Communications requirements in low-voltage smart grids

Fernando Kuipers
Network Architectures and Services
Delft University of Technology
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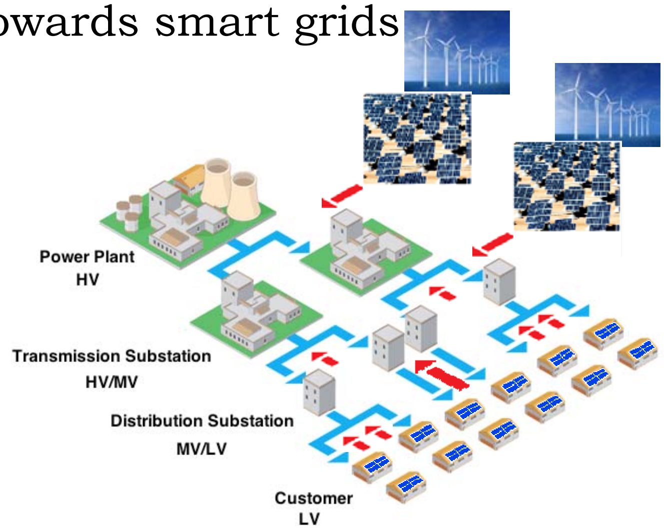
http://www.nas.ewi.tudelft.nl/people/Fernando/

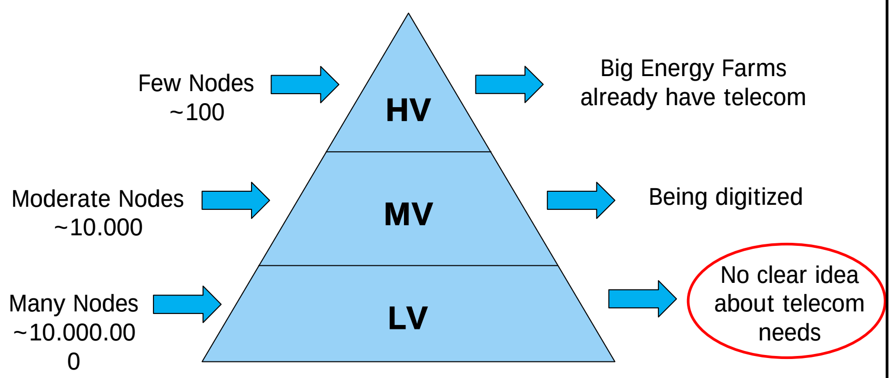
Environmental concerns

Towards smart grids



ICT needed to make the grid smart

Focus on LV networks

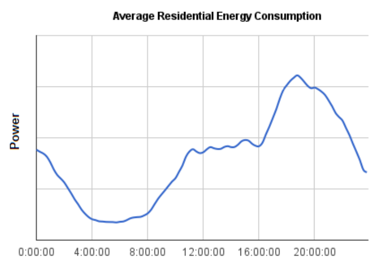


Challenges

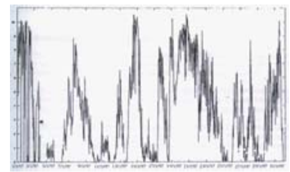
- Integration and intermittency of renewable generators
  - **Load balancing, energy storage**
- Integration of new energy consumers: Electrical Vehicles and Heat pumps
  - **Peak shaving**
- Energy trading by former consumers
  - **Prosumers, energy brokers, ...**
- Physical limitations of the power grid
  - **Voltage and congestion control**
- Multi-layer dependencies
  - **Multi-layer control**

Balancing problems

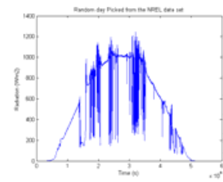
Match consumption with generation



Match consumption with available wind and sun power



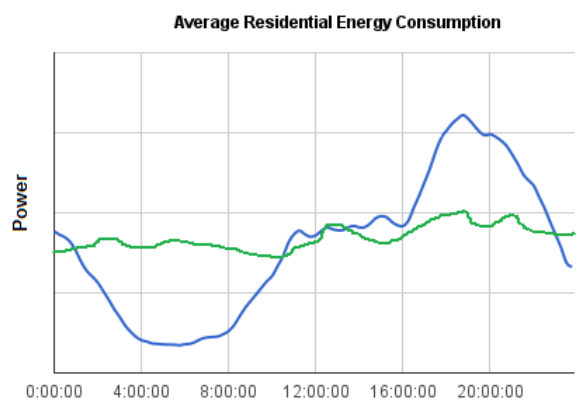
Wind



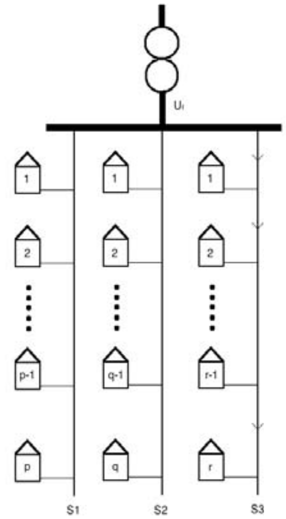
Sun

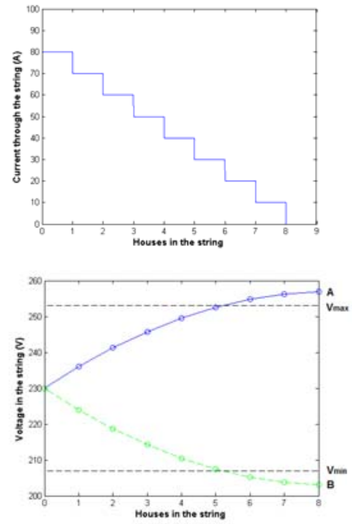
Avoiding peaks

Peak shaving



Voltage and congestion problem





Communication time requirements

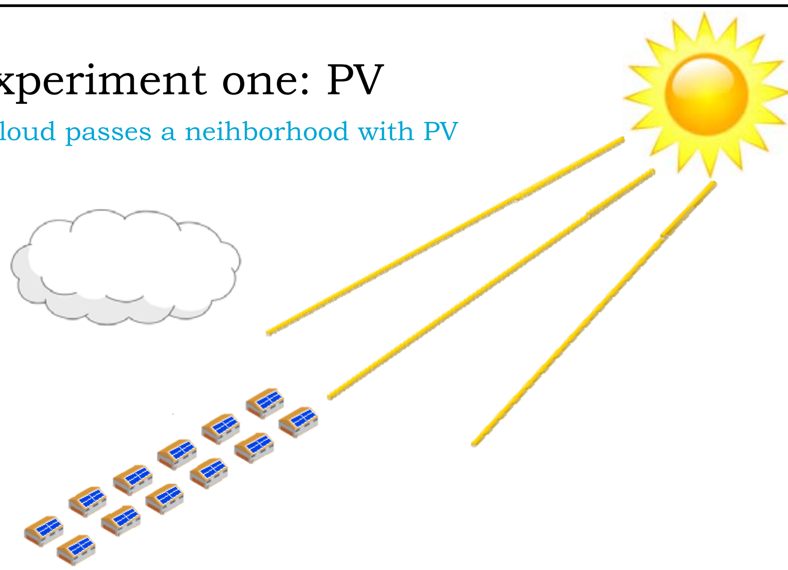
- Load balancing and Peak shaving
  - In the order of minutes
  - E.g. PowerMatcher
- Local power exchanges
  - Communicating price signals in the order of minutes
- **Voltage and congestion control**
  - Directly linked with safety of the grid
  - Voltage and load vary real-time
  - Sub-second response time requirement

Experiments V&C control

- We consider a low voltage (LV) grid with prosumer households
- Based on study of distribution networks:
  - Representative LV network selected
- Considered (futuristic) scenarios:
  - Solar panels at each house
  - Electric vehicle at each house

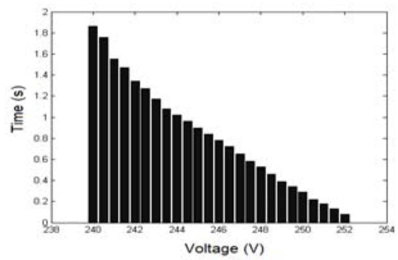
Experiment one: PV

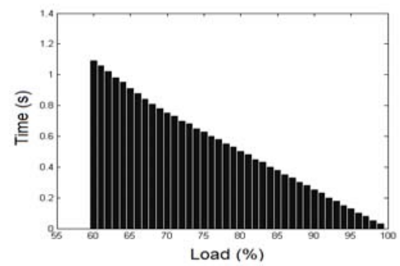
A cloud passes a neihborhood with PV



Results PV experiment

- Used an annual 1 Hz frequency solar radiation dataset
- Selected periods showing extreme variations

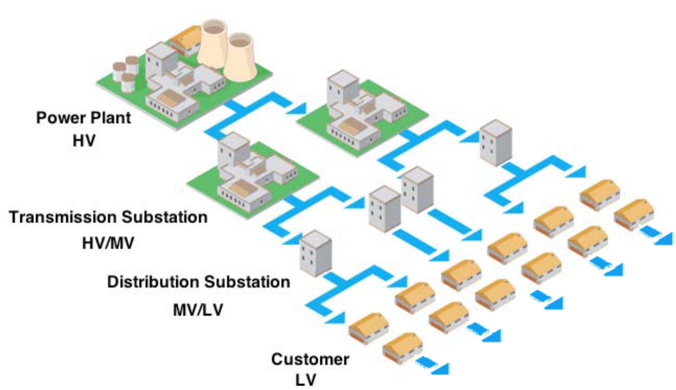




- 600 ms from 80% of overvoltage (248 V) to the maximum
- 500 ms from 80% load to maximum capacity
- Overvoltage burns fuses, brief overload is tolerable

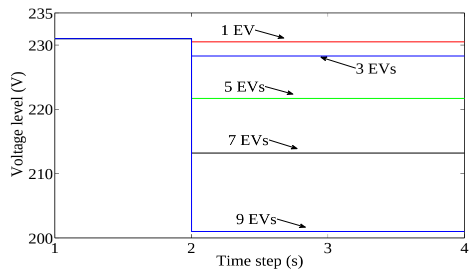
Experiment two: EV

Time at which charging of electrical vehicles begins



Results EV experiment

- EV charged as soon as it arrives at home
- EVs start to charge in the same second (Figure)



- Chances are very small that 2 or more start to charge in the same second
- The EV load dynamics pose less constraints on the response time for voltage and congestion control

Response time constituents

For a centralized control scheme:

1. Measurement time: 10 ms
2. Upward communication time
3. Computation time: about 5 ms
4. Downward communication time
5. Control time: about 5 ms

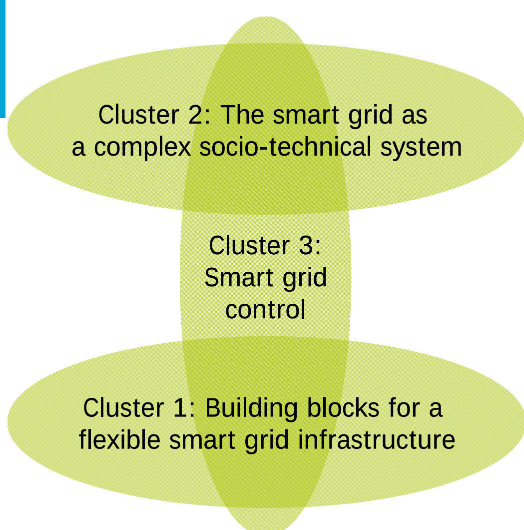
- Communication time (2 and 4) at 80% overvoltage
  - Communication Latency = (600 ms - 20 ms)/2 = 290 ms

Trigger point (% overvoltage)	40	50	60	70	90	95
Latency constraint (ms)	990	740	490	390	90	25

PowerWeb

- TUDelft interdisciplinary research consortium working on the challenges in realizing a robust and reconfigurable smart energy grid
- Steering board:
  - Prof. Lou van der Sluis
  - Prof. Paulien Herder
  - Dr. Fernando Kuipers
  - Prof. Kees Vuik
  - Prof. Cees Witteveen
- Industry:
  - Alliander, Tennet, TNO, Siemens, Phase2Phase, JRC Petten, ...

PowerWeb overview



A system of energy prosumers, subjected to governmental regulations

A system of systems having to meet overall robustness criteria and being able to reconfigure itself if necessary

Real-time power control system optimizing functions in relation to physical infrastructure and environment

Cluster 1: Smart grid infrastructure

- Observation: Power grid is rapidly changing (distributed renewable sources) and increasingly complex to manage
- Challenges:
  - How to model the changing grid and its physical properties?
  - How to ensure stability?
- First steps:
  - Efficient solvers to compute transients in power grids
  - Quantify operational limits of smart grid
  - Build simulators

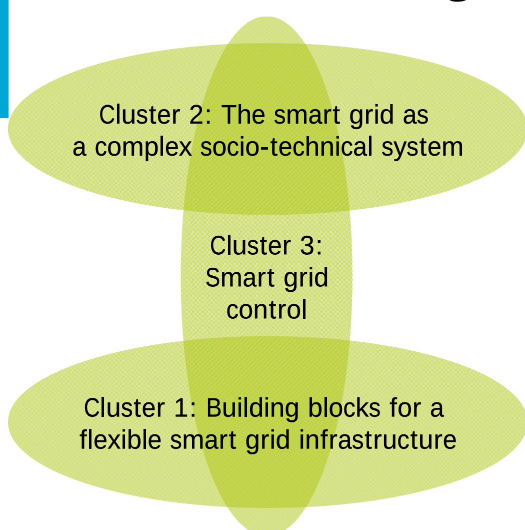
Cluster 2: Smart grid and society

- Observation: The smart grid is a complex socio-technical system governed by “prosumers” and government
- Challenge:
  - To identify the right institutional and market concepts to predict and control the smart grid as a dynamic multi-actor system
- First steps:
  - Multi-actor model to capture relationships between changes in the energy supply, demand patterns or regulations and prosumer behavior
  - Mechanism design to control through proper incentives

Cluster 3: Multi-level ICT control

- Observation: Control actions to enhance stability and robustness performed on one level of a multi-layered system might have repercussions on other levels
- Challenges:
  - Create a multi-layered model
  - ICT-based control of dynamic interactions between the physical and societal layers
- First steps:
  - Description of each layer as a discrete event system
  - Coupling the layers and study of interdependent networks
  - Optimizing equilibria

PowerWeb challenges summarized



- Optimize economical operation
- Optimize environmental effects
- Provide consumers with choice options

- Ensure reliability/security of supply
- Reconfigure to maintain QoS

- Facilitate power generation
- Improve plants to run system
- Reduce environmental impact

PowerWeb objectives

- Gateway for energy work at TUDelft
- 3 PowerWeb PhD students on 3 research themes
- Links to industry
- Participate in call for projects
- Collaborations
- http://powerweb.tudelft.nl
- Fernando Kuipers: F.A.Kuipers@tudelft.nl