ANALYSIS OF MULTIPLE-GENERATOR DRIVETRAIN CONFIGURATION IN WIND TURBINES

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ABSTRACT

A single generator drivetrain in a large wind turbine can be replaced by a multiple-generator drivetrain (MGD) configuration to increase the efficiency and reliability and reduce the cost of wind power. This poster investigates the benefits of a MGD configuration in large capacity wind turbines. Qualitative and quantitative comparisons of a MGD configuration to a conventional drivetrain configuration is provided to better understand the advantages and disadvantages of having the MGD configuration in wind turbines.

INTRODUCTION

Major goals of the wind industry in designing modern wind turbines with higher rated powers are:

- Reducing the cost of energy (COE)
- Increasing the wind power capturing
- Increasing the efficiency and reliability of the turbine gearbox and generator systems
- Reducing the size and weight of the turbine gearbox and generator systems

To achieve these goals, Wind Partnership for Advanced Component Technology (WindPACT) started studying a range of configurations in early 2000 :

- Direct drive by Northern Power Systems
- Single stage drive with a medium speed generator by Global Energy Concepts
- **Distributed drive with multiple generators** by Clipper Windpower
  (US 7042110 B2; May 09, 2006 & US 6304002 B2; Oct. 19, 2001)

Figure 1 shows a conventional drivetrain configuration that is the baseline concept (1.5 MW wind turbine with an induction generator) in this study, and a schematic diagram of a MGD configuration is shown Figure 2. A single stage gearbox has multiple outputs to multiple generators, and the output of the generators is connected to the grid.

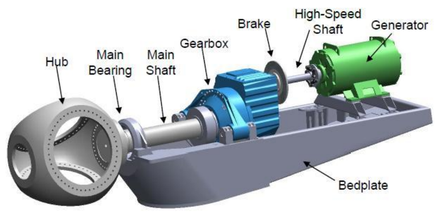

Figure 1- Conventional drivetrain configuration (The Baseline Concept)

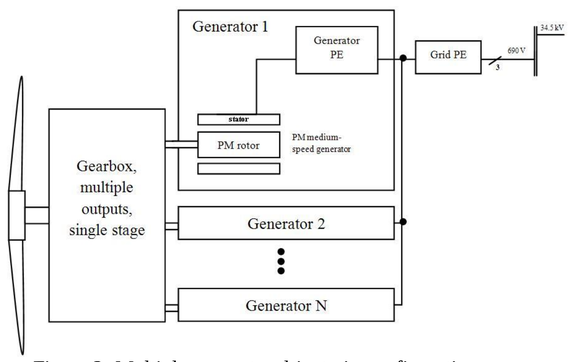

Figure 2- Multiple-generator drivetrain configuration

The 2.5 MW Liberty wind turbine, as the largest wind turbine manufactured in the United States, is proposed in four versions with different rotor blade lengths. It has four synchronous permanent magnet generators and each has a rated power of 660 kW at 1133 rpm.

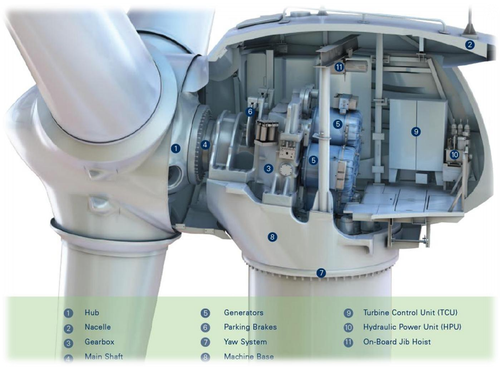

Figure 3- 2.5 MW Liberty wind turbine components

MATERIALS AND METHODS

Three major sources have been used to explore the use of a MGD configuration in wind turbines:

- Technical reports
- Scientific papers
- Patents

The advantages and disadvantages of this new configuration on major components (gearbox, generator, and tower) of a wind turbine are studied, and new ideas on improving the performance of a wind turbine with a MGD configuration are proposed.

RESULTS

- Table 1 summarizes the advantages and disadvantages of three major components of a wind turbine with a MGD configuration compared with the baseline (Cortell 2002, NREL/CP-500-3117).
- Figures 4 and 5 provide the efficiency and cost comparisons of a MGD versus the baseline drivetrain (Poore 2002, NREL/SR-500-33196).
  - The MGD reduces the turbine cost by up to 35% over the baseline concept (Mikhail 2011, PIER)
  - The MGD provides a constant high efficiency at different input power values; the efficiency curve with the baseline concept decreases rapidly at lower input power values.
- Main components of a MGD configuration that have shown technical difficulties have been studied and some new techniques to solve them have been proposed.

GENERATOR	
Advantages	**Disadvantages**
1. Ease of Maintenance ↑	1. Power Electronics (PE) Cost ↑
2. Reliability ↑	2. Dynamic Effects ↑
3. Efficiency ↑	
4. Generator Cost ↓	
5. Capacitor Cost ↓	

(a)

GEARBOX	
Advantages	**Disadvantages**
1. Efficiency & Reliability ↑	1. Diameter Seal ↑
2. Gear Ratio ↑	2. Gear Diameter ↑
3. Weight and Cost ↓	3. Noise Damping ↓
4. Frequency Noise ↓	
5. Gear Tooth Stress ↓	

(b)

TOWER	
Advantages	**Disadvantages**
1. Site Specific Design ↑	1. Blade Pitch Location ↓
2. Support Structure Cost ↓	
3. Hub Mass ↓	
4. Difficulties in Assembly ↓	
5. Difficulties in Transportation ↓	

(c)

Table 1- Advantages and disadvantages of a multiple-generator drivetrain configuration compared with the baseline conventional drivetrain configuration for the same rated power wind turbine in (a) the generator, (b) the gearbox, and (c) the tower.

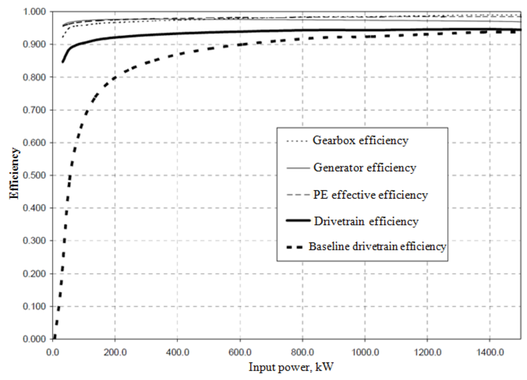

Figure 4- Multiple-generator drivetrain efficiency by components compared with the baseline drivetrain efficiency

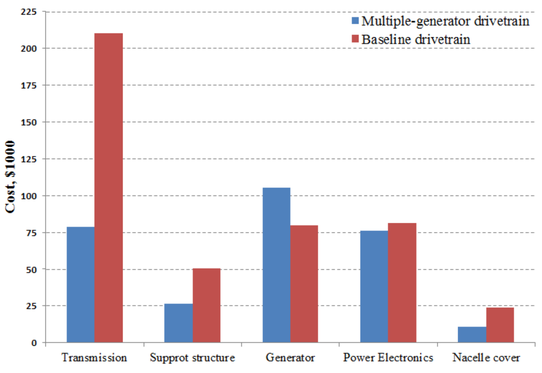

Figure 5- Multiple-generator and baseline drivetrain component costs comparison

The technical difficulties of the manufactured wind turbines with a MGD configuration in Lackawanna, NY, showed the need of improving this design in such aspects for future wind turbines with a MGD as:

- Gearbox: Advanced technologies (Ragheb 2010, INREC10)
- Sealing: Combined labyrinth seal and screw-type gasket bearing sealing arrangement (US 7946591 B2)
- Power electronics: Control on the generator electromagnetic torque summation (Deng 2010, IEEE)
- Grid connection: Best converter options (Gupta 2012, IPCSIT **28**)

There are several interesting concepts that can be incorporated into a MGD to reduce the COE and increase the reliability of the system components.

- Using high-temperature-superconductor (HTS) generators in a MGD configuration to reduce the size and weight, and increase the efficiency of a wind turbine (Lewis, 2007, PESGM2012, IEEE).
- Using Variable Electromotive-force Generators (VEG) in combination with other regular generators to expand the overall operational range of a wind turbine (Goudarzi 2012, IMCE2012, ASME; Zepp 2011, US 7863789 B2; Zepp 2002, US 6492753 B2).
- Implementing different capacity generators to increase the overall operational range of a wind turbine, decrease the COE, and increase the reliability and efficiency of the generators.
- Improving the gearbox system with an infinitely variable speed convertor.
- Hybrid power-generating systems (US 7518257 B2; April 14, 2009 & US 7936078 B2; May 03, 2011).

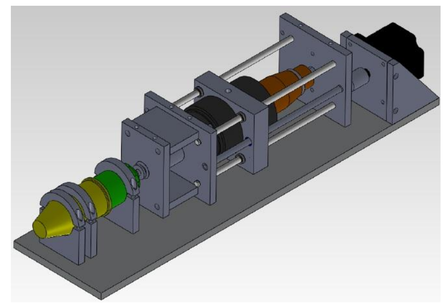

Figure 6- Completed CAD assembly of a VEG

CONCLUSIONS

Implementing a MGD configuration in a large capacity wind turbine has such advantages as:

- ✓ Significant cost and weight reduction of the drivetrain
- ✓ Increasing the efficiency and reliability
- ✓ Simpler assembly

It seems that more research is needed on:

- The gearbox and bearings sealing
- The system COE
- Expensive power electronics
- Drivetrain noise emission