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Some Prognostic and Diagnostic Methods for Determining Wind Turbine Failures - A Review

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ABSTRACT

Wind power situated in renewable energy resources has been supported by the world in recent years. Especially Number of wind farm is increasing because of the high energy production capacity day by day. However, maintenance costs in wind turbines are high because of the cost of production, logistics, installation, phase consistence and control etc. Prognostics are applied to develop high-quality design with a cost-effective maintenance strategy. In this study the basic faults of occurring in wind turbines were reviewed and prognostic approaches were discussed. This review focused on blade failures, generator failures, gearboxes and yaw system failures. Moreover, in this study were seen that technical prognez is a rapidly advancing field in engineering.

Keywords: Wind turbines, Failures of wind turbine, Prognostic approaches, Technical prognez

Rüzgar Türbini Arızalarını Belirlemek İçin Bazı Prognostik ve Diagnostik Metodlar

ÖZET

Yenilenebilir enerji kaynakları arasında yer alan rüzgar enerjisi son yıllarda dünya tarafından desteklenmektedir. Özellikle yüksek enerji üretim kapasitesinden dolayı rüzgar çiftliklerinin sayısı gün geçtikçe artmaktadır. Fakat rüzgar türbinlerinde bakım maliyetleri; üretim maliyeti, lojistik, tesisat, faz tutarlılığı ve kontrol vb. nedenlerden dolayı yüksektir. Prognostikler, uygun maliyetli bir bakım stratejisi ile yüksek kaliteli tasarımı geliştirmek için uygulanmaktadır. Bu çalışmada rüzgar türbinlerinde meydana gelen temel hatalar gözden geçirilmiş ve prognostik yaklaşımlar tartışılmıştır. Bu inceleme bıçak arızaları, jeneratör arızaları, dişli kutuları ve yaw sistemi arızaları üzerine odaklanmıştır. Ayrıca, bu çalışmada teknik prognezin mühendislik alanında hızla ilerleyen bir alan olduğu görülmüştür.

Anahtar Kelimeler: Rüzgar türbinleri, Rüzgar türbini arızaları, Prognostik yaklaşımlar, Teknik prognoz

1. Introduction

After the Industrial Revolution, amounts of fossil fuels i.e. coal, oil, gasoline and natural gas in energy production or consumption have been started to use. This situation

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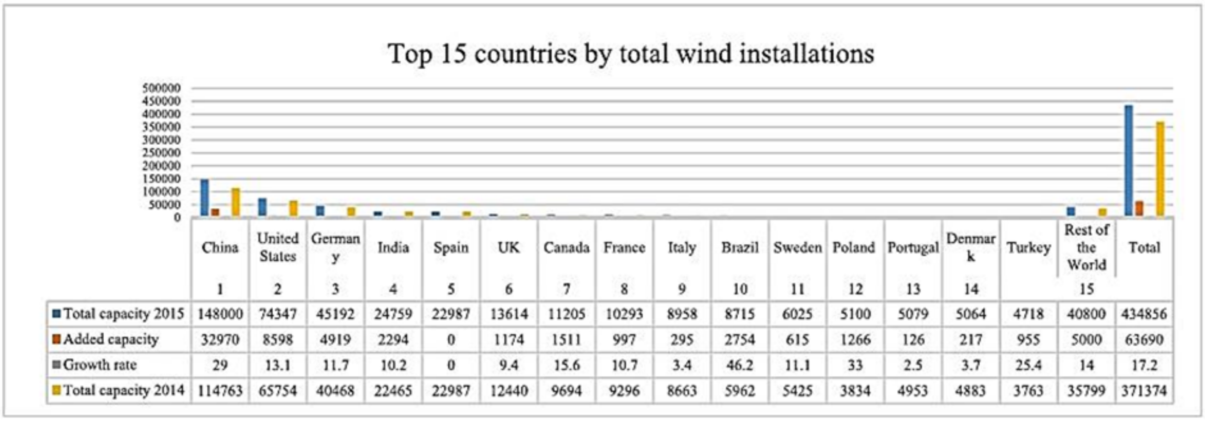
caused global warming and climate change. Especially CO2 has an important role in global warming. In addition, industrialization and population growth have forced countries to seek new sources. In this context, many studies are being carried out in the field of renewable energy. If the average annual tendency for increase does not change, the International Energy Agency (IEA) expects a 90% increase in the world energy demand by 2035 (Göktürk and Tokuç, 2017).

Wind energy is the most important energy source between renewable energy sources. Because wind energy is inexhaustible, abundant and renewable energy source. The installation of wind energy has increased worldwide to a cumulative installed capacity of 432 GW, most of which is located in China (145 GW), the United States (74 GW) and Germany (45 GW) (Langer et.al., 2017). Top 15 countries by total wind installations is shown in figure 1 (Sagbansua and Balo, 2017)



	China 1	United States 2	Germany 3	India 4	Spain 5	UK 6	Canada 7	France 8	Italy 9	Brazil 10	Sweden 11	Poland 12	Portugal 13	Denmark 14	Turkey 15	Rest of the World	Total
Total capacity 2015	148000	74347	45192	24759	22987	13614	11205	10293	8958	8715	6025	5100	5079	5064	4718	40800	434856
Added capacity	32970	8598	4919	2294	0	1174	1511	997	295	2754	615	1266	126	217	955	5000	63690
Growth rate	29	13.1	11.7	10.2	0	9.4	15.6	10.7	3.4	46.2	11.1	33	2.5	3.7	25.4	14	17.2
Total capacity 2014	114763	65754	40468	22465	22987	12440	9694	9296	8663	5962	5425	3834	4953	4883	3763	35799	371374

Figure. 1. Top 15 countries by total wind installations (Sagbansua and Balo, 2017)

Wind farms satisfy 2.3% of the electricity needs of the world. The construction of wind farms proceeds rapidly worldwide. According to the 2020 improvement scenario, wind energy could be supply 2.600 TWh. This value is approximately % 12.3 of global electricity supply (Soua et al., 2013).

Commonly horizontal and vertical axis WT's are used in wind energy system. Therefore life, efficiency, availability and reliability performance of turbine should be improved that is necessary. In particular, the reliability of the design is the most important feature. During design essential strategies and techniques must be developed to define errors and weaknesses encountered before and for reduction them to minimum. From this point forth in this study; the failures encountered in the horizontal axis WT and prognostic methods for detecting are presented.

2. The General Structure of WT's

WT's are a kind of electromechanical systems. These systems convert kinetic energy of wind into electrical power. This energy conversion is classified into two groups. Firstly, the kinetic energy of the wind that is captured by blades is converted mechanical power. Then, the generator converts the mechanical power into electrical power in Figure 2.

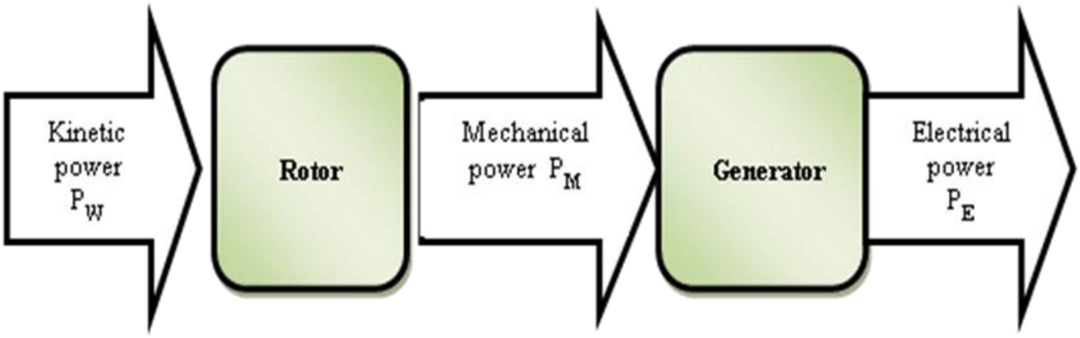


Figure 2. Energy conversion flow on wind turbines (Daneshi-Far et al., 2010)

Most of the WTs have three blades and a horizontal axis including the major components as shown in Figure 3.

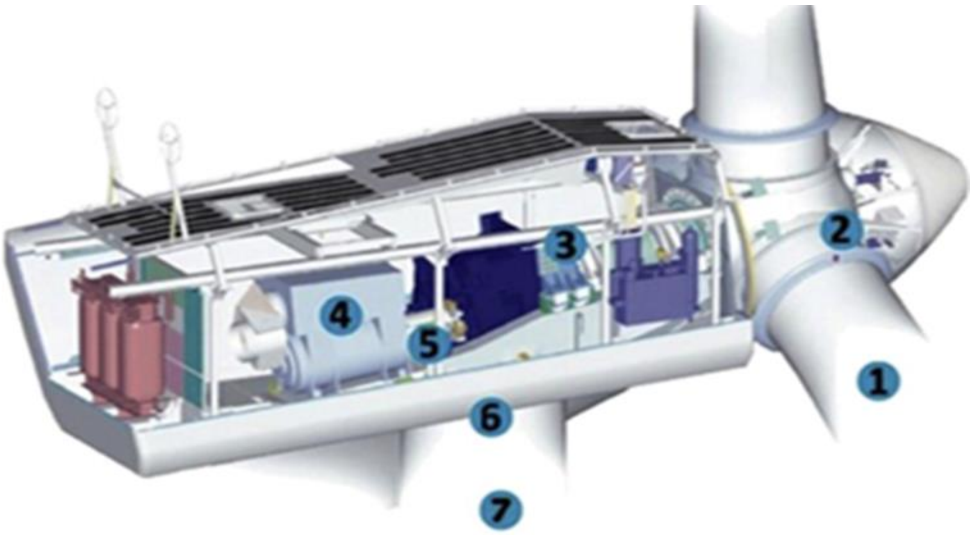


Figure 3. Wind turbine components. (1) blades, (2) rotor, (3) gearbox, (4) generator, (5) bearings, (6) yaw system and (7) tower (Liu et al.,2015)

Almost all of the component parts of the turbine needs to be maintained. This situation may occur to be diversity and poliferation on the faults of WTs. Blades, gearbox and generator are very important components for WT. Because these parts are more exposed to corrosion. As a result of this corrosion, replacement costs of wind turbine blades, the gearbox and generator are up to 15-20% of the cost of new turbines (Eker, 2009).

3. Typical Failures of WT's

The most common fault components of WT are blades, generator, yaw system and gear box. These failures lead to extra maintenance costs and precautionary approach in physical design. Failures and cause-effect relationships of these parts are classified as follows:

3.1. General blade failures

Reliability of WT blades is important. Blades harvest total kinetic energy possessed by the wind and are exposed to stochastic effects and fluctuations (Harman, 2014). However, they work in wind, rain, snow and other challenging environment. This stringent conditions are encountered as the problems that are needed to be solved in the design stage of blades. The delicate balance is needed between structural strength and aerodynamic properties.

First starting point in the occurence of blade faults starts with removed from the mold and transported from the factory. Therefore blade surface cracks and composed of blade fractures occur (Yonggang et al., 2016). Minor damages could occur in blade root connection during the conveyance. This can mostly be triggered during montage. Climatic conditions and aerodynamic loads affect in the direction to increase this. Additionally, the blades of WT is selected largely to capture the wind. This leads some faults on the blades, hub and blades corrosion, crack, the rotor imbalance, and serious aeroelastic deflections (Ma et al., 2012). As a result of all these, many accidents were encountered in the wind farms about blade fracture (Caithness, 2012).

Therefore, many countries are taking some arrangements for prohibiting wind farms being established near the civil settlements such as The United States, Germany etc. (PEPA, unpublished).

3.2. Generator failures

Generally AC generator that converts the mechanical rotational energy into electrical energy is used in WTs. Many kinds of generator are used in wind energy system such as synchronous generator, Alternating Current (AC) excited generator, brushless doubly-fed generator, cage induction generator, etc. Especially the double-fed asynchronous generator is more preferred (Abadi et al., 2014). The research on faults of the wind energy conversion system shows that %8.9 of WT are becoming unusable because of the generator failures (Ribrant and Bertling, 2007).

Generator failures mainly include mechanical failures, electrical failures and cooling system failures. The mechanical failures are mostly rotor failures, deflection from the axis and bearing failures (Nandi et al., 2005). Deflections from the axis could occur three different species as deflection from static axis, deflection from dynamic axis and deflection from static-dynamic axis. Approximately %80 of mechanical failures are due to deflection from axis (Faiz and Ojaghi, 2009). Deflection from axis can be caused by environmental and mechanical constraints as gear system, blade movement etc. (Tavner et al., 2006). Bearing failures constitute %40 of all machine failures (IAS Motor Reliability Working Group, 1985). This profile is a larger proportion than %45 for WTs (Watson et al., 2010). Bearing failures are composed of inner ring, outer ring, lattice and ball failure (Doğan, 2012). The coil failures occur as a result of mechanical, electrical and environmental stresses.

3.3. Yaw system failures

The yaw system is system for controlling the tower turns. The nacelle rotation is controlled via yaw control systems by using angle of blades. This system contains a yaw motor, gearwheels, bearings and brakes. Therfore the yaw system malfunctions are examined in three groups: electrical failures, hydraulic failures and mechanical failures. The most common yaw drive failures are tooth face abrasions, which are caused by particle permeation or a lack of Grease (Lin et.al., 2016). Other yaw drive failures include gearbox failures and yaw bearing failures (Zhou, 2012). The hydraulic failures consist of hydraulic oil leakage and unstable braking forces caused by hydraulic component failures. Electrical failures include yaw counter failures, cable abrasions, drive motor failures and angle transducer failures (Lin et.al., 2016).

3.4. Gearbox failures

The wind energy is transfered to generator by using gearbox. A variable ratio gearbox increases aerodynamic efficiency (Hall John and Dongmei 2012). Generally, gearboxes are designed in parallel shaft structure for the transmission ratio and high input speed.

The factors that cause deterioration of a gearbox are;

- Misalignment or mis-assembly
- Vibrations
- Higher loads
- Declination from optimal operating temperatures
- Poor lubrication conditions
- Presence of water or metal content in the oil
- Reduced material strength due to thermal stress or corrosion

4. Prognostic and Diagnostic

In recent years, many studies have been done about prognostic methods. Prognostic means “the ability to perform a reliable and sufficiently accurate prediction of the remaining useful life of equipment in service (Lebold and Thurston 2001). Prognostic is defined as “a prediction of machine’s the future state” by Byington (Byington et al., 2002). Prognostic methods are divided into 3 groups (Jardine et al., 2006), (Heng et al., 2009), (Vachtsevanos et al., 2007): Model based (MB), Based on experience and Data driven. The steps of prognostic process is another charateristic of prognostic (Guillaume, 2014). Generic prognostic steps have been proposed (Voisin et al., 2010). Initialize Condition Mode and Performances, Project and Remaining Useful Life. Diagnostic process means localization, the detection and the cause of failure/breakdown (Maintenance Terminology, 2001), (Isermann, 1984), (Zhang and Jiang, 2008).

The diagnostic process has two main characteristics. The first one is the type of methods and the other is the parts. The methods are Quantitative model-based, Qualitative model-based and Process history based. The parts are respectively data acquisition, data manipulation, condition monitoring and fault diagnosis (Venkat and Raghunathan, 2003), (I.S.O., 2003).

4.1. Model-based prognostic

Mathematical models could be developed from system's failures for Model-based prognostics (Lıang et al., 2010). Mathematical models are used to estimate deterioration that may occur in the future (Luo et al., 2008), (Chelidze and Cusumano, 2004). Models are divided into two groups: One of them is quantitative. The other is qualitative. The quantitative model defines input-output of system by using analitic methods. Qualitative models determines qualitative functions also (Vachtsevanos et al., 2006). Real applications are limited in this area. Therefore; it is very complex and sensitive approach. For suspension system, MB approach has been created. Especially quantitative model consists two parts: parameter estimation, and output observer based approaches. Bayesian network and particle filter approach are commonly used in most technique for estimation (Saha et al., 2009). Kalman filter is generally preferred to evaluate the differences between the actual and the estimated outputs (Bouthaina et al., 2014). The advantage of MB approach is the results that obtained are more sensitive. Also because of the mathematical MB, the amount of sensed parameters can be reduced and some parameters can be directly determined from a model.

4.2. Based on experience prognostic

The methods used for Based on Experience Prognostic, work with probabilistic and stochastic models by using data and information are obtained during the operation of the industrial system (Keller et al., 1982), (Groer, 2000). In some cases, to determine the full dynamic model by using differential equations for system inputs and outputs may not be practical.

Therefore probabilistic methods are highly effective in this approach. This method doesn't need more detail as MB techniques. Because the necessary information for the prognosis is found in various probability density function not in the dynamic differential equations. Weibull and exponential distribution for probabilistic methods are most common in distribution functions. The time-dependent failure rate is called the "bathtub curve" and is still prevalent in the literature (Krupa, 2012).

4.3. Data driven prognostic

This approach uses reliable behavior patterns. The collected data are processed to obtain the corresponding features. Then, these data are used to calculate parameters models. The main methods used for this aim; signal analysis (FFT, auto-regressive models, filters, etc.), graphical models (Hidden Markov model, Bayesian networks), decisions trees and fuzzy rule based systems, self-organizing feature maps, statistical methods (least squares and canonical variate analysis, linear and quadratic discriminant, static and dymanic principle component) to black-box methods based on artificial neural networks (radial basis functions, probabilistic neural networks, multi-layer perceptrons) (Luo et al., 2003), (Schwabacher, 2005). Graphical Comparison of prognostic methods are shown in Figure 4.

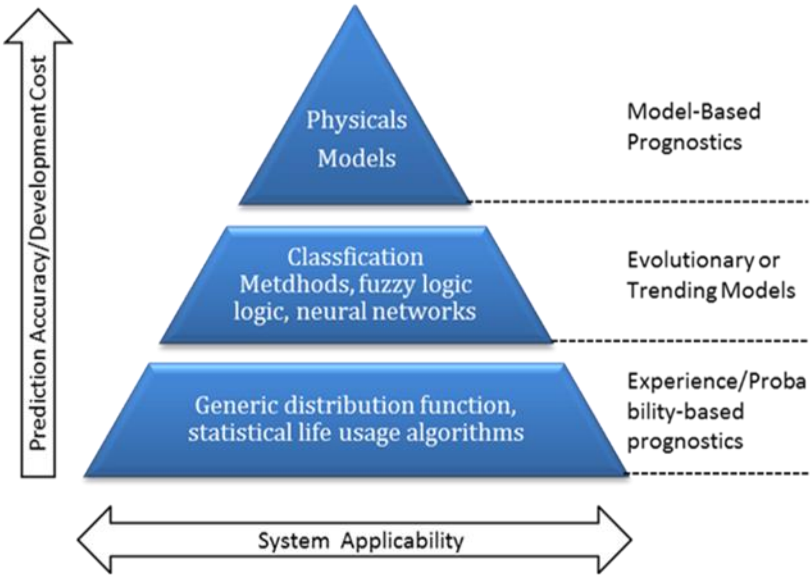


Figure 4. Graphical Comparison of prognostic methods (Vachtsevanos et al., 2006)

5.Diagnosis and Prognosis Approaches of WT's Failures

5.1. Blade failure diagnosis

Aeroelastic considerations are very important for modern turbine design. Especially in the WT that has a rotor diameter, fluid-structure interaction analysis of WT blades comes to the foreground (Lee Jong et al., 2012).

Gomez Munoz et.al. have prepared a paper that presents a novel fault detection and diagnosis system that combines ultrasonic techniques with Wavelet transforms for detecting ice on the blades. They have applied three scenarios: at room temperature; the frozen blade without accumulation of ice, and; the frozen blade with accumulation of ice on its surface.Especially they have preferred Morlet wavelet transformation (Gomez Munoz et.al., 2017).

Joshuva et.al. have classified an algorithm-based vibration signal for evaluation of wind turbine blade conditions. Because various vibration forces may cause damage to the blades. They have developed two models using data modeling techniques from the obtained vibration data. They obtained that only the functional tree leaves (FT_Leaves) algorithm can be used practically to monitor the state of the wind turbine blade (Joshuva and Sugumaran, 2017).

Sierra Perez et.al. have installed a fiber optic sensor into the blade during the production of the blade. For strain detection two different FOS technologies have been placed on the blade. They have used Hierarchical nonlinear principal component analysis technique. The results have showed that every damages could be prognosed by using different sensing techniques (Sierra Perez et.al., 2016).

Lee et.al. have proposed a deflection monitoring system that uses a wireless networking system with strain sensors for wind turbine blades. A wireless monitoring system have been installed on to a 300W scale wind turbine,and the vibration response of a rotating blade have been monitored. They have found that working with the SCADA system is more beneficial for operators (Lee et.al., 2017)

5.2. Generator failure diagnosis

Zhan et.al. have used Kurtosis based convex optimization technique to diagnose bearing faults. The study has been shown that the computational complexity of KurWSD is similar to fast Fourier transformation. They found that the KurWsd algorithm is necessary for many complex industrial applications (Zhang et.al., 2016).

Stability analysis are executed to compare the dynamic characteristics of wind farms. Especially the spectral analysis methods are commonly preferred in winding faults for double feed asynchronous generators that are used in WTs (Dicorato et al., 2012).

Bi et.al. have aimed to propose a new pitch fault detection procedure using performance curve (PC) based NBMs. The advantage of the proposed approach is that it can be improved by using the specifications of the wind turbine generators. A second advantage is that training data is unnecessary prior to application of the system. They could easily explain the behavior of the wind turbine during the fault conditions with this approach (Bi et.al., 2017).

Fast fourier transform method and the wavelet transform are used to to detect winding faults FFT and wavelet analysis were used by Watson et al. for detecting generator rotor misalignment and bearing faults (Watson and Xiang, 2006).

Djeziri et. al. have proposed a hybrid system for estimating the life of turbine systems. They have taken into account multiple breakdown prognoses for this. They first created a physical model and made structural analysis. By placing sensors, they clustered normal operation and faulty situations. They evaluated the results with prognosis horizon and relative accuracy measures (Djeziri et.al. 2017).

A wavelet-based adaptive filter was used by Yang et al for electrical and mechanical faults diagnosis (Yang et al., 2008). Amirat et al. made fault detection by using the Hilbert transformation of the motor current data (Amirat et al., 2010).

Model-based diagnostic methods were also used in winding failure diagnosis. Bennouna et al. used model-based approach. This approach has an advantage to determine condition of physical parameters in the generators (Bennouna et al., 2005), (Bennouna et al., 2007), (Bennouna et al., 2009). Durovic et al. studied different model-based diagnosis on double-fed induction generator WT (Durovic et al., 2009). A dynamic state space model can be created to determine the short circuit failures occurred in the stator windings (Lu et al., 2011). Wilkinson et al. used shaft speed data to detect turn-to-turn faults (Wilkinson et al., 2007).

Ogidi et.al. have used fault detection techniques to find two common faults in the generator (static eccentricities and interturn short circuit faults). Parametric spectral estimation technique was applied as an alternative to the Fourier transform to process the fault signatures. Thus the non-stationarity of the signals was removed. The results are expected to contribute to the status monitoring standards of wind turbine generators (Ogidi et.al., 2016).

In addition, artificial neural networks and fuzzy logic techniques are also used. Wang and Guo used a neural network based model for the model of double-fed induction generator WT (Wang and Guo, 2007).

5.3. Gearbox and yaw system failure diagnosis

Teng et.al. have used using complex wavelet transform for failure analysis of wind turbine gearbox. They converted the signal to a different scale using complex wavelet transform and obtained a multi-scale enveloping spectrograp and have detected the crack fault in inner race of rear bearing (Teng et.al., 2016).

Vibration analysis is a commonly used method in the diagnosis of faults in the transmission chain system. Vibration spectrum analysis has been studied by Huang et al. They analysed gearbox fault classification using wavelet neural network (Huang et al., 2008).

Acoustic emission techniques (AE) are widely used especially in the detection of fault location. Zhang et.al. have proposed a method to determine the fault gear in the wind turbine gearbox. They have determined the exact arrival time of the AE signals with this method. This method has offered several advantages to fault localization in complex structures (Zhang et.al. 2017). For health monitoring Lekou et al. revealed a study using AE, rotating speed data, vibration and temperature (Lekou et al., 2009).

Time-frequency method is used in the detection of gear cracks. Ming Liang introduced an iterative atomic decomposition method (Feng and Liang, 2014) to deal with complex signal analysis for WT planetary gearbox fault diagnosis. Baoping Tang introduced a fault diagnosis method based on manifold learning and Shannon wavelet support vector machine (Tang et al., 2014).

Ossai et.al. have developed a Markov approach to detect the risk of malfunction of wind turbine components such as gearbox, rotor hub and mechanical brakes This work has shown that gearbox is an important part of wind turbines to prevent interruption (Ossai et.al. 2016).

Parra and Vicuna have used the phenomenological and lumped-parameter models to examine the frequencies of gearbox vibrations under non-fault and fault conditions. Results of both models are not directly comparable because the phenomenological model provides the vibration on a fixed radial direction,lumped-parameter model provides the vibrations on the basis of a rotating reference frame fixed to the carrier. To overcome this situation, they have presented a function to decompose the lumped-parameter model solutions to a fixed reference frame (Parra and Vicuna , 2017).

SCADA measurements have been studied with a fault detection method by Kim et al. Beside they used clustering technique and components analysis to diagnose gearbox faults (Kim et al., 2011). Graham Li et al. were studied failure of yaw systems for WT with a combine system (Graham et al., 2013).

6. Conclusions

In this paper; failures of WTs and prognosis-diagnosis methods are reviewed. At the beginning of the study; structure of WT's components and failures are determined. Then some research results were analyzed on prognosing-diagnosing WT components.

This article focused on three components of the wind turbine. Blade failures, generator failures and gearbox-yaw system failures and diagnosis. It has been seen that wavelet transform is most preferred in fault diagnosis of all three components. It is also preferred in SCADA systems. Various data mining algorithms have been used in many studies. But Experimental measurement devices are less frequent.

Technical prognez that is still developing was observed as new a branch of engineering. Quantitative models are depends on the load conditions. Qualitative models have the ability to control the behavior of sub-systems. Diagnostic and Prognostic system that may be combined in various ways has been detected. Model-based fault came to the fore.

7. References

Abadi, M.B., Cruz, S.M.A., Gonçalves, A.P., Gonçalves, P.F.C., Mendes, A.M.S., Ribeiro, A., Silva, F. 2014. Detection of Stator and Rotor Faults in a DFIG Based on the Stator Reactive Power Analysis. IEEE Trans. Industrial Electronics, 2037-2043.

Amirat, Y., Choqueuse, V., Benbouzid, M.E.H. 2010. Wind turbines condition monitoring and fault diagnosis using generator current amplitude demodulation. Proceedings of IEEE Energy Conference and Exhibition (EnergyCon), 310-315.

Bennouna, O., Heraud, N., Camblong, H., Rodriguez, M. 2005. Diagnosis of the doubly-fed induction generator of a wind turbine. Wind Engineering, 29(5), 431-448.

Bennouna, O., Heraud, N., Rodriguez, M., Camblong, H. 2007. Data reconciliation and gross error detection applied to wind power. Proceedings of the Institution Mechanical Engineers, Part I: Journal of Systems and Control Engineering, 221(3), 497-506.

Bennouna, O., Héraud, N., Camblong, H., Rodriguez, M., Kahyehl, M.A. 2009. Diagnosis and fault signature analysis of a wind turbine at a variable speed. Proc. Inst. Mechanical Engineers, Part O: Journal of Risk and Reliability, 223(1), 41-50.

Bi, R., Zhou, C., Hepburn, D.M. 2017. Detection and classification of faults in pitch-regulated wind turbine generators using normal behaviour models based on performance curves. Renewable Energy, 105, 674-688.

Bouthaina, A., Diana, F., Moamar, S.M., Houari, T., Bruno, F., Nicolas, G. 2014. Fault Diagnosis Methods for Wind Turbines Health Monitoring: a Review. European Conference Of The Prognostıcs and Health Management Socıety, 1-8.

Byington, C.S., Roemer, M.J., Kacprzynski, G.J., Drive, T.P. 2002. Prognostic Enhancements to Diagnostic Systems for Improved Condition-Based Maintenance. 1. In Aerospace Conference Proceedings, 6, 2815-2825.

Caithness Wind Farm Information Forum. 2012. Summary of Wind Turbine Accident data to 31 December 2011.

Chelidze, D., Cusumano, J. 2004. A dynamical systems approach to failure prognosis. Journal of Vibration and Acoustics, 126(1), 2 – 8.

Daneshi-Far, Z., Capolino, G.A., Henao, H. 2010. Review of failures and condition monitoring in wind turbine generators. in Proceedings XIX International Conference on Electrical Machines - ICEM 2010; Rome, 1-6.

Dicorato, M., Forte, G., Trovato, M. 2012. Wind farm stability analysis in the presence of variable-speed generators. Energy, 39(1), 40–47.

Djeziri, M.A., Benmoussa, S., Sanchez, R. 2017. Hybrid method for remaining useful life prediction in wind turbine systems. Renewable Energy, https://doi.org/10.1016/j.renene.2017.05.020.

Doğan, Z. 2012. Ayrıklaştırma Yöntemleri ve Yapay Sinir Ağı Kullanarak Asenkron Motorlarda Arıza Teşhisi. Doktora Tezi, Marmara Üniversitesi Fen Bilimleri Enstitüsü, İstanbul, 168s, (in Turkish).

Durovic, S., Wiiliamson, S., Yang, W., Tavner, P. 2009. Condition monitoring artifacts for detecting winding faults in wind turbine DFIGs. in Proc. EWEC 2009, Scientific Track – Wind Turbine Electrical Systems & Components, Marseille, France, 16-19.

Eker, B. 2009. Maintenance engineering applications in wind turbines. Engineer and Machine, 50(598),66-69.

Faiz, J., Ojaghi, M. 2009. Different Indexes for Eccentricity Faults Diagnosis in Three- phase Squirrel-cage Induction

Motors: A Review. Mechatronics, 19(1),2–13.

Feng, Z., Liang, M. 2014. Complex signal analysis for wind turbine planetary gearbox fault diagnosis via iterative atomic decomposition thresholding. Journal of Soundand Vibration, 333(20), 5196–5211.

Graham, L., Susumu, T., Takanori, U. 2013. Application of CFD for Turbulence Related Operational Risks Assessment of Wind Turbines in Complex Terrain. EWEA 2013; Conference Proceedings, Feb.

Gomez Munoz, C.Q., Jimenez, A.A., Marquez F.P.G., 2017. Wavelet transforms and pattern recognition on ultrasonic guides waves for frozen surface state diagnosis. Renewable Energy, http://dx.doi.org/10.1016/j.renene.2017.03.052, 0960-1481

Groer, P. 2000. Analysis of time-to-failure with a weibull model. Proceedings of the Maintenance and Reliability Conference 2000; 59.01 - 59.04.

Göktürk, G., Tokuç A., 2017. Vision for wind energy with a smart grid in Izmir, Renewable and Sustainable Energy Reviews, 73, 332–345.

Guillaume, B. 2014. Some Diagnostic and Prognostic Methods for Components Supporting Electrical Energy Management in a Military Vehicle. European Conference of The Prognostıcs and Health Management Socıety, ISSN 2153-2648, 1-4.

Hall John, F., Dongmei, C. 2012. Performance of a 100kW wind türbine with a Variable Ratio Gearbox. Renewable Energy, 44, 261–6.

Harman, J. 2014. Wind Turbine Optimization. presented at Maintenance and Repair Summit Toronto, 8-9, Canada, Dec.

Heng, A., Zhang, S., Tan, A.C., Mathew, J. 2009. Rotating machinery prognostics: State of the art, challenges and opportunities. Mechanical Systems and Signal Processing, 23(3), 724–739.

Huang, Q., Jiang, D., Hong, L., Ding, Y. 2008. Application of wavelet neural networks on vibration fault diagnosis for wind turbine gearbox. Lecture Notes in Computer Science, 5264 LNCS, n PART 2, Advances in Neural Networks, 313-320.

IAS Motor Reliability Working Group. 1985. Report of Large Motor Reliability Survey of Industrial and Commercial Installations: Part I and Part II. IEEE Transactions on Industry Applications, 21(4), 853 – 872.

Isermann, R. 1984. Process Fault Detection Based on Modeling and Estimation Methods A Survey. Automatica, 20 (4), 387-404.

I. S. O. Condition monitoring and diagnostics of machines ISO. 13374-1. Standard. 2003.

Jardine, A.K., Lin, D., Banjevic, D. A. 2006. Review on machinery diagnostics and prognostics implementing condition-based maintenance. Mechanical Systems and Signal Processing, 20(7), 1483 – 1510.

Joshuva, A., Sugumaran, V. 2017. A data driven approach for condition monitoring of wind türbine blade using vibration signals through best-first tree algorithm and functional trees algorithm:A comparative study. ISA Transactions 67, 160–172.

Keller, A., Perera, U., Kamath, A. 1982. Reliability analysis of cnc machine tools. Reliability Engineering, 3(6), 449 – 473.

Kim, K., Parthasarathy, G., Uluyol, O., Foslien, W., Sheng, S., Fleming, P. 2011. Use of SCADA data for failure detection in wind turbines. In International Conference on Energy Sustainability, 2071-2079.

Krupa, M. 2012. Methods of Technical Prognosis – Review. IX Internatıonal Congress Machines, Technologies, Materials, September 19 –21 2012 Varna, Bulgaria.

Langer, K., Decker, T., Menrad, K. 2017. Public participation in wind energy projects located in Germany: Which form of participation is the key to acceptance?, Renewable Energy, 112, 63-73.

Lebold, M., Thurston, M. 2001. Open standards for condition-based maintenance and prognostic systems. presented at MARCON 2001, 5th AnnualMaintenance and Reliability Conference, Gallinburg, USA.

Lee Jong, W., Lee Jun, S., Han Jae, H., Shin Hyung, K. 2012. Aeroelastic analysis of wind turbine blades based on modified strip theory. J. Wind Eng. Ind. Aerodyni, 110, 62–69.

Lee, K., Aihara, A., Puntsagdash, G., Kawaguchi, T., Sakamoto, H., Okuma M. 2017, Feasibility study on a strain based deflection monitoring system for wind turbine blades. Mechanical Systems and Signal Processing 82, 117–129

Lekou, D.J., Mouzakis, F., Anastasopoulos, A., Kourousis, D. 2009. Emerging techniques for health monitoring of wind turbine gearboxes and bearings. in Proceedings EWEC 2009; Scientific Track – Operation and Maintenance, Marseille, France, Mar. 16-19.

Lıang, T., Decastro, J., Kacprzynskı, G., Goebel, K., Vachtsevanos, G. 2010. Filtering and prediction techniques for model-based prognosis and uncertainty management. Prognostics and Health Management Conference 2010; PHM, 1-10. E-ISBN: 978-1-4244-4758-9, ISBN: 978-1-4244-4756-5, Jan.

Lin, Y., Tu L., Liu, H., Li W. 2016. Fault analysis of wind turbines in China. Renewable and Sustainable Energy Reviews 55, 482–490.

Liu, W.Y., Tang, B.P., Han, J.G., Lu, X.N., Hua, N.N., He, Z.Z. 2015. The structure healthy condition monitoring and fault diagnosis methods in wind turbines: A review. Renewable and Sustainable Energy Reviews, 44, 466–472.

Lu, Q., Breikin, T., Wang, H. 2011. Modelling and Fault Diagnosis of Stator Inter-Turn Short Circuit in Doubly Fed Induction Generators. Preprints of the 18th IFAC World Congress 2011, 1013-1018, Aug.28- Sep.2.

Luo, J., Namburu, M., Pattıpatı, K., Qıauıo, L. 2003. Model-based Prognostic techniques. AUTOTESTCON 2003, IEEE Systems Readiness Technology Conference; Proceedings. September, 330-340. ISSN : 1080-7725, Print ISBN: 0-7803-7837-7.

Luo, J., Pattipati, K., Qiao, R.L., Chigusa, S. 2008. Model-based prognostic techniques applied to a suspension system. Transactions on Systems, Man, and Cybernetics, 38(5), 1156–1168.

Ma, Y., He, C., Feng, X. 2012. Institutions Function and Failure Statistic and Analysis of Wind Turbine. Physics Procedia, 24, 25–30.

Maintenance Terminology, EN. 13306., 2001.

Nandi, S., Toliyat, H.A., Li, X. 2005. Condition Monitoring and Fault Diagnosis of Electrical Machines-A Review. IEEE Transactions on Energy Conversion, 20(4), 719-729.

Ogidi, O.O., Barendse, P.S., Khan, M.A. 2016. Fault diagnosis and condition monitoring of axial-flux permanent magnet wind generators. Electric Power Systems Research, 136, 1-7.

Ossai, C.I., Boswell, B., Davies, I.J. 2016. A Markovian approach for modelling the effects of maintenance on downtime and failure risk of wind turbine components. Renewable Energy, 96, 775-783.

Parra, J., Vicuna, C. M. 2017. Two methods for modeling vibrations of planetary gearboxes including faults: Comparison and validation. Mechanical Systems and Signal Processing, 92, 213-225.

Penicuik Environment Protection Association (PEPA). Blade loss or failure. unpublished.

Ribrant, J., Bertling, L.M. 2007. Survey of Failures in Wind Power Systems with Focus on Swedish Wind Power Plants during 1997&2005. IEEE Trans. Energy Conversion, 22(1), 167-173.

Saha, B., Goebel, K., Poll, S., Chrıstopherson, J. 2009. Prognostics Methods for Battery Health Monitoring Using a Bayesian Framework. IEEE Transactions On Instrumentation and Measurement, 58(2), 291 -296.

Sagbansua, L., Balo F. 2017. Decision making model development in increasing wind farm energy efficiency. Renewable Energy 109, 354-362.

Schwabacher, M.A. 2005. A Survey of Data-Driven Prognostics. American Institute of Aeronautics and Astronautics, 1-5, AIAA-2005-7002. Sep.

Sierra-Pérez, J., Torres-Arredondo, M.A., Güemes, A. 2016. Damage and nonlinearities detection in wind turbine blades based on strain field pattern recognition. FBGs, OBR and strain gauges comparison. Composite Structures 135, 156–166.

Soua, S., Van Lies Hout, P., Perera, A., Gan, T.H., Bridge, B. 2013. Determination of the combined vibrational and acoustic emission signature of a wind turbine gearbox and generator shaft in service as apre-requisite for effective condition monitoring. Renewable Energy, 51, 175–181.

Tang, B., Song, T., Li, F., Deng, L. 2014. Fault diagnosis for a wind turbine transmission system based on manifold learning and Shannon wavelet support vector machine. Renewable Energy, 62, 1–9.

Tavner, P.J., Xiang, J., Spinato, F. 2006. Reliability Analysis for Wind turbines. Wind Energy, 10, 1-18.

Teng, W., Ding, X., Zhang, X., Liu, Y., Ma, Z. 2016. Multi-fault detection and failure analysis of wind turbine gearbox using complex wavelet transform. Renewable Energy 93, 591-598.

Vachtsevanos, G., Lewıs, F., Roemer, M., Hess, A., Wu, B. 2006. Intelligent Fault Diagnosis and Prognosis for Engineering Systems. John Wiley & Sons, Inc. New Jersey, Pages 434. ISBN:978-0-471-72999-0.

Vachtsevanos, G., Lewis, F.L., Roemer, M., Hess, A., Wu, B. 2007. Intelligent fault diagnosis and prognosis for engineering systems. John Wiley & Sons, Inc. 2006; ISBN: 978-0-471-72999-0, Published Online: 23 MAR.

Venkat, V., Raghunathan, R. 2003. A review of process fault detection and diagnosis Part I: Quantitative model-based methods. Computers & Chemical Engineering, 27(3), 293–311.

Voisin, A., Levrat, E., Cocheteux, P., Iung, B. 2010. Generic prognosis model for proactive maintenance decision support: application to pre-industrial e-maintenance test bed. Journal of Intelligent, 21(2), 177-193.

Wang, Z., Guo, Q. 2007. The Diagnosis method for converter fault of the variable speed wind turbine based on the neural Networks. in Proceedings of 2nd International Conference on Innovative Computing, Information and Control, Kumamoto, Japan, 615-618.

Watson, S.J., Xiang, J. 2006. Real-time condition monitoring of offshore wind turbines. in Proceedings EWEC Paper #BL-3.

Watson, S.J., Xiang, B.J., Wenxian, Y., Tavner, P.J. 2010. Condition Monitoring of the Power Output of Wind Turbine Generators using Wavelets. IEEE Transactions on Energy Conversion, 25, 715-721.

Wilkinson, M.R., Spinato, F., Tavner, P.J. 2007. Condition monitoring of generators and other subassemblies in wind turbine drive trains. in Proceedings IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives, 388-392.

Yang, W., Tavner, P.J., Crabtree, C.J., Wilkinson, M. 2008. Research on a simple, cheap but globally effective condition monitoring technique for wind turbines. In International Conference on Electrical Machines, 1-5.

Yonggang, L., Le, T., Hongwei, L., Wei, L. 2016. Fault analysis of wind turbines in China. Renewable and Sustainable Energy Reviews, 55, 482–490.

Zhang, Y., Lu, W., Chu, F. 2017. Planet gear fault localization for wind turbine gearbox using acoustic emission signals, Renewable Energy, 109, 449-460.

Zhang, Y., Jiang, J. 2008. Bibliographical review on reconfigurable fault-tolerant control systems. Annual Reviews in Control, 32(2), 229–252.

Zhang, H., Chen, X., Du, Z., Yan, R. 2016. Kurtosis based weighted sparse model with convex optimization technique for bearing fault diagnosis. Mechanical Systems and Signal Processing 80, 349–376.

Zhou, X. 2012. Fault and solution of offshore wind turbine yaw brake actuator. Constr Mater Decor, 1: 164–5.