Do We Need to Implement Multi-Interval Real-Time Markets?

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With increasing penetration of intermittent generation in wholesale electric power markets, there is growing concern that, due to large swings in the supply/demand balance, ramp rate constraints on generation resources may bind from time to time. When ramp rate constraints are anticipated to bind in future dispatch intervals it may be efficient, or even essential, to 'pre-position' some resources in advance, so as to reduce the cost of dispatch during the period when ramp rate constraints are binding.

But how to achieve such pre-positioning? Several wholesale power markets have extended the real-time dispatch process to optimize over several dispatch intervals at once, into the near future. This is known as 'look-ahead dispatch' or a 'multi-interval real-time market'. The idea is to anticipate future binding ramp rate constraints and allow those constraints to be correctly and efficiently incorporated into current and forecast prices and dispatch.

But there is a problem. Several papers have pointed out that the resulting prices may be *time inconsistent*: This can be explained as follows: At the outset, the look-ahead dispatch process forecasts a sequence of efficient prices and dispatch. Faced with these prices, it can be shown that the generation resources in the market have an incentive to voluntarily comply with the dispatch instructions, including any prepositioning where it is efficient to do so. But each dispatch interval, only the first price in the sequence (known as the spot price) is used for settlement purposes. The next dispatch interval the look-ahead dispatch process is run again. Importantly, even in the case of perfect foresight (where the subsequent supply and demand conditions are exactly as originally forecast) the resulting sequence of spot prices may not be the same as the prices forecast at the outset. Faced with this out-turn sequence of prices, a generating resource may not have an incentive to comply with the dispatch instructions which were determined to be efficient at the outset. Even if pre-positioning is efficient the generating resource may have no incentive to do so.

To address this problem a couple of papers have proposed extensions or augmentations to the dispatch process to ensure the time-consistency of the resulting prices and dispatch. But the proposed extensions only work in the special case of perfect foresight. The proposed solutions effectively tie the dispatch and pricing outcomes to outcomes that were forecast at an earlier time, potentially for quite different forecast demand, supply or network conditions. In the real world, new information on supply, demand, and network conditions arrives all the time. The power system should be able to adjust efficiently to this new information as it comes along.

This paper sheds new light on the look-ahead dispatch task and the time-inconsistency problem. We point out that the time-inconsistency problem is not inherent in look-ahead dispatch, but only arises in a context where both the cost function of generators and the utility function of loads is linear. In this case there can arise an ambiguity in the definition of the wholesale price (i.e., the marginal value of the energy balance constraint) in each dispatch interval. Bellman's Principle shows that dispatch and prices which are optimal at an earlier time remain optimal (under perfect foresight) at a later time. But it turns out that the size of the set of efficient prices may increase over time. As a consequence the dispatch process may not happen to choose a price at a later time which is within the forecast set of optimal prices for that interval at an earlier time. We consider the case of

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linear cost and utility functions to be a special case. If either the supply curve of each generator or the demand curve of each load is continuous and upward sloping, this problem of time inconsistency does not arise.

Second, we highlight the problem of efficient response to new information. The standard formulation of look-ahead dispatch and the extensions to solve the time-inconsistency problem discussed above, assume only a single state of the world in each dispatch interval in future. In other words, these formulations assume that no new information about demand, supply, or network conditions arrives over time. This is not realistic. In all real world power systems demand, supply, and network conditions change all the time. How can such new information be accommodated?

New information can be efficiently handled in a one-off or ex ante dispatch if the dispatch itself is made contingent on that new information as it arrives in the future. This is known as state-contingent dispatch. In theory, the extensions discussed above to resolve the time-inconsistency problem (and the look-ahead dispatch itself) could be made contingent on new information as it arrives over time by applying them in a framework of state-contingent dispatch. In practice, the very large number of potential contingencies in a real-world power system makes this a practical impossibility.

But how then are we to achieve dispatch in the face of binding future ramp rate constraints? Fortunately it turns out that we do not need to implement look-ahead dispatch or multi-interval real-time markets to achieve efficient dispatch in the face of binding ramp rate constraints. We show that provided certain conditions hold, the one-shot dispatch is sufficient to achieve overall efficient dispatch outcomes. The reason is straightforward: Intertemporal constraints are private constraints for each generation resource individually. Provided that each resource forecasts the correct (state contingent) prices, each resource individually has an incentive to make the efficient dispatch and pre-positioning decisions. Neither look ahead dispatch nor other, more significant interventions (such as ex ante procurement of ramping capability or extended operating reserve) are necessary to achieve efficient outcomes.

In summary, look-ahead dispatch at best plays a role in improving forecasts of near-term prices. However, this role could be improved and made more valuable for market participants by making those price forecasts contingent on credible contingencies that may occur in the near future. Multi-interval real-time markets are not an essential feature of an efficient wholesale power market.