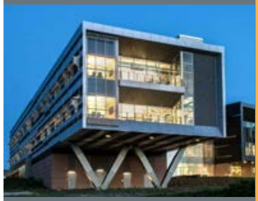
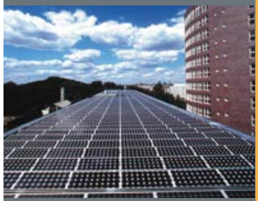
NATIONAL RENEWABLE ENERGY LABORATORY

CAPABILITIES



Microgrid-Ready Solar PV - Planning for Resiliency

With resilience at the forefront of energy planning, microgrids are rapidly moving into the mainstream. A major driver for this trend includes the increase in natural and man-made disasters and the need to secure crucial services and critical infrastructure in the event of an extended power outage. Microgrids that include solar photovoltaics (PV) as a generating source have the ability to not only provide power when the grid is down, they can also reduce energy costs when the grid is available. For solar project designers future microgrid considerations are becoming increasingly important.

This fact sheet provides background information on microgrids with suggested language for several up-front considerations that can be added to a solar project procurement or request for proposal (RFP) that will help ensure that PV systems are built for future microgrid connection.

What is a Microgrid?

A microgrid is a group of interconnected loads and distributed energy resources that is usually attached to a centralized grid and designed to connect and disconnect from the grid. Grid-connected, microgrid assets can provide economic benefits to owners through activities such as peak shaving, demand response and ancillary services; while also helping to facilitate the integration of renewable energy. In island-mode, microgrids are disconnected from the utility grid and can produce and distribute electricity independently. Serving areas as small as a single building to an entire community, microgrids can allow hospitals, campuses, universities, data centers, and other critical facilities to operate in the event of a grid outage.

Microgrids that include solar PV have the added benefit of delivering clean, cost-effective electricity. With solar PV as a generating source, microgrids can provide localized power for an extended period of time when the grid is down.

Microgrid-Ready Solar PV

When designing a solar PV project, consider the PV system as a generation resource in a future microgrid. The microgrid could include conventional (engine) generators, other renewable resources, and/or energy storage. If there is no isochronous generator in the system that sets microgrid frequency and voltage, a "master inverter" with battery storage can be selected that will provide this function. Therefore, suggested RFP language and inverter functionality includes:

- The inverters and their functionality as distributed resources in planned electrical islands shall comply with applicable provisions described in the *IEEE Series of Interconnection Standards*, specifically current and revised versions of IEEE Std. 1547 *Standard for Interconnecting Distributed Resources with Electric Power Systems.*
- Selected PV inverters [typically the larger inverters] shall be multi-mode DC to AC inverters capable of switching between grid-interactive mode and microgrid (intentional island) mode. These inverters, in conjunction with a system supervisory controller, shall be capable of bi-directional real and reactive power flow.

Additionally, optional RFP language may be necessary to address space considerations for future storage equipment and microgrid communication connections. For example, a site could request that spare communications raceway(s) be installed that could be used to route future communications cabling between the inverter and the microgrid controller at a later date.

Inverters for Grid Support

The core job of a PV inverter is to convert the DC from solar cells into AC, however, inverters are currently being engineered for additional responsibilities useful to both the PV system and microgrid, such as grid integration and monitoring. For example, if PV generation needs to be reduced to help balance generation and load in a microgrid, the inverter can curtail PV output via control set-point(s). Inverters also have the capability to "ride through" frequent minor disturbances, as in the case of weak grids or microgrids. Adjustments to inverter trip levels and clearing times that are acceptable to the utility can allow the PV system to stay online and respond accordingly to relatively short-term, minor events. In some cases, this function can actually help the grid to self-heal from a disturbance.

Inverters have a wide variety of designs, capabilities, and features and inverter technology continues to evolve at a rapid pace. It is important to ensure that the selected inverters have the advanced capabilities necessary to ensure microgrid-ready status. Suggested RFP language and inverter functionality requirements include:

- The inverter shall be capable of curtailing its output in logical steps, with controllable ramp rates, in response to commands from a microgrid controller or other source.
- The inverter shall have adjustable trip limit and clearing capabilities as determined by electrical studies, and as permitted by IEEE Std. 1547a. Important capabilities include fault ride-through to stay online during transient grid disturbances, such as sags and swells, and extended operating voltage and frequency ranges to avoid nuisance tripping.
- The inverter shall be capable of real-time data logging, alarm reporting, and communication with a remote power system controller.

Power Factor Considerations

PV systems can affect the power factor (PF) in an electrical system and microgrids can have unique power factor needs. The solar PV project should be analyzed for PF impact and benefit from a technical and economic perspective in grid-connected and islanded modes. If it is determined site load PF will be affected; inverters, dedicated power electronics, or traditional capacitor banks can provide reactive power (VAR) support and improve PF. The full cost of all the options should be considered. Suggested RFP language and inverter functionality includes:

- Inverters shall be capable of sourcing or sinking reactive power for the purpose of improving PF. This can help mitigate or eliminate monthly PF charges in grid connected mode and improve microgrid operations during islanded scenarios. Reactive power levels (absorption or supply) shall be either programmed locally or be controlled through set-point commands provided by a remote controller. The control system shall adjust inverter reactive power based on actual system conditions. The inverter shall be capable of sourcing VARs even when daylight is not present. Oversizing the inverter to allow for both reactive power and planned real power requirements may be necessary.

If a power purchase agreement or other performance contract is involved and savings are based on real power, then PF correction or VAR support needs to be accounted for in the savings estimate and contract language. Consider the following:

- The Contractor shall propose how they should be compensated for any lost real power kWh in exchange for sourcing VARs. (For example, use the inverters to record potential kWh vs. actual kWh.)

Conclusion

Cities, utilities, businesses, universities, and the U.S. military are turning to microgrids for supplemental and backup power. It isn't hard to see why. Microgrids, with the integration of renewable energy resources and storage, continue to operate when the grid is down; serve as a grid resource; provide economic benefits to owners; and help move the nation toward a resilient, clean energy future. And NREL is helping to move this transformative technology into the mainstream.

NREL has experience and expertise supporting solar PV and microgrid projects. We can provide technical assistance, project development support, and *microgrid testing at the NREL Energy Systems Integration Facility* to ensure that your PV project is microgrid-ready.

NREL knows solar. NREL knows microgrids.

Our partnerships enhance U.S. infrastructure and strengthen national security. Raytheon and NREL collaborated to validate an advanced microgrid system at U.S. Marine Corps Air Station Miramar that draws on batteries and solar energy for its power. The system maintains power for mission-critical facilities under many adverse conditions—including loss of the local power grid. This partnership project received the Environmental Security Technology Certification Program's 2016 Project-of-the-Year Award. Building on this project, NREL is supporting the execution of a larger U.S. DoD funded microgrid at Miramar that is currently in engineering design with construction expected to start in summer 2017 that will increase the resiliency of the installation by providing approximately 100 buildings with more reliable power from a new microgrid.

Miramar is just one example project. NREL works with many partners in governments, utilities, businesses, and universities, as well as internationally in support of microgrid projects.

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