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Research Paper

Operation Studies of Power Systems Containing Wind Farms Considering both Deterministic and Probabilistic Reliability Criteria

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Abstract— *In many different nations around the world, renewable energy sources are increasingly being used to generate electricity. It is because renewable resources are sustainable, have no operating costs, and are environmentally friendly. Wind power develops quickly among renewable units, and nowadays, several wind farms with large installed capacity are operating in the world. However, the erratic property of wind velocity causes generated power of wind parks to vary, which has an impact on various parts of electric network connected to wind parks and needs to be studied using new methods. In order to address reliability-based operation studies of electric network in presence of wind parks, the current research suggests a method taking into account both probabilistic and deterministic approaches for reserve scheduling. The PJM method has been modified for this reason, for incorporating wind production into the electric network. For wind farms, a several-state reliability presentation that considers hazard of assembled elements and change in produced power is developed at first stage. The appropriate amount of spinning reserve is then computed using matrix multiplication method through modified PJM methodology. Numerical simulations related to reliability test networks are provided for assessing efficacy of suggested methodology. It is concluded from numerical outcomes that the wind farms lead to the reduction of required spinning reserve. However, due to the variation of output power of wind farms arisen from variation of wind velocity, the impact of wind units in reduction of spinning reserve is less than the conventional units with the same capacity. Besides, spinning reserve calculated by well-being approach of wind farms that combines the probabilistic and deterministic indices is more accurate than the value obtained by risk indices.*

Keywords—Reliability, well-being approach, wind farm, spinning reserve, operation studies.

1. Introduction

1.1. Research motivation

Fossil fuel use must be reduced in light of the issues caused by these fuels. Different nations around the world decide to restrict the use of fossil fuels for this reason, particularly in electric networks. Therefore, electric networks are using more and more renewable resources, like wind, to generate electricity. Construction of wind parks is happening quickly all over the world by development of wind turbine technologies. Amount of energy produced by wind turbines depends on wind velocity, and as wind speed varies, so does the amount of power that can be produced. Different facets of electric networks contained wind parks are impacted by unpredictability of wind turbines. Determining how large-scale wind farms affect various components of electric network, requires development of new methodologies. For this reason, new methods should be developed to study the impact of large-scale wind farms on operation studies of the power system.

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1.2. Literature review

Due to the importance of wind farms effect on various aspects of power system, many researches are carried out to study the impact of these renewable resources on power networks. In this part, some papers studied about wind farms are reviewed. In according to the scenario approach, unit selection in electric network containing substantial wind parks is carried out in [1]. Traditional operation costs and losses related to the unload operation of wind farms, are all taken into account in the paper's proposed model. The operation risk of electric networks integrated wind production units is investigated using a novel data-driven approach in [2]. In this study, by K-means clustering methodology, proposed model is relied on time. An improved methodology for power dispatching program is suggested in [3] that takes into account fatigue effect of wind turbines. To distribute real power of wind units and forecast ultra-short-term wind velocity, this paper uses a look-up table. [4] studies frequency and stability of large-scale wind farm-containing power systems during storms. In order to prevent the frequency instability of wind turbines during bad weather, this paper suggests appropriate controls and strategies, such as load shedding and high-voltage direct current control. In paper [5], a time-dependent scheduling approach is suggested for combined systems made up batteries, thermal units, wind turbines, and PV systems. The suggested scheduling model consists of three levels, including daily, hourly, and a quarter-hour plans. An optimal several-source presentation for an electric network during operation phase is developed in [6] while taking into account the risk related to the peak shaving of power produced by nuclear plant and use of wind

Table 1. The advantage and disadvantages of reviewed papers.

References	Advantages	Disadvantages
[1]	Operation studies of the power system containing wind units in primary frequency regulation is performed.	Reliability-based operation studies of power system are not considered.
[2]	Data-driven operation risk assessment of wind-integrated power systems via mixture models and importance sampling is performed.	The mixture of probabilistic and deterministic indices is not considered.
[3]	Optimized active power dispatching strategy considering fatigue load of wind turbines during de-loading operation is introduced.	Reliability indices of power system are not considered.
[4]	Frequency stability of power system with large share of wind power under storm conditions is performed.	Reliability indices of power system are not considered.
[5]	Scheduling of a system including wind power, photovoltaic, thermal generator, hydro pumped storage, and batteries is performed.	Reliability-based operation studies of power system are not considered.
[6]	Optimal operation model considering the risk of nuclear power peak shaving and wind power consumption is developed.	The mixture of probabilistic and deterministic indices is not considered.
[7]	Operation of stand-alone microgrids considering the load following of biomass power plants and the power curtailment control optimization of wind turbines is performed.	Reliability-based operation studies of power system are not considered.
[8]	Optimal operation of hydro and wind power plants is studied.	Reliability of units is not considered.
[9]	Reliability evaluation of power system containing wind units is performed.	Operation studies of the power system is not considered.
[10]	Planning and economic operation studies of the power system containing wind units, pumped storage and thermal power plants are carried out.	Reliability-based operation studies of wind turbines is not performed.
[11]	Security assessment of power system containing wind farms are carried out.	Reliability-based operation studies of wind turbines is not performed.
[12]	Unit commitment of the power system considering uncertainty of renewable resources is performed.	The mixture of probabilistic and deterministic indices is not considered.
[13]	Reliability analysis of power system containing renewable resources, combined heat and power plants, energy storage devices and demand response program is performed.	Operation studies of the power system is not considered.
[14]	Operation studies of the power system containing combined heat and power plants is carried out.	Operation studies of power network containing wind units is not carried out.

energy. Based on quantity of failures and power losses experienced by the understudied region over the course of a year, this paper calculates risk of demand adjustment. [7] describes the operation of a standalone microgrid with biomass units. In suggested microgrid, a wind energy interruption control optimization strategy is implemented for reducing frequency and magnitude of pitch controller. The issue of optimizing the generation of power from wind and hydro generation units during the operational phase of the pool market is formulated in Paper [8]. This paper solves the operation problem for a straightforward three-reservoir cascade case for testing influence of methodology. [9] performs reliability analysis of electric networks with substantial wind parks. For electric networks with high penetration level of wind production plants, a novel reliability evaluation technique is suggested in this paper along with a probabilistic forecasting methodology for output of wind units. An electric network with a wind turbine, a pumped storage power plant, and a thermal power unit is taken into consideration in [10], and operation studies of this system are carried out using a dynamic approach. In this study, problem is optimized and the model's inertia weight is improved using particle swarm optimization method and hypercube sampling approach. In [11], static security of the power network integrated with wind farms is assessed using complex network theory. In this research, a comprehensive risk-based technique is introduced that quantifies the effect of contingency-induced change in structure by using complex network theory metrics. Paper [12] performs uncertainty management of a power network in operation phase by Harris Hawks optimization algorithm. In this paper, short-term self-scheduling unit commitment of various generation units including wind turbines, photovoltaic panels, small hydro power plants and pumped storage power plants is carried out. In [13], reliability evaluation of power network considering renewable resources, combined heat and power units, energy storage devices and demand response program is performed. In this research, a reliability model is developed for renewable energy-based power plants such as wind units. In the proposed multi-state reliability model of wind power plants, both failure of assembled elements and variation of output power are considered. Paper [14] performs reliability-based operation studies of the power networks containing combined heat and power plants. In this paper, reliability modeling of various technologies of combined heat and power plants used for operation assessment of the power system containing these units is carried out.

1.3. The necessity of the research based on challenges of the literature

In the previous section, 14 papers are reviewed in the field of wind power plants, reliability and operation studies of the power system. The advantages and disadvantages of these papers are given in Table 1.

As can be seen in the table, so far, operation studies of the power system integrated with large-scale wind generation units considering both deterministic and probabilistic indices are not performed. For this purpose, the current study uses analytical approach to conduct operation studies of electric networks that integrate wind parks. A well-being model of electric network that considers both deterministic and probabilistic indices is used to determine the spinning reserve of electric network. It is proposed because of uncertain property of wind farms caused by variation in electric produced power of wind units. It is suggested to use a modified PJM method to incorporate the wind farm reliability model into electric networks studies in operation phase.

1.4. Novelty and main contributions of the paper

The current paper determines the required spinning reserve of the power system integrated with wind generation units considering both deterministic and probabilistic approach. Thus, the main contributions of the paper would be:

- A multi-state reliability model suitable for operation studies of the power system is developed for wind farms. In the proposed model, both failure of composed elements and variation of output power are considered.
- An analytical approach based on the modified PJM approach is proposed to calculate the risk of power system containing wind farms in operation phase.
- To determine the required spinning reserve of power system integrated with wind farms, both deterministic and probabilistic indices are considered.

1.5. Organization and structure of the paper

This paper organizes as follows in accordance with its objectives: in Section 2, a wind farm reliability presentation appropriate for electric network studies in operation phase, is developed. in Section 3, develops the power system's well-being model with large-scale wind farms integrated. in Section 4, provides numerical simulations related to operation evaluation of IEEE-RTS and Roy Billinton (RBTS) test systems. Finally, Section 5 includes an overview of the paper's conclusion.

2. Reliability Model of Wind Farms

The wind generation unit, which consists of a turbine, gear-box, generator, power electronic converter, transformer, and cable, is used to convert kinetic energy of wind into electric energy. In installed wind units, various kinds of generators are used. They are brushless double-fed asynchronous generators, synchronous generators with exciter winding, wound-rotor asynchronous generators, squirrel-cage asynchronous technology, double-fed asynchronous generators, and permanent magnet synchronous technology [15]. Effect of component failure on overall plant failure as well as variations in the generated power of the unit resulting from variations in wind speed must be considered when developing reliability model of wind generation units. Up and down states of the components are presented in this paper using a 2-state Markov presentation. In according to [16], failure of wind unit elements of double-fed induction technology causes the unit as a whole to fail. The wind generation unit can therefore be modeled using an equivalent two-state model from the perspective of reliability. The equivalent failure rate in this model can be computed by adding hazard rates of assembled elements [17].

$$\lambda_{eq} = \sum_{k=1}^{n} \lambda_k \tag{1}$$

Where λ_{eq} denotes the equivalent failure rate of wind unit, λ_k denotes hazard rate of k^th component, and n denotes total number of wind unit's assembled parts. Due to the limited time available, repairs cannot be made in power system operation studies, so they are excluded from repair rate in component reliability presentation. Variation in electric produced power of wind unit must be considered in complete reliability presentation of wind turbine in addition to influence of composed element hazard. Power produced by wind turbines varies along with the wind speed, which varies significantly over time. As a result, there may be a number of states in produced power from wind unit that need to be reduced. The fuzzy c-means clustering (FCM) technique is suggested in paper [16] as a solution for this problem. Comprehensive reliability presentation of a wind park made up n wind units that is suitable for electric network studies in operation phase is shown in Fig. 1. After implementation of proposed clustering methodology, the states of wind unit related to variation in wind velocity have been reduced to m.

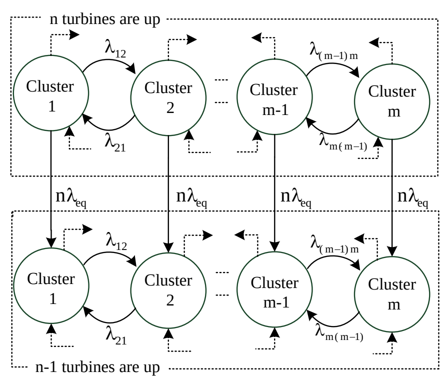


Fig. 1. The complete reliability presentation of a wind park in operation studies.

In proposed reliability presentation of wind farm, λ_{eq} is equivalent hazard rate of each wind unit, λ_{ij} is transition between i^{th} and j^{th} states associated to variation in wind speed. Repair rate is neglected in reliability model of wind unit at operation phase.

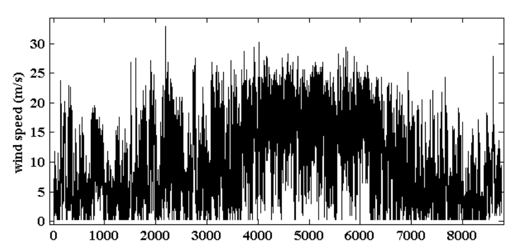


Fig. 2. Hourly wind velocity in Manjil region in 2019 [18].

3. Well-Being Model of Power System including Wind Farms

When electric network operates electric produced power must equal required demand. For preventing demand interruption, when

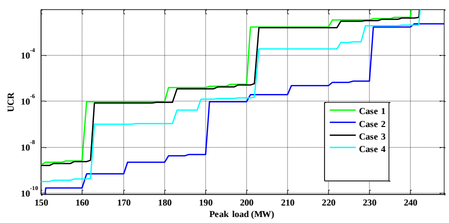


Fig. 3. UCR associated to four cases considering demand.

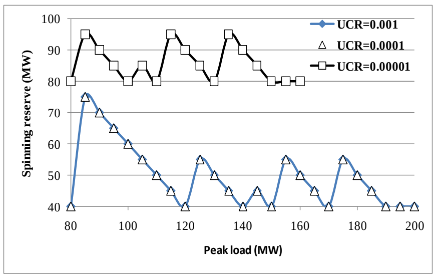


Fig. 4. Amount of spinning reserve associated to case 1.

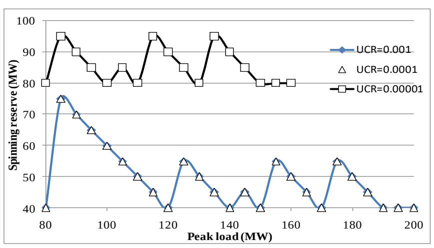


Fig. 5. Amount of spinning reserve associated to case 3.

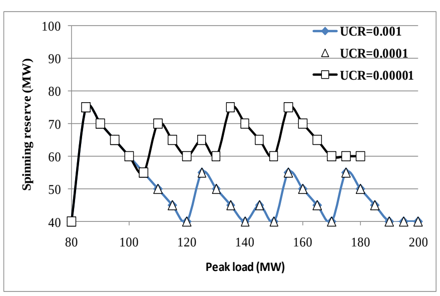


Fig. 6. Amount of spinning reserve associated to case 4.

various disturbances happen, spinning reserve should be provided in electric network. For determining suitable value of spinning reserve, deterministic or probabilistic methods can be used. In the deterministic methods, the value of spinning reserve is several percent of demand, several percent of the capacity of generation units, or equal to the largest generation unit capacity. Based on $N-1$ criterion, if one component of network fails, remaining elements of network must perform the associated function, correctly. Thus, based on this criterion, the spinning reserve equals to power of largest plant. In probabilistic approaches, the spinning reserve is computed so that reliability indices are satisfied. In the PJM method introduced in 1963 for spinning reserve determination in Pennsylvania, New Jersey and Maryland states of USA, amount of the spinning reserve is computed so that network risk be less than allowable value [17]. In this method, traditional plants are presented with a 2-state model including perfect and broken states.

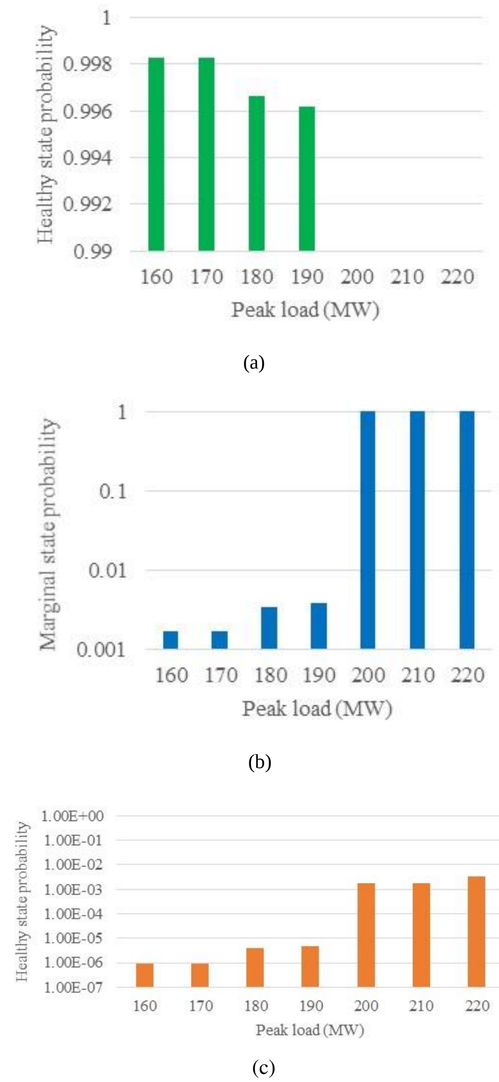


Fig. 7. Probabilities of three states of well-being model of case 1.

Unavailability of these units during operating time T is computed by [19]:

$$u(T) = \frac{\lambda}{\lambda+\mu}(1-e^{-(\lambda+\mu)T}) \tag{2}$$

It is not taken into account when calculating repair rate (μ) because of short operation times. In electric network studies in operation phase, likelihood of the generation units being in a down state is computed by [19]:

$$u(T) = 1 - e^{-\lambda T} \tag{3}$$

Since there isn't much time for operation study, the following approximate exponential expansion can be used [19]:

$$e^{-\lambda T} \approx 1 - \lambda T \tag{4}$$

As a result, the following can be used to calculate the two-state generation units' unavailability in power system operation studies [19]:

$$u(T) = \lambda T \tag{5}$$

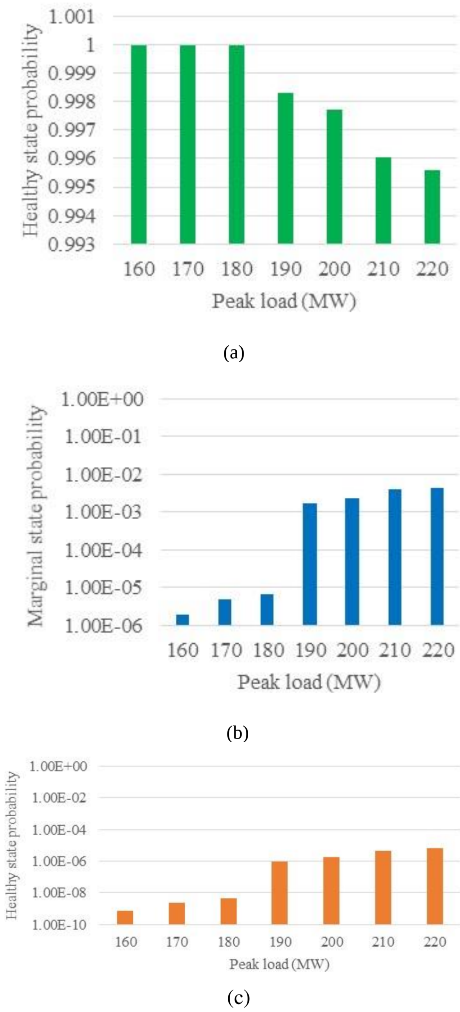


Fig. 8. Probabilities of three states of well-being model of case 2.

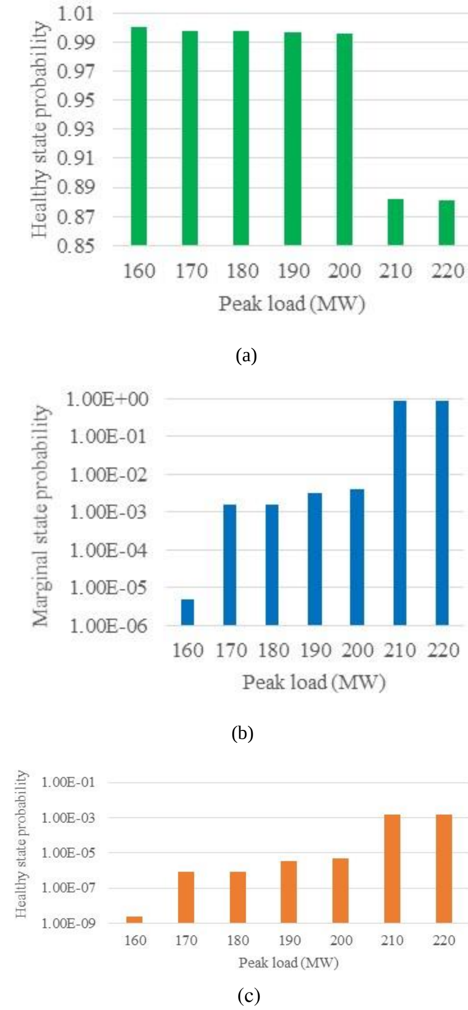


Fig. 9. Probabilities of three states of well-being model of case 3.

A reliability model for wind farms is developed in second part. Since reliability presentation of a wind farm would have more than two states because of change in power generated by wind units caused by variation in wind seed, Eq. (5) cannot be used for determining probability of various states of them. To do this, reliability presentation of wind parks uses a matrix multiplication methodology for calculating probabilities of various states [19]:

$$\mathrm{mat(P(t=T))} = \mathrm{mat(t=0).[stochastic-transitional-probability-matrix]^{\frac{T}{\Delta t}}} \tag{6}$$

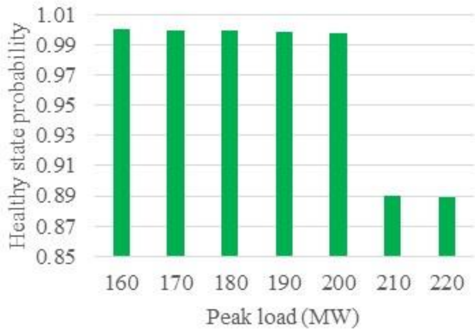
Where $mat(P(t = T))$ is a row matrix that determines the likelihoods of various model states at study time. T, $mat(t = 0)$ is a row matrix that displays initial probabilities of the model's various states, stochastic-transitional-probability-matrix displays the rates at which various states change at time Δt, and Δt is the operation study's time steps. Computation accuracy enhances when time step decreases, but computational volume increases. The accuracy of the calculation increases with decreasing time steps, but computational volume increases. In according to PJM approach, capacity-outage-probability-table ($COPT$) of every production unit must be combined together for producing overall $COPT$ of network in order to compute risk of electric network. The unit commitment risk (UCR), determined by summing probabilities related states that their capacity is less than the system's peak load, is computed by comparing peak load of electric network with capacity of various $COPT$ states.

$$UCR = \sum_{k=1}^{m} P_k(if\ C_k < L) \tag{7}$$

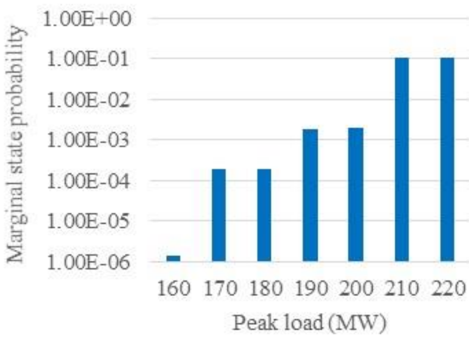
Here, P_k is probability of state k, C_k is its carrying capacity, and L is the system's peak load. In according to the PJM approach, production units are incorporated to electric network based on the priority order, and for each level, the UCR is calculated for determining value of spinning reserve of electric network. Up until the UCR is lower than the permitted amount, the system keeps adding generation units. For computing spinning reserve, network's generation capacity's peak load is reduced.

$$SR = GC - L \tag{8}$$

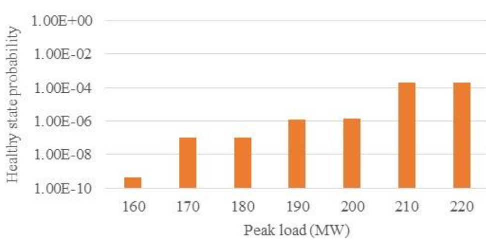
where L is the system's peak load, GC is the value of the generation capacity, and SR is amount of spinning reserve. This paper suggests well-being model of electric network for spinning reserve determination of electric network including wind parks with high installed power due to unpredictability of wind generation units. Power system's wellbeing model combines deterministic and probabilistic standards. Unlike traditional models, which only define two states—perfect and risk—this model defines 3 states. They are healthy, marginal, and risk states. The following are the states of the power system's well-being approach:



(a)



(b)



(c)

Fig. 10. Probabilities of three states of well-being model of case 4.

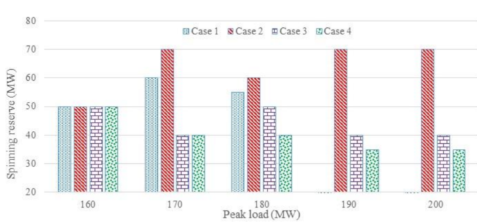


Fig. 11. Amount of spinning reserve for four cases.

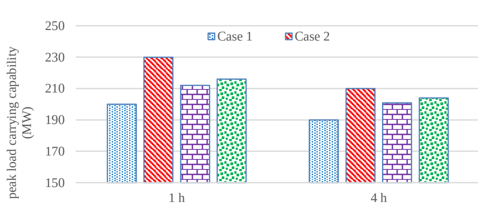


Fig. 12. Peak load carrying capability in MW for four cases.

Healthy: the system can provide demand and spinning reserve of electric network is more than capacity of largest generation unit.

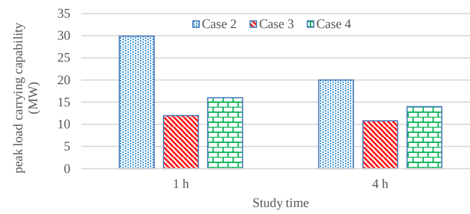
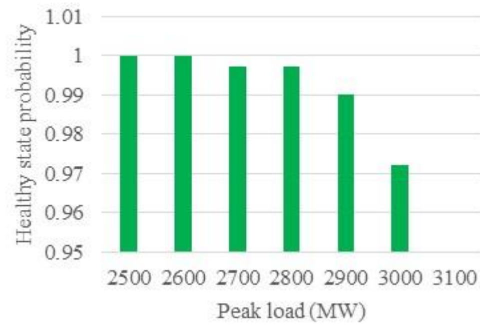
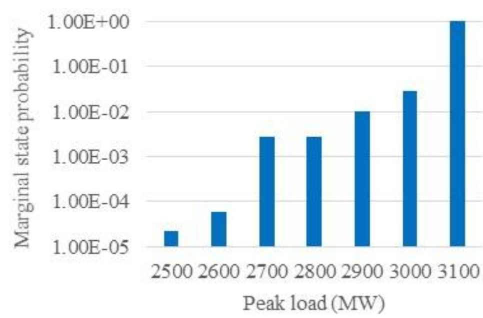


Fig. 13. Increased demand (MW) for different cases.



(a)



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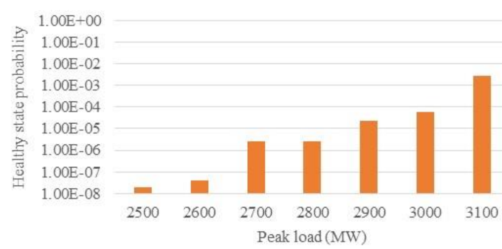

(c)

Fig. 14. Probabilities of three states of well-being model of case 1.

$$P(H) = \sum_{i=1}^{k} P_i, \;\; (C_i > (\text{load} + \text{capacity of largest unit})) \tag{9}$$

Marginal: the system can provide demand, but spinning reserve of electric network is less than power of largest generation unit.

$$P(M) = \sum_{i=1}^{k} P_i, \; (C_i > \text{demand but } \mathrm{C_i} < (\text{demand} + \text{power of largest plant})) \tag{10}$$

Risk: the system cannot provide the peak load.

$$P(R) = 1 - P(H) - P(M) \tag{11}$$

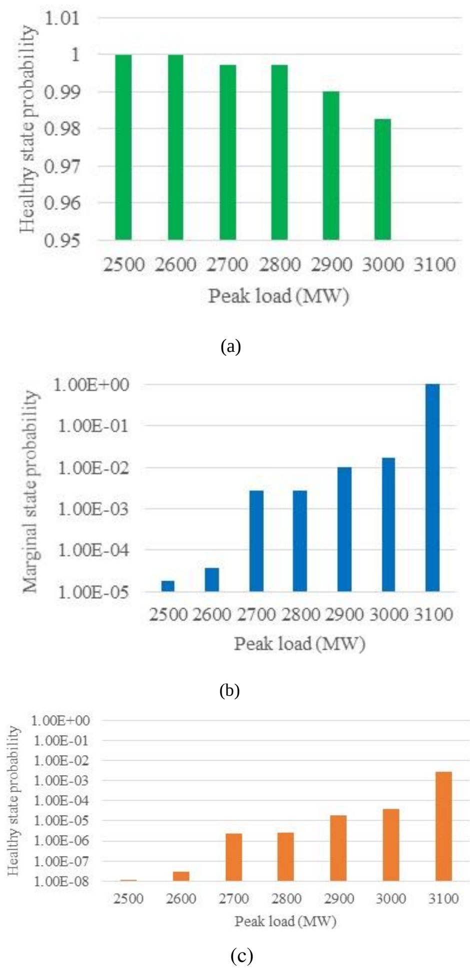

Fig. 15. Probabilities of three states of well-being model of case 2.

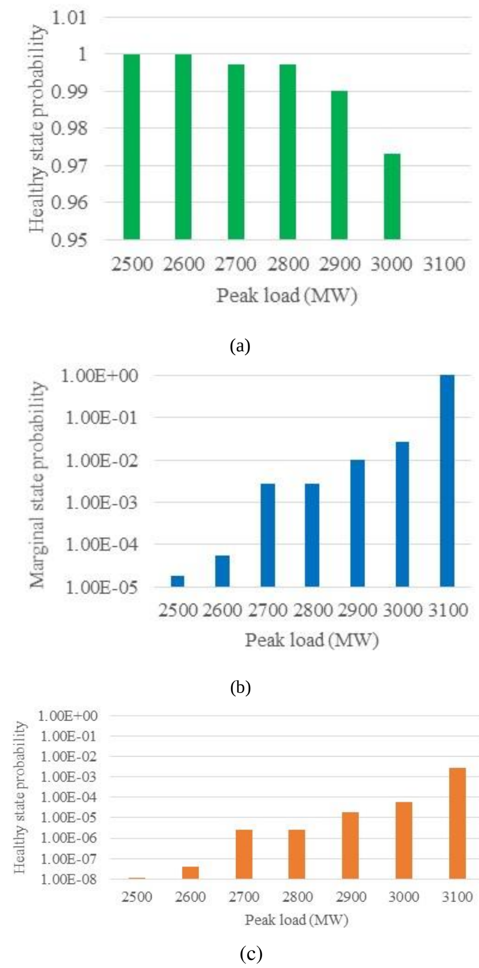

Fig. 16. Probabilities of three states of well-being model of case 3.

In according to the power system's well-being model, production plants are incorporated to electric network based on their priority order for computing spinning reserve of electric network that contains large-scale wind parks. Three states from the well-being model's probabilities are calculated for each level. The system continues to add generation units until probability of healthy states is greater than permitted amount and probability of risky states is lower than the permitted value. So, by lowering the peak load on the system's generation capacity, spinning reserve of electric network is computed.

4. Numerical Results

Here, suggested method is implemented on RBTS and IEEE-RTS, as well as a large-scale wind farm, to determine spinning reserve. Specifications of RBTS production plants are listed in [20]. In Iran's Manjil region, it is planned to install a 30-MW wind park made up ten 3-MW units. In 2019, Manjil region's hourly wind speed data was gathered and displayed in Fig. 2 [18].

Each wind turbine is estimated to fail at a rate of 0.35 times annually. The simulation of test systems is performed in MATLAB software. For calculating reliability-based operation indices of test systems integrated with wind farms, m-file coding is implemented. The annual power generated by each turbine is calculated using power chart of wind turbine. States of the generated powers are then condensed into 7 states, including 3, 2.5, 1.9, 1.3, 0.8, 0.3, and 0 MW, using FCM methodology. Following is wind farm's stochastic transitional probability matrix.

$$STPM = \begin{bmatrix} 0.9190 & 0.0628 & 0.0050 & 0.0016 & 0.0007 & 0.0005 & 0.0104 \\ 0.2210 & 0.6007 & 0.1181 & 0.0388 & 0.0136 & 0.0056 & 0.0023 \\ 0.0388 & 0.3005 & 0.3484 & 0.2004 & 0.0722 & 0.0302 & 0.0095 \\ 0.0107 & 0.1114 & 0.2218 & 0.3448 & 0.2155 & 0.0817 & 0.0141 \\ 0.0065 & 0.0429 & 0.0660 & 0.1999 & 0.3707 & 0.2465 & 0.0674 \\ 0.0021 & 0.0135 & 0.0222 & 0.0604 & 0.1766 & 0.4289 & 0.2963 \\ 0.0111 & 0.0007 & 0.0007 & 0.0024 & 0.0089 & 0.0463 & 0.9299 \end{bmatrix}$$

Four cases are taken into consideration in this section for examining influence of wind parks on the operation studies of electric network. Case 1 represents RBTS, Case 2 represents RBTS incorporated a 30-MW traditional generation plant with a hazard rate of 5 failures per year, Case 3 represents RBTS incorporated understudied wind park with low initial wind velocity, and Case 4 represents RBTS incorporated understudied wind park with high initial wind velocity. Fig. 3 displays UCR for 4 cases over the course of an hour while taking into account demand. As can be seen in the figure, the operation risk of the power system increases when the peak load of the system increases. Besides, when a new generation unit is added to the power system, the operation risk of the system decreases. Compared to the conventional unit with the same capacity, the impact of wind generation units on reducing the operation risk of the power system is less. Additionally, the impact of wind farms on the operation risk of the power system depends on the initial wind speed. In the case of high initial wind speed, the wind farm has significant impact on reducing the operation risk of the power system. However, the reduction in risk value is negligible in the case of wind farms with low initial wind speeds.

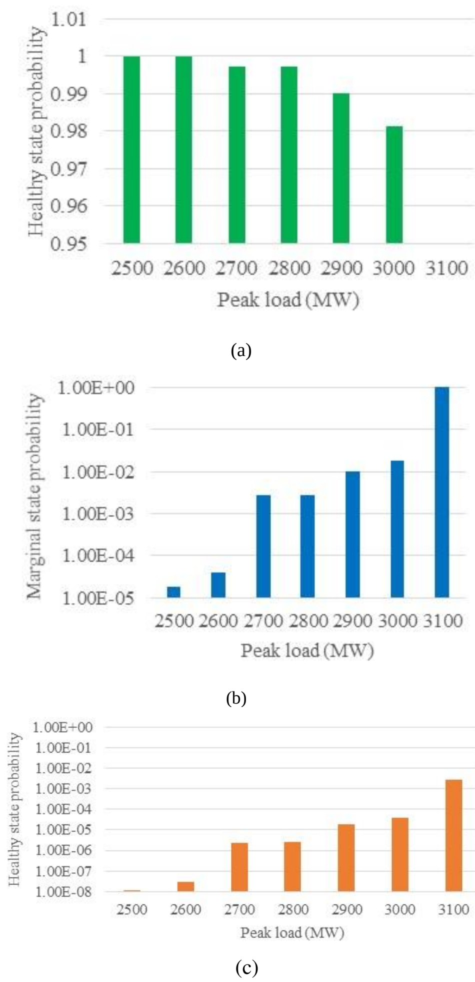

Fig. 17. Probabilities of three states of well-being model of case 4.

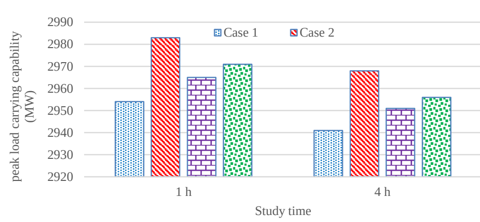

Fig. 18. Provided demand in MW for 4 cases.

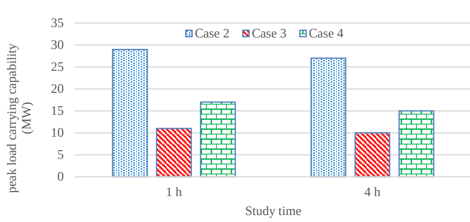

Fig. 19. Increased provided demand (MW) for different cases.

At cases 1, 3, and 4, required spinning reserve amount for each reliability criterion (risk=0.001 for high risk level, risk=0.0001 for medium risk level, and risk=0.00001 for low risk level) has been calculated and is shown in Figs. 4, 5, and 6. As can be seen in the figures, for understudied test system, the results related to high and medium risks are exactly the same. Thus, associated graphs are completely overlapping. It is concluded from these figures, higher reliability criteria (lower risk level), as shown in the figures, lead to a higher value of required spinning reserve.

The amount of spinning reserve is calculated based on the risk criteria in Figs. 4, 5, and 6. This section uses the power system's well-being model to calculate the spinning reserve of electric network that houses a wind park. The probabilities of well-being model states of electric network are shown in Figs. 7, 8, 9, and 10. As can be seen in the figures, when new generation units are added to the power system, the probability of healthy state increases and the probability of risk state decreases. However, the impact of wind farms on the indices of well-being model is more when the initial wind speed is high. Unfortunately, the wind farms with low initial wind speed have negligible impact of the indices of well-being model. It is assumed that probability of a healthy state is greater than 0.985, and risk is lower than 0.0001 in order to calculate the spinning reserve value for various cases. Fig. 11 displays the spinning reserve for four cases. As can be seen in the figures, the value of the required spinning reserve calculated by reliability indices of well-being approach is larger than the value of spinning reserve determined based on risk criteria. However, due to the uncertainty nature of wind units arisen from variation of output power, spinning reserve calculated by well-being approach that combined probabilistic and deterministic indices is more accurate than spinning reserve determined by risk criteria.

In this period, the system's capacity to carry a maximum load in four scenarios is calculated, ensuring that $P_{health} > 0.985$ and $UCR < 0.0001$. In Fig. 12, the outcomes are displayed. In Fig. 13, it is shown how much the system's peak load carrying capacity will increase in four different scenarios if a new production plant is committed. Besides, when the study time of the operation of power network increases, the uncertainty of the generation power plants increases. Thus, the impact of the wind power plants on the peak load carrying capability of the system in the case of high study time is less than values associated with the low study time.

At this stage, the IEEE-RTS integration model for wind farm well-being is chosen. In [21], the IEEE-RTS's characteristics are listed. Four cases are taken into consideration in order to assess how a wind farm affects power system operation studies. Cases 1 and 2 involve the original IEEE-RTS and IEEE-RTS incorporated with a 30 MW traditional production unit with hazard rate of 5 occurrences in one year. Case 3 involves an understudied wind park with small initial wind velocity and Case 4 involves an understudied wind park with high initial wind velocity. Reliability indices of these cases are computed and illustrated in Figs. 14 to 17, respectively. They are probabilities of well-being model states of electric networks related to four cases. As can be seen in the figures, when new generation units are added to IEEE-RTS, the probability of healthy state increases and the probability of risk state decreases. However, the impact of wind farms on the indices of well-being model is more when the initial wind speed is high. Unfortunately, the wind farms with low initial wind speed have negligible impact of the indices of well-being model. In order to ensure that the probability of a healthy state is greater than 0.985 and the probability of a risk state is less than 0.0001, provided demand of electric network associated with four cases is calculated. Fig. 18 presents the outcomes. In addition, Fig. 19 displays the system's increased demand if a new production unit is incorporated IEEE-RTS. The value of the peak load carrying capability calculated by reliability indices of well-being approach is more accurate than the value determined based on risk criteria. However, due to the uncertainty nature of wind units arisen from variation of produced power, the value of peak load carrying capability associated with wind power plants is less than value related to the conventional units. Additionally, the wind farms with low initial wind speed has insignificant impact on the peak load carrying capability of the power system.

5. CONCLUSION

The current research conducts electric network studies at operation phase when wind parks are incorporated to the network through modified PJM methodology. This paper combines the deterministic and probabilistic reliability criteria to establish the appropriate level of spinning reserve due to uncertainty property of wind turbines associated to change in electric produced power of them that is caused by variation in wind speed. To do this, the spinning reserve of electric networks containing renewable sources is calculated using power system's well-being model. For wind farms, a reliability model with multiple states that takes into account both hazard of assembled elements and change in electric produced power of wind units is constructed. The fuzzy c-means clustering methodology is recommended to help model have fewer states. PJM method is used to determine the unavailability of traditional production units with 2 states. But the wind farm model's probabilities for various states are calculated using the matrix multiplication method. The development of the power system's wellbeing mode allows for the determination of the appropriate amount of spinning reserve of wind farm-containing electric network. Probabilities of a healthy, marginal, and risk state are computed in this model. Both deterministic and probabilistic criteria are used in the power system well-being model. The $N-1$ criterion as a deterministic index can be met in a healthy state, i. e. A generation unit's failure cannot cause a load reduction in a healthy state. As a result, the reserve in a healthy state must be greater than the largest generation unit's capacity. Production plants are incorporated to electric network in accordance with well-being approach until both probability of a healthy state is greater than allowable value and risk is less than allowable value. As a result, the size of appropriate spinning reserve in electric network, which includes massive wind farms, is established. Operation studies of RBTS and IEEE-RTS are carried out for examining effectiveness of suggested methodology. Numerical outcomes lead to the conclusion that the risk value decreases by integration of wind farms into electric network. However, wind parks have a smaller impact than conventional power plants because of their unpredictable nature. Additionally, the initial wind speed determines how the wind farms change electric networks indices at operation phase considered reliability criteria. Power system's reliability indices improve more as wind speed increases. Additionally, it is shown by the numerical results related to spinning reserve that electric network's overall health, which includes large-scale wind units, can be used to calculate the spinning reserve.

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