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MinISO: A Minimal Independent System Operator*

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Abstract

The Independent System Operator or ISO is the lead actor in the various proposals for a deregulated, competitive electric power industry. The ISO has three possible objectives: security maintenance, service quality assurance, and promotion of economic efficiency and equity. To achieve these objectives the ISO may be authorized to set the rules for transactions between suppliers and consumers, scheduling and dispatch of generators, loads and network services, and energy markets. Proposals differ in their specification of the ISO's objectives and authority. Two ISO structures are contrasted. MaxISO, based on the UK-Poolco model, has ambitious objectives and much regulatory authority. Its scientific merit derives from an Optimal Power Flow dispatch model. MinISO's objective is restricted to security, and its regulatory authority is correspondingly modest. MinISO seeks to provide direct consumer access. Its scientific merit is based on the Coordinated Multilateral Trades model.

By locating in the ISO both the transmission-security function and the generation-economic efficiency function, MaxISO ends up being a hindrance to structural reform. By separating those functions, MinISO maximizes consumer choice and technical and financial innovation. The California PUC decision of December 1995 is, understandably, a compromise between the two proposals. The unexpectedly rapid response nationwide of utility and non-utility entities to the potential opportunities of a deregulated industry, however, threatens to make irrelevant the MaxISO model and to shorten the life of California's compromise decision. MinISO remains an option that is flexible enough to accommodate the choices that consumers and producers may want.

1. Introduction

In its original 1994 proposal—the so-called Blue Book—the California Public Utility Commission (CPUC) announced its intention to further long-term efficiency gains, cost savings and economic growth through a broad range of structural reform of the electric utility industry. To achieve these objectives, the proposal was organized around consumer choice and retail competition.

The year-long debate that followed obscured those objectives. The focus of the debate was set by the utilities. That focus was on a particular form of market structure that emphasized standardization of commodities and the determination of their prices, and regulation of the conditions under which producers and consumers would make their generation, transmission and consumption decisions in a way that would guarantee conformity with the proposed commodity and price standards. Despite a lack of consensus among themselves, the utilities put forward a proposal based on this UK-Poolco model.

Countering this proposal was one based on "bilateral transactions" in which producers and consumers (individually or through aggregators) entered into direct negotiations, with minimal regulatory intervention. The alternative proposal was not as well articulated as the UK-Poolco proposal, its advocates did not have the concentrated resources that the utilities had to push it aggressively, and it received relatively little attention.

The UK-Poolco proposal effectively precluded direct transactions that would rapidly bring to consumers a reduction in price and the flexibility to make innovative arrangements. An impasse developed between the proponents of the UK-Poolco proposal and key stakeholders who saw that the proposal would delay the benefits from direct transactions. The impasse was broken by a compromise brokered by California Governor Wilson. The compromise eventually led to the CPUC decision of December 1995.[1]

The debate around market structure took the form of proposals for the Independent Systems Operator or ISO. This paper contrasts two models of ISO. The first

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[1] The dissension among the utilities in their 1996 filing to FERC indicates that not all of them have accepted the compromise.

model, called MaxISO, is based on the UK-Poolco proposal. The second model, called MinISO, is based on the "coordinated multilateral trades" model [1]—a formalization of the alternative proposal calling for direct transactions between producers and consumers.

The ISO has three possible objectives: security maintenance, service quality assurance and promotion of economic efficiency and equity. To achieve these objectives the ISO may be authorized to set the rules for transactions between suppliers and consumers, scheduling and dispatch of generators, loads and network services,[2], and energy markets.

The two models differ in their specification of the ISO's objectives and authority. MaxISO has ambitious objectives and much authority, including that of making the market for electric power. Its scientific merit derives from an optimal power flow dispatch model, whose Lagrange variables are interpreted as "spot" prices [2]. MinISO's objective is restricted to security, and its authority is correspondingly modest. In particular it has no market role. MinISO seeks to provide direct consumer access. Its scientific merit is based on the the analysis of the coordinated multilateral trades model.

Section 2 presents MaxISO and discusses some of its limitations. Section 3 presents MinISO and some of its advantages. Section 4 provides a comparison of the two ISO structures. It points out how the December 1995 CPUC decision tries to achieve a compromise between the two. In the concluding section some recent developments in the electric power industry are noted to suggest that the UK-Poolco proposal has been overtaken by events, and the CPUC compromise itself may have a short life.

2. MaxISO

We first discuss MaxISO's operation, and then the limitations of the commodity specification and price signals.

Operating rules

MaxISO's rules of operation have three phases.

Twenty-four hours ahead: MaxISO

- Receives supply *curve* $S_t^g(p_t)$ from each generator g and demand *curve* $D_t^l(p_t)$ from each load l for energy for each hour $t = 1, ..., 24$;
- Determines a feasible schedule $\{S_t^g, D_t^l\}$ that maximizes welfare.[3] Generators and loads commit to the schedule;
- Estimates location (or nodal) marginal costs and congestion transmission prices.

In real time: MaxISO

- Dispatches generation, load and network services based on the solution to an optimal power flow dispatch. Deviations from schedule are penalized.

After real time: MaxISO

- Calculates settlements, locational or nodal prices of energy, and transmission congestion surcharge. Settlements include marginal fuel cost, capacity cost, startup cost, congestion transmission charges, fixed transmission charges, network services charges.

Thus MaxISO requires (short-run) cost data from every generator, and daily demand from every consumer or load, obtains (by means of some algorithm) the unit commitment and dispatch that maximizes social welfare, and sets transmission congestion prices (as the Lagrange or dual variables corresponding to the transmission capacity constraint in the optimal power flow program), see [3]. These are sometimes called day-ahead *spot prices*. After the dispatch is over, MaxISO calculates settlement charges.

This form of ISO has two disadvantages, one concerned with the definition of the commodity as standardized by MaxISO, the second concerned with the adequacy of the spot price signal.

MaxISO defines a *standard commodity* as one unit of energy generated and consumed in one hour, specified one day ahead. (The transfer of commodity requires network services.) The examples below show that transactions with contingent or inter-temporal dependencies cannot be constructed using standard commodities.

Example 1 Suppose a consumer's demand is uncertain one day ahead but known, say, two hours ahead, and suppose there is a generator that is willing to meet this demand. The consumer's demand cannot be expressed in terms of the standard commodity, which requires the consumer to state his demand 24 hours in advance. But if a direct transaction between the consumer and generator were permitted, the consumer's demand would be met.

[2] Jeff Dasovich first substituted "network" services in place of the more traditional "ancillary" services. We, too, find "network services" a more descriptive term.

[3] How this welfare maximizing schedule is achieved by MaxISO has not been specified by proponents of MaxISO. Presumably, MasISO solves an optimal unit commitment problem. See below.

Example 2 Suppose a consumer has a demand for energy over a 24-hour period, but doesn't care when that demand is met. Suppose there is a generator that can use this consumer's flexibility to meet this demand at a lower price. This direct transaction between consumer and generator cannot be expressed as a transaction involving only the standard commodity.[4]

Example 3 Consumer 1 has a highly variable power demand over one hour compared with consumer 2, but both have the same energy demand. Thus they have the same demand as measured by the standard commodity, even though consumer 1 requires a larger peak generation capacity.

Example 4 Suppose a generator's average cost is lower if the plant is operated for six hours (say) than for one hour. So this generator would prefer to sell six-hour load-duration slices of energy rather than the one-hour slices required by the standard commodity.

Limitations of the price signal

According to MaxISO's rules

$$p(t) = p^{\text{scheduled}}(t) + p^{\text{uplift}}(t),$$

where

$$\begin{aligned}
p(t) &= \text{settlement price, calculated ex post} \\
p^{\text{uplift}}(t) &= p^{\text{cap}}(t) + p^{\text{adj}}(t) + p^{\text{cong}}(t) \\
&\quad + p^{\text{trans}}(t) + p^{\text{net}}(t) + \ldots \\
p^{\text{cap}}(t) &= \text{capacity charge} \\
p^{\text{adj}}(t) &= \text{adjustment for startup,} \\
&\quad \text{non-dispatched plant, balancing costs} \\
p^{\text{cong}}(t) &= \text{transmission congestion charge} \\
p^{\text{trans}}(t) &= \text{transmission fixed charge} \\
p^{\text{net}}(t) &= \text{network services charge.}
\end{aligned}$$

The information required by MaxISO is enormous—it includes the entire cost structure that is private to each generator and the demand structure that is private to every load—and it well exceeds the information currently available to utility regulators. No other industry is required to reveal such information.

Based on this information, MaxISO calculates prices by *simulating* a market.[5] Thus, these are *administered* prices and not market prices, as advocates of MaxISO misleadingly describe. In an actual market, there would be direct transactions between buyer and seller and the "equilibrium" price would be approached through an iterative process of bids. The parties to such market transactions would determine how much private information to reveal.

Second, the centralized computation of unit commitment and dispatch that MaxISO undertakes will require the development of new algorithms, since such algorithms don't currently exist. A simulation case study using a state-of-the-art Lagrangian relaxation-based unit commitment algorithm modified to simulate second-price auction procedures is reported in [4]. The study shows that (1) the shadow prices (Lagrange multipliers) at a local optimum are highly sensitive to parameters; and (2) small changes in those prices lead to large fluctuations in the profit and loss of individual generators even though the change in the total profit is negligible. Thus, MaxISO's price-setting scheme places large risks on generators.

Third, as shown in [5], derivative concepts such as Transmission Congestion Contracts (TCCs) that are based on MaxISO, are not robust to manipulation by the MaxISO. A more telling criticism is revealed in [6]. Using a Cournot model of competition in a congested transmission network, the study shows that passive transmission can result in implicit collusion among generators who will capture congestion rents and preempt TCCs.

Lastly, up to 40 percent of the settlement price is made up of charges for capacity, startup and shutdown costs, etc.—all computed on an *ad hoc* basis. In the UK this has opened the way to gaming strategies on the part of generators and significant inefficiencies [7].

3. MinISO

The operation of MinISO is first described in terms of the open access single bus paradigm, illustrated in Figure 1. That is, we are assuming that transmission constraints and losses are insignificant. Later we consider transmission constraints. A *multilateral trade* comprises one or more generation and consumption profiles $\{S_t^g, D_t^l\}$, and a profile of network services $\{\nu_t\}$—the duration of a profile may range from one hour to several days—so that:

1. Aggregate generation and load are balanced for each hour t, i.e., $\sum_g S_t^g = \sum_l D_t^l$; and
2. The network services support the generation and consumption for each hour t. (Network services in-

[4] It might be thought that the direct transaction could be constructed from a standard commodity and a "contract for difference (CFD)." This is not the case since the time (hour) of the standard commodity and the CFD must be specified 24 hours ahead.

[5] This is the same way that economic planners in the former Soviet Union calculated prices. (The idea of replacing the real market by simulating one goes back to the 1920s.) It seems grotesque that the regulatory system that failed in the Soviet Union is now proposed for California, under the banner of deregulation!

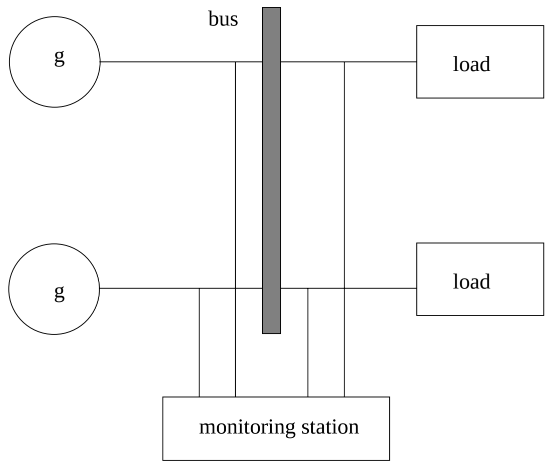

Figure 1: Basic open access (single bus) paradigm

clude: regulation, reserve, losses and voltage support.)

Thus a multilateral trade is required to be self-supporting in terms of generation and load balance and network services. Different trades interact because they share the same transmission resources. There is no other restriction imposed by standardization. Here are some examples of (bilateral) trades.

Example 1 Continuous provision of power for, say, six hours. Generator may give discount for power over longer duration.

Example 2 Contingency trade: customer willing to be interrupted if, say, there are fewer than five interruptions per month, for a total duration of 30 minutes.

Example 3 Customer wants a certain amount of energy over a 24-hour period to be delivered at the convenience of the generator.

Example 4 Supplier handles customer's entire energy end use: HVAC, lighting, etc.

These examples show the flexibility of multilateral trades. These trades must be coordinated so that they don't endanger system security. Security is assured as follows.

Twenty-four hours ahead or earlier:

- Generators, consumers, aggregators make multilateral trades (of varying durations);
- MinISO is informed of generation and load schedules $\{S_t^g, D_t^l, \nu_t\}$ for each t, 24 hours ahead;
- MinISO checks if each trade is feasible, i.e., satisfies power balance and network services requirements;
- Schedule for t is committed at $(t-24)$.

In real time: MinISO

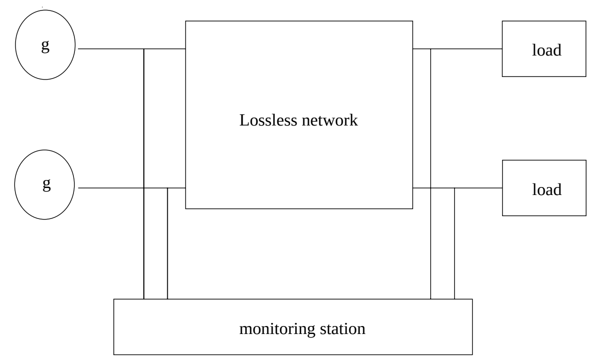

Figure 2: MinISO must monitor network and curtail trades if they violate transmission capacity

- Dispatches schedule and monitors each trade. Deviations from schedule are compensated, measured and penalized; and
- Power imbalances are corrected and charged to defaulting parties.

In this open access paradigm there is a minimal role for MinISO. Its functions are to verify feasibility of trades 24 hours ahead; dispatch and monitor trades in real time; eliminate imbalances and charge commitment violations. MinISO has no data about supplier costs, consumer benefits or financial arrangements. The network services needed to support power transfer may either be provided by MinISO and offered for sale to trademakers or they may be privately procured.

Operating rules for lossless network

Assume a linear, lossless network with nodes $n = 0, 1, ..., N$ as in Figure 2. Ignore network services. Denote net injection by a vector $(q_0, q_1, ..., q_N)$ with $q_n > 0$ $[< 0]$ if node n is a net supplier [demander]. A trade is then represented by a profile $(q_0(t), ..., q_N(t))$ for some duration such that

$$q_0(t) + ... + q_N(t) = 0, \text{ for each } t.$$

The operating rules are as follows:

- Generators, consumers, aggregators make multilateral trades (of varying durations);
- MinISO is informed of generation and load schedules $\{S_t^g, D_t^l, \nu_t\}$ for each t, 24 hours ahead;
- 1. MinISO checks if each trade is feasible, i.e., satisfies power balance. It then checks if transmission limits are met. Otherwise, it *curtails* proposed trades in a reasonable way

and broadcasts *loading vectors* that reflect transmission limits. There is one loading vector $\mu(i)$ for each congested link i.

2. Generators and loads start with curtailed trades and modify them according to loading vectors and return new trades. This imposes constraints on the modifications $\Delta q_n(t)$:

$$\sum_n \langle \mu(i), \Delta q_n(t) \rangle \leq 0, \text{ for each congested line } i.$$

New trades are feasible. If the transmission constraint are met, go to the next step; otherwise return to previous step.

- Schedule for t is committed at $(t - 24)$;

In real time: MinISO

- Dispatches schedule and monitors each trade. Deviations from schedule are compensated, measured and penalized; and
- Power imbalances are corrected and charged to defaulting parties.

The calculation of the loading vectors is explained in [1]. It involves solving the power flow equations using the proposed trades at time t. In essence, the loading vector specifies "feasible directions," such that if trades are modified accordingly, the modified trade will better meet the transmission limits. The curtailed trades always meet those limits.

Reasonable curtailment can be carried out in many ways. In [1], all trades are curtailed proportionately. Price-based schemes are proposed in [8, 9]. Note that MinISO is not involved in market-making or setting nodal prices.

Advantages of MinISO

The chief advantage of MinISO is that its objective is limited to security. It leaves questions of electric energy price to the market. MinISO has an "open" structure, so that if markets for energy and network services do not develop, then MinISO can offer to serve as broker or even as provider. MinISO does not claim to guarantee efficient allocation. However, the following proposition is proved in [1].

Proposition The MinISO is efficient provided traders always find profitable opportunities when they exist.

The feasibility of a trade requires calculation of network services (losses, reserves, voltage support, etc.) that support the energy transfer. Initially, these calculations may not be automated. In that case, MinISO may resort to *ad hoc* rules, procure these services on its own account, and allocate their costs to the individual trades. Over time, suppliers of these services may emerge, and MinISO would progressively extricate itself from supplying those services. For example, [1] proposes a means to allocate losses.

4. Comparison of MaxISO and MinISO

The table below lists some of the key differences between the two structures.

Comparison of MaxISO and MinISO structures

MaxISO	MinISO
Ideal is minimum cost generation	Ideal is open access bus
Transmission constraints dominate in commodity design; other transactions are required to conform to standards	All transactions are permitted; transmission constraints are treated as side constraints
Wheeling is treated separately	Wheeling is treated like any other transaction
Inter-temporal and contingent transactions face extra costs	Inter-temporal and contingent transactions are not penalized
Requires large amounts of private cost and benefit data	Requires no private cost, benefit data
Transactions must be monitored	Transactions must be monitored
Accommodates bilateral transactions with difficulty	Accommodates pooled transactions

MinISO can accommodate a "hybrid" arrangement in which some trades are conducted through a power pool. The December 1996 CPUC decision adopted such an arrangement. It requires that all utilities and certain distribution companies must carry out their transactions through a centralized market or power pool which sets prices according to the UK-Poolco model[6], but trades that can bypass the pool may be bilateral. It is not possible for MaxISO to accommodate bilateral trades.

5. The reality

The debate in California focused on the structure of ISO, i.e., on short-run considerations. The reason for this may be the utilities great and understandable concern with the means to recover their "stranded" costs.[7] The CPUC decision assures that those costs will be born by consumers through a surcharge.

[6] This pool is known as WEPEX.

[7] Stranded costs are embodied in: nuclear power plants that

However, other entitites seeing long-run opportunities in deregulation are moving forward to position themselves to take advantage of those opportunities. The December 1996 decision permits some large consumers to opt out of the poor pool, WEPEX. Four central valley irrigation formed the Eastside Power Authority, announcing they intend to cease taking service from Southern California Edison in favor of shopping around. (They may become suppliers themselves, taking advantage of arbitrage opportunities.) BART may terminate its contract with Pacific Gas and Electric. Enron has announced it will buy Oregon's Portland General, possibly to enter the California market.

These examples are replicated around the country. CILCO is giving consumers direct access in its service territory. Pilot consumer choice programs have been announced for Orange and Rocklin's Utilities' service territory and Cape Cod, and Pacific Power and Light, a Pacificorp company serving Northern California, may offer a pilot program. Massachusetts intends to offer consumer choice beginning January 1, 1997. Cinergy and Wheeled Electric will market power in the Northeast. Competition in generation is forcing utilities to renegotiate expensive fuel contracts. The $3.8 billion merger between two Houston companies—Houston Industries and NorAm Energy—suggests that electric and gas utilities are merging to reduce costs and to offer customers a choice of fuels. Working Assets and Ben & Jerry's will add retail electric service to their list of socially responsible products and services.[8]

In short, consumers and suppliers are not waiting for the various regulatory bodies to come up with new rules that accommodate competition and greater choice. They are moving ahead. The pressure that these moves will create will, sooner or later, overwhelm the CPUC's "go slow" process. The CPUC's compromise decision has made the UK-Poolco model obsolete, although it has not fully embraced the MinISO model. But the rapid changes occurring in California and elsewhere will bring the CPUC closer to some version of the MinISO model.

References

[1] F.F. Wu and P. Varaiya. Coordinated multilateral trades for electric power networks: Theory and implementation. http: //www.eecs.berkeley.edu/~varaiya, June 1995.

[2] F.C. Schweppe, M.C. Caramanis, R.D. Tabors and R.E. Bohn. Spot pricing of electricity. Norwell, MA: Kluwer. 1988.

[3] W.W. Hogan. Contract networks for electric power transmission. Journal of Regulatory Economics, 4: 211-242. 1992.

[4] R.B. Johnson, S.S. Oren and A.J. Svoboda. Equity and efficiency of unit commitment in competitive electricity markets. Presented at POWER Conference, 15 March 1996. POWER working paper, PWP-039. University of California Energy Institute.

[5] F.F. Wu, P. Varaiya, P. Spiller and S. Oren. Folk theorems on transmission access: proofs and counterexamples. POWER working paper, PWP-023. University of California Energy Institute. October 1994. To appear in Journal of Regulatory Economics.

[6] S.S. Oren. Preemption of TCCs and deadweight loss in centrally dispatched electricity systems with competitive generation. Preprint. July 1996.

[7] D. Newbery. Power markets and market power. The Energy Journal, 16(3): 39-67. 1995.

[8] F.L. Alvarado, R.J. Camfield and R. Rajaraman. Open transmission access and congestion: an efficient minimal role for the ISO. Preprint. L.R. Christensen Associates. April 1996.

[9] H-P. Chow and S.C. Peck. A market mechanism for electric power transmission. Journal of Regulatory Economics, 10. July 1996.

are no longer economic, long-term expensive contracts with Independent Power Producers, and long-term tax liabilities. In the case of California, utility stranded costs are estimated at $20 billions.

[8] We are indebted to Jeff Dasovich for these references.