Reliability Analysis of Sub Assemblies for Wind Turbine at High Uncertain Wind

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Reliability Analysis of Sub Assemblies for Wind Turbine at High Uncertain Wind

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Abstract. The wind energy plays a vital role in the world renewable energy scenario. The modern wind turbine system has a complex and repairable components due to sophistication and centralized control. The failure characteristics of the onshore wind turbines depend on the terrain conditions. In the main mountain pass and hill area, there is a heavy uncertainty in the wind that is due to the frequent change in the direction of wind and the change in the velocity. It causes a rapid failure in the individual sub assemblies. There is a substantial need for improving the reliability in the stages of design, manufacturing, operation and maintenance. Normally the infant mortality failures are more in the onshore wind turbine and the failure rate is constant during normal operating period. It is a surprise that the failure rate has rapidly increased during normal operating period of the wind turbines placed exactly in the mountain pass and hilly area due to the high uncertainty in the wind. This paper deals with reliability analysis of major components of wind turbine system and its sub system such as rotor system, gear box, brake system, generator, hydraulic system and yaw system. This paper also investigates the reliability of wind turbines and its sub assemblies placed at Aramboly pass in India by using Weibull software as reliability tool for a grid connected 250 kW wind turbine. This analysis yields some surprising results about some sub assembly like yaw system, brake system and generator which are most unreliable.

Introduction

The wind energy has proved its potentiality to generate electricity by considering the social, economical, technical and environmental viability [3]. The main purpose of determining the system reliability of wind turbine is to identify the weakness of the system and quantify the impact of the different components. The reliability is a function of operating time, type of failure and repair characteristics of the system and all its components [4]. In wind turbine the components are complex. The system reliability is used to analyze the important factors that affect the individual components.

The main objective of this paper is to increase the efficiency of generation by identifying the failure trends, establishing benchmark for reliability performance and providing excellent information to operation and maintenance team to make precautions. The earlier paper [1] assumed that the constant failure rate for calculating reliability of onshore wind turbines, but some components like generator, yaw motor and brake system failed rapidly. It shows that the assumption of constant failure rate is no longer valid. In this paper mechanical sub assemblies are mainly considered because they are affected heavily by dynamic loads due to frequent change in the direction and wind velocity at normal operating period. In the modern age, the higher reliability requirement systems are getting complicated because of control system, computing system multistage interconnection and critical power system. This complexity causes frequent failure in the wind turbines.

Wind Turbine Components

The wind power system is comprised of one or more units, operating electrically in parallel, having the following components such as the tower and control system, rotor system with blades, hub, nose cone and tip mechanism, yaw mechanism, gear box, electrical generator, brake system, the speed sensors and control [3]. The modern system often has the following additional components such as power electronics and wireless control incorporating a centralized control.

Analysis of Wind Turbine

Weibull analysis software provides the life data analysis tools necessary to analyze data from all phases of product life. The intuitive interface tools together with a comprehensive selection of plots and graphs enable to predict failure behavior. We can define a cumulative probability function by [4]

$$F(x,k,\lambda) = 1 - e^{\left(x/y\right)^{k}}$$

For $x \geq 0$, and for $x < 0$.

Obviously the probability is 0 at t = 0 and increases monotonically to 1 as t goes to infinity [5]. The corresponding density distribution f (t) is the derivative of this cumulative probability function. This enables us to define a probability density distribution with any specified rate function as

$$\lambda(t) = \frac{\beta}{\eta}\left[\frac{\tau-\rho}{\eta}\right]^{\beta-1} e^{-\left[\frac{\tau-\rho}{\eta}\right]^{\beta}}$$

$\lambda(t) \geq 0$, $T \geq 0$ or γ, $\beta > 0$, $\eta > 0$, $-\infty < \gamma < \infty$

The β determines the trend of the curve and it is called shape parameter. The η is a scale factor which has units of the reciprocal of time and ρ is the location parameter. For $\beta < 1$ or $\beta > 1$ the curve shows respectively a downward or an upward trend [8]. The parameter β is a dimensionless pure number. The failure of WT components are calculated based on field data by using Weibull software. The failure distribution data is shown in the table 1.

Table 1 Failure distribution of Wind Turbine components

Component Number	Component Name	Failure Distribution
C1	Rotor	Weibull (β=1.8257, η=84678)
C2	Gear box	Weibull (β=1.2327, η=66122)
C3	Brake system	Weibull (β=1.7459, η=82942)
C4	Generator	Weibull (β=0.7653, η=59252)
C5	Yaw system	Weibull (β=1.8665, η=58930)
C6	Hydraulic – Tip Control	Weibull (β=1.1027, η=78273)
C7	Hydraulic – Brake Control	Weibull (β=1.6059, η=89672)
	WT System	Weibull (β=1.2639, η=71004)

Result and Discussion

The shape factor β values obtained are greater than 1 for all components except generator. The failures are rapid and random for all components and it will deteriorate at an early time due to fatigue. The figure 1 illustrates a considerable amount failure occurred in infant mortality period that is below 10000 hours. In between 10,000 and 25,000 hours, the failure is very less. After 1,00,0000 hours the failures are massive. It shows that failure is rapid. The life of the wind turbine is generally designed for 25 years but it is reduced to 20 to 22 years in actual practice. The rotor failure is due to rotor bolt failure, dirt in the blades, tip open while running, blade rope cut and blade hydraulic failure. The main reason for the rotor failure is it occurs during high wind. The rotor has β value of 1.8257. The majority of wind turbine gearbox failures appear to initiate in the bearings and shaft. The gear box has a β value of 1.2327 and the failure is due to random cyclic loading and temperature changes.

The generator has a β value of 0.7653. It clearly illustrates that incredibly frequent failures occur from starting to normal operating period of the generation. If the wind speed changes between average wind speed (9 m/sec) and rated wind speed (11 m/sec) then the contactor for generator G1 and generator G2 actuates frequently and makes the generator fail. Most of the generators are over hanging therefore the sleeve ring and shaft of generator habitually fail as shown in figure 2.4.

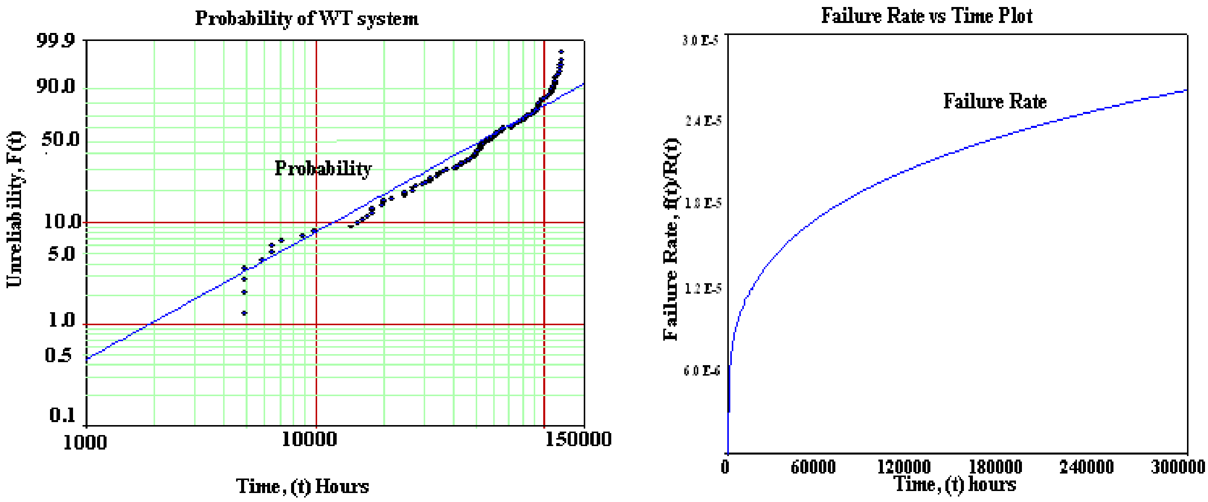

Figure1. Probability Failure of Wind Turbine system

If the changeover of the generator is from high speed generator G1 to low speed generator G2 then the mechanical brake is applied and tip is opened to reduce the speed. The brake system is the active part of the protection system of wind turbines. The reliability of a brake system is of the utmost importance to ensure that the system will serve its purpose effectively. The frequent usage of brake to reduce the speed, over speed and abrupt grid failure at high wind causes failure in the brake system as shown in the figure 2.3.

The general objective of a wind turbine yaw drive is to direct the wind turbine into the direction of the wind. The most common type of yaw mechanism is based on a rolling slew ring bearing with a cogged inner or outer race and pinions driven by electrical motors over high-reduction gearboxes. The frequent actuation of the yaw system causes an extreme failure in yaw planetary gear, yaw bed bolt, pinion, yaw brake and yaw motor thus causes frequent failure of yaw mechanism. The direction of wind abruptly changes within an hour at Muppandal site located in the Aramboly Pass.

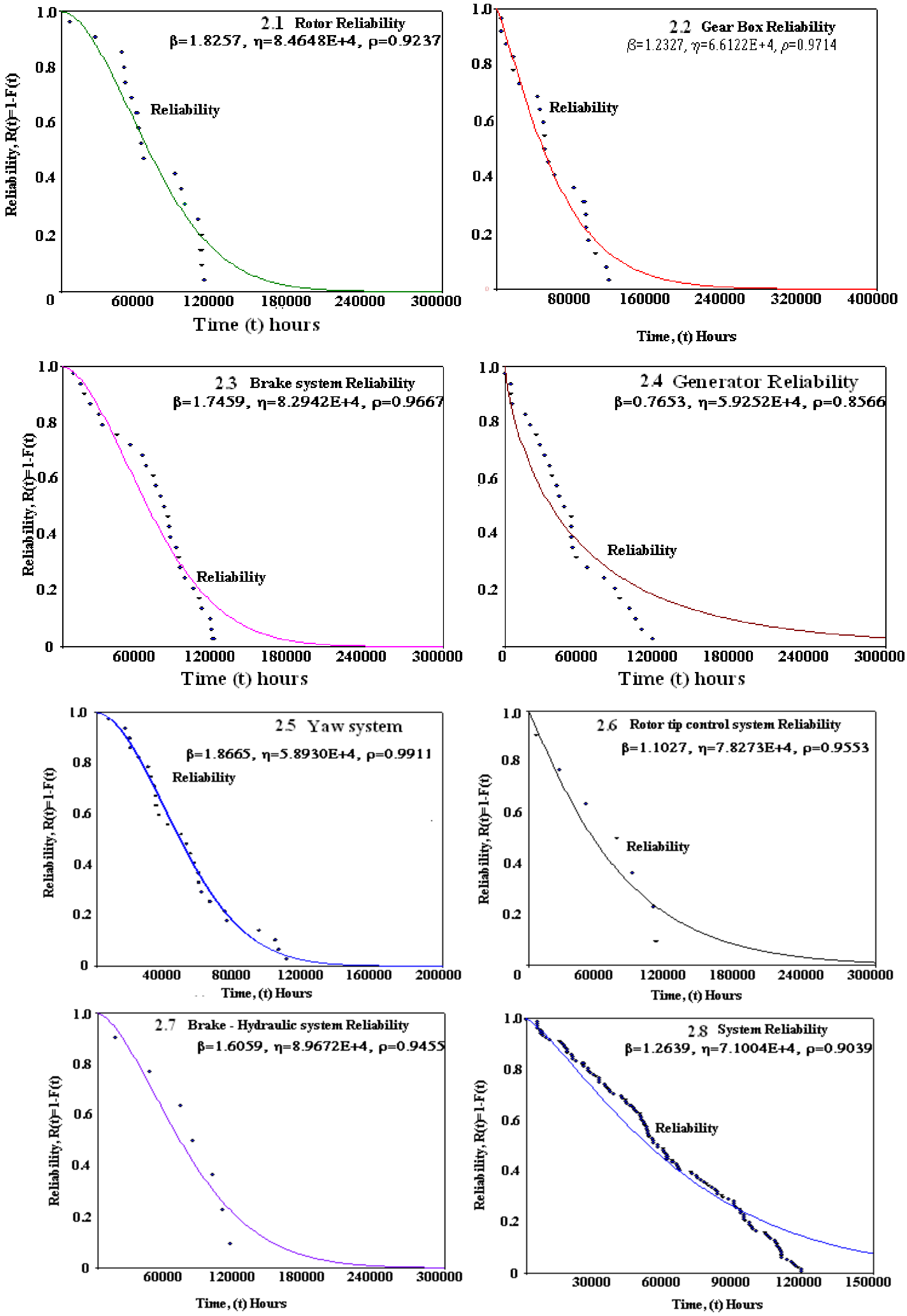

Figure2. Reliability analysis of Wind Turbine components

From figure 2.5, it is clear that the failure of yaw system makes heavy reduction in the power generation and the β value becomes 1.8665. The tip of blade open slightly due to the low pressure developed in the hydraulic system and it make reduction in power generation. The repairs to generator [8], drive train, hub, gearbox and blades have often caused standstill periods of several weeks. The turbine availability is a function of both the failure distribution as well as repair distribution of individual components. The reliability of the entire wind energy system is shown in figure 2.8 and the overall β value is 1.8665. The table 2 shows that the overall reliability with time of wind turbines system.

Table 2 Overall Reliability of Wind Turbine System

Sl. No	Time (hour)	Reliability
1	1	1
2	10	1
3	100	0.9998
4	1000	0.9954
5	10000	0.9195
6	100000	0.214
7	1000000	5.08E-13

Conclusions

The ReliaSoft's Weibull analysis software is used for the analysis to determine the reliability of wind turbine components. The reliability is important because the wind turbines are mostly located in remote regions where the cost of inspections and repairs are very high. In a good high wind period a 250 kW wind turbine can typically produce about 5000 kWh per day. The maximum failures are obtained in the high wind period only. This paper analyzes the reliability of different components which cause break down of the system and to identify the critical failure occurred to make the system unavailable. In general, the failure rate of wind turbine decreases with time but the result of this paper shows the rapid failure occurred in critical components like generator, yaw system, rotor system, brake system and gear box. This paper also indicates how to prevent the failure before occurring and recommends that the wind turbines need not be designed as common for all onshore plant. It can be designed with some modifications to meet challenges of the heavy uncertainty wind in the mountain pass, hilly area or other topology. These modifications are recommended in design stage such as the redundant yaw system with soft yaw drives without yaw brake, redundant hydraulic system, the proper design to align the generator and proper gear box cooling with extended surface area to improve the reliability and availability of the wind turbines. In order to further improve the reliability of wind turbines, the preventive maintenance at low wind period, spare parts at site and high quality electric and electronic components are necessary. Besides failure rate, the restore time of the machines after a failure is an important value to describe the reliability of a wind turbine.

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