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Substation Expansion Planning With the Presence of Loads with Uncertainty in Size and Location and Wind Power Plant in Satisfying the Load

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Abstract

Due to the increase in power consumption and the emergence of different distribution loads than in the past, it is necessary to plan the development of SEP substations. However, uncertain loads will always be inadequate in long-term planning. Regular development planning will lead to an unreliable network. In this article, in order to cover the uncertainties of location and size in the substation expansion Planning, the minimum load distance from the location of the posts is found and if necessary, the need to build a new post will be announced. Also, in the vicinity of post number 2, a 10 MW wind power plant has been designed and provided to satisfy the load. The wind farm is also simulated taking into account wind uncertainty. The method is based on finding the minimum load distance from existing posts and extending it as needed. The presence of cryptographic devices in the power grid as an indefinite burden has been the need to conduct this research. As a result of this research, the target post in load satisfaction is identified and in case of inefficiency in load satisfaction, the development planning of that post is considered to satisfy the load.

Introduction

Planning the development of sub-distribution substations in different time horizons plays an essential role in achieving the goals of the electricity industry because electric energy cannot be easily stored. Load forecast is one of the most important data that determines the amount of posts needed to satisfy the load in the future. In other words, the main prerequisite for planning the above distribution posts in different time frames is to predict the future load of the network. For long-term forecasting, it is in the range of several years. Due to the random behavior of the load, there is always some error in the predictions. Also, the presence of digital land codes and digital land mining devices that appear legally or illegally on the network makes the forecasts face double problems. High-level forecasting will cause additional investment to create unused reserves and capital loss, as well as low-level forecasting will cause power shortages and equipment damage due to overload. Since the nature of the power generation source of wind power plants is completely random, as a result, the production of these power plants at different times cannot be accurately predicted [44] compared to conventional generators, the output of wind turbines is a function of wind speed. There is a non-linear relationship between them. . [19] In addition to its random nature, the hourly wind speed also depends on its speed during the previous hours. As a result, an ARMA model that includes both random inputs and previous values of the output is proposed for wind speed in [11].

With the increasing expansion of electricity consumption and industrial development, the need to increase production and expand production units is felt more than ever. In the meantime, the use of renewable resources in power generation is increasing day by day for various reasons. Among these reasons, the following can be mentioned:

1) Attention to diversity in the energy portfolio of energy production
2) Cleanliness and less impact on the environment
3) The extent of these resources and no need to transport fuel
4) The increase in the price of fossil fuels and the mid-term economic justification of using these wind power plants with free fuel [13]

Doi:

Theoretical framework and research background:

A) Development of above distribution posts:

The growth of the demand for electrical loads that can be fed by sub-distribution substations and can be done under the conditions of security and adequacy of the network has caused long-term, medium-term and short-term planning in this direction. One part of the main load growth is residential loads, but another part of the unexpected loads is special loads that in the last few years have an indefinite weight on the above distribution networks in terms of size and location. In this regard, various studies have been conducted in the world with uncertain results. Jamati growth, changes in the pattern of mozaf, environmental conditions, weather conditions seem to be different subjects [13].

The response to the demand is one of the uncertain things, for example, due to the process of clearing the market, the price of electricity in the energy market and the elasticity of consumption [13] There are various methods in optimizing this development of super distribution substations, such as the Mochegan algorithm, the genetic algorithm, and the movement of birds. and ... have been used. In [45], a general framework for the design of distribution systems is presented. In articles [46-47], the complexity of the process of designing an optimal distribution system is investigated. In [48], the colonial competition algorithm is used to design an optimal distribution network. A number of useful articles on the design of an optimal distribution system are presented in [49-52].

b) Uncertainty assessment of availability of wind turbines: The use of renewable energies such as wind, sun, etc. in recent years and special attention to the development of this sector has attracted everyone's attention, but the uncertainty in wind energy has caused the calculations to be directed in another direction and the uncertainty in Consider this type of energy.

At first, after getting the possibilities related to the uncertainty in the primary energy, the uncertainty of the availability of the wind turbine should also be taken into consideration. If the two-state model of the Markov model is used to model the wind turbine with failure rate q, the probability of X turbine being healthy among N wind turbines can be calculated as follows (using binomial distribution) [21].

$$P(x)=\binom{N}{X}*(1-q)^X .q^{(N-X)} \quad (1)$$

where N is the total number of turbines, x is the number of healthy turbines, q is the turbine failure rate, and p(x) is the probability that x turbine is healthy. By combining this probability function with the probabilities related to the wind speed, the probability distribution function related to the wind speed, the probability distribution function of the production power of a wind turbine set (wind farm) will be obtained [21].

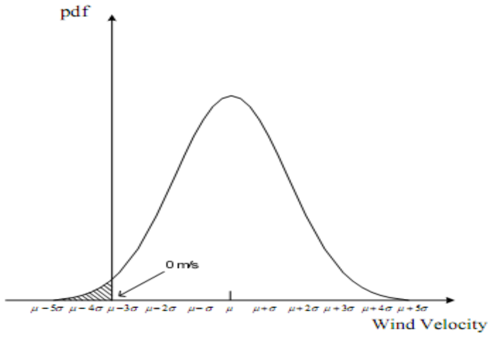

Fig1. Wind speed model

Since the nature of the power generation source of wind power plants (which is the wind) is completely random, as a result, the production of these power plants at different times cannot be accurately predicted. There are two main methods in order to investigate the impact of wind power generation on network production and judge their future production. [38]

1) Monte Carlo method: which is based on random number generation and successive calculations of probabilities.

2) The method of using the COPT table, which is based on examining the probability of each power plant exiting [13], is a two-stage model suitable for evaluating the reliability of conventional power plant units, but this model is not suitable for wind turbine generators, because the speed The wind is not constant at a certain level, and therefore the multiphase model is used for this purpose.The figure below shows the multi-stage model. [36]

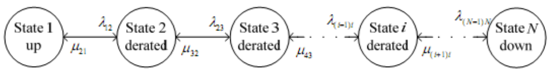

Fig2. multi-stage wind turbine model.

Each stage has a pair of interdependent parameters (normal power Pi, probability PBi) which is shown below. That is, it is meant for every possible specific power. [36]

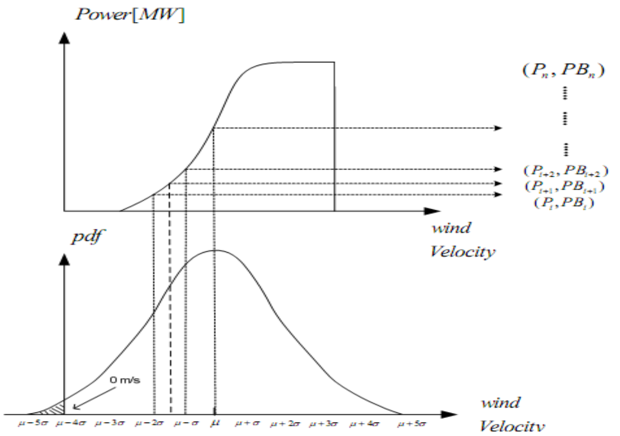

Fig3. - Dependence of output power and related possibilities

In reference [38], a 2 MW wind turbine is modeled by Markov model in a multi-stage manner. As follows:

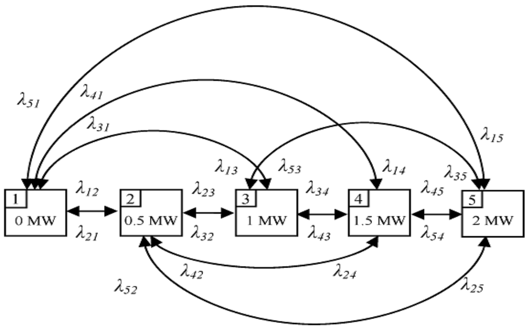

Fig4. Markov output power model for a wind turbine

And in the following, the probabilistic model of several wind turbines (wind farm), consisting of 5 wind turbines of 2 MW, has been obtained with the Karkov model and considering its FOR.

Also, a 6-stage Markov model has been presented for a 10 MW wind farm [38].

In reference [40], with the time series of the predicted wind speed, then the probability of the wind speed in a time interval is obtained. According to the following relationship:

$$P_{ai} = \frac{N_{ai}}{8760 * N_Y} \quad (2)$$

Nai: number of simulated wind speed data

Ny: number of simulated years

In reference [39], the reliability of wind farms in the power system in the HL-II area has been investigated. The power of the wind farm has been modeled in a multi-stage manner. The behavior of wind speed monthly, seasonally, and bi-seasonally for 20 years in the southeast It was carried out in the Sistan region of Iran. In this reference, the output power of the wind farm is also modeled. And it is stated that the power in a wind farm is obtained from the following relationship.

$$P = AX_1 + BX_2 + CX_3 \quad (3)$$

In this regard: A: the number of X1 type turbines, B: the number of X2 type turbines, and C: the number of X3 type turbines. Also, considering the coefficient of 0.95, the output power of the wind farm is will be. [39]

Description of the problem:

Usually, in the power grids, the above distribution substations and other power supply equipment and tools are installed based on the previous information obtained in the network and whether this power supply equipment meets the needs of the new loads that are uncertain in size and location are among the characteristics of these loads. whether or not it is one of the important questions that the planning in the development of the above distribution substations is a part of this power supply cycle that must be addressed. and the distance of the existing tap stations is calculated, the post which has the closest distance to the load is calculated, because in order to supply the load power, it is necessary to build a line and invest in the distribution supply system.

Therefore, as a rule, the shortest distance will have a lower cost.. So, after determining the post that should supply the desired load, the existing capacity of the post and the load will be compared, and if the planning is satisfied, it will not be developed, and if the existing post The target was not able to supply the load power, the development of the post is being done. Of course, with the exception of station number two, which is adjacent to 5 wind power plants each with a capacity of 2 megawatts, the capacity of this wind farm will be used to satisfy the load if there is a need for development.

suggested method:

A) Uncertainty evaluation in wind turbine production power:

First, we get the 2 MW wind turbine modelIn Table 1,the different power generation modes of a wind turbine with a capacity of 2 megawatts at different wind speeds and its possibilities are calculated and included.

Table 1. Functional modes of 2 MW wind turbine

Probability (Wayball distribution)	Generated power (kw)	wind speed (m/s)	state
0/0984	50	8<V<25	1
0/0823	45/2046	7.5<V<7	2
0/0825	36/5029	7<V<7.5	3
0/0798	28/9224	7.5<V<6.5	4
0/0748	22/3856	6. 5<V<6	5
0/0682	16/8154	6<V<5.5	6
0/0605	12/1343	5.5<V<5	7
0/0524	8/2651	5<V<4.5	8
0/0443	5/1305	4.5<V<4	9
0/0366	2/653	4<V<3.5	10
0/0296	0/7555	3.5<V<3	11
0/2997	0	V< 25 , V<3	12
1/00	0	--	Total

2 MW wind turbine power calculation:In this research, a 2 megawatt wind turbine has been selected:

Table 2: (wind turbine**GAMESA G83-2.0 MW**)

Generator 2.0 MW	
Type	Doubly-fed machine
Rated power	2.0 MW
Voltage	690 V ac
Frequency	50 Hz / 60 Hz
Protection class	IP 54
Number of poles	4
Rotational speed	900:1,900 rpm (rated 1,680 rpm) (50 Hz) 1,080:2,280 rpm (rated 2,016 rpm) (60 Hz)
Rated Stator Current	1,500 A @ 690 V
Power factor (standard)	0.98 CAP - 0.96 IND at partial loads and 1 at nominal power. *
Power factor (optional)	0.95 CAP - 0.95 IND throughout the power range. *

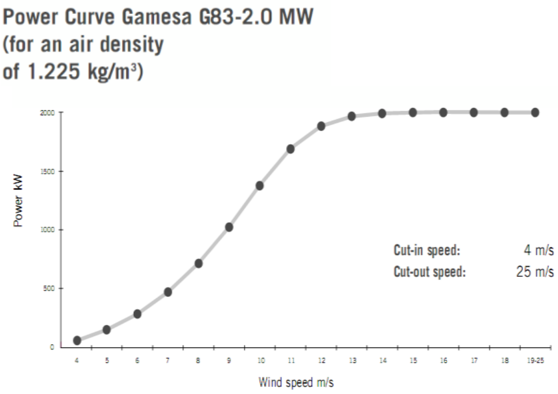

Fig5. Power change curve in proportion to wind speed changes in a 2 MW wind turbine.

Also, as can be seen in the above curve, the wind speed below 4 m/s has zero kw output power and more than this value up to 25 m/s corresponds to the curve and based on the power equation mentioned above.

Of course, these values are provided by the manufacturer in the table 3. In this research, first, the wind speed data of Manjil region in the north of Iran was prepared. Of course, this information is from 2008. This information is in the form of 49,980 wind speed data, which was taken every 10 minutes by the meteorological center.

According to the table 3 and a simple relationship, the probability of occurrence in each of the stages of the table 3 is obtained. Now, by multiplying the resulting power by the wind speed, the probability of occurrence obtained in each stage and at the end the algebraic sum of these multiplications is the amount of power that Power is expected from a 2 MW turbine mentioned above. These relationships are shown below

$$P_{ri} = \frac{n_i}{49979} \quad (4)$$

Pri=probability of each state and i value from 1 to 16 states.

So pr1………pr16 is the probability of 16 occurrences of the aforementioned table 3 and n1…………n16 is the number of times that the wind speed was in that state out of 49980 data.

Table 3: Multi-stage model of wind speed

levels	wind speed	Power out put	Possibility
1	V<4	0	X1
2	4<V<5	65/1	0.08333
3	5<V<6	152/4	0/044238
4	6<V<7	285/2	0/053701
5	7<V<8	470/8	0/031052
6	8<V<9	715/8	0/041675
7	9<V<10	1024/8	0/038635
8	10<V<11	1377/4	0/026831
9	11<V<12	1690/8	0/041136
10	12<V<13	1881/9	0/028792
11	13<V<14	1963/8	0/046058
12	14<V<15	1990/3	0/047039
13	15<V<16	1997/6	0/030512
14	16<V<17	1999/4	0/042677
15	17<V<18	1999/9	0/039316
16	18<V<19	2000/0	0/023509
17	19<V<25	2000/0	0/12077
18	V>25	0	X2

By multiplying the two columns on the right, in each row, the potential power of the wind turbine is obtained in multi-stage mode.

$$Pt=\sum_{i=1}^{16} pi \times pri \quad (5)$$

which: ((the power produced at each speed in the above table)*(probability of occurrence of that speed)) = ∑ pt = 0.9696 in terms of perunit Paying attention to the above calculations, we have assumed ptotal = MW.

Wind histogram with SPSS software:In this research, the wind information of Manjil region in the north of Iran in 2008, which was measured every 10 minutes, was prepared and the frequency and normal function curve and other information were obtained by SPSS software, which is given below:

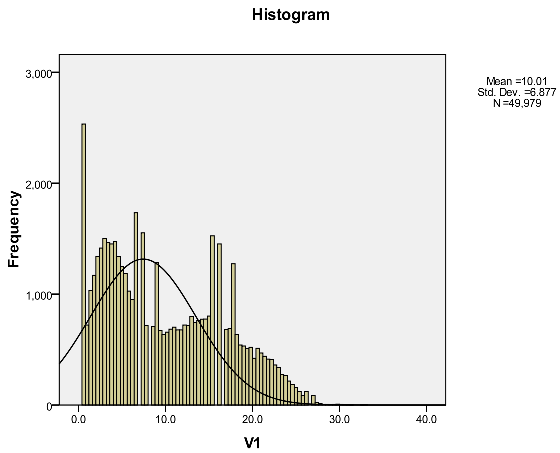

Fig6.

By using the data in Table 1, the position of the available posts is determined. Also, the capacity of each post is shown in this table.

Each time the program is run, it appears for an undetermined electrical charge in capacity and location. First, one of the existing substations should take action to satisfy the requested power due to being closer to the substation. If the capacity of the substation is not sufficient for this task, according to the needs of the location and the desired capacity, it will be announced that the capacity needs to be expanded. It has a certain amount of 15 MW or 30 MW. Of course, there is an exception for the existing substation No. 2, which is specified in Table 1, and that is that there is a wind farm next to this substation that has 10 wind turbines. Satisfying the load takes place in case of inability to supply power by the post office Every time the program is executed, due to the uncertainty of the load, both in terms of size and size, this load may appear near one of the posts. In this case, the power status of the post close to the load is checked, and if satisfied There will be no need to develop a new substation by the existing substation, otherwise, according to the need and load, the new substation will be installed in two sizes, 15 MW or 30 MW. Wind in the area of Post No. 2, where there is a suitable wind speed in that location, and a wind farm should be built in the vicinity of Post No. 2, but due to the uncertainty in the wind, this issue will be investigated separately.

Table 4: details of available positions

Station number	Longitude km	latitude km	Available capacity MW	Expandable capacity MW
1	20	30	15	15و30
2	50	30	15	15و30
3	80	40	30	15و30
4	90	80	15	15و30
5	30	70	15	15و30

In the table 5, the information extracted from MATLAB software is placed. First, the latitude and longitude of the unknown load and its capacity are generated randomly. The software calculates the distance of the load to the posts and the nearest post is determined to feed the load. In this case, by comparing the existing capacity of the substation and the load capacity, the need to construct the substation or its lack is determined.

table 5:

Latitude (km)	Longitude (km)	uncertainty load capacity (MW)	The shortest distance from the load to the sustation (km)	expected energy not supplied (EENS)	Substation number To transfer power to the load
75	77	2	13.92	0	4
69	60	21	22.82	15	3
14	59	2	18.95	0	2
11	82	25	29.06	15	3
77	50	9	21.18	0	5
78	15	29	17	29	5
65	44	29	14.86	44	5
53	87	24	14.76	15	3
23	3	22	18.38	15	1
66	9	2	21.37	0	5

Conclusion:

The increasing consumption of electrical power and the appearance of various loads compared to the past has made planning the development of essential posts undeniable. Uncertain loads will always cause inadequacies in long-term planning. Development planning without taking into account the uncertainty in certain loads that have uncertainty will cause problems in responding to the network's needs. In this article, in order to cover the uncertainties of the location and size of the load in the planning of the development of the super distribution substations, the shortest distance of the load from the location of the existing candidate substations has been found. If the selected post is not satisfactory enough, the need to build a new post will be announced. Also, in a specific case, a 10 megawatt wind power plant was designed and presented in the vicinity of station number 2 to satisfy the load, and the wind power plant was simulated considering the uncertainty of the wind. The method of doing the work is based on finding the shortest load distance from the existing posts and expanding it if needed. The presence of cryptocurrency mining devices in the power grid as an uncertain burden has made it necessary to address this research. As a result of this research, the above distribution post calculated to satisfy the load is identified and in case of inefficiency in satisfying the load, the development planning of that post is considered.

Reference:

[1] Oliver Andersen, Analysis of time series and forecasting, translated by Abulqasem Bozhernia, Astan Quds Razavi cultural center, 1366

[2] Ali Akbar Abdos, Asghar Akbari Froud, "Dynamic Design of Transmission Network Development in Restructured Environments", Modares-Electronic Technical and Engineering Magazine, No. 38, Winter 2018.

[3] Gholamreza Kamiyab, Mahmoud Fatuhi of Firozabad, Masoud Rashidinejad, "Market-oriented planning of transmission network development based on the percentage of customers' surplus", Modares-Electronics Technical and Engineering Magazine, 10th Volume, Number 4, Winter 2019.

[4] Maryam Ramezani, Mahmoud Reza Haghi Pham, Mohsen Parsa Moghadam, Hossein Saifi, Probabilistic evaluation of the overall exchange capability of transmission networks in the presence of wind farms, Iranian Electrical and Computer Engineering Journal, Year 7, Number 3, Fall 2018

[5] Mohammad Kazem Sheikh Salam, "Production development planning in competitive electricity markets by multi-attribute decision-making method"

[6] Sajad Najafi Rawadaq, Hamid Khatami, optimal distribution network design and authority regarding the uncertainty of load estimation

[7] Saeed Jalilzadeh, Hossein Hadadian, Maisham Mahdavi, Hadi Hosseinian, Sejad Galvani, "Planning the development of the transmission network in order to optimize the adequacy of lines with the help of genetic algorithm", psc2007, 22nd International Electricity Conference

[8] Roy Billinton, Ronald Allen, Reliability of Engineering Systems, Concepts and Methods, translated by Mohsen Rezaian, Amir Kabir University of Technology Publishing Center (Tehran Polytechnic)

[9]Roy Billinton, Ronald N. Allen, Reliability assessment of power systems, translated by Mahmoud Reza Haqi Pham, Mohammad Ismail Artman, Jihad Dakhani

[10] Ahmad Salehi Dobakhshari, Mahmoud Fatuhi, Firozabad, Planning the development of production units in the presence of wind power plants from the point of view of reliability.

[11] Mahmoud Reza Haqi Pham, Sina Soltani, Hossein Damroudi, "Providing a method to investigate the effect of installing wind power plants in different parts of Iran on grid reliability indicators", the first conference on renewable energies and distributed generation in Iran

[12] Mahmoud Reza Haqi Pham, Sina Soltani, "Investigating the effect of wind power on the reliability of power systems", 7th National Energy Conference.

[13] Sajjad Najafi Rawadaq, Hamid Khatami, "Designing an optimal distribution network and resistant to load estimation uncertainty", Tabriz University Electrical Engineering Journal.

[14] Mahmoud Fenderski, Mohammad Taghi Arab Yar Mohammadi, Hassan Rostgar, Abolfazl Piraysh Niqab, "Reliability assessment of Manjil and Neishabour wind power plants", 22nd International Electricity Conference.

[15] Saima Aghajani, Mohsen Kalanter, simultaneous planning of storage and energy in power systems considering uncertainty in wind load and power forecasting., 25th International Electricity Conference.

[16] Mohammad Rahmani, The role of planning in reducing power outages, the 9th Conference on Power Distribution Networks.

SANA (New Energy Organization of Iran)

[17] Mahmoud Reza Haqi Pham, Sina Soltani, Prediction of reliability indicators in networks including wind power plants using wind repetition patterns, the first conference on renewable energy and distributed generation in Iran.

[18] Mahmoud Reza Haghi Pham, Sina Soltani, A new method in determining the equivalent capacity of wind power plant based on reliability indicators, 25th International Electricity Conference, 2010

[19] Hassan Siahkali, "Economic evaluation of wind turbines considering uncertainty in production", 22nd International Electricity Conference, 2007

[20]D.S.Kirscher,G.Strbac"Fundamentals of Power System Economics"

[21]pavlos S. Georgilakis"Marcket –based transmission expansion planning by improved differential evolution"

[22]H.yazdanpanahi,G.B.Gharehpetian,IEEE senior member,S.H.Hosseinian,IEEE member,"Application of FACTS Devices in Transmission Expansion Planning to Overcome Problems of Projects Delays"

[23]M.Gholami,H. yazdanpanahi,G.B.Gharehprtian,"An Approach to Find Most Find Most Flexible Plan among Solution of Transmission Expansion Planning(TEP) Problem"

[24]X.Wang,j.r.McDonald,"Modern Power System Planning"

[25]D. Finon, T. A. Johnson, and A. Midttun,"Challenges when electricity markets face the investment phase", Energy Policy, vol. 32, pp. 1355-1362, 2004.

[26]A. G. Kagiannas, D. T. Askounis, and J. Psarras,"Power generation planning: a survey from monopoly to competition," International Journal of Electrical Power and Energy Systems, vol. 26, pp. 413-421, 2004.

[27]I. Dyner, and E. R. Larsen, "From planning to strategy in the electricity industry", Energy Policy, vol. 26, pp. 1145-1154, 2001.

[28]M. Armstrong, S. Cowan, and J. Vickers, Regulatory Reform, MIT Press, Cambridge, MA. 1994.

[29]Energy Information Administration (EIA). Electric Power Annual 2000 volume 1. [Online]. Available: http://www.eia.doe.gov/cneaf/electricity/epav1/epav1.pdf.

[30]M. Ilic, F. Galiana, and L. Fink, Power System Restructuring: Engineering and Economics, Kluwer Academic, Netherlands, 1998.

[31]Goldberg, David E (1989)," Genetic Algorithms in Search, Optimization and

[32]Bipul Karki," Operating Reserve Assesment of Wind Integerd power system",

[33]Mohammad Hossein Abedi,Hadi Hoseeeini,Abolfazl Jalilvand,"sub-transmission substation expantion planning considering load center uncertainties of size and location",

[34] Liang Wu,Jeongje Park,Jaeseok Choi,A.A.EI-Keib,"Probabilistic Reliability Evaluation Of Power Systems Including Wind Turbine Generators Considering Wind Speed Correlatiuon";2009, IEEE

[35]Jinxiang Zhu,Mo-yuen Chow,"A Review of Emerging Techniques on Generation Expansion Planning",1997,IEEE

[36] Ahmad Salehi Dobakhshari,Mahmud Fotuhi-Firuzabad,A Reliability Model Of Large wind Farms for Power System Adequacy Studies,IEEE

[37]M.-R.Haghifam,M.Omidvar,"Wind Farm Modeling in Reliability Assessment of Power System",

[38] Rajesh Karki,Po Hu,Roy Billinton,"A Simplified Wind Power Generation Model for Reliability Evaluation"

[39]Wijarn Wangdee,Roy Bilinton ,Fellow,IEEE,"Considering Load-Carrying Capability and Wind Speed Corrlation of WECS in Generation Adequacy Assessment"IEEE,2006

[40]Chao Lian,Peng Li,"An Improved Strategy of Wind Power Generation Expansion Planning"

[41]Kaigui Xie,Roy Bilinton,"Energy and Reliability benefits of wind energy conversion system",journal,2011

[42]IEEE RELIABILITY TEST SYSTEM,Nove./Dec.1979

[43]X.Wang,J.R.McDonald," Modern Power System Planning"McGraw-HILL BOOK COMPANY

[44]Roy Billinton,Life Fellow,IEEE,Guang Bai,"Generating Capacity Adequacy Associated With Wind Energy",IEEE TRANSACTION,2004.

Adequacy

[45] S. Najafi, and S.H. Hosseinian, M. Abedi, A. Vahidnia, and S. Abachezadeh, "A framework for optimal planning in large distribution networks," IEEE Transactions on Power Systems, vol. 24, no. 2, pp. 1019-1028, 2009.

[46] T. Gönen, Electric power distribution system engineering, New York, McGraw-Hill, 1986.

[47] E. Lakervi, and E.J. Holmes, "Electricity distribution network design," IET, no. 21, 1995

[48] E. Atashpaz-Gargari, and C. Lucas, "Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition," IEEE Congress on Evolutionary computation, pp. 4661-4667, 2007.

[49] S.K. Khator, and L.C. Leung, "Power distribution planning: a review of models and issues," IEEE Transactions on Power Systems, vol. 12, no. 3, pp. 1151- 1159, 1997.

[50] F. Gómez, H.M. Khodr, P.M. De Oliveira, L. Ocque, J.M. Yusta, R. Villasana, and A.J. Urdaneta, "Ant colony system algorithm for the planning of primary distribution circuits," IEEE Transactions on Power Systems, vol. 19, no. 2, pp. 996-1004, 2004.

[51] V. Parada, J. Ferland, M. Arias, and K. Daniels, "Optimization of electrical distribution feeders using simulated annealing," IEEE Transactions on Power Delivery, vol. 19, no. 3, pp. 1135-1141, 2004

[52] E.C. Yeh, S.S. Venkata, and Z. Sumic, "Improved distribution system planning using computational evolution," IEEE Transactions on Power Systems, vol. 11, no. 2, pp. 668-674, 1996