Investigating CVT as a Transmission System Prospect for Wind Turbine

Pranav Upadhyay, Suraj Pandey, Rachit Saxena, Yash Dixit, Vimal Yadav, Pikesh Bansal, and Shivam Sharma

Abstract Wind energy is a renewable source of energy besides being a clean source of energy. At a time when conservation of resources is the need of the hour, the better utilization of the present reusable sources should be the utmost priority. One of them being the wind turbines. A wind turbine is a device, which converts the energy of wind into mechanical energy, and this mechanical energy with the help of a generator is converted into electrical energy. The conservation of energy is at the top for a sustainable and quality environment and wind energy is one of the few yet best renewable resources. The vast potential of wind energy has never been in doubt however, access to abundance has always been a challenge. This paper covers the possibility of enhancing the existing methods of power transmissions and thereby the better efficient performance of the wind turbine The present electrical methods to cover for the variation in speed of the wind and variable input to the generator is doing a good job but this paper encroaches the mechanical aspect of the system something which has not been looked at while this time. The arrival of Continuously Variable Transmission (CVT) in the automobile industry was a breakthrough in automatic power transmission. We credit our inspiration and approach the CVT only, the ability to provide optimal gear ratio in varying conditions is what we engulfed upon. We are proposing the design of a system based on CVT to provide the solution to the varying input problem to the generator.

Keywords Wind turbine · Wind turbine transmission · Continuously variable transmission (CVT)

1 Introduction

The current ecological condition is a recent cause of worry for a large number of environmental activists. The two main reasons that appear to be the highlight, first, the increasing pollution and its ill effects and second, the unavailability or successful

P. Upadhyay (✉) · S. Pandey · R. Saxena · Y. Dixit · V. Yadav · P. Bansal · S. Sharma
Department of Mechanical Engineering, ABES Engineering College, Ghaziabad, India
e-mail: upad.pranav1202@gmail.com

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usage of green sources of energy, which forces us to shift towards the conventional fuels such as coal, crude oil, etc. Solar energy and wind energy are the most common renewable energy resources. Out of them, solar energy has always been a center of development. But with the recent growing trends, wind energy is the fastest growing renewable source of energy. This has been the common center of discussion for researchers across the world.

In February 2019, an initial statistic was released by WWEA according to which the total wind turbine capacity worldwide touched 597 GW till the end of 2018. In the year 2017, a total of 52.552 MW was added worldwide whereas in 2018 only 50.100 MG were added. In 2017 the growth rate of new installations was around 10.8% and in the consecutive year of 2018, the growth rate of new installations was 9.1%. Estimated 6% of the worldwide demand for electricity will be covered by all the turbines installed worldwide by the end of 2018 [1]. With this increasing capacity several designs have been proposed and practiced for the transmission system of wind turbine. But, the demand for creating a simpler and more reliable system for transmission in wind turbines still exists. This paper reviews the various techniques used in designing the transmission techniques and presents an innovative solution to the existing transmission system which is inspired by the principle of working of Continuous Variable Transmission, commonly abbreviated as CVT. CVT has been a topic of research for wind energy researchers and has also proved its worth in the field of effective transmission of energy using mechanical engineering methods and power electronics. CVT bargains a range of gear ratios between anticipated boundaries. This gives more time for the engine to operate in the optimum range. Whereas, in a traditional gear setup, a lot of limitations pertaining to several fixed transmission ratios forces the engine to operate outside the optimum range.

2 Literature Review

Denis Alkan [2] investigated the possibility of using CVT as means of transmission and also covers the need to do so. The paper presents a comparative study of the existing power electronics method and conventional gearbox not only the cost basis but the performance as well. With the help of a designed mathematical model, the possibility of CVT has been confirmed by the help of analysis. The efficiency of the energy production of the wind turbine increases with CVT has been clearly shown with the results.

The above graph clearly shows the dependency of efficiency on factors like gear ratio and torque generation. Figure 1 concludes that the efficiency can be up to 98% in optimum cases, which according to this study occurs at wind speed greater than 7 m/s. But at a low speed, the CVT offers a much-improved performance and during the best and worst months, the performance is much better. The frequency control with the CVT system is a strong replacement for the existing expensive power electronics ultimately reducing the maintenance and overall cost. Though, the factors such as friction torque and mechanical efficiency of the CVT are not considered in this overall

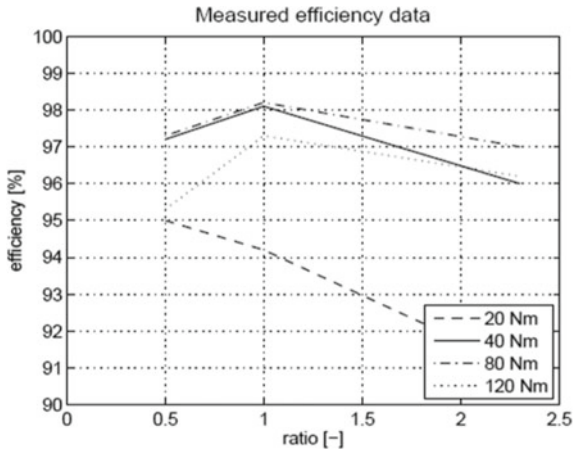

Fig. 1 Measured mechanical efficiency data of 30 mm GCI chain CVT (Verdonschot 2009)

analysis. The heating effects and lubrication mechanism needs to be figured out and then needs a careful study, also the strength analysis of the system has not been done.

Verdonschot [3] has covered the possibility of maximum energy capture and limiting the dynamic loads while using CVT with the help of MATLAB/SIMULINK. The entire wind turbine model is prepared first consisting of every main component and suitable assumptions are made for further analysis. The specific set points and control points help in achieving the highest possible energy capture. The wind speed range is assumed based on the previous existing numbers and the algorithm is used. However, for controlling the system there is another series of operations, and the whole process is completed in two steps. The controlling method stated in the paper is sufficient for the application but on the aspect of limiting the dynamic loading other operations may offer more. The possibility of CVT with certain modifications is well established. Still, in order to attain and obtain the best out of the intended mechanism, the configuration and uncertainties need to be looked at and better backups and improved ideas will be needed to avoid sudden failure and below-par performance.

Vishnu Seelan [4] has investigated the design, analysis, and applications of CVT. The paper has expressed every component of the CVT in detail starting from high-density belt, set of cone pulleys, actuator, torque converter, and so on. Evidence of the multi advantages offered by CVT has been well proved in the present study. It provides not only an unlimited gear ratio but also without any "shift shock". VT helps in running the machine on its optimum RPM range, providing a quicker better acceleration with low cost and lower number of parts. However, everything is not so green about CVT as it has limitations as well. Problem of friction between the belt and pulley causes wear and tear, also the material used in manufacturing of the belt affects the torque transmitting capacity of the system. The transmission fluid used is also costly.

Cotrell [5] assessed the implementation of CVT in place of power electronics (PE) which is currently used across all types of wind turbines. The main advantage of CVT overpower electronics is that it can go through rapid ratio changes and can

also soak up torque spikes. Therefore, this offers an economical solution in place of power electronics. This paper also focuses on potential economic and performance benefits when CVT is used in conventional wind turbine systems. The analysis of this paper shows that when a CVT is used then it lowers the starting speed to 5 m/s which is usually 6.5 m/s when a CVT is not used. This lower speed provides an approximately 0.6% increase in energy production which is roughly 32 MWh per year.

Claudio Rossi et al. [6] considered the possibility of using power slit electric driven CVT as key to wind energy conversion system. It is installed between the gearbox and generator. The CVT has a planetary gear system along with an electric device. It allows maintaining the constant speed of the generator while controlling the turbine rotor speed. This concept provides a complete dynamic model of transmission which is based on CVT. It also provides a design criterion for the size of CVT that will be used in that system. The combination of CVT and generator provides the best solution. It is an epicyclic gearing also known as a planetary gear system. The CVT disassociates the variable speed output from the constant speed of the generating machine.

The reliability problems linked with the gearbox associated wind turbines were researched by Ragheb et al. [7]. It also points out that the Continuous Variable Transmission (CVT) generally used in the automobile sector can be of use in place of existing transmission systems in the wind turbines. Almost over 1000 damage claims were reported due to gearbox and had to be replaced by Allianz, the German industry giant as per German Insurance Association.

Mangialardi et al. [8] focusses on the conversion of wind energy into electrical power which is particularly problematic owing to the changes in wind speed. It states incorporation of Continuous Variable Transmission (CVT) in between a wind turbine and generator. It also focuses on the type of regulator or control system to be used for the CVT. It also provided proper proof of the advantages of using CVT as a Transmission system in locations with available wind data.

From the literature review, it is quite evident that the wind turbine efficiency is affected due to variable wind speed. The wind speed is variable throughout any area, this issue needs to be addressed. Many solutions related to this has been submitted is based on electronics, no mechanical design solution is prevalent. The authors have worked in this area and proposed a preliminary design for the resolution of this problem.

3 Problem Statement

The inability to utilize full potential of wind energy is primarily due to the varying speed of the wind. As stated earlier the problem is somehow reduced by the electrical systems but the power electronics used are very expensive. Also, the constant gear ratio from the gearbox arrangement limits the usability of the lower wind speed and thus restricting the complete efficient utilization. The life of gears is also a

factor in increased maintenance cost as well. The generators require the rotation speed in a certain bracket range for quality electricity. Due to this requirement, the limitations are there when the speed varies. The quality of electricity produced is directly proportional to the load and the rotor speed though in a limit but the dead-end is way too far. Wind turbine is a very big installation and it becomes very difficult to provide maintenance again and again in a short duration. So, the necessity to implicate new measures is pivotal for the natural growth in renewable energy and the environment as well. The CVT used in the wind turbine is the field of interest in wind energy. Though not much significant practical work has been done as of yet researches has been going on for quite some time. This paper has analyzed and covered maximum researches for a better upcoming ideas and perfect implementation of the project. The designed system is based on CVT and will provide an excellent solution to the existing problems and the possibilities are immense for the development of the wind turbine.

4 Proposed Solution

We are proposing a design that is an alternative to the traditional gearbox as used in wind turbines. Here, we have used a Cone CVT with slots cut throughout the surface of the cone, and teeth of suitable thickness will be inserted in those slots (shown in Fig. 2). Teeth, free to move between the slots, will be connected through a chain drive between the two cones (one being driver and the other being driven). Teeth connected together with a circular mechanism for constant movement along with the chain is used as a transmission system.

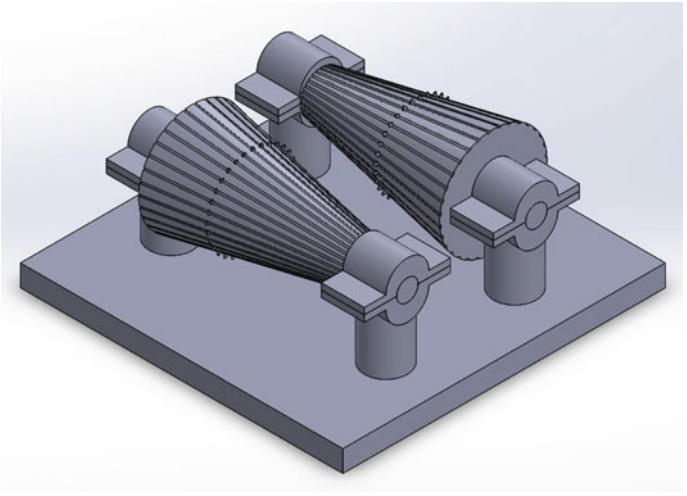

Fig. 2 Proposed design (isometric view)-designed in solid works 2018

5 Conclusion

In this review paper, the study of various research papers in context to the use of Continuously Variable Transmission as an alternative of gearbox in the wind turbines to provide a constant input to the generator of wind turbine is done. We are proposing a design that is an alternative to the traditional gearbox as used in wind turbines. Here, we have used a Cone CVT with slots cut throughout the surface of the cone, and teeth of suitable thickness will be inserted in those slots. Teeth, free to move between the slots, will be connected through a chain drive between the two cones (one being driver and the other being driven). The chain and sprocket mechanism may be used for the transmission from the variable output from the blades to provide a constant input to the wind turbine and thus eliminating fluctuations in the power output and also minimizing the use and reducing the cost of power electronics being used in the wind Turbines.

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