Real-Time Implementation of Synchrophasor-based Wide-Area Power Oscillation Damping Control System

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***Abstract*—The modern power grid in increasingly being used under operating conditions of increasing stress, for which it was not designed. The increasing levels of variable sources such as wind and other other renewables also present stability problems. One of the these stability issues is the phenomenon of low frequency, electro-mechanically induced, inter-area oscillations. Research has been carried out into the area of wide area oscillation damping to study and damp these inter-area modes. Also, the adoption of synchrophasor measurement data from Phasor Measurement Units (PMU's) is rising annually. This paper takes an established Phasor based oscillation damping method and combines it with modern PMU measurements to produce a hardware prototype of a real-time oscillation damping control system using remote PMU signals sent over a communications network. The developed prototype is tested with various inputs to demonstrate the flexibility and advantages of using wide area measurements in power system control.**

***Keywords*—IEEEtran, journal, synchrophasor, PMU, damping control, Wide Area measurements**

I. Introduction

THE goal of this paper is to demonstrate the flexibility in oscillation damping controller design that is provided by using synchrophasors. The Phasor Power Oscillation Damping algorithm originally developed by Ängquist and Gama [2] is run on a National Instruments real-time controller. A slightly modified, SIMULINK model of the four-machine, two-area network developed by Klein-Rogers and Kundur [3] is run on the eMEGASIM [4] platform from OPAL RT. This allows interfacing an externally generated control signal with the simulated model. The flexibility of the developed controller is also demonstrated by extracting various data from the synchrpohasor input and using each as a damping input to the controller. A brief analysis of the performance of each input is also presented.

A. Methodology

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This project was supported by the Nordic Energy Research through the STRONg^2rid project.

II. Setup Preparation

III. Testing

IV. Additional Inputs

V. Challenges

A. Time Delays

B. Analogue Limits and Noise

C. Loop Rates and FPGA Resources

VI. Conclusion

This work has demonstrated the feasability of using wide-area power system data in the design of an oscillation damping controller. The real-time simulation results prove that the design goals of the controller were met. The flexibility of synchrophasor data was demonstrated and the wide range of inputs possible from this were also tested.

Appendix A
Proof of the First Zonklar Equation

Appendix one text goes here.

Appendix B

Appendix two text goes here.

Acknowledgment

The authors would like to thank...

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

[2] L. Ängquist and C. Gama *Damping Algorithm based on Phasor Estimation* in Power Engineering Society Winter Meeting, 2001. IEEE, Volume 3, pp. 1160 - 1165

[3] M. Klein, J. G. Rogers and P. Kundur *A fundamental study of inter-area oscillations in Power Systems* IEEE Trans, PWRS, no. 6, pp. 914-921, 1991.

[4] *eMEGASIM Power Grid Real-Time Digital HArdware in the Loop Simulator* Available Online at : http://www.opal-rt.com/

Michael Shell Biography text here.

John Doe Biography text here.

Jane Doe Biography text here.