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Operational Programme Research, Development and Education

EMEE - Lecture n. 9

Determination of the exchanged goods quantity in the ES

"With every purchase, each customer must define what he wants to buy and how much he wants to buy. Then he should look for the supplier with the best offer. The brand plays no role in energy, we buy work with it we have to save so that we don't get too busy.

e.d.

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Lecture content

1) **What is the subject of exchange in the ES? ?**
2) **How is the ES exchange process implemented (in a market environment)?**
3) **How to determine the required amount of goods for the customer?**
4) **Determination of the price for delivered goods.**
5) **Methods of reducing the value of consumed power.**

Energy goods

- **Energy products are the final forms of energy coming from energy supply chains that transform and transport primary energy sources to consumers.**
- **The utility value of products in energy (final = utility energy form) is the ability of a product to do work.**
- **Physical expression of energy goods:**

Force = mass * acceleration : F = m. a [kg. m/s^2 = N]
Work =constant force acting on the track: W = F. l [N. m = J]
Power = work expended for time : P = W/t [J/s = W]

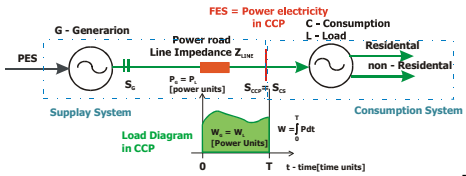
electric work - W_E = electricity [Ws]
heat work - Q (heat quantum) = shared heat [J]

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Goods (product) as the exchange subject

- **The goods enter to the process of exchange in the ES (exchange object) between the supplier and the customer (customer).**
- **It is offered through its utility that it can fulfill.**
- **The useful value of the product is given by the *physical properties* of the goods, and determines how the goods will serve the desired purpose of the customer:**

The ability of the gods in ES is to ensure the work W = Power Electricity in the Common Coupling (Connection) Point - whose quantity of the supply is defined by the Load Diagram in CCP.



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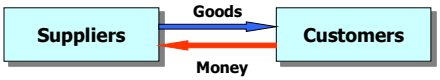
Performance requirements of electric appliances

- **The utility value of electricity is the ability to do work W [Ws] (electricity does work on appliances).**
- **The appliances transform into operation only the active component of the electrical power at the CCP [W], connection point.**
- **Most appliances (induction motors) also need a non-productive component of electrical power = Reactive Power Q [VAr] for their operation, which is not consumed. It travels from source to appliance and back at twice the frequency.**
- **Total power in CCP = Apparent Power S_{CCP} [VA].**
- **The supply of reactive power to the point of CCP increases the total required electricity in the CCP, and in addition loads the line, which reduces its transmission capacity and increases losses → the supply of reactive power will be charged.**

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The basic scheme of interconnections between the supplier and the customer

- The method of commodity exchange implementation on the market:



The mutual link is via commodity and cash flows:

1. **Customers want to buy goods**
2. **Looking for suppliers of goods**
3. **Suppliers will ensure supply of it**
4. **Customers pay for the delivery**

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The problem of the energy goods exchange proces

Time sequence of exchange process:

1. **The customer must provide the necessary quantity you want to buy.**
2. **Than he looking for supplier with offer at the suitable price at which he is able to deliver the goods – market.**
3. **Agreement shall be concluded on the implementation of trade.**
4. **Than the delivery of goods will take place - measurement of supply.**
5. **There will be payment for the delivery.**

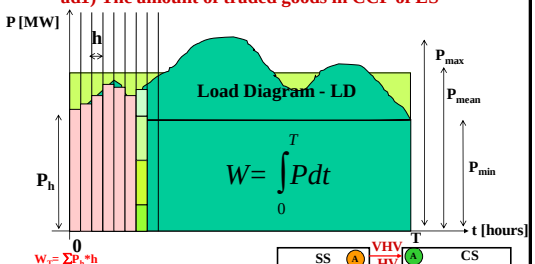
Ad 1. **The customer should determine the amount of goods (Load Diagram) in the period T of delivery time – He must know it or be able to determine it as accurately as possible – by using method of Typical Load Diagrams .**

Ad 4. **The supplier is not always, in the given period of time, able to meet the delivery of the goods (loss of production) - the system must constantly keep manufacturing or warehouse inventory balances, the law of conservation of energy. The measuring device is usually able to make the determination only of the exchanged goods = amount of work, but not its time dependence (immediate value = power).**

Ad 5. **Payment for the delivery = price of goods should respect all the costs that were caused by the collection from the supplier system.**

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ad1) The amount of traded goods in CCP of ES

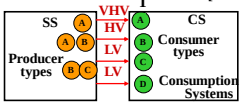


$W_T = \Sigma P_h * h$

Electricity is traded after 1 hour = h =1, for period T=24 = 1 Day, t = 0 - 24:

Work in 1 hour = 1 MWh = 1 MW

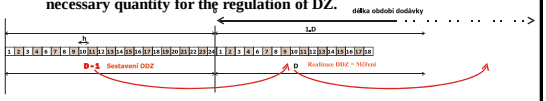
More P_{max} we want to buy, more we have to pay = Electricity prices are composed by two parts:
price for value of consumed work W_h,
price for P_{max} maximal power value



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Detrmination LD in day D-1 and its evolution (metering) in D

- The SS must know as accurately as possible the day before realisation (D-1) what will be the approximate course of the quantity of goods exchanged in the ES on day D - LDD, in order to be able to plan the necessary quantity for the regulation of DZ.



- The course of LD in D-1 can be determined on the basis of measured data from previous periods.
- The measurement in D determines the actual amount of supplied or consumed active or reactive electricity (PE) and its time course.
- Each supplier of PE to the CS and the customer from the CS must be legally equipped with measuring devices capable of recording LD values.
- Electricity metering and transmission of technical data is stipulated by National Decree of each country (in the Czech Republic by the Ministry of Industry and Trade by No. 359/2020 Coll.).

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Metering in coupling poins CP (Generating, Consumptions) in ES and recording equipment

- Measuring devices are used to measure electricity and evaluate the data, in order from the highest type A (measured at the highest voltage value in ES - VHV) to the lowest type C (LV). Measurements of LD course are single-tariff or multi-tariff - see. section 4 of the lecture.
- They recording the LD courses:
  - A - continuous measurement with remote daily transmission (duration of LDD is T = D). It measures the continuous recording of the mean value of active and reactive power for interval ¼ h – $P_{mean,1/4h}$.
  - B - continuous measurement with remote non - daily data transmission. Performs continuous recording of the mean value of active and reactive power for the measuring interval ¼ h; if it is not possible to carry out the remote data transmission for technical reasons, the data transmission may be carried out in a physical way.
  - The recording only mean value of the work during T – only P_{mean}:
  - C continuous measurement (integral), with or without remount data transmission.

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Metering point category of C without communication interface - C4

Measurement type C = integral, does not allow to measure the course of LD, i.e. it is able to determine only the total work in measure period in T with P_{mean} in CP, without maximal value – P_{max}.

- The value of the purchased / delivered P_{max} is limited (measured) by the necessary to be equipped in the CCP / CGP with a safety device (circuit breaker) that does not allow to pass of a higher value than P_{max} value of the breaker.
- C4 - basic type of mandatory CCP or CGP equipment (simplest) in place C of the electricity system on LV voltage level, which can be common if the coupling point is the same as for consumption and generation. This measurement may or may not be equipped with:
  - remote data transmission,
  - disconnection of the load / production, or its part (blocking).
- At least by measuring category C4, electricity must always be measured:
  - if it is only CCP and not CGP, which consumed electricity from the distribution system on LV,
  - and it is not necessary or impossible to equip the CP with a communication interface (respectively it is not required).

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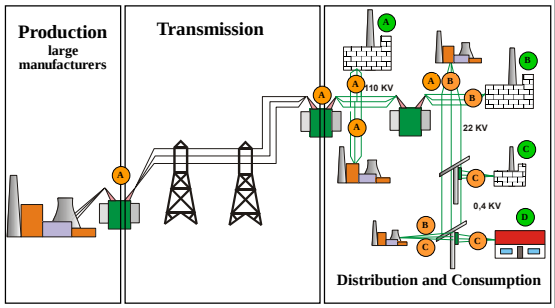
Metering category type of C with communication interface - C1 ÷ C3

The task of the communication interface (similar to remout load control) is the possibility of disconnecting and connecting the power consumption as well as the power supply to the ES. Metering interval is 1/4h and period of LD T is 1 month.

- C1 - for CCP with $W_{T^*CCP} > 6$ MWh during T and CGP and with $W_{T.CGP} > 6$ MWh, with $P_{G,\,max} < 10$ kW
  - the interface must allow remote disconnection/connection or limitation of power, i.e. the magnitude of the instantaneous power value, in CCP (consumption), so that it can be step-regulated. If it is not possible to carry out the remote data transmission for technical reasons, it is possible to carry out the data by a physical way.
- C2 - for CCP with $W_{T,\,POM} > 6$ MWh and CGP and with $W_{T.CGP} > 6$ MWh, with $P_{G,\,max} < 10$ kW
  - the interface must enable the function of technical blocking of appliances. If it is not possible to carry out the remote data transmission for technical reasons, it is possible to carry out the data in a physical way.
- C3 - for CCP and CGP without possibilities disconnection or blocking
  - If it is not possible to carry out the remote data transmission for technical reasons, it is possible to carry out the data by a physical way.
- If the supplier (CGM on LV) applies for hourly green bonus, he must be equipped with at least a type B measurement or a type C measurement of category C1, C2 or C3

Location of measurements LD in ES

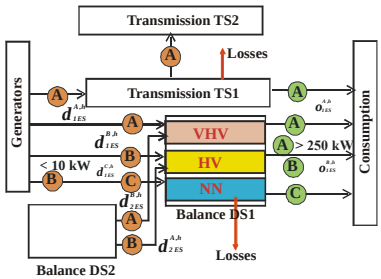
A B C Load diagram measurement Type of connected consumers (CCP)



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Measurement among TS a DS - balance

It is not possible to determine LD in C point, the measurement is only integral reading is performed once a year = duration T of diagram.



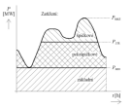
Energy Conservation - Production (supply d_h in hours h) = consumption (consumption o_h) + losses in transport = LDD duration of the diagram.

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Composition and tariffing of the price for electricity - price for work

- **The physical price of electricity per unit of electricity consumed (expressed in monetary units in hours h - c_{Eh}) in the evaluation period T (invoicing), is, with regard to the course of LD and the nature of the load, composed of several items = multi-component price:**
- **The main item is the price, in a given hour h, in monetary units for the amount of work consumed by the consumer:**

$c_{W,h}$ [m.u./Ws]



  - **$c_{W,h}$ depending on the suitability of the sampling to cover the LD by the supplier can be trifled, i.e. there is a difference in price when taking in the defined time of the DLD, subject to its use for defined types of appliances:**
    - **peak tariff (PT) at the time when the DLD performance reaches the value between Pmax-Pmean**
    - **semi-peak tariff (ST) in the power range Pmean - Pmin**
    - **low tariff (LT) below the value of Pmin**
  - **The total price for the labor consumed in the evaluation period T [hours] of delivery is given by the sum of the durations of the individual tariffs during the time T:**

$$C_{W,T} = c_{w,h}^{PT,T} \sum_h W_h^{PT,T} + c_{w,h}^{ST,T} * \sum_h W_h^{ST,T} + c_{w,h}^{LT,T} * \sum_h W_h^{LT,T} \quad [m.u./\ for\ T] \qquad [1]$$

  - **Exceeding (+) or under spending (-) may be penalized for non-compliance with the terms of the contract:**

$$C_{W,T}^{+/-} = c_{w,h}^{+/-} * \sum_h W_h^{+/-} \quad [m.u./\ for\ T] \qquad [2]$$

Composition of electrisity price – price for power

- **Price for consumed power $C_{P,T}$ in [m.u./for T] in the time of LD_T, i.e. for the total time of evaluation interval T can be composed from:**
  - **prices for the maximum values of the consumed average power in ¼ h during T - $c_{1/4hPmax,T}$ [m.u./ W], which is the evaluation interval. The customer can negotiate this value in advance or pay according to the actual measured value:**

$$C_{Pmax,T}^{tech} = c_{Pmax,T}^{tech} * P_{max,T}^{tech} \quad [m.u./\ for\ T] \qquad [3]$$

  - **prices for the maximum values of the consumed average power in ¼ h during T - $c_{1/4hPmax,T}$ [m.u./ W], which is the evaluation interval. The customer can negotiate this value in advance or pay according to the actual measured value+:**

$$C_{Pmax,T}^{1/4h} = c_{Pmax,T}^{1/4h} * P_{max}^{1/4h} \quad [m.u./\ \ for\ \ T] \qquad [4]$$

    The actually measured value is suitable for consumption whose value during the duration of DDZ T = month varies (seasonal consumption). The price is usually higher than the contracted value
  - **(exceeding +) / (under spending -) of the value 1 / 4hPmax may be a burdened payment for non-compliance with the contractual conditions c +/-, 1 / 4P, T [p.j./ W]**

$$C_{Pmax,T}^{+/-,1/4} = c_{Pmax,T}^{+/-,1/4} * \sum_h P_{Pmax,T}^{+/-} \quad [m.u./\ for\ T] \qquad [5]$$

  - **Exceeding the power factor value is calculated from the ratio of the measured values of reactive inductive energy in kVArh and active energy in kWh at the same time, and the corresponding cosφ is added to this.**

Composition of electricity price – price for consumed reactive power

- **The price for the consumed reactive power of the consumer is given by the price for 1 unit $c_{Q,T}$ [m.u./VArh] of the consumed reactive power in a given hour when the limit value of the power factor cosφ is exceeded - (0.95 - inductive):**

$$C_{Q,T} = c_{Q,T} * \sum_h Q_h \quad [m.u./\ for\ T\ \ period] \qquad [6]$$

- **Exceeding the power factor value is calculated from the ratio of the measured values of reactive inductive energy in kVArh and active energy in kWh at the same time, and the corresponding cosφ is added to this. :**

$$tan\varphi = \frac{\sum_h Q_h}{\sum_h W_h} \left[\frac{kVAr}{kW}\right], cos\varphi = \frac{sin\varphi}{tan\varphi} [-] \qquad [7]$$

- **The method of determining the price surcharge for non-compliance with the power factor is given for the relevant ES price decision of the Energy Regulatory Office.**

Power factor band	Taxes for p.f.				
	tg φ min [-]	tg φ max [-]	cos φ min [-]	cos φ max [-]	[-]
1	0	0,328	0,95	1	0
2	0,329	0,484	0,9	0,949	0,0285
3	0,485	0,750	0,8	0,899	0,1238
4	0,751	1,020	0,7	0,799	0,2807
5	1,021	1,333	0,6	0,699	0,4858
6	1,334	a vice	0,0	0,599	1,0000

- **Payment for reactive energy consumption is not made for the category of customers with measurement C - it is not equipped with the relevant 4-square measurement (reactive power measurement).**

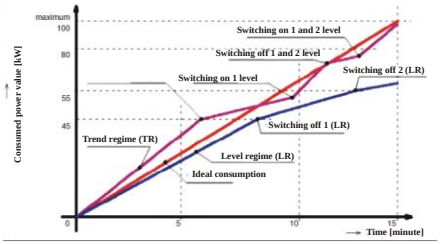
Conclusion with electricity price

- Defining the required exchange quantity between suppliers and consumers is the basic point for carrying out the exchange.
- In the ES, this quantity is set by the consumption, which is the power demanded by the consumer.
- Due to the accumulation of consumption in the time zones of the day, LD is not uniform (peak load) and its coverage must be ensured by overproduction in sources and greater load on transport routes / losses / - costs increase that must be covered by price - the price is multicomponent respecting both time of consumption , as well as the value of power consumed.
- If the appliance also needs a non-transforming power component (reactive power), it must also pay for it or make it itself (compensation).).
- If customers or suppliers are equipped only with integral measurement (category C), they cannot measure the course of LD, therefore it is necessary to find an alternative methodology for LD determining of their LD, which would be able to determine it with the least possible error.
- The price for power taken from the ES is always relatively high, so it is appropriate for customers to reduce this value. Although the customer needs a technical Pmax, he can use organizational measures to transfer it outside the peak part of the LD and determine the value of ¼ h Pmax.
- Failure to exceed this value, and the increased costs here, can prevent regulation capable of maintaining this value.

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Regulation of consumed power P_{max} – regulator of 1/4h P_{max}

- The purpose of using 1 / 4hPmax controllers is to limit power peaks and thus limit technical and 1 / 4h maximum power.
- The restriction is reflected in the total price of C_E [m.u. / per T], when the period T (invoicing) is one month.
- Regulation is performed by disconnecting / connecting appliances, which can be done organizationally or using automation
- Regulation takes place in two basic modes:



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Level regulation mode P_{max}

- Level regulation Pmax - level regime (blue curve) evaluates the collected work in 1 / 4h = $W_{1\,/\,4hPmax}$, (production line W = f (t)) - consumption of the consumer system is taken at a constant value of $P_{1\,/\,4hmax}$.
- If a higher value is taken than the planned value $P_{1\,/\,4h,\,max}$, the time of reaching the maximum value of consumed work W_{HR1} for the period $T_{HR1,Actual}$ compared to the planning time $T_{HR1,Plan}$, The basic trend plan (proportional to the production line directive) is shortened, because it must be true that the production $W_{1\,/\,4hPmax,\,Plan}$ is achieved at a shorter time:

$$W_{HR1} = P^{1/4h}_{P\max,Plan} * T_{HR1,Plan} = P^{1/4h}_{P\max,Actual} * T_{HR1,Actual}$$

When this time TR1 is reached, the light signaling switches on,
When TR2 is reached, the audible alarm sounds.
When TR3 is reached, consumption is switched off.
After reaching 1 / 4h, the consumption is switched on again

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Conclusion

- Knowledge of the course of LD for the monitored (invoicing) period is the necessary condition for evaluating the exchange process in the ES - prices for consumption,
- The basis of the exchange rate of goods is the more we take goods from the ES (work W), the more we pay.
- In the market economy, however, the principle of the wholesale discount is quite often.
- If he accepts the assumption that the evaluation interval LD of the exchange process in the ES must be the same for all customers (at least one day D), then its amount is limited only by the value of the consumed power.
- The cost of consumption will increase with the amount of power consumed by ES consumers.
- The effort of consumers is therefore to take consumption at the value of the average output in the consumption period T. This value is able to ensure the required value of work for appliances.
- Consumption at a constant = mean power, during T is usually impossible. However, this does not affect the fact that we should not try to do that, because it is possible to use organizational and technical means - to optimize the operation of consumption.
- These conclusions we can prove by real computation.

Nothing in a lifetime, let alone the amount of work required, remains constant. Our requirement is to look for methods to reduce the amount of work required while maintaining the required outputs. In the present, however, we must strive to maintain at least a constant value, because it brings us stability in any case.

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