EIHP

ELECTRICITY TRANSMISSION AND DISTRIBUTION NETWORK

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CONTENTS

- Quality of Service
- Network Losses
- Ancillary Services
- Congestion management
- T&D planning

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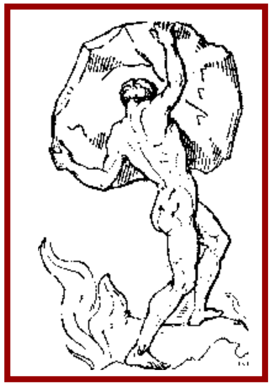
WORK EQUIVALENT TO 1 kWh



- -Ironing of 50 shirts
- -Preparing 70 cups of coffee
- -Watching TV for 7 hours
- -Washing 5 kg of loundry
- -Lighting of 100 W bulb for 10 hours
- -Warming up 80 liters boiler for 11’C

-1000 X 36 KG BAGS TO 3RD FLOOR= 1 kWh !

0.1 €/kWh !?

TRANSMISSION AND DISTRIBUTION MISSION

T&D networks are supposed to:

- Reach all consumers that want to be connected
- Meet their demands
- Provide satisfactory power supply reliability
- Provide power supply quality

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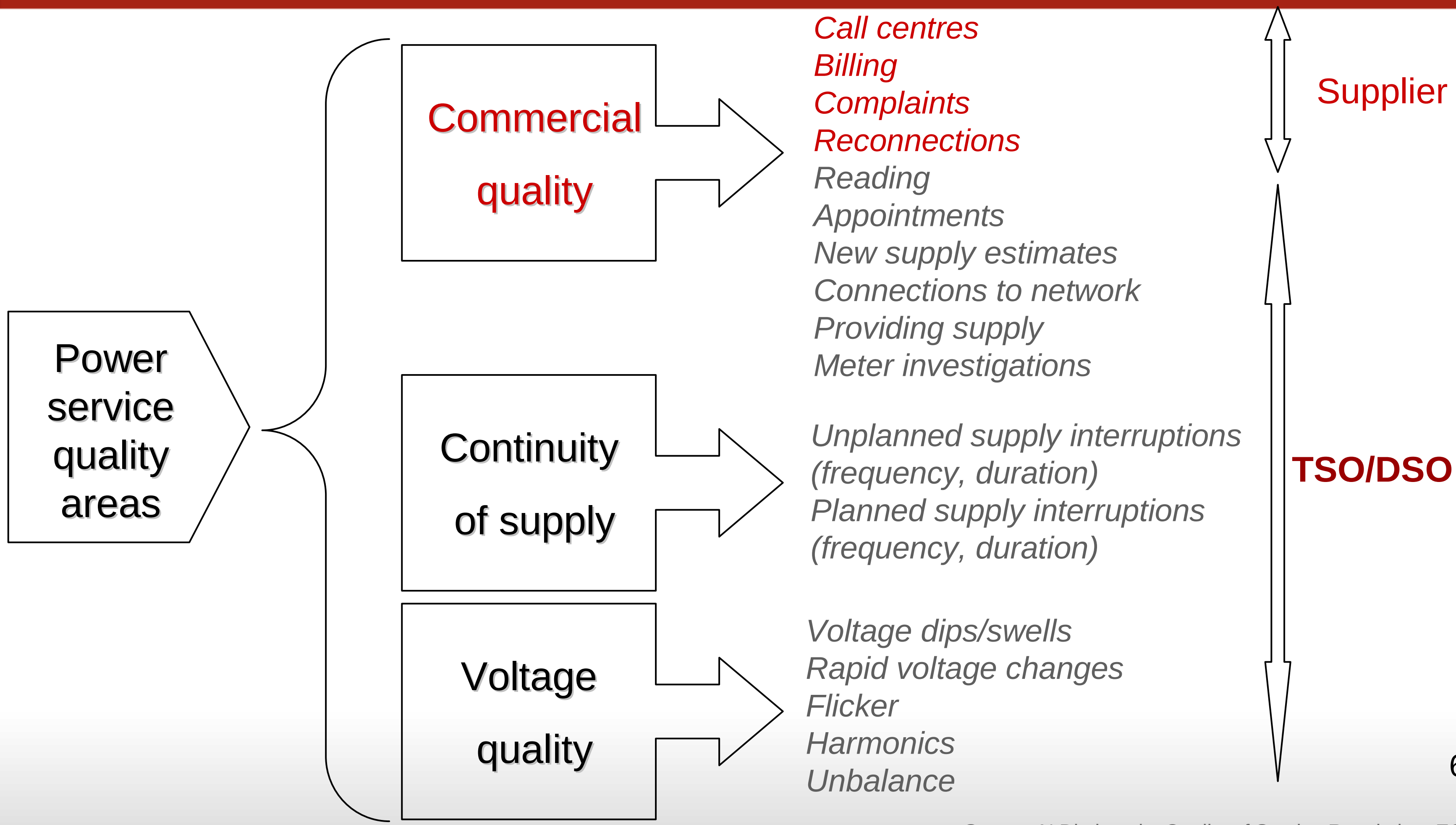
QUESTION

HOW TO MEASURE QUALITY OF TSO/DSO SERVICE?

TSO/DSO SERVICE QUALITY



Source: N.Dizdarevic, Quality of Service Regulation, ECS, 2010

TSO/DSO SERVICE QUALITY

ENS is a total amount of energy that would have been supplied to interrupted customers if there would not have been any interruptions

$$ENS = \sum_{i=1}^{K} P_i \cdot D_i$$

P_i is power disconnected during interruption i which can be extracted from customer load curve

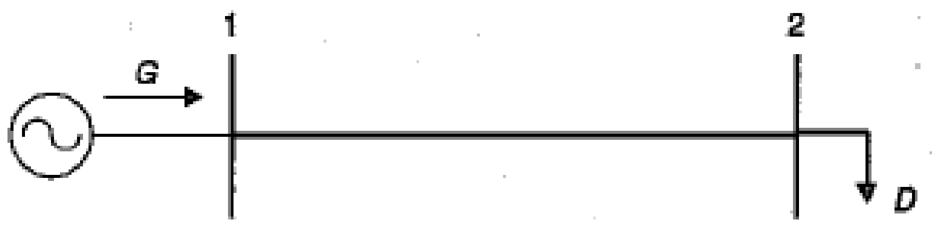
- ***measured and designed for a particular customer or***
- ***standardised load curve for a particular customer group to which the customer belongs***

TSO/DSO SERVICE QUALITY

Transmission networks and connected generators	Distribution networks
Designed to prevent interruptions in case of one-component outages (N-1 planning criteria) Interruptions only exceptionally due to significant failures of the power system	Usually operate radially (without redundancy) N-1 planning criteria not obligatory and even when applied not designed to prevent but to minimise the effects of interruption Generally, every component outage leads to interruption More components of generally lower reliabilities
About 5% of all interruptions	**About 95% of all interruptions**

NETWORK LOSSES

NETWORK LOSSES



Losses:

$$Loss = K \cdot P^2 = K \cdot D^2$$

Generation as a sum of demand and losses:

$$G(D) = D + L = D + K \cdot D^2$$

Generation increase due to demand increase:

$$\Delta G = G(D + \Delta D) - G(D) = \Delta D + 2\Delta D \cdot D \cdot K = (1 + 2 \cdot D \cdot K) \cdot \Delta D$$

Generation cost increase due to demand increase:

$$\Delta C = c(1 + 2 \cdot D \cdot K) \cdot \Delta D \qquad \frac{\Delta C}{\Delta D} = c(1 + 2 \cdot D \cdot K)$$

NETWORK LOSSES

Nodal prices are:

$$c = c_1$$
$$c_2 = c_1(1 + 2 \cdot D \cdot K)$$

Merchandizing surplus (MS) as value of energy sold at 2 minus cost of purchasing at 1:

$$MS = c_2 \cdot D - c_1(D + K \cdot D^2)$$

$$MS = c \cdot (1 + 2 \cdot K \cdot D) \cdot D - c \cdot (D + K \cdot D^2) = c \cdot K \cdot D^2$$

This is cost of supplying the losses.
Relevant for 2-bus system with one GEN with defined marginal cost (c) → difficult to define strict method for cost of loss quantification in more complex system

MS is rough indication of cost of losses

NETWORK LOSSES

In vertical organization: network losses are extra load

In market environment: must be shared in transparent and non-discriminatory way:

- **not separable of the transactions**
- **impossible to calculate it exactly**
- **significant arbitrariness in loss allocation**

LOSS ALLOCATION SCHEMES

Pro rata – proportional to active L or G no matter of location

Proportional to contribution of each G to each circuit flow
- Not possible to simultaneously allocate loss due to G and L

Proportional to sensitivities of loss to bus injections (ITL-incremental transmission loss)

Normalized quadratic function of bilateral transaction

…

NETWORK LOSSES

Three types of losses:

1. Variable losses (load or copper losses)
2. Fixed losses (iron or no-load losses)
3. Commercial losses (not billed or not paid)

Losses range in Europe:

Transmission: 2-4% of generated energy
Distribution: 4-9% of generated energy
South East Europe:
commercial loss ≈ 2 x variable loss

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NETWORK LOSSES

REGULATORY APPROACH:

1. Set “acceptable” level of losses

2. Determine incentive system for loss reduction

3. Measure real level of losses

4. Periodically update acceptable level of losses

NETWORK LOSSES

HOW TO DEFINE ACCEPTABLE LEVEL OF LOSSES?

1. Actual level of annual losses

2. Estimated target level of acceptable losses

3. Transitional mechanism through regulatory asset

NETWORK LOSSES

HOW TO SOLVE PROBLEM OF COMMERCIAL LOSSES?

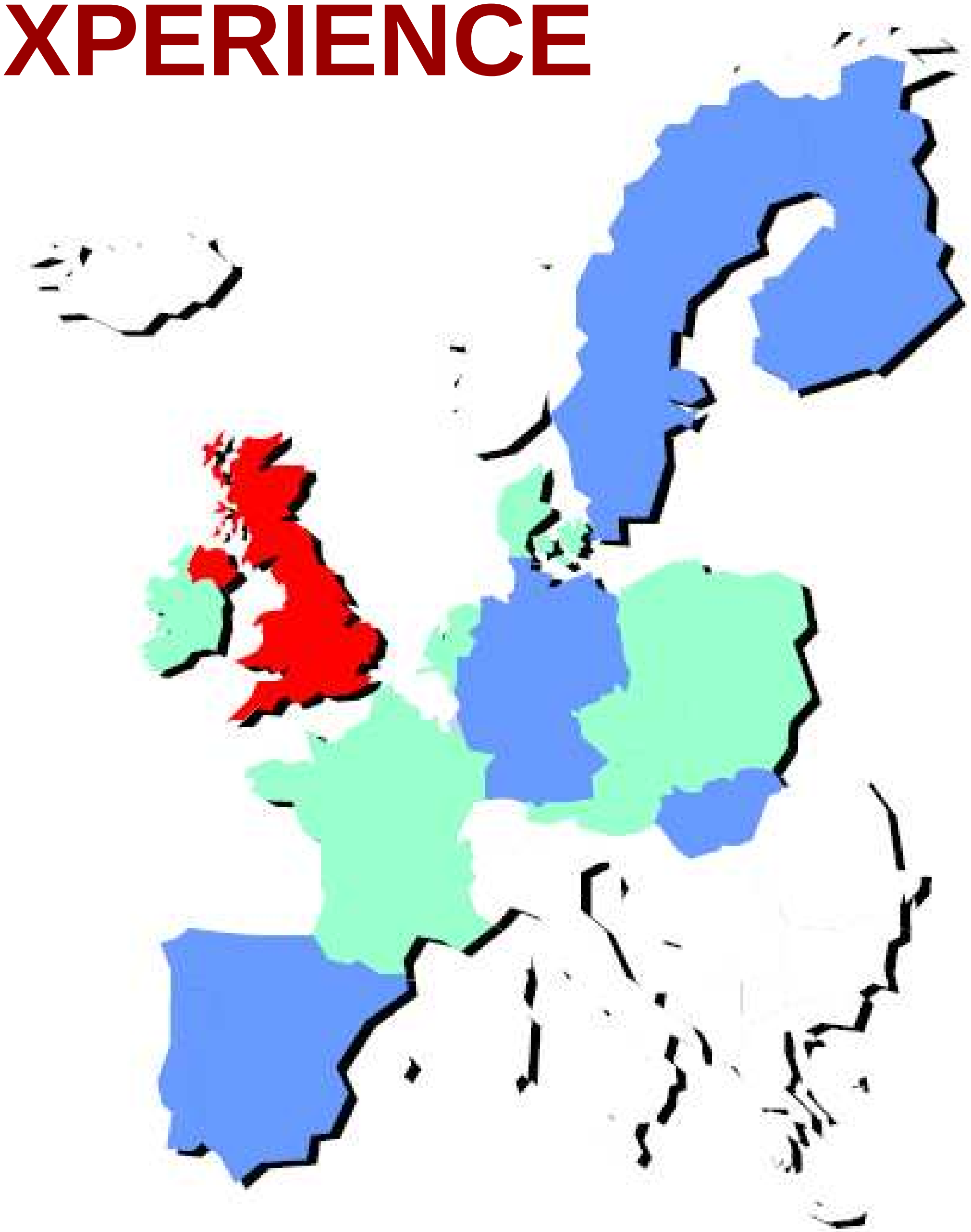
1. Penalties greater than interest rates
2. Disconnection for nonpayment with no exceptions
3. Socially vulnerable customer protection programs outside electricity prices
4. Privatization ?!

REGULATORY APPROACH:

1. Incentive commercial loss reduction program – definition of program costs, program benefits and duration
2. Investment costs in metering, data and billing system
3. Benefit from the program should be shared

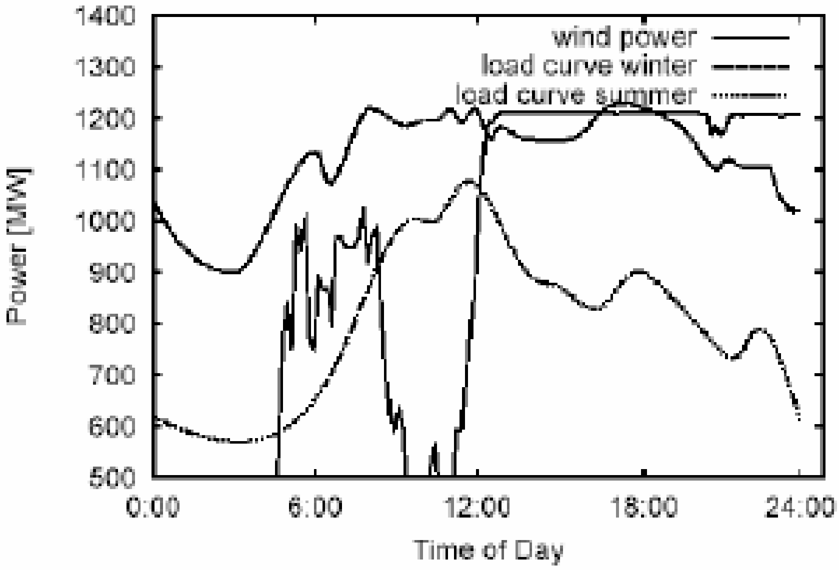
ANCILLARY SERVICES EXPERIENCE

- over 10 years
  - *United Kingdom*
- 5 to 10 years
  - *Finland*
  - *Germany*
  - *Hungary*
  - *Portugal*
  - *Spain*
  - *Sweden*
- 2 to 5 years
  - *Austria*
  - *Czech Republic*
  - *Denmark*
  - *France*
  - *Ireland*
  - *Netherlands*
  - *Poland*
  - *Slovakia*
- less than 2 years (or no answer)



How long current AS system has been used?
Source: EURELECTRIC, 2006

ANCILLARY SERVICES DEFINITION



Source: EURELECTRIC: Ancillary Services

"services required by the TSO and DSO to enable them to maintain the integrity and stability of the transmission or distribution system as well as the power quality."

What is considered as AS?

	AT	BE	CZ	DK	FI	FR	DE	HU	IE	IR	NL	NO	PL	PT	ES	SE	SK	UK
FC	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
VC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
ST			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
BS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓
RG	✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	
GL	✓		✓			✓	✓		✓									
EC	✓		✓			✓	✓		✓		✓						✓	

FC Frequency control	*VC Voltage control*	*SP Spinning reserve*
ST Standing reserve	*BS Black start capacity*	*RG Remote automatic generation control*
GL Grid loss compensation	*EC Emergency control actions*	

What is the payment method?

	AT	BE	CZ	DK	FI	FR	DE	HU	IE	IR	NL	NO	PL	PT	ES	SE	SK	UK
FC	OM		M	N	N	NT	N O M	N	O	O	O	N	N	O	O	N	R	N
VC	OM		N	N	N	NT		N	O	R	N	N	N	ON	T	O	R	TN
SP			M	N	N	M		N	O	R	N	N			M	N	R	
ST			M	N	N	M		N	O	R	M	M	N	ON		N	R	M
BS	N		N	N				N	O	R	N		N			O	R	
RG	N		M		N			N	O					ON	M		R	
GL	N		M		N	M		N	O		M					N		
EC	N					O			O		N							

FC Frequency control	*VC Voltage control*	*SP Spinning reserve*
ST Standing reserve	*BS Black start capacity*	*RG Remote automatic generation control*
GL Grid loss compensation	*EC Emergency control actions*	

N=Negotiated contracts; O=Obligation, no payment; M=Open market; T=Tariff; R=Regulated price

Source: EURELECTRIC

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ANCILLARY SERVICES

General regulatory recommendations:

- **use market mechanisms** whenever possible
- **mandatory:** primary reserve
- **market mechanism:** secondary (and tertiary) reserve;
- **limited market mechanisms:** reactive power and black start

ANCILLARY SERVICES

- **Market mechanisms whenever possible**→ provides more economical and more flexible approach than compulsory
- **Possible AS market power in voltage control** → not appropriate for market
- **Black start typically based on long-term contract** → negotiated
- **Inclusion of demand side** in AS would be beneficiary (increasing competition, improves utilization of existing equipment, may be more reliable)

CONGESTION MANAGEMENT

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CONGESTION MANAGEMENT

WHY DO WE NEED IT?

1. To solve the congestion before security is jeopardized,
2. To ensure non-discriminatory, transparent electricity market and improve its competitiveness,
3. To set fair prices of transmission capacity allocation based on equivalent principles of tariffication
4. To minimize market power

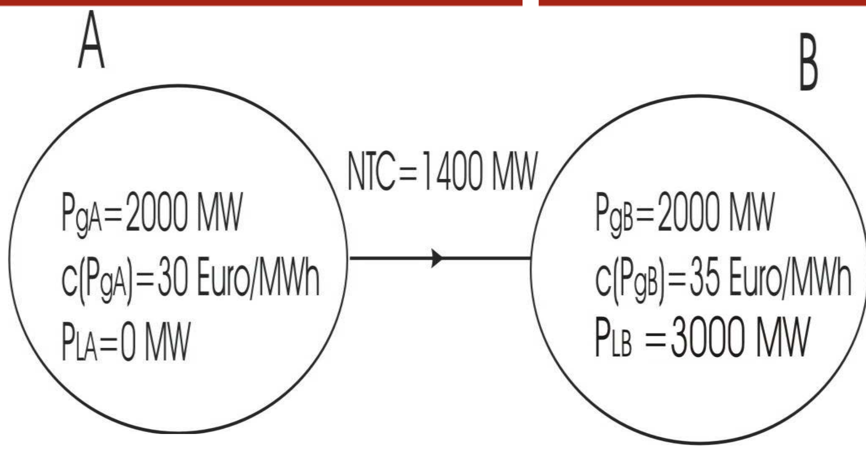
CONGESTION MANAGEMENT

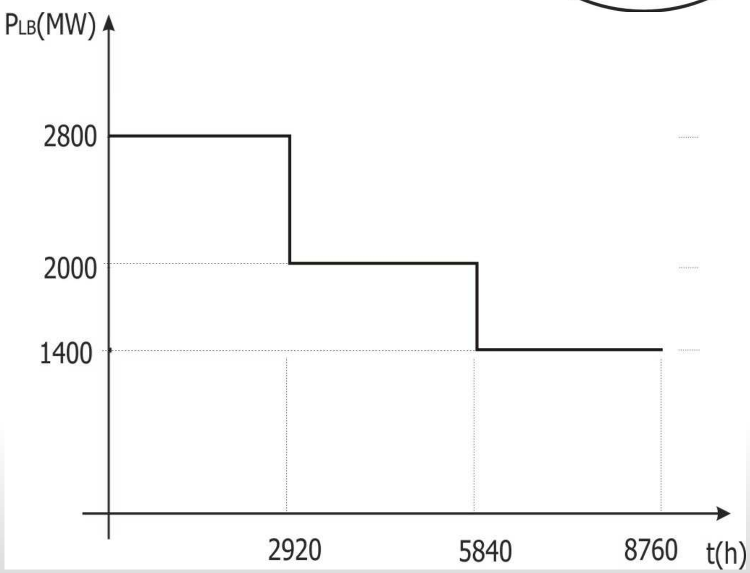
EXPERIENCES ?

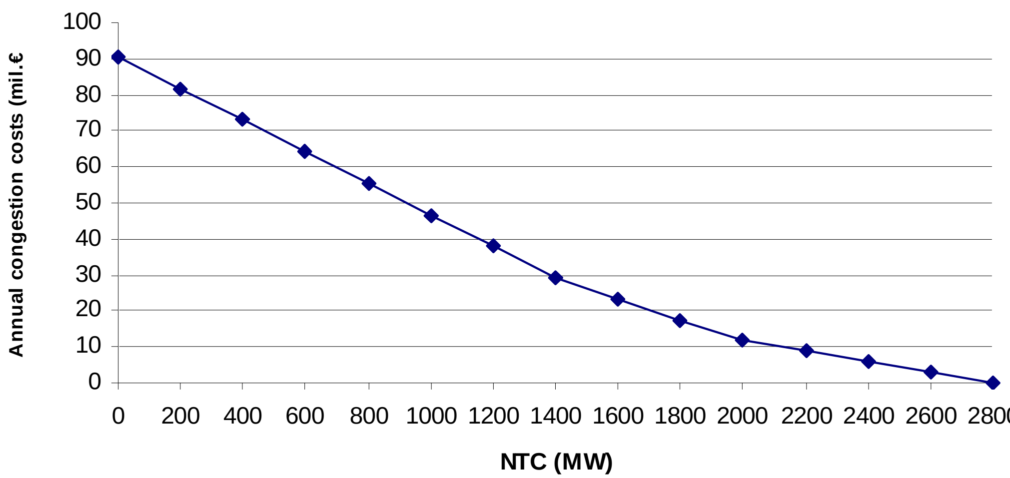
Non-market methods	1. depending on contract type
	2. depending on application time
	3. depending on transaction value
	4. depending on ratio between declared and available capacity (pro-rata)
	5. depending on real power flows
Market methods	1. explicit auction
	2. implicit auction
	3. market splitting
	4. redispatching
	5. counter trade

…Still developing…

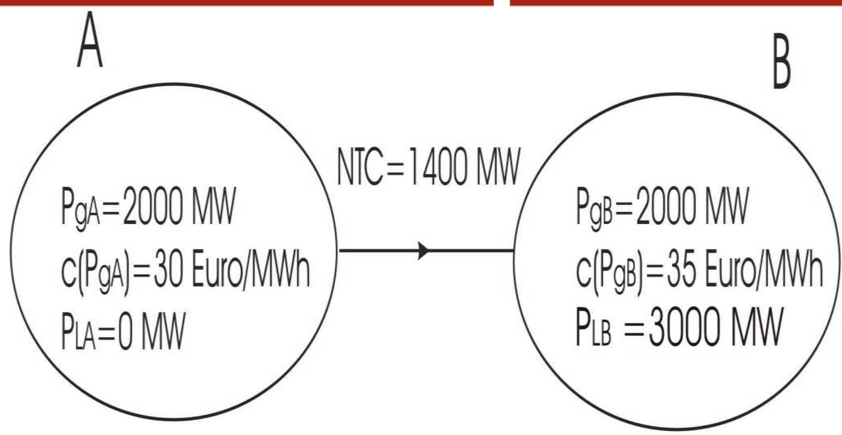
CONGESTION MANAGEMENT example

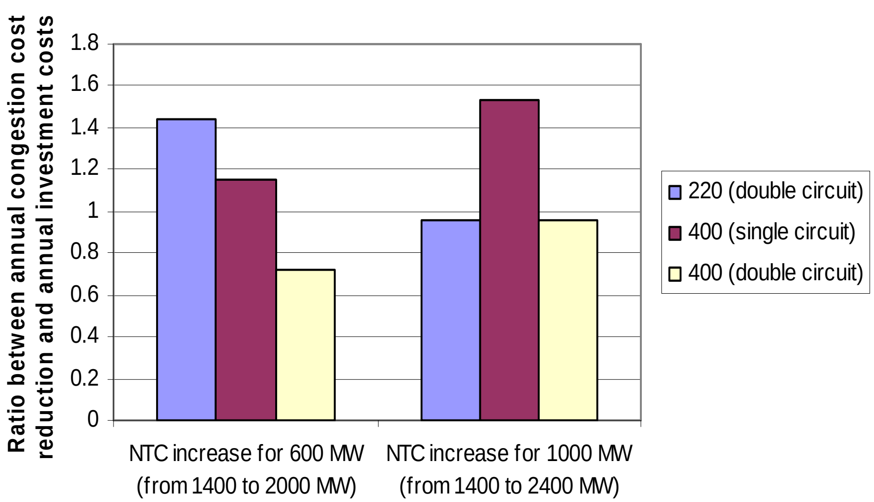


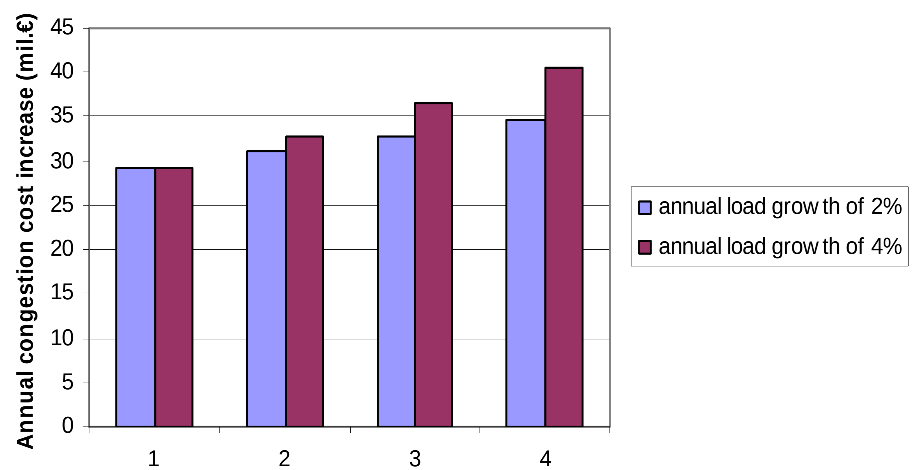




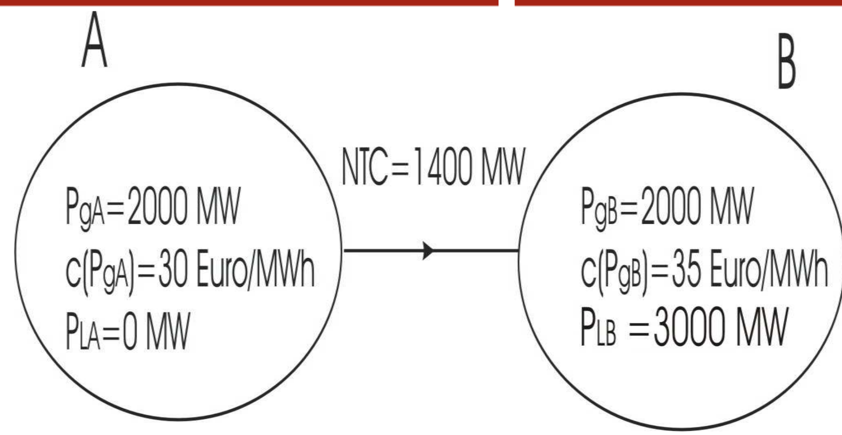
CONGESTION MANAGEMENT example

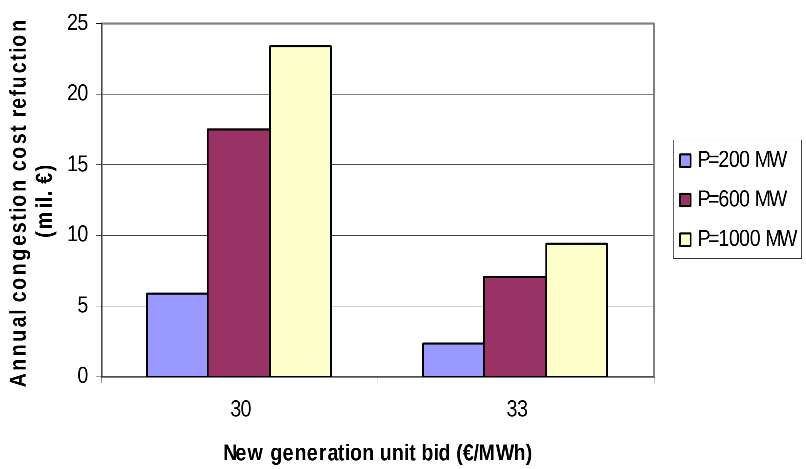


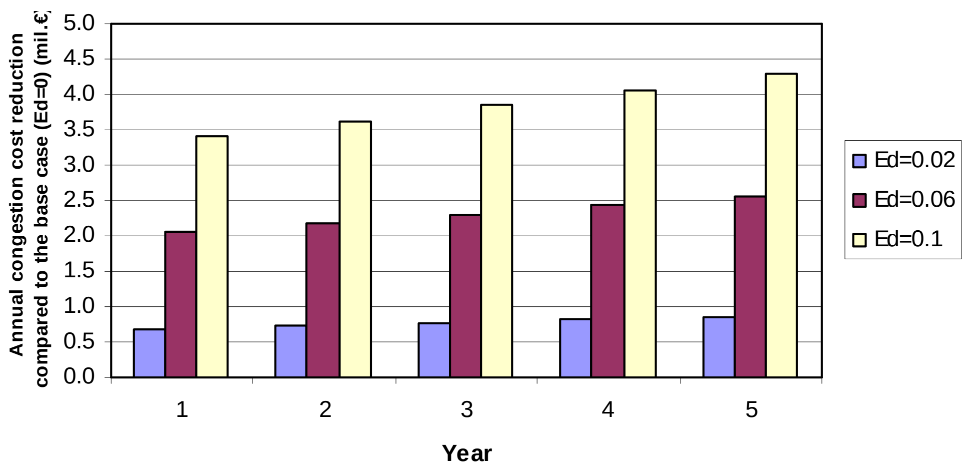


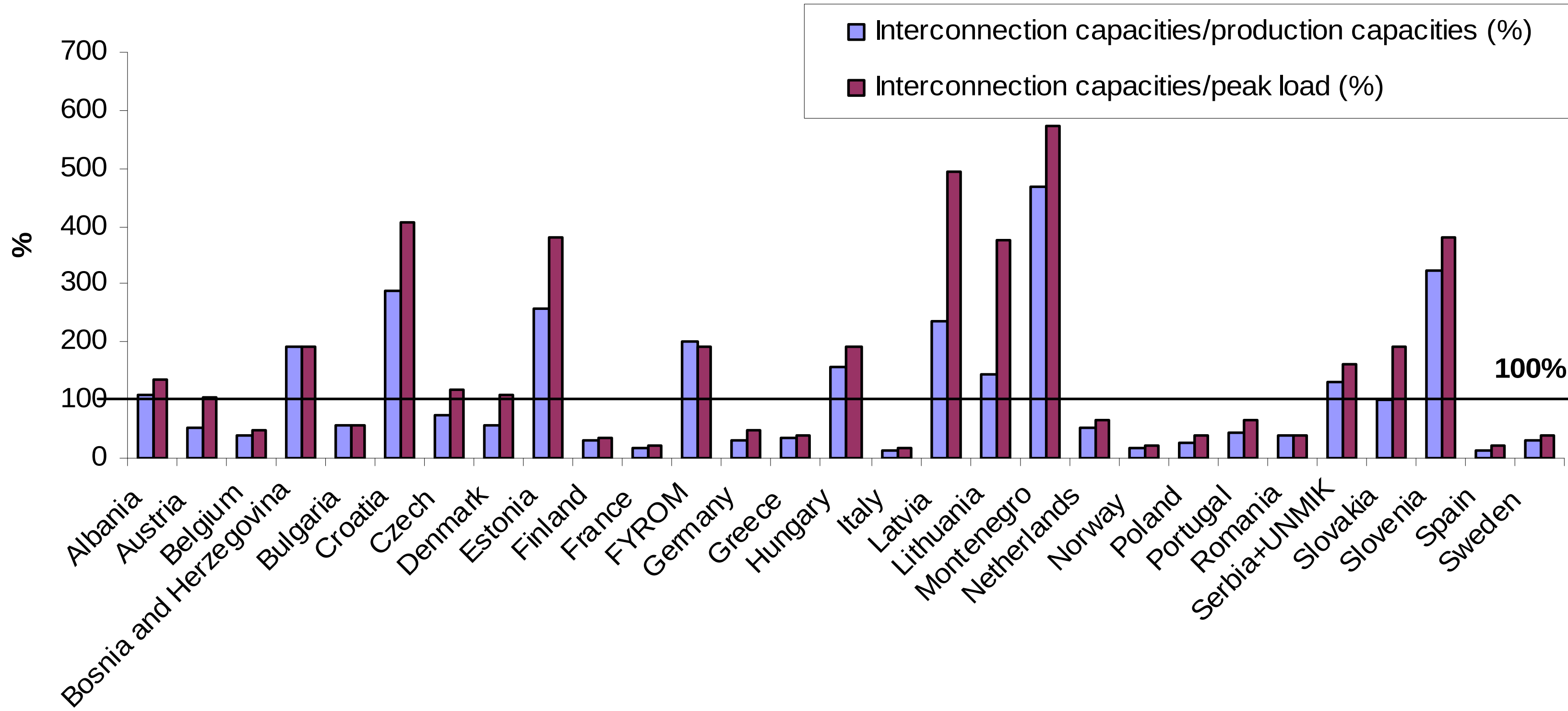


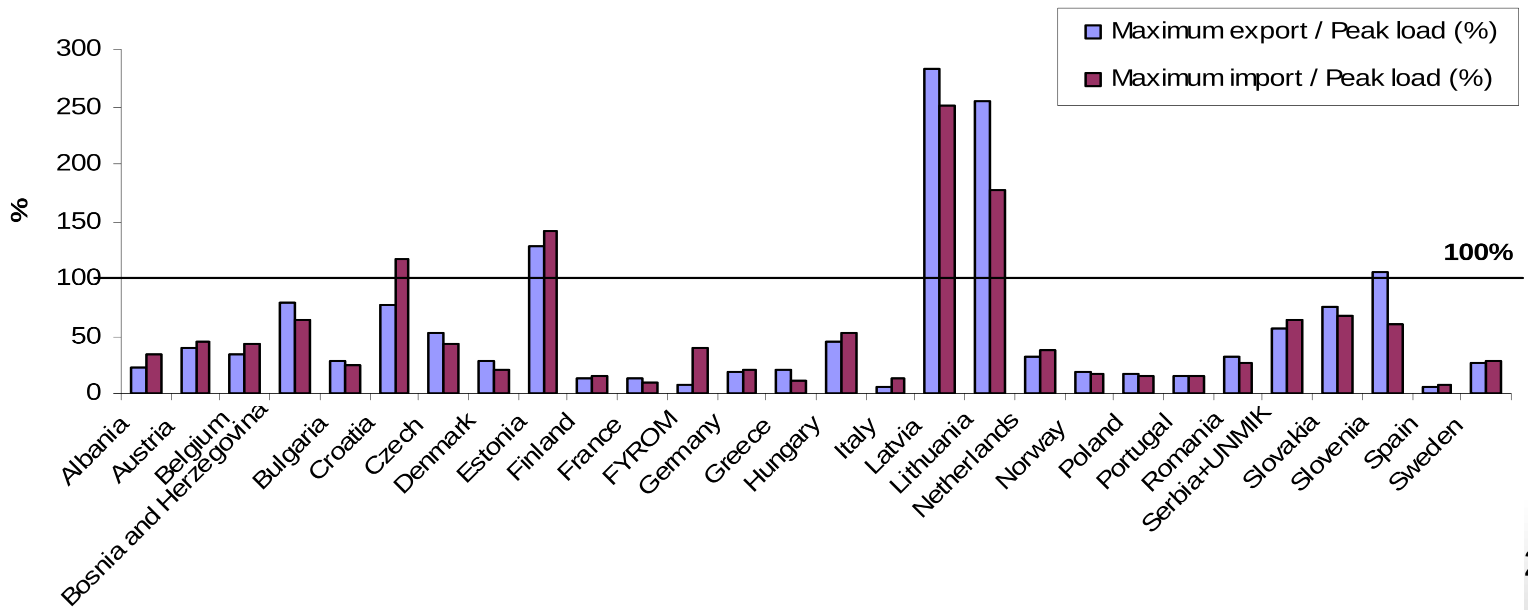
CONGESTION MANAGEMENT example








Interconnection capacities/production capacities (%)
Interconnection capacities/peak load (%)
%
700
600
500
400
300
200
100
0
100%
Albania
Austria
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Czech
Denmark
Estonia
Finland
France
FYROM
Germany
Greece
Hungary
Italy
Latvia
Lithuania
Montenegro
Netherlands
Norway
Poland
Portugal
Romania
Serbia+UNMIK
Slovakia
Slovenia
Spain
Sweden


Maximum export / Peak load (%)
Maximum import / Peak load (%)
%
300
250
200
150
100
50
0
100%
Albania
Austria
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Czech
Denmark
Estonia
Finland
France
FYROM
Germany
Greece
Hungary
Italy
Latvia
Lithuania
Netherlands
Norway
Poland
Portugal
Romania
Serbia+UNMIK
Slovakia
Slovenia
Spain
Sweden

CONGESTION MANAGEMENT

WHAT THE REGULATORS SHOULD CHECK?

- CM should be performed by **non-discriminatory methods**,
- TSO should receive **financial compensation** for transit flow from the exporters and importers of electricity in transit.
- The transit charges should **cover the loss-incurred costs**, investment in new infrastructure and adequate proportion in the costs of using the existing infrastructure.
- The network access charges must be transparent and reflect actual costs and **should not be distance-related.**

CONGESTION MANAGEMENT

WHAT THE REGULATORS SHOULD CHECK?

- The level of charges borne by G and L **should provide location-related market signals**.
- The charges for cross-border access **must not vary in dependence of states and origin of traded electricity.**
- TSO should establish a **coordination and information mechanism to ensure the security** of operation in the context of CM,
- Safety, operational and planning rules, TTC and TRM determination methods **must be available to the public,**

CONGESTION MANAGEMENT

WHAT THE REGULATORS SHOULD CHECK?

- TSO must **publish estimates of available transfer power** and expected reliability of the available capacity,
- Do not allow capacity reservations to result in **market dominance,**
- Do not allow any **single buyer to control a large fraction of the auctioned capacity** (even by putting capacity caps that can be bought),
- Unused capacity **must be available for any buyer.**

CONGESTION MANAGEMENT

WHAT THE REGULATORS SHOULD CHECK?

Revenues resulting from the allocation of interconnection capacity shall be used for:

- **Guaranteeing the actual availability of the allocated capacity**
- **Network investment**
- **As an income to be taken into account for network tariffs reduction**

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CONGESTION MANAGEMENT - coordinated auction -

2000 – Netherlands (Arnhem): Tennet, E.ON Netz, RWE Transportnetz Strom, Elia set up independent body ‘TSO Auction BV’

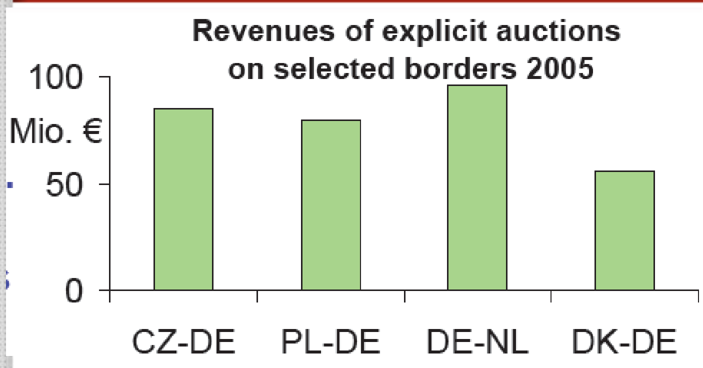
2006 – Central Eastern Europe (Prague): CEPS, VET,E.ON Netz, PSE-O, SEPS started to operate joint auctions (ATC-based) coordinated capacity calculations / definitions and joint capacity allocation

2008 – CEE CAO in Freising, Germany…

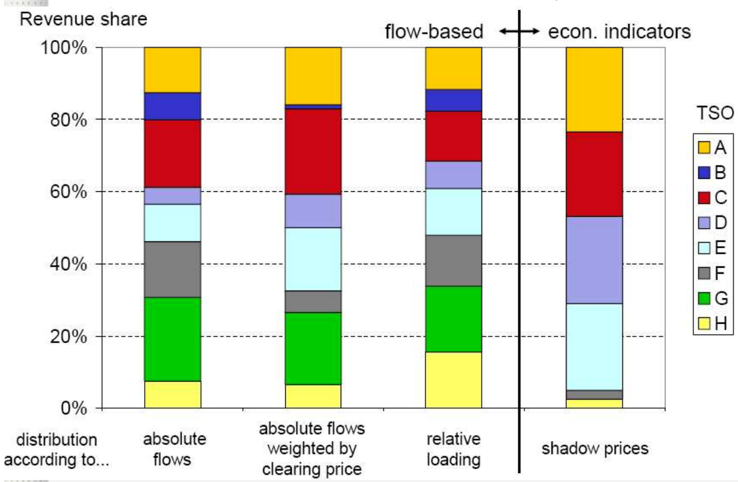
2011 - SEE CAO (Podgorica (MN) ?

CONGESTION MANAGEMENT

- coordinated auction revenue distribution -



Source: TSOs web sites auction offices, Consentec



Congestion revenue distribution based on SEE dry run
Source: Consentec

Distribution of Congestion Revenue ?
Prepared by Consentec and EnC Regulatory Board:

1. Distribution based on economic value ("shadow price" model)
2. Distribution based on Relative usage of interconnectors
3. Distribution based on Absolute usage of interconnectors
4. Variants and weighting factors ("hybrid" models)

Majority of SEE Regulators are in favor of "absolute flow" distribution key

NETWORK PLANNING

QUESTION

IS TRANSMISSION NETWORK WITH NO CONGESTION INEFFICIENT?

TRANSMISSION PLANNING

Congestion level depends on:

- **The amount and availability of transmission capacity**
- **The desired generation pattern and interchanges**
- **The accuracy of generation development pattern**

No requirement on TSOs to invest to increase cross border capacity to meet all traders' needs

TRANSMISSION PLANNING

N-1 (or N-2) outage must not jeopardize power transfer, but consumers must not pay for network overbuilding

OVERALL OBJECTIVE: coordinated network expansion in order to contribute security and market integration, no matter whether transmission investment is "internal"or "cross border"

TRANSMISSION PLANNING

- transmission planning criteria - national Grid Codes
- transmission plans 1- 15 years ahead
- ENTSO-E 10yr development plan

TECHNICAL CRITERIA:

- (n-1) security criterion, (n-2) criterion
- Somewhere: short-circuit or stability criteria -
- Somewhere: probabilistic analyses

TRANSMISSION PLANNING

- additional planning criteria for interconnection lines:
  - mostly not applied
  - based on system operational costs
  - based on the difference between energy prices
- uncertainties (multi-scenario analysis)
  - new power plants size and location
  - generators engagement
  - hydrological conditions
  - market transactions
  - country power balance
- no risk assessments
- **REGIONAL ASPECTS** – usually not mentioned in national Grid Codes

TRANSMISSION PLANNING

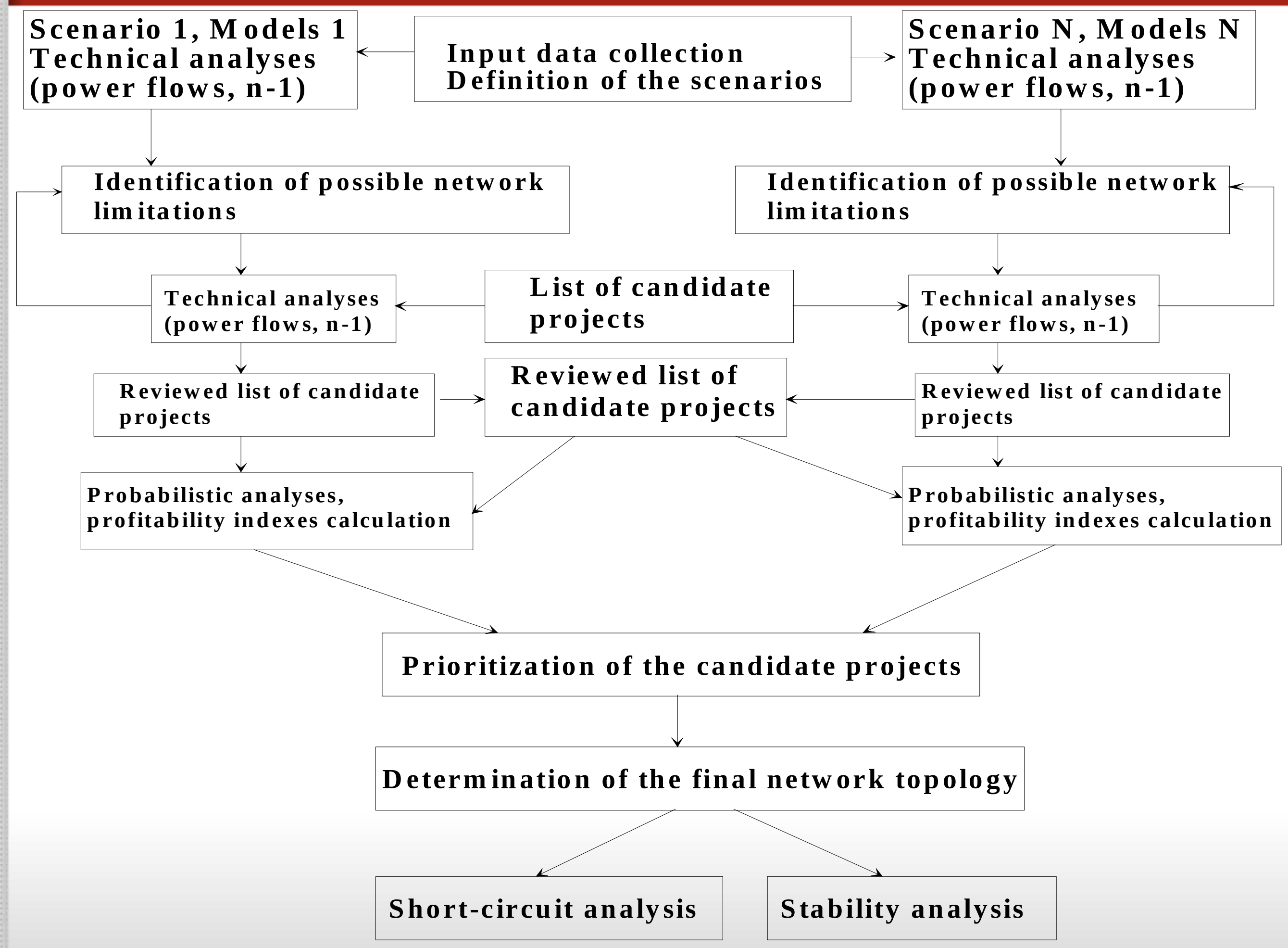
$$PI_i = \frac{EB_i}{EC_i}$$

- **TYPES OF BENEFIT:**
  - **benefit due to reduction of expected annual undelivered electricity costs**
  - **benefit due to annual losses reduction**
  - **benefit due to reduction of annual re-dispatching costs**
  - **benefit due to annual congestion costs reduction**

$$EC_i = \frac{d \cdot (1{,}02 \cdot I)}{1 - \frac{1}{(1+d)^N}}$$

- **TYPES OF COSTS:**
  - **investment costs**
  - **operation and maintenance costs**

TRANSMISSION PLANNING



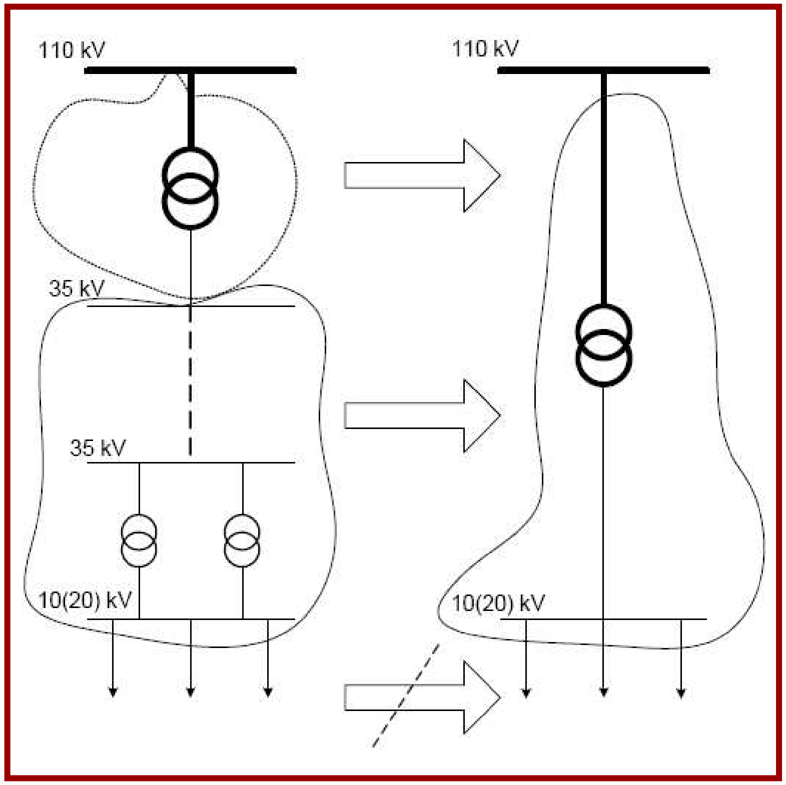
- LIST OF CANDIDATE PROJECTS
- TECHNICAL ANALYSIS
- REVIEWED LIST OF CANDIDATE PROJECTS
- ECONOMIC ANALYSIS
- PRIORATIZATION
  - technical
  - economic

DISTRIBUTION PLANNING

WHAT ARE THE TARGETS OF DISTRIBUTION PLANNING?

- **Reliable and economically acceptable power supply** with regards to network user future needs
- **Adequate dimensioning** to sustain reliable operation and desirable power quality level
- Harmonized operation with transmission network and different customer devices
- Economically optimal harmonization between needs of two types of network users: **distributed generators and consumers**

DISTRIBUTION PLANNING



General MV development principle:

lower number of votage levels (in the cases of two distribution system transformation levels i.e. 110/35 kV and 35/10 kV) and two MV levels (35 kV and 10 kV)

long term target is to have:

- **one existing MV level system (20 kV) and**
- **one direct transformation (110/20 kV).**

DISTRIBUTION PLANNING

General LV development principle:

- short LV feeders and simplification of TS 10(20)/0.4 kV
- transformers with relatively low capacity

This concept assumes limited investment in upgrading of each LV feeder while additional supply would be reached by increasing number of LV feeders along with new TS 10(20)/0.4 kV in existing network.

WHERE ARE POWER NETWORK LIMITS TODAY?

- **Highest AC transmission voltage:**
  1150 kV Ekibastuz-Kokshetau (Kazakhstan)
- **Highest DC transmission voltage:**
  +/-600 kV on HVDC Itaipu (Brazil)
- **Highest pylons:**
  345 m at Yangtze River Crossing (China)
- **Longest powerline:**
  1700 km at Inga-Shaba (Congo)
- **Longest span of powerline:**
  5376 m at Ameralik Span (Greenland)
- **Longest cable:**
  290 km at Basslink, Bass Strait (Australia)
- **Deepest cable:**
  1000 m HVDC link Galatina (ITA)-Arachtos (GR)

WHAT ABOUT FUTURE ?