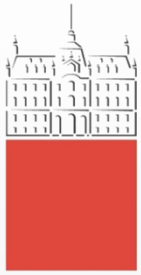
University *of Ljubljana*
Faculty *of Electrical Engineering*
Laboratory of Electricity Networks and Devices



Role of Distributed Generation in Advanced Power Networks of the Future – SmartGrids

Uloga distribuirane proizvodnje u naprednim elektroenergetskim mrežama budućnosti – SmartGrids

Tematski seminar “Uklanjanje prepreka za prihvat distribuirane proizvodnje” HO CIRED i HKIE

Zagreb, 14.10.2010

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Content

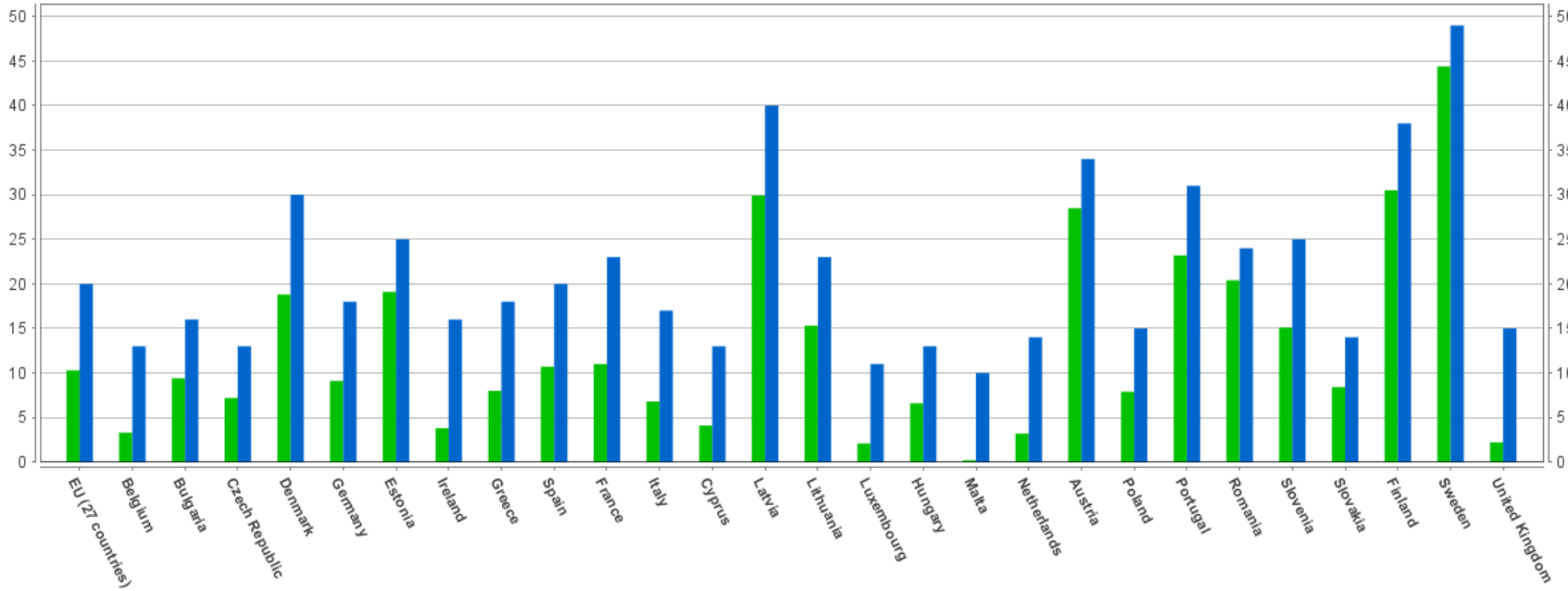
- European Energy Policy and Targets
- European Strategic Energy Technology Plan
- Power networks – why changes are necessary?
- What are the characteristics of today's (yesterday's) networks and the networks of tomorrow?
- How to realize the common European vision?
- Slovenian Technology Platform SmartGrids
- Impact of Distributed Energy Resources on Network Operation
- Concept and implementation of active networks
- Overview of some projects in the area of active networks
- The state of play – vision or reality

EU Energy Policy

- decrease energy dependency (fossil fuels)
  - today 50% of energy is imported
- increase energy efficiency
  - demand for energy is increasing
- sustainable development
  - climate changes
  - lower CO_2 emissions
- world leader in energy technologies
- public environmental awareness
- common European strategy for energy

EU Energy Policy Targets

- reducing greenhouse gas emissions by at least 20% (compared with 1990 levels) by 2020
- improving energy efficiency by 20% by 2020
- raising the share of renewable energy to 20 % by 2020 (share in 2008, target by 2020)
- at least 10% share of renewable energy in transport by 2020



Slovenian renewable energy action plan

- Directive 2009/28/EC
- national energy action plan 2010-2020
  - published in July 2010
  - http://www.mg.gov.si/fileadmin/mg.gov.si/pageuploads/Energetika/Porocila/AN_OVE_2010-2020_final.pdf
- Slovenian national targets

[%]	reference year 2005	target by 2020	obligation
RES - heating and cooling	20,0	30,8	
RES - electrical energy	28,5	39,3	
RES - transport	0,3	10,5	10
RES	16,2	25,3	25

- DG integration is very important for reaching targets

European Strategic Energy Technology Plan – SET Plan

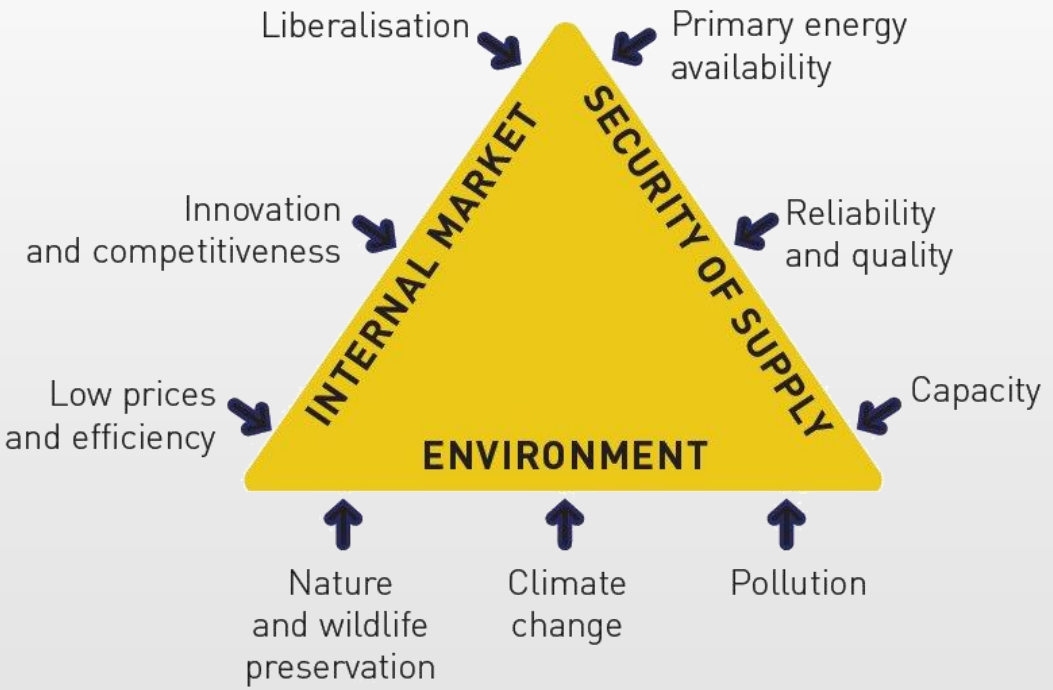
- to make low-carbon technologies affordable and competitive – a market choice
- EU approach focuses on the European Industrial Initiatives – EII
  - European Industrial Bioenergy Initiative (to be launched)
  - European CO_2 Capture, Transport and Storage Initiative
  - European Electricity Grid Initiative
  - Fuel Cells and Hydrogen Joint Technology Initiative (to be launched)
  - Sustainable Nuclear Initiative (to be launched)
  - Energy efficiency – Smart Cities Initiative (to be launched)
  - Solar Europe Initiative
  - European Wind Initiative
- SET Plan
  - http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm

European Electricity Grid Initiative

- aims
  - enable up to 35% of electricity from dispersed and concentrated renewable sources by 2020
  - make electricity production completely decarbonised by 2050
  - further integrate national networks into a truly pan-European network
  - guarantee a high quality of electricity supply to all customers and engage them as active participants in energy efficiency
  - anticipate new developments such as the electrification of transport
- activities
  - an integrated R&D and demonstration programme
  - network of up to 20 large-scale demonstration projects
- investments
  - €2 billion over ten years excluding costs of generic assets used in demonstration
- www.smartgrids.eu

Power networks – why do we need changes?

- the same driving factors in all EU countries
  - security and quality of supply
  - energy market
  - environment



Characteristics of today's (yesterday's) power networks

- power flows in one direction
- generation, transmission, distribution, consumption
- large generation units
- centralized control
- limited interconnections between national systems
- passive role of customers
- balance between generation and consumption

Characteristics of the networks of tomorrow

- large number of small generation units (distributed generation):
  control, protection, voltage quality, planning
- still large generation units
- active role of customers
- bi-directional power flows
- strong interconnections between national systems
- still balance between generation and consumption

European vision of the networks of tomorrow

- flexible – fulfilling customer's needs
- accessible – granting connection access to all network users
- reliable – assuring and improving security and quality of supply
- economic – providing best value through innovation, efficient energy management, competition and regulation

How to realize the vision?

- by activating all the relevant actors in the electricity sector and those influencing its operation
  - operators of transmission and distribution networks, generation companies
  - equipment manufacturers
  - research and education institutions
  - politics
  - customers

Slovenian Electricity Networks Technology Platform

- first meeting of the Initiative Committee on 20 April 2006
- letter of support of the Minister of the Economy of RS
- acquired funds for promotion of development of technology platforms in year 2006
- national workshop on 25 September 2006
- setting up a web page www.smartgrids.si
- other activities (national research programs, demonstration proposals, …)

- today – upcoming reorganization
  - new organizational structure
  - more professional approach (membership fee)

Members of the Electricity Networks Technology Platform

- Transmission Network Operator – Elektro Slovenija
- University of Ljubljana, Faculty of Electrical Engineering
- Electric Power Research Institute Milan Vidmar
- Distribution network operator SODO
- Elektro Ljubljana
- Elektro Primorska
- Elektro Maribor
- Elektro Gorenjska
- Elektro Celje
- HSE Group - power generation
- University of Maribor, Faculty of Electrical Engineering and Computer Science
- Institut Jožef Stefan, Energy Efficiency Center

… members of TP

- Istrabenz Gorenje energetski sistemi
- Iskra Sistemi
- TSN
- C&G
- Korona
- Iskraemeco
- Ensico
- Elpros
- Esotech
- Iskra MIS
- INEA
- …

- coordination of activities with the Directorate for Energy, Ministry of the Economy

Strategic goals

- to find new technical solutions that will enable efficient and viable connection of new energy sources to the existing networks
- to harmonize legislation, regulations and conditions on the market
- to develop technical standards and procedures that will enable free access to the network and services
- to develop information, computer and telecommunication technologies for efficient utilization of new services
- to connect new sources and technologies with undisturbed operation of existing control and operational functions of the power system
- …

Research & Technology
Development areas

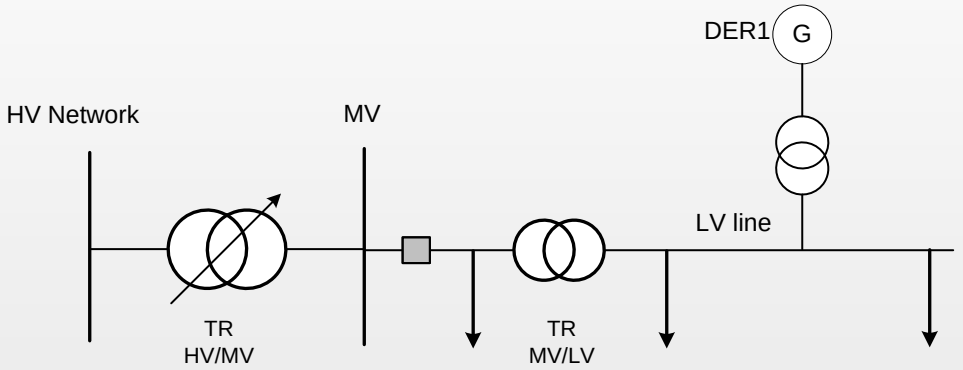
- development and integration of renewable energy sources (PV, biomass, fuel cells, small hydro power plants, …) into the electricity network
- use of FACTS technology for control and improvement of transmission capabilities
- development of secondary equipment for protection and control of electricity networks
- power electronics modules
- switchgear technology
- intelligent metering
- ICT

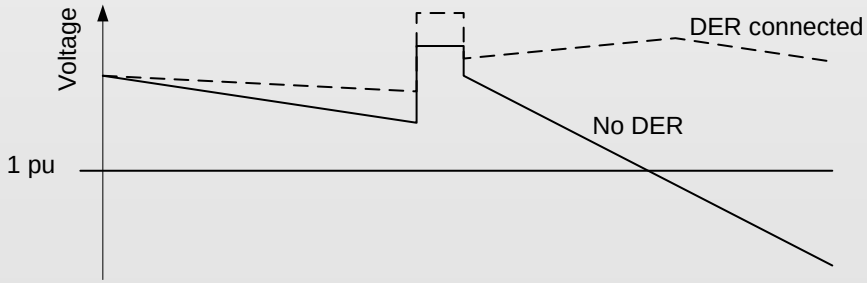
Impact of DER on network operation

- impact on network operation depends on DER penetration
- small DER share causes local problems (Austria, Slovenia, …)
  - unsuitable voltage profile
  - malfunction of protection operation
  - lower power quality
- large DER share my also cause system problems (Denmark, Spain, …)
  - adverse effect on network stability
  - uncontrolled reactive power flows
  - impact on power reserves
  - need for active network management
- where is the limit?

Impact on voltage profile

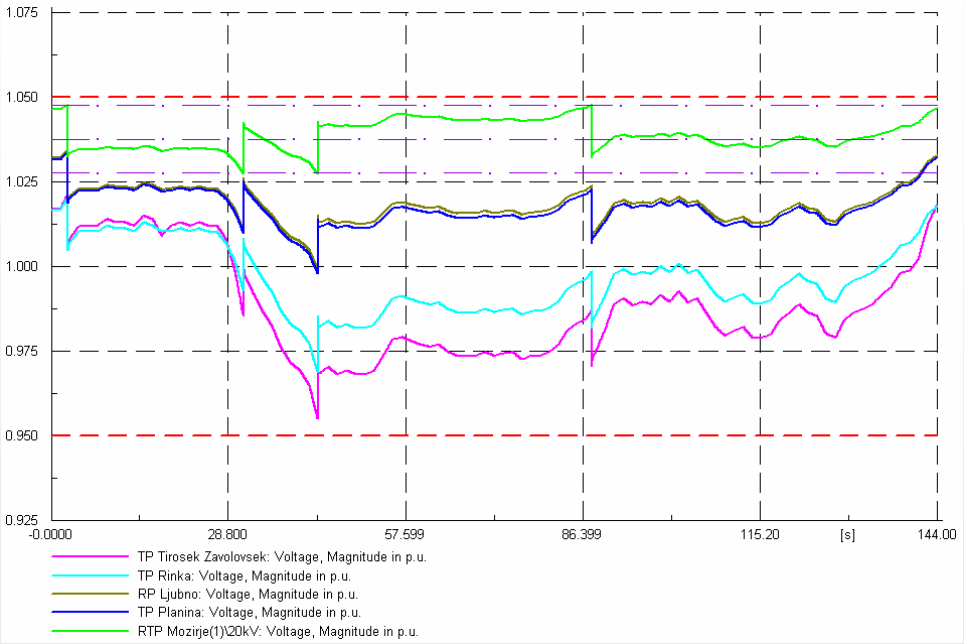
- difficult to control the network voltage profile only with the HV/MV transformer
  - low consumption / high DER generation
  - high consumption / low DER generation
- solutions
  - more complex transformer voltage regulation
  - voltage regulation with DER
  - active compensators



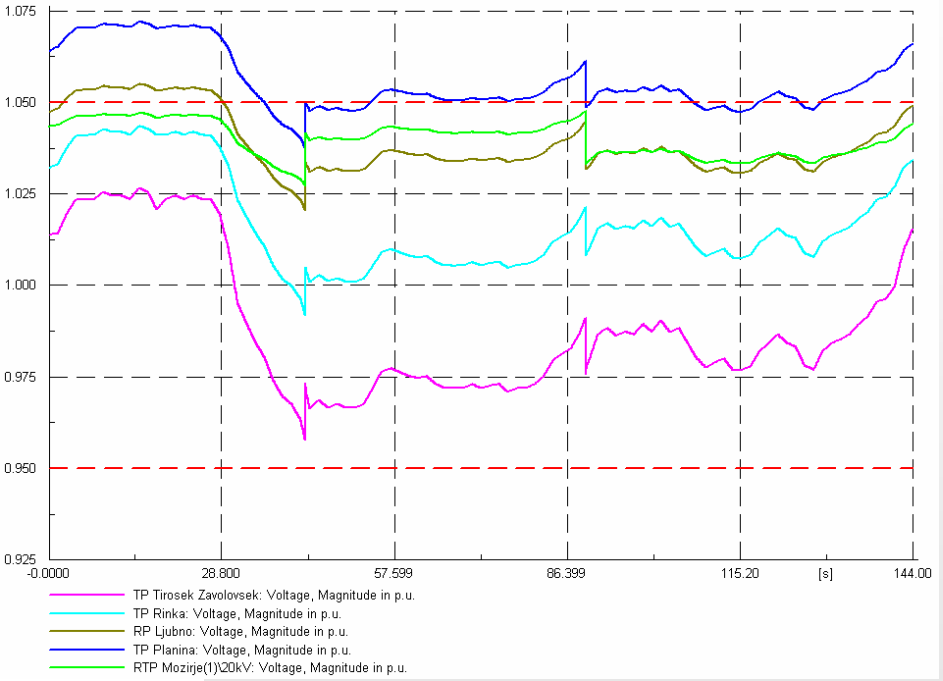


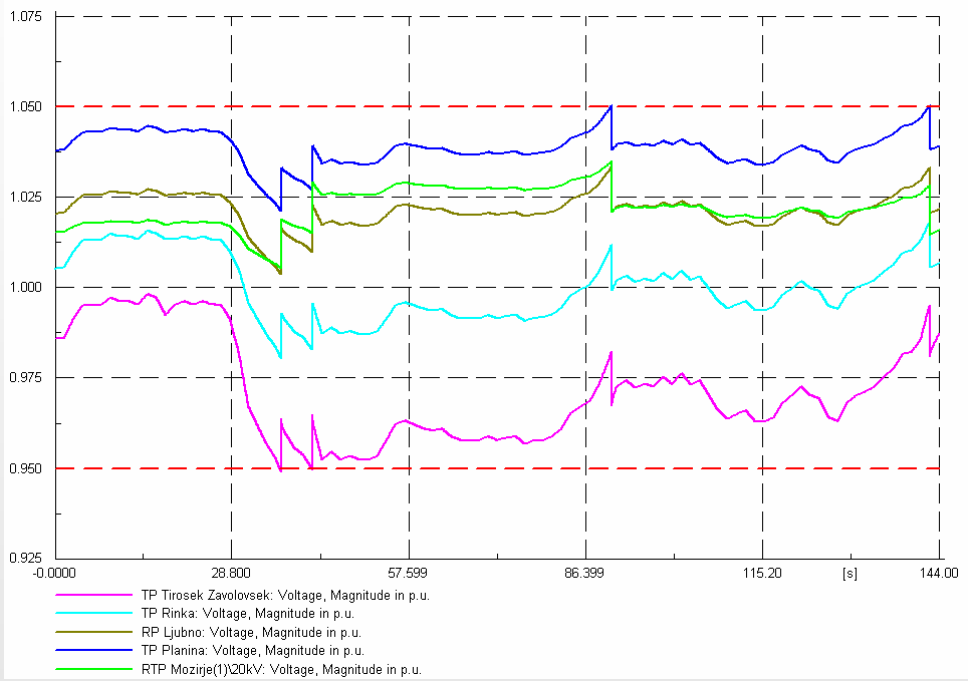
Impact on voltage profile – case study

- case study – voltage profile simulation along the 20kV feeder
  - consideration of characteristic daily load diagrams
  - simulation without DER (small hydro power plants)
  - existing voltage control maintains the voltage profile within the prescribed limits, voltage measurement only in substation



… impact on voltage profile – case study





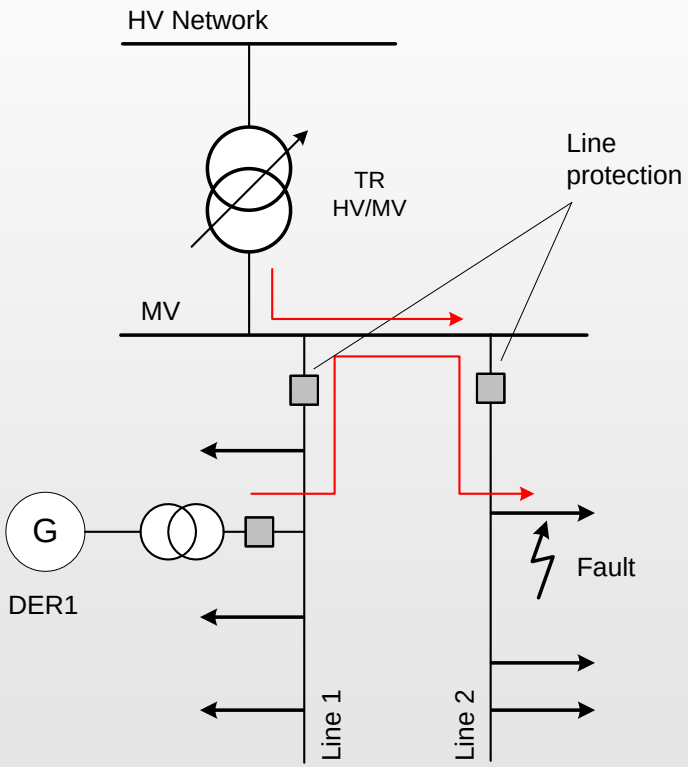
- simulation of voltage profile along the line with DER (left)
- simulation of voltage profile with a new centralized control – voltage measurements along the line (right)

Impact on voltage profile – voltage control with reactive power

- voltage control in distribution network
- voltage gain with shunt compensators depends on the network character, i.e. R/X ratio
  - resistive network – compensation with active power
  - inductive network – compensation with reactive power
  - when R/X is above 1, active power exchange has larger influence on voltage profile
- voltage gain with series compensators depends on the load power factor
  - resistive load – compensation with active power
  - inductive load – compensation with reactive power

Impact on protection operation

- DER contribute to short circuit currents in case of faults
  - malfunction of standard protection schemes
- solutions
  - protection coordination
  - DER connect on a separate feeder
  - new protection equipment (e.g. directional protection)
- islanded operation
  - usually not allowed
  - unintentional islanding may occur in case of local production/consumption balance
  - consequences:
    - voltage and frequency outside the limits (danger for the connected equipment)
    - electricity shock hazard for maintenance staff
    - problem of auto-reclosure!

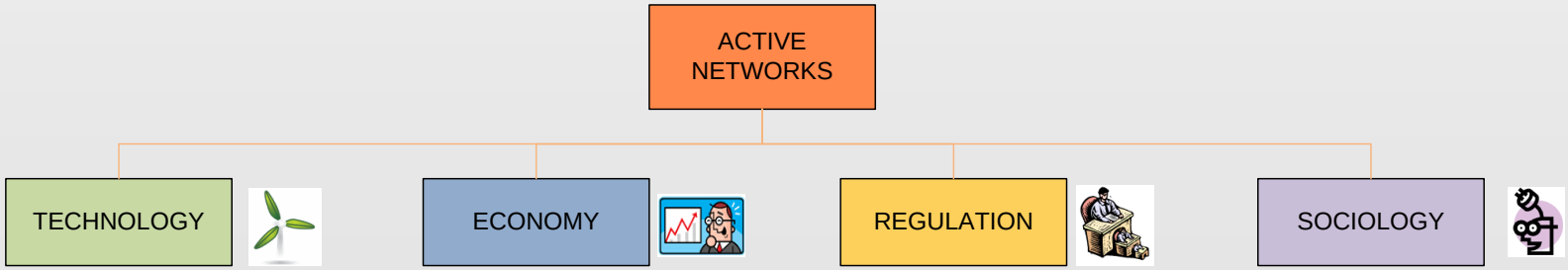


… other impacts

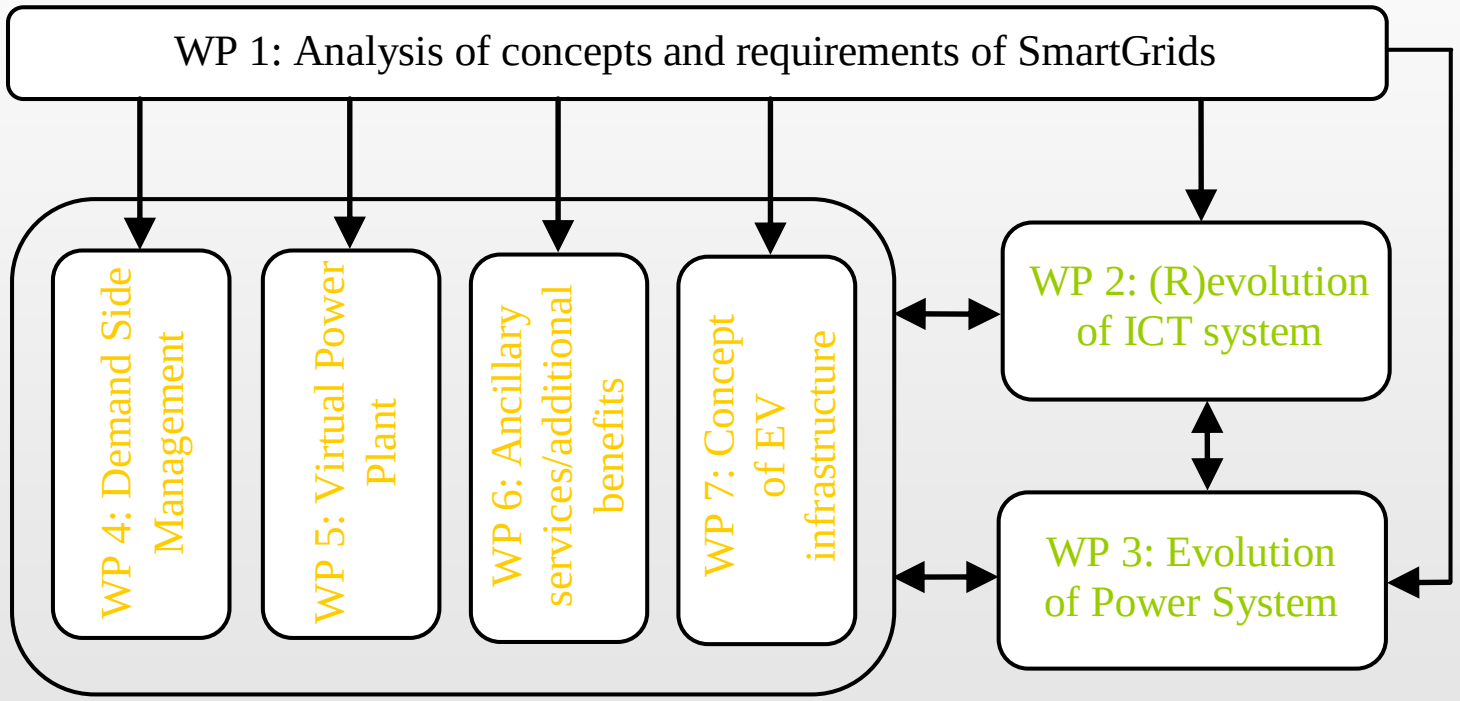
- power quality
  - transient voltage variations (e.g. connection or disconnection of DER)
  - flicker (especially wind turbines)
  - harmonics (e.g. from power converters)
  - DER can improve power quality (suitable control and operation coordination of sources is required)
- reserve capacity
  - DER often an intermittent source (wind, water levels, sun…)
  - power reserves needed for production/consumption balancing
- required changes at the level of network planning

Active network concept

- terminology
  - smart grids
  - intelligent networks
  - active networks
- active network concept is based on solid foundations of conventional power systems
- active network is more than just interconnection of DER
- active network enables efficient use of energy at the system level (not just at end-users)
- global concept

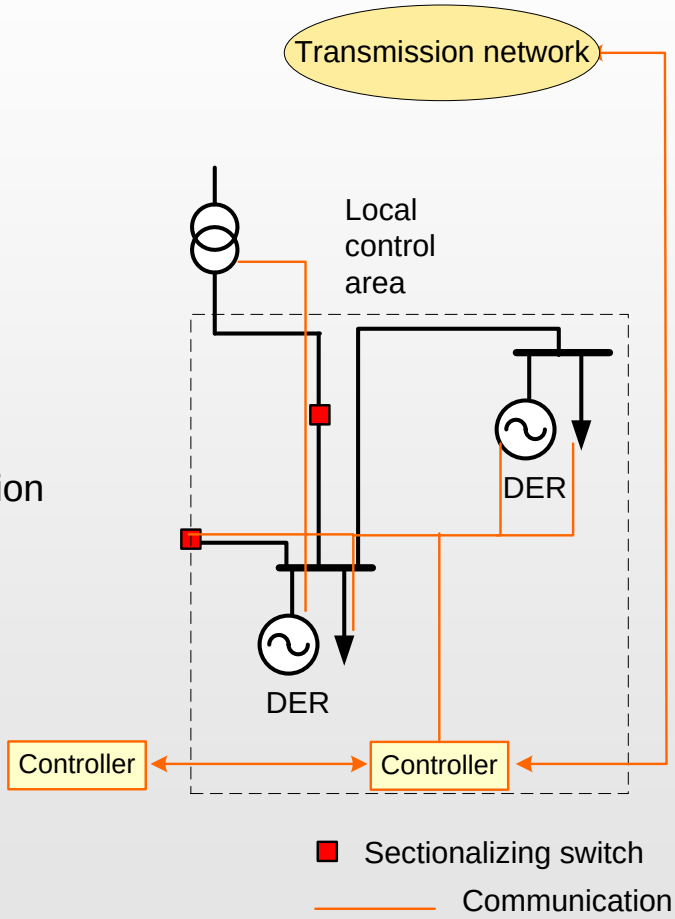


National strategic demonstration projects proposal



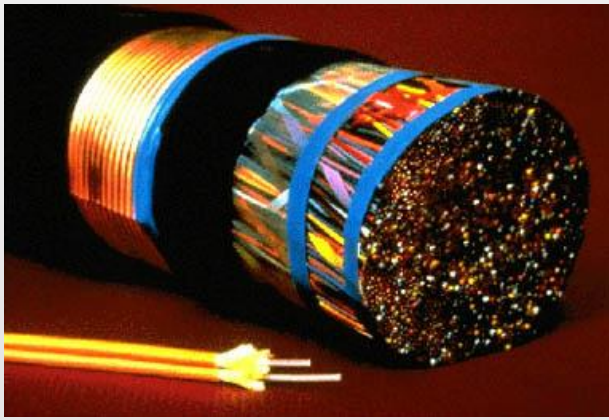
Evolution of power network and (r)evolution of ICT system

- efficient ICTs are essential
- network control concepts
  - central control
  - peer-to-peer control
  - combination
    - to some extent autonomous sources
    - central controller for optimization of operation
- evolution of power systems will be gradual
  - substation automation
  - controllable DER
  - feeder automation
  - controllable loads



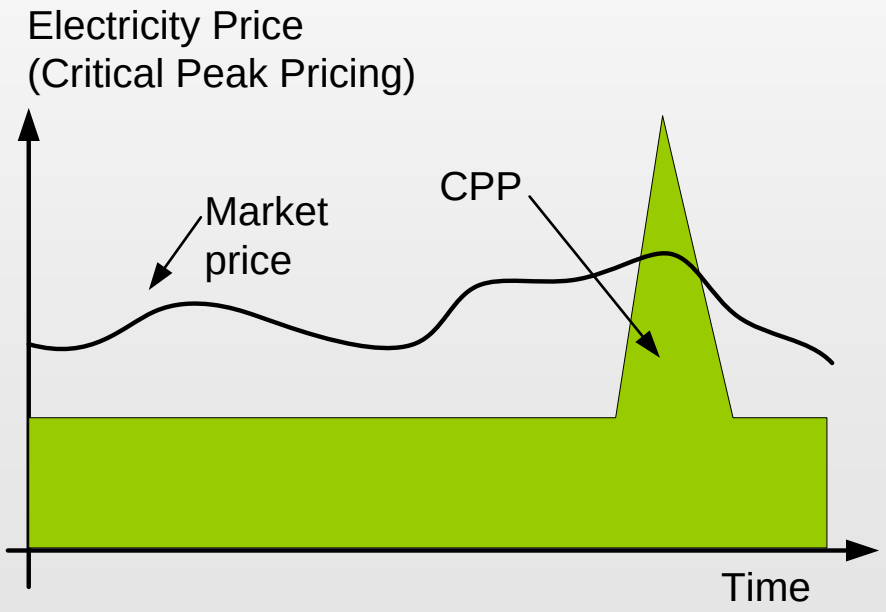
Enabling technologies for implementation of active networks

- controllable DER
  - normal operation: maximization of revenues
  - emergency operation: maintain system stability
- energy storage
  - enable production and consumption balancing
  - virtual system storage – e-mobility
- advanced power electronics equipment
  - active compensators
  - connection of sources and loads to the network
- information and communication technologies
  - monitoring, storing, processing and distributing information
  - widespread communication between controllable devices and control units
  - prediction of consumption, production and prices



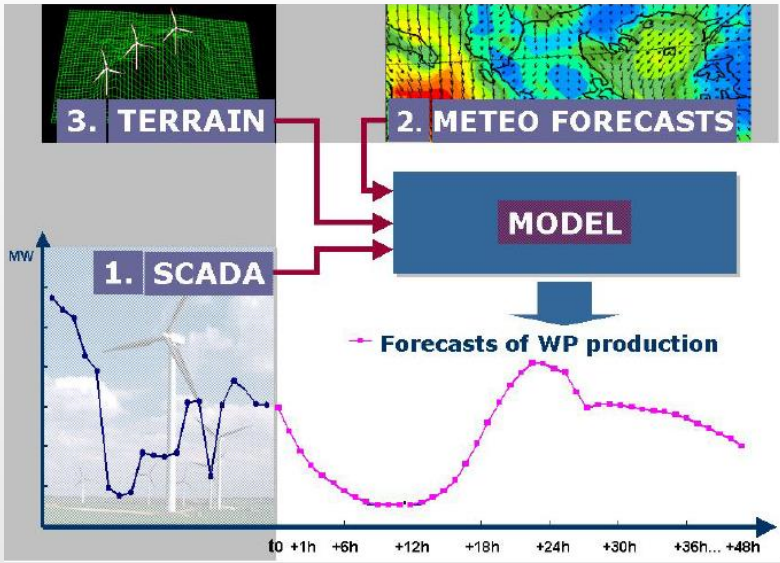
Business models of active networks

- Demand Side Management
  - incentives for increase in energy efficiency
  - sending price signals to customers
  - disconnection of consumers (according to contract)
  - consumers offer disconnection of a certain load at a certain price



… business models of active networks

- Virtual Power Plant
  - aggregation of available production from DER
  - optimization and production planning of individual sources
- ancillary services / additional benefits
- concept of EV infrastructure
  - vehicle to house
  - vehicle to grid

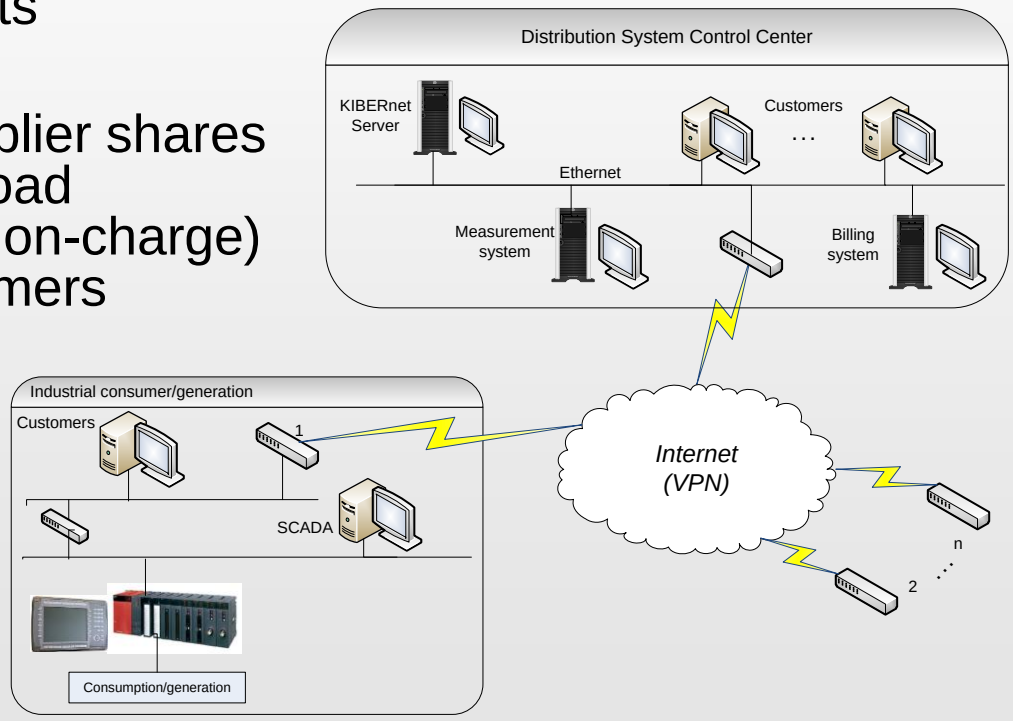


Industrial project KiberNet

- Development of a prototype system for control of industrial loads and distributed generation in a distribution power system
- duration: 24 months
- co-financed by:
  - Slovenian Technology Agency
  - European Regional Development Fund
- project costs: 1.7 million €
- partners:
  - INEA - coordinator
  - Elektro Ljubljana
  - 5 large industrial customers
  - Electrical Power Research Institute Milan Vidmar
  - University of Ljubljana, Faculty of Electrical Engineering
  - Institute Jožef Stefan
- www.kiber-net.com

… Industrial project KiberNet

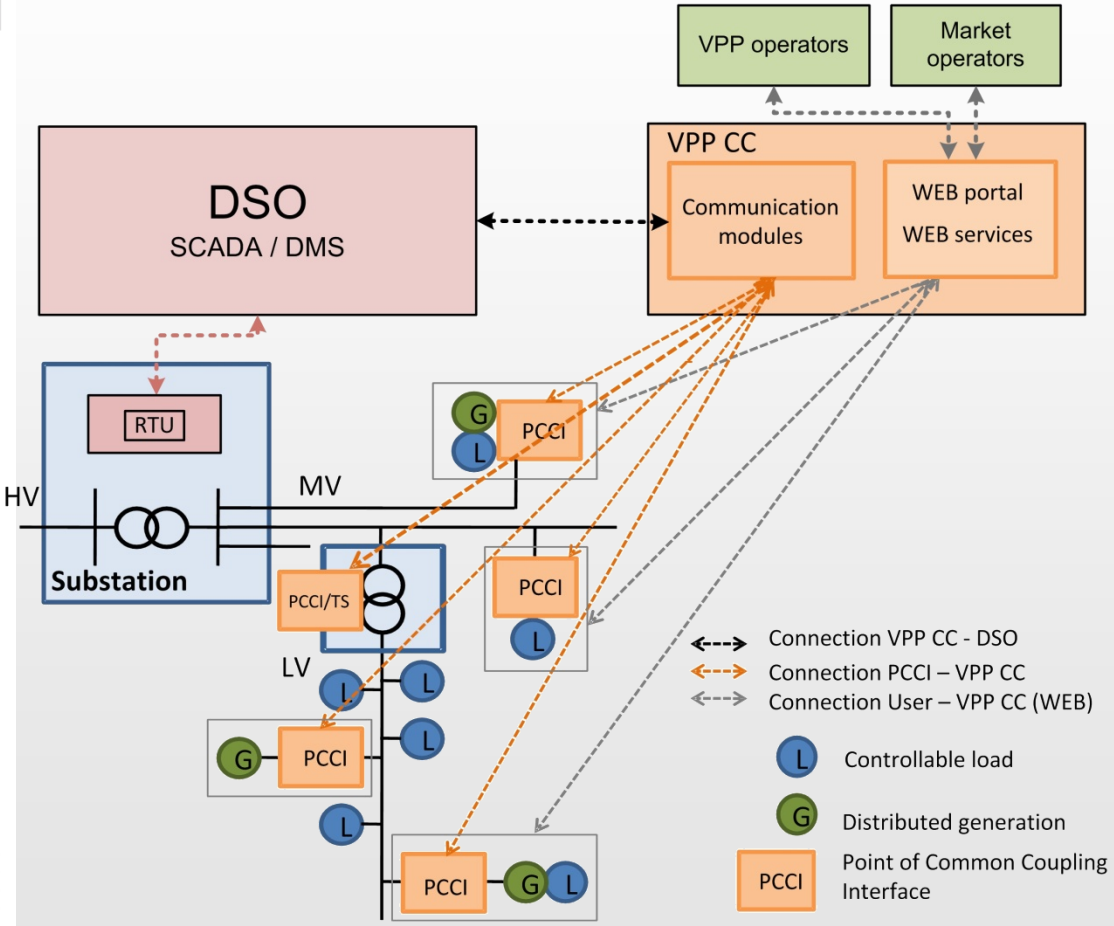
- adaptation of industrial customers' electrical energy consumption to the needs of supplier – customers as virtual peak power plants
- economic solution: supplier shares part of savings due to load adaptation (load-deviation-charge) with participating customers



Industrial project SUPERMEN

- Intelligent power system platform for supervision and control of distributed generation and customer demands
- duration: 24 months
- co-financed by:
  - Slovenian Technology Agency
  - European Regional Development Fund
- project costs: 2.1 million €
- partners:
  - Iskra MIS – coordinator
  - Solvera Lynx
  - Elektro Gorenjska
  - Gorenjske elektrarne
  - Electrical Power Research Institute Milan Vidmar
  - University of Ljubljana, Faculty of Electrical Engineering
- www.projekt-supermen.si

… Industrial project SUPERMEN



- new ICT infrastructure
- Point of Common Coupling Interface - PCCI
- middleware for communication of PCCIs with the system control centre
- centralized control of DG units - VPP

EU project MetaPV

- European 7FP project
- **Metamorphosis of Power Distribution: System Services from Photovoltaics**
- Multiple benefits of PV systems
  - PV transforms from the cause of the problem to a part of the solution
  - increasing the hosting capacity of a grid by new and distributed control facilities while limiting reinforcements within the economic rules imposed to a DSO
  - local ancillary services for network operation to improve its power quality, security and efficiency" and thus actively contribute to system reliability
  - extensive demonstration in Belgian region of Limburg (Infrax)
  - over 20 million €

Participation in EU projects

- DGFACTS – Improvement of the Quality of Supply in Distributed Generation Networks through the Integrated Application of Power Electronic Techniques
- VBPC-RES – The Virtual Balkan Power Center for Advance of Renewable Energy Sources in Western Balkans
- SOLID-DER - A Coordinated Action towards the promotion and consolidation of all RTD activities for large-scale integration of DER in the electricity market
- RISE – Renewables for Isolated Systems - Energy Supply and Waste Water Treatment
- FENIX - Flexible Electricity Networks to Integrate the Expected“ Energy Evolution”
- CEUBIOM – Classification of European Biomass Potential for Bioenergy Using Terrestrial and Earth Observations
- REALISEGRID – REseArch, methodoLogIes and technologieS for the effective development of pan-European key GRID infrastructures to support the achievement of a reliable, competitive and sustainable electricity supply
- MetaPV – Metamorphosis of Power Distribution: System Services from Photovoltaics
- …

Thoughts and dilemmas

- centralized and/or distributed generation
  - Christmas tree example
  - can PV systems replace a nuclear power plant
- centralized and/or local control
  - railway network example
- power flows in one/both directions
  - one-way street example
- introduction of active network concepts is “work on live system”
  - mobile network example

Where are we now?

- electricity networks of tomorrow are becoming reality
- customers are dictating current activities
- network operators are facing new technical challenges
- equipment manufacturers are responding with new solutions
- research institutions were/are always willing to participate

- We need more Research and Development!
- We will not reach 20-20-20 targets without introduction of SmartGrids concepts!