Tutorial Title: Simulation of Renewable Energy in Power System

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Abstract

Renewable energy is the energy source of the future, with none or minimum pollution impact. Among the many available renewable energy sources, wind and photovoltaic power are the most commonly used in power system environments. The well-established power system network is a mature technology, over a century old. The workhorse used in such power systems is a synchronous generator, operated at constant voltage and frequency. To convert renewable energy into electrical energy, different types of generation are introduced into power systems: generators are operated at variable speeds and many of the power processors used include power converters and attempt to maximize captured energy.

The **R**enewable Energy **P**ower System **M**odular **Sim**ulator (RPMSim) was developed to study and to simulate renewable energy in the power system environment. It is based on a modular concept where components of a power system can be connected to form a power system network, allowing us to examine different aspects of renewable generation (e.g., wind-diesel operation, power quality assessment, variability of wind and loads, energy storage, etc.). RPMSim facilitates an application-specific and low-cost study of system dynamics and allows for the development of control strategies able to balance the system power flows under different generation/load conditions. This software package, developed by the National Renewable Energy Laboratory (NREL) using the VisSim™ visual environment and available for public domain (ftp://ftp2.nrel.gov/pub/Incoming/RPMSim.zip), comes with a manual, a viewer, and a set of modules in its library.

In the manual, we present the principal modules of the simulator. Using case studies of a hybrid system, we also demonstrate some of the benefits that can be gained from understanding the effects of the designer's modifications to these complex dynamic

systems. In these systems, the diesel generator, working as a master, controls the voltage and the frequency. The wind speed varies with time, as does the village load. Therefore, we regard the diesel generator as a controlled energy source, whereas the wind is an uncontrolled energy source and the village load is an uncontrolled energy sink. The diesel generator balances the difference between the power consumed by the village load and the power generated by the wind turbine. On occasion, the wind speed can be very high, resulting in energy generation that exceeds the energy demand of the village load. Under such circumstances, the power from the diesel generator becomes very low, and the wind may try to drive the diesel engine. Should the wind turbine override the diesel, the frequency control could be lost, and the system would become unstable. To avoid this, the dump load is controlled so that the power generated by the diesel will always be higher than a minimum value. In addition, the energy surplus can be saved for future use by utilizing the inverter/battery assembly. By properly choosing the sequence of events programmed for our case studies, we demonstrate that all operational aspects of the hybrid power system, briefly discussed above, can be easily taken into consideration.

In this tutorial, we present the principles of the RPMSim applications illustrated by selected simulations that demonstrate its usefulness in engineering practice.

Presenter(s) background/biography

Jan T. Bialasiewicz received the M.S. degree from Warsaw University of Technology, Warsaw, Poland, and the Ph.D. and D.Sc. degrees from Silesian University of Technology, Gliwice, Poland, all in electrical engineering. Since 1985 he has been with the Electrical Engineering Department, University of Colorado Denver. He also is a Professor with the Polish-Japanese Institute of Information Technology, Warsaw, Poland.

In 1997, he was a Visiting Professor with the Faculty of Electronics, Warsaw University of Technology. In 2005, he was a Visiting Professor with the Catalonia University of Technology, Barcelona, Spain, and a Visiting Professor with the Queensland University of Technology, Brisbane, Australia. For over 10 years he has been cooperating with the researchers of the National Renewable Energy Laboratory's National Wind Technology Center, Golden, Colorado. His research interests include control theory, modeling and identification of dynamic systems, renewable energy systems, and theory and applications of wavelets. He is the author of two books and numerous research publications.

Dr. Bialasiewicz is an Associate Editor of the IEEE Transactions on Industrial Electronics, a member of the IEEE Industrial Electronics Society Technical Committee on Renewable Energy Systems and a Registered Professional Engineer in the State of Colorado. He served as a Guest Editor of Special Section on Renewable Energy and Distributed Generation Systems, published in IEEE Transactions on Industrial Electronics, Vol. 53, issue 4 and 5.

Eduard Muljadi received his Ph.D. (in Electrical Engineering) from the University of Wisconsin, Madison. From 1988 to 1992, he taught at California State University, Fresno, CA. In June 1992, he joined the National Renewable Energy Laboratory in Golden, Colorado. His current research interests are in the fields of electric machines, power electronics, and power systems in general with emphasis on renewable energy applications. He is member of Eta Kappa Nu, Sigma Xi and a Senior Member of IEEE. He is involved in the activities of the IEEE Industry Application Society (IAS) and Power Engineering Society (PES). He is currently a member of Industrial Drives Committee, Electric Machines Committee, and Industrial Power Converter Committee of the IAS, and a member of the Working Group on Renewable Technologies and the Dynamic Performance of Wind Task Force of the PES. He holds two patents in power conversion for renewable energy.

Publications relevant to the tutorial:

[1] **Bialasiewicz, J.T**., Renewable Energy Systems with Photovoltaic Power Generators: Operation and Modeling, IEEE Trans. Ind. Electronics, accepted, to be published in 2008.

[2] **Bialasiewicz, J.T., Muljadi, E.**, Analysis of Renewable-Energy Sysytems Using RPM-SIM Simulator, IEEE Trans. Ind. Electronics, Vol.53, issue 4, pp. 1137-1143.

[3] Carrasco, J.M., Franquelo, L.G., **Bialasiewicz, J.T.**, Galvan, E., PortilloGuisado, R.C., Prats, M.A.M.; Leon, J.I., Moreno-Alfonso, N., Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey, IEEE Trans. Ind. Electronics, Vol.53, issue 4, pp. 1002-1016.

[4] **Bialasiewicz, J.T., Muljadi, E.**, Nix, G., Simulation-Based Analysis of Dynamics and Control of Autonomous Wind-Diesel Hybrid Power Systems, International Journal of Power and Energy Systems, Vol. 22 (2002), No. 1, pp. 24-33.

[5] **Bialasiewicz, J.T., Muljadi, E**., The Wind Farm Aggregation Impact on Power Quality, Proc. IEEE IECON'06, Paris, France.

[6] **Muljadi, E., Bialasiewicz, J.T.**, Hybrid Power System with a Controlled Energy Storage, Proc. IEEE IECON'03, Roanoke, Virginia.

[7] **Bialasiewicz, J.T., Muljadi, E.**, Power Transfer and Time-Domain Analysis of a Wind-Turbine Water-Pumping System, Proc. IEEE IECON'03, Roanoke, Virginia.

[8] **Bialasiewicz, J.T.**, Furling Control for Small Wind Turbine Power Regulation, Proc. ISIE'03, Rio de Janeiro, Brazil.

[9] **Bialasiewicz, J.T., Muljadi, E.**, Nix, R.G., RPM-SIM–Based Analysis of Power Converter Applications in Renewable Energy Systems, Proc. IEEE IECON'01, Denver, Colorado.

[10] **Bialasiewicz, J.T., E. Muljadi**, R.G. Nix, and S. Drouilhet , Renewable Energy Power System Modular Simulator RPMSim, User's Guide, NREL/TP-500-29721, March, 2001,171 pages.

Intended audience

This tutorial is intended for engineers interested in renewable energy generation who want to study dynamic behavior of power system when renewable energy sources are present in the grid. Also, it will be beneficial for utility system planners, engineering students, renewable energy developers, consultants, and university instructors.

expected knowledge in the material: basic, medium, advanced
A medium knowledge in electric circuit theory is needed.

topics as listed in the conference call for papers: Controls, Power Electronics, Power Generation, Power Transimission, Power Distribution, Electric Machines.