IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
ISSN: 2278-1684, PP: 27-34
www.iosrjournals.org

Review on Eclipse Gearbox Reliability

R. R. Salunkhe[1] Prof V. R. Gambhire[2] R. S. Kapare[3]
[2] *(Head of mechanical engg dept. T.K.I.E.T. Warananagar)*
[1,3]*(T.K.I.E.T. Warananagar)*

Abstract: Wind *turbine gearbox reliability is a well documented industry-wide concern. The Eclipse Gearbox is a high-reliability; novel gear set that can significantly reduce reliability problems. The gear set embodies a speed ratio of up to 150 to 1 in a single stage, which is achieved through an original configuration of gears: One gear rotates and provides a circular path for another gear. A rotational gear is attached a high torque shaft. Another gear is engaged with the rotational gear and translates on a circular path. The second gear is connected with linkages to a low torque shaft that resembles a crankshaft.*

1. INTRODUCTION

The fastest growing renewable energy source is wind power. Wind power is currently responsible for about 1:5% of the world's electricity use. Because of this high interest in wind energy, it becomes more and more important to increase the efficiency of wind energy conversion systems (WECS), also called wind turbines. The complete system required to convert the energy in the wind to electricity is called a wind energy conversion system (WECS). Such a system consists of a rotor to capture the energy in the wind, a gearbox configuration to speed up the rotational speed of the shaft and a generator to convert the mechanical energy into electrical energy. The efficiency of the total system is not only determined by the efficiencies of the gearbox and generator, but also by the amount of energy that can be extracted from the wind [1].

A wind energy conversion system consists of a number of components to transform the energy in the wind to electrical energy. One of these components is the rotor, which is the component that extracts energy from the wind. The operating regime of a wind turbine is divided into three regions. Region 1(wind speed up to (4m/s) is the low wind speed region for which the turbine does not produce any power, the rotor is standing still and the turbine is disconnected from the grid. When the turbine would be connected to the grid at these low wind speeds, the generator would start working as a motor, driving the turbine. The turbine would then actually be working as a huge fan, consuming energy instead of producing. The second region, region 2(wind speed 4 to 14m/s), is the region between the wind speed at which the turbine starts to operate (V_W;cut¡in) and the wind speed at which maximum power is produced (V_W;rated). This is the region for which maximizing energy capture is very important, but limitation of dynamic loads also becomes more important [5].

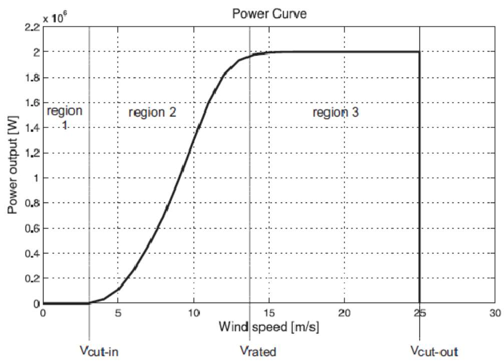

Fig1. Power o/p Vs Wind speed

In a typical wind turbine, region 2 operation accounts for more than 50% of the annual energy capture. This indicates the importance of efficient operation in this regime. Finally there is region 3(wind speed 14 to 25m/s), which is the region from the rated wind speed to the wind speed at which the turbine is stopped to prevent damage (V_W;cut¡out). In this region, energy capture is limited such that the turbine and generator are not overloaded and dynamic loads do not result in mechanical failure. The limitation in energy capture is generally controlled by pitching the rotor blades, by suitable control methods. Blade pitch control is used to control the aerodynamic power captured from the wind. By pitching the rotor blades along their longitudinal axis, the aerodynamic efficiency of the rotor is changed. A disadvantage of using blade pitching below rated speed is that less energy is extracted from the wind, decreasing the efficiency.

2. CURRENT PRACTICES

The literature review points out that research have been done on transmission of power in wind turbine by using various transmission drives but still, there is scope to improve the design of a gearbox that features a shortened load path through a single pair of gears combined with linkages and a crank shaft.

1. Jelena Stefanovic-Marinovic [2] Have Worked In Selection Of CVT Transmission Construction Design For Usage In Low Power Wind Turbine, In That Necessity of multiplicator application as a component of wind turbine is implication of incompatible number of rpm of rotor and number of rpm of generator. Currently approach (method) connecting turbine with permanent convertible number of rpm and generator with constant number of rpm by multiplicators with constant transmission ratio came out non- effectively.

2.Miltenivic [3] discussed regarding New concept of wind turbine power transmission, which instead of multiplicators with constant transmission ratio, uses variable transmission ratio (CVT) is increasing. In order to exceed multiplicators with constant transmission ratio disadvantages, new concept of wind turbine power transmission anticipates differential power transmission and power transmitters with variable transmission ratio (CVT) instead of multiplicators with constant transmission ratio. It is used for adjusting turbine impeller work with generator work. The capacity of power generation increase in wind turbines but generated many technical problems. Many of those problems are related to power transmission. Actual transmission types in wind turbines include planetary differential transmitters. Differential planetary transmitters have significant function in those concepts.

3.Dipl. Ing. ETH Hanspeter Dinner, [4] have worked in The overall trends in wind turbines and their drive trains are opposing: multi unit offshore installations vs. local single units in local grids, small wind turbines vs. multimegawatt turbines, classical drive trains vs. regulated CVT drive trains, medium vs. high speed gearboxes and so on. While the need for smaller gearboxes leads to the requirement for low cost yet noise optimized gears, the need for large gearboxes leads to technological challenges in gearing, large bearings and highly stressed structural members like planetary carriers.

4. M.J. Verdonschot, [5] Worked in Modeling and Control of wind turbines using a Continuously Variable Transmission. In that, Conventional variable speed wind turbines obtain their variable speed operation by a controlling the generator torque. This control uses the power electronics that connect the generator to the electrical grid. The range of variable speed in these systems is limited and the power electronics are one of the main sources of failure in wind turbines. Therefore, the possibility of using a continuously variable transmission for the control of a wind turbine is investigated.

5.Frank et al [6] Worked on wind turbine systems using CVT & various controls. A wind turbine system is disclosed comparing a plurality of turbine blades; a continuous variable transmission coupled to said plurality of turbine blades; a generator coupled to said continuous variable transmission; wherein said generator generates electricity & outputs said electricity to a load/grid; and controller providing control signal as a filtered function of power to said a continuous variable transmission. The controller of said wind turbine system may also continuously maintain the parameter dP/dR substantially zero where P is power & R is the ratio of transmission. 6.Gold, A [9] Discussed regarding CVT History, Categories, Efficiency, Positive Engagement CVT: Problem correction class, problem elimination class, tooth conforming family.

7.Terry Lester [7] discussed about Wind turbine gearbox reliability, Premature gearbox failures present major issues in the wind energy industry. Gearbox unreliability and high repair costs combine to result in critical negative effects on the cost of wind energy production. Lost revenues result from long down-times when energy cannot be produced, the substantial expense of the large crane needed to lift a replacement gearbox into place and the cost of the gearbox itself. The gearbox is the critical component prone to failure in the load path between the turbine and the generator. Traditional wind turbine gearboxes utilize an indirect path through a multi-stage planetary system.

8.P. C. Sen [8] discussed regarding Power Electronics as a solution of reliability problem in that variable speed operation of the generator results in the production of current with a variable frequency. The frequency of the produced current is determined by the electrical angular speed of the generator. When the frequency of the generator varies too much, in the order of 2 Hz, circuit breakers cause the generator to disconnect from the system, preventing damage to the grid. Power electronics is a technology that is developing rapidly. Higher current and voltage ratings are available, efficiency increases and costs decrease. Therefore, power converters are widely used in the wind turbine industry to improve the performance of wind turbines. However, there are also a number of disadvantages of using power electronics The biggest disadvantage of power electronics is reliability. Mechanical components show wear
& tear and therefore any failures in these components can be predicted, maintenance can be scheduled before failure occurs. Unfortunately power electronics do not show signs of degrading, therefore failures cannot be predicted and these sudden failures are very expensive to repair.

3. Eclipse Gearbox Introductions

Premature gearbox failures present major issues in the wind energy industry. Gearbox unreliability and high repair costs combine to result in critical negative effects on the cost of wind energy production. Lost revenues result from (1) long down-times when energy cannot be produced, (2) the substantial expense of the large crane needed to lift a replacement gearbox into place and (3) the cost of the gearbox itself

Fig 2.-Wind Turbine Gearbox Installation

The gearbox is the critical component prone to failure in the load path between the turbine and the generator. Traditional wind turbine gearboxes utilize an indirect path through a multi-stage planetary system. Introduced here is a gearbox that features a shortened load path through a single pair of gears combined with linkages and a crankshaft.

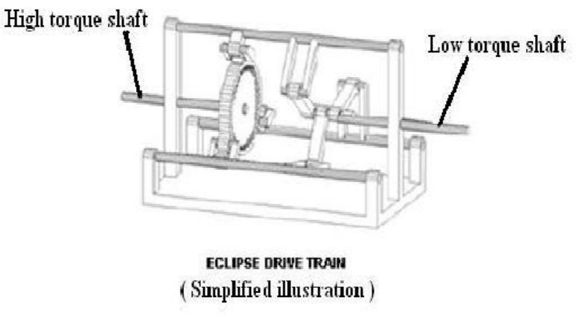

Fig 3. -Eclipse Gearbox

Traditional wind turbine gearboxes utilize a two- stage planetary gear with a one-stage parallel shaft

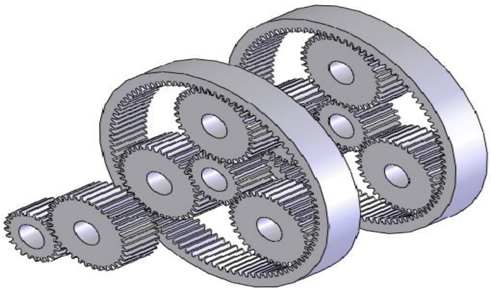

Fig.4a -Traditional Wind Turbine Gearbox

The substantial ring gear forces are distributed to the sun gear through the planetary gears, where the ring gear and sun gear forces are equal in magnitude. The planet gear bearing forces are the sum of the ring gear and sun gear forces. The combination of large forces and limited bearing size create a critical failure point. Advanced lubrication systems and other planetary gear improvements have not resulted in increased service life. As such, the physical limits of planetary gear sets have been reached. Traditional designs have a finite space for the bearings required to carry the loads of the planetary gears.

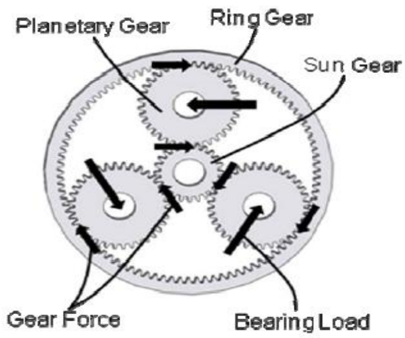

Fig 4b.-Planetary Gear Set Loads

The Eclipse Gearbox overcomes the limitations of the planetary gear set and offers a practical,high-reliability gearbox for 200 kW to 10 MW wind turbines. It is a single-stage gearbox that can distribute the loads through multiple linkages.

4. Mechanics

A simplified version of the Eclipse Gearbox is illustrated in Fig. 3. One gear rotates and provides a circular path for another gear. The second gear translates on a circular path. The second gear is connected with linkages to the output crankshaft. The load path begins with the high torque shaft and ends with the low torque shaft. Components of the gearbox are shown in Figs. 5 through 11 relative to the load and torque paths.

Fig. 5-High Torque Shaft and Spur Gear

The high torque shaft and spur gear (Fig. 5)
are directly connected to the wind turbine and rotate about the central axis of the high torque shaft. The spur gear drives the translational gear (Fig. 6) about a circular path.

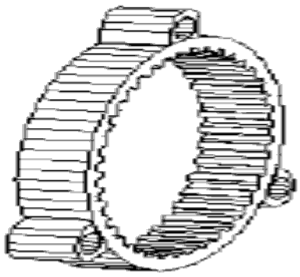

Fig. 6-Translating Gear

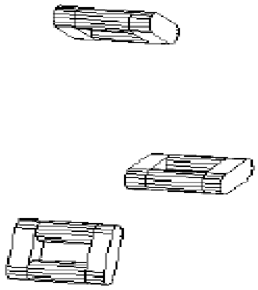

Fig. 7-Short Links

The motion of translational gear is only translational. It does not rotate. Through the short links (Fig.7), the energy is transferred from the translational gear to the short rocker arm. The short rocker-arm, rocker-shaft and long rocker-arm (Fig. 8) are fixed together as a single part and rotate back and forth about 15 degrees. Through the long links (Fig. 9), the energy is transferred from the long rocker-arm to the crankshaft and the low torque shaft (Fig. 10).

The frame (Fig. 11) is the support structure.

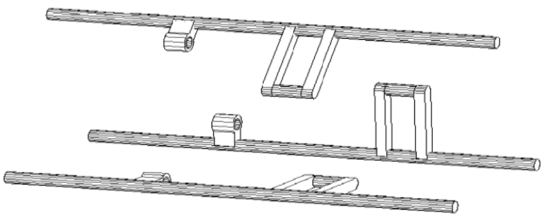

Fig. 8-Short Rocker-Arm, Rocker-Shaft and Long Rocker-Arm

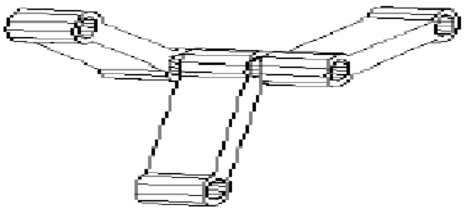

Fig. 9-Long Links

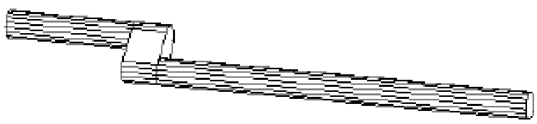

Fig. 10-Crank Shaft and Low Torque Shaft

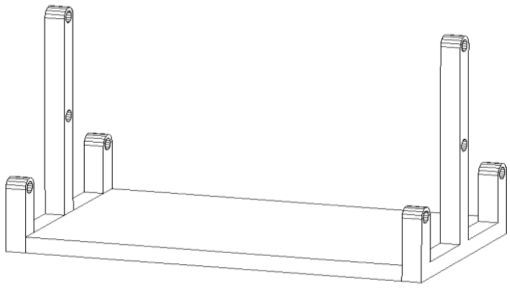

Fig. 11-Frame

The crankshaft and a minimum of three linkages are required to control the translational motion of the translational gear.
Additional linkages are used to distribute the translational gear reaction loads. The Eclipse accommodates speed ratios up to 150 to 1 in a single stage. This speed ratio limit is based on the practical limit to the gear tooth size.Where NS is the number of teeth on the spur gear and NT is the number of teeth of the translating gear.

5. 1.6 MW Eclipse Gearbox

The 1.6MW Eclipse Gearbox is equivalent to the size of a traditional gearbox but with half the weight, The estimated weight is 15,000 pounds and the estimated service life exceeds 50 years when using industry standard materials and assembly techniques. There is no magic in the high torque and long service life capacity of the Eclipse Gearbox. The endurance life and power rating of the Eclipse Gearbox are dependent on the number of linkages and the sizing of the bearings and gears. In comparison, for traditional gearboxes to be sized for successful operation in high power wind turbines, their cost, weight and size would be prohibitive.

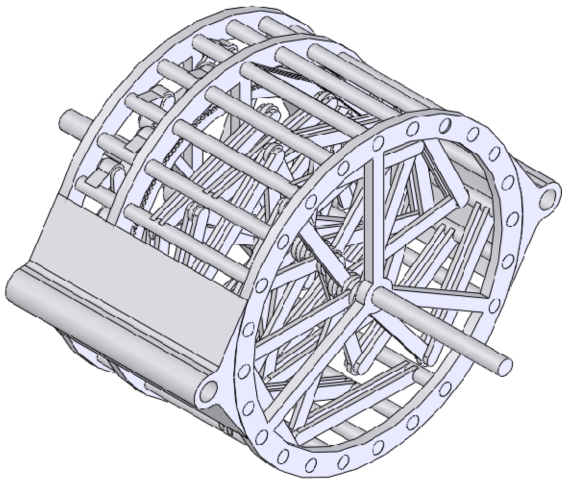

Fig. 12-1.6 MW Eclipse Gearbox

The link load cycle for a 1.6 MW gearbox is illustrated to show the distributed load through several linkages. depicting an input torque of 600,000 lb-ft. The summation of the linkage loads are equal to 75 percent of the bearing forces in the planetary gears of a traditional planetary gear set. The linkages are designed with respect to manufacturing tolerances, joint free play and stiffness to maintain evenly distributed linkage loads throughout the Eclipse system, regardless of the loads applied to the windmill blades. The linkages act in parallel to distribute the translational gear loads. The gear
Speed Ratio :to 1 loads are distributed over multiple bearings. The bearings in the linkages rotate back and forth
about 15 degrees. Only the bearings on the crankshaft and the alignment bearings for the high and low torque shafts rotate a complete 360 degrees. The amplitude of the gear tooth stresses are substantially reduced due to the loads being distributed over a greater number of teeth, (Fig.14). The lower gear tooth stresses substantially increase the fatigue life of the gears.

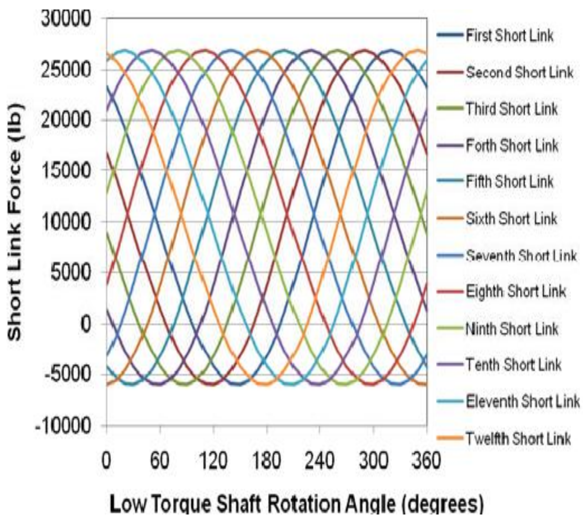

Fig. 13-Short Link Forces for One Rotation of the Low Torque Shaft

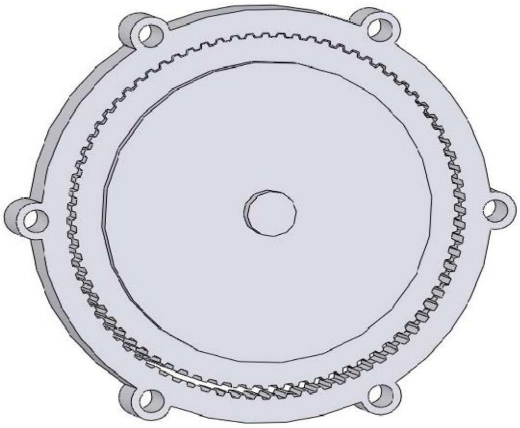

Fig. 14-Torque Distributed Over Several Gear Teeth

6. Efficiency

The mechanical design efficiency of the Eclipse Gearbox results in significantly greater efficiency than traditional planetary gearboxes, due to the reduced number of energy dissipating components and to the fact that energy travels though only one set of gears and bearings. There are two primary components that dissipate energy in a gearbox system: the gear tooth contact and the bearing contact. A basic rule of thumb in gearbox design for energy loss through gear tooth contact is approximately one half of one percent (1/2 of 1%) for every stage of gear interaction that the energy passes through. Bearing contacts contribute energy loss through rolling motion. The linkage bearings in the Eclipse are small in size in relation to traditional gearbox bearings and rotate back and forth about
15 degrees, producing only minimal energy losses. Only the crankshaft bearings rotate a complete 360 degrees and are similarly relatively small in size. Traditional gearbox systems routinely suffer energy losses amounting to four to five percent(4-5%) due to multiple stage planetary gear sets and massive bearings. The Eclipse gearbox will operate with a total mechanical efficiency of approximately
95percent. Until this claim is validated by testing, a conservative estimate would be a mechanic al efficiency no less than 85 percent.

7. Endurance Life, Size and Weight

The long endurance life, small size and light weight are the primary strengths of the Eclipse Gearbox. Its size is equivalent to a traditional gearbox with half the weight. Even with half the weight, the Eclipse Gearbox handles greater torque loads with gears and bearings selected to handle all the requirements of the most challenging wind turbine applications, while maintaining endurance over a greater length of time.Gear tooth contact stress is substantially lower due the increase in the number of gear teeth that are simultaneously engaged. The decreased tooth contact stress directly increases the endurance life and torque capacity of the gears.

8. Gear Alignment

Gear alignment is a critical factor for endurance life. Small misalignments quickly and severely reduce the endurance of gears. Another enhancement of the Eclipse Gearbox is a gear self-alignment capability between the spur and translating gears, which is accomplished through alignment guides on the spur and translating gears. The centrifugal forces acting on the translating gears keep the alignment guides together.

9. Conclusion

The Eclipse gearbox is scalable for 200 kW to 10 MW wind turbines with speed ratios up to 150 to 1. Retrofitting existing structures is possible. The weight of the Eclipse amounts to approximately 10,000 pounds per MW with a service life in excess of 50 years. Manufacturing costs are substantially reduced due to replacing traditionally high-cost machined components with smaller, less expensive parts. All of these advantages, combined with long endurance life and optimal efficiency, dramatically lower wind turbine operating expenses and solve the gearbox reliability problem.

References

[1]. Renewable Energy World : http//www.renewableenergyworld.com/rea/news

[2]. Stefanovic-Marinovic J.,Banic M.,Miltenovic A.:Selection of CVT Transmission Construction Design for Usage in Low Power Wind Turbine, Machine Design, Monograph on the Occasion of 49th Anniversary of the Faculty of Technical Sciences, Faculty of Technical Sciences,Novi Sad, 2009, pp. 101-104.

[3]. Miltenovic, V., Velimirovic M., Banic, M.: Contribution to Development of Wind Generator Continuously Variable Transmission, Balkan Power Transmission 2009 (BAPT '09), Kallithea, Greece, 2009.

[4]. Trends in wind turbine drive trains- Dipl. Ing. ETH Hanspeter Dinner, EES KISSsoft GmbH, Switzerland

[5]. M.J. Verdonschot Modeling and Control of wind turbines using a Continuously Variable Transmission-M.J. Verdonschot DCT 2009.028

[6]. Gold,A CVT Aug 2007 HTTP://cars.about.com/OD/CVT.htm

[7]. Terry Lester ,Texas USA, Traditional Gear box reliability Terry Lester ,Texas USA.

[8]. P. C. Sen, Principles of Electric Machines and Power Electronics, 2nd ed. John Wiley & Sons,1997.

[9]. US Patent #1,613,344 "Power Transmission"

[10]. -George Constantinesco http://www.renewableenergyworld.com/rea/n ews/reworld/story?id=52694

[11]. http://www.windpower-renewable- solutions.com/PDFs/News- Events/SKF%20Nautilus%20Bearings.pdf

[12]. .KISSsoft software10-2008, www.KISSsoft.ch