8. Comparison

MAXISO	MINISO
Paradigm is minimum cost gener	Paradigm is open access bus
Transmission constraints dominate in commodity design; other transactions forced into standard	All transactions/commodities permitted; transmission constraints are side conditions
Wheeling treated differently from standard transactions	No difference between wheeling and other transactions
Inter-temporal and contingent transactions face extra costs	Inter-temporal and contingent transactions are not penalized
Bilateral transactions accomodated with additional cost data	Pooling transactions accommodated like others
Requires private cost, benefit data	Requires no data on cost, benefit

7. Extensions

1. Non-convex case gives local efficiency.
2. Losses accommodated without marginal cost pricing.
3. Ancillary services accommodated through direct provision (as in loss) or purchase from ISO.

(lossless network, contd)

1. Multilateral trades $\{q^k(t)\}$ indexed by k (of varying durations) are made.

2. For each t, ISO is informed 24 hours (preferably less) in advance of schedules $\{q^k(t)\}$ for each k.

3a ISO checks if each trade is feasible. Then checks if transmission limit is met. Otherwise it curtails trades arbitrarily and announces the loading vectors that will meet security constraints. There is one loading vector $\mu(i)$ for each congested line i.

3b Generators and consumers start with curtailed trades and modify them according to loading vectors and return new trades. This imposes the constraint

$$\Sigma_k \langle \mu(i), \Delta q^k(t) \rangle <= 0, \text{ for each congested line } i$$

New trades feasible. If transmission limit is met go to 4; otherwise return to 3a.

4. Schedules for t are committed at (t - 24).

5. At real time t, schedule is dispatched, and ISO monitors each trade.

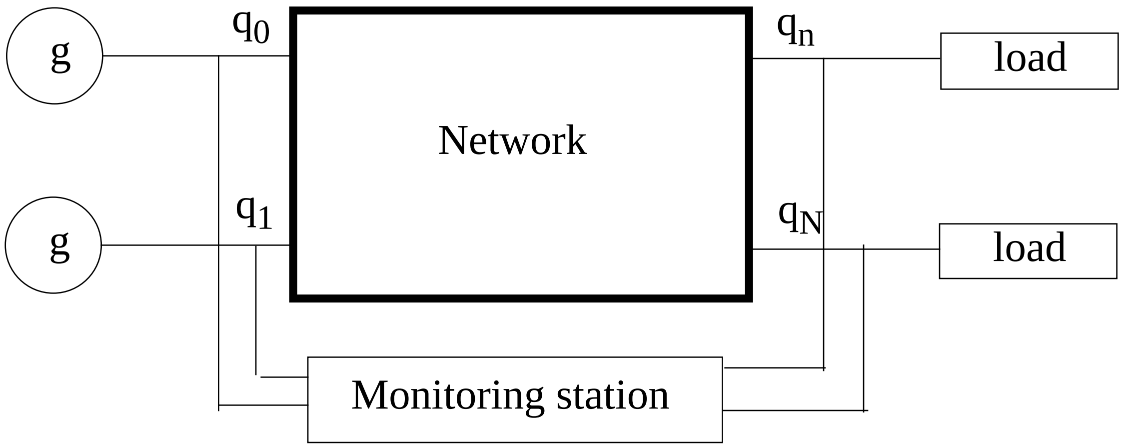
6. Imbalances are corrected by ISO and charged to defaulting trades.

Proposition The schedule is efficient provided traders always find profitable opportunities if they exist.

6. Coordinated MLT in lossless network

Assume linear, lossless network with nodes n = 0, 1, ... , N. Ignore ancillary services. Injection is $(q_0 , q) = (q_0 , q_1 , \ldots , q_N)$, with $q_n > 0$ for supply and $q_n < 0$ for demand. A trade is a profile $(q_0 (t), q(t))$ for some duration such that

$$q_0 (t) + q_1 (t) \ldots + q_N (t) = 0 \text{ for each } t$$



(Example, contd)

Traders try to negotiate profitable changes $\{\Delta q_k\}$ satisfying (1), (2). For example, suppose $MC_1 > MC_2$. Then the generators will find it profitable to reduce generator 1 ($\Delta q_1 < 0$) and to increase generator 2 ($\Delta q_2 > 0$) by the same amount.

The end result is an efficient schedule provided traders always find profitable opportunities if they exist.

Notes.

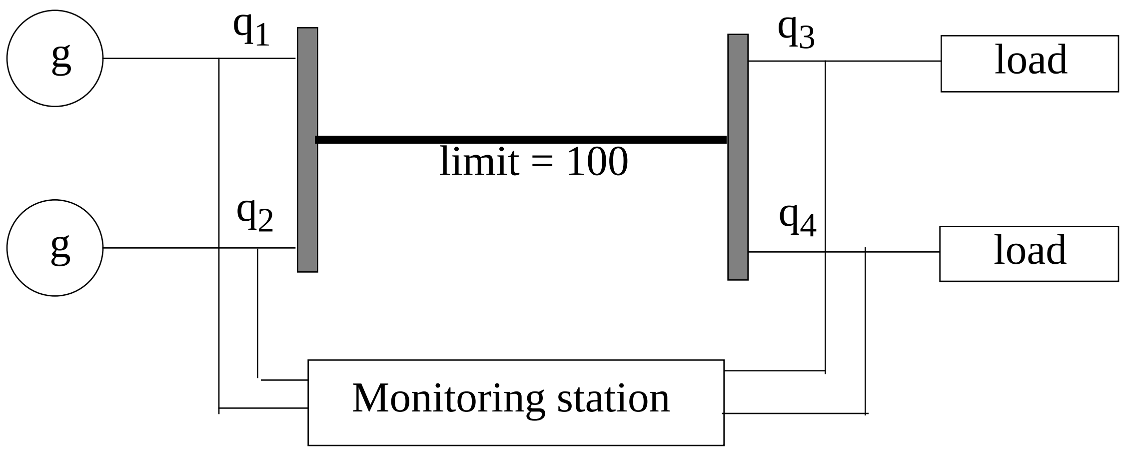
1. Wide latitude in the choice of adjustments to curtailment. In place of the market based choice above, the ISO could choose $\{\Delta q_k\}$ to minimize cost, if ISO has reliable cost data.

2. No transmission congestion charge, unlike in standard model. Congestion “rents” are distributed among trades.

3. Fixed costs of transmission collected through charges (eg., postage stamps, MW-mile).

4. Wheeling transactions are not distinguised from non-wheeling transactions.

Example



Suppose initial trade is (q_1 = 60, q_2 = 50, q_3 = -60, q_4 = -50). ISO checks if trade is feasible (yes) and meets transmission limit (no). (Ancillary services ignored.)

ISO curtails trade to (q_1 = 55, q_2 = 45, q_3 = -55, q_4 = -45). ISO announces that the permitted changes are (Δq_1 , Δq_2 , Δq_3 , Δq_4) so that:

(1) $\Delta q_1 + \Delta q_2 + \Delta q_3 + \Delta q_4 = 0$

(2) $\Delta q_1 + \Delta q_2 <= 0$

Transmission constraints: Single line (lossless)

Generators and customers connected by a single transmission line.

1. Multilateral trades (of varying durations) are made.

2. For each t, ISO is informed 24 hours (preferably less) in advance of schedules $\{S^g_t, D^l_t, \alpha_t\}$ for t.

3a ISO checks if each trade is feasible. Then checks if transmission limit is met. Otherwise it curtails trades arbitrarily and announces the loading vector that will meet security constraint.

3b Generators and consumers start with curtailed trades and modify them according to loading vectors and return new trades. New trades feasible. If transmission limit is met go to 4; otherwise return to 3a.

4. Schedules for t are committed at (t - 24).

5. At real time t, schedule is dispatched, and ISO monitors each trade.

6. Imbalances are corrected by ISO and charged to defaulting trades.

Same procedure as in paradigm, except step 3 is modified to 3a, 3b.

(open access paradigm, contd)

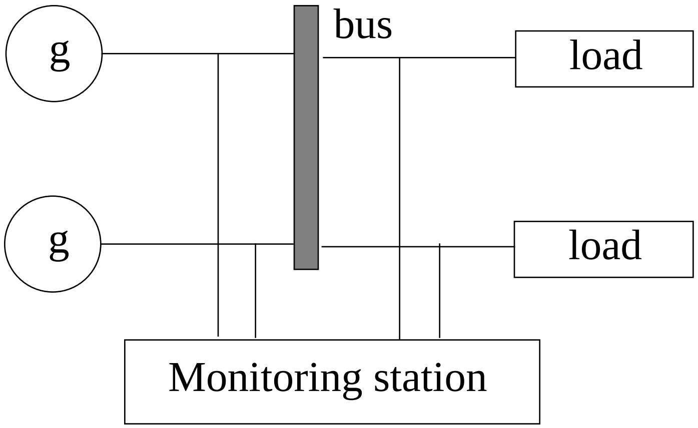
6. In real time imbalances are corrected by ISO and charged to defaulting trades.

The open access paradigm has minimal role for ISO (Miniso or Mediso). Its functions are to verify feasibility of trades 24 hours ahead; dispatch and monitor trades in real time; eliminate imbalances and charge commitment violations.

ISO has no data on costs or financial arrangements.

Ancillary services may be privately procured or purchased through ISO.

Basic open access (single bus) paradigm



All generators and loads are connected to a single, lossless bus.

1. Multilateral trades (of varying durations) are made.
2. For each t, ISO is informed 24 hours (preferably less) in advance of schedules $\{S^g_t, D^l_t, \alpha_t\}$ for t,
3. ISO checks if each trade is feasible.
4. Schedules for t are committed at (t - 24).
5. At real time t, schedule is dispatched, and ISO monitors each trade.

4. A coordinated multilateral trade model

A multilateral trade comprises one or more generation and consumption profiles $\{S^g_t, D^l_t\}$, and a profile of ancillary services $\{\alpha_t\}$ so that:

1. Aggregate generation and consumption are balanced for each hour t, i.e., $\Sigma_g S^g_t = \Sigma_l D^l_t$;
2. The ancillary services support the generation and consumption for each t. (Ancillary services include: regulation, reserve, losses, voltage support.)

The duration of a profile may range from one hour to many days.

Examples of (bilateral) trades

1. Continuous provision of power for, say, six hours. Generator gives larger discount for power with a longer duration.

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

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

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

(varieties of ISO, contd)

- Functions 1-2 have system-wide impact; however, these functions do <u>not</u> require centralized ISO; they can be carried out by several control centers (distributed ISO), coordinated by protocols and communications facilities.
- Functions 3-5 have some system-wide aspects; however, congestion management can be fully decentralized with ISO playing coordinating role; other ancillary services could gradually be decentralized, with coordination achieved by market incentives.
- Functions 6-8 can be fully decentralized, with regulatory oversight for market power. Decentralization requires that transactions be monitored---sensors and real-time communication, which seems feasible for $250 per meter.
- As argued above, standard ISO model will not achieve efficiency.

3. Varieties of ISO

ISO mediates between generators and consumers for:

I1 1. Security, voltage stability (real time)
2. Dispatch and regulation (real time)
3. Congestion management (day ahead and real time)
I2 4. Ancillary services, eg. reserves, VAR support (day ahead and real time)
5. Scheduling (day ahead)
6. Creating spot market, setting locational energy prices, transmission congestion
I3 surcharge, regulation charges (ex post)
7. Administering various uplift charges (ex post)
I4 8. Supervising transmission contracts

Objectives:

I1 • System security
I2 • Service quality
I3,4 • Economic efficiency

I1 + I2 + I3 + I4 = Maxiso
I1 = Miniso
I1 + I2 = Mediso

(inadequate price signal, contd)

Conclusion

ISO model of 24-hour ahead standard energy commodity and ex post settlement prices with large administered “uplift” charges:

- requires private cost and benefit data;
- reduces commodity and contractual choices available to consumers and generators;
- ignores inter-temporal linkages in production and consumption;
- hinders innovations taking advantage of diversity in consumer preferences and generator technologies that cannot be captured through standard commodities and settlement charges.

- Note: Open access in telecommunications encouraged major innovations in new services, data communication, terminal equipment.

(inadequate price signal, contd)

- During 1994-95 in England capacity charge was 20% of scheduled price (marginal cost), so uplift charge may be more than 50% of marginal cost.
- Consumer and generator settlement prices are known after transactions are complete, so decisions are based on price forecasts and not on actual price.
- Uplift charges are based on average revenue reconciliation requirements and not on individual supplier cost or consumer benefit; has encouraged “gaming” behavior and large investment inefficiencies in England (Newberry, 1995).
- Efficiency of scheduled prices requires (Schweppe et al, 1984):

  1. Producers provide marginal cost functions,

  2. Consumers provide marginal benefit functions,

  3. No contingent or inter-temporal dependencies in generation and in consumption.

But there are large inter-temporal dependencies in generation.

Simulations show large fluctuations in unit commitment schedules (and profits of individual plants) due to small fluctuations in cost/demand parameters.

3. Day-ahead “spot” price gives inadequate signal

According to rules

$$\underbrace{p(t)}_{\text{settlement price}} = \underbrace{p^{scheduled}(t)}_{\text{known day ahead}} + \underbrace{p^{uplift}(t)}_{\text{known after real time}}$$

where

$$p^{uplift}(t) = p^{cap}(t) + p^{adj}(t) + p^{cong}(t) + p^{trans}(t) + p^{anc}(t) + \ldots$$

$p^{cap}(t)$ = capacity charge

$p^{adj}(t)$ = adjustment for start up, non-dispatched plant, balancing costs

$p^{cong}(t)$ = transmission congestion surcharge

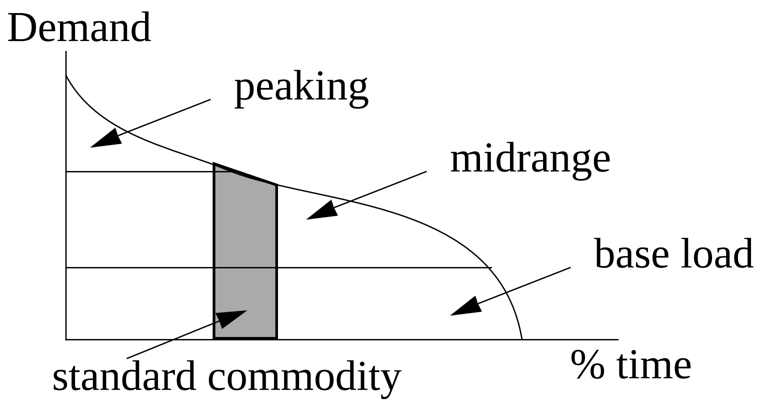
$p^{trans}(t)$ = transmission fixed charge

$p^{anc}(t)$ = ancillary services charge

(Insufficient standard, contd)

Example 4 (cf Example 2) Generator’s average cost is lower if plant is run continuously for six hours (say) than for one hour.

- Cost function $C(S_1, \ldots, S_{24})$ cannot be expressed as $\Sigma_t C_t(S_t)$, as required by standard commodity.
- Planning and unit commitment today are based on load-duration curves; generators with different costs are assigned to different “duration slices”.
- ISO could make ad hoc settlement changes ... but no longer standard ISO.
- Cost to consumers of “duration slices” and standard commodity is different.



(Insufficient standard, contd)

Example 3 Consumer 1 has highly variable power demand (but fixed energy demand) over one hour, consumer 2 has same energy demand but constant power demand.

- Generator finds it more costly to meet variable demand of consumer 1 compared with demand of consumer 2. Standard commodity gives “free rider” opportunity to consumer 1.
- Standard commodity could be differentiated by “peak power” or “capacity” or “variability” attribute ... but no longer standard commodity.

(Insufficient standard, contd)

Example 2 Consumer has energy demand over 24 hour period, doesn't care which hour demand is met. Generator can meet demand but is uncertain about delivery time.

Transaction cannot be constructed using standard commodities:

- Consumer demand curve over 24 hours is $D(\min \{p_1 , \ldots , p_{24}\})$, which cannot be expressed as $\Sigma_t D_t(p_t)$ as required by standard commodity.
- Generator and consumer could come to ISO and make special deal ... but no longer standard ISO model.

2. Day-ahead energy is insufficient commodity

A standard commodity is a unit of energy generated and consumed in one hour, specified one day ahead. The transfer of commodity requires ancillary services.

Claim: Some transactions with contingent (example 1) or inter-temporal (examples 2-4) dependencies cannot be constructed using standard commodities.

Example 1 Consumer’s demand is uncertain one day ahead, but is certain 12 hours ahead. Generator willing to meet demand stated 12 hours ahead.

Within standard model

- Consumer could forecast demand 24 hours ahead in terms of standard commodity and bear the risk of deviation of actual demand from forecast.
- Aggregator could “sum up” uncertain demands of consumers and reduce risk.
- ISO could introduce new commodity of hourly energy specified 12 hours ahead. This would also increase welfare.

1. ISO model based on British system

ISO rules of operation have three phases:

Twenty-four hours ahead ISO

- receives supply curve $S^g_t(p_t)$ from each g and demand curve $D^l_t(p_t)$ from each l for energy for each hour $t = 1, 2, \dots, 24$.
- determines a feasible schedule $\{S^g_t, D^l_t\}$, based on welfare maximization. Generators and loads commit to schedule.
- estimates locational marginal costs and congestion transmission prices.

In real time ISO

- dispatches generation, load and ancillary services; dispatch may be different from schedule. Deviations from schedule are penalized.

After real time ISO

- calculates settlements, location prices of energy, and transmission congestion surcharge. Settlements include marginal fuel cost, capacity costs, startup costs, congestion transmission charges, fixed transmission charges, ancillary service charges.

Summary

1. An ISO model based on British system.
2. Day-ahead energy is an insufficient standard commodity.
3. Day-ahead “spot” price gives inadequate signal.
4. Varieties of ISO: Maxiso, Miniso, Mediso.
5. A coordinated multilateral trade model---“open access” paradigm.
6. The lossless case.
7. Extensions.
8. Comparison of Maxiso and Miniso.

For details see: http://www.eecs.berkeley.edu/~varaiya/

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