Virtual Reality Enhanced Education for Electric Power Engineering

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Overview:
Ensuring a reliable and efficient supply of electricity requires highly trained and experienced engineers to design, operate, and maintain electric power systems. Traditional power systems engineering education covers material on modeling individual system components and analyzing their connections in large-scale power grids. There exists a wealth of educational materials (e.g., textbooks, course notes, homework problems, etc.) related to mathematical modeling and analysis techniques, both of which are essential to being a successful power engineer.

However, unlike many other engineering disciplines where students get significant amounts of hands-on experience with the systems they are studying, it is difficult for instructors to have power engineering students work directly on real utility-scale hardware due to the safety and security concerns associated with critical infrastructure such as electric power grids. While very valuable to students' educations, taking field trips to substations, generating plants, industrial facilities, etc. is costly and difficult, so many power engineering students graduate without ever seeing utility-scale hardware outside of pictures in a textbook. This challenges instructors' ability to communicate practical aspects of power systems engineering. Thus, utility companies must spend significant effort training junior engineers in the practical aspects of power systems before they can make major contributions to the industry.

The recent development of low-cost virtual reality headsets[1] provides opportunities to teach students practical engineering lessons in highly realistic settings while bypassing safety, security, and organizational challenges of actual site visits. Utility companies are already exploiting the advantages of virtual reality to train their workforces.[2] Power systems engineering education at Georgia Tech would significantly benefit from similar approaches, particularly in courses such as ECE 3072: Electrical Energy Systems, ECE 4320: Power Systems Analysis and Control, and ECE 4321: Power Systems Engineering.

Approach:
Several steps would be required to bring virtual reality into power systems engineering education.

- **Virtual reality hardware and lab space**: Typical power systems engineering courses at Georgia Tech have enrollments of 20 to 35 students per semester. By offsetting when the students use the virtual reality headsets, a modest number (approximately five to ten) headsets would likely suffice. Depending on how the students accessed the headsets (check out for use at home vs. use in a particular laboratory space on campus), laboratory space may be needed as well. This space and the headsets could be reused for multiple courses and across multiple semesters. To create virtual reality content, cameras such as a GoPro MAX that cost on the order of $400 provide high-quality recordings.

- **Content**: As the very first attempt for this project, virtual reality (VR) experience for students will start from a power substation. This will also allow us to set up and test the platforms, both for hardware and software. The VR gallery can be expanded in the future to include other US power plants (and even international ones), such as the hydro power plant of Hoover Dam and the nuclear power plant of Plant Vogtle.

  To be useful, utility companies must allow access to their facilities and engineering experts in order to make virtual reality recordings for the students to view. Relevant facilities include substations, generating plants, and industrial facilities. A utility engineer could explain the hardware in a similar manner to the training programs for junior engineers at their company. One potential risk is that utilities would be unwilling to allow access to their facilities due to safety or security concerns. This

[1] With state-of-the-art headsets like Oculus Quest 2 costing $300, a class of students could be outfitted with virtual reality headsets at a cost of several thousand dollars.

[2] See, for instance, the developments from members of the National Rural Electric Cooperative Association (NRECA) `https://www.cooperative.com/topics/data-analytics/Pages/Industrial-Augmented-and-Virtual-Reality.aspx` as well as Southern Company `https://www.slideshare.net/AugmentedWorldExpo/vincent-williams-southern-company-digitizing-our-workforce-through-wearable-technology-and-virtual-augmented-and-mixed-reality-150064866`.

risk could be mitigated by having the utility engineers or technicians do the recordings themselves and not releasing the location of the facilities.

Other then showing students the power system in the real world, this VR platform can include simplified 3D models of different kinds of key electric apparatus, which are able to further enrich students' learning experience by 'gaming'. For example, students could be asked to identify the miswiring for a power substation in abnormal conditions.

- **Lesson plans and assessments**: The virtual reality content must be integrated into course curricula through the development of related homework assignments and assessments. This will require additional effort from the course instructors.

  Two forms in which this VR experience can be integrated into courses include 1) individual learning experience, such as "walking" in a power plant and identifying key components; 2) teamwork, through which students need to collaborate, for example, to plan, build and run a substation (in 3D models) with given system ratings.

- **Potential outcomes**: It is a great example of integrating cutting-edge technologies into courses for excellent learning experience. In addition, this project will be an amazing tool for outreaching activities for the ECE department.

Initial work:
During the summer of 2022, Daniel Molzahn, Lukas Graber, and Zhiyang Jin worked with Kruti Maheshwari, an undergraduate student in the College of Design, to pilot a VR walkthrough of a substation. This pilot was deployed in Daniel Molzahn's Fall 2022 course on electric power systems engineering (ECE 4320) and will also provides the foundation for further extensions as discussed above.