Analysis of demand-response and distributed generation use-case scenarios in a virtual microgrid

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Testing smart grid information and communication (ICT) infrastructures is imperative to ensure that they meet industry requirements and standards and do not compromise the grid reliability. Within the smart grid design hierarchy, microgrids are integrated energy systems, with the possibility of bidirectional power flows, consisting of interconnected loads and Distributed Energy Resources (DERs), which can operate in parallel with the grid or in an intentional island mode (see Figure 2). As such, microgrids present many new challenges from the standpoint of control and communication infrastructures. In response to these challenges, the European Institute of Technology (EIT) Information and Communication Technology (ICT) Labs (`http://www.eitictlabs.eu/`) has introduced the action-line Smart Energy Systems (SES) to develop a Europe-wide coalition of academic and industrial partners and resources in the ICT sector to accelerate innovation in energy management and green ICT management. Within the EIT ICT Labs SES, and motivated by ongoing smart grid pilot research within the Stockholm Royal Seaport project (`http://stockholmroyalseaport.com/`), partners from industry and academia have combined resources to develop a Virtual MicroGrid Laboratory (VMGL) for testing and evaluating distributed generation and demand-response capabilities.

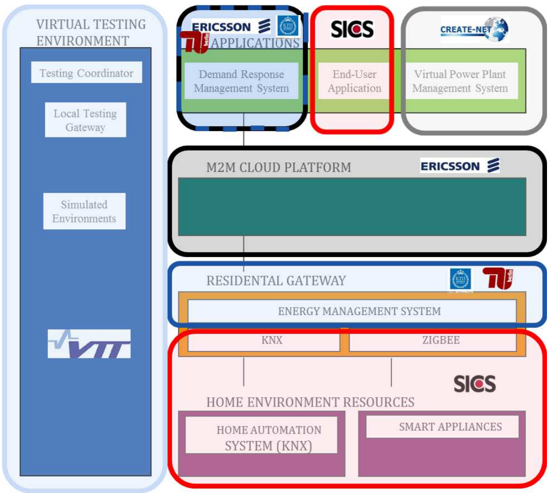

Figure 1: Virtual MicroGrid Laboratory architecture.

1 Background

There are several aspects in a microgrid the control structure must take care of, which involve different control approaches and different time scales (e.g., seconds for fast electrical control of phase,

frequency, and voltage of individual components, hours for unit commitment and economic dispatch of all generating units and storages, demand-side optimization). Thus, a reasonable control approach is to develop a hierarchical control structure to address each requirement at a different control level: a high level controller (tipically called MicroGrid Central Controller, (MGCC) is on the top of the hierarchy, while the second level of controllers is formed by load controllers and distributed energy resources controllers. The objective of the high level control algorithm is to generate suitable set points for all sources and storages so that economically optimized power dispatch will be performed and a given demand is met. The local controllers have to guarantee that the system tracks the power reference values, ensuring the voltage stability.
The high level controller deals with the long-term behavior of the integrated system and is weakly dependent on the transient behavior of the fast dynamics: its model does not need to include all possible equations representing the dynamics of all possible microgrid generating units, which would make it intractable (this is a typical tradeoff of the systems approach).
The testing to be performed in the virtual environment will concern high-level control: the investigations will be focused both on single buildings (residential microgrids, see Figure 2) and on microgrid comprising industries and residential buildings. In the first case, the target is to optimally schedule consumption of electrical loads like ventilation, dishwashers, washing machines, fridges, heat pumps, lighting, from a centralized controller; in the latter case, the aim is to optimally plan the microgrid operations, i.e., how to schedule internal production by Distributed Generators (DG), as well as controllable loads, to cover the whole microgrid demand and optimize a performance criteria.

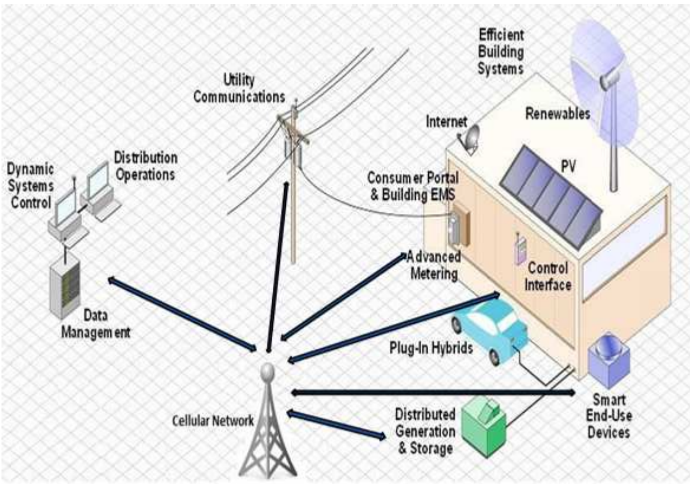

Figure 2: A typical residential microgrid.

2 Thesis Objectives

The objectives of the thesis are:

- carrying out tests on demand response and distributed generation in the virtual laboratory;
- investigating the effects on demand profile of:
  - time-varying electricity prices on a day-ahead or hourly basis (in order to evaluate price elasticity of demand, i.e. is demand sensitive to change in prices);
  - a cleaner mix of energy to meet the electrical demand;
  - having a lager storage capacity;

- assessing the control strategy in terms of:
  - energy savings;
  - energy efficiency (energy savings while keeping a given level of service);
  - emission reduction;
  - effects on the demand peak (capability to flatten the aggregate energy demand);
  - scheduling algorithm performance (e.g., computational times, scalability);
  - comparison with benchmark and current practice.

3 Required skills

The thesis work involves implementation and simulation tasks. The student is required to have good programming skills (e.g., Matlab) and basic knowledge of optimization and control will be considered with priority.

4 Contact

The starting time for the thesis work is May 2013. Supervisor: Prof. Karl Henrik Johansson (kallej@kth.se)
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