The power market of Russia

WP 5.3.1 Market development in Russian energy market

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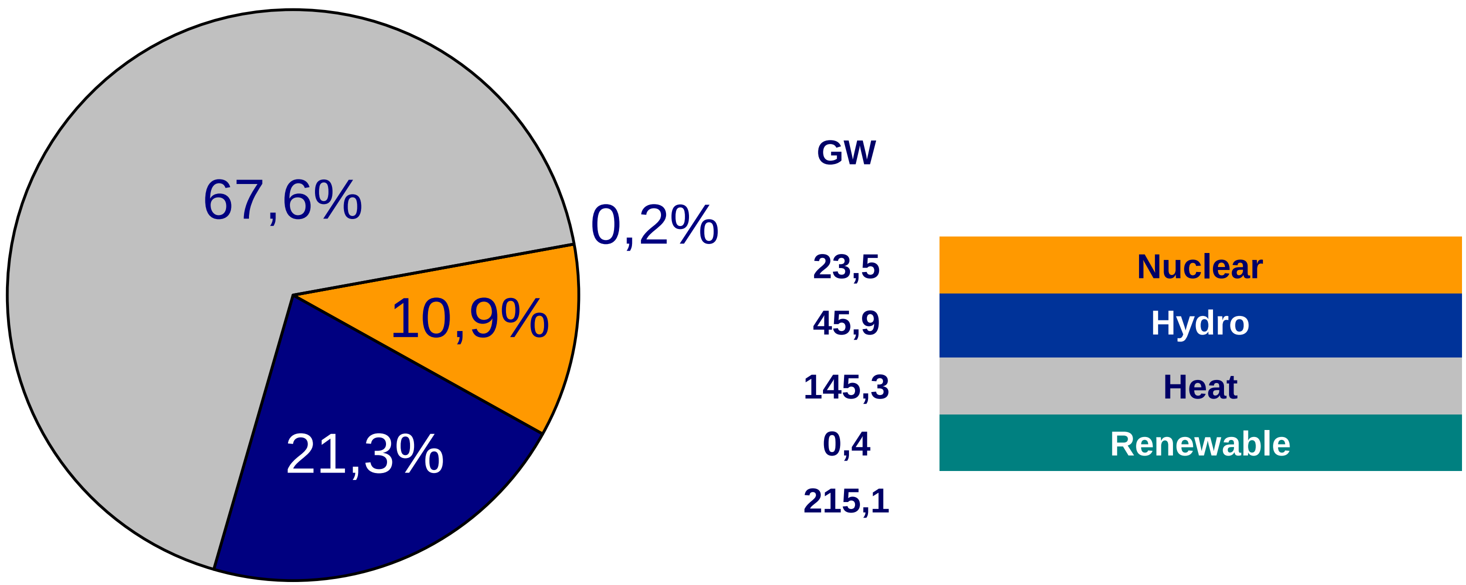
Power sector performance

- Number of power producers ~22 large generation companies
- Number of distribution companies~1 000
- Volume of consumed electrical energy ~1 023 TWh (as of 2008 year)
- Number of enterprises ~4 772 000 (26 000 of them are engaged in electricity production and distribution)
- Residential consumption ~ 117 TWh
- Total revenue ~35 000 M€

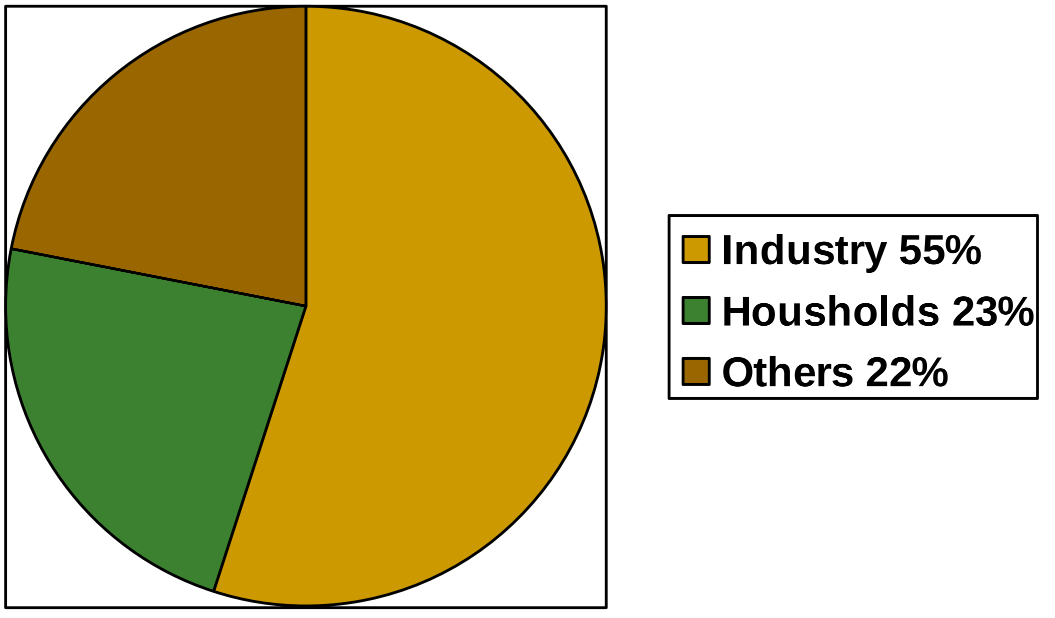
Source: Russian Statistical Yearbook 2009

Structure of power generation



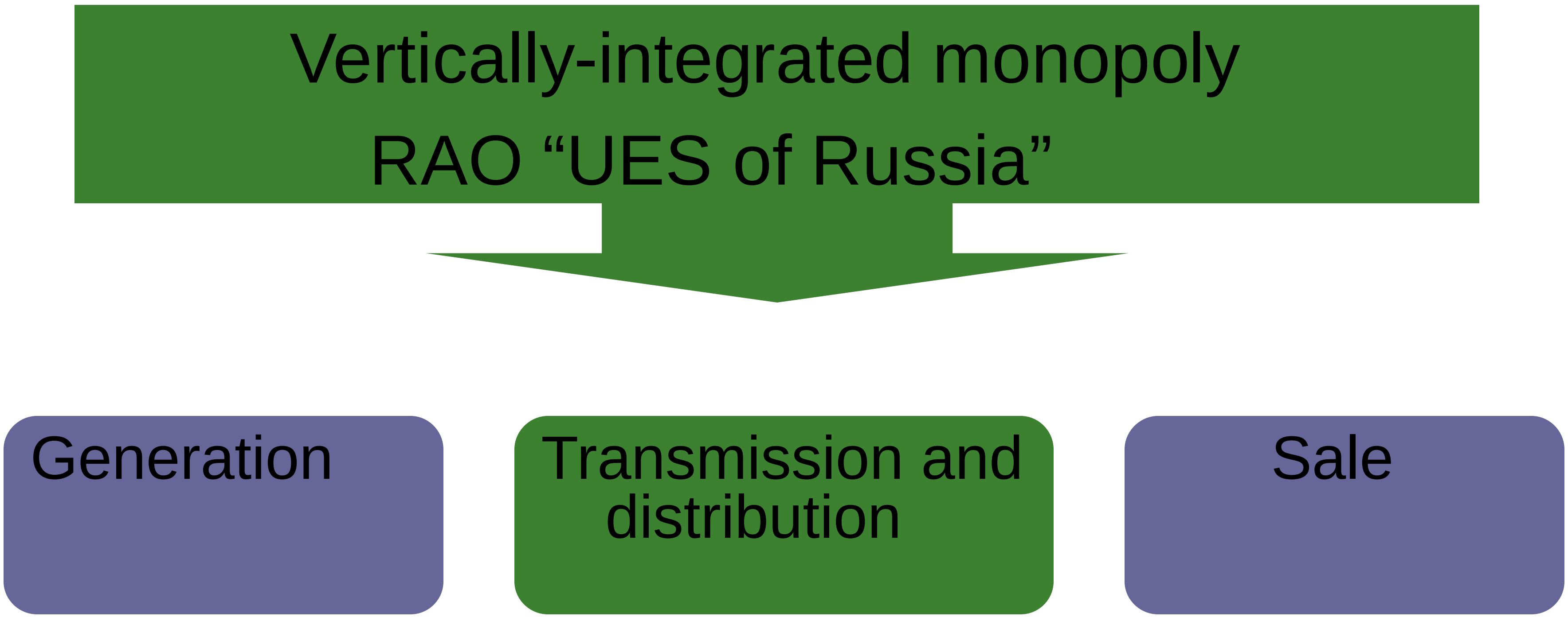
Source: "Agency of Forecasting of Balances" 2010

Structure of power consumption



More than a half of the total energy demand is formed by mining operations, manufacturing activity and industrial production (including production of energy, gas and water)

Power industry restructuring



Sectors of competition

Generation:

✓**6 Wholesale Generating Companies pool 31 power stations most of which are thermal with total installed capacity 53.9 GW**
✓**14 Territorial Generating Companies ingress cogeneration and hydro stations with total installed capacity 55.6 GW**
✓**Concern “RosEnergoAtom” exploits 10 nuclear stations with total capacity 24.2 GW**
✓ **JSC “RUSHydro” runs 21 hydro stations with total installed capacity 25.5 GW**
✓**JSC “Inter RAO UES” pools 4 heat stations with total capacity 1833 MW**

Sales:

✓**Suppliers of last resort. Responsible for supplies to population. Supply of small and medium end-users mainly**
✓**Independent sale companies. Supply of big industrial consumers mainly**

Transmission and distribution

Transmission grid operator - JSC "Federal Grid Company"

- **Eight subsidiaries supervising all parts of the national grid and providing services of technological connection to networks. Assets include 121096 km of lines and 797 substations**

Distribution networks operator - Holding "MRSK"

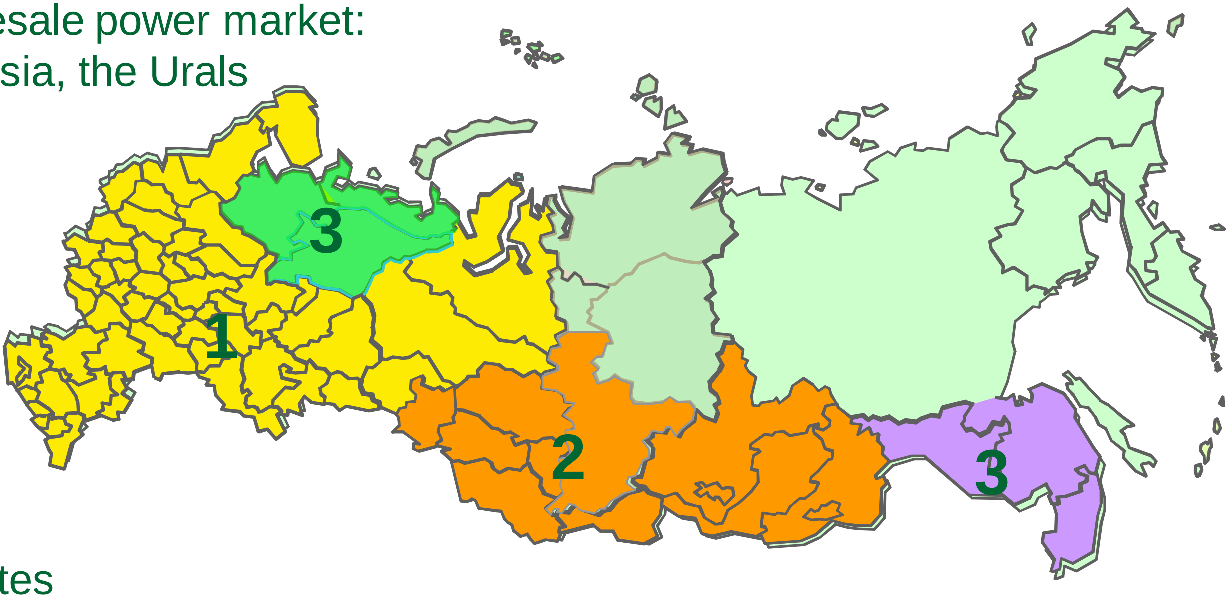
- **Responsible for running of distribution networks of the country. The Holding includes eleven interregional sub-companies each of those, in turn, comprises several regional distribution companies**

Infrastructure organizations

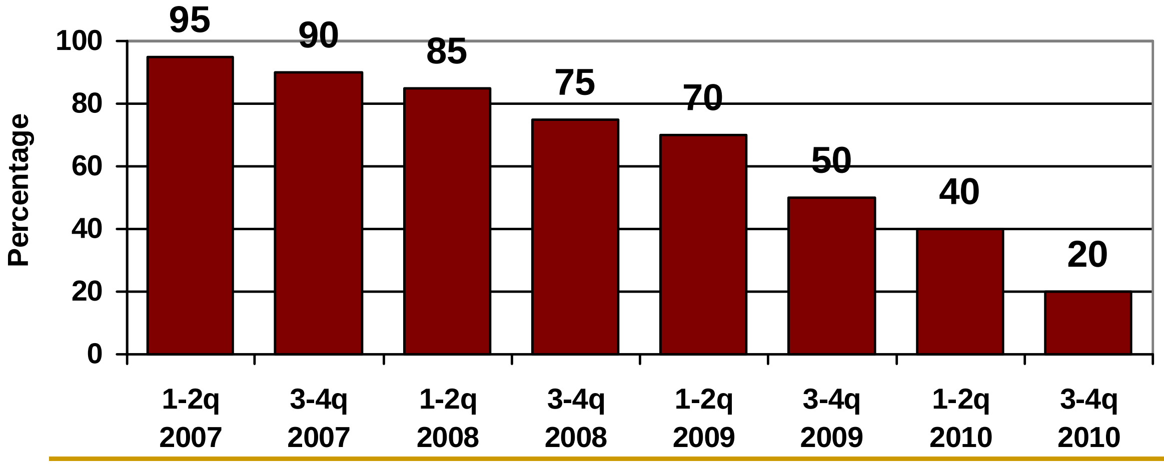
- **System Operator**
- **Commercial Operator**
- **Federal Tariff Service**
- **Federal Antimonopoly Service**

Energy and capacity markets liberalization

The territory of the Wholesale power market:
1 – European part of Russia, the Urals
2 – Siberia
3 – non-price zones



Market liberalization rates



Source: Energy Fund Development 2008

Energy and capacity markets liberalization

- **Liberalized volumes of energy and capacity in Russia:**

  - 2010 year – 54%
  - 2011 year – 82%

  - 2011-2030 years – 81%~84%

Source: General plan of the power industry development up to 2030

Energy Market model

In place:

- Regulated trade
- Spot-market
- Balancing market
- Energy forward contracts
- Energy futures
- Market of ancillary services

To be introduced later:

- Market of transmission rights

Regulated contracts

At present:

- Still remain in the non-competitive areas of Russia
- Concluded with few generators in the wholesale market for the purposes of supplies to population

Nodal pricing

- Used in the spot and balancing markets of energy in Russia
- Perfectly fits in the conditions of insufficient transmission capacities and very different costs of generation in different regions of the country

What is nodal pricing?

- Nodal pricing is a method to calculate the prices of electricity and to manage network congestions. Nodal prices indicate the true costs of using the electricity system by taking into account the marginal electric energy costs, congestion costs, and the costs of losses

- High prices at nodes indicate local demand for increase of generation output or transmission capacity

Nodal pricing in Russia (computing model)

The power system is divided into nodes (6040 nodes in the European part of Russia and 602 in Siberia). Market clearing prices are determined for each node of the system

$$\sum_{h}\left\{\sum_{t\in h}\sum_{c}\sum_{l}c_{ct}^{l}P_{ct}(l)-\sum_{g\in I}\sum_{l}c_{gh}^{l}\sum_{t\in h}P_{gt}(l)-\sum_{g\notin I}\sum_{t\in h}c_{gt}^{l}P_{gt}(l)\right\}\rightarrow \max_{P_{gt}(l),Q_{gt},P_{ct}(l),V_j^t,d_j^t}$$

Nodal pricing (boundary conditions in computing model)

$$\sum_i p_{ij}^t + \sum_g P_{gt} - \sum_c P_{ct} = 0$$

$$\sum_i q_{ij}^t + \sum_g Q_{gt} - \sum_c Q_{gt}^{\max} = 0$$

$$p_{ij}^t = G_{ij}[V_i^{t2} - (V_j^t V_i^t / t_{ij})\cos(d_i^t - d_j^t + \alpha_{ij})] + \Omega_{ij}(V_j^t V_i^t / t_{ij})\sin(d_i^t - d_j^t + \alpha_{ij})$$

$$q_{ij}^t = \Omega_{ij}[V_i^{t2} - (V_j^t V_i^t / t_{ij})\cos(d_i^t - d_j^t + \alpha_{ij})] - G_{ij}(V_j^t V_i^t / t_{ij})\sin(d_i^t - d_j^t + \alpha_{ij}) - V_i^{t2} B_{cij}$$

$$P_{gt}^{\min} \le P_{gt} \le P_{gt}^{\max}$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max}$$

$$0 \le P_{ct} \le P_{ct}^{bid} \le P_{ct}^{\max}$$

$$0.8 \cdot V_j^{ном} \le V_j^t \le 1.3 \cdot V_j^{ном}$$

$$0.5 \cdot V_j^{ном} \le V_j^t \le 1.5 \cdot V_j^{ном}$$

Nodal pricing

- **Lagrange multipliers**

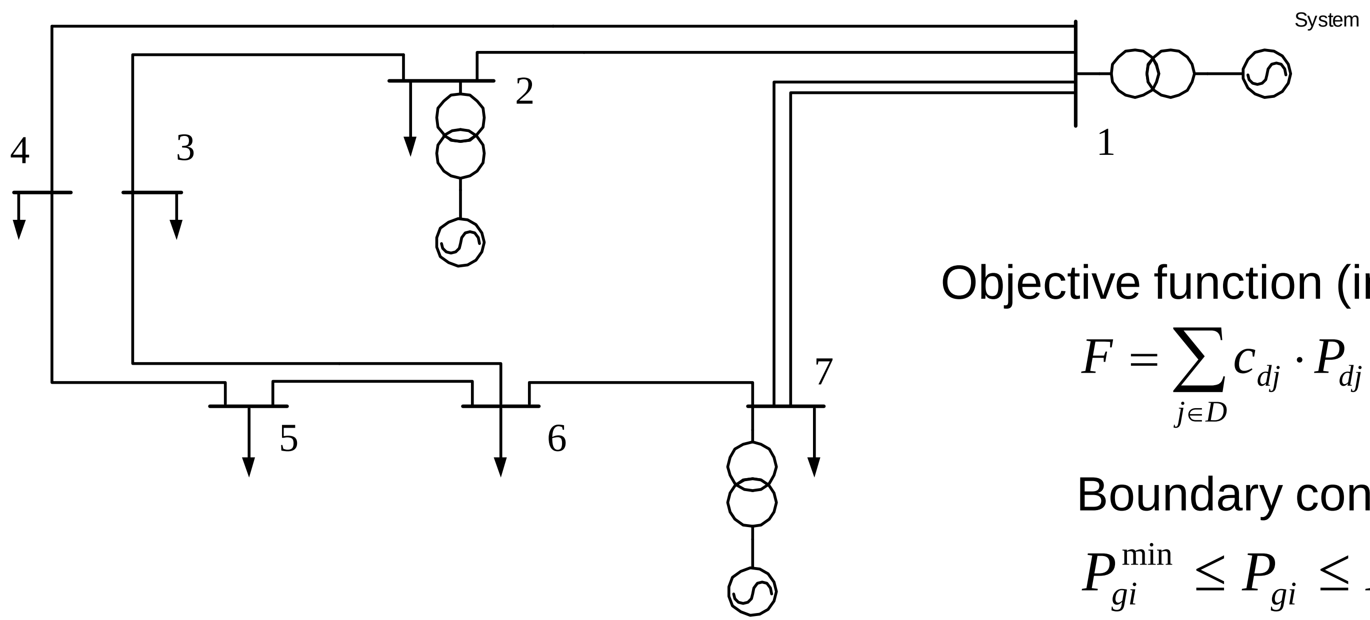
f(x1,…,xn) $\rightarrow$ *max*

L(x1,…,xn;λ) = f(x1,…,xn) — λg(x1,…,xn)

$$\frac{\partial L}{\partial x_i} = 0, i = 1,\dots n;$$

$$\frac{\partial L}{\partial \lambda} = 0$$

Nodal pricing (simple example)



Objective function (inelastic demand):

$$F = \sum_{j \in D} c_{dj} \cdot P_{dj}$$

Boundary conditions:

$$P_{gi}^{\min} \leq P_{gi} \leq P_{gi}^{\max}$$

$$P_l \leq P_l^{adm}$$ -power flow limits in lines

$$\sum_i P_{gi} - \sum_j P_{dj} - \sum_l \Delta P_l = 0$$

Table 1. Input parameters

Node	Load (MW)	Generation limits (MW)	Price offer (€/MWh)	Branch	Impedance (Om)
1	0	400 – 500	100	1-2	1
7	300	200 – 300	150	2-3	1
6	250	0		3-6	1
5	45	0		1-4	1
4	40	0		4-5	1
3	50	0		5-6	1
2	30	50 – 100	300	7-6	1
				1-7	1

We assume that the demand is inelastic i.e. that loads submit price accepting offers only.

Nodal pricing (simple example)

Lagrangian:

$$L = c^T \cdot \mathrm{P}_g + \lambda \cdot (P_D - u^T \cdot \mathrm{P}_g) + \mu_L^T \cdot (\mathrm{P}_l^{adm} - A \cdot \mathrm{P}) + \nu_p^T \cdot (\mathrm{P}_g^{adm} - \mathrm{P}_g)$$

λ -price of the cheapest generator (no constraints)

μ -reflects price increment caused by system restrictions

ν -reflects price increment caused by limitations in generation

.

$$\frac{\partial L}{\partial P_g} = 0, \qquad \frac{\partial L}{\partial \lambda} = 0, \qquad \frac{\partial L}{\partial \mu_L} = 0, \qquad \frac{\partial L}{\partial \nu_p} = 0$$

Nodal pricing (optimization with simplex algorithm)

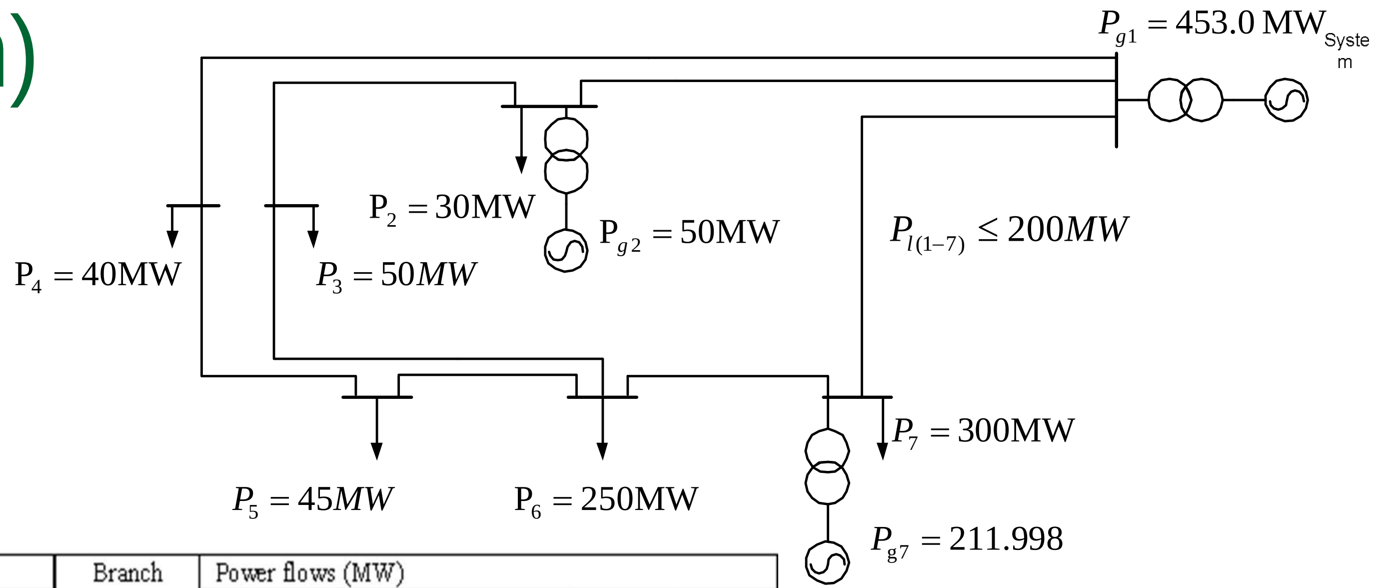


Table 2. Power flows in the system

Node	Nodal capacities (MW)		Branch	Power flows (MW)	
	Load	Generation		Power flow components	Value
1	0	453	1-2	$1230/7 - Pg7/7 - (16 \cdot Pg2)/21$	107.3336
7	300	212	2-3	$(5 \cdot Pg2)/21 - Pg7/7 + 1020/7$	127.3336
6	250	0	3-6	$(5 \cdot Pg2)/21 - Pg7/7 + 670/7$	77.3336
5	45	0	1-4	$1265/7 - Pg7/7 - (2 \cdot Pg2)/21$	145.6670
4	40	0	4-5	$985/7 - Pg7/7 - (2 \cdot Pg2)/21$	105.6670
3	50	0	5-6	$670/7 - Pg7/7 - (2 \cdot Pg2)/21$	60.6670
2	30	50	7-6	$(2 \cdot Pg7)/7 - Pg2/7 + 410/7$	111.9994
			1-7	$2510/7 - (5 \cdot Pg7)/7 - Pg2/7$	200.0014
Total	715	715			

Nodal pricing (simple example)

$$\left.\begin{aligned} &\sum_{i=1}^{3} P_{gi} = 715, \\ &P_{g2} = 50, \\ &\frac{2510}{7} - \frac{(5 \cdot \mathrm{P}_{g7})}{7} - \frac{\mathrm{P}_{g2}}{7} = 200 \end{aligned}\right\}$$

Lagrangian:

$$L = 100 \cdot P_{g1} + 300 \cdot P_{g2} + 150 \cdot P_{g7} + \lambda \cdot (715 - \sum_{i \in G} P_{gi}) + \mu_8 \cdot (200 - \frac{2510}{7} + \frac{(5 \cdot \mathrm{P}_{g7})}{7} + \frac{\mathrm{P}_{g2}}{7}) +$$

$$+ \nu_2 \cdot (50 - \mathrm{P}_{g2})$$

$$\frac{\partial L}{\partial P_{g1}} = 100 - \lambda = 0,$$

$$\frac{\partial L}{\partial P_{g2}} = 300 - \lambda + \frac{\mu_8}{7} - \nu_2 = 0,$$

$$\frac{\partial L}{\partial P_{g7}} = 150 - \lambda + \frac{5 \cdot \mu_8}{7} = 0,$$

$$\frac{\partial L}{\partial \lambda} = 715 - P_{g1} - P_{g2} - P_{g7} = 0,$$

$$\frac{\partial L}{\partial \mu_8} = 200 - \frac{2510}{7} + \frac{(5 \cdot \mathrm{P}_{g7})}{7} + \frac{\mathrm{P}_{g2}}{7} = 0,$$

$$\frac{\partial L}{\partial \nu_2} = 50 - \mathrm{P}_{g2} = 0$$

Nodal pricing (simple example)

Values of multipliers:

$\lambda = 100$ $\mu_8 = -70;$ $\nu_2 = 190$

$$\mu_L^T = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & \mu_8 \end{pmatrix}$$

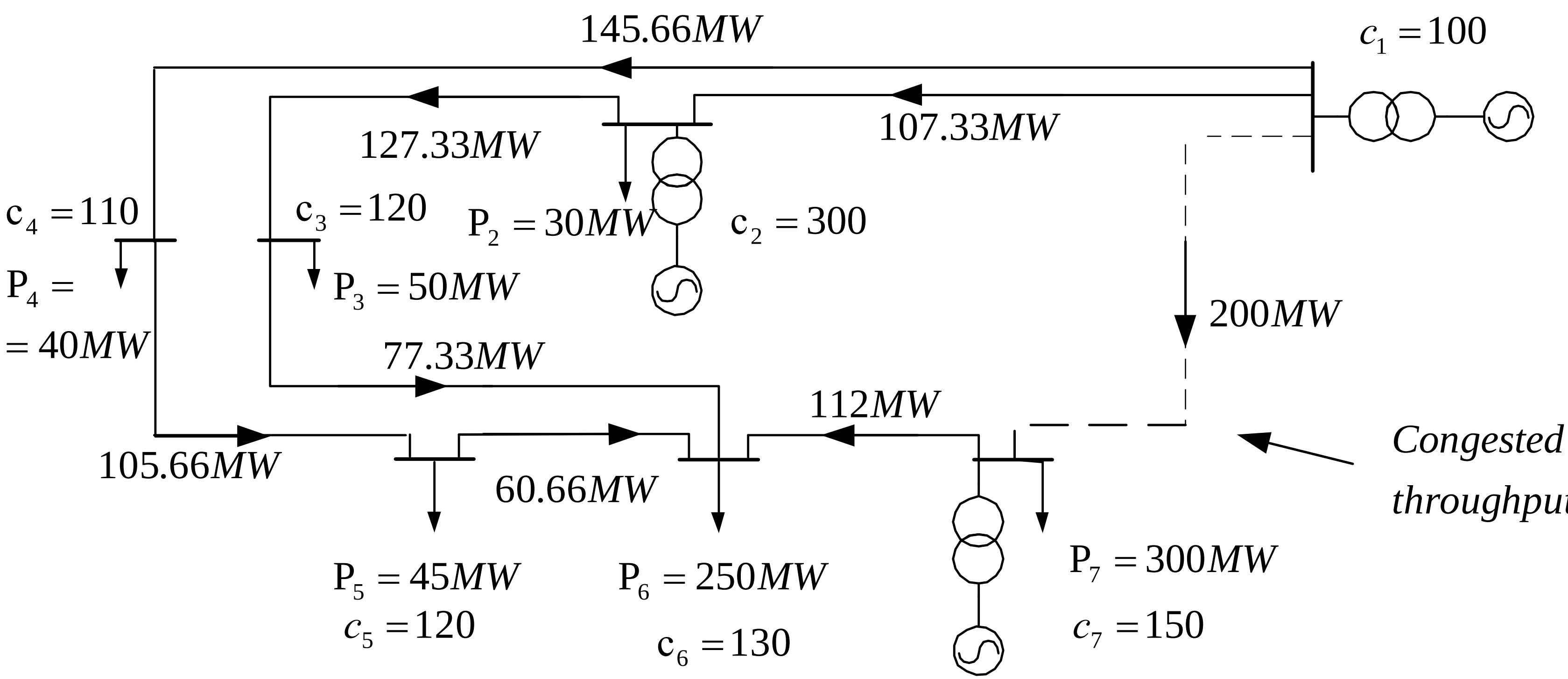
$$\nu_p^T = \begin{pmatrix} 0 & \nu_2 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$c_n = \lambda \cdot u + \nu_p + A^T \cdot \mu_L$$

Nodal prices in the system:

$$c_n = \begin{pmatrix} c_{n1} \\ c_{n2} \\ c_{n3} \\ c_{n4} \\ c_{n5} \\ c_{n6} \\ c_{n7} \end{pmatrix} = \begin{pmatrix} 100 \\ 100 \\ 100 \\ 100 \\ 100 \\ 100 \\ 100 \end{pmatrix} + \begin{pmatrix} 0 \\ 190 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 10 \\ 20 \\ 10 \\ 20 \\ 30 \\ 50 \end{pmatrix} = \begin{pmatrix} 100 \\ 300 \\ 120 \\ 110 \\ 120 \\ 130 \\ 150 \end{pmatrix}$$

Nodal pricing (simple example)

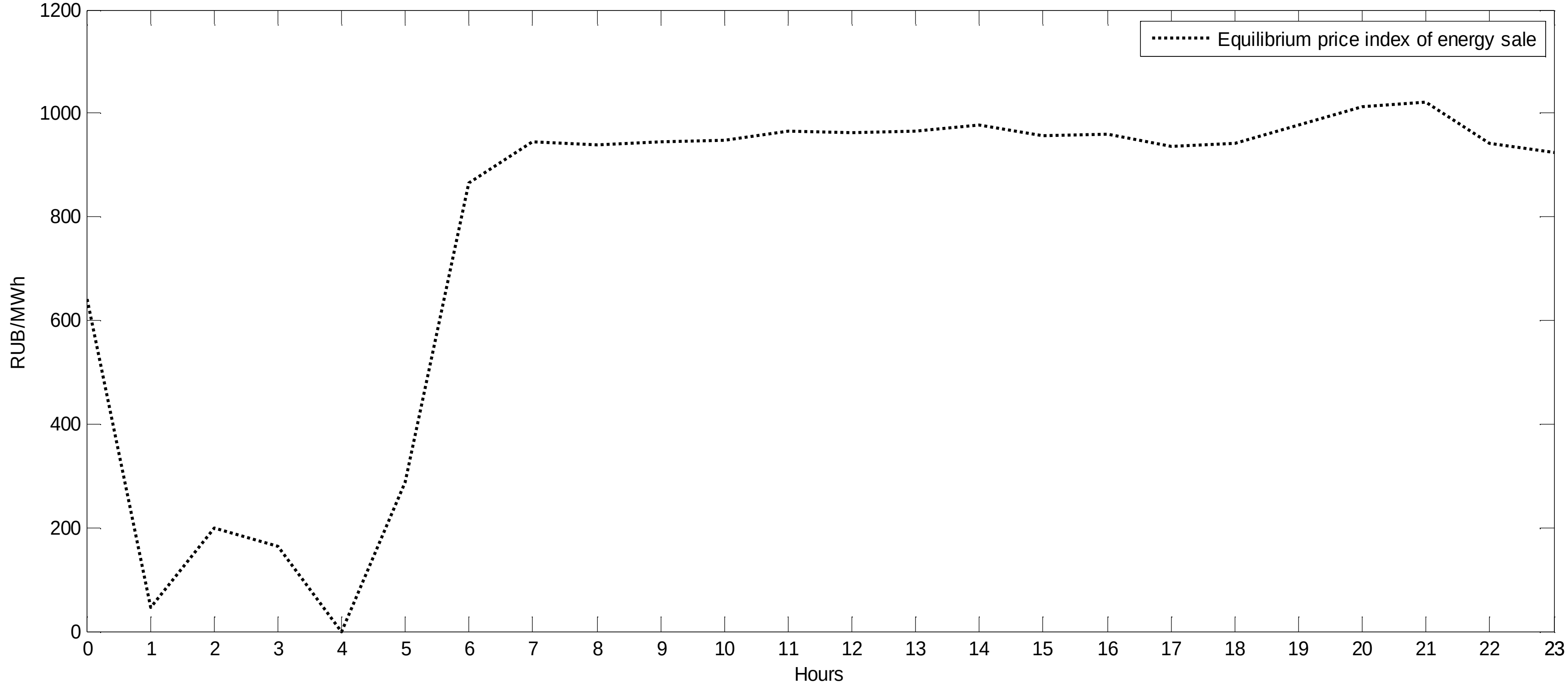


Nodal pricing

- Less opportunities for the generators without dominating position to exercise market power – additional loading of transmission line can be “cheaper” than activating “expensive” capacities
- Simultaneous increase of prices at several nodes by more than 30% “draws attention” of the “Federal Antimonopoly Service”
- Constant presence of production and purchase prices imbalance

Energy market risks

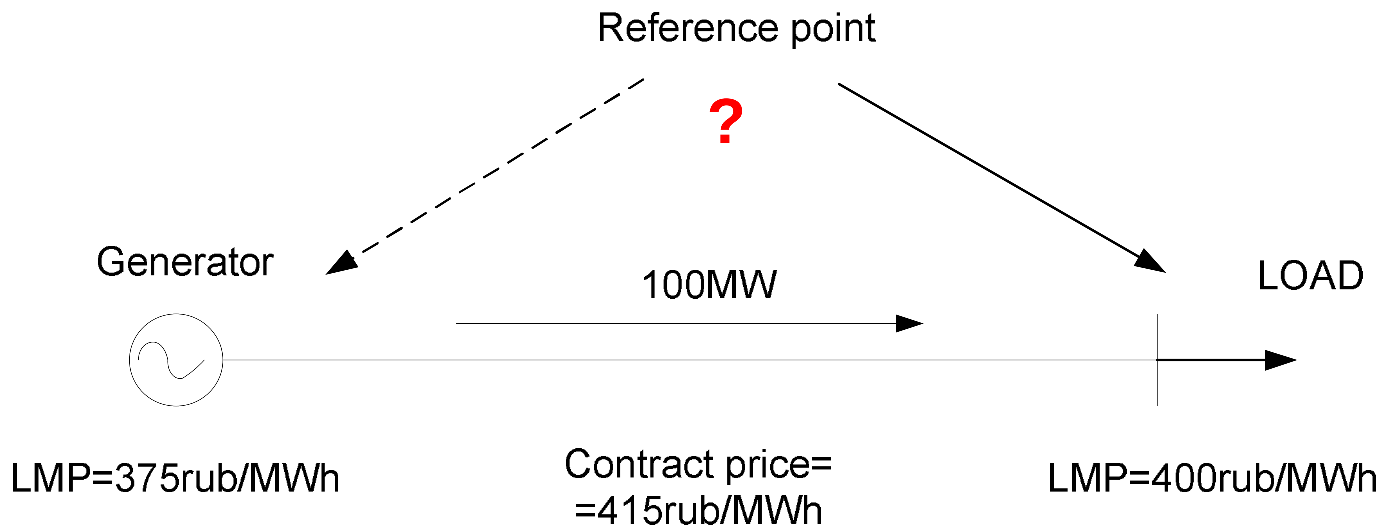
Example of the average day-ahead prices of energy in UES “South” (Operation day 23.09.2010)



Forward contracts

- Hedge the market participants against undesirable spot price changes
- Purely financial contracts (all energy is sold and purchased in the spot)
- OTC and exchange forward contracts

OTC forwards (example)



Generator	Purchaser
Gets from a purchaser: (415-400)*100=1500 rub	Transfers to a generator: (415-400)*100=1500 rub
Sales in the spot market: 375*100=37500rub	Buys in the spot-market: 400*100=40000
Total revenue: 37500+1500=39000rub	Total cost: -1500-40000=-41500rub

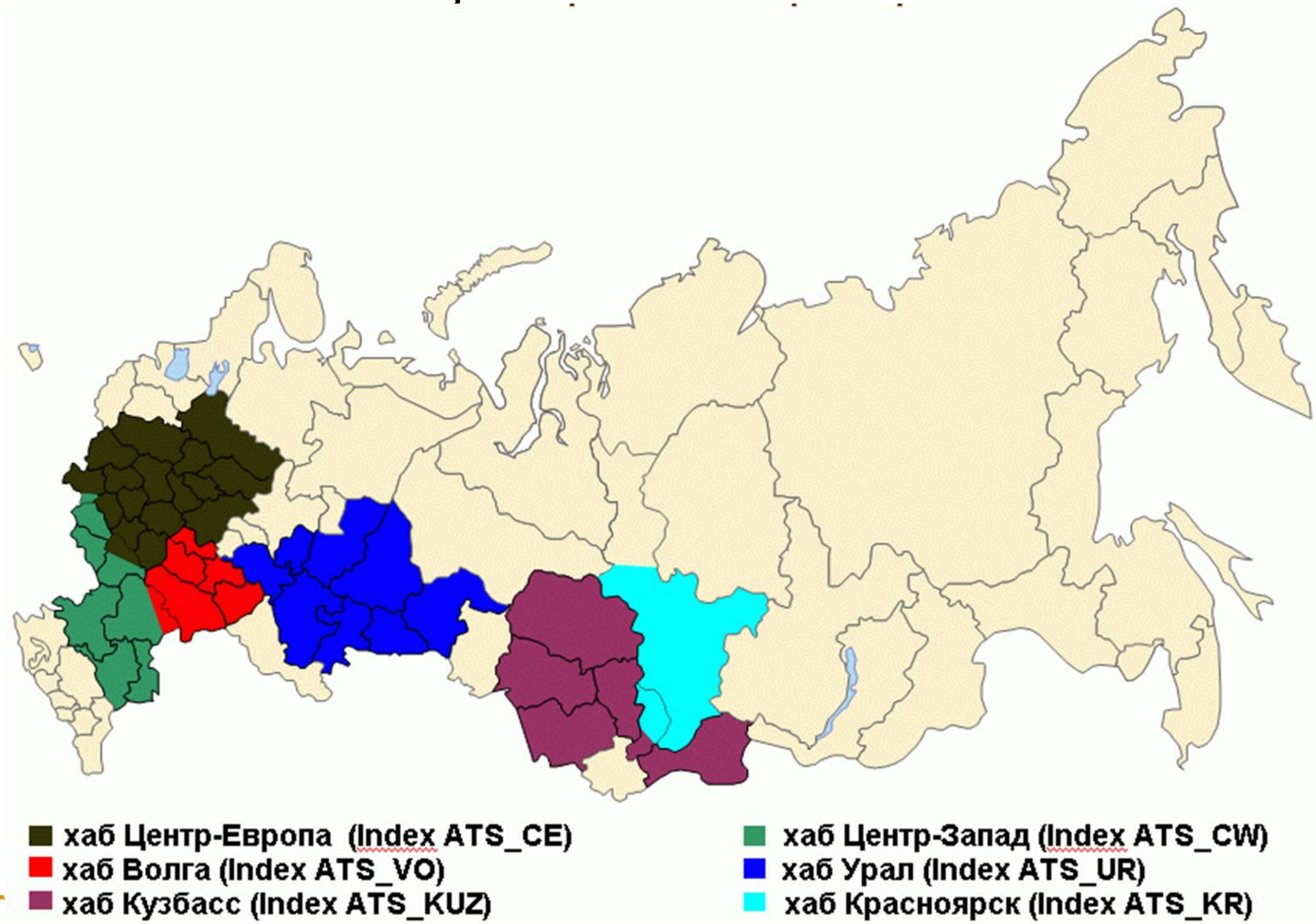
Exchange forwards

- Counterparties: the market participants located in the same price areas
- Time horizon: weeks and months (6 months at maximum)
- Volumes in contracts : are determined by the market participants in their offers to the Exchange
- Contract price : matching of prices in counter offers
- Reference point to a contract: Hub

Spread the risks of nodal price difference payments between the counterparties!

Exchange forwards

Hubs on the power market

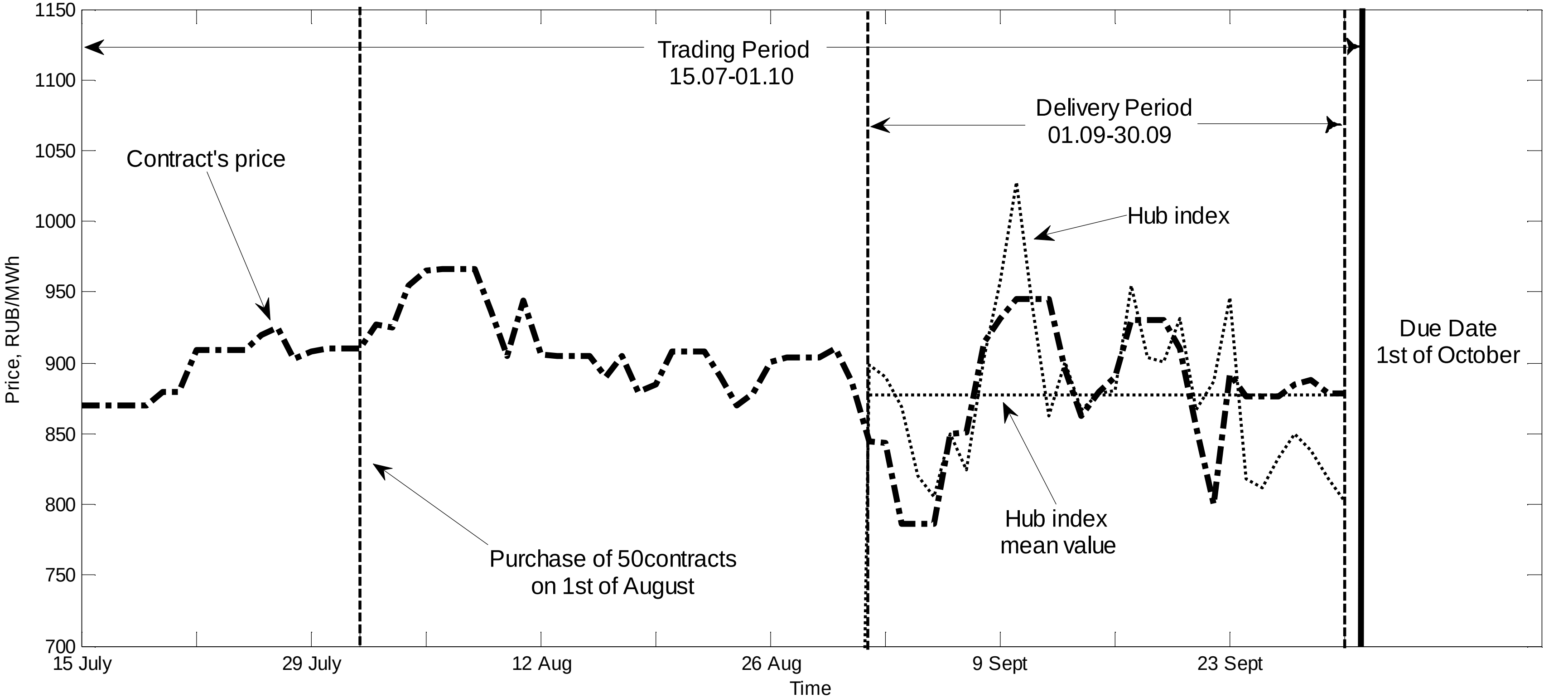


Source: Commodity Exchange "ARENA" 2008

Futures

- Highly standardised exchange-traded monthly base and peak load contracts
- Standard energy delivery rate 100 kW
- Underlying assets are the monthly average spot-market prices in the hubs “Central” and “Ural”
- Daily mark-to-market and final spot reference settlement
- Performance bond defines on a daily basis and makes up 4-15% of the contract’s cost
- A little risk of a counterparty’s default

Futures (example)



Some conclusions

- The forwards and futures do not protect the market participants against basis risk! They serve as a mean of additional revenues or losses but barely could be used as a hedging instrument.
- Solution: market of financial transmission rights!

Capacity market

Capacity market

- Sale of capacity means obligation of a generator to produce energy in amounts sufficient to cover consumption at peak hours

- Purchase of capacity means a right of a consumer to claim readiness of generating equipment to produce power at peak hours

Capacity market model

- Regulated contracts
- Capacity auctions
- Capacity forwards
- Long term agreements with new hydro/nuclear generation
- Capacity Delivery Agreements with new heat generation
- Contests of investment projects

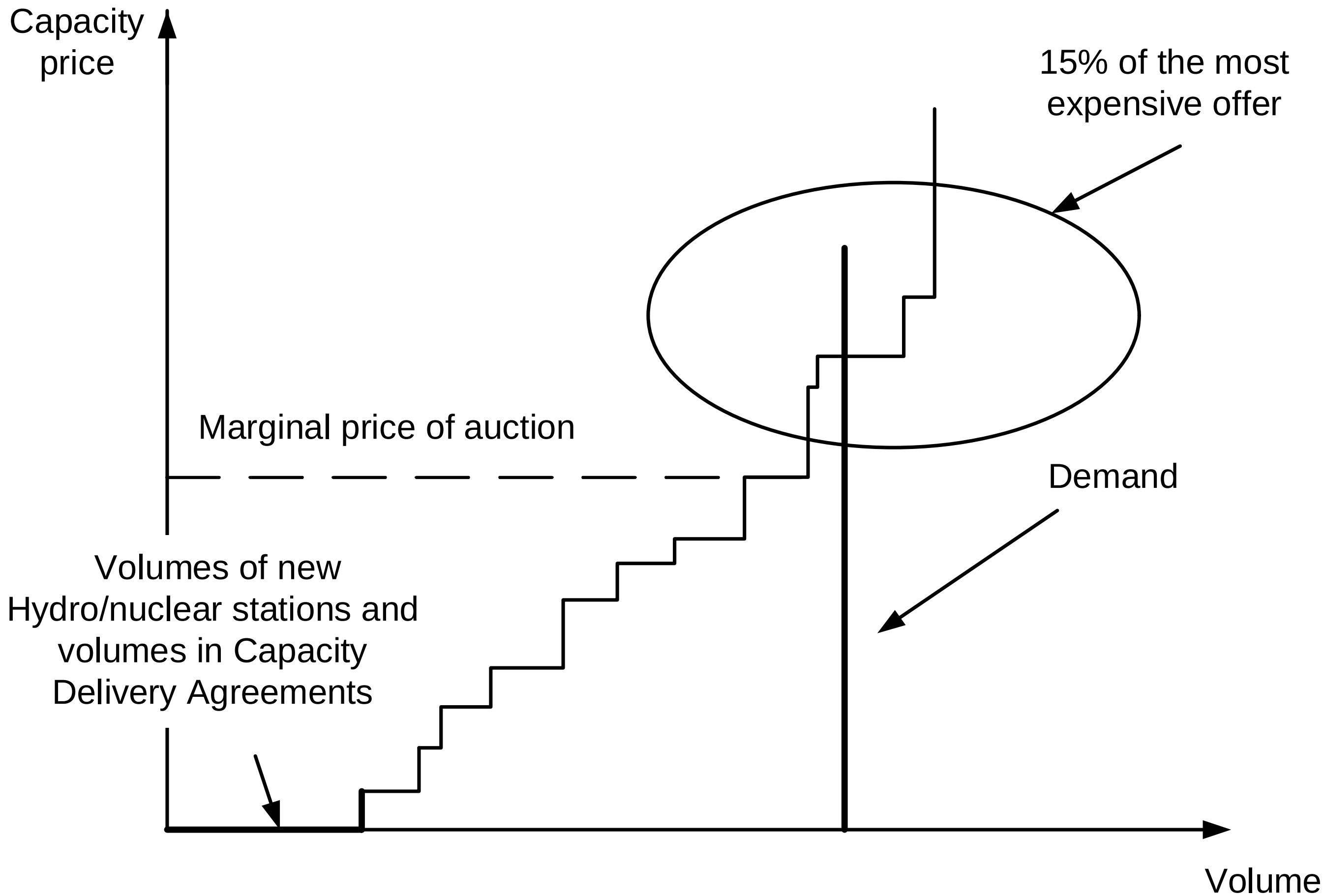
Capacity market

Long-term auction model

- Annual competitive auctions to select capacity 4 years ahead
- “Price caps” in the areas of free power flow with restraint of competition
- Generators get payments at marginal price of auction
- 15% of generation with monopoly position and 15% of the most expensive generation do not participate in price formation

Capacity market

Long-term auction model



Capacity market

Long-term model

Reduced incentives to conclude bilateral forward contracts for capacity:

- Fixed price of auction for the next 4 years
- Contracts are not allowed between the counterparties from different areas of free power flow

Capacity market

Capacity Delivery Agreements

- Invented by the Ministry of Economical Development to get the guaranties of new stations' construction from private generators
- Allow generators to reimburse substantial share of their investments in new capacities

Capacity market

Capacity Delivery Agreements

- Payback period: 15 year
- Guaranteed payments under an agreement during the first 10 years only
- Basic rate of return under an agreement is 14% but this value is rectified each year in accordance with IRR of the state bonds
- Penalties at a rate 25% of investments and obligation to submit the price accepting offers to auctions in case of late start-up

Capacity market

Capacity Delivery Agreements (Example)

Capacity Prices for gas generation 200 MW under an agreement

Year	Price, RUB/MW per month
1	655540
2	657570
3	660040
4	663010
5	666520
6	670640
7	675430
8	680970
9	687340
10	694660
11	703020
12	712560
13	723450
14	735850
15	749970

Approximately 4-6 times higher than capacity prices in the auctions 2008-2010 and “price caps” in 2011

Capacity market

Capacity Delivery Agreements

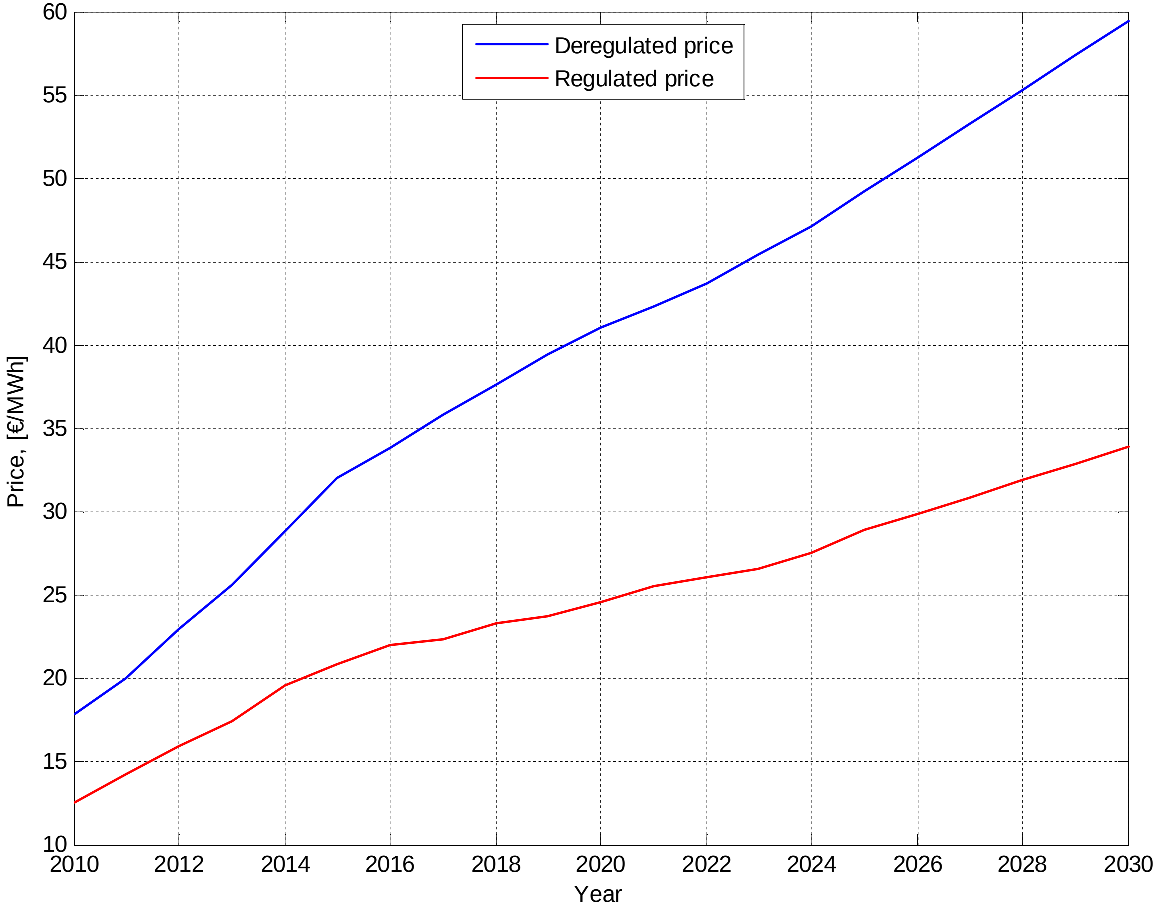
- The total volume of capacity put into operation under Capacity Delivery Agreements between 2007 and 2017 will be 30475 MW. Presumably, it will cover most of capacities deficit in the upcoming years

Energy and Capacity Prices

- **Average energy prices in 2010:**
- **Russia (**1st Price Area) – 21.7 €/MWh
- **Russia** (2nd Price Area) – 12.5 €/MWh
- **Nordpool** – 53.1 €/MWh
- **EPEX** – 50.4 €/MWh

Energy price forecast

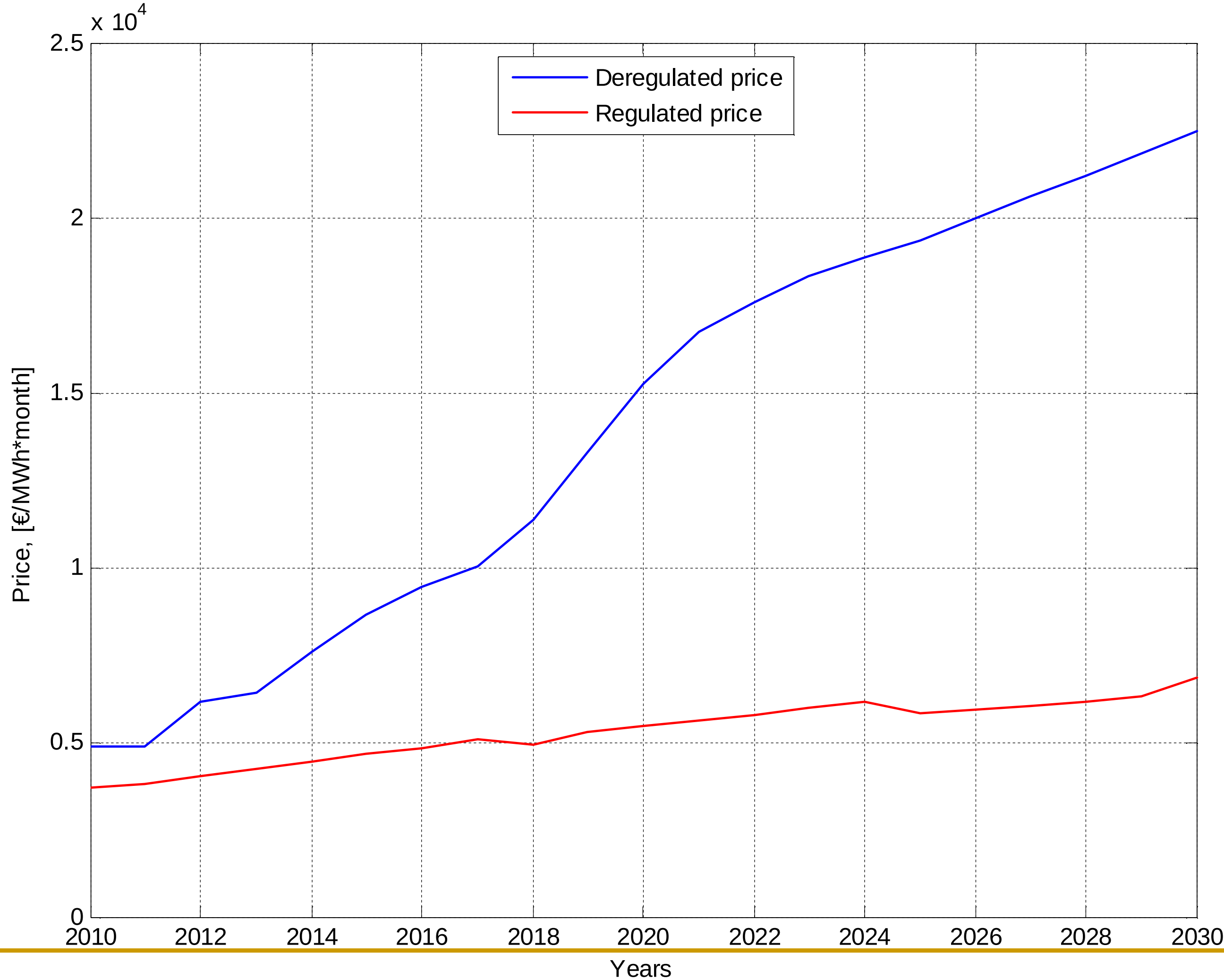
Electricity price growth forecast in Russia (€/MWh)



Source: General plan of the power industry development up to 2030

Capacity price forecast

Capacity price growth forecast (€/MWh*month)



Source: General plan of the power industry development up to 2030

Thank you for attention!