Solar Energy in Florida

Response to FPSC Request for Comments

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Nhu Energy

-- Energy, Controls, and Mission Critical Systems --

P.O Box 12155
Tallahassee, FL 32317
850-385-5100

Rick Meeker
rmeeker@nhuenergy.com

WHERE ARE WE TODAY?

Solar PV accounts for a minuscule amount of total electric energy produced and consumed in Florida (about 0.1%)[1]. Though Florida is now the third most populous state in the U.S., and, in fact no. 1 in terms of total electric utility capacity and net generation[2], it is ranked 13th in the U.S. in terms of installed solar PV capacity[3]. The cost of solar PV has continued to decline, and, there is considerable consumer support for moving towards greater amounts of PV generation – through the first quarter of 2015, nearly one-fourth of cumulative residential solar PV installations have come on-line without any state incentive.[4] The levelized cost of energy (LCOE) of utility-scale solar ($72 to $86 / MWh) is now close to grid parity with other generation choices, and, in fact, is in the same cost range as the predominant traditional dispatchable generation that has been constructed in the last 25 years, natural gas combined cycle ($61 to $87 / MWh).[5]

THE SOLAR RESOURCE IN FLORIDA

Florida has a significant solar energy resource available. Most of Florida has over 5.0 kWh/m^2/day of solar irradiance, with some areas (most of SW Florida) having over 5.5 kWh/m^2/day, comparable to central and southern Spain and significantly better than one of the world's leading countries in installed solar, Germany, which is mostly <4 kWh/ m^2/day. The best locations in the U.S., in the desert southwest, experience over 6.5 kWh/m^2/day.[6]

COINCIDENCE OF SOLAR POWER AND LOAD

One of the most frequently cited obstacles to solar PV constituting a substantially greater portion of the generation mix is the fact that the load peaks don't coincide with the periods of maximum solar generation. Consequently, installed dispatchable generation capacity must be available, even if for relatively short periods to cover peak load plus planning reserve margins. Innovative approaches, including energy storage, demand response, conservation and efficiency improvements, deployment of other complementary clean-energy sources, improved load and intermittent generation forecasting, system optimization techniques such as conservation voltage reduction, and possibly even reviewing and reducing local reserve margin requirements may all help reduce the amount of total installed generation currently required to serve peak load in a power system with much more solar generation.

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[1] FRCC 2014 Regional Load and Resource Plan, July 2014.

[2] Florida Electricity Profile 2012, U.S. Energy Information Administration (EIA), May 2014.

[3] The OpenPV Project, National Renewable Energy Lab, https://openpv.nrel.gov/rankings

[4] SEIA/GTM Research Solar Market Insights Report™ 2015 Q1, http://www.seia.org/research-resources/solar-market-insight-report-2015-q1

[5] Lazard's Levelized Cost of Energy Analysis – Version 8, Lazard, Sept. 2014.

[6] Photovoltaic Solar Resource Maps, National Renewable Energy Laboratory (NREL)

Even accepting the current scenario where solar does *not* allow reduced capital investment in all of the traditional generation capacity needed to serve peak load, reducing the power output of fossil plants for substantial periods of time *does* reduce fuel costs, operating and maintenance costs, fossil fuel dependence, and emissions. Nearly 60% of Florida's energy is now generated with natural gas[1]. This is a substantial economic risk in and of itself, irrespective of the requirement to maintain the availability of the traditional generating assets to serve peak load. Solar can be part of the solution to achieving greater generation "fuel" diversity and reducing risk to fuel price shocks and the attendant, potentially severe, economic consequences.

Certainly, there is the limitation that solar generation is not available at all at night and is variable even during the day. But, the fact remains that most of the load occurs during the day. And, though, on average, Florida loads peak early morning and late evening in winter and mid-to late afternoon in summer (Figure 1, top), solar still can supply a substantial portion of the load during the periods it is normally available (Figure 1, bottom).

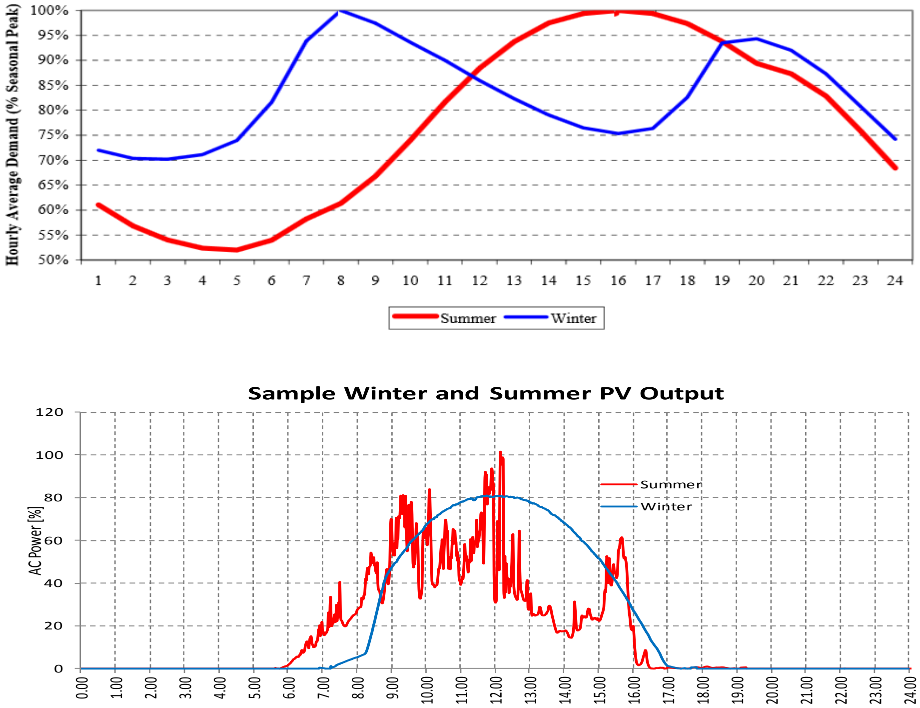

Figure 1. Top, Florida average daily load shapes[7]; Bottom, typical solar PV output in summer.

Further, circuits with heavy commercial loads and university campuses, offices, and business parks actually have loads that coincide rather well with solar PV (Figure 2).

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[7] "FEECA, Annual Report on Activities Pursuant to the Florida Energy Efficiency & Conservation Act" (figure data derived from utility 10-year site plans), Florida Public Service Commission, Feb. 2015.

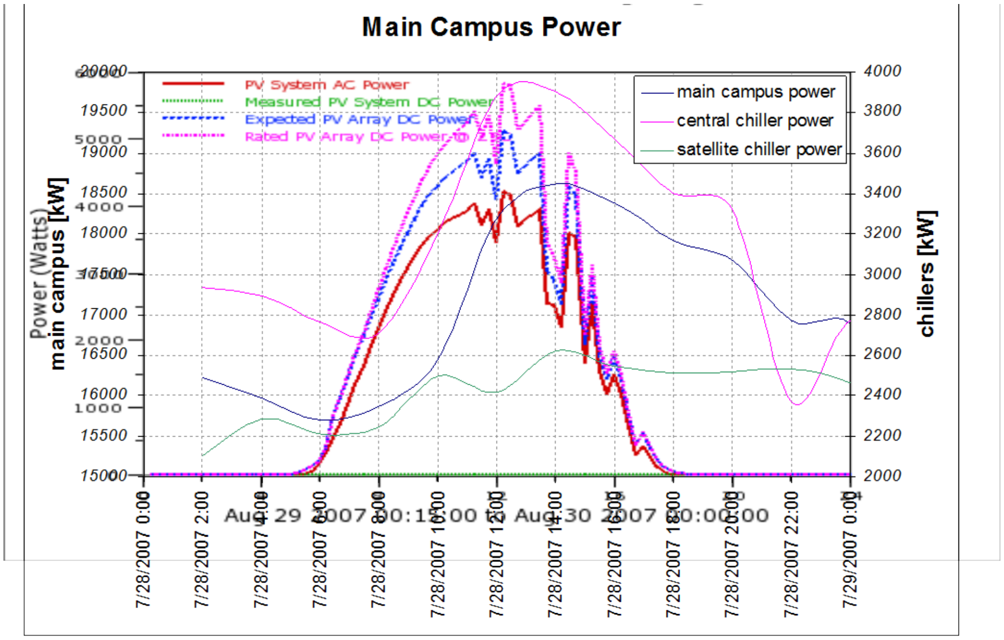

Figure 2. An overlay of typical Florida summertime PV output on a typical summertime load profile for a large Florida university campus (thick traces are solar PV AC and DC power, thin lines are campus loads; y-axis scales are not the same, but not important – the point of the figure is the trendline over the course of a day and the degree of coincidence or overlap of areas under the curves).

SOLAR PV VARIABILITY AND INTERMITTENCY

Solar PV irradiance and PV plant power output varies in a predictable way due to rotation and orbit of the earth and in less predictable ways, due to weather patterns. Florida's weather patterns result in greater variability in solar PV irradiance, and, consequently, solar PV plant output, when compared to California and Nevada, with Florida variability patterns more similar to Hawaii and exhibiting greater overall variability than the southwestern U.S. If solar resource variability in Las Vegas, NV is taken to be representative of the desert southwest, then summertime variability in that region of the U.S. is around 50% *less* than what it is other times of the year, while in Florida, summertime variability is on the order of 50% to over 100% *more* than what it is other times of the year.

The variability of solar PV is often raised as a concern when considering high levels of solar PV generation in the electric power grid. In the summertime in Florida, PV plant power output changes on the order of 50% of rated capacity per minute are not unusual due to typical weather patterns. However, studies conducted by the Center for Advanced Power Systems (CAPS) at Florida State University and the Florida Solar Energy Center (FSEC) at the University of Central Florida on solar PV variability for locations connected to or in the vicinity of four Florida distribution circuits that were also studied in detail suggest that the solar PV variation and ramp rates are well within the ability of the power system to respond, due to the physics of electrical circuits and systems, which already accommodate fairly large, frequent, and somewhat unpredictable changes in load, and are now doing the same for solar PV. To state it simply, electrons move much faster than clouds, provided the grid infrastructure and generation are there to deliver them.

The conclusion that the power system handles the short-term intermittency rather well applies to individual distribution circuits with high levels of solar PV. More research is needed on the effects of high penetration levels of solar PV pervasive across large portions of the power grid, though the short term intermittency over large areas is reduced due to averaging effects. This is due to the fact that cloud-induced variation is inherently a local effect. Outputs of larger PV plants are less variable than smaller ones, and, the aggregated output of multiple solar PV systems spread over some area is less variable that of any single system.

GRID-CONNECTED SOLAR PV

Individual distribution circuits in the electric power grid can accommodate varying levels of solar PV, depending on a number of factors. Some may be able to accommodate PV systems with a total installed capacity of only 25% of the peak circuit load, while other circuits may be able to accommodate PV in excess of 500% of the peak circuit load without adverse effects (Figure 3).

A widely accepted practice historically employed by electric utilities in the U.S. for screening and approving connection of solar PV systems to the power system was “the 15% rule”. This rule came about as a formally accepted screening practice in a 1999 revision of California Public Utilities Commission (CPUC) Rule 21 and eventually spread to broad use nationwide. This 15% threshold then became part of the FERC Small Generator Interconnection Procedures (SGIP), which, in turn, became a model for many states regulators and utilities even for situations where interconnection was not under FERC jurisdiction.

Based on early results from the Dept. of Energy-funded High Penetration Solar PV Deployment projects, including SUNGRIN, and based on the cumulative prior field experience and observations with grid-connected solar PV up to that time, it became increasingly clear that the 15% rule was too conservative in many situations, and that supplemental studies triggered by generation exceeding 15% of peak load were often unnecessary. Nonetheless, this guideline remains somewhat entrenched, with 15% still used by some utilities as the threshold at which more costly and protracted studies may be required before PV can be interconnected to the electric power system.

In fact, in many cases, penetration levels far above 15% are possible with no significant impact on circuit operation or reliability. Figure 3, from one of the Florida distribution feeders studied, shows load and PV production data representing a PV penetration of around 600% of peak, with routine reverse power flow back to the substation, and no significant issues with voltage regulation or protection.

Considerable research has been performed over the last several years by teams across the U.S., much of it funded by the U.S. Dept. of Energy, aimed at understanding and enabling high-penetration levels of solar PV in the electric power grid. These efforts have provided insights and tools to aid in better understanding these "hosting capacity" limits. Research by multiple groups agrees that the 15% rule has been too conservative and too rudimentary, when most circuits, in reality, can accommodate much higher penetration levels without adverse effects.

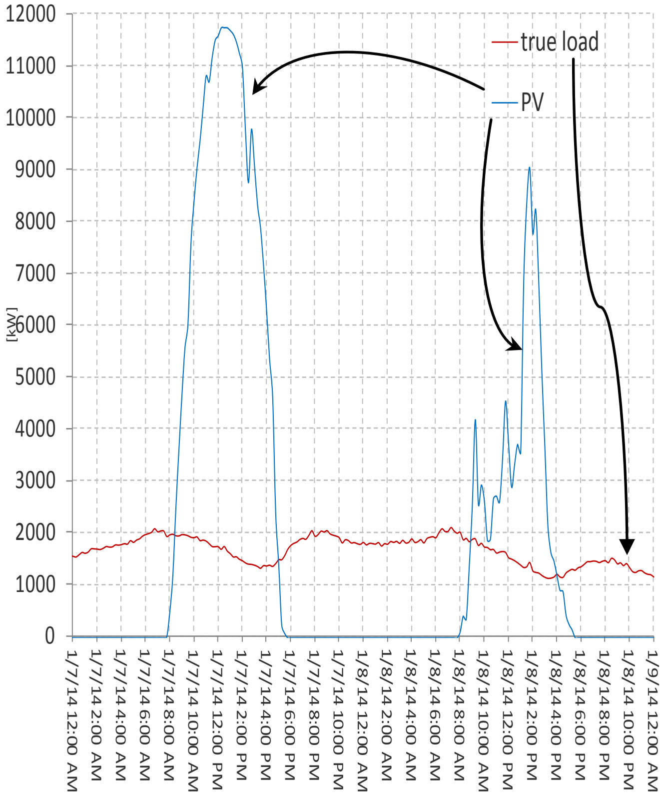

Figure 3 . Load and PV, winter, very high PV penetration, on a Florida circuit

One of these Dept. of Energy funded "High Penetration Solar PV Deployment" projects has been a Florida-focused effort known as the Sunshine State Solar Grid Initiative (SUNGRIN). This 5-year project, led by the Center for Advanced Power Systems (CAPS) at Florida State University has recently completed. Results, resources, tools and techniques arising from this initiative may be useful as Florida moves forward with the question of increasing grid-connected solar PV generation in the state.[8]

REALIZING THE FULL VALUE OF GRID-CONNECTED SOLAR PV

Up to now, solar PV has been utilized almost exclusively as a source of "real power", that is, the power to produce useful work or output from loads. In some cases, as with most residential systems, solar PV is installed to offset local load and export any excess energy to the electric utility ("Net Metering"); While, in other cases, it is installed primarily to export the energy produced to the electric power system.

When solar PV not owned by the electric utility is installed for the purpose of providing the majority of the energy production to the grid, it is normally under a power purchase agreement (PPA) or a feed-in tariff (FIT) program[9]. In these cases, real power production is maximized, with the PV plant usually operating at a power factor of 1 or a constant power factor as may be required by the utility in the PPA.

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[8] Contact the author of this document, R. Meeker, who was also project lead for SUNGRIN.

[9] The only FIT program in Florida has been the one established by Gainesville Regional Utilities in 2009.

For the most part, integration policies employed by the utilities have been a “do no harm” approach that assumes solar PV is an operational and safety risk and requires it to trip offline on any grid disturbance (such as low voltage) or on detection of a possible island (a portion of the power system having become disconnected from the larger electric grid and having some local energy sources that may continue to supply load).

DC current and voltage produced by Solar PV is converted for connection to the AC electric power system by power electronics (PE) inverters. The high-speed switching that produces essentially a synthesized AC waveform at the grid connection side of the inverter also inherently provides the capability for very fast, highly-granular control of the AC waveform characteristics, including power factor and frequency. These are fundamental capabilities of solid-state power-electronics switching technology. The extent to which these fundamental capabilities are exploited and reflected in the specifications and capabilities delivered in any particular solar PV inverter is most often governed by economic rather than technical considerations.

Solar PV capacity factors vary between about 11% and 32%, with a typical or average expected value around 25%[10,11]. Using a capacity factor of 25%, then, on an energy basis, 75% of the inverter capacity over time is not utilized. Yet, inverters have the capability to continue to operate to fundamentally alter the waveform at the AC point of connection, whether there is power being produced on the DC side or not[12].

So, while solar irradiance is not at the maximum for a given location at any particular time, or, perhaps, even zero, such as at night, a sophisticated piece of equipment, the solar PV inverter, is already present, connected, and potentially available for grid support, though, currently rarely utilized for that purpose.

Detailed studies on different SUNGRIN Florida utility partner high-penetration solar PV feeders have shown that PV can provide very good voltage regulation on a circuit with proper coordination with existing regulation device control schemes or, in many cases, it can likely reduce or eliminate the need for additional regulation devices on the distribution circuit.

Figure 4, from a 2.3 MW plant in central Florida, shows a day when PV production is well below capacity for the entire day due to clouds, with multiple regulation device operations occurring (as evidenced by voltage, second trace from the bottom). This is a clear opportunity to extract additional value from solar PV by having it provide voltage regulation during these periods.

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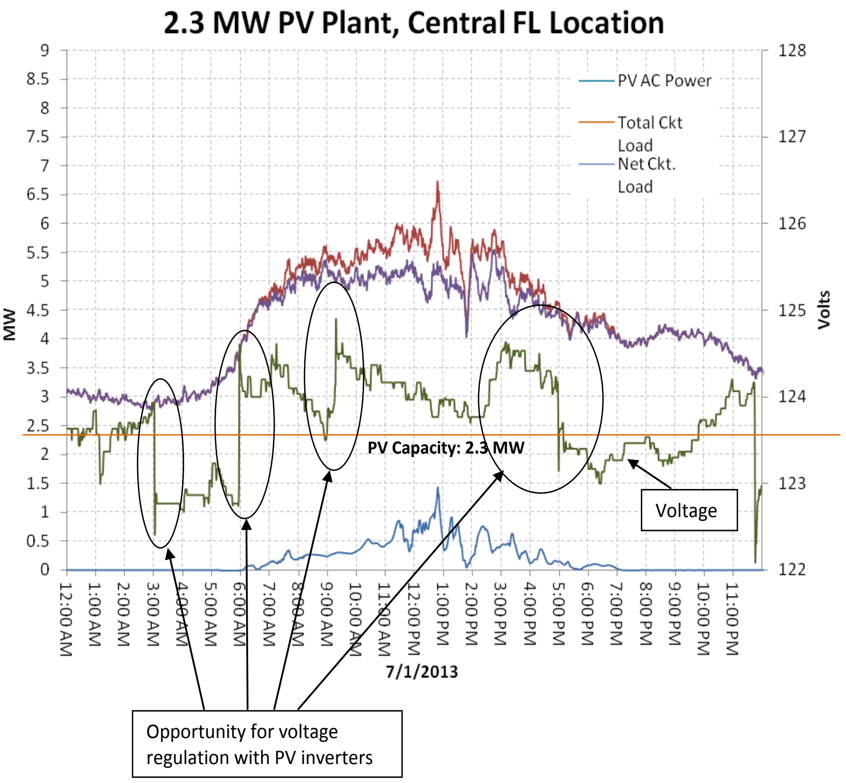
[10] http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b

[11] http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf

[12] Much the same as Flexible AC Transmission System (FACTS) power electronics devices employed at the transmission system level, along with similar purpose-specific devices, such as distribution-Static VAR Compensators (dSVC’s), employed at the distribution system level.

In fact, there are a range of capabilities being increasingly offered in modern “smart” inverters, including the ability to “ride through” system faults or disturbances (such as voltage or frequency), curtail real power production, connect/disconnect from the system, and, as mentioned, participate in volt/VAR support. When a “smart” inverter becomes part of a “smart” grid, then overall system performance and reliability can potentially be enhanced.



Solar PV generation may be distributed, i.e. placed closer to loads being served, or, in the case of large utility-scale plants, may be located much in the same way traditional baseload and intermediate generation is located, i.e. based more on the availability and overall suitability of a site to host a large-scale generating facility. Placing solar PV generation close to load provides significant advantages, including enhancing system reliability and resiliency and reducing transmission and distribution system losses.

There is substantial opportunity to realize additional value from solar PV by integrating it into local distribution systems serving mission critical loads such as military bases, health care facilities, and emergency management facilities and shelters. In this way, solar PV forms part of “microgrid” and can help improve reliability and support more rapid restoration of critical loads.

IT IS TIME FOR A CHANGE

There is not only the glaring issue felt by many that Florida, “the Sunshine State”, is lagging in terms of total installed solar generation and the rate of growth in new solar installations in the state, but, also the fact that, aside from lower installed cost, new solar projects planned in Florida today are barely distinguishable from projects deployed five to six years ago.

For example, in April, the PSC approved three large solar projects, totaling 120 MW, to be installed at three military bases in Northwest Florida. While the scale of the projects and the fact that they will be located at an Air Force base and two Navy bases is laudable, in most other respects, there appears to be very little that is unique about these projects. A third party will build, own, and operate the facilities and sell real power to the electric utility under a fairly typical power purchase agreement (PPA). The full potential value of solar PV is not being realized with this type of arrangement, particularly with the solar being sited at mission critical facilities.

As the installed cost of solar PV continues to decline, the greatest remaining disadvantage to solar power is the fact that it is *not* available nearly continuously, around the clock, at rated power, as traditional generation sources *are*. Yet, the solar PV advantages of operating with a free, non-fossil, non-imported “fuel” source, no emissions, and no water requirements, are readily understood by policy makers and the public at large. The appetite and impetus to make greater use of this energy source will be unrelenting. As the 3rd most populous state and the 1st in electric utility generation capacity, Florida can and should begin to lead in the smart adoption and use of solar energy.

Solar energy presents us with an opportunity to improve how we generate and use energy in the state, and to accrue substantial economic benefits by playing a major role in the total supply chain and innovation ecosystem needed to support it, providing also the possibility to benefit from the solar industry growth beyond Florida’s borders[13]. To do so will require partnership and collaboration, a greater alignment of mutual interests amongst industry, government, consumers, research and academia, and thoughtful changes to policy and regulation.

Energy policy in the state should seek to create a level playing field to allow innovation to flourish, while still adequately protecting the consumer in a regulated market. This requires a thoughtful and balanced approach, recognizing that utility culture is rightly risk averse and consequently slow to adopt new approaches, further reinforced by a regulatory environment similarly aligned. Policy, statutes, and rule-making need to provide mechanisms to extract the full value from solar PV and to allow new market entrants along with utilities a fair and equitable playing field to develop and deploy solar energy where it contributes to cleaner, more reliable, and more affordable energy choices.

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[13] Including leveraging Florida’s proximity to the Caribbean, where the economics of solar are even more compelling.