Testbed for Transactive Energy and its Effects on the Grid & Protective Devices

SUNY Buffalo State
Electrical Engineering Technology

Introduction

The introduction of renewable energy sources has significantly diversified the supply of power in the modern grid. However, these assets create the need for more advanced techniques to manage supply and demand. To introduce alternative energy sources at the distribution level, new methodology is needed to maintain system reliability and efficiency. This distributed generation (DG) system requires sensors, monitors, and protective relays to perform in unison. To manage the extensive network of equipment, the concept of transactive energy has been discussed. Transactive energy (TE) is defined by The *Gridwise Architecture Council (GWAC)* as "A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using the value as a key operational parameter." Using SUNY Buffalo State's Smart Grid Lab, a test bed for TE was created with the purpose of studying the effects of multiple renewable energy assets in modern power systems with controls derived from relevant economic and physical constraints. The project initially focused on the creation of a microgrid which emulates a system utilizing a diverse range of power generation sources in conjunction with up to date techniques for monitoring, controlling and protecting modern power systems.

Preparation

To accomplish the outlined project, ETAP® power systems simulation software was used extensively to simulate the project before and during the construction and testing phases. The hardware used to build the microgrid consisted primarily of modules sourced from Lucas-Nuelle® (LN) that model various components of the power system. The modules include a utility source, double-fed induction generators, photovoltaic (PV) systems with grid inverters, wind turbines, overhead and underground transmission lines, pump storage, and smart meters. A rheostat module simulates a variable load on the microgrid. Lucas-Nuelle® Supervisory Control and Data Acquisition (SCADA) software was utilized in conjunction with the previously mentioned equipment. Schweitzer Engineering Laboratories® SEL-751 protective relays were incorporated into the project and programmed using the AcSELerator QuickSet Software. Preliminary experiments with separate subsystems were conducted to gain a working knowledge of the individual components.

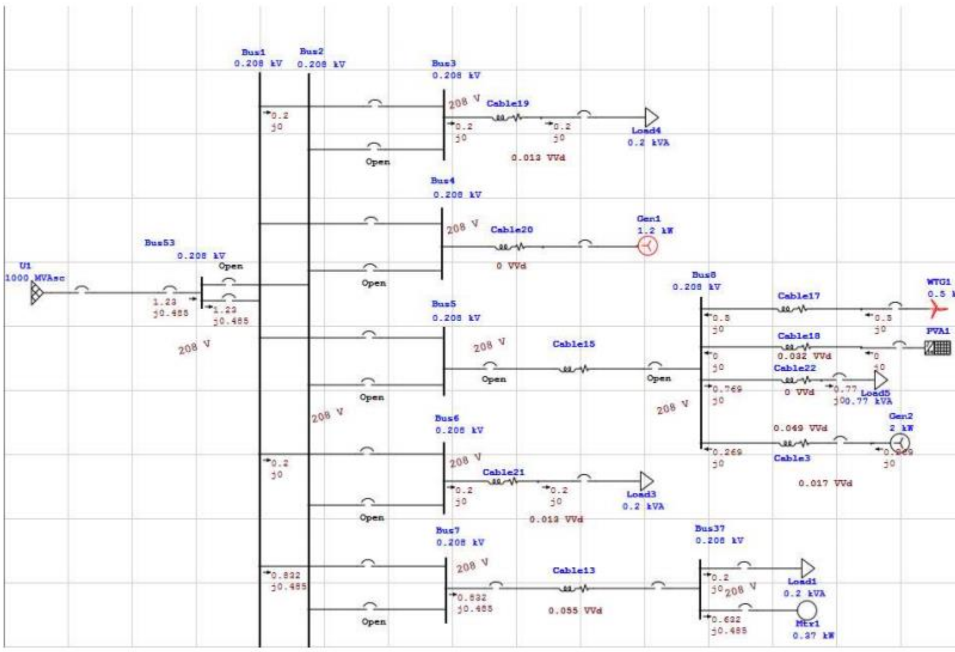

Fig. 1. ETAP® Load Flow study of proposed configuration

Execution

Construction of the testbed began with designing a microgrid utilizing the previously outlined equipment. The first iteration simply consisted of a generator (emulating combined heat and power, or CHP, source) and a utility source supplying a static load. The utility supplied the power through a transmission line, while the generator was connected in close proximity to the load. SEL relays were applied at both ends of the transmission line to provide overcurrent protection.

The purpose of the initial design was to prove that the utility and CHP generator could share the load and test the control system associated with microgrid human-machine interface (HMI). Early on, a problem with power system stability was encountered. When the generator was synchronized to the utility, power levels began to oscillate until the system became unstable and protective devices tripped. After troubleshooting the system and consulting with LN engineers, it was discovered the LN control system software was tuned for a 50Hz instead of 60Hz used in North America. As a result of extensive testing and troubleshooting together with engineers from LN, modification was applied to a coefficient in feedback loop of the control system software. After modification, stability of the system was achieved. Multiple iterations of testing showed the utility carrying the majority of the load without aid from the generator. However, when service from the utility was disconnected and the relays opened the breaker, the generator was able to reliably supply power to the system.

The next step was integration of the wind turbine module as part of the microgrid. Various tests were conducted to verify the generator and wind turbine had the capability to share the load without the utility. Reclosing functions were added to the relays protecting the feeder line in order to conduct tests with simulated faults, then reconnect to the utility. When service from the feeder line was interrupted, the distributed generation sources provided continuous service until the breaker has reclosed. If the fault was cleared, the utility resumed supplying power to the load. If the fault persists, the microgrid successfully operates in “Island Mode”.

The transactive energy component of the project is done by a sunlight dependent switching operation which is demonstrated in Figures 2 and 3. The program to control switching sequence was developed and implemented via SCADA control software associated with PV system equipment. Various tests were completed to collect harmonic and transient data during switching operations between the utility and PV system. Full implementation of the PV system with the generator and wind turbine was not achieved due to software of the control system and firmware related issues with the LN equipment. Communication is currently underway between the team and LN to create a solution and allow the PV unit to function within the microgrid.

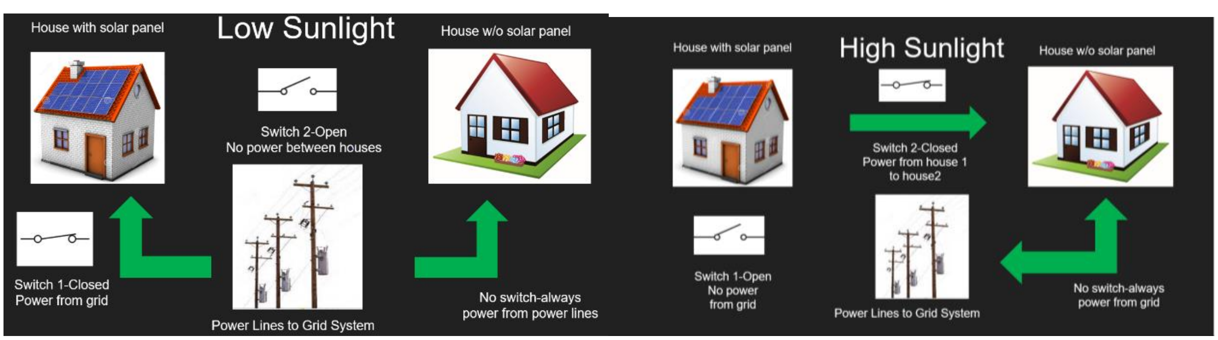

Fig. 2. Transactive energy switching concept flow charts

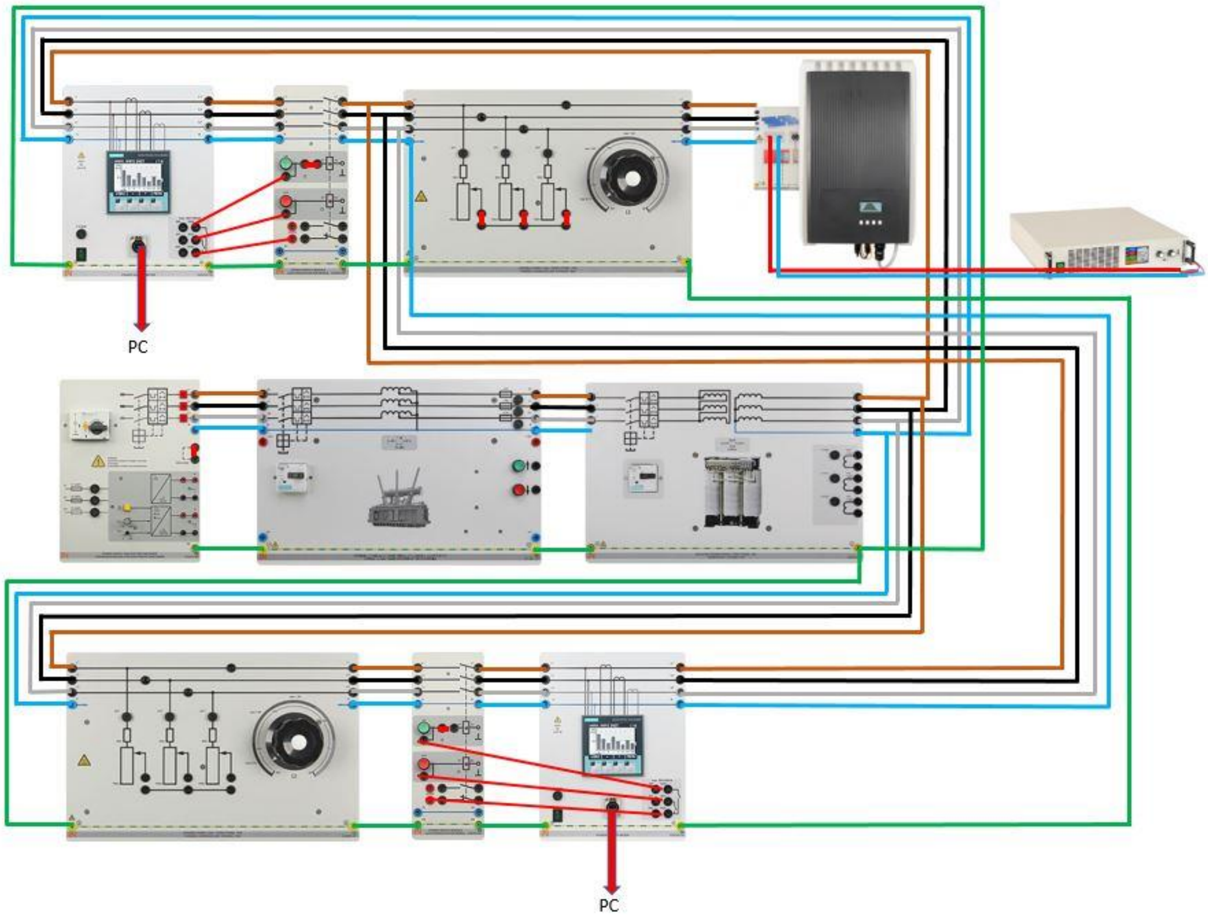

Fig. 3. Schematic of PV integration to microgrid

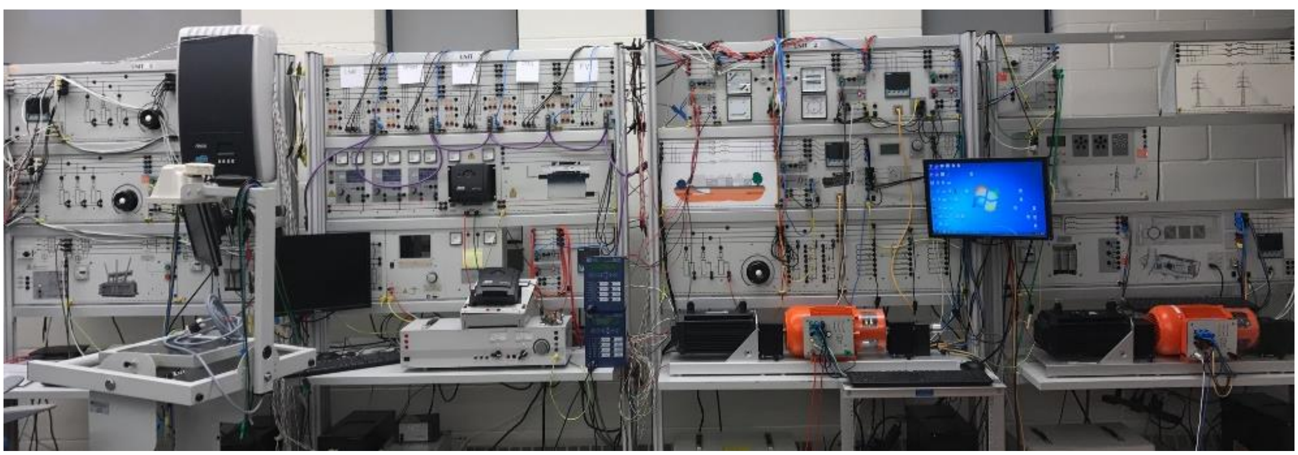

Fig. 4. The functional microgrid at SUNY Buffalo State Smart Grid Lab

Conclusions and Future Plans

A successful model of a microgrid was designed and built using the Smart Grid lab at SUNY Buffalo State. Undergraduate students were able to apply the concepts of power systems and renewable energy to create a testbed for the microgrid and elements for transactive energy.

Future plans for the testbed include the integration of photovoltaic power sources. Initial experiments involving PV cells and inverters have been completed and successfully tested. Integration of PV source to the microgrid testbed requires extensive work involving software for the control system and firmware for the inverter to be developed, which could be done only in cooperation with LN (equipment manufacturer). The addition of PV source to the test bed will be completed during the 2017-2018 academic year. The new team responsible for this will also work on the full automation of the programmable logic controller. Enhanced system will include a dynamic variable load capable of emulating demand of a distribution feeder. Pump storage will be added to the integrated system to examine its demand-response. If cost permits, the testbed will also include battery storage for PV unit. The long-term goals of the project will involve the adaptation of economic-based controls and power quality analysis at the undergraduate and graduate levels. This project will educate undergraduate students at Buffalo State and graduate students at surrounding universities in the design and analysis of the modern grid. The testbed will also assist in the validation of theoretical concepts aimed at increasing reliability, efficiency, and sustainability of tomorrows energy systems.

Acknowledgements

Project Coordinator

Dr. Ilya Grinberg, Professor and Coordinator of Electrical Engineering Technology at SUNY Buffalo State

Team Members

Kris L. Hammerick

Lacy M. Taylor

Bashar A. Ajwed

William C. Hall

Dean J. Nelipowitz

Thomas J. O'Brien

Kyle Nadolinski

Andrew Ludtka

Team Advisors

Matin Meskin

The team acknowledges financial and technical support from the following institutions:

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

GRIDED The Center for Grid Engineering Education

USDidactic Educational Equipment & Training Systems

SEL

LN LUCAS-NÜLLE