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# Common Methods Used in Load Research

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# INTRODUCTION

- **Different tasks (phases) in Load research require different methods for their calculation.**
- **In general, methods can be divided into three group:**
  - 1. methods for preliminary data analysis,**
  - 2. methods for measurement campaign definition,**
  - 3. methods for model development.**

# Methods for preliminary data analyses

- **Mainly related to preliminary analysis of data from billing files**
- **Based on statistic analysis of available data**
- **Simple calculations like: mean value and/or standard deviation**

# Methods for measurement campaign definition

- **The number of consumers in each class is voluminous, and it is certainly too expensive to collect and analyze the load data of the entire population.**
- **Therefore, a sampling design for each consumer class should be done.**
- **A sample design can be described by two factors:**
  - **Sampling method**
  - **Estimator**

# Methods for measurement campaign definition

- **Sampling method refers to the rules and procedures by which some elements of the population are included in the sample.**
- **Some common sampling methods are:**
  - simple random sampling,
  - stratified sampling, and
  - cluster sampling.

# Methods for measurement campaign definition

- **Estimator**
  - The estimation process for calculating sample statistics is called the estimator.
  - Different sampling methods may use different estimators.
  - Formula for computing a mean score, standard deviation or standard error may vary from one sampling method to the next.

# Methods for measurement campaign definition

- **The first decision is related to the "right" sample size for a particular application.**
- **Decision factors include the following:**
  - **Cost considerations.**
  - **Administrative concerns (e.g., complexity of the design, research deadlines).**
  - **Minimum acceptable level of precision.**
  - **Confidence level.**
  - **Variability within the population or subpopulation (e.g., stratum, cluster) of interest.**
  - **Sampling method.**

# Methods for measurement campaign definition

- Number of samples could be calculated by Gaussian (Normal) distribution of consumption like

$$n_i = 1.96^2 \frac{\sigma_i^2}{\mu_i^2}$$

where  $\sigma_i$  and  $\mu_i$  are standard deviation and mean of annual kWh consumption of consumer group  $i$ , respectively.

The confidence interval is appointed on 95%

# Methods for measurement campaign definition

- **Sampling validation**
- **Quality of results could be described by:**
  - mean value (compare sample average consumption of each type of consumers by average consumption of population),
  - variance (pattern deviation),
  - standard error,
  - margin of error.

# Methods for model development

- **Method selection depends on defined tasks in a Load Reserach Project and available data and results obtained in previous steps.**
- **There is diversity in methods that could be applied**
- **In general, thay could be divided into:**
  - **Classical methods (clasical statistic clustering, time series anaylises, ...)**
  - **Advanced methods based on artificial intelligence.**

# Methods for model development

- **Disadvantages of classical methods:**
  - need accurate, reliable, well organized and large historical database
  - based on assumption about static load shapes
  - influence factors can not be fully utilized
  - difficult to capture nonlinear behavior between inputs and outputs
  - complex modeling techniques and heavy computation efforts to produce reasonably accurate results

# Methods for model development

- **Advanced methods based on artificial intelligence are the methods with very “exotic” names:**
  - **Artificial Neural Networks**
  - **Fuzzy Inference System**
  - **Approximate Reasoning**
  - **Heuristic methods (Evolutionary Computation, Particle Swarm Optimization, Simulated Annealing)**
  - **Hybrid intelligence systems**

# Methods for model development

- **Advantages of methods based on artificial intelligence:**
  - **information better extracted from historical database**
  - **assumption about dynamic load shapes**
  - **model the non-linear relationship between inputs variables and outputs (universal approximations)**
  - **have capability to learn and to draw inferences about process**

# Conclusions

- **Depending on data quality and availability as well as defined tasks in Load Research, methods are chosen.**
- **Methods used in Load Research range from very simple statistical tools to advanced artificial intelligence-based methods.**
- **Simple statistical tools are used for preliminary data analysis, sample definition for measurement campaign and validation of collected data of each consumer group.**

# Conclusions

- **Consumer clustering, load profiling, loss estimation and allocation, load forecasting and other tasks could be a part of load research and solved by advance methods based on artificial intelligence.**
- **Methods based on artificial intelligence have the capability to behave as an expert.**
- **No single methodology can be applied to load research!**

**Thank you!**