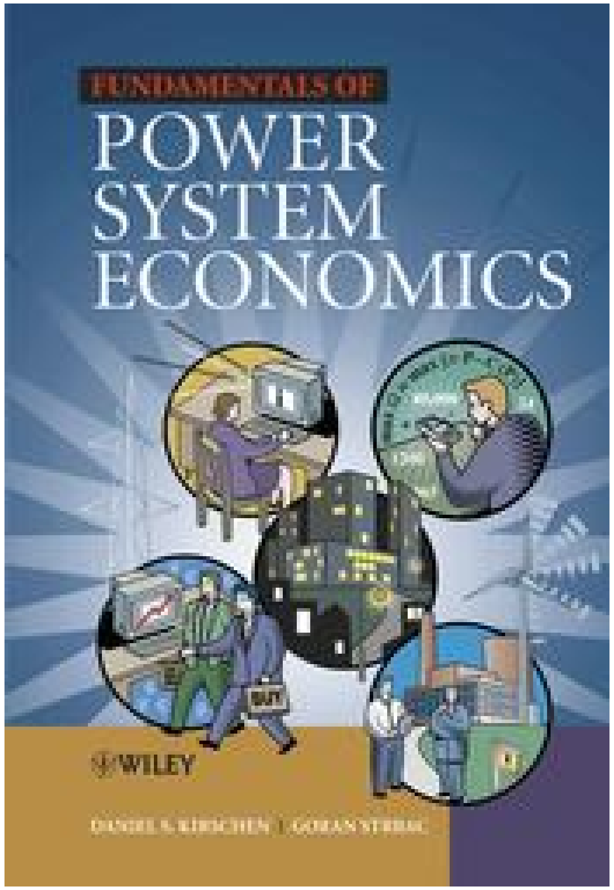
Energy markets in short

Material of this presentation based on the following book:



Part 1. The actors of a power system

Key points on electricity market liberalization

Vertically integrated structure (monopoly): same company produces, transmits and distributes (directly or not) the product to the consumers at a single imposed price.

Since the 1980s, it has been argued that this model was inefficient:
1] no incentive to operate efficiently and encourages unnecessary investments
2] politics interfering with good economics, ...

Unbundled structure: generation company and transportation company are different. The consumers choose the provider(s). Price components: product + transportation. Product and transportation managed commercially by different companies. Product traded on specific market(s) according to transactions or contracts (buyer, seller, quantity, price and time of delivery).

Shift in many countries from an vertically integrated to an unbundled structure. Unfortunately, electricity is not a simple commodity...

How to move towards an unbundled structure & competition?

Break up of large electrical generations companies into smaller ones.

Allow the creation of new companies.

Create ISO (Independent System Operator) to perform transmission/distribution in coordination with power plants operation (Europe: TSO / DSO).

Create appropriate trading infrastructures (market places).

Determine the eligibility of the consumers.

Install appropriate metering devices to monitor the transaction performance.

Create a regulating organism to ensure fair and efficient operations for both: electrical energy systems & markets.

Solve all the technical problems appearing with the unbundling of the original system.

Operation and development not taken anymore by a single organization. Is it possible to coordinate the different entities to achieve least cost operation? (e.g., maintenance of transmission system done jointly with the maintenance of operation line, coordination of long-term development in generation and in transmission, etc.)

Will free markets ensure that generation will always match demand?

Definition of the actors & the components

GENco: Generating company (single plant or portfolio of plants). Sells electrical energy through competition in wholesale market. Could compete also to sell ancillary services.

TRANSco: Transmission company. Operates its equipments according to ISO instructions.

ISO: Independent system operator. Responsible for maintaining the security of power system operation. Could also play the role of the Market Operator (MO).

MO: Market operator. Matches generating bids (sellers) and consumption offers (buyers) and issues the contracts according to the mechanism used.

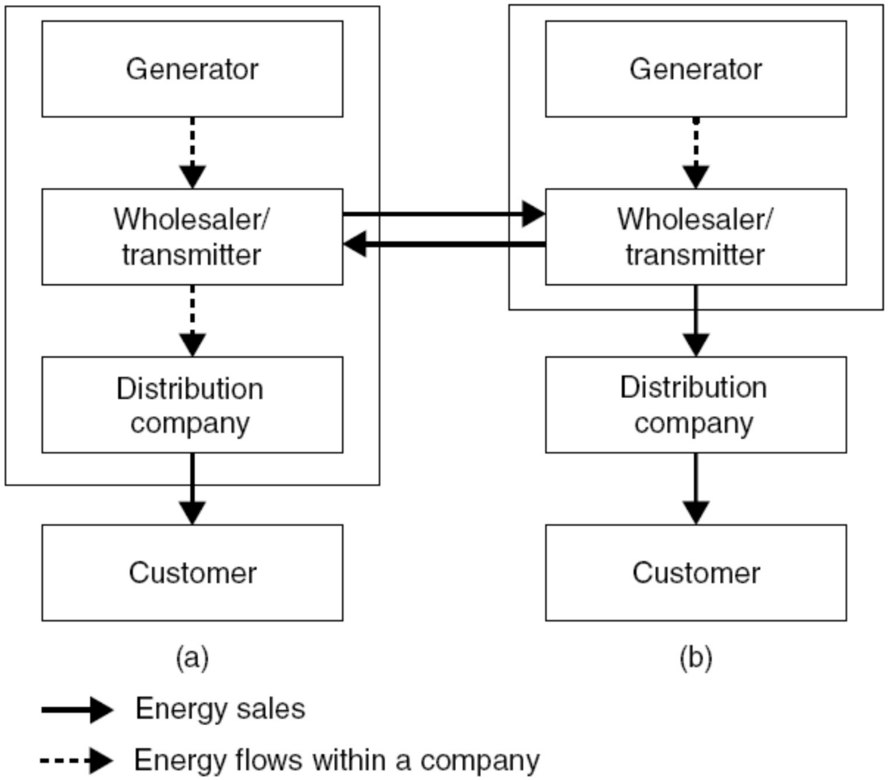
DISco: Distribution company. It operates the distribution network. The sale of electrical energy to the consumers could be through the DISco itself (monopoly or partial deregulation) or retailers (retail markets in fully deregulated environment).

Retailer: buys electrical energy on wholesale markets. Resells it through a retail market to consumers not participating to the wholesale market. DISco can be a particular retailer.

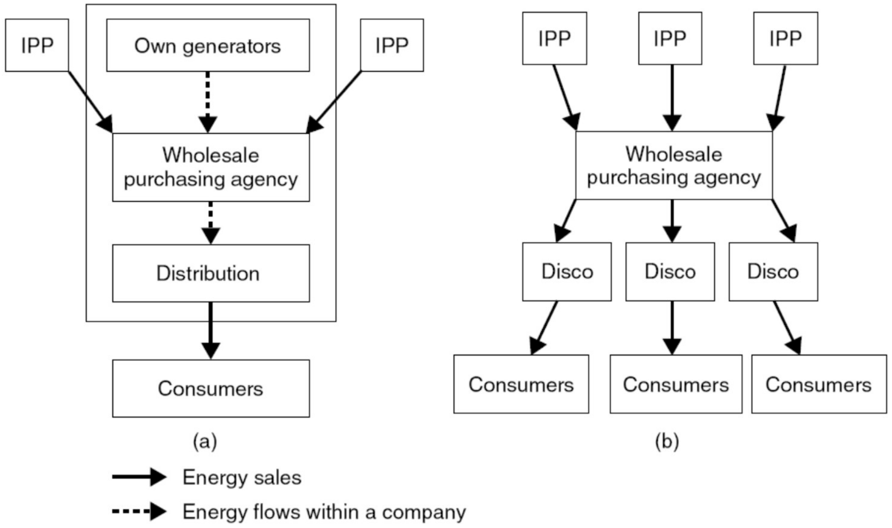
Consumer: large consumers buy the electrical energy through wholesale market. Small consumer buy the electrical energy through retail market or from the DISco to which it is connected.

Regulator: determines or approves the electricity market rules and investigates the suspect cases of abuse (market power). Sets or controls the prices of products and services in the case of monopolies.

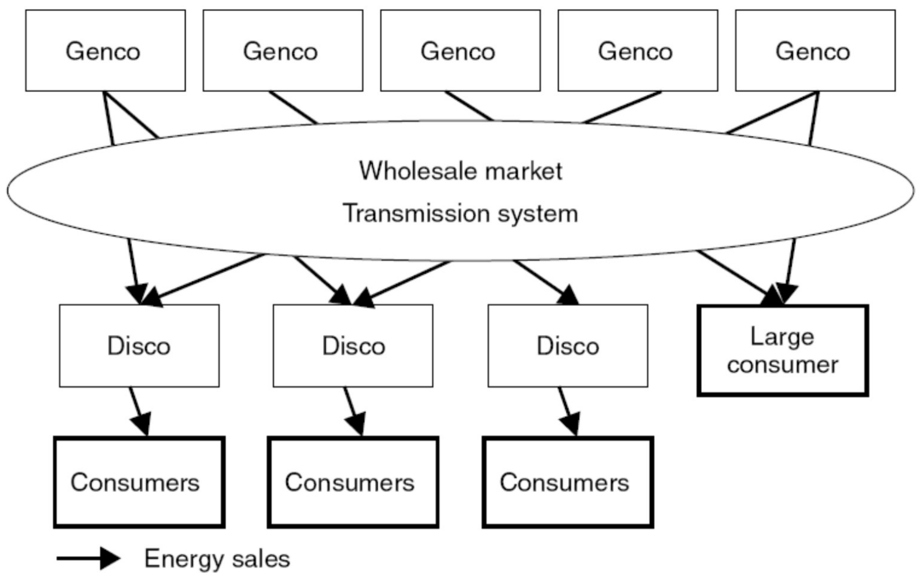
Models of competition



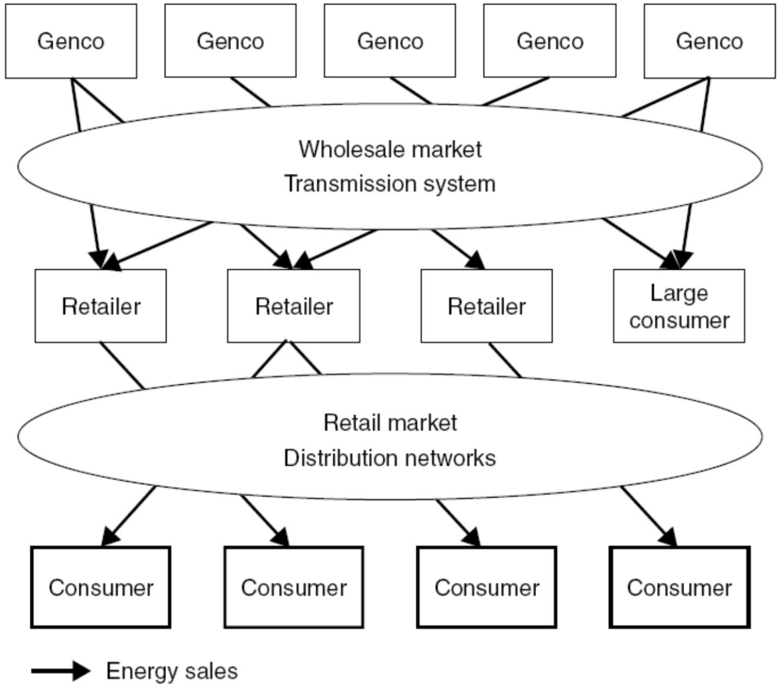
Monopoly: *(a) utility integrates generation, transmission and distribution. (b) one utility integrates generation and distribution which sells energy to local monopoly distribution companies.*



Purchasing agency model: *(a) integrated version (b) disaggregated version.*



Wholesale competition model



Retail competition model

Part 2. Markets for electrical energy

Introduction

Assumption: All the generators and loads are connected to the same bus or connected through a lossless network of infinite capacity $\Rightarrow$ we ignore on the complexities introduced by the transmission and the distribution networks.

Not economical to store large quantities of electrical energy $\Rightarrow$ energy must be produced at the same time it is consumed $\Rightarrow$ Trade in electrical energy refers to an amount of megawatts-hours to be delivered over a specific period of time.

Period length : one hour, half an hour, quarter of hour, depending on the region/country.

Demand not the same over the period length $\Rightarrow$ Adjustments to be made on a shorter basis to keep the system balanced.

Megawatt-hours not barrels of oil

Electrical energy linked to a physical system where supply and demand need to be managed on a daily second-by-second basis, otherwise blackouts may occur.

Energy produced by a generator cannot be directed to a specific consumer. Energy is pooled on its way to the load.

Rapid cyclical variations in the demand of electricity.

Rapid cyclical variations in the price of electricity.

The need for a managed spot market

Large consumers and retailers forecast their consumption or the consumption of their own consumers for every market period. GenCos schedule the production of their units to deliver at the agreed time the energy that they have sold.

But in reality, neither party can meet its exact obligations (forecasting never exact; unpredictable technical problems). Danger for the integrity of the system.

A possible solution: a market that would operate on a second-by-second basis but technology not yet feasible to implement and would be expensive.

$\Longrightarrow$ A managed market is essential for balancing load and generation and should supersede the open energy market (where most of the trading would occur) as the time of delivery approaches.

Bilateral trading for open electrical energy markets

Involves a buyer, a seller and no third parties involved.

Different forms of bilateral trading depending on the amount of energy to be traded and the time available:

Customized long-term contracts: negotiated privately; usually involve the sale of large amounts of energy; large transaction costs.

Trading "over the counter": Involve smaller amount of energy to be delivered according to a standard profile (how much energy should be delivered during the different periods of the day and the week). Much lower transaction costs; use to refine positions.

Electronic trading. Offers to buy energy or bids to sell energy are traded. Bids and offers can be seen by everyone but they are anonymous.

(i) When party enters new bid, the system checks to see whether it matches an existing offer (offer with a price greater or equal to the bid).

(ii) If yes a deal is struck. Otherwise, bid added to the list of the bids.

(iii) Similar procedure with offers.

Remarks: Electronic trading is fast and cheap. Used to refine positions in the minutes or seconds before the market closes.

Example: *Borduria Power* trading in electricity market

Unit	Type	P_{min}	P_{max}	MC
		(MW)	(MW)	(\$/MWh)
A	Large coal	100	500	10.0
B	Medium coal	50	200	13.0
C	Gas turbine	0	50	17.0

Unit A and unit B have large start-up costs (better to be synchronized all the day).
Unit C no start-up cost.

We focus on the period between 2:00pm and 3:00 pm on 11 June for trading electricity.

Bilateral contracts:

Type	Contract date	Identifier	Buyer	Seller	Amount	Price
					(MWh)	($/MWh)
Long term	10 January	LT1	Cheapo Energy	Borduria Power	200	12.5
Long term	7 February	LT2	Borduria Steel	Borduria Power	250	12.8
Future	3 March	FT1	Quality Electrons	Borduria Power	100	14.0
Future	7 April	FT2	Borduria Power	Perfect Power	30	13.5
Future	10 May	FT3	Cheapo Energy	Borduria Power	50	13.8

Borduria power has contracted 570MWh of contracts for 750 MW of capacity.

Bids and offers posted on the screen-based Bordurian Power:

11 June 14:00 to 15:00	**Identifier**	**Amount (MW)**	**Price ($/MWh)**
Bids to sell energy	B5	20	17.50
	B4	25	16.30
	B3	20	14.40
	B2	10	13.90
	B1	25	13.70
Offers to buy energy	O1	20	13.50
	O2	30	13.30
	O3	10	13.25
	O4	30	12.80
	O5	50	12.55

Actions from the trader: Grab offers O1, O1, O3 (the trader believes that better offers are not likely to occur - cost of production around 13 $/MWh)

Revised production orders : Unit B has to generate 130 MW. Unit A output stays maximal (500 MW).

Just before the BPex closes trading for the period 14:00-15:00, the trader is made aware that there is a problem at plant B. Can remain on-line for a few more hours but cannot produce more than 80 MW.

Three solutions: (1) do nothing, leaving Borduria Power short of 50 MWh that will have to be paid for at the spot market price (2) Make up this deficit by starting up unit C (3) Try to buy some replacement power on BPex.

Trader would like to avoid to buy energy at the spot price and look at the possibility to buy energy on BPeX for less than the marginal cost of unit C:

11 June 14:00 to 15:00	**Identifier**	**Amount** (MW)	**Price** ($/MWh)
Bids to sell energy	B5	20	17.50
	B4	25	16.30
	B3	20	14.40
	B6	20	14.30
	B8	10	14.10
Offers to buy energy	O4	30	12.80
	O6	25	12.70
	O5	50	12.55

At the end it selects bids B8, B6 and B3.

Electricity pools

Electricity naturally pooled when flowing from the generators to the loads $\Rightarrow$ It was felt that trading could be done in a centralized manner through electricity pools.

No repeated interactions between suppliers and consumers to reach the market equilibrium.

A pool provides a mechanism for reaching this equilibrium in a systematic way.

How do they work?

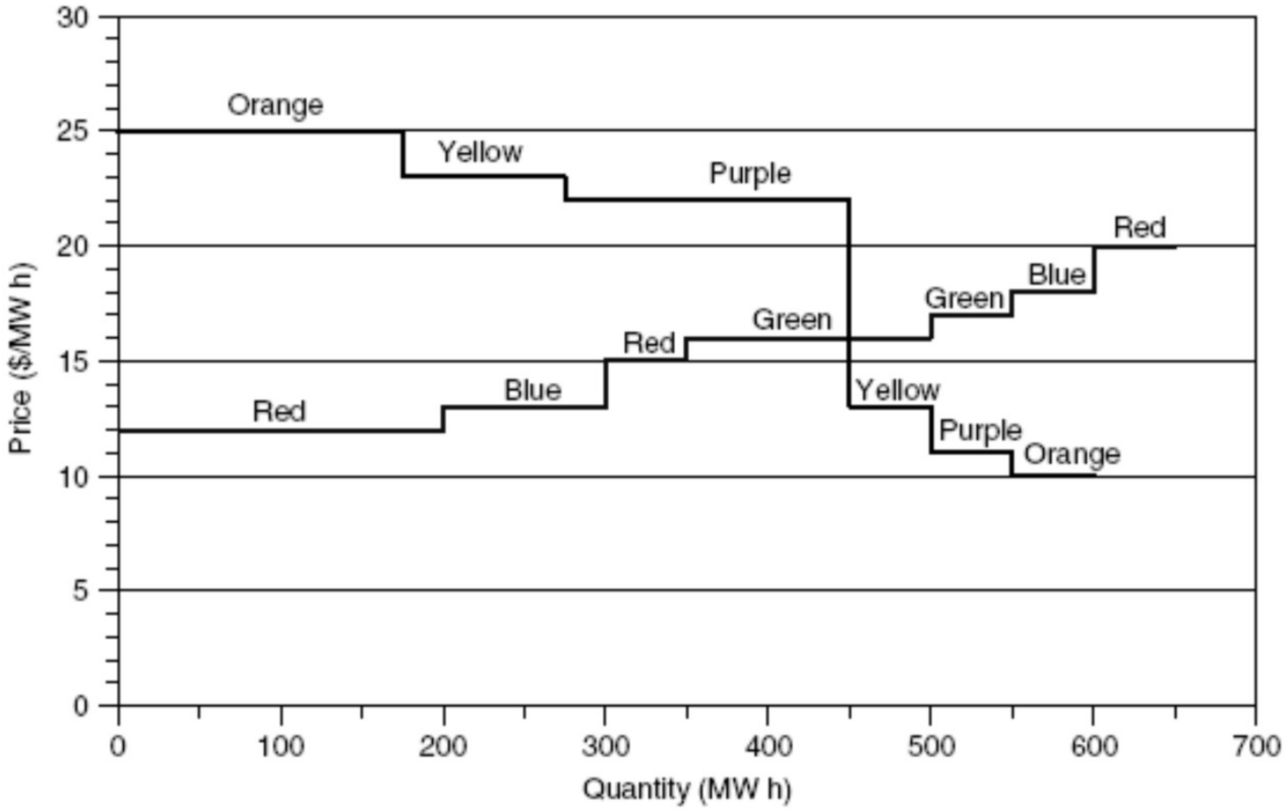
Generators submit bids for the period under consideration. Bids $=$ amount of electrical energy at a certain price. Bids are ranked according to increasing price and a supply curve of the market is built.

Consumers submit offers (amount of energy they are willing to buy at a certain price). A demand curve is built.

Intersection of demand and supply curves represent the market equilibrium price, also called the system marginal price (SMP). Bids inferior to the market equilibrium price and offers above this price are accepted.

Example: Building supply and demand curves from bids and offers

Bids	Company	Quantity (MWh)	Price ($/MWh)
	Red	200	12.00
	Red	50	15.00
	Red	50	20.00
	Green	150	16.00
	Green	50	17.00
	Blue	100	13.00
	Blue	50	18.00
Offers	Yellow	50	13.00
	Yellow	100	23.00
	Purple	50	11.00
	Purple	150	22.00
	Orange	50	10.0
	Orange	200	25.00



Orange
Yellow
Purple
Red
Blue
Green
Green
Red
Blue
Red
Yellow
Purple
Orange
Price ($/MW h)
Quantity (MW h)
0
5
10
15
20
25
30
0
100
200
300
400
500
600
700

Remarks on electricity pools

Due to the inelasticity of the load, the demand curve is sometimes represented by a vertical line.

Why are all generators paid the SMP? They could be paid only the price of their bids which could lead to a decrease of the price of electricity. But, with such a scheme, all the generators will try to guess the system marginal price and, eventually, some cheap generators may be left out of the scheduling $\Rightarrow$ May lead to an inefficient used of resources and even possible increase of the price of SMP (generators are likely to increase their prices to compensate for the risk of being left out of scheduling).

More complex bids can be submitted in some pools by the generators. Bids that may reflect cost characteristics of the unit (including marginal, start-up and no-load costs). Market clearing done by solving a 'unit commitment' problem with for example a time horizon of one day divided into periods of half an hour or one hour.

The managed spot market

Imbalances always arise between the amount that a party has contracted to buy or sell and the amount that it actually needs or can produce.

Spot market not quick enough to correct these imbalances.

System Operator is given the responsibility to maintain the system balance using a managed spot market (or also reserve market or balancing mechanism).

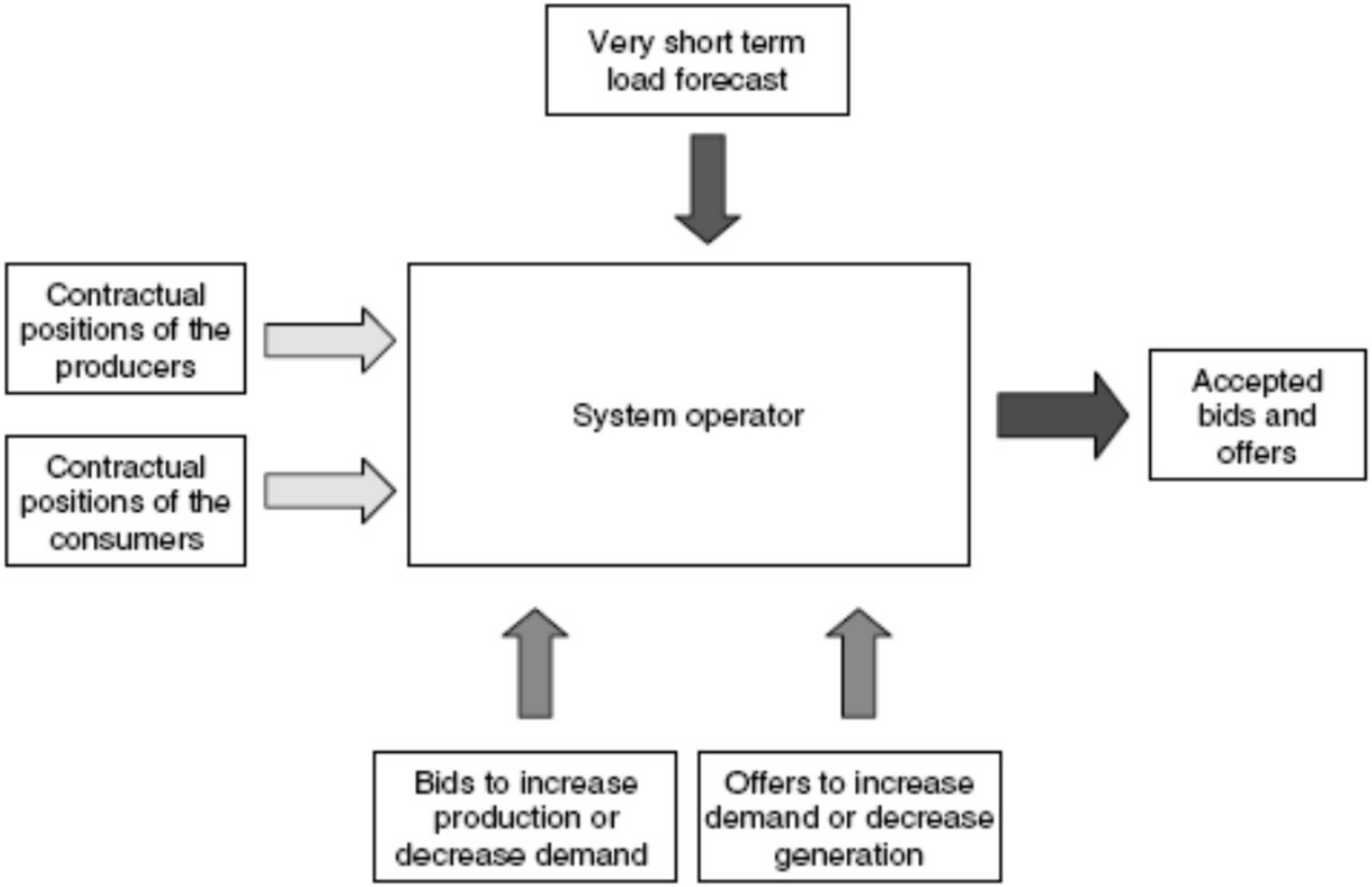
Obtaining balancing resources

Wide range of balancing options: bids to increase generation, offers to decrease generation, demand side balancing resources (very quick to activate).

The SO can also buy balancing resources on a long-term basis to guard against related to the amount and price of the balancing resources that will be offered on a short-term basis.

Under long-term contracts, a supplier is paid a fixed price (called the option fee) to keep available generation capacity. The contract also specifies the exercise fee to be paid for each MWh produced at the request of the SO using this capacity.

Operation of the managed spot market



Gate closure: time at which energy trading must stop. The producers and the consumers inform the SO of their contractual positions just afterwards.

Time that should elapse between gate closure and real-time: very small for consumers and generators (to reduce their exposure to risk (bad load forecast, sudden generator outage, etc); large for SOs.

Managed spot market price: should reflect the incremental cost of balancing energy.

This "balancing market" cannot solve all the balancing problems $\Rightarrow$ ancillary services are needed (e.g., primary frequency regulation).

Back to the *Borduria Power* trading example

Unit	P^{sched}	P^{min}	P^{max}	MC
	(MW)	(MW)	(MW)	($/MWh)
A	500	100	500	10.0
B	80	50	80	13.0
C	0	0	50	17.0

Type	Identifier	Price ($/MWh)	Amount (MW)
Bid	SMB-1	17.50	50
Offer	SMO-1	12.50	30
Offer	SMO-2	9.50	400

The settlement process

For the bilateral agreements: The buyer pays the seller the agreed price as if the agreed quantity had been delivered exactly. If anonymous transactions are arranged by the intermediate power exchange, they are settled through it.

If a producer produces less than committed, the SO buys the rest for him on the spot market. If it produces more, the SO sells the rest for him on the spot market. Similar approach with a retailer or a large consumer.

For this settlement process, each producer must report the net amount of energy it had contracted to sell for each period. This amount is subtracted from the amount of energy it has indeed produced. Same approach with a retailer or a large consumer.

Imbalances are charged at the spot market price.