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Swing Contracts for Flexible Reserve Provision in Wholesale Power Markets  

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Abstract  The need for dependable flexible reserve provision in electric power systems has dramatically increased in recent years. Growing reliance on variable energy resources and greater encouragement of demand-side participation have led to greater volatility and uncertainty in net load, i.e., power usage net of non-dispatchable generation. Consequently, market operators are finding it harder to secure reserve with sufficient flexibility to permit the continual balancing of net load, a basic requirement for power system reliability. This study reconsiders the design of wholesale power markets in light of these concerns. Four design principles are stressed: (i) Wholesale power markets must necessarily be forward markets due to the speed of real-time operations; (ii) Only one type of product can effectively be offered in a wholesale power market: namely, reserve, an insurance product offering availability of net load balancing services during future real-time operations; (iii) Net load balancing services offered into wholesale power markets primarily take the form of power paths that can be dispatched at specific grid locations over time; (iv) All dispatchable resources should be able to compete for the provision of power paths without regard for irrelevant underlying technological differences. If these four principles are accepted, current trade and settlement arrangements for wholesale power markets need to be fundamentally altered. This study proposes a new swing-contract market design, consistent with principles (i)-(iv), that could meet the needs of wholesale power markets better than currently implemented designs.

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Chapter 1

Introduction

Variable energy resources are renewable energy resources whose power cannot be fully dispatched in a controlled manner to match changes in power usage or to meet other system requirements. Examples include solar panels and wind turbines that are not fully firmed by storage. The increased participation of variable energy resources within wholesale power markets, together with the increased encouragement of active demand-side participation, increases the volatility of net load, i.e., power usage net of non-dispatchable generation.

In consequence, as discussed more fully in Chapter 2, U.S. ISO/RTO-managed wholesale power markets are finding it harder to secure dependable reserve with sufficient flexibility to permit the continual balancing of net load, a basic requirement for power system reliability. Trade and settlement arrangements in these markets are still largely based on rigid reserve definitions, eligibility requirements, and settlement processes that make it difficult to ensure adequate provision and appropriate compensation of needed reserve from multiple types of resources. Emphasis is placed on the designation and compensation of artificially-separated product concepts such as capacity, energy, and ramp-rate whereas value in power markets in fact principally arises from the dispatchable availability and delivery of power paths at specific grid locations during designated operating periods.

This study reconsiders the design of ISO/RTO-managed wholesale power markets in light of these concerns. Four market design principles are stressed:

[MD1:] All wholesale power markets must necessarily be forward markets due to the speed of real-time operations.

[MD2:] Only one type of product can effectively be offered in a wholesale power market: namely, reserve, an insurance product offering availability of net load balancing services in future real-time operations.

[MD3:] Net load balancing services offered into wholesale power markets generally take the form of power paths that can be dispatched at specific grid locations over time.

[MD4:] All dispatchable resources should be able to compete for the provision of power paths without regard for irrelevant underlying technological differences.

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1 The U.S. Federal Energy Regulatory Commission [40] defines an ISO/RTO-managed wholesale power market to be the collection of all capacity, energy, and/or ancillary service markets operated by an Independent System Operator (ISO) or a Regional Transmission Organization (RTO). The key difference between an ISO and an RTO is that RTOs have larger regional scope.

2 A forward market is a market involving the purchase and sale of a product for which the payment method for the product is contractually determined in advance of its delivery date. In contrast, in a spot market the payment and delivery of a product are determined at the same time. See Chapter 11 for additional discussion of these and other standard market concepts.

3 As discussed in [28, 41], primary frequency response is synchronized reserve capacity that autonomously responds to changes in system frequency; consequently, it is not dispatched. The provision and compensation of primary frequency response is not considered in the current study.
A swing-contract market design is proposed that is in accordance with principles MD1-MD4. This design envisions an ISO-managed wholesale power market $M(T)$ organized as a reserve market for some designated future operating period $T$. Reserve consists of dispatchable power paths for period $T$. As illustrated in Fig. 1.1, a power path for period $T$ refers to power injected and/or withdrawn at a single designated grid location during period $T$. Dispatchable resources offer reserve (dispatchable power paths) into $M(T)$ by means of “swing contracts.”

More precisely, as carefully explained in Chapter 3, a swing contract $SC_m$ issued by a dispatchable resource $m$ is a reserve contract that $m$ can offer into a swing-contract market $M(T)$ in either firm or option form. $SC_m$ consists of four components, each specified by $m$: (i) an offer price $\alpha_m$; (ii) an exercise set $T_{ex}^m$; (iii) a physically characterized set $PP_m$ of power paths for period $T$, each of which $m$ could feasibly deliver at a designated grid location during $T$ in response to dispatch signals; and (iv) a performance payment method $\phi_m$.

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4 Since a power path refers to the injection or withdrawal of power at a single grid location over time, transmission is not a consideration. As illustrated in Fig. 1.1, power paths can be depicted in a time-power plane.

5 As explained more fully in Chapter 3, a firm contract is a non-contingent contract that imposes obligations on both the issuer and the holder. An option contract is a contingent contract that gives the holder the right, but not the obligation, to exercise the contract at one or more contractually specified exercise times. The exercise of an option contract converts it into a firm contract.
If SC\(_m\) is cleared, the offer price \(\alpha_m\) is paid to \(m\) either directly or in amortized (payment schedule) form. The offer price thus permits \(m\) to cover ex ante any cost that \(m\) would have to incur to ensure the availability of the power paths in \(PP_m\). This availability cost could include capital investment cost, start-up cost, shut-down cost, no-load cost, and lost opportunity cost. The exercise set \(T_{ex}^m\) consists of designated times between the close of M(T) and the start of T at which the ISO can exercise SC\(_m\), assuming SC\(_m\) has been cleared. The number and positioning of these exercise times determines whether SC\(_m\) is a firm contract or an option contract in European, American, or Bermudan option form.

The dispatchable power paths in \(PP_m\) are characterized in terms of attributes such as delivery location, start-time, minimum down/up time, active and reactive power limits, ramp-rate limits, duration limits, and energy capacity. The precise specification of these attributes determines the degree of swing (flexibility) in \(m\)'s offered reserve. Finally, the performance payment method \(\phi_m\) permits resource \(m\) to recover ex post any cost that \(m\) incurs for verified period-T service performance, i.e., for the verified period-T delivery of a power path in \(PP_m\) in response to dispatch signals. This performance cost could include fuel cost, labor cost, and machinery wear and tear caused by fast ramping.

Reserve offers submitted into M(T) take the form of portfolios of swing contracts offered by dispatchable resources for operating period T. These dispatchable resources can include generators, demand-response resources, and various forms of prosumers and storage facilities. Reserve offers in firm form effectively constitute regulation reserve whereas reserve offers in option form effectively constitute contingency or planning reserve.

These reserve offers encompass, as special cases, standard forms of supply offers submitted into current U.S. ISO/RTO-managed wholesale power markets. Examples include: must-run energy blocks; hourly step-function power supply schedules with a separate price ($/MWh) designated for each power-step; and power self-scheduled by power traders to secure needed transmission for the power outcomes of privately negotiated physically-covered bilateral contracts.

However, as demonstrated in Chapter 4, the general formulation of a swing contract can accommodate reserve offers with a much broader range of offered attributes than envisioned in these standard types of supply offers. Moreover, the issuer \(m\) of a swing contract SC\(_m\) can use the performance payment method \(\phi_m\) included in SC\(_m\) to specify \(m\)'s required compensation ex post for dynamic aspects of a delivered power path, such as ramping, duration, and reactive power support, as well as static aspects such as total delivered energy.

Reserve bids submitted into a swing-contract market M(T) take the form of price-sensitive and/or fixed (non-price-sensitive) demands for power-path delivery during operating period T. Reserve bids can be submitted by load-serving entities to service the forecasted loads of their end-use customers during T, and by power traders who need to self-schedule the power outcomes of privately negotiated physically-covered bilateral contracts in order to secure needed transmission.

As detailed in Chapters 5-8, an ISO managing a swing-contract market M(T) solves a contract-clearing optimization problem to determine which reserve offers
and price-sensitive reserve bids to clear for operating period $T$. The goal of the ISO is to maximize the expected total net benefit of the market participants, subject to system constraints that include power-balance constraints and transmission line limits. Total net benefit consists of total benefit net of avoidable cost. The system constraints incorporate, as exogenous inputs: (i) all fixed reserve bids; (ii) all forecasts for non-dispatchable generation; (iii) all of the power-path attributes included by dispatchable resources in their reserve offers; and (iv) zonal and system-wide reserve requirements set by the ISO to ensure coverage of net load uncertainty sets as a robust means of protection against possible net load forecast errors.

The ISO functions as a clearing house for $M(T)$, collecting payments and overseeing payouts to market participants. However, the ISO does not have any financial stake in market operations. To maintain this independent status, all net reserve cost and transmission service cost (including line losses) incurred through market operations are passed through to market participants. Net reserve cost is allocated across market participants on the basis of their net fixed power usage. Transmission service cost is allocated across market participants on the basis of the power imbalance at their bus locations.

More generally, Chapter 9 proposes a linked collection of swing-contract markets whose look-ahead planning horizons for designated future operating periods can range in duration from multiple years to minutes. The linkage among these markets is to be achieved by having the swing contracts cleared in earlier markets be carried forward on the books of the ISO as a portfolio of contracts that can be adaptively adjusted in subsequent markets. This linkage facilitates reserve procurement by permitting a successively refined understanding of resource capabilities and net loads for future operating periods.

The key features of this linked swing-contract market design in comparison with current market designs, elaborated in Chapters 9-14, are summarized below:

- permits the robust-control management of uncertain net load
- handles uncertain net load by ensuring dependable flexible reserve supply
- eliminates the need for detailed net load scenario specifications
- facilitates a level playing field for resource participation
- recognizes the forward nature of wholesale power markets
- recognizes all offered product in these forward markets is a form of reserve
- identifies reserve as dispatchable power paths available for future operations
- requires resources to internally manage commitment and capacity constraints
- permits co-optimization across a wide spectrum of reserve attributes
- compensates reserve availability ex ante and reserve deployment ex post

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6. *Net reserve cost* is reserve procurement cost net of any price payments for cleared price-sensitive reserve bids and net of any penalty payments for real-time deviations from dispatch signals.

7. The *net fixed power usage* of a market participant at a particular grid location is the amount of its fixed power usage (if any) at that location minus the amount of its non-dispatched power generation (if any) at that location.

8. *Power imbalance* is said to occur at a particular bus in a transmission grid if there is a non-zero net power injection at this bus that requires the transmission of power to or from other buses in order to ensure power balance across the transmission grid as a whole.
• permits resource owners to cover ex ante their full costs of availability
• permits resource owners to recover ex post their full real-time performance costs
• eliminates the need for out-of-market payment adjustments
• provides system operators with real-time flexibility for net load balancing
• encourages close following of dispatch signals through performance incentives
• reduces the complexity of market rules

Finally, Chapters 15-16 consider how current U.S. ISO/RTO-managed wholesale power markets could gradually transition to a linked swing-contract market design. Special attention is focused on the possibility that Independent Distribution System Operators (IDSOs), functioning in distribution systems as grid-edge resource aggregators,\(^9\) could use swing contracts to facilitate their participation in transmission systems as prosumers able to offer ancillary services (dispatchable down/up power paths) into wholesale power markets in useful flexible forms; see Fig. 1.2. This IDSO participation would permit a more direct representation of retail customer interests at the wholesale power market table.

![Fig. 1.2 GER aggregators as linking entities for integrated transmission and distribution systems.](image)

As shown in Chapter 15, a swing contract offered by a dispatchable resource into an otherwise standard U.S. ISO/RTO-managed wholesale power market can in principle be incorporated as follows. First, the swing-contract’s offer price and performance payment method can be incorporated into the objective function of the SCUC/SCED optimization used by the ISO/RTO to solve for unit commitments,

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\(^9\) In this study a grid-edge resource (GER) is defined to be any power resource with a direct point of connection to a distribution grid. A GER aggregator is any entity that manages power usage, power supply, and/or ancillary service provision for a collection of GERs.
reserve, and scheduled power dispatch levels. Second, the power-path attributes designated by this swing contract can be incorporated into the system constraints for this SCUC/SCED optimization.

However, in order for this incorporation to result in accurate merit-order dispatch, the objective function for the SCUC/SCED optimization would have to fully account for the remuneration paid to (or received from) all market participants. At present this is not the case. In consequence, swing contracts could be unfairly penalized because they fully specify, up front, all compensation required ex ante for reserve availability and all compensation required ex post for any actual reserve deployment. To address this issue, an extended SCUC/SCED optimization formulation has been developed that permits remuneration for market participants to be more fully incorporated into the SCUC/SCED objective function.

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10 SCUC is an acronym for Security-Constrained Unit Commitment, and SCED is an acronym for Security-Constrained Economic Dispatch.
References


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