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A review of the value of aggregators in electricity systems

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ABSTRACT

Distributed energy resources ("DERs") are being adopted throughout the world. Aggregators are lauded by some as critical in enabling DERs to provide these valuable electricity services at scale; in this light, regulatory and policy bodies are discussing the role of aggregators and even the need to support their market entry. In order to shed light on the economically efficient regulation of aggregators in electricity systems, this paper systematically assesses the economic fundamentals of aggregators. We perform a critical review of the value of aggregators, defining the factors that determine their role in power systems under different technological and regulatory scenarios. We identify three categories of value that aggregators may create: fundamental, transitory, and opportunistic. Fundamental value is intrinsic to aggregation and is independent of the market or regulatory context. Transitory value can be significant in the near term, but may be diminished by technological or regulatory advances. Finally, opportunistic value emerges as a result of regulatory or market design flaws and may endanger the economic efficiency of the power system. This paper provides a template for regulators to encourage the efficient development of aggregators while eliminating the potential for economic inefficiencies through opportunistic aggregation.

1. Introduction

Electricity systems are currently facing significant changes as a result of the deployment of information and communication technologies (ICTs), power electronics, and distributed energy resources (e.g., gas-fired distributed generation, solar PV, small wind farms, electric vehicles, energy storage, and demand response). Distributed energy sources (DERs), unlike "traditional" centralized generating units, are characterized by their small capacities, and their connection to low and medium voltage electricity distribution grids. These technologies have the potential to not only deliver the valuable electricity services that have traditionally been provided by centralized generating units, but also new services enabled by their distributed nature. Many industry stakeholders claim that DER aggregators create economic value by enabling DERs to provide these services at scale [1–4].

Citing the untapped value of aggregators, regulators and policy makers in both Europe and the United States are debating the role of aggregators. In Europe's liberalized retail markets, debate is centered around the functioning of retail markets, the ability of retailers[1] to deliver desired levels of consumer engagement and value-added services, and the value or disvalue of superimposing third party aggregators over these retailers [5–9]. On the other hand, new independent aggregators are highly active in U.S. markets, and stakeholders are attempting to design market rules to ensure these aggregators flourish due to true value creation as opposed to regulatory arbitrage [10,11]. A single question pervades the regulatory and policy debates in the U.S. and Europe: what value do aggregators provide to electricity systems? If aggregators create significant system value, regulators and policy makers may want to take action to encourage aggregator development. On the other hand, if aggregators harm power

Abbreviations: CAISO, California Independent System Operator; DER, Distributed Energy Resource; DSO, Distribution System Operator; ERCOT, Electric Reliability Council of Texas; GW, Gigawatt; ICT, Information and Communication Technologies; ISO, Independent System Operator; ISO-NE, New England Independent System Operator; LMP, Locational Marginal Price; MISO, Midcontinent Independent System Operator; MW, Megawatt; MWh, Megawatt-hour; NYISO, New York Independent System Operator; RTO, Regional Transmission Operator; SO, System Operator; TSO, Transmission System Operator

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[1] Retailers or retail electricity providers (REPs) are aggregators in that they aggregate a number of disperse consumers (and, at some times, producers) and act as a liaison between these agents and wholesale markets. These REPs also comply with power system regulations, perform hedging functions, and other activities on consumers' behalf. Some REPs, such as MP2 Energy in the U.S., are performing roles traditionally attributed to third party aggregators such as brokering demand response for capacity and ancillary services market participation [68].

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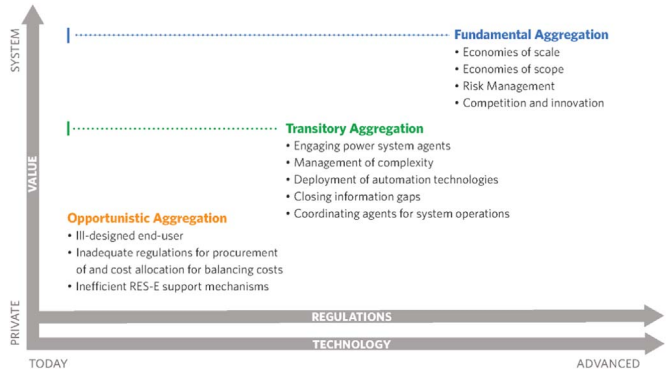

Fig. 1-1. Value of aggregators based on technology and regulatory contexts.

system efficiency, regulators and policy makers may want to take actions to ensure aggregators only develop where they can create value. This review, for the first time, explores the value of aggregators in a systematic fashion, in order to shed light on current debates.

Clarifying the value that aggregators create in power systems has implications for many related questions, such as: should the power system accommodate many aggregators or only one centralized aggregator? Who can or should be an aggregator (transmission and distribution system operators, retailers, third parties, etc.)? What market design elements may need to be adapted or adopted to accommodate DERs?

This paper has several key contributions. First, we establish an economically grounded "rational template" with which to analyze the role of aggregators in power systems. Based on our review, we find that, with "perfect" information, economically rational agents,[2] and "perfect" regulations, aggregators will only create value by capitalizing on economies of scale and scope and by managing risks (we term these "fundamental values"). We find that maximizing the benefits of these sources of value could lead to a single, centralized aggregator, which might harm other power system objectives such as competition, agent engagement, and innovation; thus, we find that the role of aggregators should be determined by analyzing the tradeoffs between fundamental values and the value of competition. In addition, recognizing that power systems today do not exhibit perfect information, regulations, and rational agents, we identify "transitory" values of aggregation that may exist as power system technologies and regulations advance; aggregators will create transitory value by engaging agents in electricity markets, closing information gaps, and coordinating distributed resource operations. Finally, we identify a number of regulations and market designs that create "opportunistic" aggregations; these opportunistic aggregations harm power system economic efficiency. Thus, we recommend that the regulations that enable opportunistic value be removed or improved.

1.1. Defining aggregators

Aggregation is defined here as the act of grouping distinct agents in a power system (i.e. consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to the system operator(s). This paper adopts the definition of an aggregator promulgated by Ikäheimo, Evens, and Kärkkäinen [12][3]; in the context of this paper, *"an aggregator is a company who acts as an intermediary between electricity end-users and DER owners and the power system participants who wish to serve these end-users or exploit the services provided by these DERs"*. We recognize the existence of other definitions of aggregators; in practice, the definition of an aggregator can be restricted or expanded depending on regulations that define the roles and activities that aggregators can perform.

1.2. The present and future value of aggregation

One may hypothesize that, at some point in the future, the present limitations of the power sector (i.e. incomplete information, imperfect coordination of responses of all agents to economic signals, and economically irrational response to prices) may disappear due to advanced regulation and technological innovation, among other reasons. This document addresses the question of whether aggregators can provide value to the power system as a whole, or whether they provide value to a small set of agents while harming others. Furthermore, this document identifies whether the value (or disvalue) that aggregators create will exist temporarily or on a more permanent basis.

To answer the question of for whom aggregation creates value, this paper discusses two types of economic value: system and private. Aggregation has system value if it increases the economic efficiency of the power system as a whole. Private value is an increase in the economic wellbeing of a single agent or subset of agents. Private value creation may or may not align with system value creation; as we will demonstrate, aggregations with private value may create economic value for certain agents at the expense of system-wide economic efficiency. Aggregation may also simply lead to a rent transfer between market actors.

We can distinguish three broad categories of aggregation (see Fig. 1-1). First, aggregations with *"fundamental"* or "intrinsic" value do not depend on the specific regulations, level of market awareness of consumers, or technologies in place in the power system, and will be permanent or near permanent in time. Aggregations with *"transitory"* value contribute to the better functioning of the power system under the present and near-future conditions; however, the value of transitory aggregations may wane as technical, managerial or regulatory conditions improve. Finally, aggregations with only *"opportunistic"* value emerge in response to regulatory or market design "flaws." Due to inherent tradeoffs in regulatory principles, there is no single ideal regulatory system. Regulations on system design and operations are inherently plagued by imperfect or asymmetric information, technology constraints, political interferences and conflictive regulatory principles, etc.; this reality opens the door to different levels of arbitrage. As indicated in the figure, aggregations creating transitory value may exist both now (under current regulatory and technology contexts) and in the future (under advanced but "imperfect" regulations and advanced technologies).

The following sections attempt to identify the ways in which aggregation can create fundamental, transitory, or opportunistic value. Where aggregation creates fundamental or transitory value, regulators or policy makers may want to take steps to remove barriers to its realization or to encourage it outright. However, where aggregation only creates private opportunistic value, regulations should be modified, unless this fact is explicitly acknowledged and desired as a form of subsidy.

2. The fundamental value of aggregation

Fundamental value stems from factors inherent to the act of aggregation itself. While regulation and policy may influence whether or not this value is captured and by whom, the value itself is regulation, policy, and agent-independent. In the context of the power system, aggregation may create fundamental value through capitalizing on economies of scale and scope and by managing uncertainty. However, these fundamental value streams must be weighed against transitory value streams that may emerge from the presence of competing aggregators. Competition may incentivize aggregators to provide

[2] In this paper we refer to agents as opposed to consumers, producers, or the oft-referred to "prosumers." The term agent refers to all three of these possibilities. Agents can own and operate DERs and therefore they can become active parties in the power system.

[3] Ikäheimo et al. define an aggregator as "a company who acts as intermediator between electricity end-users, who provide distributed energy resources, and those power system participants who wish to exploit these services" [12]