Demand side management in power grid enterprise control: A comparison of industrial & social welfare approaches

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HIGHLIGHTS

• We model, simulate and compare two demand side management market designs.
• We holistically address unit commitment, economic dispatch, and regulation service.
• We show the industrial baseline errors result in higher energy consumption and costs.
• We show quantitatively higher industrial baseline errors require higher regulating reserves.

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ABSTRACT

Despite the recognized importance of demand side management (DSM) for mitigating the impact of variable energy resources and reducing the system costs, the academic and industrial literature have taken divergent approaches to DSM implementation. The prequel to this paper has demonstrated that the netload baseline inflation – a feature particular to the industrial DSM unit commitment formulation – leads to higher and costlier day-ahead scheduling compared to the academic social welfare method. This paper now expands this analysis from a single optimization problem to the full power grid enterprise control with its multiple control layers at their associated time scales. These include unit commitment, economic dispatch and regulation services. It compares the two DSM formulations and quantifies the technical and economic impacts of industrial baseline errors in the day-ahead and real-time markets. The paper concludes that the presence of baseline errors – present only in the industrial model – leads to a cascade of additional system imbalances and costs as compared to the social welfare model. A baseline error introduced in the unit commitment problem will increase costs not just in the day-ahead market, but will also introduce a greater netload error residual in the real-time market causing additional cost and imbalances. These imbalances if left unmitigated degrade system reliability or otherwise require costly regulating reserves to achieve the same performance. An additional baseline error introduced in the economic dispatch further compounds this cascading effect with additional costs in the real-time market, amplified downstream imbalances, and further regulation capacity for its mitigation.

1. Introduction

1.1. Motivation

The prequel [1] to this paper explains that the industrial and academic literature are taking divergent approaches to DSM implementation. DSM with its ability to allow customers to adjust electricity consumption in response to market signals provides additional dispatchable resources to mitigate the variable effects of renewable energy [2,3], enhance electrical grid reliability and reduce system costs through load shaping and emergency response [4–9]. Research on DSM has studied the promotion effect of demand response on distributed generation [10], characterized the load shaping behavior of responsive demands in commercial, residential, and water sectors [11–14], and developed algorithms [15,16] to achieve several optimization goals including minimizing customer discomfort and energy consumption [17,18]. Recent studies have also addressed the effect of DSM energy & reserve...
The industrial trend, best exemplified by FERC order 745 [36–38], compare these DSM market designs on an even footing despite industrial DSM models respectively. 

...dispatchable demand reduction... are treated as "virtual generators". For the sake of brevity, DSM program [39,40]. In this way, dispatchable demand reduction is estimated from historical data after enrollment in the industrial DSM program. It is the sum of curve estimation of customers participating in the industrial DSM program. Subtracting the stochastic generation (e.g. wind & solar PV generation) from curve a gives curve b; representing the stochastic net load in the SW model. Note that this net forecasted time series is composed of two terms, does not include a baseline, and sets the aggregate values to which the controllable generation and demand must dispatch. In Fig. 1(b), curve c represents the stochastic net load in the industrial model. It is the sum of curve a and the baseline estimation of customers participating in the industrial DSM program. Subtracting stochastic generation from curve c results in curve d; representing the stochastic net load in the industrial model. Note that this net forecasted time series is composed of three terms, one of which includes the industrial DSM baseline, and sets the aggregate values to which the controllable generation and "virtual" generation must dispatch. In other words, the industrial stochastic net load curve d is obtained by adding the industrial DSM baseline to the SW net load curve b. In the (likely) event [41,42] that the industrial DSM baseline is erroneously inflated, an error term is...
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