6,10)=(9,10) = (17,10) =(20,10)=10. (14,12) = (15,12) = (16,12) = 12. (12,13)=13. (4,15)=(18,15)=15. (17,16)=16. (19,18)=18. (19, 20)=20. (10, 21)=21. (10,22)=(21,22)=(23,22)=(24,22) =22. (15,23) =23. (24,25) = (26,25) =25. (25,27) = (28,27) = (29,27) =(30,27)=27. (6,28)=28. (30,29)=29.
$b(j)$	(1) = (13) = (22) = (27) = 1

operation, this index represents the discharge degree of each generator in operation. Economic target μ_C is obtained from the cost F_{cost} (Japanese Yen/hr), this index responds to the cost level of EPS in producing electricity.

To ensure the correction of previous selection, a synthetic index μ_D is introduced. This index is derived from the previous 4 indices by listing the smallest indices of each bus. Assuming that $\mu_D(k)$ is synthetic index [4] of bus k, it can be expressed by (6)

$$\mu_D(k) = \min(\mu_L(k), \mu_E(k), \mu_C(k), \mu_S(k)) \qquad (6)$$

In this research, the synthetic index is used for all buses in order to investigate if there is any other bus that has better indices level than determined one.

IV. DETERMINATION OF WPG LIMITATION

After the best bus is selected, it is essential to ensure if EPS operates within system constraints [5] after connecting to WPG. The maximum WPG that satisfies the up-limit of EPS constraints is regarded as WPG limitation; it is can be estimated from the EPS simulation. Supposing EPS operating in steady condition, the increment of ΔP_{WPG}, ΔQ_{WPG}, ΔV_{WPG} and ΔV_{WPG} are caused from installed WPG, then, the system constraints can be expressed as:

$$\begin{cases} P_{\min l\,i} \le P_{l\,i} + \Delta P_{WPG} \le P_{\max l\,i} & \text{(constrains on line i)} \\ Q_{\min l\,i} \le Q_{l\,i} + \Delta Q_{WPG} \le Q_{\max l\,i} & \text{(constrains on line i)} \\ V_{\min bi} \le V_{bi} + \Delta V_{WPG} \le V_{\max bi} & \text{(constrains on bus i)} \\ f_{\min bi} \le f_{bi} + \Delta f_{WPG} \le f_{\max bi} & \text{(constrains on bus i)} \\ P_s = \sum_{i=1}^{n} P_{\max g\,i} + \Delta P_{WPG} & \text{(constrains on generator i)} \\ Q_s = \sum_{i=1}^{n} Q_{\max g\,i} + \Delta Q_{WPG} & \text{(constrains on generator i)} \end{cases}$$

where, $P_{\min l}, P_{\max l}, Q_{\min l}, Q_{\max l}, Q_{\min g}, P_{\max g}$ as well as $V_{\min b}, V_{\max b}$ respectively indicate constraints on system lines, buses and generators. P_s and Q_s are entire system power. $\sum_{i=1}^{n} P_{\max(g\,i)}$ and $\sum_{i=1}^{n} Q_{\max g\,i}$ are the

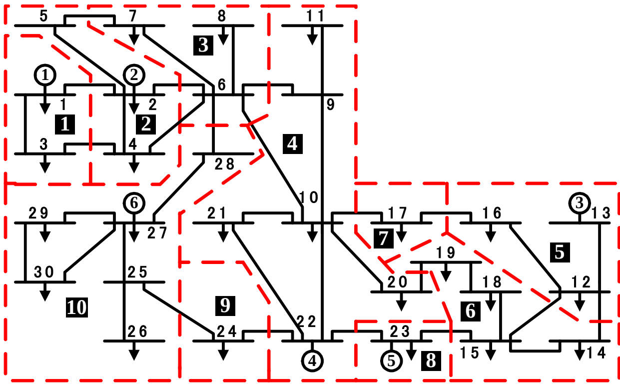

Fig. 3. The IEEE 30-Bus Test Power System.

maximum outputs of generators used to verify the power flow in power lines. Line power flow $P_{l\,i}$ and $Q_{l\,i}$ include line loss, line loss caused from increment of ΔP_{WPG} and ΔQ_{WPG} are ignored due to small quantity. Load development for 25-years are considered in $P_{l\,i}$ and $Q_{l\,i}$ to match for normal service life of wind turbine of 25-years (turbine service life depends on maintenance and operation quality) [6]. In solution of WPG, ΔQ_{WPG} and ΔP_{WPG} should be gradually increased until the limitation of constrain is reached, the WPG limitation is consequently obtained. Optimal Power Flow is used for simulation.

In practical application, number of wind power turbine is decided based on the final result of ΔQ_{WPG} and ΔP_{WPG} .by considering the rated capacity of wind power turbine.

V. APPLICATION RESULTS

The proposed methodology is illustrated using the 30-Bus IEEE Test System shown in Fig. 3, Table I indicates the related system parameters (tables of impedance and load are omitted here), and entire system capacity is 275 MW. As indicated in section 4, WPG to be installed is 22,500 kW (30 sets of 750 wind power turbines), total WPG therefore equals to 8.18% system capacity.

In according to the calculated direction of power flow, the numbers of buses are given as shown in Fig. 3. Now, establish matrixes **G**, **U** and **B** based on the principle proposed in section 2, related non-null elements in the matrix **G**, **U** and **B** are given in Table II.

Matrix **G** can be easily developed by **U** and **B** (here omitted). By leading **G** to (4), 30 numeral results are obtained from calculation for 30 buses. Summing up the buses that have same numeral result, 10 domains are produced as shown in Table III. First column shows domain number and numeral results (those in bracket), buses inside each domain are shown in second column indicated by their numbers, upside links provide power for a domain and downside links absorb power from a domain. Number inside the bracket behind links number indicates the number of transmission line.

Fig. 4 shows the relation of domains and links with generators derived from Fig. 3. Direction of each link follows the direction of power flow. By comparing all domains in Fig. 4 and Table III, it is known that domain 3 has more upside links that contain 5 transmission lines providing power and it is supported by 4 generators (see Fig. 4), this result indicated that domain 3 has very good reliability and it therefore is deemed to be the best domain

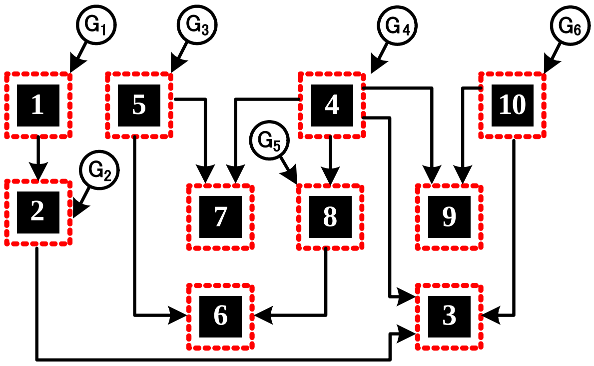

Fig. 4. Domains and links decomposed from EPS.

TABLE III
DOMAINS AND LINKS OF TEST POWER SYSTEM

Domain (result)	Bus number inside the domain	Links up -side the domain	Links down -side the domain
1 (32)	1, 3	0 (0)	1 (2)
2 (48)	2, 2, 2	1 (2)	1 (2)
3 (53)	2, 2, 2	3 (5)	0 (0)
4 (4)	2,10,11,20,21,22	0 (0)	4 (5)
5 (8)	12, 13, 16	0 (0)	2 (3)
6 (14)	14, 15, 18, 19	2 (3)	0 (0)
7 (12)	17	2 (2)	0 (0)
8 (6)	23	1 (1)	1 (1)
9 (5)	24	2 (2)	0 (0)
10 (1)	25,26,27,28,29,30	0 (0)	2 (2)

TABLE IV
RESULTS OF SYSTEM FOUR INDICES

Bus installed	μ_L	μ_E	μ_C	μ_B
No-installation	0.9623	0.0418	0.2926	0.2531
Bus 6	0.3688	0.3399	0.3200	0.3424
Bus 7	0.3806	0.3424	0.3570	0.3555
Bus 8	0.1457	0.7441	0.1378	0.2539

fitting for installation of WPG. In Fig. 4, line that connects two domains can be called Link $_{ij}$, for example, the line from domain 2 to domain 3 can be defined as Link $_{23}$, since the direction of line arrow is pointing from domain 2 to domain 3, we know domain 2 provides power flow for domain 3, on the other words, domain 3 absorbs power flow from domain 2.

However, there are three buses in domain 3 such as Bus 6, Bus 7 and Bus 8, it is necessary to classify the most optimal bus among them. Based on the proposed methodology and (6) in section 3, the thresholds are given as:

- For load index μ_L, $a = R_{\min} = 0.7R_n$ and $b = R_{\max} = R_n$. R_n is rated capacity of transmission line.
- For n-1 security index μ_S, $a = R_{\min} = 0.9R_n$ and $b = R_{\max} = 1.5R_n$. R_n is rated capacity of transmission line.
- For environment index μ_E, $a = F_{\min} = 0.94F_{\max}$ (t/hr) and $b = F_{\max} = 4.235$ (t/hr).
- For economical index μ_C $a = C_{\min} = 145\times10^4$ (JPY/hr) $b = C_{\max} = 152\times10^4$ (JPY/hr), here, JPY is Japanese money, unit is Yen.

Based on related parameters of the testing system shown in Fig. 3, results of system four indices are shown in Table IV.

Results in Table IV shows Bus 7 has good economic index and Bus 6 also has good load index. To select the most optimal bus that has general good indices that averagely shows the good indices in all related indices, it is necessary therefore to introduce synthetic index $\mu_D(k)$, Fig. 5 shows the synthetic indices $\mu_D(k)$ of three buses based on the (6) shown in section 3. Here, the smallest indices of three buses are listed, and simultaneously, the other indices that represent the other four indices are necessary to be considered avoiding the obvious differences among the indices.

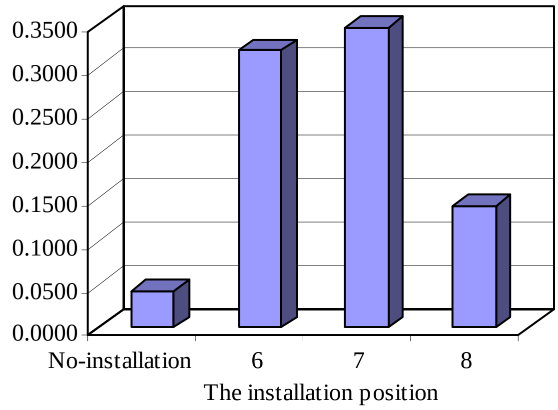

Fig. 5. Synthetic index $\mu_D(k)$ of Bus 6, Bus 7, and Bus 8.

TABLE V
RESULTS OF SYSTEM WITH FIVE INDICES THAT VALUE ARE OVER 0.3000

Bus installed	μ_L	μ_E	μ_C	μ_B	μ_D
4	0.3591	0.3436	0.3179	0.3408	0.3179
5	0.3570	0.3493	0.3188	0.3410	0.3188
6	0.3200	0.3688	0.3399	0.3424	0.3200
7	0.3570	0.3806	0.3424	0.3555	0.3424
12	0.3180	0.3354	0.3399	0.3309	0.3180
14	0.3081	0.3474	0.3446	0.3267	0.3081
16	0.3200	0.3099	0.3886	0.3416	0.3099
18	0.3062	0.3247	0.3898	0.3361	0.3062
19	0.3121	0.3091	0.4125	0.3431	0.3091

Fig. 5 indicates that Bus 7 has better synthetic index $\mu_D(k)$ than Bus 6 and Bus 7, it is therefore regarded as the best optimal bus fitting for connecting the WPG.

Regarding all buses in EPS, there may be the bus which synthetic index $\mu_D(k)$ is better than Bus 7 although that bus is not inside the best domain, in case it happens, to ensure the indeed best bus is necessary by considering and comparing all operational factors of EPS. In our case, system four indices and synthetic indices that have value over 0.3000 among all buses of EPS is shown in Table V, the results also indicate that Bus 7 is the best bus for installing WPG, hence the bus selection may by closed here. One of the advantages of this methodology is that the next installation may be carried out based on the system constrains after present installation.

As the final step, system operation stability [7] need to be verified to know if EPS can work within system constrains. Driving by natural wind energy, WPG always changes following wind speed. In this research, WPG changes from 900 kW (30 kW per turbine) to 22500 kW (rated output of 750 kW per turbine). Although the occurrence frequency of full output occupies only 0.8 % in operation due to wind characteristics, it can represent all other output in verifying EPS stability and reliability, therefore the rated output is used in calculation. Here, allowed system margins are denoted as: bus voltage $\pm10\%$;

TABLE VI
VARIATION OF OUTPUT POWER FROM SYSTEM GENERATORS BEFORE AND AFTER INSTALLING WPG

Installed buses No.	The output power from system generator [MW]					
	Bus 1	Bus 2	Bus 13	Bus 22	Bus 23	Bus 27
No installation	30.69	31.33	32.12	27.47	27.8	38.6
	30.58	31.22	32.08	27.52	27.81	38.76
	31.41	32.03	32.37	30.73	29.35	31.6
	30.69	31.33	32.12	27.47	27.8	38.6

system frequency ±2%. Table VI and Table VII shows the variation of generator output and line power flow after and before installing WPG, it shows system generators still work within thermal limitation of rated capacity. However, if generator output is too small to keep economic operation in the case of installing large amount of WPG, applicable adjustment is necessary based on the system $P_{\min}$ margin.

Characteristics of system stability and transmission lines are shown in Table VII. from this table it is known that power flow [8] of some lines is increased but the increment is within thermal capacity of transmission lines, Table VII shows the line thermal capacity and the power flow after installation WPG on Bus 6, Bus 7 and Bus 8. Voltage and frequency of power system are also within the limited margin of ±10 % and ±2 % that we proposed for this system.

VI. CONCLUSION

This paper presents a novel approach to determine the optimal process to install WPG into an EPS by considering system constrains, the technique provides a simple and easy method to make decision on how and where wind power resources can be economically and safely introduced. It is proved that stability and reliability of newly established hybrid system is available. The important advantages of this research is that the optimal buses is selected from the defined domain that supported by the most of system generators and transmission lines, this case makes the target buses keeping relative higher level in reliability and stability than other buses in system. Comparing with the index method [9] that determines optimal buses by indices and shows efficiency in application for a small sized power system, this approach can be applied for any sized power system, and the future successive installation can also be easily realized based on the system constrains formed from the present installation, four system indices provide the detail operational information. Comparing with the power flow method [10] that shows optimality in investigating the buses state and determining introducible limitation of WPG, this research may cover the all necessary aspects that exert directly influence on the installation process such as capacity of transmission line and system synthetic index derived from economic, security, environment and load demand, the efficiency of this research is therefore obvious.

Depending on the necessity of EPS, indices used for verifying the best bus may feasibly use other kinds of indices that can indicate the operational characteristics of EPS, but not limited in proposed indices, anyway, synthetic index is necessary to classify indices of all EPS buses,

TABLE VII
VARIATION OF POWER FLOW IN TRANSMISSION LINES WHEN WPG IS INTRODUCED INTO DIFFERENT BUSES [MW]

Line	From bus to bus	Thermal capacity	No-installation	Bus 6	Bus 7	Bus 8
1	1-2	24.00	19.38	9.50	18.68	19.62
2	1-3	24.00	12.16	10.82	11.90	11.79
3	2-4	16.00	8.53	13.29	8.29	8.51
4	3-4	24.00	9.68	9.45	9.48	9.32
5	2-5	24.00	9.80	13.47	8.86	9.85
6	2-6	32.00	11.47	23.58	10.97	11.53
7	4-6	24.00	14.72	2.15	13.52	15.23
8	5-7	24.00	9.74	9.45	8.82	9.79
9	6-7	24.00	13.18	13.47	10.39	13.12
10	6-8	32.00	23.48	23.58	23.55	20.85
11	6-9	16.00	2.70	2.15	2.20	1.92
12	6-10	16.00	1.54	1.23	1.25	1.10
13	9-11	16.00	0.00	0.00	0.00	0.00
14	9-10	16.00	2.70	2.15	2.20	1.92
15	12-13	48.00	32.92	32.12	32.08	32.37
16	12-14	16.00	4.58	4.58	4.58	4.29
17	12-15	16.00	5.15	5.15	5.14	4.36
18	12-16	16.00	7.71	7.17	7.70	7.45
19	12-15	16.00	1.66	1.66	1.66	1.94
20	16-17	16.00	4.10	4.10	4.09	3.89
21	15-18	16.00	9.28	9.28	9.27	9.14
22	18-19	16.00	5.95	5.95	5.95	5.84
23	19-20	16.00	3.58	3.58	3.58	3.68
24	10-20	16.00	5.82	5.82	5.82	5.92
25	10-17	16.00	4.96	4.96	4.96	5.14
26	10-21	16.00	11.04	11.04	11.08	10.99
27	10-22	24.00	8.92	8.92	8.94	8.89
28	21-22	32.00	28.58	28.58	28.62	28.52
29	15-23	16.00	14.40	14.40	14.05	14.95
30	22-24	16.00	0.01	0.01	0.02	4.02
31	23-22	16.00	10.38	10.38	10.37	11.00
32	24-25	16.00	8.69	8.69	8.72	4.73
33	25-26	16.00	3.54	3.54	3.54	3.54
34	25-27	16.00	12.41	12.46	12.49	8.31
35	28-27	16.00	13.07	12.63	12.77	9.93
36	27-29	16.00	6.16	6.16	6.16	6.16
37	27-30	16.00	7.10	7.10	7.10	7.10
38	29-30	16.00	3.68	3.68	3.68	3.68
39	6-28	16.00	6.34	5.99	6.10	4.34

especially when installation bus (or site) is limited by wind condition. Actually, to obtain the best installation bus, synthetic analysis of entire EPS is essential in each installation step. The results under steady constrains have to be verified again by dynamic constrains, this will be our next research.

Along with the development of multi-renewable resources in an EPS, the proposed methodology may be also used for installing other types of dispersed power resources by considering their electric particularities performing in EPS.

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