# Reduction of the total utility peak load by applying demand response measures

Nikola Lj. Rajakovic

Faculty for Electrical Engineering, University of Belgrade

Belgrade, Serbia

# Faculty of Electrical Engineering
# University of Belgrade

www.etf.bg.ac.rs
dekanat@etf.bg.ac.rs

# History

Teaching in EE started in the 19th century.
The education was modeled following the methods tested and perfected in France and Germany.

**Faculty of Electrical Engineering (ETF)**
was founded **in 1948.**

# Mission

The educational system was and is constantly being upgraded to include teaching methods and tools that were verified in the leading teaching institutions in the world.

The teaching has a strong theoretical component.

The emphasis on design centered education is at the graduate level (final engineering, master, and doctoral projects).

# Structure of Studies

- **Undergraduate studies**
  - duration: 4 academic years
  - two study programs (“Electrical Engineering and Computers” and “Software Engineering”)
- **Master degree studies**
  - duration: 1 academic year
  - one study program
- **Doctorial academic studies**
  - duration: 3 academic years
  - one study program

# Organization of Studies

## DIVISIONS:

- POWER ENGINEERING
- ELECTRONICS
- PHYSICAL ELECTRONICS
- SIGNALS AND SYSTEMS
- COMPUTER ENGINEERING AND INFORMATICS
- TELECOMMUNICATIONS AND INFORMATION TECHNOLOGIES
- SOFTWARE ENGINEERING

# Some Statistical Data

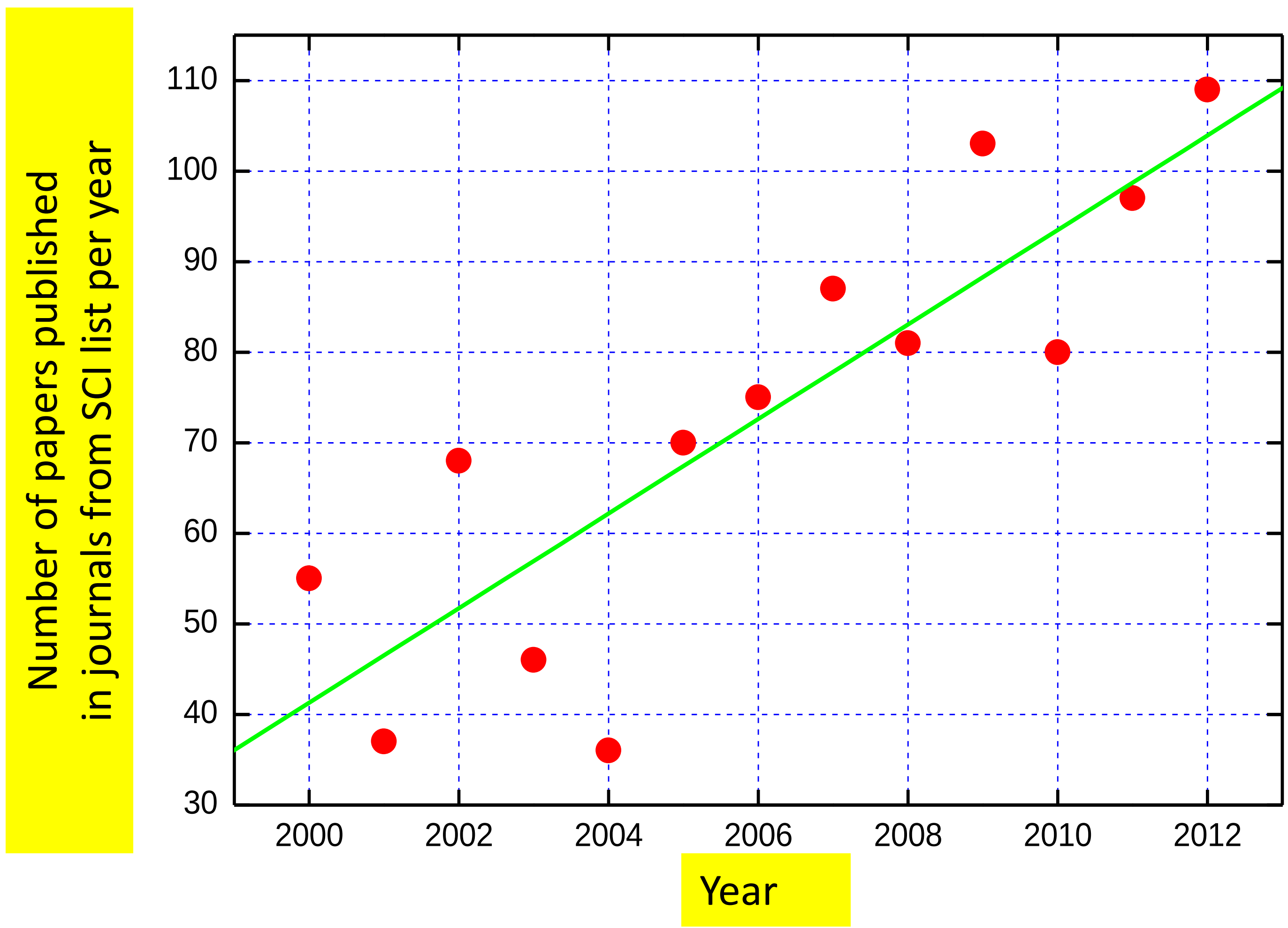
The number of students who received:

**Diploma Engineer Degree** since the foundation of the Faculty is 19.253 (in the last academic year – 379)

**Master Degree** since the foundation of the Faculty is 3.078 (in last academic year – 367)

**Doctorial Degree** since the foundation of the Faculty is 620 (in last academic year – 18)

# Research and Development Work



# Content

- Introduction
- Methodology elaboration
- Wider research frame and DSM/DR program
- Results /case study of ED Belgrade/ with
  a sensitivity analysis
- Conclusions

# Nomenclature

- AC – air conditioning
- AMR – automated meter reading
- DR – demand response
- DG – distributed generation
- DSM – demand side management
- EDB – Electricity Distribution Company Belgrade
- EE – energy efficiency
- HAN – home area network
- HS – heat storage
- LV – low voltage
- MV – medium voltage
- RES – renewable energy sources
- TA – thermal accumulating

# Introduction

- Options for peak reduction versus options to investment in new distribution facilities.
- DSM, DR, and EE options in the context of higher DG and RES presence
- Financial incentives and targeted information to influence individual customer decisions.
- Critical issue: how much does it cost to reduce peak through such programs?
- Different assessments of (cost-)effectiveness…

# *Demand response method for total utility peak load reduction - 1*

- Objective is to select the best schedule for shiftable load (appliances) in order to reduce the total utility peak load
- Energy used by consumers is the same
- Household appliances have been categorized as controllable and uncontrollable
- Demand of controllable appliances can be shifted

# ***Method - 2***

- Heating / cooling, water heating, as well as refrigerators and freezers, i.e. devices that have thermostats, are best candidates for load shifting
- Natural thermal storage enables to maintain the temperature within the certain range
- Devices can be controlled fully automatically within constraints

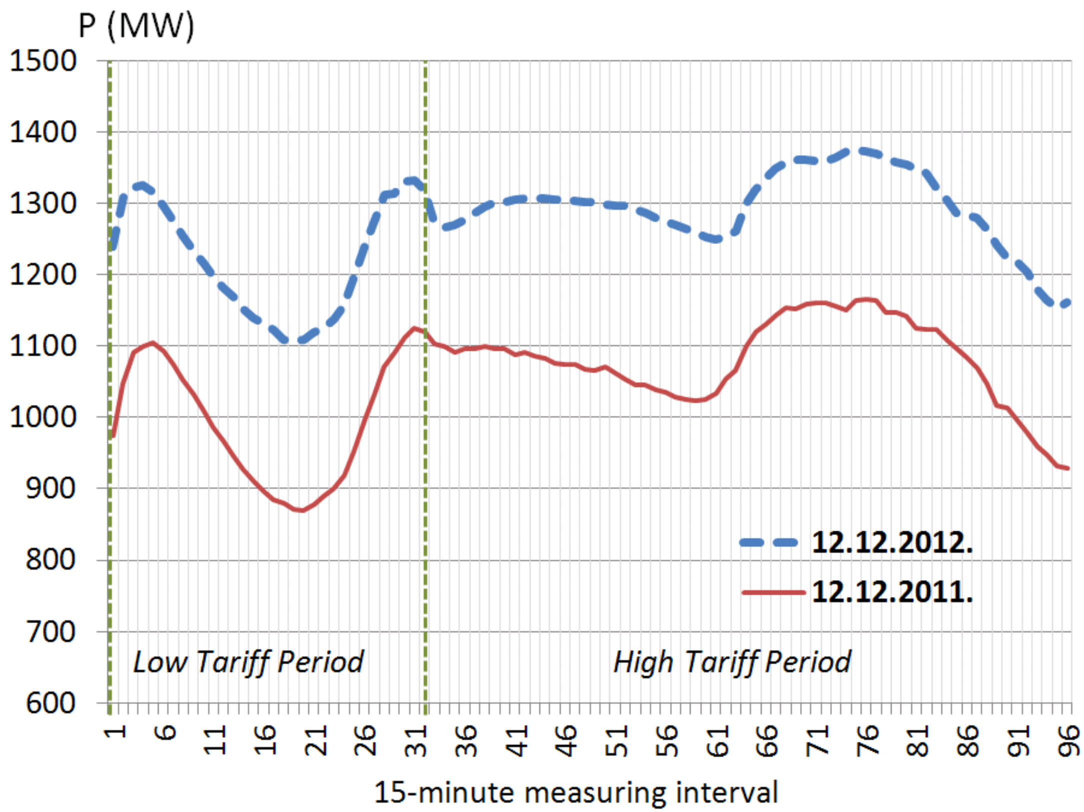
# *Method - 3*

- Controllable appliances are further classified according to their load-shifting flexibility (time period of shifting)
- A. 15 minutes shiftable load (refrigerators,…) - they participate with 5 % in total controllable load during winter and with 10 % during summer
- B. 30 minutes shiftable load (air-conditioners,..) - they participate with 25 % in total controllable load during winter and with 60 % during summer
- C. 1 hour shiftable load (heaters, water heaters) - they participate with 70 percent in total controllable load during winter and with 30% during summer

# *Method - 4*

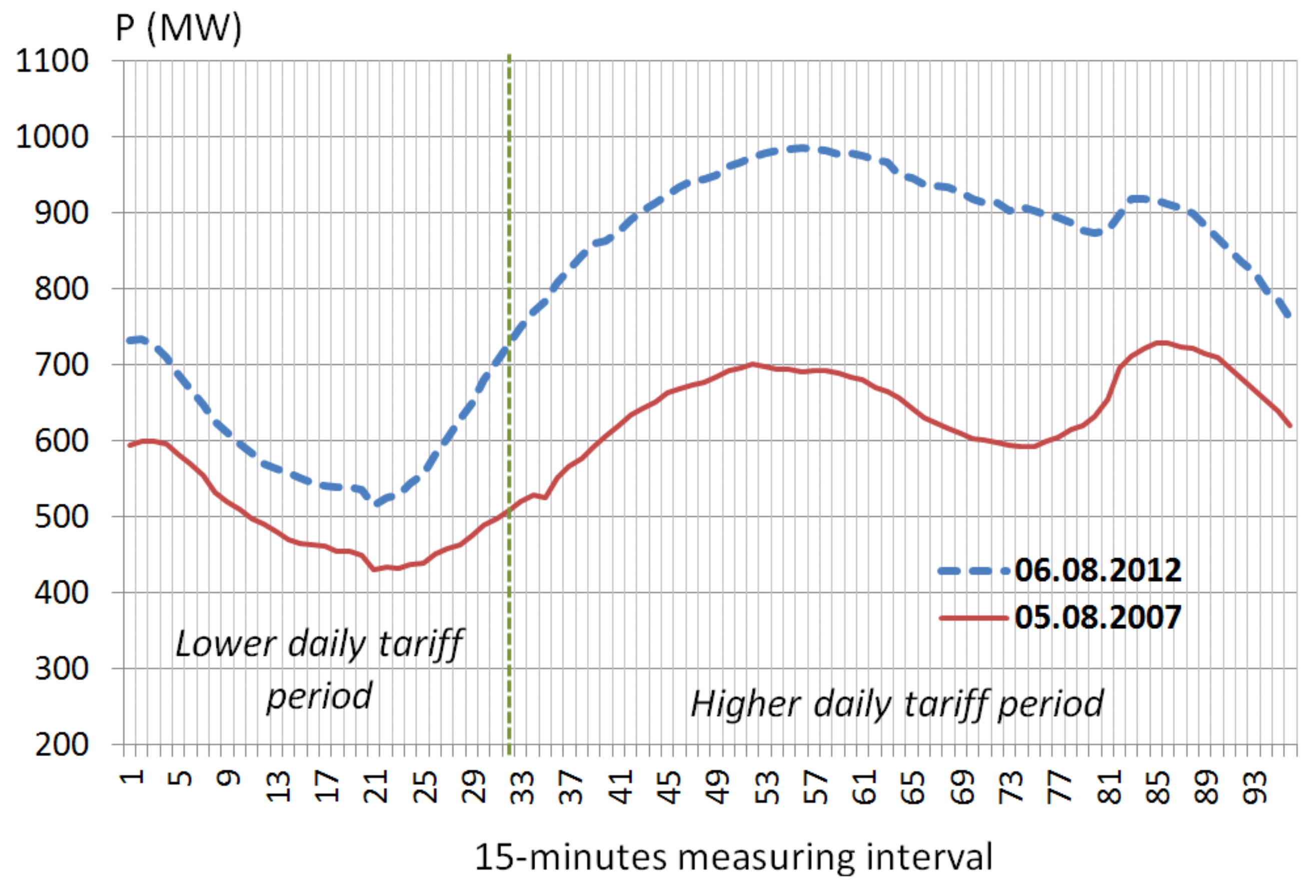
- The proposed model has been implemented and solved in MATLAB software tool
- In simulation it is taken that shiftable appliances participate with the same percentage every hour
- Comparison with scheduling problem on generation side has been examined (hydro – thermal coordination)

# Specific winter load profiles



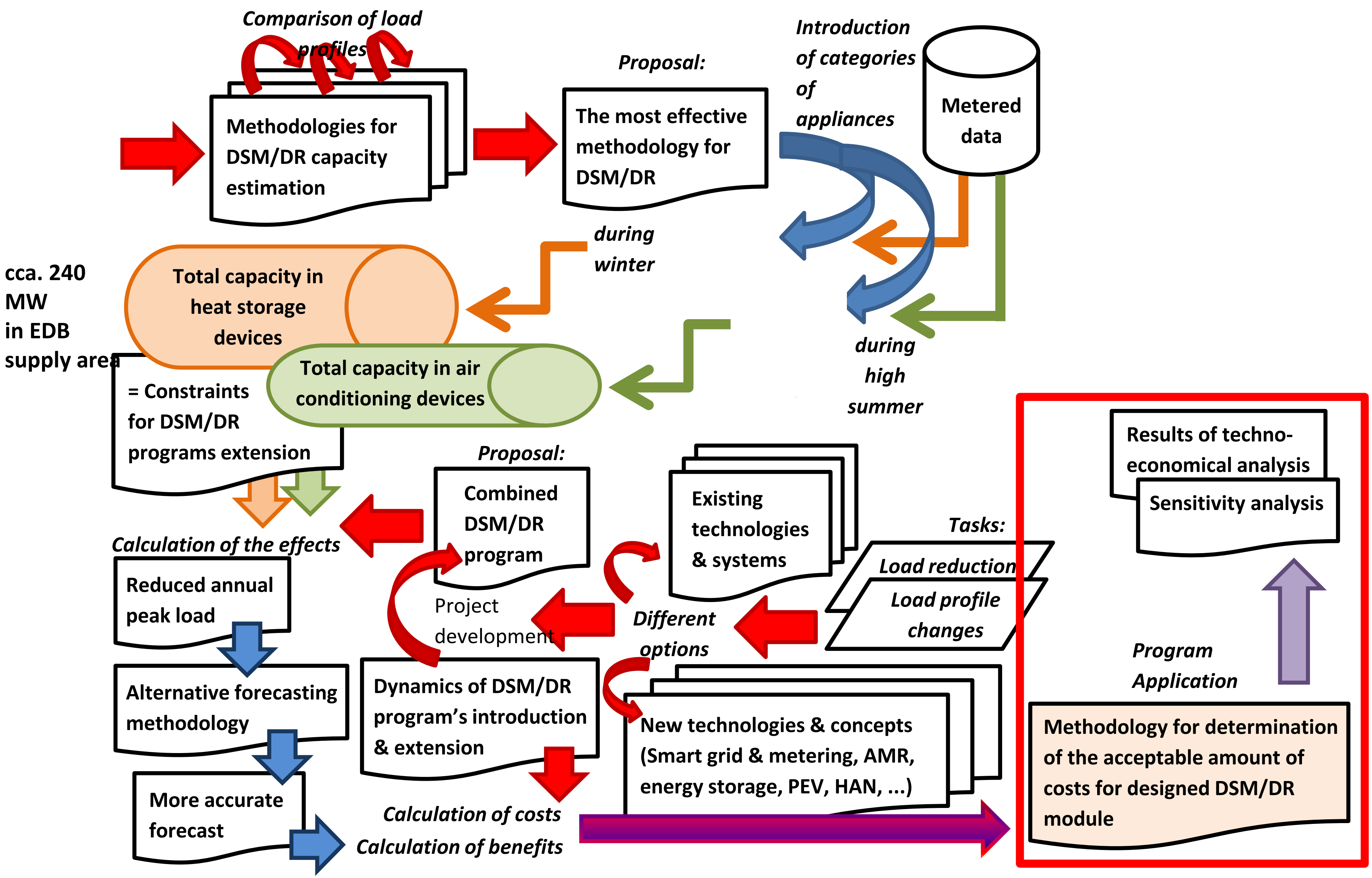

The pair of daily load profiles of the major part of Belgrade's supplying area for the same date in 2011 and 2012, with different weather conditions

# Specific summer load profiles



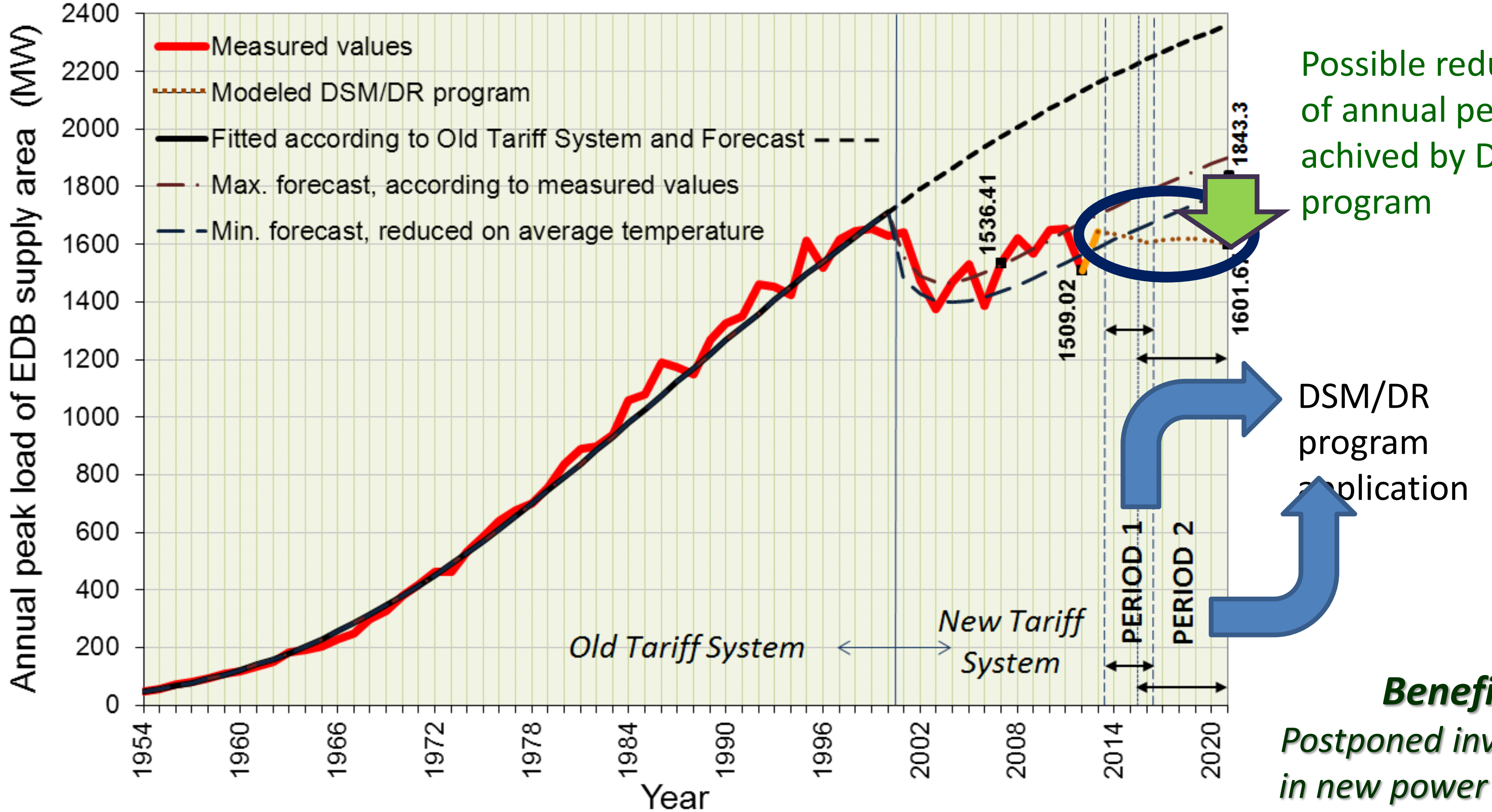

A pair of daily load profiles for almost the same date during summer 2012 and 2007, with opposite weather conditions (upper curve at higher average daily temperature)

# Wider research frame



# DSM/DR program simulation

(The impact on the annual peak load reduction)




***Benefit:***

*Postponed investment in new power facilities*

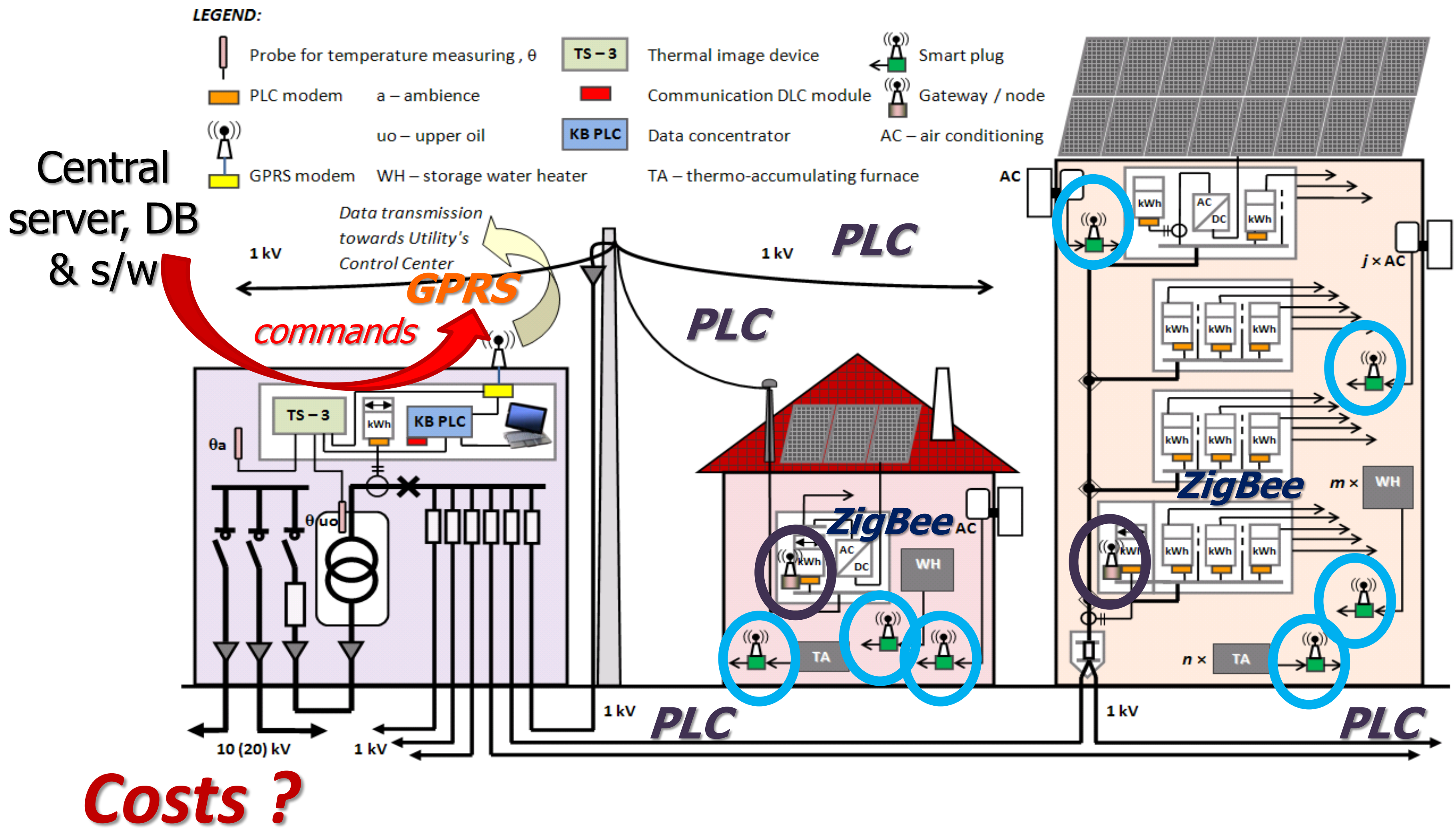
- Achieved and forecasted annual peak loads of EDB - until 2021/22

# *Elaboration of previous figure*

- The end of the introduction period of proposed DSM/DR project is in winter season 2021/22
- Previously forecasted annual peak load has been 1843.3 MW
- Reduction with implemented DSM/DR project is of 241.66 MW
- It is equal to full capacity for DSM/DR of thermal-accumulating devices
- EDB does not need to build four substations 110/10 kV/kV less, $S_{inst}$=2·40 MVA each

# DR solution

## Necessary hardware and software support for remote control




**Costs ?**

# *Elaboration of previous figure -1*

- The above technical solution is based on combined use of AMR system and/or MV/LV power transformer monitoring (left), home area network (HAN) concept and additional devices (right)
- On the threshold of each HAN (right), some gateway device or decentralized controller has to be deployed
- Within the HAN the appropriate household devices should be used (compatible to load management)
- The way of connection of PV-panels and arrays is shown.

# *Elaboration of previous figure - 2*

- The innovative load control system based on stochastic distributed computing and the use of additional devices to select the availability of connected home appliances for load control is designed
- Customers will perform that selection by their own
- Second type of HAN devices is designed to control thermostats of AC devices
- Solution of dynamic instantaneous control problems is achieved based on compromise between occupants' comfort and expenses
- The monitoring of loads at LV boards (left) is to be introduced and data to be sent to the Utility's Control Center

# *Comparison of the costs in two planning alternatives*

- **DSM/DR program's introduction costs:**

  - Replace / re-program old control receivers and smart meters in AMR system
  - Installation of h/w and s/w of DSM module: smart plugs, gateway devices, data concentrators with communication equipment, central server and s/w...
  - Incentives to customers for their participation in DSM

*Details & math model – in Study*

- **Investment costs for new power facilities:**

  - Four substations 110/10 kV (75% loaded, each 2x40 MVA)
  - Supplying lines 110 kV
  - MV and LV grids and substations MV/LV

Total costs: ca. 146 M EUR

***Present value: ca. 101 M EUR***

The upper limit for **cost-effective DSM/DR program**, as it has been designed and proposed here

***All costs are made comparable***

# RESULTS – CASE STUDY OF EDB

Results for the **base case scenario** (for realistic input data):

- Total costs of DSM/DR module introduction, reduced to present value: 47.2 M EUR
- Costs per single "smart" plug: 94.4 EUR
- Costs per participant (customer): 236 EUR

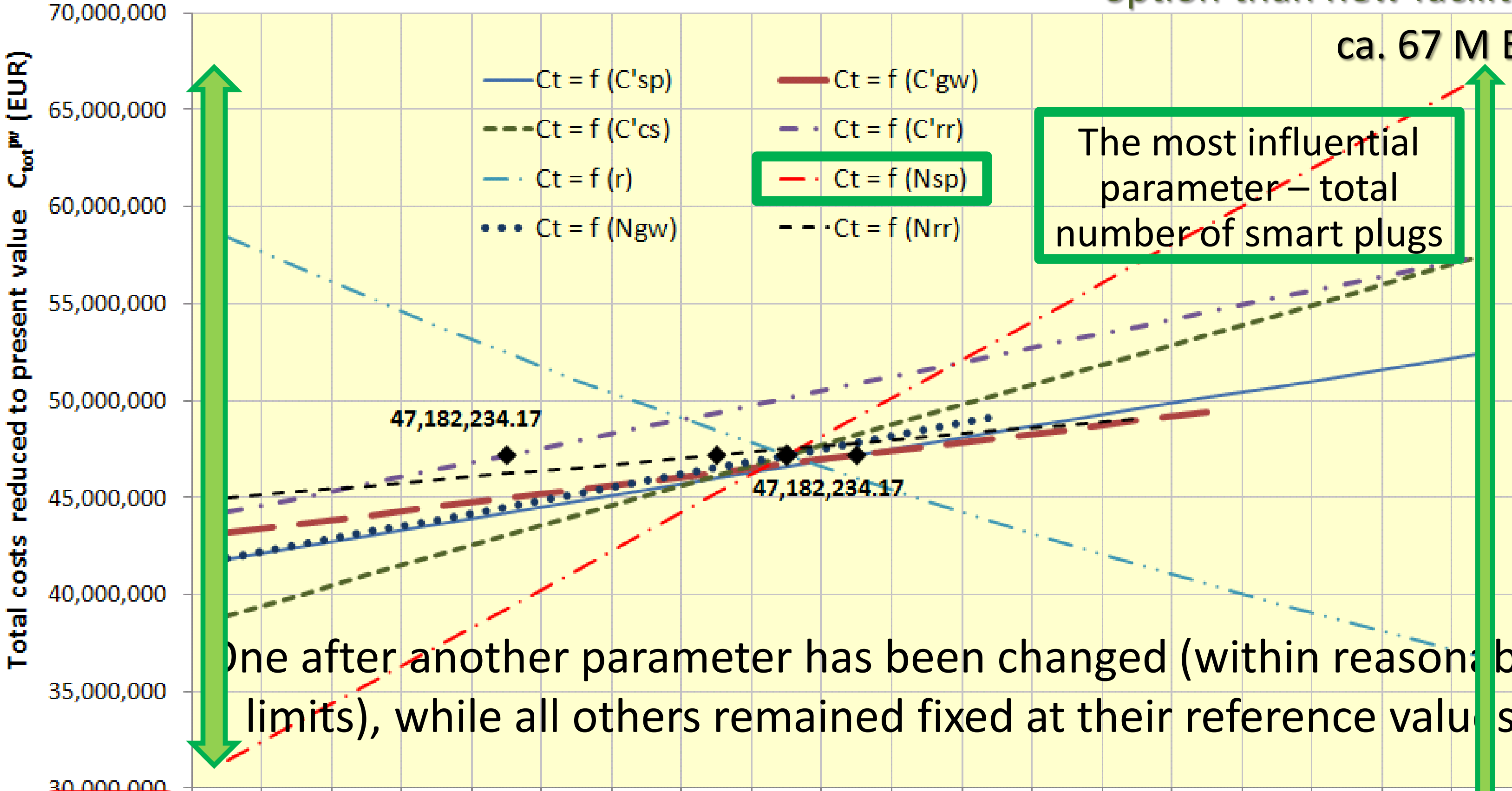
Results for **the worst case scenario:**

- Total costs (net present value): ca. 113.2 M EUR
- Costs per single "smart" plug: 151.0 EUR
- Costs per participant (customer): 377.4 EUR

The option of building the new power facilities is better

# Sensitivity analysis results

DSM/DR program is still better option than new facilities !




| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C'_{sp}$ (€/piece) | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | [illegible] |
| $C'_{gw}$ (€/piece) | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | | | | |
| $C'_{cs}$ (€/piece) | 4,500 | 4,750 | 5,000 | 5,250 | 5,500 | 5,750 | 6,000 | 6,250 | 6,500 | 6,750 | 7,000 | 7,250 | 7,500 | 7,750 | 8,000 | 8,250 | 8,500 | 8,750 | [illegible] |
| $C'_{rr}$ (€/piece) | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 28 | 30 | 33 | 35 | 38 | 40 | 43 | 45 | 48 | [illegible] |
| r (%) | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 | 13.5 | [illegible] |
| $N_{sp}$ (pieces) | 300,000 | 325,000 | 350,000 | 375,000 | 400,000 | 425,000 | 450,000 | 475,000 | 500,000 | 525,000 | 550,000 | 575,000 | 600,000 | 625,000 | 650,000 | 675,000 | 700,000 | 725,000 | 750,000 |
| $N_{gw}$ (pieces) | 30,000 | 45,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 135,000 | 150,000 | 165,000 | 180,000 | 195,000 | | | | | | | |
| $N_{rr}$ (pieces) | 175,000 | 200,000 | 225,000 | 250,000 | 275,000 | 300,000 | 325,000 | 350,000 | 375,000 | 400,000 | 425,000 | 450,000 | 475,000 | 500,000 | | | | | |

**Input parameters**

# Conclusions

- DSM/DR programs represent a serious alternative to the option of building new power facilities
- Important steps:
  - ✓ proper initial estimation of DSM/DR capacity of considered supply area
  - ✓ appropriate DSM/DR program design
  - ✓ examination of individual prices for every single element within DSM/DR program design

# Conclusions (2)

Case study of Belgrade Utility entire supply area shows that DSM/DR program introduction is the better option than construction of new power facilities, in the wide range of variations of influential parameters

# Thank you for your attention !

- Prof Nikola Rajaković, PhD

  +381-11-337-01-68; +381-63-555-375;

  rajakovic@etf.rs