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Integrating solar into Florida's power system: Potential roles for flexibility

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ABSTRACT

Although Florida has very little photovoltaic (PV) generation to date, it is reasonable to expect significant deployment in the 2020s under a variety of future policy and cost scenarios. To understand these potential futures, we model Florida Reliability Coordinating Council operations in 2026 over a wide range of PV penetrations with various combinations of battery storage capacity, demand response, and increased operational flexibility. By calculating the value of PV under a wide range of conditions, we find that at least 5%, and more likely 10–24%, PV penetration is cost competitive in Florida within the next decade with baseline flexibility and all but the most pessimistic of assumptions. For high PV penetrations, we demonstrate Florida's electrical net-load variability (duck curve) challenges, the associated reduction of PV's value to the system, and the ability of flexibility options–in particular energy-shifting resources–to preserve value and increase the economic carrying capacity of PV. A high level of demand response boosts the economic carrying capacity of PV by up to 0.5–2 percentage points, which is comparable to the impact of deploying 1 GW of battery storage. Adding 4 GW of battery storage expands the economic carrying capacity of PV by up to 6 percentage points.

1. Introduction

Much of the detailed analysis of high solar photovoltaic (PV) penetrations has focused on California because of that state's PV market leadership (Margolis et al., 2017). These previous analyses reveal the grid integration challenges associated with PV generation starting quickly in the morning and dropping off quickly in the late afternoon, which on low load days creates a net-load pattern that conventional generators must be dispatched around (Fig. 5). At high PV penetration these net-load lines vaguely resemble a duck and have thus come to be referred to by the shorthand name "duck curves" (CAISO, 2016). When the net-load challenges become severe enough relative to the constraints on conventional generator operations, the result can be a reduction in the value PV provides to the system. On high penetration systems, these issues can occur on enough days of the year to result in significant PV value loss on an annual basis (Denholm et al., 2015; Obi and Bass, 2016). Previous work also shows how increased power-system flexibility could mitigate this loss of value in California (Brinkman et al., 2016; Denholm et al., 2016). Less research, however, has focused on the unique characteristics and lessons associated with high future PV penetrations in other potentially important U.S. PV markets.

Florida is one such important but understudied market. It has high solar potential located close to load centers, ranking eighth in the country for rooftop PV potential (Gagnon et al., 2016) and 16th for utility-scale solar potential (Lopez et al., 2012). Yet its solar deployment lags behind other states with similar or worse resource potential. In 2015, solar generation accounted for just 0.1% of Florida's electricity generation, compared with 2.4% in Vermont, 1.4% in Massachusetts, and 1.1% in North Carolina (EIA, 2016b). Steward and Doris (2014) finds that PV market development is highly correlated with state-level policies. The most developed markets in the U.S. are in states with net-metering and best-practice interconnection policies plus at least one other supporting policy. That supporting policy may authorize or allow third-party ownership, or may be a renewable portfolio standard with a solar set-aside. Florida does have a state-wide net metering policy, however, there is no renewable portfolio standard, and third-party ownership is generally disallowed.[1] Thus Florida could be considered both a prime target and a blank slate–the state's PV deployment could rise rapidly if PV costs continue to decline (NREL, 2016; Lazard, 2016) and state-level policies become more supportive. Solar deployment in Florida also depends in large part on the actions of its vertically integrated utilities. Florida is served by two large investor-owned utilities, a number of smaller municipal and co-op utilities, and several coordinating entities. Because these organizations are all very focused on operational reliability, a better understanding of grid integration issues could facilitate this growth or ease potential challenges associated with increasing PV penetration. In addition, Florida is an

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[1] http://www.dsireusa.org/resources/detailed-summary-maps/.

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Acronyms

AEO	Annual Energy Outlook
ATB	Annual Technology Baseline
CC	combined cycle
CT	combustion turbine
DLC	direct load control
DR	demand response
ECC	economic carrying capacity
EIA	U.S. Energy Information Administration
EMS	energy management system
ERGIS	Eastern Renewable Generation Integration Study
FRCC	Florida Reliability Coordinating Council
LBNL	Lawrence Berkeley National Laboratory
LCOE	levelized cost of electricity
NREL	National Renewable Energy Laboratory
PV	photovoltaic
SERC	SERC Reliability Corporation
VO&M	variable operating and maintenance

interesting analytical case because its main power system–the Florida Reliability Coordinating Council (FRCC)–serves almost the entire state and is largely isolated from other systems. This isolation enables direct analysis of flexibility technologies with relatively few inter-system interactions.

After a brief section on methods (Section 2), we analyze the grid integration challenges associated with high PV deployment in Florida (Section 3.1), and we examine how additional system flexibility from enhanced operational practices, battery storage capacity, and demand response (DR) might help Florida achieve a cost-effective, high-penetration PV future (Section 3.2). Following Denholm et al. (2016), we evaluate the economic carrying capacity (ECC) of PV in the FRCC power system and how it is impacted by flexibility options (Section 3.3). We also examine the impact of flexibility on system emissions (Section 3.4). One novel aspect of our analysis is our method for simulating flexibility from aggregated DR at new levels of fidelity. In this, we extend a growing body of work examining the value of DR in the bulk grid (Hummon et al., 2013; O'Connell et al., 2015), and the ability of DR to provide flexibility in power systems with high variable generation penetrations (Denholm et al., 2016; Brinkman et al., 2016; Denholm and Margolis, 2016). We use an updated dataset to model fifteen different demand end-uses providing DR services in various combinations of energy shifting, contingency reserves, and regulation reserves for two different levels of demand response penetration. Our other contributions include examining high-penetration systems under mid and low natural gas prices, and exploring how future PV costs and social cost of carbon assumptions could impact the potential deployment of PV in Florida. In total we analyze 270 high-fidelity production cost simulations. Our high-level findings are summarized in Section 4. Supplemental Information Section 6 provides additional information on methods; Supplemental Information Section 7 presents additional results.

2. Methods

This study is primarily an exercise in production cost modeling of the FRCC power system. The detailed modeling assumptions required to create a realistic model of FRCC in 2026 under a wide range of PV penetrations are documented in Bloom et al. (2016), Denholm et al. (2016), and the Supplemental Information Section 6. Fig. 1 depicts the elements we borrow alongside our contributions. In the remainder of this section we describe the methods and data we use to compute the value of PV in FRCC and model flexibility options. We conclude with a description of our scenario framework.

2.1. PV value and economic carrying capacity

We determine the economic carrying capacity of PV in the FRCC power system by equating PV's levelized cost of electricity (LCOE) with the value it provides to the system. The total value changes as more PV is added; we calculate and report the value of the next increment of PV to reflect the value added to the system by new investments. The increments are defined using a sequence of pre-curtailment PV-penetration scenarios, from 5% to 45% of annual load, with each scenario differing by about 5 percentage points. We calculate incremental value by comparing a higher-penetration system to the one just below it, holding everything else about the system constant. Three sources of value are measured: operational value, capacity value, and emissions-

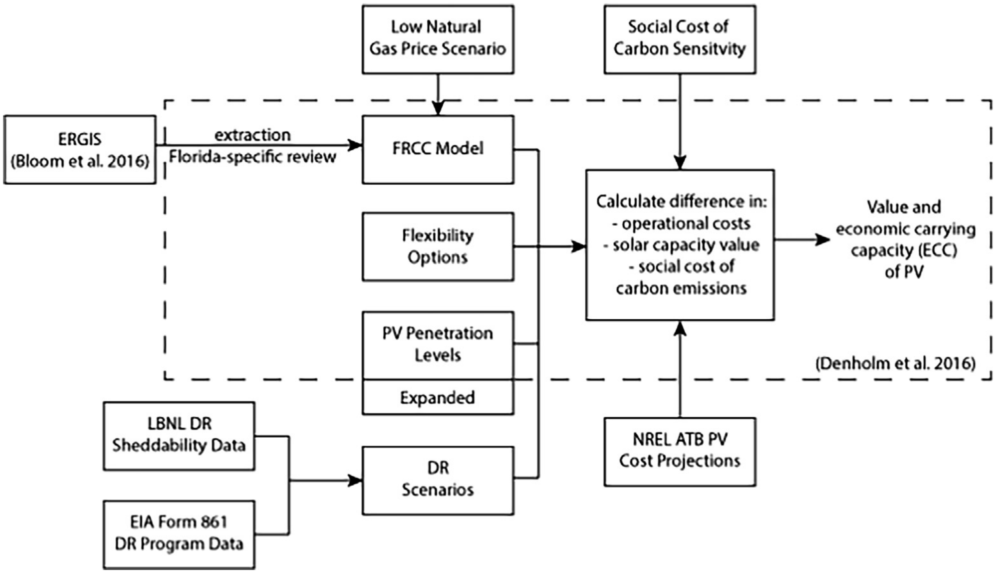

Fig. 1. Schematic of methodology and data flow. The inclusion of all items not labeled with a citation into the methodological framework established by Denholm et al. (2016) is a main contribution of this paper. The sources of these data are described and cited in the text below.