Communication and Control for Integrated PV and Storage Systems

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1. Summary

This paper describes the system architecture of a PV-storage control system implemented by SolarCity. The hardware components and the communication protocols used to interface with components are described. The standards and communication protocols that are most suitable for an integrated PV-storage solution are discussed.

2. Introduction

The SolarCity FirmPV system is a firm, dispatchable, grid-interactive combined photovoltaic (PV) and battery energy storage system designed for deployment in distributed, small increments. Remote, fully bidirectional control of distributed storage assets that can firm otherwise intermittent renewable resources will enable both site specific peak demand reduction benefits and system-wide grid network benefits that will reduce costs and carbon emissions and improve grid reliability.

The communication platform for the FirmPV system builds upon the SolarCity SolarGuard PV monitoring platform. The existing SolarGuard platform provides real-time monitoring via a central server for thousands of PV systems. The FirmPV communication system adds modular, scalable support for inverter/charger and Battery Management System (BMS) protocols, onsite control intelligence, and bidirectional server control for a fleet of FirmPV systems.

During the design and preliminary implementation of the FirmPV system, SolarCity observed a significant lack of industry accepted public communication standards at each link within the system. Because of this, the initial implementation required use of a number of third party proprietary protocols. This paper will highlight what standards could be adopted and where new standards are required. When discussing specific components, this paper will focus on Commercially available Off-The-Shelf (COTS) components intended for generation and storage power densities less than 100 kilowatts.

3. Communications System Architecture

Figure 1 shows the key components of the FirmPV communications system. The components include:

1. Battery Module and Battery Management System (BMS)
2. Battery Inverter/Charger
3. PV Inverter
4. Site Gateway
5. **SolarGuard Server**

![Diagram of SolarGuard Server components](image)

**Figure 1**

**Battery Module and BMS**

The BMS is typically packaged with the battery. It provides data acquisition and safety control for the battery system. The BMS provides charge and discharge limits to the battery inverter/charger.

**Battery Inverter/Charger**

The battery inverter/charger controls charge and discharging of the battery. The inverter/charger receives control commands from the site Gateway and control limits from the BMS.

**PV Inverter**

The PV inverter data interface enables interaction with the inverter command set and provides access to inverter monitoring data registers.
Site Gateway

The Gateway serves a central role in the FirmPV communication systems. It performs the following functions:

1. Data collection from onsite components including the battery system, PV inverters, and load meters
2. High speed, secure communications to the server for performance logging and central control over either IP based cellular or existing broadband Internet connections
3. Local intelligence and control for times when a server connection is not available
4. Arbitration between the BMS and inverter/charger in cases where the systems do not have directly compatible interfaces

The FirmPV Gateway supports a wide variety of industry standard hardware communication interfaces including RS232, RS485, CAN, ZigBee Smart Energy Profile, and Ethernet, providing support for a broad range of interfaces. Similarly, the Gateway software is designed to be modular to support a plug and play system design. The software design supports a heterogeneous system architecture that self-configures on system commissioning. This enables a wide range of storage capacity or hardware components using the same Gateway solution.

SolarGuard Server

The SolarGuard server provides centralized coordination and scheduling of a fleet of FirmPV systems. The server also provides long-term logging and analysis of system performance.

4. Communication Protocols

In the preliminary implementation of the FirmPV control platform, it was quickly discovered that few open communications standards exist and none are widely adopted for any of the components within the system. Open standards reduce development, integration and interoperability testing time and cost. A single manufacturer can integrate multiple components using proprietary protocols and present a unified standards compliant interface, but this prevents quickly switching to new best-of-breed subsystems as they become available.

The following sections discuss the individual interfaces between each component and suggested areas for standards adoption.

Gateway to PV Inverter/Charge Controller

COTS PV inverters have communications interfaces requiring a variety of interface standards including RS232, RS485, Bluetooth, Zigbee, and CAN. Supporting a large variety of physical interfaces increases the complexity and cost of the Gateway. Additionally, wired interfaces add
additional cost as it is not always advantageous or possible to mount the Gateway in close proximity to other components.

COTS inverters also use a variety of proprietary communications protocols. Even in cases where manufacturers have chosen public standards such as Modbus\(^1\), there is significant variability in the implementation.

*Suggested Protocols: Draft ZigBee Smart Energy Profile 2.0\(^2\), EPRI Specification for Smart Inverter Interactions with the Electric Grid Using IEC 61850\(^3\)*

**Inverter/Charger to Battery Management System**

Battery inverter/chargers and BMS systems both use a variety of physical layer and higher layer protocols. Even in cases where both vendors use a similar protocol, CAN\(^4\) for example, there are many options for incompatibility in the implementation.

*Suggested Protocols: CANopen CiA 418/419\(^5\)*

**Gateway to Inverter/Charger**

The Gateway to inverter/charger interface should adhere to the same specification as the Gateway to PV Inverter interface. Current COTS inverter/chargers implement a variety of proprietary protocols. Additionally, support for grid-interactive control is limited.

*Suggested Protocols: Draft ZigBee Smart Energy Profile 2.0, EPRI Specification for Smart Inverter Interactions with the Electric Grid Using IEC 61850*

**Gateway to Server**

In the first implementation of the FirmPV communication system, both the Gateway and control server are implemented by SolarCity using a proprietary protocol. However, future use of COTS Gateways and third-party servers will necessitate open standards.

There are well accepted standards for security, authentication, and encryption over public IP networks. The FirmPV implementation adheres to the security policy described in the OpenADR specification\(^6\).

*Suggested Protocols: OpenADR*

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1 [www.modbus.org](http://www.modbus.org)
2 [www.zigbee.org](http://www.zigbee.org)
4 ISO 11898
5 [www.can-cia.org](http://www.can-cia.org)
5. Conclusion

The communications and controls for an integrated PV and storage system can represent a significant portion of total system cost, especially when required to support many proprietary protocols. The FirmPV communication system demonstrates a flexible platform that can accommodate proprietary interfaces. However, technology is expected to improve rapidly in the storage industry and proprietary protocols limit rapid adoption of new best-of-breed products. Creation and industry adoption of open standards for communications will better enable deployment of energy storage solutions.