Progress Report

Project Name	*Continuously Variable Hydraulic Transmission for a Small Wind Power Drive Simulator*
Report compiled by	*Jose M. Garcia*
Reporting period	*01-01-2013 to 10-31-2013*

Section One: Summary

This progress report describes in section two the major activities accomplished for the current reporting period. According to the grant proposal submitted in 2012, the design activities proposed are underway with a 5-month delay with respect to the proposed timeline. The project goal of educating and rising awareness of fluid power systems among the students is being fulfilled, as the students had instruction and exposure to hydraulic components as a result of their participation in the design process of this project. A whole course will be taught around this project in the spring 2014

Section Two: Activities and Progress

First: A group of four volunteering students in the Engineering Technology program began the design project in early February, initial discussion was cantered about the power requirements of the system to be built and the source of power.

Second: The students and faculty advisor decided to use an electric motor with a controller as the source of mechanical power to the hydrostatic transmission. It was also determined that the location for the construction and operation of the proposed instructional test bench should be the laboratory space in Room KC 149. This fact bounded the power limit of the test system to 6 kW.

Third: Given that the proposed setup was originally intended for demonstration of a 10 kW system, the students and advisor contemplated the possibility of using a regenerative option that would allow recovering a portion of the 6 available kW to reach a maximum simulated power of 10 kW. Due to the complexity of the design and lack of experience with hydraulics, it was decided that this feature would be implemented at a later time.

Fourth: The students visited a local facility in April, 2013 with an installed 1MW wind power turbine, and also reached out to the local electrical energy provider: Duke Energy who promised to advise on electric components.

Fifth: Sizing of the components began in April and was found that bent axis units would be preferable for maximum gear ratio range. Students found that a mechanical speed reducer was needed to make the hydrostatic operate at optimal RPM. A frame for the simulator was acquired and adapted for the construction of the simulator.

Sixth: Students left for summer activities and no other students were recruited to continue work on the project, the faculty then, revised and redefined the 382 Mechanical Engineering Technology course for the spring semester of 2014, Industrial Automation Control. This course is going to be a Project Based Learning course where the students will build the simulator and will design and build the controller as part of the requirement for their class. Additional funding was provided by the College of Technology to complete this task by May 2014.

Seven: IIT Graduate student Zhi Yang, performed a simulation analysis and tests of a variable ratio wind power turbine to calculate possible power optimization of small scale wind generators.

Section Three: Institutional & Project Issues

The lack of volunteer students during the summer time and in the fall semester forced the faculty to delay the project one semester. This opened up the opportunity to find alternatives to complete the project. The alternative is to include the building process of the simulator in the MET 382 class "Industrial Automation Control" as a Project based course, where all the material and effort of the class is cantered around building the project itself.

Section Four: Outputs and Deliverables

At the end of the spring semester I expect to have a running prototype so that students taking fluid power courses in the school of Mechanical Engineering technology and Electrical Engineering technology can use the simulator to learn about variable ratio drivetrains and how hydraulic machines are used to achieve such variable ratios. Once the simulator is completed it will be used in the fluid power class MET 230. It may also be used in the Electrical engineering technology department to teach hybrid electric drives.

The simulation model will also be implemented with hydraulic components to test and scale for larger generators

Section Five: Outcomes and Lessons Learned

All four students involved in this project got exposed to fluid power components and systems for the first time. Furthermore, they learned how to size the components of a system based on the job requirements.

Section Six: Evaluation

The proposed design was presented at ASME, SMASIS conference in Utah. Where preliminary background research showed that variable ratio drivetrains can improve the efficiency of wind power turbines

Section Seven: Risks, Issues and Challenges

So far, the greatest challenge has been to find students available to work on the project on a voluntary basis, as seniors graduating this year are not interested or lack experience in hydraulics. To overcome this issue, the students in the ET and AS MET programs taking the 383 class will help finish the project by the end of May 2014

Section Eight: Collaboration and Support

- Industry collaboration: Hydraforce and Parker-Hannifin have donated components to build the hydraulic system. The college of technology Purdue gave matching funds for the project.
- Interdisciplinary collaboration: This project has expanded from the mechanical engineering department to the electrical engineering department at IIT. An additional goal is to impact as many students in both academic institutions as possible (Purdue and IIT).

Section Nine: Next Steps

- Finalize design and sizing of minor components. (Faculty) By December 15, 2013
- Prepare course deliverables and time line for students taking MET 382 in the spring of 2014, 5 registered so far which is sufficient to open the course. By December 15, 2013 (Faculty)
- Buy the components and build the simulator in four months as part of the requirement for the class. By May 2014 (students and faculty)

Total Grant	**$ 5,000**	**Duration of project**	**12 to 18 months**
Reporting Period	**Months 1 to 10**		

Appendix

SMASIS Paper:

1. Yang, Z., Krishnamurthy, M., **Garcia J.**, "Modeling and Control of a Continuously Variable Planetary Transmission for a Small Wind Turbine Drivetrain", (SMASIS 2013), Proceedings of the ASME 2013 Conference on Smart Materials, Adaptive Structures and Intelligent Systems, Snowbird UT, September 16-18, 2013.

PURDUE
COLLEGE OF TECHNOLOGY
KOKOMO

Continuously variable hydraulic transmission for a small wind power drive train HIL simulator

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ILLINOIS INSTITUTE OF TECHNOLOGY

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Introduction

Usually, in wind power turbines the rotor rotates at approximately 15 to 25 revolutions per minute (RPM) in large wind power generators and up to 60 RPM in small wind power generators, while the output shaft speed of the electric generator must rotate at 1800 to 2200 RPM to operate at its optimal conditions. A gearbox or series of gearboxes are used to couple the turbine hub and the generator. These gearboxes have fixed gear ratios and therefore the amount of power captured by the wind turbine is limited by the available wind speed and the pitch angle which is usually fixed in small wind power turbines. This mechanisms are unreliable and could be improved to capture more energy from the wind

Background

Recent studies[1-4] have proposed the use of hydrodynamic, hydrostatic or mechanical Continuously Variable Transmissions (CVT) to replace fixed rario gearboxes. The idea is to improve the overall reliability of the wind turbine, reduce the weight of the nacelle components, reduce down time and significantly reduce the cost of installation and operation. Additionally, the overall efficiency of the turbine could be increased because the generator's shaft could turn at its optimal speed while maintaining an ideal λ to achieve a maximum C_p

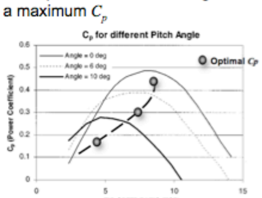

Figure 1 Power coefficient vs. tip speed ratio

Objectives

1. To design and build a wind power drive train simulator fitted with a hydrostatic transmission
2. To develop a training tool that will allow students apply technical skills needed in industry by:

- Assisting them in the design and construction process
- Teaching about the benefits of using continuously variable transmissions in wind power and other drive train applications

Students using the simulator will reproduce the effect of real wind speed profiles. The simulator will be instrumented to measure the input and output power transferred by the system

Educational Outcomes:

- Students will learn to estimate the available power from the wind,
- Students will learn how mechanical power is transmitted using a variable hydrostatic transmission
- Students will learn how mechanical power can be converted into electricity.

This training station will be used to support instructional laboratory activities in the College of Technology at Purdue University in Kokomo, IN.

References

1. Thul, B., Dutta, R., & Stelson, K. (2011). Hydrostatic Transmission for Mid-Size Wind Turbines. 2011 IFPE (pp. 1023-1038).
2. Schmitz, J., Vatheuer, N., Reinertz, O., & Murrenhoff, H. (2011). Hydrostatic Drive Train in Wind Energy Plants. 2011 IFPE (pp. 1017-1022).
3. Mangialardi, L., & Mantriota, G. (1996). Dynamic Behaviour of wind power systems equipped with automatically regulated continously variable transmission. Renewable Energy, 7(2), 185-203.
4. Artemis Intelligent Power. (2010). A hydraulic alternative to mechanical gearboxes. (p. 3)
5. Zhao, X. (2003). A novel power splitting drive train for variable speed wind power generators. Renewable Energy, 28(13), 2001-2011. doi:10.1016/S0960-1481(03)00127-7

Preliminary Simulation Results with Mechanical Transmission

A Mathematical model was implemented in MatLab/ Simulink® environment according to the block diagram shown in the figure below. Each block represents the corresponding component in the experimental test stand. It includes a simulated wind profile, the turbine rotor, gearbox, Continuously Variable Planetary (CVP) and the induction generator. A simple control strategy is also included in the loop to tune the CVP ratio

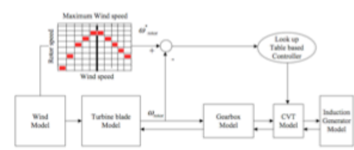

Figure 2 Block diagram of the simulated wind power turbine drivetrain

When the wind speed is between 4m/s and 11m/s, the wind turbine system with CVP can optimize the CVP ratio, thus more power is harvested form wind. As the wind speed increases above 11m/s, the wind turbine system with CVP can maintain the peak power through cut-out precisely. However, the power drops significantly in the system without CVP

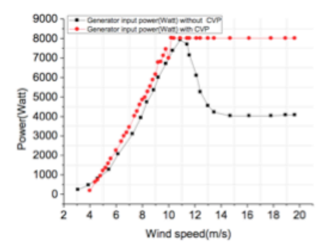

Figure 3 Simulated comparison between a fixed ratio and variable ratio wind power drivetrain