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Supervisory Controls and Data Acquisition Instructional Materials and Resources for Energy Education Programs

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Abstract

The CREATE Supervisory Controls and Data Acquisition (SCADA) project is an industry driven initiative brought about by three colleges, working with an industry utility partner. The project began in July 2019 with the goal of integrating 21st century SCADA technology into existing energy education programs. The project delivered both in-person and online faculty professional development for 28 faculty representing 17 U.S. states. Products produced and distributed through the project network include a SCADA job task analysis, curriculum modules, control board trainers and lab activities, computer-based labs, and a web based open-source SCADA platform. The SCADA open-source platform allows colleges to connect their renewable energy generating systems and provide analytical training to their students using their own data, along with data from other regions and simulation sets. This resource will foster student engagement and ownership of learning through generation, visualization, and analysis of long term and large data sets. This study demonstrates the value of collaboration between multiple academic institutions, and how educational programs can benefit from collaboration with industry partners.

Introduction

Supervisory Controls and Data Acquisition (SCADA), as the name makes explicit, is a system which acquires data and facilitates supervisory control. SCADA is a type of automation control system that is a core technology for the operation of many industrial processes, including oil and gas refining, food and beverage production, water treatment, electric power production, and many other production, manufacturing and distribution industries [1]. SCADA is a centralized system that monitors and controls individual processes and entire sites. At the site or operator level, a SCADA system enables operators to manage the day-to-day performance of a process or plant site as efficiently and profitably as possible; prevent failure, damage, or other costly equipment issues by alerting operators of problems, maintenance needs, and operational anomalies; and Monitor processes, adjust to changes, and troubleshoot issues by providing real-time data at their fingertips. A SCADA system enables business owners or stakeholders to leverage process data to make more informed projections and financial decisions, and efficiently manage a network of plants or assets to maximize overall profitability [2].

How SCADA is used in the Energy Industry

SCADA systems allow engineering technicians to control energy systems in real time, and log data for monitoring of system performance. SCADA data analytics allow for system optimization, preventive maintenance scheduling, and for rapid detection and correction of faults and alarms to prevent or minimize system downtime. SCADA systems are used in the energy industry for monitoring, controlling, and logging data from energy production and distribution assets. Alarms and alerts are triggered by various factors such as an asset being damaged by natural or human events, being responsive, or by component failures. These alarms/alerts enable rapid responses. The energy generation asset can be shut down immediately and taken offline if needed for safety, the cause of the alarm can be identified and addressed remotely without undue loss of time, or if the issue needs to be identified and addressed on-site, Operations and Maintenance team or SCADA personnel can be dispatched without delay and have the proper equipment upon arrival. Additionally, the status of individual components within an energy asset can be monitored thus allowing preventative maintenance to occur rather than unnecessary and more costly routine maintenance [3-5].

The use of "big data" derived from SCADA systems of different energy generation categories (e.g. solar, wind, battery storage) and from different geographic locations have enabled the energy industry to become increasingly sophisticated. The combined technological advancements using SCADA and big data analytics allows energy companies to optimally coordinate which of their assets are operational at different times to match the market's consumption needs nearly instantaneously. Data analytics and predictive analysis also are used to discern trends and forecast weather conditions to produce safe, reliable, and clean energy at the lowest possible cost to the consumer. Thus SCADA systems are taking on increased importance for the operation of a complex, interactive, resilient and smart electrical gird [6].

Overview of CREATE

Funded by the National Science Foundation Advanced Technological Education Program, the CREATE Energy Center (www.createenergy.org) was originally founded in 1996 by College of the Canyons, and is now led by Madison Area Technical College. The goal of the CREATE Center is to advance the field of renewable energy by supporting two-year college programs while serving as a source of mentoring, industry networking, faculty professional development, and educational materials [7]. CREATE has produced renewable energy program profiles, faculty and alumni interview spotlights, an ongoing newsletter, blog, and a robust collection of hands-on laboratory instructional materials. The CREATE community of practice includes over 900 energy educators representing all fifty U.S. states and three U.S. territories. The CREATE Center delivers hands-on Renewable Energy Institutes for educators [8], provides guidance in the development of energy infrastructure and instructional campus laboratories [9], and has conducted a number of international faculty programs related to renewable energy [10-13].

Prior CREATE work in SCADA Technology

Over the past decade, CREATE has expanded renewable energy academic programs in partnership with industry organizations including NABCEP, IREC, PG&E, SCE, NextEra, Solar City, and First Solar. As part of these efforts, CREATE conducted a pioneering curriculum analysis for Wind Turbine Technicians in 2010 that identified SCADA as a key job component [14]. This curriculum analysis was made available nationally through coordination with CREATE and the American Wind Energy Association Education committee. Cuesta College led a CREATE initiative on SCADA systems for solar monitoring from 2010-2015, producing SCADA faculty professional workshops, a peer reviewed publication, and a presentation on SCADA systems at the national ASEE meeting in Seattle in 2015 [15]. In the years following these early works, renewable energy systems became increasingly complex networked systems, the data sets generated by renewable installations grew exceedingly large, and CREATE's industry partners expressed the growing need for engineers and technicians with knowledge of SCADA technology. Accordingly, CREATE launched a further initiative to examine SCADA for energy applications, and to help educators embed this technology into existing energy education programs. This most recent effort forms the basis for this publication.

Development of the CREATE SCADA Curriculum

To ensure appropriate curriculum development that was aligned with industry needs, practices and standards, a SCADA Job Task Analysis (JTA) was first developed. As described by the Interstate Renewable Energy Council [16], "Conducting a Job Task Analysis is a formal process for determining what people do, under what working conditions, and with what knowledge and skills." The data provided by a JTA is useful to support development of educational curriculum, instructional materials, performance standards, and assessment tools to judge knowledge, experience, work, and mastery of key skills. Simply put, a Job Task Analysis tells you exactly what is included in a particular job, and exactly how the work is supposed to be done.

JTAs are used both to form the basis of the development of education and training programs, and also to support human resource managers in the areas of developing position descriptions, hiring personnel, setting staffing standards, and structuring career development programs. The Department of Energy and other federal agencies have recognized JTAs as powerful tools, and have incorporated them into their training and accreditation programs [17].

A draft JTA for the SCADA sector was developed by CREATE in the winter of 2019 and 2020. A committee of subject matter experts from two-year colleges with renewable energy programs was convened to assemble and review the draft. The document was shared with others in industry, including CREATE's major primary industry partner NextEra Energy along with smaller regional companies serving on the CREATE's industry advisory board for further commentary and refinement.

Many individuals in the renewable energy field are familiar with the Job Task Analyses produced by the North American Board of Certified Energy Practitioners (NABCEP) for the wind and solar sectors. The SCADA JTA was designed to mirror the format of the NABCEP products. The scope of the JTA encompasses the knowledge and fundamental principles across five content domains covering the Application, Installation, Operation & Maintenance, Data Analytics, and Cybersecurity of SCADA systems for renewable energy applications.

Energy Technologies are diverse, and different sectors such as wind, solar, hydroelectric, geothermal, bioenergy, and energy storage all integrate SCADA systems to different degrees and having different capabilities. As a result, the JTA is broad in scope. Technicians employed in the renewable energy industry will not perform all of the tasks described in the JTA, but it is likely that at least some aspect of their job will involve SCADA technology.

The draft SCADA JTA was shared with industry representatives from NextEra Energy and two industry conversations were held as part of the RENEW Energy Summit in January 2021 where the SCADA JTA was shared along with a similar JTA developed by CREATE for Energy Storage technology.

With the JTA drafted and validated, a systematic process guided the curriculum development and review. This happened in several phases. Phase 1 included naming six curriculum learning modules that both matched the JTA and the existing renewable energy programs. A modularized curriculum was chosen to be able to embed modules by learning outcomes into individual courses and programs; these six modules became SCADA Overview, Components and

Functionality, Basics of SCADA Communications, Human/Machine Interface, Applications within Renewable Energy Industry, and Emerging Trends in SCADA for Renewables. Phase 2 included developing 6-7 learning outcomes for each module that align with the JTA, aligning learning outcomes to hours of lecture, lab, and level of knowledge assessment. Phase 3 included a Curriculum Review Committee (CRC) composed of six faculty experts reviewing the applicability and accuracy of the curriculum design framework. Each CRC member completed a review sheet with eight questions; their answers and comments were compiled and discussed over a facilitated CRC virtual meeting to gain clarity and consensus.

Figure 1: Course Design Summary for the CREATE SCADA modular curriculum

Course Design Summary					
Learning Module	**Format (Lecture/Lab)**	**Material Lectures**	**Material Labs**	**Related JTA** (v022520)	**Assessment**
SCADA Overview	• 4 * 1-hour lectures • 0 lab or field trip	• What is SCADA and Why Used • Terminology and Component Overview • Application overview for Renewable Energy	• Chris B's intro simulation • Optional - visit a local business using SCADA for their operation as real world examples	Dom 1, Task 1 – 2 Dom 1, Task 4	Assessment Quiz at end of first Module
Components and Functionality	• 4 * 1-hour lectures • 1 * 3-hour lab	• Field instruments/sensors (Analog vs Digital) • PLC/PAC/RTU • Master Terminal and HMI • Communications and Software	• Evaluate the purpose of various components – sensors, PLC, etc. • Perform various wiring tasks to connect SCADA systems (AC and DC, proprietary vs open, TCP/IP, etc. • (Chris A's solar panel lab setup?)	Dom 1, Task 3 Dom 2, Task 2	
Basics of SCADA Communications	• 2 * 1-hour lectures • 1 * 2-hour lecture • 1 * 3-hour lab	• Communication Types (Proprietary vs Open or Mixed Systems) • Communication Protocols (radio, cellular, wireless, satellite, etc.) • Communication/Data Security	• Apply various communications methods for SCADA systems (serial communication, TCP/IP, Modbus, etc.) • Configure and program controllers • Perform tagging operations • (Chris A's solar panel lab setup?)	Dom 2, Task 1 Dom 2, Task 3 Dom 5, Task 1 - 4	
Human/Machine Interface	• 2 * 1-hour lectures • 1 * 2-hour lecture • 1 * 3-hour lab	• Basics of HMI (function, design, etc.) • Operational Troubleshooting Tools • Data Analysis Tools	• Analyze SCADA software operation and analytical features (Chris A's solar panel lab setup?)	Dom 3, Task 1 – 3 Dom 4, Task 1 - 4	
Application in Industry – Renewables Focus	• 1 * 2-hour lecture • 2 * 1-hour lectures • 1 * 3-hour lab	• Solar, wind, etc. • Combine with Energy Storage • Utilizing for efficient and effective Grid Response	• Create SCADA project scenarios for testing and analyzing data (Chris B's simulation?)	Dom 1, Task 1	Lab project write-ups/output Assessment
Emerging Trends and Technology	• 2 * 1-hour lectures • 0 lab or field trip	• Cybersecurity • Autonomous Devices/Vehicles, Networked Learning, AI and Machine Learning, etc.	• None • Optional – Advanced SCADA site tour	Dom 5, Task 1 - 5	Final Assessment Quiz

After the Course Design Framework was completed and reviewed by the CRC, Phase 4 included reviewing curriculum from participating schools and online resources and complete gap analysis identifying best in class material for each learning outcome and where gaps exist. Phase 5 included completing gaps by developing curriculum, which was completed by assigning one SME faculty (who attended the in-person professional development) to each of the six modules. In Phase 6 the CRC reviewed each of the five modules in which they did not develop material for. This occurred by the CRC reviewing the completed draft modules independently. Again each CRC member completed a review sheet with six questions for each Curriculum Module, along with comments directly in a shared document version of the draft curriculum modules. CRC answers and comments were compiled and discussed over a facilitated CRC virtual meeting to gain clarity and consensus. Phase 7 included the curriculum developers making refinements and the CRC reviewing and approving the final documents.

The end product became a complete six module course, “Introduction to Supervisory Controls and Data Acquisition (SCADA) for Renewable Energy. Each module is focused by its specific learning objectives. The goal of the modular course is to advance renewable energy education by enabling faculty leaders to integrate SCADA into existing energy technician educational programs. The modular course has been distributed to the CREATE network of educators and is available for free download at www.CreateEnergy.org.

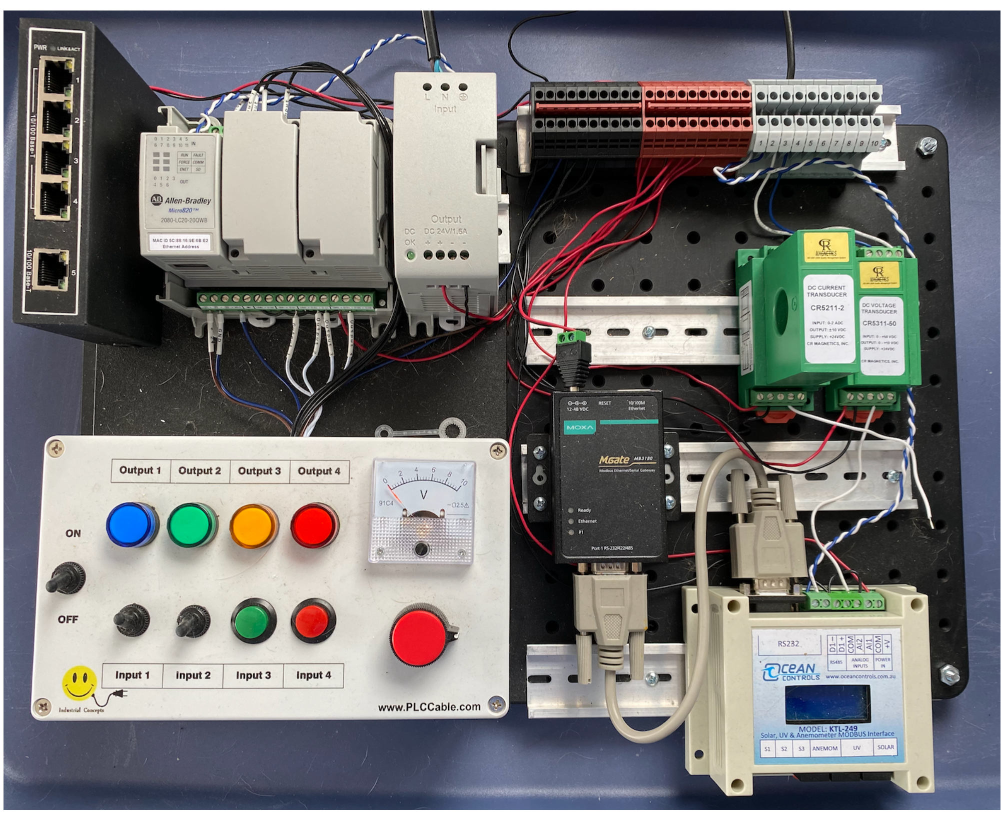
Figure 2: Screenshot of the SCADA Curriculum Modules available for download

Development of the CREATE SCADA Lab Trainer Board

A SCADA Lab Trainer Board was designed to reflect common equipment for systems controlling and monitoring large plant operations such as water, power, or waste utilities. The SCADA Lab Trainer Board is meant to provide a platform for aspiring plant technicians, and engineers, to experiment with common components, communication protocols and software packages used in SCADA systems. The lab activities were designed to address the knowledge and skills needed by technicians that were identified in the SCADA job task analysis. Portions of the lab sequence can be used in existing courses, or the entire package could be incorporated into dedicated classes in SCADA systems or Programmable Logic Controllers (PLC) to better prepare the students for all the concepts the lab work covers.

The SCADA Lab Trainer Board attempts to answer two important questions: first, how to fit normally large, expensive, and complex, industrial SCADA equipment into a small space so all students of a classroom have access to it; and second, how to fit complex hands-on SCADA training into existing courses as modules without dedicating the entire course to the subject. The importance of answering these questions is crucial since nearly every public utility and many manufacturing plant operations use SCADA systems thus need employees that better understand them. Moreover, most college vocational programs cannot afford installing large SCADA system equipment and the expensive software needed to run it; therefore, a primary goal of the SCADA lab training system was to CREATE the most compact and least expensive equipment solution possible while at the same time utilizing free industrial grade versions of software.

Figure 3. Photo of the CREATE SCADA Lab Trainer Board



Functionality of the CREATE SCADA Lab Trainer Board

The lab activities provide two possible sequences to help achieve the goal of making SCADA training accessible to multiple training environments, the first is SCADA training without the need of a PLC and the second requires a PLC with knowledge of PLC programming to complete the lab sequence. The lab activities help increase the understanding of SCADA Human Machine Interfaces (HMI) development and PLC programming to support SCADA system data processing, but they should be augmented with other general subject matter training and support coursework as previously noted.

The SCADA Lab Trainer Board lab activities attempts to maximize student exposure to industrial software by using partially completed projects so students do not have to build entire SCADA HMI Interfaces from scratch. The partially completed projects are used as the basis for experimentation, analysis, and modification to help teach concepts. A large portion of lab activities involve familiarization of communication protocols. The training board provides instruction in both Serial point to point and Serial network communications using RS232, RS485, and Modbus RTU protocols. The lab activities also cover internet protocols with TCP/IP and Modbus TCP protocols.

The SCADA lab activities are built around two industrial software packages. The first is IGSS SCADA, which is a subsidiary of Schneider Electric, that has a size limited but full featured version of the software called IGSSFREE50. The second is a free PLC programming package from Allen Bradley for its Micro800 series of PLC's called Connected Components Workbench which is modeled after RSLogix 5000 (or Studio 5000 Logix Designer) and can share program files between them. Between the two software packages industry relevant training is achieved.

The lab activities are broken into labs with multiple exercises so that students can complete them in small segments. The labs start with introducing communication and networking concepts needed to support the subsequent training, then progresses to show how to access data from sensors. Sensor data is evaluated in several formats that require various degrees of mathematical and digital number processing. Also, for advanced students, analysis of error sources and correction processing are investigated to more accurately and precisely present data.

Lab activities based on the predefined project files give training on how the sensor data is retrieved, identified, and manipulated for presentation in the Human Machine Interface of the SCADA system. More advanced lab activities use the PLC as an intermediate intelligent pre-processing computer for the SCADA HMI system. Lastly the PLC allows for more advanced programing of SCADA applications using a simulated motor so that bidirectional SCADA monitoring and control can be investigated.

Pilot testing CREATE SCADA Lab Activities with faculty and students

The SCADA lab activities have been pilot tested by two groups of students from Cuesta College. and one group of faculty through the CREATE grant. At Cuesta College, the lab activities were introduced in the last third of a semester based Programmable Logic Controller course that is part of the Electricians Training Program. The first year there were 14 students that completed the communications lab and 3 that went on to complete the full lab sequence. Based on student feedback from the first year, modifications were made, and the lab work was reviewed by 6 CREATE faculty members who attended previous CREATE SCADA workshops.

Based on feedback from these initial pilots and reviews, a second round of revisions were made to address the main stumbling blocks in the activities, and reduce the complexity surrounding network communication protocols and sensor calculation theory. In the second year of implementation, the lab activities were completed by 19 students at Cuesta College giving them two options for completing the networking configurations (one designed to be simpler than the other for novice students and the latter being the more complicated option but more reflective of common industrial practices). Based on student feedback a final round of revisions were made, and the lab activities were the shared with the CREATE network of energy educators.

Assessment of the CREATE SCADA Lab Activities

During the student lab experiences many strengths and limitations of the SCADA training system and lab activities were observed by the lead instructor, which are summarized as follows:

Observed Strengths

- The compact training system was easy for the students to carry, set up, and configure
- The basic configuration of the SCADA board and components was easy for the students to follow and few of them needed assistance understanding how the various devices worked
- Students who chose to attempt the more advanced portions of the lab activities were able to complete them, so conceptually the lab activities functioned as intended
- Students seemed satisfied and even excited at points when they got parts to work and saw data presented in various display formats
- Pictures and screenshots in the lab documentation made most of the lab steps easy to follow

Observed Limitations

- Many students were not able to fully grasp the networking concepts. Challenges included:
    i. Students enrolled in the electrician training program lacked a networking background, so the concepts included in the lab activities were unfamiliar to most of them
    ii. The networking concepts have many layers and levels of abstract concepts that are difficult to present in a condensed instructional format
    iii. Students needed more repetition with some concepts than the lab activities provided
- Although students were able to complete the individual steps in the lab activities, many struggled to see how individual components and functionalities contributed to the big picture and overall operation of a complete SCADA system.
- The IGSS SCADA and Connected Components Workbench are industrial tools that are not easy to learn, even for advanced students with previous industrial backgrounds
- Although the mathematical underpinnings of sensor operation, digital processing, and number conversions are necessary for proper SCADA operation, these concepts are not easy to introduce into groups of vocational students.
- Since electricians typically have limited work experience with industrial networked equipment and protocols, some students did not appreciate the need to learn those concepts. In particular, younger and novice students may need to gain more work experience before they see the relevance of SCADA technology to the energy industry and to their future occupations.

General observations
The lab training board performed as intended, and the lab activities successfully guided students through the intended learning objectives. Therefore, the training board, lab activities, and associated software have the potential to help energy technology educators to integrate SCADA technology into their curriculum. Considering the range of background knowledge of students enrolled in the courses at Cuesta College, the lab activities could not foresee or address all of the various ways students interpreted the instructions. At some point in the lab sequence, most of the students encountered sticking points, and needed some form of instructor assistance to supplement the written lab instructions. The lab exercises were facilitated by the instructor providing individual help and instruction to each student as needed. Students benefitted from extra assistance and summary explanations to help understand the most difficult concepts and complete some of the more challenging lab tasks. This speaks to the value of face-to-face instruction, and also indicates that the CREATE SCADA lab activities may be too complex to be used in a remote or distance learning format.

The flexible functionality of the training board provides a hardware package that can support additional lab activities that may be written in the future. We foresee that the lab activities could be augmented or differentiated to address varying levels of students' prior knowledge and experience. It is also possible that new lab activities may be created to leverage the value of the lab training boards and address additional SCADA concepts.

Development of the CREATE Open-Source SCADA Platform
The CREATE Open-Source SCADA Platform was designed to allow students to learn SCADA and solar fundamentals in a classroom-friendly environment. Modern SCADA systems are often built with a target audience of industrial and utility customers. The installation of these systems may be complex and require the intervention of IT support staff. Once installed, the software will generally communicate with expensive control hardware, adding additional cost and maintenance.

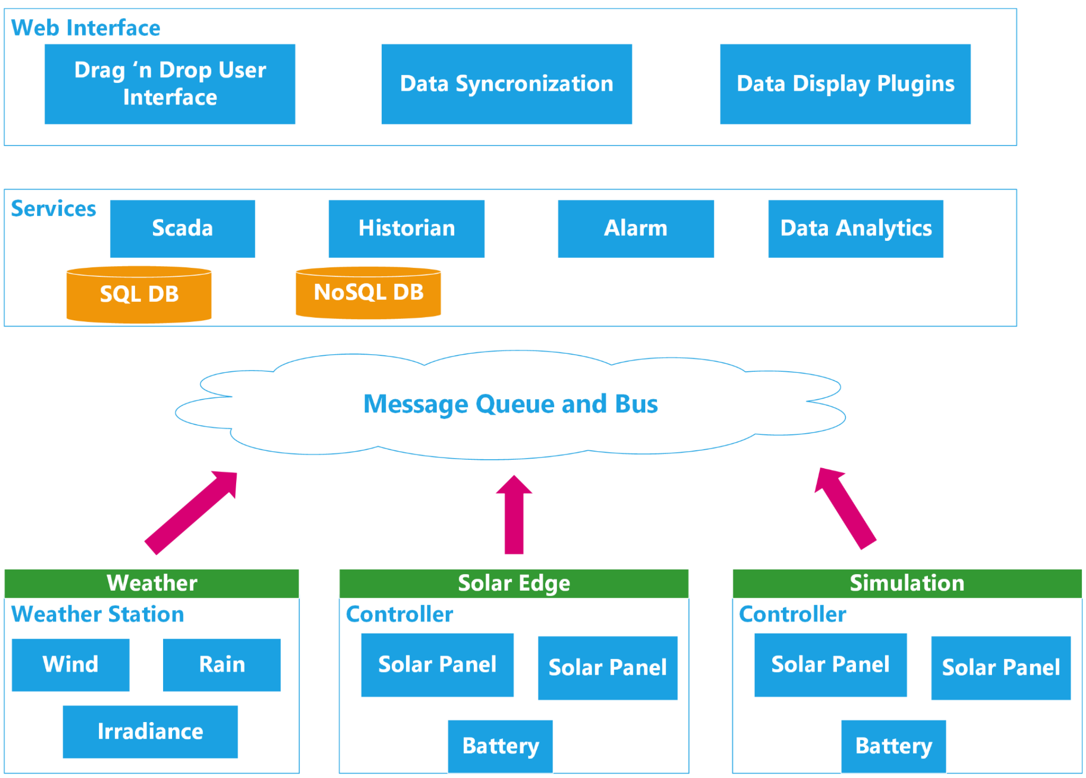
Classroom labs however have a fundamentally inverted focus. Students need software which can be used with little setup and maintenance, since the primary focus should be on science and engineering fundamentals. Each student must be allowed access to a sandboxed environment which does not affect other students. Additionally, students require access to simulated hardware to make training costs feasible. The CREATE Open-Source SCADA Platform attempts to address these concerns.

Although student training and education is a primary goal of the system, a secondary goal of Open-Source SCADA Platform is to provide researchers with a platform to participate in a community of data sharing. Researchers and other organizations can stream their solar farm data to a centralized server, allowing a wide variety of geographic regions and PV technologies to be studied. As this data is studied, interesting events and trends can be captured and provided to form the basis for new student lab activities, forming a symbiotic relationship between researchers and student instruction.

How the CREATE Open-Source SCADA Platform was built

The CREATE SCADA Platform is an open-source web based database and user interface available as a cloud hosted service that was conceived and developed by the CREATE team. The only computer requirement is a web browser and internet connection. This greatly expands the accessibility of the platform since outside support staff do not need to install and maintain additional software. Upgrades and maintenance of server equipment are planned around semester schedules, allowing users stability during active times of instruction.

Figure 4. The software architecture of the CREATE SCADA system can be broadly categorized into frontend (top) and backend (bottom) systems.



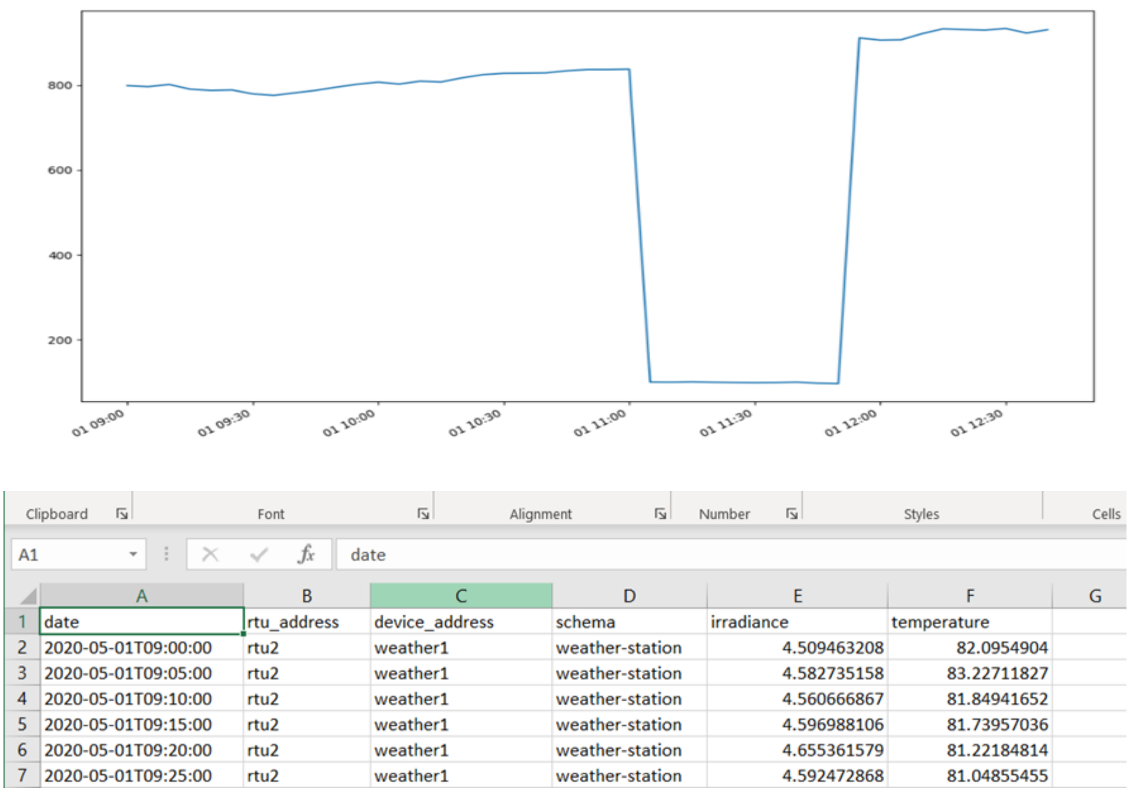
The backend of the Open-Source SCADA Platform is responsible for interacting with communication drivers, alarm systems, historical data storage, and other non-user facing concerns. Data communication is achieved through driver plugins which broadcast normalized data to the receiving backend system. The data is normalized to a set of schemas, allowing for disparate data formats to be ingested to a database. Currently, drivers for Solar Edge, Enphase, Also Energy, SMA, and Victron Energy systems are available. However, due to the open-ended nature of the schema format, systems from most controller equipment can be incorporated, and uses with the necessary programming skills are encouraged to develop new drivers to support their own specific hardware. Users interact with the frontend system of the Open-Source SCADA Platform through a web browser. A rich frontend web framework allows users to interact with the GUI through a drag and drop interface. Minimal page refreshes allow users to operate the SCADA system in a manner similar to traditional SCADA systems.

Using the CREATE Open-Source SCADA Platform with students

The Open-Source SCADA Platform has two primary audiences: Students and Researchers. Written lab activities have been developed to walk students through the process of creating an HMI and interfacing with simulated hardware. Alarms and other system monitoring techniques are included in the lab materials to train students for recognizing exceptional events. Normal operation scenarios are included as well.

Students begin the lab activities by starting a sandboxed session. During the creation of a sandboxed lab session, the backend provisions a separate SQL database, NoSQL database, and simulated hardware drivers, allowing students to independently work through labs. Students then implement an HMI design and step through simulated hardware data communications. The simulated data are catered toward various scenarios such as a low power due to partial or complete shading and other potential hardware failures. A simplistic analysis tool is included to view time-series data and perform additional filtering. Advanced analysis techniques are performed by exporting the data and incorporating Microsoft Excel.

Figure 5. Screen shots illustrating data visualization using the CREATE SCADA Platform historian function, and of SCADA data exported in .csv format and imported into a MC Excel spreadsheet for further analysis.



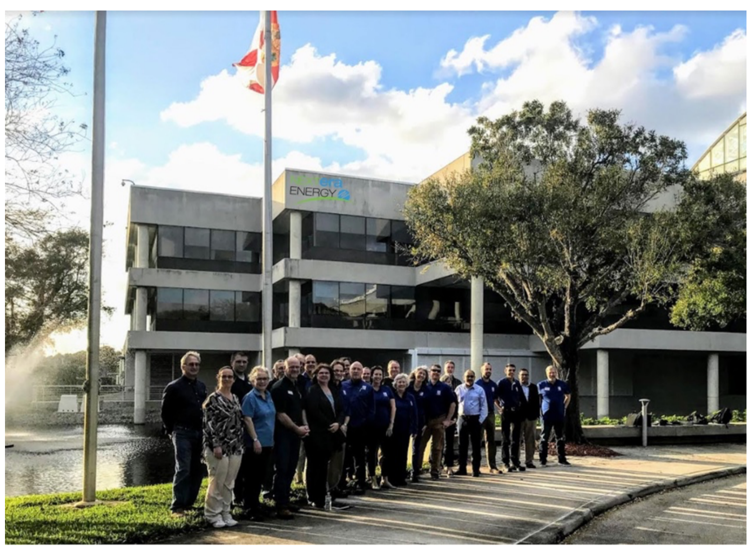
	A	B	C	D	E	F	G
1	date	rtu_address	device_address	schema	irradiance	temperature	
2	2020-05-01T09:00:00	rtu2	weather1	weather-station	4.509463208	82.0954904	
3	2020-05-01T09:05:00	rtu2	weather1	weather-station	4.582735158	83.22711827	
4	2020-05-01T09:10:00	rtu2	weather1	weather-station	4.560666867	81.84941652	
5	2020-05-01T09:15:00	rtu2	weather1	weather-station	4.596988106	81.73957036	
6	2020-05-01T09:20:00	rtu2	weather1	weather-station	4.655361579	81.22184814	
7	2020-05-01T09:25:00	rtu2	weather1	weather-station	4.592472868	81.04855455	

Delivery of CREATE SCADA Professional Development for Educators

CREATE and NextEra Energy delivered two days of in-person professional development in January 2020 for 28 faculty representing 17 U.S. states, with a composition of 15 male and 13 female participants. The first day was hosted at NextEra, the world's largest generator of renewable energy. The day included panel sessions with a range of executives and SMEs, renewable energy project development breakout sessions, and a tour of the Renewable Operations Control Center (ROCC), which serves as the monitoring and operations center of NextEra Energy Resource's wind, photovoltaic solar, and battery energy storage fleet. Participants learned about ROCC Operations processes including plant Start-Up/Shutdown, Curtailment, Daily Work Management, Troubleshooting and Outage restoration, and Energy Market Communications. Workshop participants also contributed to the draft SCADA job task analysis to identify key knowledge and skills necessary for the energy workforce. A curriculum scoping activity also laid the groundwork for forthcoming SCADA curriculum development. The second day was hosted at Indian River State College and included a first glimpse training on the Open-Source SCADA Platform, along with data analytics, inverter and transmission installation at IRSC's solar field, and continuation of the discussions regarding appropriate SCADA for Renewable Energy JTA and instructional course and labs.

More recently in response to COVID, faculty professional development shifted to virtual training. A webinar with NextEra Energy on battery technology and control systems of FPL Manatee Energy Storage Center (the world's largest solar-powered battery), and a CREATE SCADA Workshop of Human Machine Interface (HMI) were completed in 2021, and recordings of these presentations are available for viewing on the CREATE YouTube Channel. CREATE acquired a second batch of SCADA lab boards that were direct shipped to faculty participating an additional SCADA technology virtual workshop in April and May 2022.. The complete results from this workshop were not yet available at the time of this publication, but we intend to report on these in future communications.

Figure 6. SCADA workshop faculty at the NextEra Energy headquarters.



Next Steps and Future Plans

The SCADA Job Task Analysis, curriculum, and lab activities are available for free download at the CREATE website (CreateEnergy.org). The lab trainer boards are available for purchase through Industrial Concepts (www.plccable.com). The Open-Source SCADA Platform has drivers for several major DC→AC inverter and energy monitoring OEMs (including Enphase, SolarEdge, SMA, and AlsoEnergy), and CREATE is currently seeking schools with renewable energy installations to share their data with others. Future faculty workshops are also being planned that we hope to announce later this year. Many of the faculty involved in this project plan to pilot the SCADA curriculum and lab activities with their students in the upcoming year. CREATE is working to support these instructors through creation of additional student assessment tools, and we hope to have data quantifying student learning outcomes that we can share in the near future.

Recommendations for Schools with Energy Technology Programs

The diverse group of faculty who have participated in the CREATE SCADA project were instrumental in illustrating how schools with energy education programs can utilize the SCADA materials and resources developed. Faculty and programs interested in working with the CREATE SCADA project may wish to engage through one of more of the following mechanisms:

1) Use the entire six module Introduction to SCADA curriculum as the basis for introducing an entirely new course into existing energy technology programs.

2) Use the Introduction to SCADA curriculum and/or SCADA trainer board and lab activities in a modular format, by integrating applicable pieces selected by Learning Outcomes, into existing energy technology courses.

3) Implement the SCADA curriculum modules and/or SCADA trainer board and lab activities in courses other than energy technology. Related areas that may find these instructional materials useful include courses in electrical circuits, programable logic controllers, and cyber security.

4) The SCADA curriculum modules and/or SCADA trainer board and lab activities are also relevant to other industries such as water technology, advanced manufacturing, food and beverage processing, and agriculture.

5) Schools with renewable energy generating systems can integrate their data streams into the CREATE Open Source SCADA Platform to contextualize their students' learning using their own infrastructure to produce energy and provide data from their campus.

In conclusion, SCADA technology is core technology for the operation of renewable energy and many other industrial processes. The CREATE SCADA project has provided several free resources for faculty to help integrate SCADA technology into existing courses and programs, and to help provide a more highly skilled technical workforce for the energy sector. The authors hope that this work will empower a new generation of renewable energy engineers and technicians with SCADA knowledge and expertise to advance the clean energy sector.

Acknowledgements

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