GridEd Undergraduate Design Project Summary of Results

Matthew Sonnenberg

Dr. Ewan Pritchard

Department of Electrical and Computer Engineering

North Carolina State University

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Summary of Grant and Project Description

On October 28th 2016 a GridEd undergraduate design project grant was awarded to Matthew Sonnenberg under the sponsorship of Dr. Ewan Pritchard. The design project is based around distributed energy generation and storage systems and their role in the future of electrical distribution. The goal of the project is to provide a study to categorize and optimize these systems with regards to controls and design. The project was proposed using a model-based methodology to evaluate and validate various topologies and controls. Another goal of the project is to provide an undergraduate student with exposure to distributed energy generation and storage systems, model-based design methodology, Matlab and Simulink software, power system controls and validation, and experience with rapidly increasing technology.

Work conducted

In order to satisfy the requirements of the proposed study, the researchers committed to evaluating and elaborating upon an existing microgrid model. A microgrid model was selected as it embodies all the aspects of distributed energy generation and storage systems and more included interconnect with the existing electric grid. These aspects combined with the recent attention microgrids have been receiving in both industry and literature make it a more practical and relevant application. The microgrid model and controls were developed using a model-based design paradigm, reference Fig 1. The timeline for the project is displayed in Fig 2.

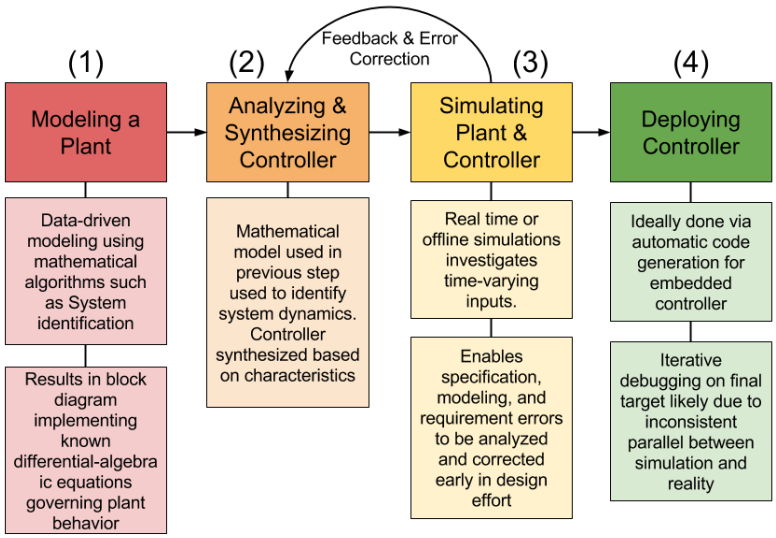

Fig 1. Summary of model-based design flow

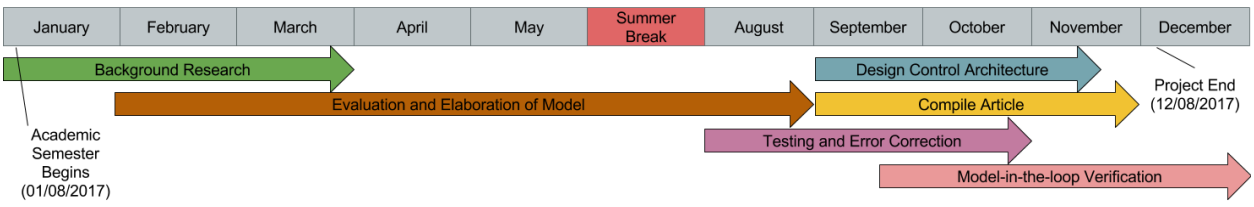

Fig 2. Project timeline

The funds secured by the grant enabled the researcher to acquire a new Lenovo T470 laptop and load it with the necessary MATLAB, Simulink, and dSPACE hardware in the loop software. This laptop was used to develop the Simulink microgrid model shown in Fig 2. The model contains input from solar, hydro, wind, genset, and electric grid energy sources as well as energy storage and both AC and DC loads. The model was intended to be inclusive of all popular distributed energy sources in order to evaluate various environments, architectures, and control paradigms. To this purpose, MATLAB scripts were written to initialize the model with customizable parameters according to our needs. This led to the development of several different architectures, the base architecture is shown in Fig 2.

Once the testing infrastructure was in place, the focus became to increase the resolution of the existing model. This was done by elaborating on thermal elements of the microgrid such as battery and genset temperature. Heat shedding equations (1) proportional to ambient temperature where added to the model in order to develop more accurate and realistic controls.

$$E = hA\Delta T \qquad (1)$$

Table 1. Equation variables

Variable	Meaning
E	Heat energy dissipated
h	Constant thermal dissipation coefficient
A	Surface area of structure
T	Ambient Temperature

The current state of the project is in the model elaboration phase in which additions and refinements were conducted on the model to make it as accurate as possible. The model based design methodology employed to create and simulate the model was compiled into a conference article, see the subsequent section for further information.

Publications

A conference article titled “Microgrid Development using Model-Based Design” was written as a result of this work and submitted article to IEEE Green Technologies conference in Austin Texas [1]. The paper presents and argues for a model-based design approach to developing microgrid systems and their associated controls, using the microgrid study conducted as a basis and support for the argument. The document goes in to detail about the developed microgrid model and associated process. The abstract is shown below for reference. The publication is pending acceptance and will be made available to Grid-Ed and supporting parties upon request.

***Abstract*— Microgrids are recognized as highly efficient and economical ways to promote distributed resources, energy storage devices, advanced electronic controls, loads and to integrate smart grid technologies. As microgrids and associated technologies advance in popularity and complexity, it becomes ever more important to institute robust design methods to control these systems. Advances in communication, controls, power electronics, protection, and other intelligent techniques must also be accounted for. Model-based design (MBD) methodology developed for electric vehicle and industrial controls accounts for these factors as well as facilitates system verification, locates and correct errors, and enables reuse of developed designs. Our work described in this paper demonstrates how model-based design may be applied to microgrids to reap the same benefits as widely received in vehicle and**

industrial production. We present a novel microgrid design to demonstrate the effectiveness of the proposed methodology.

What was Learned

The awarded grant went a lot farther than supporting a research study, it created an infrastructure for learning and experiencing model based design, microgrid systems, distributed energy sources, and control development and validation. Through the work funded by GridEd, I was able to grow academically from being ignorant of model based design and its electrical applications to becoming confident in my ability to present the work I have done to a technical audience. This experience has helped me grow as both a researcher and a person. Further, the hardware infrastructure and models may be used to support and develop future students with valuable power systems experience

Future work

The scope of the proposed project is too great to be completed in two academic semesters, future work is proposed to continue it. The assets secured with the grant combined with the existing ones at the FREEDM Systems Center will enable researches to complete the model and begin the hardware and software validation and verification process. Additional work is necessary to complete steps 3 and 4 in design process shown in Fig 2. The future work will consist of thoroughly simulating the controller with the plant model, correcting any errors and instilling confidence of it operation to complete step 3. Step 4 will consist of deploying the code to a hardware controller and conducting simulations with hardware in the loop, which will validate the system for live testing. The control architecture in Fig 5 displays the proposed control signals to be used in subsequent hardware testing. Further work will likely result in another publication.

References

[1] http://ieeegreentech.org/

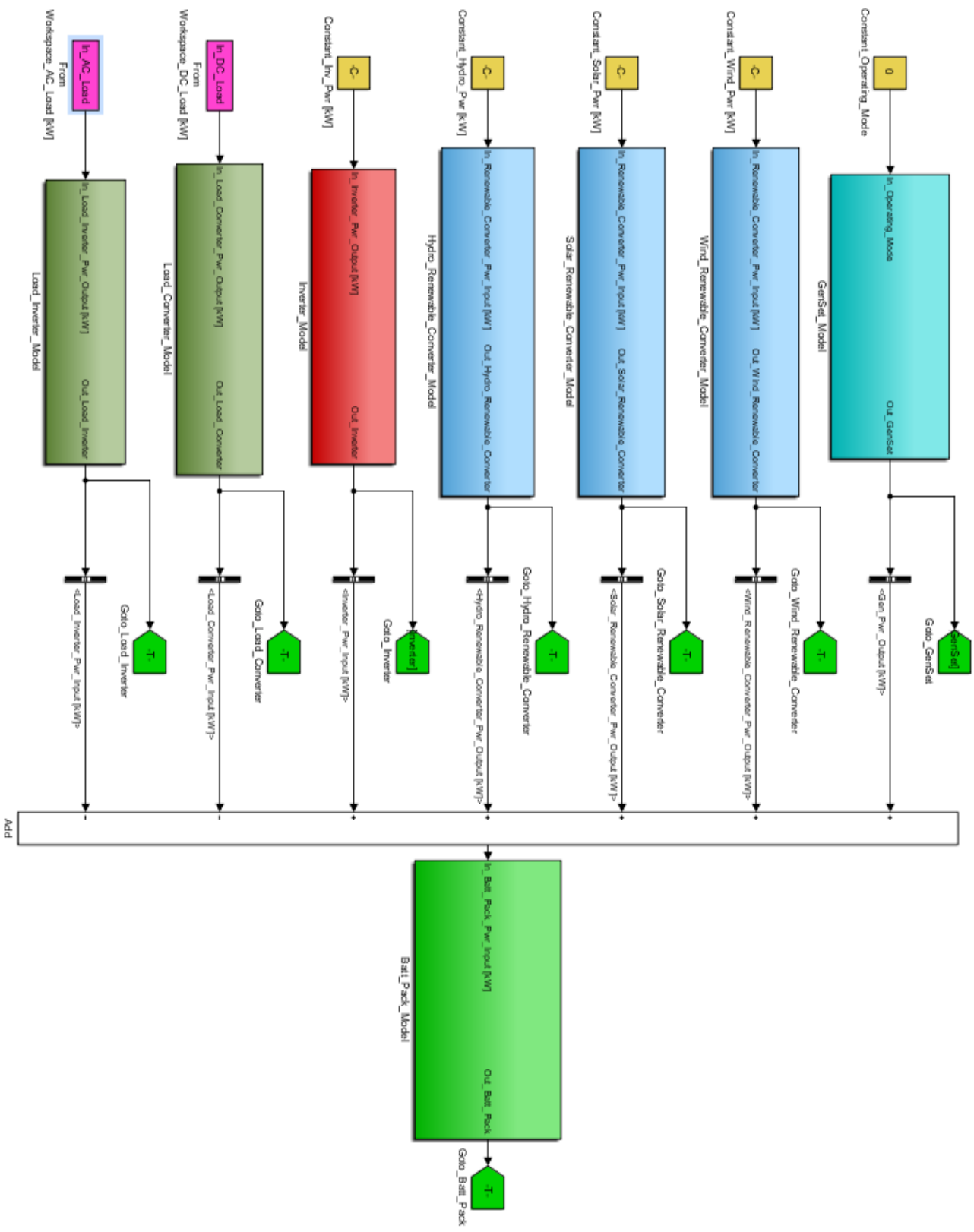

Fig 3. Simulink model of microgrid

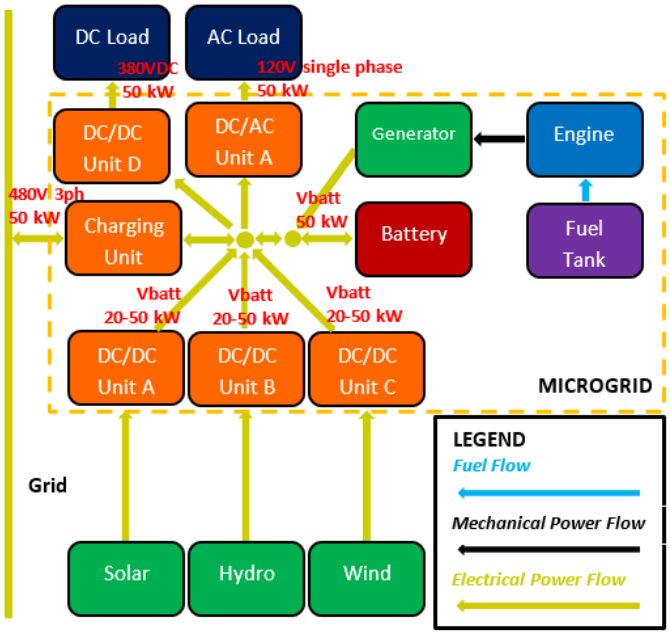

Fig 4. Microgrid Architecture

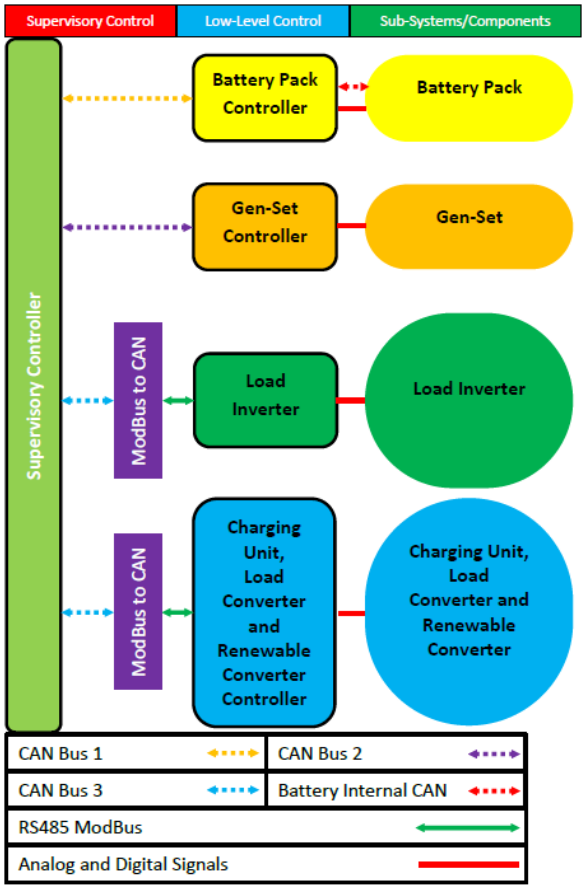

Fig 5. Control system architecture