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Work-in-Progress: From Cloud APIs to Local Intelligence: Restoring Weather data and Thermostat Control in a Smart Residential Microgrid

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Abstract

Legacy smart residential microgrid systems used for academic purposes often depend on third-party cloud APIs that may eventually become restricted or discontinued over time, causing major system failures and loss of core functionality. This work summarizes two technical and educational case studies from the recent revitalization of Bucknell University's smart residential microgrid testbed. Our work illustrates the need for engineering students to learn to apply critical and innovative thinking to plan for and overcome eventual platform obsolescence, which too often quickly affects technological solutions, forcing the thoughtful design of resilient local solutions in a rapidly evolving communications and security landscape. In the initial example, a Weather Underground API, originally opted for in 2015 to retrieve temperature, irradiance, humidity, and pressure data from the application, was retired, halting the system's ability to automatically retrieve weather-based control information. To achieve similar capability, our system needed to be redesigned to use a Davis Vantage Pro2 weather station via a TP-Link TL-MR3020 router in access-point mode running Meteobridge firmware. This important fix now pushes live weather data every 15 minutes directly to the Raspberry Pi controller of the microgrid. While eliminating cloud dependency, it afforded accurate local sensing capability, core to device real-time algorithm modification when forecasts were different than actual site weather. In the second case, the proprietary Ecobee thermostat API became restricted after the manufacturer suspended new developer registrations for security reasons, preventing further system communications and integrated control when newer modes of these smart thermostats were installed. In answer to this challenge, our team redesigned the communication/control pipeline to pair both the upstairs and downstairs thermostats with the Raspberry Pi through Apple HomeKit using Homebridge, enabling secure, local communication needed for microgrid prediction and control algorithms. The brains of our microgrid, the Pi, now receive live outside weather data and forecasts as well as internal temperature and mode data from each thermostat and can send hourly control setpoints to maintain comfort and efficiency for the occupants. These revisions to the system were first operated and tested in simulation mode (DEBUG=True) to verify successful behavior before running in live mode (DEBUG=False) for real-time control. These experiences highlight the growing risk of API dependence in engineering design and the educational importance of adaptability, creativity, and independent problem-solving on the part of student engineers. Students must be encouraged to anticipate similar (and more regular) technological discontinuities in our ever more rapidly evolving world and be trained to consider and build alternative control paths based on what is coming next. Having these experiences can help them more readily transform constraints into opportunities for innovation.

1. Introduction

Smart residential microgrids provide a powerful instructional platform for exposing students to the interaction between sensing, communication, control, and decision-making in modern energy systems. Many such platforms, however, depend on third-party cloud services for data acquisition and device control. While convenient during initial deployment, these dependencies introduce long-term risks when application programming interfaces (APIs) are modified, restricted, or discontinued.

In academic environments, such disruptions can render otherwise functional systems unusable for teaching and research, limiting opportunities for experiential learning. Rather than treating these failures as isolated technical issues, this Work-in-Progress paper frames platform obsolescence as an educational opportunity. Specifically, it documents how students engaged in restoring weather data acquisition and thermostat control within a legacy smart residential microgrid after the loss of cloud-based services.

The rapid growth of Internet of Things (IoT) and cloud-enabled systems has introduced new instructional challenges, particularly in helping students understand how sensing, communication protocols, edge processing, and cloud services interact within integrated system architectures [1], [2]. Prior instructional efforts have emphasized hands-on laboratory design, modular IoT-edge-cloud integration, and project-based learning approaches to expose students to real-world system implementation challenges. However, many instructional platforms rely on externally hosted cloud services for data storage, device coordination, or analytics. While cloud services provide scalability and convenience, such dependencies can introduce architectural constraints that affect long-term system flexibility and control. Despite the increasing prevalence of these platforms, relatively few documented instructional case studies examine how disruptions to external services can be leveraged as structured learning experiences within energy systems education.

The paper focuses on how students identified failures, evaluated architectural alternatives, redesigned system interfaces, and validated restored functionality, emphasizing learning outcomes related to adaptability, system resilience, and independent problem-solving. The goal is not to present a finalized control solution but to illustrate how maintaining and modernizing cyber-physical systems can serve as a meaningful instructional experience in ECE education [3], [4].

2. System Background and Failure Context

The smart residential microgrid examined in this work was originally designed and commissioned in 2015 [5] as a teaching and research platform. The system integrates photovoltaic generation, residential electrical loads, a smart power meter, programmable thermostats, and a Raspberry Pi-based controller responsible for data acquisition and supervisory control.

At the time of deployment, several key system functions relied on cloud-based APIs. Weather data, including temperature, humidity, solar irradiance, and pressure, were retrieved automatically from a third-party service. Indoor temperature sensing and thermostat control were handled through a proprietary cloud API provided by the thermostat manufacturer. These services enabled forecast-based control strategies but also introduced long-term external dependencies.

By 2025, both services had become unavailable. The weather API was formally retired, and access to the thermostat API was restricted after the manufacturer suspended new developer registrations for security reasons. As a result, the microgrid could no longer retrieve environmental inputs or communicate with installed thermostats, significantly limiting its instructional usefulness. These failures required a redesign of the weather data acquisition and thermostat communication pathways, shifting from externally hosted cloud services to locally implemented sensing and control interfaces.

3. Instructional Context and Learning Objectives

The restoration activities were conducted within a hands-on instructional and research setting involving undergraduate and graduate students working with the microgrid platform. The initial diagnostic and subsystem restoration work was carried out during Summer 2025 as part of a graduate research effort. During the later stages of restoration, two additional students participated in testing and troubleshooting of the redesigned weather and thermostat subsystems.

Following stabilization of core monitoring functions, the restored microgrid was incorporated into laboratory experiences in ECEG 461 (Electrical Energy Conversion-Devices and Systems) and ENGR 100 (Sustainable Energy & Healthy Lifestyle-Design Seminar 2). In these settings, students engaged with the microgrid during structured lab sessions and guided lab tours, analyzing AcuRev 2020 CSV data, examining operational modes, and reviewing the Daily Look-ahead and Hourly control logic. Fifteen students interacted with the system in these laboratory sessions during the fall term.

Rather than replacing failed components outright, students were tasked with diagnosing the causes of failure and restoring functionality while maintaining system transparency and safety. This included reviewing execution logs, examining legacy scripts, identifying broken API calls, and evaluating architectural alternatives that would improve long-term resilience.

The primary learning objectives of this Work-in-Progress effort were to enable students to:

1. Recognize risks associated with long-term dependence on third-party cloud services

2. Analyze cyber-physical system failures resulting from external policy or platform changes
3. Evaluate tradeoffs between cloud-based and local control architectures
4. Redesign system communication pathways to improve resilience and autonomy
5. Apply staged testing and validation techniques prior to live deployment

These objectives align with experiential and problem-based instructional approaches that emphasize system-level reasoning and authentic engineering practice [6], [7]. While the instructional engagement during this phase was exploratory rather than formally assessed, student laboratory reports and system interaction provided preliminary evidence that restoration activities can serve as a meaningful educational framework. Formal assessment instruments specific to cloud-dependency awareness and architectural decision-making are planned for future course integration.

4. Student Activities and Design Decision-Making

Students engaged with the restoration process through a sequence of structured, problem-based activities. Initial efforts focused on diagnosing the source of system failures. This included reviewing execution logs generated by the Raspberry Pi controller, examining legacy Python control scripts and crontab schedules, and consulting vendor documentation to determine why previously functional APIs no longer responded.

For the thermostat subsystem, students discovered that the original cloud API required a developer key tied to an institutional account that could no longer be modified. Attempts to register new developer credentials were blocked by vendor policy. Students evaluated several potential recovery paths, including reusing legacy credentials, waiting for vendor access, or eliminating cloud dependence entirely by implementing a locally managed communication interface.

Similarly, for weather data acquisition, students confirmed that the original cloud service had been fully retired. Rather than substituting another external service, students were encouraged to consider local sensing alternatives that would reduce reliance on third-party platforms. This led to the implementation of an on-site weather station configured to push real-time data directly to the Raspberry Pi-based control system.

After evaluating these options, students redesigned both subsystems to operate through local communication pathways. Weather data acquisition was restored using on-site instrumentation capable of pushing real-time measurements directly to the microgrid controller via HTTP-based communication. Thermostat communication was re-implemented using a secure local interface that enabled bidirectional data exchange without reliance on external cloud APIs.

To ensure safety and reliability, all restored functionality was first executed in a simulation or debug mode within the control scripts. Students verified data integrity, timing behavior, and control logic before transitioning the system to live operation. This staged approach reinforced best practices in control system deployment and reduced the risk of unintended system behavior. Demonstrations of this staged validation process were later discussed during laboratory sessions to illustrate professional engineering workflow.

5. Evidence of Learning and Educational Impact

Consistent with ASEE expectations for Work-in-Progress contributions, evidence of student learning in this phase is primarily artifact-based and observational rather than derived from formal summative assessment instruments. This approach aligns with experiential and active learning models commonly used in engineering education, where engagement with authentic system artifacts forms a central component of learning [8], [9]. The instructional engagement occurred during system restoration activities and subsequent laboratory integration, and evaluation at this stage focused on student interaction with the restored platform.

Learning evidence was drawn from several sources. Students participating in restoration activities generated revised scripts, updated configuration files, execution logs, and documented troubleshooting notes while diagnosing and resolving API failures. During laboratory sessions in ECEG 461 and ENGR 100, students analyzed AcuRev 2020 CSV data, interpreted operational modes, and examined control logic associated with the Daily Look-ahead and Hourly processes. Laboratory reports required students to interpret frequency stability, circuit-level power behavior, and market-driven operating decisions, providing indirect evidence of system-level reasoning.

Students demonstrated understanding by explaining why cloud-dependent architectures failed when vendor APIs were modified, articulating the rationale behind selecting locally implemented control alternatives, and describing how redesigned communication pathways improved robustness. Informal discussions during lab tours further revealed student recognition of the risks associated with external platform dependence and the importance of staged validation prior to live deployment.

Although structured surveys or pre/post assessments specific to cloud dependency were not administered during this phase, the restoration effort provided a foundation for future formal evaluation. Planned future offerings will incorporate targeted reflection prompts and rubric-based evaluation to more directly assess student understanding of architectural tradeoffs and system resilience.

These preliminary observations indicate that engaging students in the restoration and modernization of a legacy cyber-physical system can foster adaptability, critical thinking, and system-level awareness. The restored microgrid now serves not only as a technical platform but also as a live instructional case study illustrating how engineering systems must evolve in response to technological discontinuities.

6. Discussion: Educational Value of Local Intelligence

The shift from cloud-based APIs to local intelligence mirrors broader trends in modern engineering practice, where concerns related to security, reliability, maintainability, and long-term system autonomy increasingly motivate decentralized solutions. From an educational perspective, this transition provided a concrete context for discussing architectural tradeoffs and the implications of design decisions made early in a system's lifecycle.

Rather than treating API deprecation as a purely technical failure, the restoration process reframed the constraint as an opportunity to improve system resilience and autonomy. Students were exposed to the reality that engineering systems deployed in real-world environments must adapt to evolving vendor policies, security practices, and communication standards. This exposure supports the development of professional judgment and system-level reasoning.

By interacting with a system that had undergone redesign due to technological discontinuities, students engaged with a live example of engineering evolution rather than a static laboratory model. This experience reinforces the importance of anticipating external dependencies and considering alternative control paths during system design. Such awareness is particularly relevant to electrical and computer engineering (ECE) cyber-physical systems, including smart grids and IoT-enabled energy platforms [6], [10].

7. Future Work

As a Work-in-Progress effort, this paper emphasizes instructional outcomes emerging from system restoration rather than optimized control performance. The restored weather and thermostat subsystems provide a stable foundation for expanded instructional use within ECEG 461 and ENGR 100 laboratory activities.

Future work will focus on formal integration of cloud-dependency awareness and architectural decision-making into laboratory modules. Planned instructional enhancements include structured reflection prompts, guided analysis of architectural tradeoffs between cloud-based and local control implementations, and rubric-based evaluation of student reasoning related to system resilience and lifecycle risk.

In addition, future offerings will incorporate more explicit discussion of predictive and ANN-based control strategies, building on the restored local data infrastructure. This integration will allow students to compare rule-based logic with data-driven approaches while considering reliability and communication architecture constraints.

Formal assessment instruments are under development to evaluate student understanding of external dependency risks, staged validation techniques, and system-level control design. These instruments will enable more systematic measurement of learning outcomes associated with restoration-based instructional activities.

8. Conclusion

This Work-in-Progress paper presented two educational case studies arising from the restoration of weather data acquisition and thermostat control in a smart residential microgrid. The discontinuation of cloud-based APIs created an authentic engineering constraint that required architectural redesign and system-level reconsideration.

By shifting from externally hosted cloud services to locally implemented sensing and control pathways, the microgrid regained operational stability while simultaneously providing a meaningful instructional context. Students engaged in diagnosing API failures, evaluating architectural alternatives, implementing resilient communication pathways, and validating restored functionality using staged deployment techniques.

These activities demonstrate that maintaining and modernizing legacy cyber-physical systems can serve as a powerful instructional framework in electrical and computer engineering education. Exposure to real-world technological discontinuities supports the development of adaptability, critical thinking, and system-level reasoning. Rather than interacting with a static laboratory platform, students engaged with a system that evolved in response to external constraints.

As the restoration effort continues to be integrated into laboratory curricula, future work will formalize assessment strategies and expand instructional modules focused on architectural resilience and intelligent control. This Work-in-Progress highlights how technological disruption, often viewed as a setback, can be transformed into an opportunity for meaningful engineering education.

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