# Smart Sizing: A tool for long term planning of smart distribution networks


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# Need for new distribution system planning tools

- **Long-term planning** of distribution networks is becoming increasingly **complex** due to
  - — Massive penetration of **Distributed Generation**
  - — **New** type of **loads** (Electric vehicles, heat pump, …)
  - — **Demand Side Management** (load flexibility)
- Historical **fit-and-forget** approach of network planning for the **worst case** is n**ot possible any more** due to:
  - — The unpredictability of the future worst case scenarios
  - — **Possibility of sub-optimal solutions due to non-inclusion of** as active network management
- Network planning tools must **now** consider at the same time
  - — **Traditional** grid investments (transformers, cables etc.) and operation costs (cost of losses)
  - — **Active network management** (load & generation flexibility such as load shifting and generation curtailment)
    - ICT investments
    - Operation costs of load and generation flexibility

Source: wikipedia

# Smart Sizing for long-term planning of smart distribution network

- **Objective**
  - Develop a new network planning tool that fully takes into account the smart grids context
- **Approach**
  - A green field approach is envisaged in the tool
  - The target network is in that sense ideal, as it does not take into account the existing network
  - The results obtained from Smart Sizing can be used as guideline for the distribution system expansion planning
- **Three main differences with respect to the traditional planning tools**
  - The network is no longer planned on the peak load
  - Smart technologies such as distributed generation, load flexibility, and ICT
  - Distributed generation and its associated flexibility are modelled
- **Output**
  - An ideal target network in terms of size of equipment, system architecture, needed flexibility and the associated infrastructure etc.

# Smart Sizing does the techno-economic optimization of the distribution network

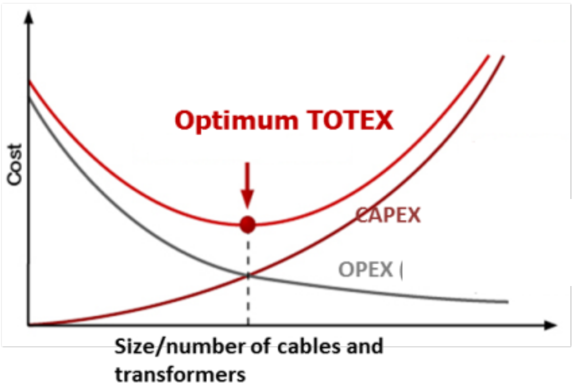
- The optimisation model aims at minimising the total cost of the network over the studied horizon as follows:

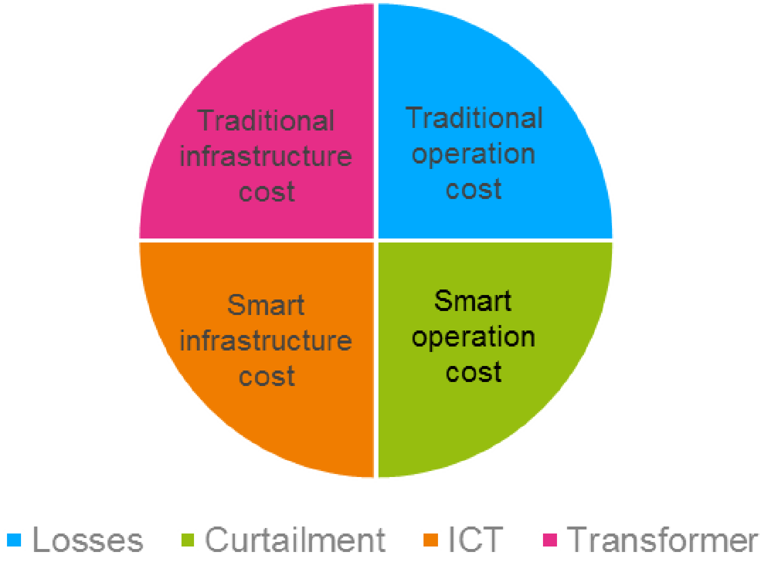
$$\text{Minimise } \left(\sum_i IC_i + CACT \sum_{i,p} w_p * OC_{i,p}\right)$$

Where *IC* is the infrastructure cost representing the CAPEX (electrical equipment and ICT infrastructure), *OC* is the Operation cost representing the OPEX (cost of losses and activation cost of flexibility), *i* is the total number of voltage levels, *p* is the number of time periods under consideration, $w_p$ is the weight of period *p* and *CACT* is the capitalised unit cost

- Constraints include restrictions on voltage drop, loading of equipment, etc.
- Mathematical formulation is a non-linear constrained optimisation problem

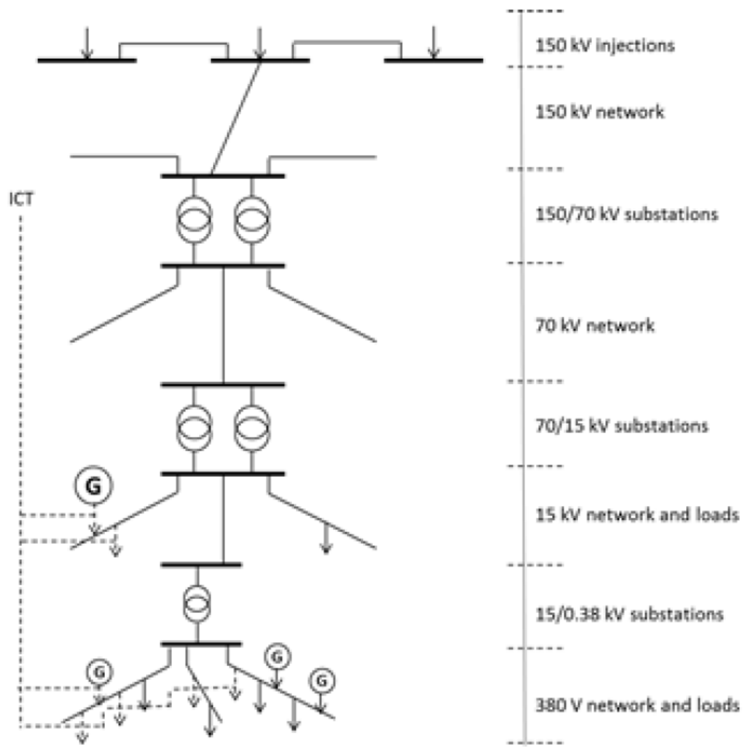
**Trade-off between CAPEX and OPEX**
**Long term: for designing grid structure**



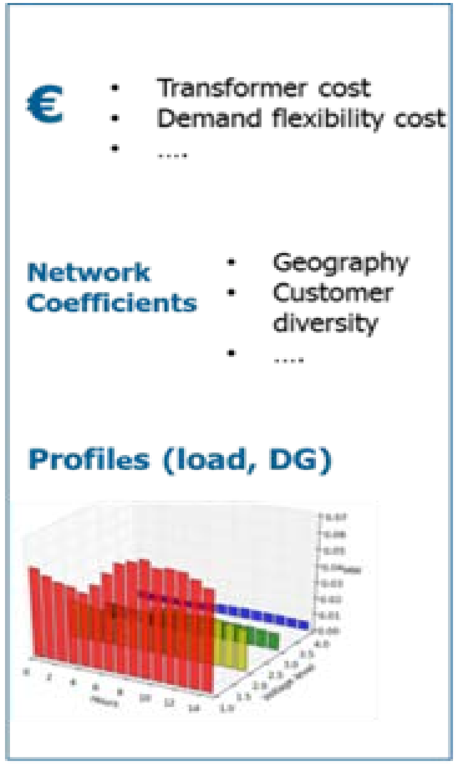
# Salient features of Smart Sizing

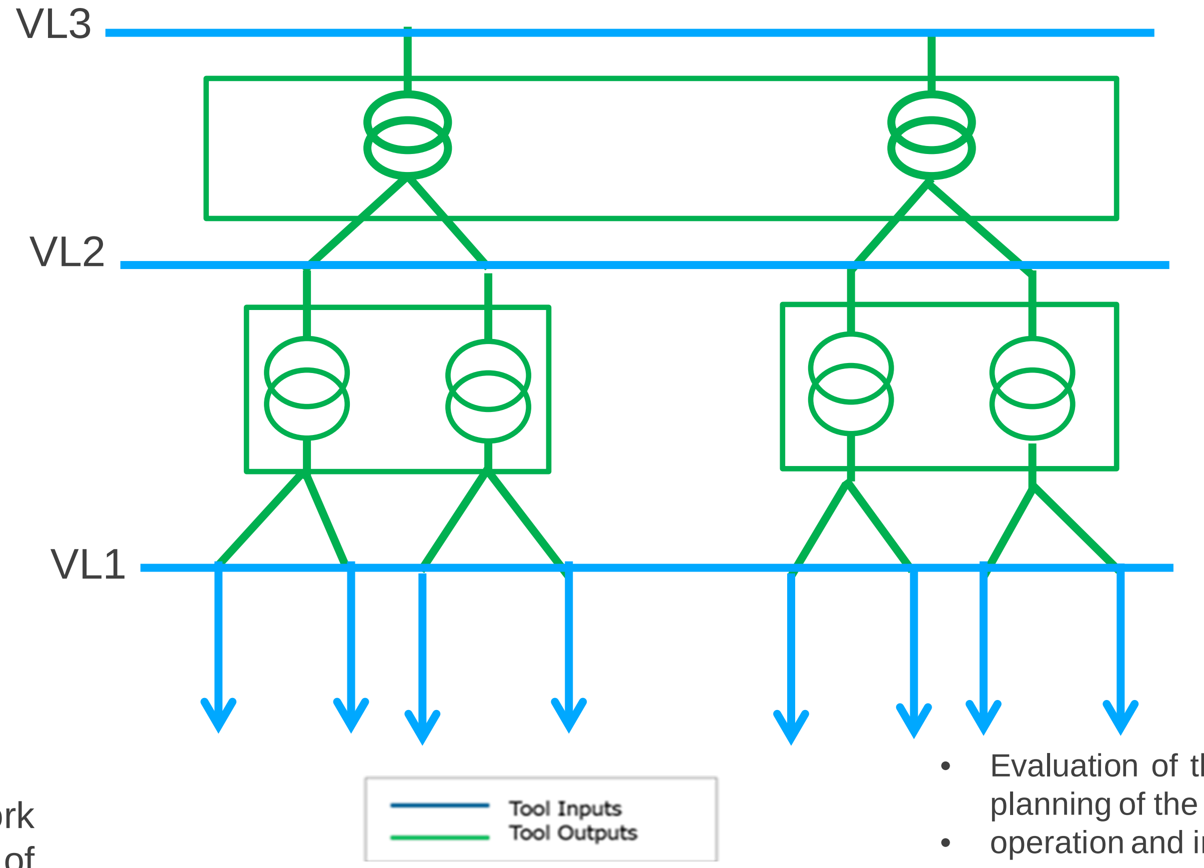
- **Integrated planning from MV down to the LV**
  - — Multiple voltage levels can be planed simultaneously resulting in over-all optimum network
- **Modelling of network possible with a few network parameters/details**
  - — Thanks to the assumption of spatial uniformity, detailed network structure data is not a necessity
- **Evaluating flexibility as one of the control options in reducing the TOTEX**
  - — Can choose between the various flexibility options
    - Load shifting
    - Load shedding
    - Generation curtailment
- **Distribution network planning encompassing reliability aspects**
  - — Can choose the degree of reliability required in the network




*Conceptual network model*

# Smart Sizing does the integrated planning from MV down to the LV



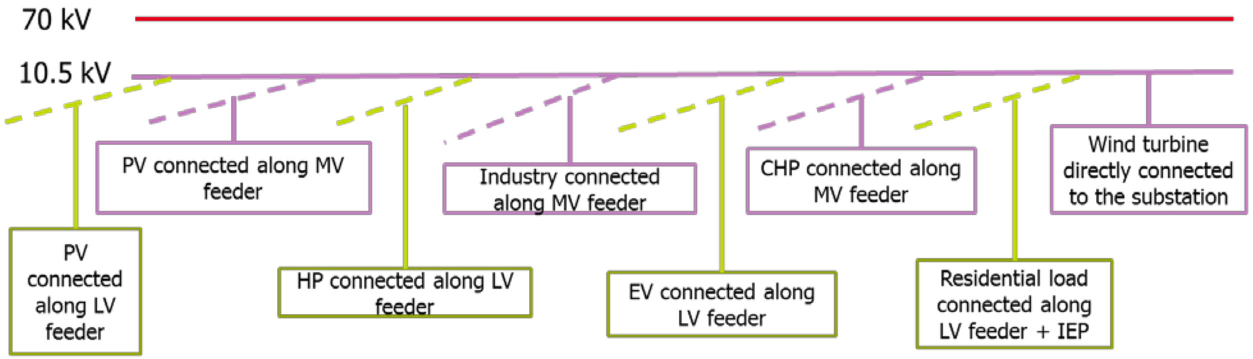





- Modelling of network with a few network details: Thanks to the assumption of spatial uniformity, detailed network structure data is not a necessity

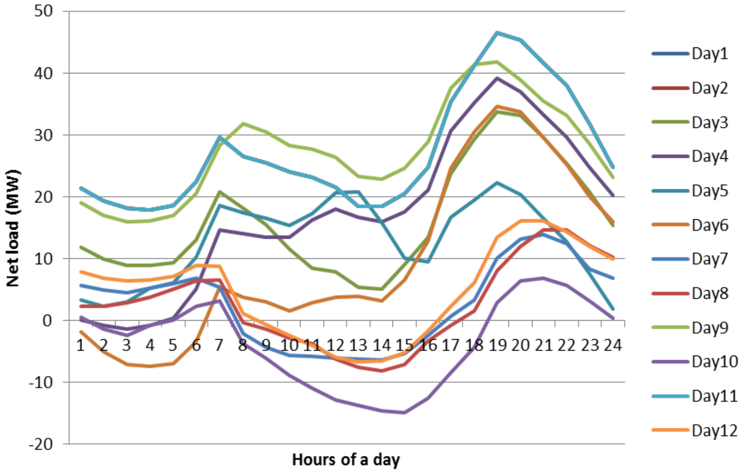
- Evaluation of the effect of flexibility on the long term planning of the network
- operation and infrastructure cost of the network
- Identification of the type & the required flexibility profile in a network
- Evaluation of the critical cost of flexibility

# YLPIC case study description




**The YLPIC network: A typical Wallonian (Belgium) network**

| Case study | Description |
|---|---|
| Case 1 | No flexibility option activated |
| Case 2 | All flexibility option activated |




**Net load profile of the 12 representative days**

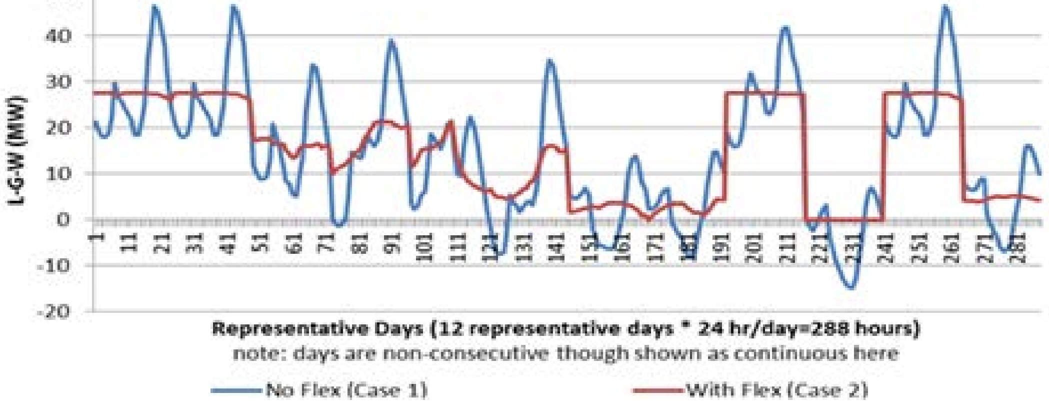
- Net energy = 109 GWh/year
- Positive peak = 46.56 MW
- Negative peak = -14.9 MW

Both the test cases were studied to analyse the impact of load and generation flexibility in the planning of the YLPIC network.

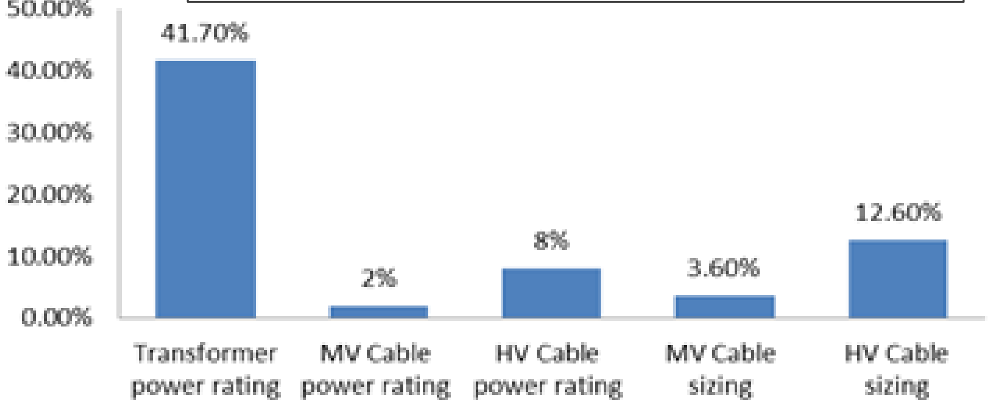
- Case1 included no flexibility option in the network
- Case 2 included the following flexibility options:
  1. Load shifting
  2. Curtailment of generation connected along feeders (PV_LV, PV_MV, CHP)
  3. Curtailment of generation directly connected to the 10.5 kV substation (Wind)

# Results & Discussion

**Net load seen by the transformer in Case 1 & Case2**




**Effect of peak reduction in the equipment sizing**

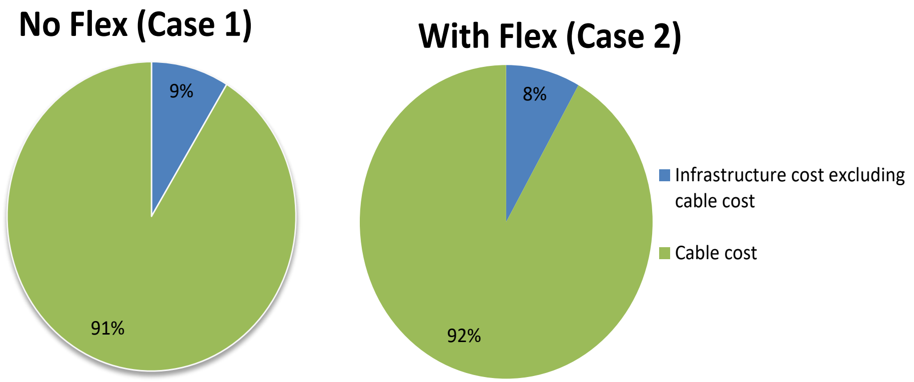



- There is a reduction in net peak by around 35% due to activation of flexibility in Case2 compared to Case1
- Case2 in turn requires the DSO will have to avail
  - 25.6GWh of load shifting and
  - 1.4 GWh of wind curtailment
  
  ➔ more load shifting than wind curtailment

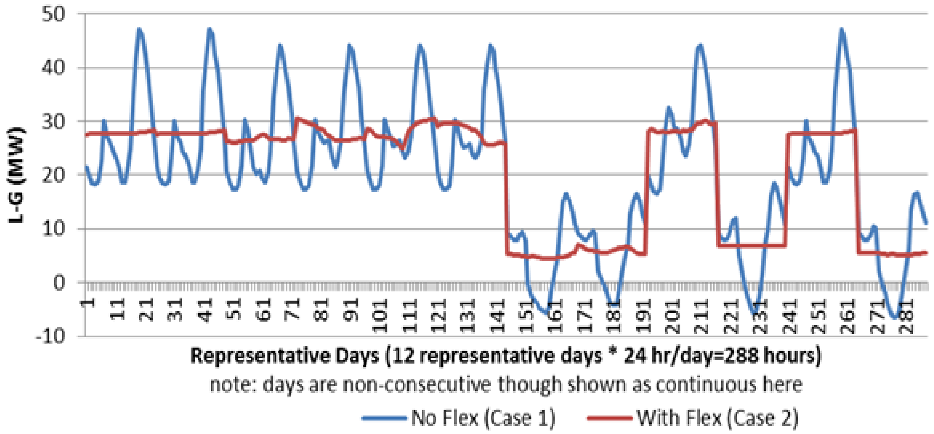
- The net load peak reduction of 35% due to activation of flexibility, resulted in a major reduction in power rating of the transformer (approx. 42%).

# Results & Discussion

**Infrastructure cost**




**Net load seen by the MV feeders in Case 1 & Case 2**




- Though there is approximately 21% reduction in transformer cost due to transformer peak reduction, the reduction of total cost is only 1.4%. This is because the cable cost takes a major part of the total cost.
- The cable cost reduction is negligible primarily because the cost contributed by the cable length outweighs any reduction in cost that may be achieved by reduction on peak load
- In addition, though a reduction in peak results in lower size of the cable it may result in increased losses, thus the cost reduction due to cable size reduction is also negligible.

Load and generation flexibility will find increased value in reducing the total cost:
- when the infrastructure is mainly dimensioned by the peak and
- there exists non-simultaneity between the load and generation

# Conclusion

- Smart Sizing is a novel long term planning tool
- Tool aims to minimize the total cost of the network over the study horizon
  - CAPEX mainly includes the infrastructure cost including ICT cost
  - OPEX includes the cost of losses & operational flexibility
  - The decision variables of the optimization problem are variables related to the investment in electrical equipment & the required flexibility in the network
  - Constraints include restrictions on voltage drop and overvoltage, and loading of equipment
- At the end of the optimization, an ideal network is proposed
- The output of the tool is not only the number of substations and transformers, the total length and size of the cables, but also the required amount of flexibility to be contracted

# Any Questions?

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