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SOLAR ENERGY GRID INTEGRATION SYSTEMS (SEGIS) PROACTIVE INTELLIGENT ADVANCES FOR PHOTOVOTAIC SYSTEMS

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ABSTRACT This paper provides an overview of the activities of the Solar Energy Grid Integration Systems (SEGIS) program from "Conceptual Designs and Market Analysis; Stage 1" through the "Prototype Development; Stage 2". Work has progressed with twelve contractors completing the Stage 1 conceptual designs and market analysis. Downsizing through best value competition resulted in hardware prototypes developed by five contractors. The contractors include: 1) Apollo Solar; 2) Petra Solar; 3) Princeton Power Systems; 4) PV Powered; 5) University of Central Florida working with SatCon. The projects span system sizes from micro-inverters (200W) through residential and commercial sizes up to 100kW, but modularity enables larger applications. This SEGIS R&D opens pathways for promising solutions for new electronic and electrical components, advanced innovative inverter/controller topologies and designs, economical energy management systems, innovative energy storage with a suite of advanced control algorithms, new islanding detection methodologies, advanced maximum-power-point tracking suited for all PV technologies, protocols and the associated communications.[1] In addition to advanced grid interconnection capabilities and "value added" features, the new hardware designs result in smaller, less material-intensive, and higher reliability products. The solutions enabled by deployed SEGIS systems will drive the "advanced integrated system" and "smart grid" evolutionary processes forward in a faster and focused manner.[2] Technical advances and economic benefits are assessed and discussed.

INTRODUCTION The SEGIS program is an aggressive and proactive program supported and funded by the U.S. Department of Energy Solar Energy Technologies Program. It is focusing on development of advanced system technologies that enables increasing the penetration of PV into the utility grid while maintaining or improving the power quality and the reliability of the utility grid. The R&D is a collaborative effort of teams that are selected in a competitive bid process (SEGIS Solicitation) conducted by Sandia National Laboratories. Highly integrated, innovative, advanced inverters, new controllers and related balance-of-system (BOS) elements for residential and commercial solar energy applications are being developed in the program. Advanced integrated inverters/controllers are incorporating energy management functionality and communication capabilities. The work focuses on grid-integrated systems but stand-alone energy management systems implement full micro-grid functionality. Portals for energy and communications enable PV system interactive operation with evolving and increasingly available smart metering systems. Hardware is being developed for the utility grid of today, which was designed for one-way power flow, for intermediate grid scenarios, and for the grid of tomorrow, which will seamlessly accommodate two-way power flows as required by wide-scale deployment of solar and other distributed resources. Several leap-frog component and system advances are being pursued through SEGIS. The roles of inverters, controllers and energy storage are better integrated into PV systems that are optimized for economics and performance and that are not disruptive in high penetrations. Figure 1 shows the stages and timetable for the SEGIS program.

SEGIS PROGRAM NARRATIVE and PROJECT GOALS The number of, and ratings of new grid-connected photovoltaic systems are skyrocketing in the United States and internationally. To date almost all of the installed systems are "dumb" in that they are designed to simply provide power to the utility grid when the sun shines. There is data monitoring of the systems done only with add-on data collection. The sample rates and accuracy of the data collected varies widely. Communications to and from the utility is practically non-existent. Communications to and from owners and installers is minimal. One critical goal of the SEGIS program was to reverse this trend, while at the same time improving the functionality and intelligence of PV systems.

A SEGIS concept paper was written as a progressive outline of needs and priorities for initiating a systems level approach to PV systems with "value added" as a primary theme.[1] The SEGIS Concept Paper was used as a guideline initiating innovative solutions for inroads for high-penetration PV applications. A continuing requirement for SEGIS is improved lifetimes and mean-time-between-failure for PV systems. Communications advantages and disadvantages are presented.

Figure 2 shows one example of an advanced SEGIS system as being pursued in the SEGIS program. Next generation SEGIS systems will include energy storage, energy management and interactive communications, which is new to PV systems. Early SEGIS work has determined that communications for more intelligent utility interconnections will likely have to be a combination of physical link topologies. SEGIS-related communications developments are already being used in micro-grid support and with utility-owned micro-inverter based installations on utility poles with direct utility monitoring and control.

The innovative SEGIS work is addressing the complex interconnect standards barriers to progressive "value added" support for the utility grid or for economic benefits of intelligent distributed PV grid-tied systems. The IEEE Std1547 does not allow for deployment of several progressive SEGIS developments such as 1) Intentional islanding to support stressed grids that results in low-voltage ride through that may last only a few seconds but that disrupts the stability of the grid support, 2) Volt-ampere reactive (VAR) production by PV inverters that has the potential to be a very dynamic and fine-grained aid in voltage support of stressed grids, and 3) Low frequency ride through.[3] Each of these features is best accomplished with communications between the PV system and the interconnected utility. All of these features are best accomplished with energy storage in order to be dispatchable and independent of PV system intermittency. The energy storage must be optimized to obtain the most economically beneficial "value added" per individual installations. SEGIS developments are addressing the array of communications methodologies. The universal concepts that include the utility controlled functionality will be discussed along with impacts for PV applications, the utilities and owners of PV systems. Other important standards and codes directly affecting SEGIS developments include applicable compatibilities with IEC61850 and the National Electrical Code.[4][5] The IEC standard 61850 for communications includes data modeling, reporting schemes, fast transfer of events for peer-to-peer communication modes, setting groups to control blocks protocol, sampled data transfer, commands and data storage protocols.

As the cost of PV modules and panels decrease, the contribution of inverter and balance-of-system cost and replacement are becoming more significant. Reducing system costs through SEGIS improvements and improving the lifetime and reliability are continuing goals and it is estimated to reduce the cost of electricity from PV inverter systems from $.083 to $.022/ kWh.[6] This, along with adding to the value of a PV installation will result in benefits beyond that of just displacing the cost of electricity. The economic benefits will be further assessed and discussed.

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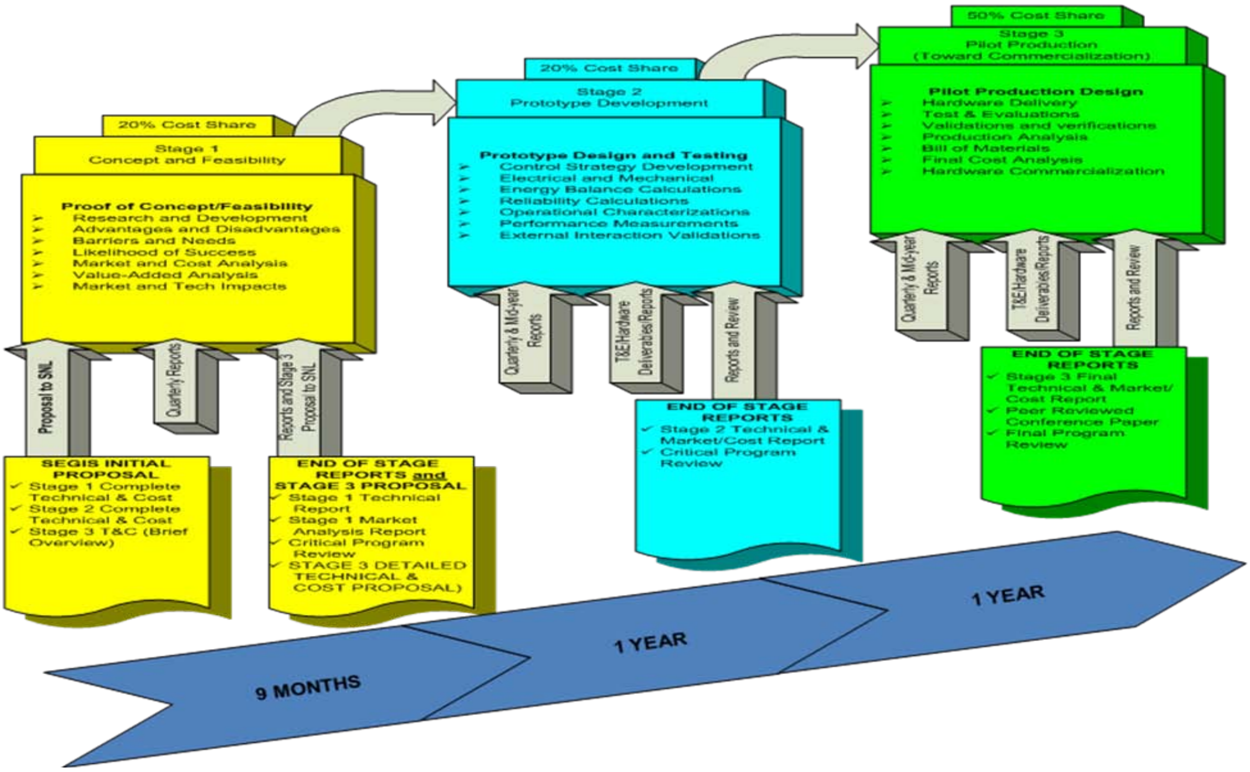

Figure 1. SEGIS Stages, Timeframes and Description

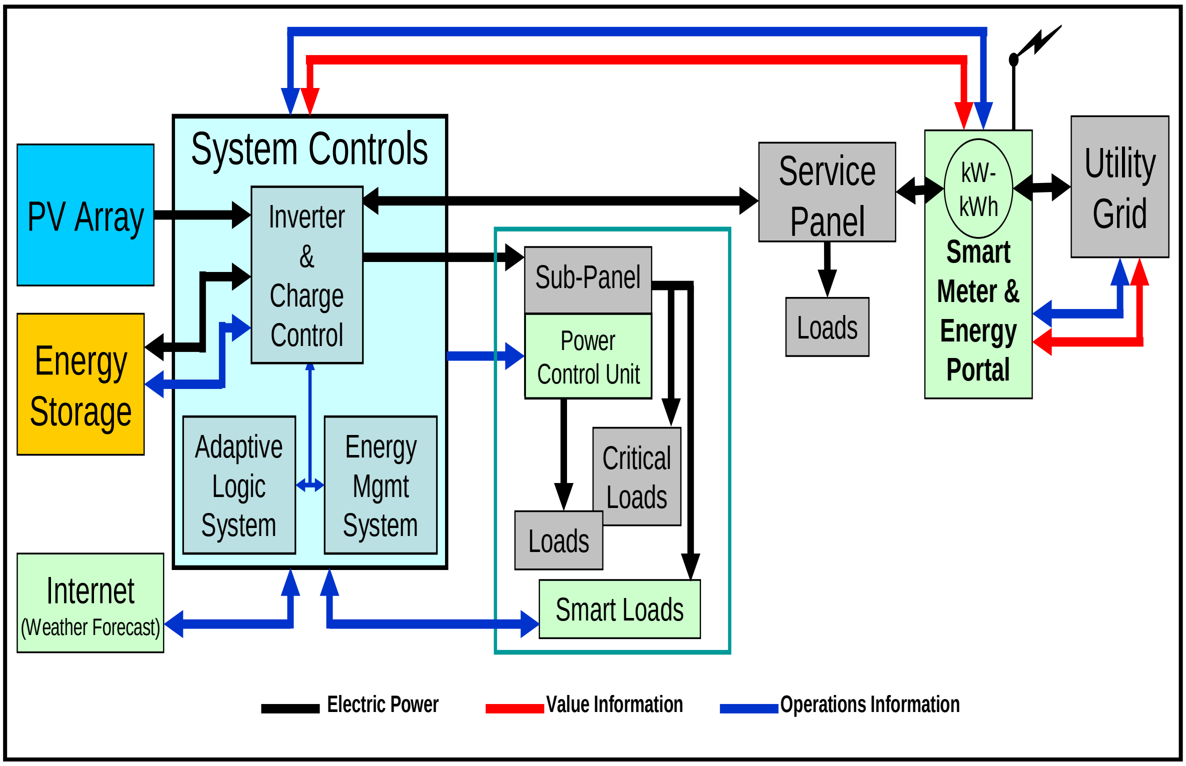

Figure 2. A SEGIS-type system for advanced distribution infrastructure with smart communications and energy storage