Optimization of Quality of Supply in Demand–Response Schemes

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Within the SEMIAH European project, CSEM is developing models to assess the available flexibility in power usage from home appliances and to optimize the quality of supply. Demand response can be used to mitigate some of the local issues associated with distributed power generation, which have been identified through measurement campaigns, as well as to provide power management services to distribution network operators. This capability opens business opportunities for demand-response schemes beyond trading on wholesale electricity markets.

The SEMIAH consortium is developing a demand-response (DR) framework based on the aggregation of the flexibility which is available at the household level. The purpose of such systems is to provide additional flexibility to the power system so that demand and production can be matched at all times without relying on expensive and polluting peaking power plants. Flexibility needs in the power system increase with the increasing use of variable, weather-dependent renewable power sources such as wind and solar power. Demand-response services can be monetized on wholesale electricity markets, through the market for ancillary services, or by providing savings to network operators or prosumers.

At the heart of demand-response systems lie forecasting and optimization algorithms to balance multiple objectives and constraints: user comfort, financial gains, regulatory constraints, etc. CSEM's contribution to the project focuses on two aspects: the modeling and forecasting of the flexibility that household appliances can provide, and the definition and validation of rules ensuring that the demand-response system maintains or improves the quality of supply.

In a first phase, CSEM investigated the number of households required to guarantee a minimum level of power reserve for tertiary control. Appliances in scope were white goods: washing machines, clothes dryers, and dishwashers.

For this purpose, a stochastic model of a typical user's consumption profile was developed based on measured data from a test site in Valais. The model was then used as load estimator and was integrated in a simulator to estimate the total load curve for a group of households. The number of households required to provide 5 MW tertiary control power was then evaluated with various time constraints for load shifting. The results are shown on Figure 1. Finally, a first scheduling strategy for load shifting was proposed.

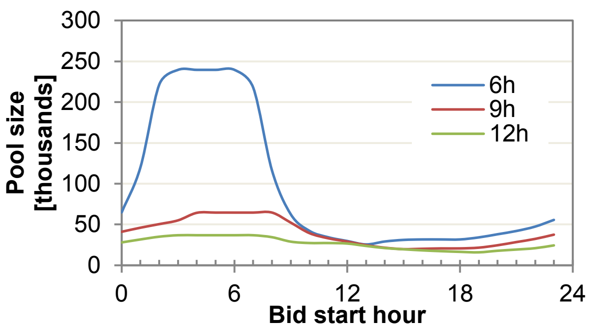

Figure 1: Minimum pool size to provide 5 MW of tertiary control power as a function of the hour at which the capacity is guaranteed (bid start hour) and the maximum shift in switch-on time (6 h, 9 h, 12 h).

While there are studies on the impact of demand response on overall system stability, few publications report on the local impact of DR systems on power quality. Yet local impacts can appear even in pilot stages, whereas system-wide disturbances are only likely to occur at high levels of deployment.

The major risks in low-voltage distribution networks which are relevant for a DR aggregation framework were then identified. The main risk from DR itself is current levels rising above the rating of transformers and lines, as already experienced with ripple control. Risks from distributed generation which can be managed with DR are reverse power flows and overvoltage. This assessment was validated through high-resolution power quality measurements on feeders with high PV penetration. Reverse power flows to the medium-voltage level at a transformer serving one of these feeders were indeed regularly observed between April and September (Figure 2).

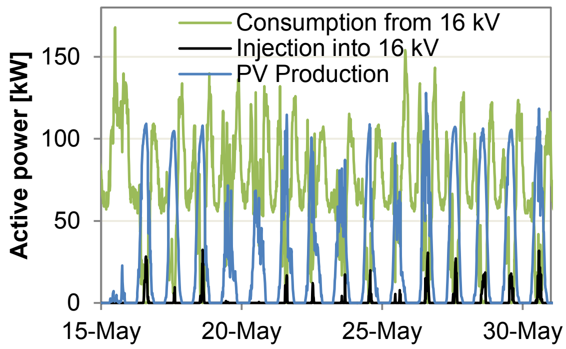

Figure 2: Net power consumption and injection from the low-voltage (seven feeders) to the medium-voltage level, and the production of a 145 kW$_p$ PV system connected to one of the feeders.

Electrical sensing capabilities in the SEMIAH framework are limited to energy and exclude voltage or reactive power measurements. As a result, we formulated constraints for the scheduling algorithms which can operate solely on active power. In the next phases of the project, these formulations will be validated through modelling under Digsilent PowerFactory of SEMIAH's test sites and benchmark feeders.

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