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GRID Interface with Electrically Excited Synchronous Generator Based Wind Energy System

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Abstract

This paper describes model for variable speed wind turbine types namely Electrically Excited Synchronous Generator (EESG). The significant advantage of Chap Drive hydraulic drive train system include controlling the rotor speed and using the rotor to absorb high frequent wind turbulence leading to creation of constant power output above rated wind speed, and thereby enabling the usage of an electrically excited synchronous generator directly connected to the grid without the need of frequency converters. Main objective in this paper is to reduce the Cost of Energy (CoE) and to increase the reliability. To support this, Chap Drive wind turbines are preferred, especially for the rising offshore wind power generation

Key Words:EESG, CoE, Chap Drive.

1. Introduction

The modern power system integrates various AC and DC systems in areas of power system distribution, transmission, and generation. Power system handles both centralized and distributed generation sources and must accommodate controllable, variable, and intermittent energy sources such as wind energy, solar energy. The integration of wind power into electrical grid is steadily increasing in United States due to the latest environmental concerns and this trend expected to continue. There are different technologies for wind turbine system and one such technology is variable speed wind turbine (VSWT). Variable speed wind turbines can operate over a wider range of wind speeds. Speed and power control enables variable speed wind turbines to yield 20 to 30 percent more energy than fixed speed turbines. Recently, several authors have studied the impact of wind energy integration into electrical grid and identified the main problems as power quality, power factor, voltage control, frequency synchronization, reactive power control and harmonics[1]

2. Hydraulic Transmission

The Chap Drive AS targets the ultimate goal of the wind industry to reduce the CoE. As the wind, turbines are increasing in size top weight reduction is increasingly critical. Mechanical gears or direct drives are the dominant types of drive trains in the wind turbine market today. They both require expensive yet high failure rates frequency converters for controlling the rotor speed from the generator. Gearbox failures are less frequent than the frequency converters, but because the turbine downtime is longer for each failure, power production loss is at the same undesirable level.

The industry is looking for a simple solution for improvements of the reliability, which is to eliminate the mechanical gearbox and frequency converters. The permanent magnet direct drive generator solves the issue with the mechanical gearbox but has still the need for frequency converters. Additionally concerns about sourcing and cost for permanent magnets reduce the attractiveness of these solutions. With the latest developments of high efficiency hydraulic technology with digital valves driven by the industry for automotive hydraulic systems, the hydraulic drive train for wind turbines is now a unique solution with compact and low top weight design; highly reliable and efficient components For offshore wind turbines, they are even more outstanding.

3. Chap Drive and Integrated Variable Hydraulic Drive Train

The Chap Drive AS has developed an integrated hydraulic drive train for wind turbines that will remove the need for mechanical gearbox, permanent magnets, frequency converters, and transformer as shown in Figure 1. The Integrated hydraulic drive train consist

- low speed hydraulic pump
- high speed hydraulic motor with variable displacement volume
- Electrically Excited synchronous generator

The concept of this hydraulic drive train described in the Norwegian patent number NO200664996 [3].

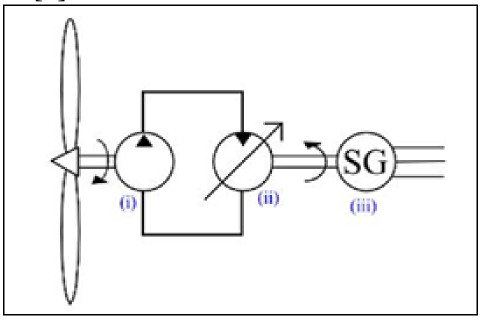

Figure 1: Integrated Hydraulic Drive Train for Wind Turbines

The variable displacement volume of the motor used to control the rotational speed of the pump and rotor when the generator connected to the grid. The motor operated at constant speed, and any changes in the displacement volume will cause a proportional change in the flow rate of the hydraulic oil from the pump, thus the motor displacement control will control the rotor speed. The difference between integrated hydraulic Chap drive with conventional type of drive as shown in Table.1

Table 1: Difference between Chap Drive with Conventional Type of Drive Train

Power Components	Gearbox wind system	Direct drive wind system	ChapDrive wind system
Transmission ratio for a 3 MW wind turbine	Fixed 1:100	Fixed 1:1	Variable 1:nnn
Generator	Double fed induction generator	Permanent magnet generator	Electrically excited synchronous generator
Frequency converter	Need	Need	Nil
Transformer	Need	Need	Nil

4. Needed of the Frequency Converters in Wind Turbines

Purpose of the frequency converter:

- Variable speed control
- Optimises energy production
- Dynamic load control
- Reduces power and torque fluctuations, extreme loads etc.
- Grid control

- Stabilises of the grid reactive power control, low voltage ride through control etc

5. Chap Drive Avoid Using Frequency Converters

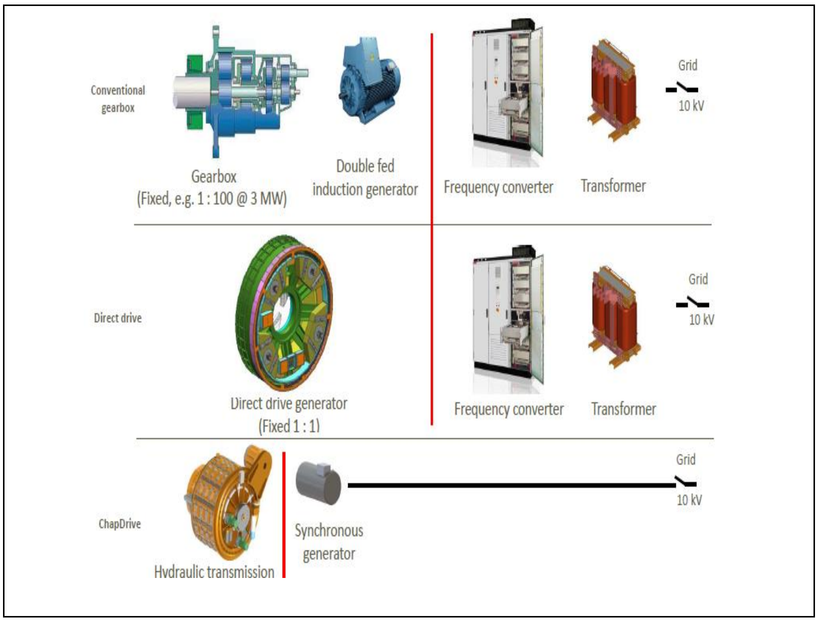

Figure 2: Integrated Chap Drive Converter

The Chap Drive Integrated Hydraulic Transmission that is essential for low top weight and robustness. Chap Drive AS has developed a new control system as shown in Figure 2. The Chap Drive Control System developed such that maximum efficiency will maintained for wind speeds below rated power. This control system handles the entire turbine, including blade pitch, variable turbine rotor speed and synchronous generator excitation. The hydraulic drive train is controlling the rotor speed without the need for a frequency converter, and with the use of a synchronous generator with an electrical voltage in the 10 kV range, eliminating the need for a voltage transformer. The Chap Drive hydraulic drive train is therefore eliminating the down time related to power electronics. Since the Chap Drive, hydraulic drive train also replaces the gearbox, the down time related to gearbox failure also eliminated. In the development of the Chap Drive Control System, an analytic model of the system has developed as shown in Figure 3.

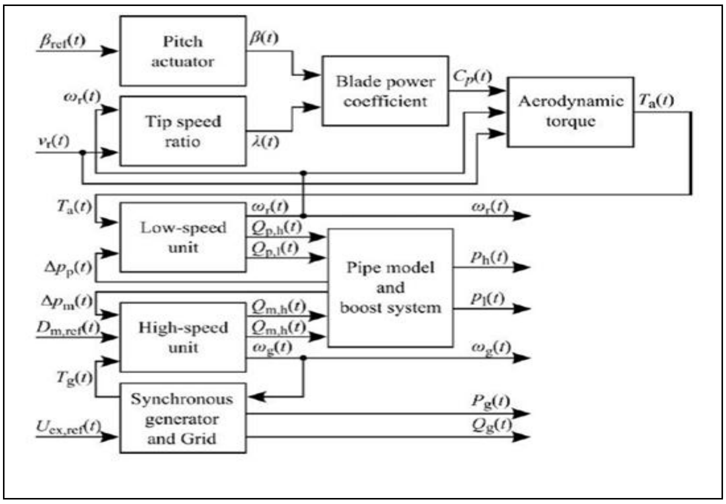

Figure 3: Overview of Simulation Model

Input Variables

- Mean wind speed over the rotor swept area, vr(t),
- Pitch angle reference, βref(t),
- Motor displacement reference, Dm, ref(t), and
- Generator excitation voltage reference, Uex, ref(t),

Output variables

- Rotor speed, ωr(t),
- Generator speed, ωg(t),
- Pressure in the high pressure side of the circuit, ph(t),
- Pressure on the low pressure side of the circuit, pl(t),
- Generator active power, Pg(t),
- Generator reactive power, Qg(t), and
- Pitch angle, β(t).

The model developed in Mat lab Stimulant. It used in a simplified form for controller design, while the full dynamic non-linear continuous time model used for controller performance evaluation. Furthermore, the model of the hydraulics and the generator also exported to GH Bladed for detailed investigation and verification of the performance and characteristics of the controller with the full dynamics of the wind turbine as shown Figure (4) and Figure (5).

Measurements-Variable Speed Control

- 10 minutes mean values are shown from the test wind turbine, Chap Drive 1, for a period of 5 month
- Optimal rotor speed at all time ensuring maximum energy yield from the wind
- Generator speed is always constant.

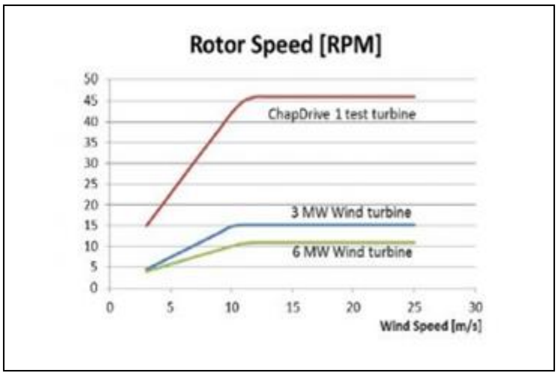

Figure 4: Variable Speed of Rotor

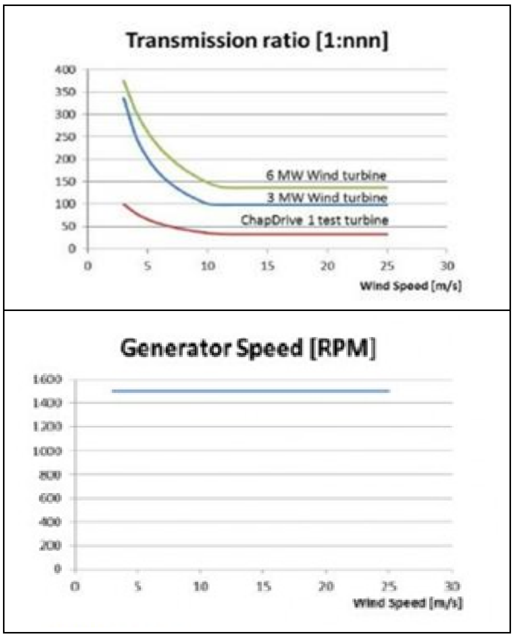

Figure 5: Variable Speed of Generator

6. Measurements and Model Verification

The performance of the analytical model described in section 6, has compared with prototype measurements.

The model was altered so that the input from the aerodynamic torque, Ta(t), shown in Figure 2, was replaced with the measured rotor torque, and the measured displacement, Dm(t),was used as an input instead of as a control parameter. Time series showing the rotor speed, ωp(t), and the power output to the grid, Pg(t), for a wind speed ranging from cut-in wind speed to rated wind speed, is shown in Figure 2. Blue lines are measured values and red lines are simulated values. The purpose of the analytic model is to simulate the dynamic behavior of the hydraulic drive train, and it expected that the simulations would resemble the measurements. The analytic model has not tuned to reproduce the steady state performance of the system, which explains the offset between the simulation and the measurements.

Technical Benefits Affect Financial Performance

The Chap Drive has developed a scaling model for comparing the various different drive train configurations as shown in Figure (6). In this model, Chap Drive has estimated the top head mass of a robust lightweight variable hydraulic drive train with an electrically excited synchronous generator directly connected to the grid.

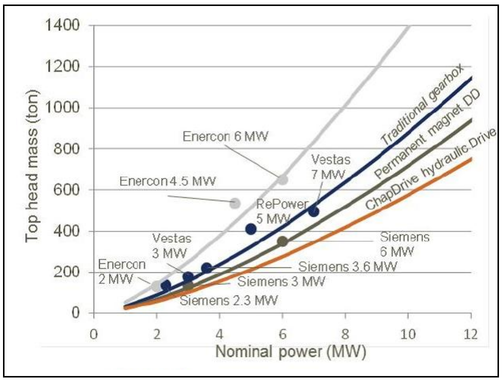

Figure 6: Various Different Drive Train Configurations

The top head mass does Chap Drive perform a result of extensive conceptual studies. As seen in the figure the benefit of eliminating the mechanical gearbox, frequency converter and transformer enables Chap Drive to develop an integrated hydraulic drive train with a top head mass below that of traditional gearbox solutions and permanent magnet solutions. The financial benefits reducing top weight and eliminating the mechanical gearbox frequency converter and transformer as shown in Figure 7. The need for permanent magnets enables to Chap Drive achieve a target of up to 20% CAPEX reduction 15% OPEX reduction and 20% CoE reduction even though the annual energy production reduced by up to 2 % compared to mechanical gearbox solutions and permanent magnet solutions.

7. Chap Drive Control System

- Pitch control
- Displacement control
- Digital valve control
- Excitation control of generator
- Turbine control (state, yaw, temperature, etc.)

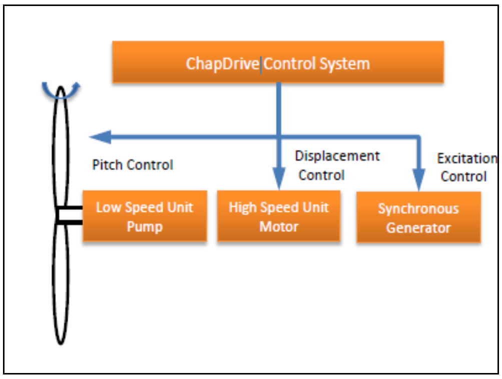

Figure 7: Mechanical Gearbox Frequency Converter

8. Conclusion

The Chap Drive hydraulic drive train can control the rotor speed and use the rotor to absorb high frequent wind turbulence creating constant power output above rated wind speed, thus enabling the use of a synchronous generator directly connected to the grid without the use of frequency converters. It also been shown that this behavior can be modeled analytically and that simulations of the behavior of this analytic model describe the measured behavior of the hydraulic system. The financial benefits include reducing top weight and eliminating the mechanical gearbox frequency converter and transformer. The need for permanent magnets enables the Chap Drive achieve a target of up to 20 % CAPEX reduction 15% OPEX reduction and 20% CoE reduction even though the annual energy production reduced by up to 2% compared to mechanical gearbox solutions and permanent magnet solutions.

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