The Electricity Journal 30 (2017) 1–8

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/electr

Grid flexibility: The quiet revolution

Eric Hsieh[a,*], Robert Anderson[b]

[a] Energy Policy and Systems Analysis Office, U.S. Department of Energy, United States
[b] Millennium Challenge Corporation, United States

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Flexibility
Storage
Demand response
Electricity markets
Power systems operations

ABSTRACT

The concept of flexibility describes the capability of the power system to maintain balance between generation and load under uncertainty. While the grid has historically incorporated flexibility-specific resources such as pumped hydro to complement nuclear generators, modern trends and the increased deployment of variable energy resources (VERs) are increasing the need for a transparent market value of flexibility. A review of analyses, docket filings, tariffs, and business practice manuals from the past several years finds substantial flexibility-related activity. These activities are categorized as market and financial structures; incorporation of new operations, and technology; and legal or procedural reforms. The cumulative outcome of these incremental changes will be a major transformation to power systems that can rapidly adapt to new needs, technologies, and conditions.

Published by Elsevier Inc.

1. Introduction

Beneath the headlines touting the future electricity grid, hearing rooms and stakeholder meetings are nurturing a steady transformation towards this future. In a review of analyses, docket filings, tariffs, and business practice manuals from the past several years, the concept of "flexibility" has emerged as a major criterion for power system planning, operations, and markets. Spurred in part by the growth of variable energy resources (VER), these disparate efforts point to the same conclusion: the grid can and should be far more nimble that it has been in the past.

1.1. Background

Flexibility is the capability of the power system to maintain balance between generation and load under uncertainty.[1] Examples of the term flexibility used in industry include "the ability of a system to respond to changes in demand and variable generation" (Bonneville Power Administration, 2014), "A flexible electricity system is one that can respond reliably, and rapidly, to large fluctuations in supply and demand" (International Energy Agency, 2008), and "the ability of a power system to respond to changes in demand and supply" (21st Century Power Partnership, 2014).

Flexibility can be characterized along three dimensions: first, the absolute power output capacity range (MW); second, the speed of power output change, or ramp rate (MW/min); and third, the duration of energy levels (MWh) (Ela et al., 2016). Resources that have a larger range between their minimum and maximum MW output can provide the flexibility to adjust to a wider range of power system conditions (Ela et al., 2016). Resources that can change their output quickly or can be easily turned on or off have a higher ramp rate and are more flexible because they adjust faster to changes in power system conditions. Resources that can deliver energy for longer durations increase flexibility because they can address prolonged disturbances or outages (Ela et al., 2016). Fig. 1 illustrates these three dimensions (Fig. 2).

Historically, flexibility capacity has evolved in conjunction with changes in generation technology. For example, the growth of U.S. pumped-storage hydropower capacity was highly correlated with the development of nuclear power plants (Deane et al., 2010). These flexibility resources provide "essential reliability services that . . . [maintain] power system balance on time scales ranging from sub-seconds to hours," which "complement high inertia nuclear power plants" and allow baseload power plants to provide constant output while demand varies through the day (U.S. Department of Energy, 2016; Deane et al., 2010).

* Corresponding author.
E-mail address: eric.hsieh@hq.doe.gov (E. Hsieh).

[1] The term "net load" is often used in the context of flexibility, but may have varying definitions across regions. For example, CAISO defines net load as "the gross load forecast less the wind and solar output" (California ISO, 2016a). An ISONE net load definition includes "net power delivered to customers . . . less passive DR, active DR, and energy efficiency" (Washington UTC, 2015).

http://dx.doi.org/10.1016/j.tej.2017.01.009
1040-6190/Published by Elsevier Inc.

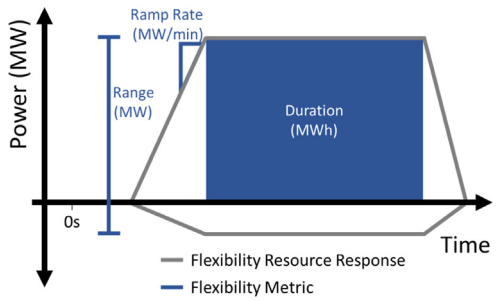

Fig. 1. Illustration of three dimensions for flexibility: range, ramp rate, and duration (Author, 2016).

VERs, as shown in Fig. 3, and the emergence of new technologies, are increasing the need for and the value of flexibility (National Renewable Energy Laboratory, 2015a).

The growing need for flexibility has been documented in recent regulatory filings and planning documents. In New England, an "increase in the amount of Intermittent Power Sources" has congested parts of the transmission system[2] (ISO New England, 2015, p. 4). In California, the California Independent System Operator (CAISO) has found that the committed generation often has insufficient flexibility to match changes to net load (California ISO, 2016a, p. 4). Increased wind generation in the Pacific Northwest has required utilities to carry more reserve resources" (Northwest Power & Conservation Council, 2016, p. 2.4).

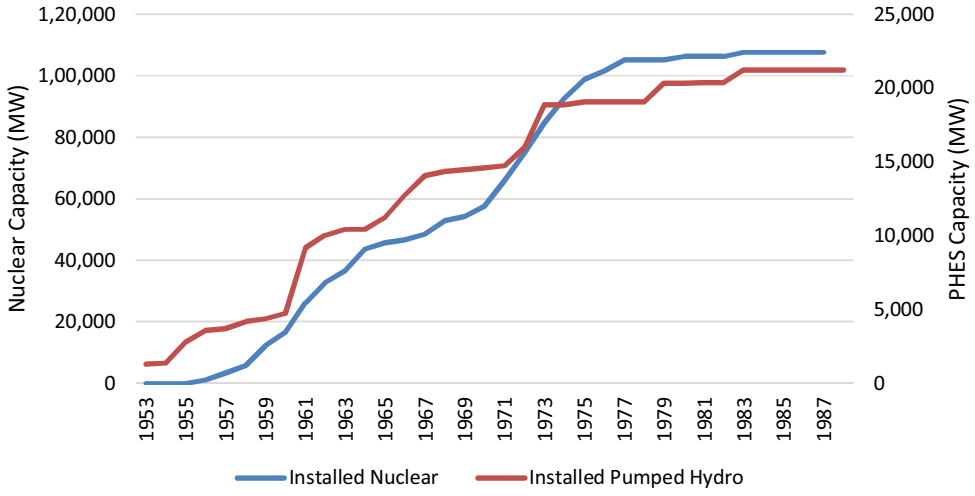

Fig. 2. Growth of pumped-storage hydropower and nuclear in the U.S. were highly correlated (Deane et al., 2010; Form EIA-860 detailed data, 2016).

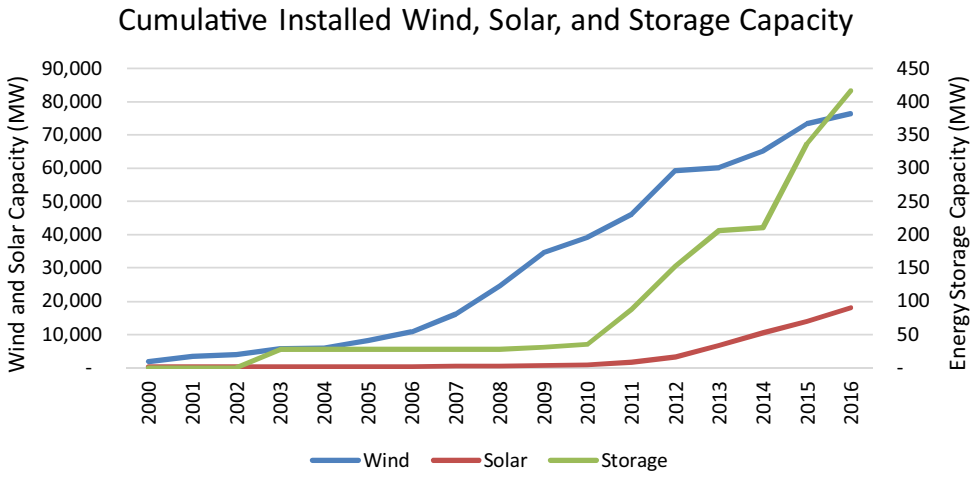

Fig. 3. Wind, solar, and storage installations in the U.S. have accelerated over the past decade (U.S. Energy Information Administration, 2016).

1.2. Gap analysis

As the power system continues to evolve, so too does the need for flexibility. While grid operators have always needed to instantaneously balance supply with demand and respond to disturbances (e.g. the loss of a generator or a transmission line), more recent changes in power systems, including the growth of

[2] ISONE has addressed the need for manual curtailment by implementing a new "Do Not Exceed" procedure, which is discussed later.