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Research Article

Implementation of Simulation of Possible Short Circuit Fault Situations in Wind Energy Plants by Power Analysis Program

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Abstract

The primary mission of electrical equipment in power systems is to provide life and property safety, and then to ensure uninterrupted and quality energy flow. Therefore, in order to ensure the continuity of an uninterrupted and quality energy flow while designing power plants, it is very important to determine the possible malfunction situations that may occur in energy systems and to calculate the minimum and maximum values of short circuit currents that may occur in the power system for the possible error situations. In order to prevent the energy flow from being interrupted in the system, it is necessary to detect every kind of malfunctions that may occur in the network beforehand, to isolate them from the system or to limit the value of short-circuit currents that may occur in the power flow system to a specified level in case of a malfunction. A generator connected to the medium voltage network is preferred to have neutral grounding so that it does not suddenly switch to island mode. The electrical connection type of the network in renewable power plants has a significant effect on limiting the value of the short circuit current that will occur in case of the most common phase-to-ground short circuit fault in these systems. Neutral grounding that must be done in the system in order to prevent the short circuit current that will occur in case of faults that may occur at weak points of insulation in the system from reaching very dangerous dimensions, ensures that the phase-to-ground fault condition is detected and the value of the fault current that will occur as a result of a short circuit is taken under control. In power flow systems, the grounding system must be selected in accordance with the power flow system to perform these two functions. In this context, a wind power plant consisting of seven wind turbines was first electrically modeled in a power simulation program. Then, possible fault scenarios of the power plant were tried to be determined on the obtained electrical modeling circuit. In case of a short circuit for the detected fault scenarios, the necessary analyzes were made on the system, solutions were presented for the most common phase-to-ground short circuit fault situation in practice with 70% and the value of the fault current was tried to be limited at certain levels. YNyn transformer connection status and 20-ohm ground resistance value obtained in the study were found to form the lowest phase-to-ground short circuit current status.

Keywords: Wind energy plant, Simulation of electrical power systems, Phase-to-ground short circuit fault, Neutral grounding resistance, Power flow quality.

Rüzgâr Enerji Santrallerinde Oluşması Muhtemel Kısa Devre Hata Durumlarının Güç Analiz Programı ile Simülasyonun Gerçekleştirilmesi

Öz

Güç sistemlerindeki elektrik ekipmanlarının öncelikli ana görevi can ve mal güvenliği sağlamak, akabinde ise kesintisiz ve kaliteli bir şekilde enerji akışını sağlamaktır. Dolayısıyla elektrik santralleri tasarlanırken kesintisiz ve kaliteli bir enerji akışını sürekliliğini sağlamak için enerji sistemlerinde ortaya çıkması muhtemel arıza durumlarının neler olabileceğinin belirlenmesi ve oluşması muhtemel hata durumları için güç sisteminde oluşabilecek kısa devre akımlarının minimum ve maksimum değerlerinin hesaplanması çok önemlidir. Sistemde enerji akışının kesintiye uğramaması için şebekede oluşması muhtemel her türlü hatanın önceden tespit edilerek sitemden izole edilmesi ya da hatanın oluşması durumunda güç akış sisteminde oluşturması muhtemel kısa devre akımlarının değerini belirlenen bir seviyede sınırlandırılmak gerekir. Orta gerilim şebekesine bağlı olan bir generatör, aniden ada moduna

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geçmemesi için nötr topraklamasının olması tercih edilir. Yenilebilir enerji santrallerinde şebekenin elektriksel bağlantı şeklinin bu sistemlerde en fazla görülen faz-toprak kısa devre hatası oluşması durumunda oluşacak kısa devre akımının değerinin sınırlandırılması üzerinde çok önemli bir etkisi vardır. Sistemde izolasyonu zayıf noktalarında oluşabilecek hata durumlarında oluşacak kısa devre akımının çok tehlikeli boyutlara ulaşmaması için sistemde yapılması gereken nötr topraklaması faz toprak hata durumunun tespit edilmesi ve kısa devre sonucu oluşacak hata akımının değerinin kontrol altına alınmasını sağlar. Güç akış sistemlerinde söz konusu iki fonksiyonu yerine getirmek için topraklama sisteminin güç akış sistemine uygun şekilde seçilmesi gerekir. Bu kapsamda yedi adet rüzgâr türbininden oluşan bir rüzgâr santrali bir güç simülasyon programında önce elektriksel olarak modellemesi gerçekleştirilmiştir. Daha sonra elde edilen elektrik modelleme devresi üzerinde santrale ait oluşması muhtemel hata senaryo durumları belirlenmeye çalışılmıştır. Tespit edilen hata senaryoları için kısa devre durumunda sistem üzerinde gerekli analizler yapılarak, pratikte % 70 oranında en çok karşılaşılan faz-toprak kısa devre hata durumu için çözüm önerileri sunulmuş ve hata akımının değeri belirli seviyelerde sınırlandırılmaya çalışılmıştır. Yapılan çalışmada elde edilen YNyn transformatör bağlantısı durumu ve 20 ohm topraklama direnci değeri için oluşacak hata akımının en düşük faz-toprak kısa devre akımı durumunu oluşturduğu tespit edilmiştir.

Anahtar Kelimeler: Rüzgar enerji santrali, Elektrik güç sistemlerinin simülasyonu, Faz-toprak kısa devre hatası,, Nötr topraklama direnci, Güç akış kalitesi.

1. Introduction

The neutral grounding of the system, which refers to the connection between the neutral point of the transformer and ground, is of great importance when an unsymmetrical fault occurs in the power system. Failure in power systems cannot be predicted [1], [2], [3]. Therefore, protection equipment protects the system after a malfunction occurs. In order not to interrupt the system, protection elements, any failure that may occur in the network should be limited to a certain level and protection elements that can isolate them from the system as soon as possible should be activated [4]. In this context, whether the protection should be done according to current or voltage is determined according to the nature of the facility.

One of the short circuit faults that may occur in an electrical system is the phase-to-ground short circuit. Network connection types determine the maximum phase-to-ground short circuit current to occur in the network. The widely used application method in electrical installations in our country is to limit the phase-to-ground short circuit current of 154/34,5 kV power transformer to 995 A [5], [6], [7]. However, it is seen in literature reviews that this current is around 360 A in overhead lines and 800 A in underground cables [8], [9], [10]. Apart from this, an increase in fault current values is observed as a result of the increase in the short circuit on the law voltage (LV) side of the system [11]. For this reason, a short circuit fault in LV line should be limited to the minimum level before relay coordination, and then the calculation of relay coordination should be made. In this way, complexity and cost increase in relay coordination will be prevented.

Neutral grounding has two significant functions as long as the large fault currents circulate in the system, which cause the isolation weak points in the system to reach dangerous dimensions; and they can be controlled provided that the ground fault status is detected and the fault current that may occur is within the specified limit values. Therefore, the most suitable grounding system should be selected depending on the characteristics of the power system. In this study, electrical modeling of a wind farm consisting of seven wind turbines was carried out in the Digsilent PowerFactory program [12]. A solution was proposed for the phase-to-ground short circuit fault, which is the most common at the rate of 70% in practice, and the value of the fault current was tried to be reduced [13]. The smallest short circuit current for YNyn transformer connection was tried to be determined by changing the transformer connection type and grounding resistance values that are among the factors affecting the phase-to-ground short circuit analysis. It was foreseen that a facility that will be established by selecting the wrong parameters with this method will be the most correct solution to prevent any possible phase-to-ground fault from switching to island mode.

2. Material and Method

In this study, a single line scheme was created by modeling a wind power plant in Konya Ardıçlı region. Especially in the system with both network and generator, it was assumed that there are only static loads. In order to reveal the existence of the problem, many scenarios were created and short circuit analysis was performed using the DIgSILENT simulation program. For the system whose single line diagram is given in Figure 1, 3 different scenarios were created and simulation was realized. In each scenario, single-phase-to-ground fault was calculated at all terminals by changing the connection types or grounding resistance of the transformer. In this study, a single line scheme was created by modeling a wind power plant in Konya Ardıçlı region. Especially in the system with both network and generator, it was assumed that there are only static loads. In order to reveal the existence of the problem, many scenarios were created and short circuit analysis was performed using the DIgSILENT simulation program. For the system whose single line diagram is given in Figure 1, 3 different scenarios were created and simulation was realized. In each scenario, single-phase-to-ground fault was calculated at all terminals by changing the connection types or grounding resistance of the transformer.

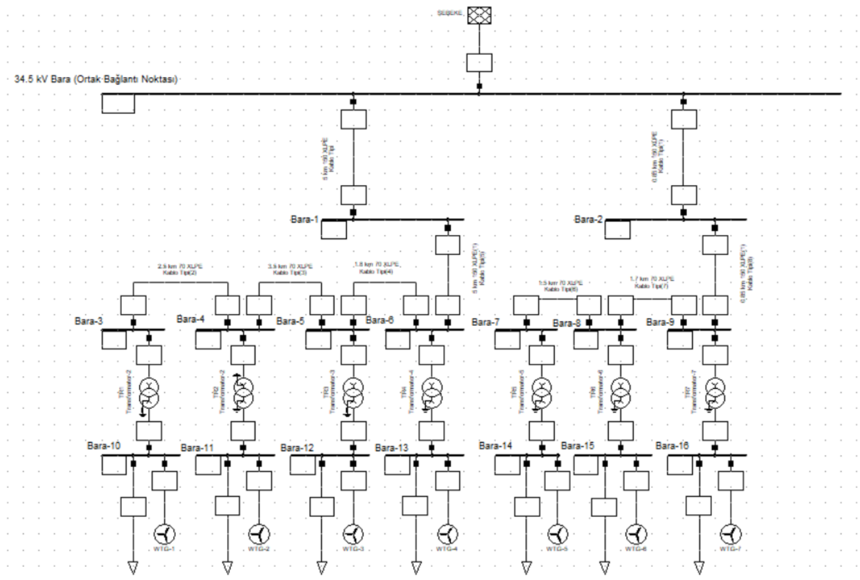

Figure 1. Single line diagram modeled in the DIgSILENT program of the wind plant

Necessary protective measures must be taken to prevent the transformer from switching to island mode. Island mode is the state of operation in connection with the loads it feeds independently by disconnecting from the network so that the transformer is not affected as a result of a fault in the network. Protection methods are important for preventing such a situation and for uninterrupted energy transfer to the network [12], [14].

In renewable energy sources operating connected to the network, the system can also be affected by any fault that may occur. The system may switch to island mode in case of a fault. This situation makes it necessary to make earth fault protection. Accordingly, first of all, the phase-to-ground fault current in the system should be reduced by using a resistor or a Peterson coil. Primarily, taking such a protection measure in the transformer is a more effective method. This situation has been interpreted by finding the most effective method in this scenario. After the fault current is reduced with this method, the fault should be eliminated by making relay coordination according to the connection type of the network.

When the wind turbines are activated and out of service, a phase-to-ground short circuit was created in the system and the output results were recorded. As a result of the calculations, impulse current, initial symmetrical short circuit current, short circuit thermal current and short circuit power values were obtained. The short circuit created was realized for the maximum state according to the IEC 60909 standard. The most important factor affecting the phase-to-ground short circuit analysis is the connection type and grounding resistance of the transformer [15]. In this context, for transformer connection group and grounding resistance;

- Dyn connection and grounding resistance is determined as 0 ohm,
- YNyn connection and grounding resistance is determined as 0 ohm,
- YNyn connection and grounding resistance is determined as 20 ohm.

Phase-to-ground short circuit current and short circuit power were compared.

2.1. Dyn Transformer Connection And 0 Ohm Grounding Resistance

When the output results were examined as Dyn transformer connection part and 0 ohm grounding resistance, very high short circuit currents were observed on the side where the wind turbines were connected. This situation may cause a disruptive effect on the protection elements as well as overheating in the transformers. Table 1 shows the values of all bus bars when the turbines are on and off.

Table 1. Phase-to-ground short circuit values for Dyn transformer connection in the modeled system[12].

Fault Point	**WPP On**		**WPP Off**	
Dyn Connection	Ik'' (kA)	Sk'' (MVA)	Ik'' (kA)	Sk'' (MVA)
WPP 34.5 kV	4.30	85.56	4.18	83.33
Bus-Bar-1	3.63	72.27	3.53	70.32
Bus-Bar-2	4.17	82.97	4.06	80.82
Bus-Bar-3	2.47	49.18	2.40	47.88

Fault Point	WPP On		WPP Off	
Dyn Connection	Ik'' (kA)	Sk'' (MVA)	Ik'' (kA)	Sk'' (MVA)
Bus-Bar-4	2.66	52.89	2.58	51.43
Bus-Bar-5	2.96	58.91	2.87	57.23
Bus-Bar-6	3.13	62.43	3.05	60.67
Bus-Bar-7	3.68	73.32	3.59	71.53
Bus-Bar-8	3.91	77.81	3.81	75.83
Bus-Bar-9	4.04	80.52	3.94	78.44
Bus-Bar-10	28.53	71.62	27.64	69.38
Bus-Bar-11	29.28	73.51	28.38	71.23
Bus-Bar-12	30.37	76.25	29.46	73.96
Bus-Bar-13	30.95	77.70	30.05	75.42
Bus-Bar-14	32.53	81.65	31.69	79.56
Bus-Bar-15	33.09	83.06	32.25	80.95
Bus-Bar-16	33.41	83.86	32.57	81.75

2.2. YNyn transformer connection and 0 ohm grounding resistance

The YNyn connection group was used by changing the transformer connection type, but the phase-to-ground short circuit current that occurs when the ground resistance is kept constant at 0 ohm was examined. Since the connection type was changed to YNyn, the fault will be fed from both the network and the wind turbines. In this situation, protection elements on both sides played an important role.

When the output results were examined, it was observed that results similar to Dyn connection were obtained, but there was a slight increase in short circuit currents on the grid side even though wind power plants were not active. It was observed hat the short circuit currents increase on both the grid and the wind turbine side with the activation of the wind turbines. This situation shows the values in all bus bars in Table 2 when the turbines are not active.

Table 2. Phase-to-ground short circuit values for YNyn transformer connection in the modeled system[12].

Fault Point	WPP On		WPP Off	
YNyn Connection	Ik'' (kA)	Sk'' (MVA)	Ik'' (kA)	Sk'' (MVA)
WPP 34.5 kV	4.38	87.33	4.27	85.02
Bus-Bar-1	3.71	73.83	3.60	71.80
Bus-Bar-2	4.25	84.68	4.14	82.44
Bus-Bar-3	2.52	50.23	2.45	48.87
Bus-Bar-4	2.71	54.06	2.64	52.53
Bus-Bar-5	3.02	60.25	2.94	58.50
Bus-Bar-6	3.21	63.85	3.11	62
Bus-Bar-7	3.75	74.75	3.66	72.89
Bus-Bar-8	3.99	79.39	3.88	77.33
Bus-Bar-9	4.13	82.18	4.02	80.01
Bus-Bar-10	35.25	14.04	34.77	13.85
Bus-Bar-11	36.04	14.36	35.57	14.17
Bus-Bar-12	37.19	14.81	36.73	14.63
Bus-Bar-13	37.79	15.06	37.35	14.88
Bus-Bar-14	38.89	15.49	38.53	15.35
Bus-Bar-15	39.46	15.72	39.10	15.58
Bus-Bar-16	39.79	15.85	39.44	15.71

2.3. YNyn transformer connection and 20 ohm grounding resistance

When the transformer connection type is YNyn and the grounding resistance is 20 ohm, the phase-to-ground short circuit current was examined. Here, the importance of grounding resistance emerged and short-circuit fault currents decreased with the grounding resistance of 20 ohm. This situation shows the values in all bus bars in Table 3 when the turbines are on and off.

Table 3. Phase-to-ground short circuit values for YNyn transformer connection and 20 ohm grounding resistance in the modeled system[12].

Fault Point	WPP On		WPP Off	
YNyn Connection	Ik'' (kA)	Sk'' (MVA)	YNyn Connection	Ik'' (kA)
WPP 34.5 kV	4.38	87.33	4.27	85.02
Bus-Bar-1	3.71	73.83	3.60	71.80
Bus-Bar-2	4.25	84.68	4.14	82.44
Bus-Bar-3	2.52	50.23	2.45	48.87
Bus-Bar-4	2.71	54.06	2.64	52.53
Bus-Bar-5	3.02	60.25	2.94	58.50
Bus-Bar-6	3.21	63.85	3.11	62
Bus-Bar-7	3.75	74.75	3.66	72.89
Bus-Bar-8	3.99	74.17	3.88	77.33
Bus-Bar-9	4.13	82.18	4.02	80.01
Bus-Bar-10	0.02	0.01	0.02	0.01
Bus-Bar-11	0.02	0.01	0.02	0.01
Bus-Bar-12	0.02	0.01	0.02	0.01
Bus-Bar-13	0.02	0.01	0.02	0.01
Bus-Bar-14	0.02	0.01	0.02	0.01
Bus-Bar-15	0.02	0.01	0.02	0.01
Bus-Bar-16	0.02	0.01	0.02	0.01

A significant decrease was observed in the fault currents in the bus bars to which the wind turbines were connected, with the use of grounding resistance in these three different situations made in the phase-to-ground short circuit. It was revealed that the use of grounding resistance in wind turbines included in the system is necessary for protection. The graphic showing how the fault current and short circuit power changes with the change of the connection type and grounding resistance in the phase-to-ground short circuit fault is shown in Figure 2.

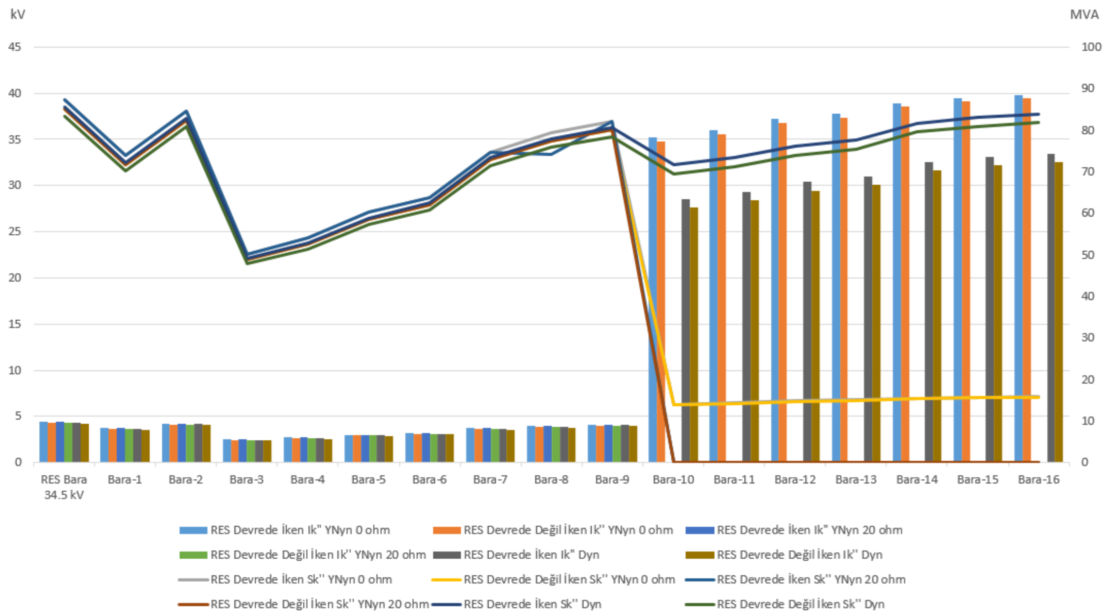

Figure 2. Phase-to-ground short circuit current and short circuit power graph

3. Results and Discussion

3.1. Result

These problems can be solved with the help of modern relays, but it is a more complex and costly method than this method. For this reason, in order to provide uninterrupted and high-quality energy, phase-to-ground short circuit faults will be limited with this method and the most probable fault in practice will be prevented.

3.2. Discussion

In this study, methods were investigated to prevent the generator from being affected by this fault and switching to island mode in the phase-to-ground short circuit that may occur in the system when the generator operates in parallel with the network. Accordingly, first of all, the phase-to-ground fault current that may occur in the system should be limited to a certain value by using a neutral grounding resistance or a Peterson coil. The short circuit current has an active and a reactive component. Therefore, the active component of the short circuit current can be limited by the resistance and the reactive component by the Peterson coil to be connected in series or parallel to the resistance. It is more effective to use such a neutral grounding medium voltage networks where generators are connected. Then, the fault should be eliminated by the relay coordination to be established according to the feature of the system and whether it is a radial or ring network.

4. Conclusions and Recommendations

In this study, the wind power plant with seven turbines was modeled electrically and a short circuit analysis was performed for three different scenarios that are likely to be encountered during the operation of the plant. In case the step-up power transformers, which are included in the system as a solution for the phase-to-ground fault encountered with a high rate of 70% as short circuit fault in practice, are connected as YNyn and a Peterson coil of 20 ohm is connected to the secondary part, it is concluded that the phase-to-ground short circuit current can be reduced from the level of 30 kA to the level of 0.02 kA. The low value of the short circuit current, which is tried to be shown by the study, played an important role in reducing investment costs by making the switchgear to be used during the establishment of the facility more economical.

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