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Externship Report: A Month at Idaho National Lab

Thanks to a generous grant from NM EPSCoR, I was able to travel to Idaho Falls, ID and stay for five weeks in order to learn about power system simulation at Idaho National Lab (INL).

Before going, I had completed one year of my masters program in mechanical engineering which included some experimentation in the capture of wind energy. While I had some knowledge of electrical systems from courses I took during my undergraduate career, I knew next to nothing about the function of power systems or microgrids before I arrived at INL. My host at the lab, Dr. Mayank Panwar, along with the rest of the Power Systems team, helped me for my first week and a half to get acquainted enough with the subject matter so that I could competently model such a simulation.

I spent the rest of my time there building computer models of power systems in Simulink and running them on an Opal-RT real-time digital simulator. The purpose of a real-time digital simulator is to provide validation testing in real time of a computer model of a power system. Such validation is cost-effective in that faults in the model can be detected and rectified prior to the construction of a physical prototype, particularly with today's increasingly complex smart grids. Knowledge of how to do this is of great immediate benefit to me because I will eventually need to determine how my own wind energy capture project is to be integrated into a microgrid.

The first power system I modelled and simulated from scratch was the IEEE 14-bus system. This particular model represents part of the electric grid in the Midwestern United States as it existed in 1962. It is relatively simple to model as it does not contain many of the safety features present in a modern-day electrical system. For power generation, it contains one power-voltage generator, one swing generator, and three synchronous compensators. Once I successfully modelled this, it became my goal to add wind turbines to the system and smooth out the resultant power fluctuations with batteries.

The first step toward this goal was to model a much simpler system consisting of one wind turbine, one capacitive load, and one swing generator. After learning that a rectifier converts AC power to DC power and that an inverter converts DC power to AC power, I added a circuit to my simple system consisting of a rectifier and an inverter in parallel with one another and in series with a battery. This construction did not smooth the power levels to a satisfactory degree, so I added switches to regulate the battery circuit. With quick reflexes, I was able to manually flip the switches and keep the power levels smooth.

The next step was to devise a control system to flip the switches for me. My first attempt established an optimal power level and controlled the switches so that the battery charged when the power level was greater than optimal, and discharged when the power level was less than optimal. Unexpectedly, this resulted in wild fluctuations. My second attempt enabled charging if the power level was rising, and discharging if the power level was falling. This also failed to smooth the power in the system. After much trial and error, I finally devised a control system that would enable discharging if the battery was charging, and charging if the battery was discharging. This control system smoothed power levels the best, even muting fluctuations caused by changing wind speeds.

Armed with this knowledge, I added three wind turbines and one battery circuit with control system to my IEEE 14-bus model. This resulted in wild fluctuations, so I placed a battery/control system next to each wind turbine. This somewhat muted the power fluctuations, but not to my satisfaction, so I attached a battery/control system to every node in the system (except for bus #7, which is neither connected directly to a generator nor a load). This achieved the desired smoothing.

Over all, this experience, which was possible thanks to the generosity of NM EPSCoR, gave me a new set of skills that will be of insurmountable importance as I move forward with my career in renewable energy. Even if my focus turns out not to be on the power systems aspect, it is nonetheless important to understand how my designs will incorporate into a larger grid for optimization purposes. Proficiency with a real-time simulator such as Opal-RT is essential to this.