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EUROPEAN UNION
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Operational Programme Research,
Development and Education



ECONOMY AND MANAGAMENT IN POWER ENGINEERING

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1st lecture

Content

- Organizational matters
- Content of the subject
- Basic economical and power engineering terms
- Specificities of electrical power system
- Technical and economical factors, which describe economics of production and supply of electrical energy

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Organizational matters

- **Credit** is conditional by:
  - Solution of semestral works
- **Exam**
  - Just written exam
  - 2 parts
    - Mathematical example
    - Theoretical questions

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Content of the subject

- Methods and instruments which are use to operate, to run and to develop electricity supply system (EPS):
  - Economical coverage of load diagram by power plants, costs of production electricity, load ratios
  - Economic device of company and their optimization
  - Interest running, amortization, accumulating
  - Criteria for weighted effectiveness (power) investment (crit. clean gain, clean prime cost, inner interest measurement etc ..)

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Basic energetic terms

- **Power engineering** – branch, which deals with question obtaining, conversion and energy utilization, investigation and formulate purposes and law behaviour energy system (system – set element and bindings between them)
- **Energetic facilities** – each technical facilities used for safeguard production, transmission, distribution and consumption of all kinds of energy
  - 3 basic kind of facilities:
    - transformative natural forms energy to forms technically usable (steam-generator, hydraulic turbines,...)
    - transformative one kind energy on other (electric generator, engine...)
    - transformative only characteristics definite energy (transformator, heat exchanger)
- **Energy power system** – set of power arrangement servant to production, transmission and distribution different forms energy (electricity, heat, gas, bearer energy)

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Energetic systems

- **System of power plants** – set of multiple cooperative power stations (and heat stations) controlled by central dispatcher services
- **Electricity supply system** – covers system of power plants and power arrangement which servant to transportation and to change parameters of electrical energy and to use by consumer
- **System of heat stations** – set of multiple cooperative heat stations controlled by central dispatcher services
- **System of heat supply** – constitution of system of heat stations which supply consumer by heat
- **Gas supply system** – system which consist cooperative and mutually interconnected gasworks and station for adjustment natural gas controlled by central dispatcher services
- **System of gas supply** – is constitution from system of gasworks, storage battery gas (gas-holder), gas main, compression and reducing station and arrangement for use supplied by gas near consumer

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Basic economical terms

- **Economy** – serviceable control of system which leads to our target with the best parameters of this system
- **Energy economy** – it is first point which is outspead to electricity supply system
- Electricity supply system can be example of **economy system**, as system element are power station and power control nets with different voltage surface and electrical appliances and where structure are e.g . sources, possibilities of placing power plants or appliance

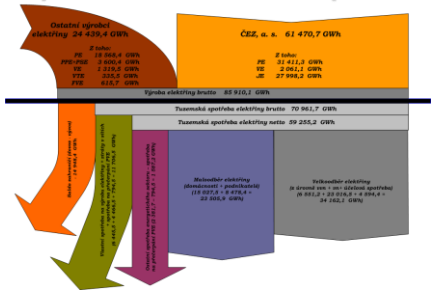
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Energy sources of the Czech Republic (CZ) - location, structure



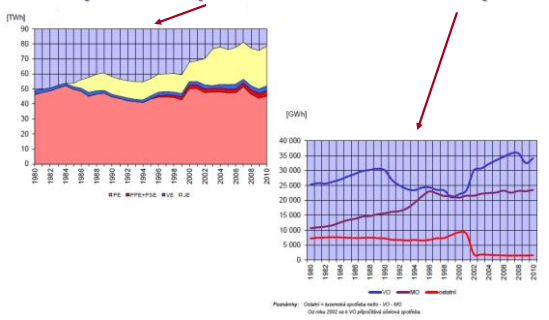
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Energy sources of the Czech Republic – production X consumption



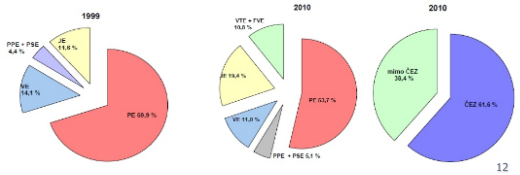
http://www.eru.cz/user_data/files/statistika_elektro/rocni_zprava/2010/pdf/energie.pdf

Energy sources of the Czech Republic – development of production and consumption

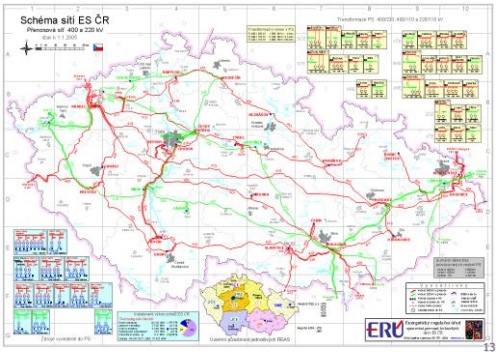


Energy sources of the Czech Republic – development and structure of installed electrical power output [%]

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PE	69,9	70,6	70,2	65,3	61,4	61,4	61,2	61,1	60,6	60,3	59,5	53,7
PPE + PSE	4,4	4,3	4,5	4,7	4,5	4,5	4,6	4,6	4,6	5,1	5,3	5,1
VE	14,1	13,7	13,0	13,1	12,4	12,1	12,4	12,4	12,4	12,3	11,0	11,0
JE	11,6	11,0	11,4	16,6	21,7	21,6	21,6	21,7	21,4	21,4	24,0	29,6
VTE + FVE	0,0	0,0	0,0	0,3	0,1	0,1	0,1	0,2	1,0	1,1	2,0	10,6
Sumy ČR	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
z toho ČEZ	85,1	85,3	85,2	69,1	70,1	69,7	69,61	69,44	69,23	69,0	67,5	61,6
instalovaný výkon [MW]	15 708,4	16 323,8	16 444,4	16 310,5	17 344,1	17 434,1	17 417,2	17 607,6	17 561,3	17 724,1	18 324,7	20 272,8

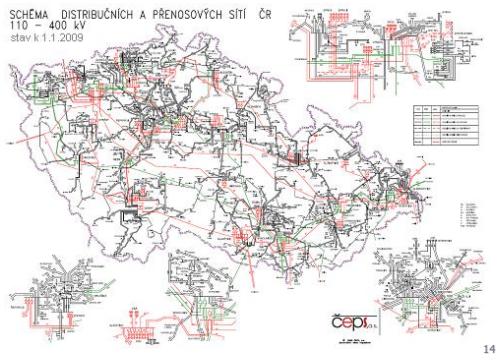


Electrical networks of the CZ EPS



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Electrical networks of the CZ EPS



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Specificities of electric power system (EPS)

They are connected with production strings:

production → storage ? → transmission → storage ? → consumption

- **Unstorability** of electrical energy
  - production have to be same like consumption ⟹ we need the reserve, e.g. in case of failure
  - further shown on load chart
- **Very fast transient processes in the EPS** ⟹ demand great investment in security system
- **Versatility in the use** of electrical energy ⟹ every fault very noticeable

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Advantage of electric energy

- Easy **conversion** into another sort of energy (mechanical, heat) or electric with other parameters in place of consumption
- Easy **regulation**
- Easy **transport** of large quantities over long distances
- **Cleanness** at it using

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Basic characteristics and parameters of EPS (1)

- For each electric power plant (machine) we can define:
  - **Nominal power output** – maximal power output that must power machine permanent supply at compliance with his basic parameters
  - **Economy power output** – optimal power output at which the power plant or machine has maximum efficiency

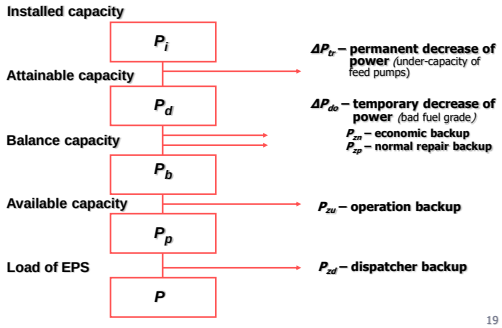
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Basic characteristics and parameters of EPS (2)

- **Installed capacity** – the sum of nominal power outputs of individual power machines
  Example: P_{iELNY} = the sum of nominal power outputs of all generator
- **Attainable capacity** – maximum output, whose it can be achieve in monitored period at given state of device (installed minus permanent power decrease)
  For example: in thermal power plant - insufficient output of feed pumps, lack of cooling water, etc.
- **Available capacity** – maximum output, whose it can be achieve in a certain time with respect to the current technical and operation conditions (attainable minus temporary power decrease)
  Example: : in thermal power station - downgrade fuel quality, repairs, ...

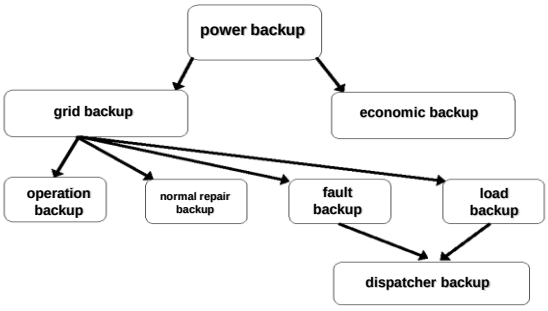
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Relations among EPS power outputs and power backups



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EPS power backups



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Indicators of EPS load (1)

- **Total Quantity of Produced Energy** $W_c = \int_0^{t_0} P dt$ [MWh]
  - the quantity of power output during monitored period t_o
- **Middle Load (Middle Power Output)**
  - the share of Total Quantity of Produced Energy and monitored period , then $W_c = t_o \cdot P_s$ **[MWh]** , which is shown in LD by rectangle about P_s , t_o sides $P_s = \frac{W_c}{t_0}$ [MW]
- **Maximum Utilization Time**
  - the time, that would power station need to production of energy quantity given by appropriate LD, if it would deliver maximum power output at all times, then $W_c = P_{max} \cdot T_m$ **[MWh]** , which is shown in LD by rectangle about P_{max}, T_m sides $T_m = \frac{W_c}{P_{max}}$ [h/den, rok]
- **Load Factor (Coefficient of Utilization)**
  - the ratio of the number of hours of Maximum Utilizition Time to the number of hours of monitored period $z = \frac{T_m}{t_0} = \frac{P_s}{P_{max}}$ [-]

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Indicators of EPS load (2)

Likewise as **Maximum Utilization Time** is:

$$T_m = \frac{\int_0^{t_0} P(t)\,dt}{P_{max}} = \frac{W_c}{P_{max}}$$

Time of Full Losses is the time during which the same amount of electrical energy would be lost in the lines at the maximum transmitted power output as in the variable load during the whole monitored period:

$$T_z = \frac{W_{cz}}{P_{max\,z}} = \frac{\int_0^{t_0} 3RI(t)^2\,dt}{3RI_{max}^2} = \frac{\int_0^{t_0} 3R\left(\frac{P(t)}{\sqrt{3}U\cos\varphi}\right)^2 dt}{3R\left(\frac{P_{max}}{\sqrt{3}U\cos\varphi}\right)^2} = \frac{\int_0^{t_0} P(t)^2\,dt}{P_{max}^2}$$

- according to technical Standard:

$$T_z = t_0\left[0{,}2\cdot\frac{T_m}{t_0} + 0{,}8\cdot\left(\frac{T_m}{t_0}\right)^2\right]$$

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Method of determination of load indicators

- **Numerical**
- **Graphic**

- Integration of load diagram (numerically and graphically)
- Construction of production curve, i. e. integration of power output duration curve (graphically)
- By help of Wolf's curve - relative formulation of power output ***p = f(t)*** (numerically)

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Wolf's curve

$$p = m + (1-m)(1-t)^k = \frac{P_{skut}}{P_{max}}$$

$$P_{skut} = P_{max}\cdot\left[m + (1-m)\left(1-\frac{T}{t_0}\right)^k\right]$$

$$m = \frac{P_{min}}{P_{max}} \qquad k = \frac{1-z}{z-m} \qquad t = \frac{T}{t_0}$$

- ***p*** ... coefficient of real load
- ***z*** ... load factor
- ***m*** ... coefficient of minimum load
- ***T*** ... time variable in time ***0 – t_0***

- Integration Wolf´s curve within limits ***0 – t_0*** we get

$$W_c = \int_0^{t_0} P_{skut}\,dt = P_{max}.t_0\left[m + (1-m)\frac{1}{k+1}\right]$$

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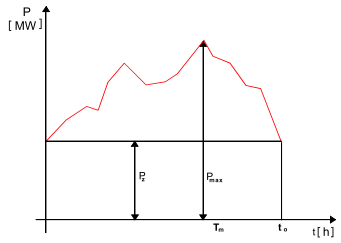
Graphic illustration of EPS, part of EPS or electric power plant load - definition

- **Load diagram** (LD) – time function of load (power output) in monitored period *0* - t_o [h] = day (DLD), week, month, year
- **Load duration diagram** (power output duration curve) – time function of a specific load over the monitored period by *0* - t_o [h]
- **Integrating curve of electric energy generation** (production curve) – dependence of produced energy quantity on load

$$W_c = \int_0^{P_{max}} t\,dP$$

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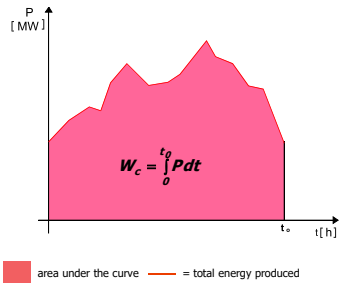
Load diagram of EPS (1)



P_z *(=* P_{min}*)* - basic (minimal) load
P_{max} - maximal load

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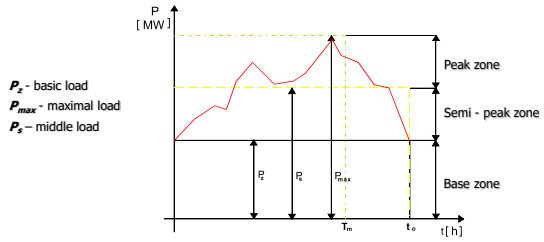
Load diagram of EPS (2)



area under the curve — = total energy produced

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Load diagram of EPS (3)

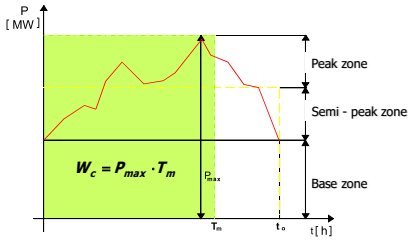


P_z - basic load
P_{max} - maximal load
P_s – middle load

area under the curve = total energy produced
= rectangle total energy produced
= rectangle total energy produced

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Load diagram of EPS (4)

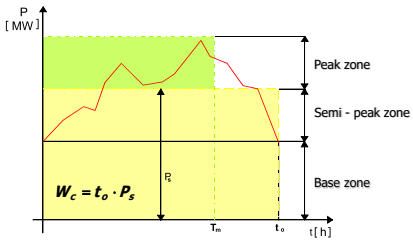


$W_c = P_{max} \cdot T_m$

rectangle = total energy produced
rectangle = total energy produced

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Load diagram of EPS (5)

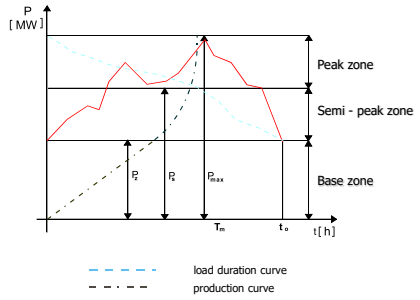


$W_c = t_o \cdot P_s$

rectangle = total energy produced
rectangle = total energy produced

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Load diagram of EPS (6)



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Allocation of power sources to the DLD

- **Base zone** - balance (exchange with other countries)
  - water though-flow power station (PS)
  - nuclear PS (Dukovany, Temelín)
  - classic thermal PS (Tisová, Prunéřov, Tušimice, Počerady, Ledvice, ...)
- **Semi-peak zone** - classic thermal PS
  - water storage PS (Vltavská kaskáda - Lipno, Orlík, Slapy, Štěchovice)
- **Peak zone** - pumped hydro PS (Dalešice, Dlouhé stráně)
  - steam-gas PS (Vřesová)

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System demand control in DLD

If load is well balanced then maximum utilization time is longer and costs are lower. There is bigger load factor which indicating utilization of power plants. If power plant is more busy then it pays sooner (installed power is saved).

- **Organization means** for leveling the DLD:
  - introduction of night rate in sale electric energy
  - regulation of working hour start
  - introduction of summer and winter time
  - ordering of LD to huge customer
- **Technical means** to ensure regulation of production according to consumer requirements (at all times a balance between production and consumption must be ensured):
  - deployment of pumping water power station (possibility of quick start if necessary)
  - introduction of HDO in important electrical appliances
  - interconnection of Europe states EPS

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