POSTER ABSTRACT P9

Load management for idle capacity of power grids

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Abstract

A major issue hampering a rapid substitution of fossil fuels by electricity from sustainable sources is the fear of congestion of the power grid and of associated costs of their reinforcement. The conventional approach prevents any rapid raise of electricity demand by encouraging other energy carriers and sector coupling. However, no approach investigates the utilization of the full capacity of the power grid alone, which are kept idle to provide sufficient reserve for the case of a failure. Therefore, we test a load management approach designed to utilize this reserve capacity. We verify in this paper the correct functionality of the system made of a device manager for cost optimization of schedules and of a grid manager to enforce the respect of power limits of the grid. This novel approach contributes to reduce emission of greenhouse gases without grid reinforcement.

Keywords: power grid capacity; load management; congestion; sector coupling

Introduction

Energy systems are undergoing transformations towards a reduction of emissions of greenhouse gases. A reduction of on-site consumption of fossil fuels in energy intensive industries may be encouraged by policies raising the taxes on CO_2, under the condition that adequate alternative supplies becomes available. The progresses and drop of prices make decentralised energy conversion (like Power–to–X units), storage and automation technologies good candidates to become these alternatives. Under the prerequisites summarized in Figure 1, we assume that many new flexible loads will be installed within a short time frame, which may increase the risk of a congestion of the power grid. We concretize then a load management system designed, by a better utilization of existing capacities, to avoid a grid reinforcement.

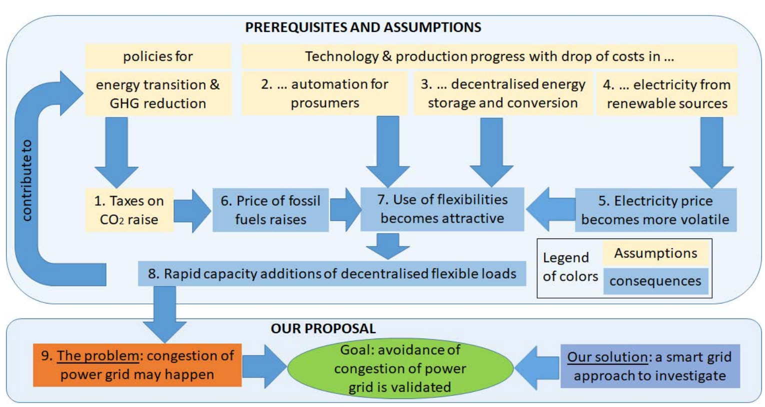

Figure 1 Prerequisites and assumptions in the context of the project

State Of the Art and Utilization of the Unused Grid Capacity

The selection and operation of available technologies of oil, gas, heat or electricity supply, their conversion or storage at end-customers and at distribution system operators (DSO) should be cost efficient. [1] and [2], which answers also the network design question, proposed a first solution for the coupled operation of several energy networks, but still can not be applied for real-sized grids. Our opposite approach is a total switch of energy carriers into only electricity. But this switch could in worst-case roughly double the load on the electricity grid and the fear of a grid congestion which would disqualify our approach. The risk of congestion, as known from high voltage grids in [3], is less documented in middle and low voltage grids where grids are designed larger than the minimal required capacity as cables are cheaper than workforce [4] and DSO would be obliged to reinforce their grid as soon as new loads are installed at their end-customers. Assuming a congestion due to new heat pumps, [4] quantified that a strong reduction of maximal capacities of each customer (from 17 to 6 kW) combined with shifts lowers the system load by only 1.5 % whereas a virtual power plant (VPP) contributes to 8.5 %. However, none of the methods utilizes the idle capacity of power grid kept for the security of supply. Indeed, the grid structure of open ring with two branches (Figure 2) supplies electricity to industrial customers in middle voltage grid. In case of a failure of one asset of the grid (the N-1 case), the power supply to its customers is guaranteed by the redundancies of the other branch (right side of Figure 2). The full capacity of power grids, designed for coping with the rare failure of one asset, has potential for flexibilities. [5] utilize the existing flexibilities with a "Traffic Light" to indicate their current limitations: major (red), some (amber) or none (green). They introduced a new category of loads, the "conditional loads" at reduced tariff (PAT), designed for all flexible loads like power-to-X units, heat pumps and batteries that do not require the security of supply. This security of supply remains hereby unchanged in all existing loads necessary to run the business (machines, ICT), renamed "unconditional loads".

Implementation

We implement the traffic light system of [5] enforcing that the sum of conditional loads is lower than a predefined part P (normally $P \leq 50\%$) of the grid capacity (green light, otherwise amber). A grid manager (GM) acts on behalf of the DSO with grid limits and a device manager (DM) on behalf of the customers with parameters of their aggregates. The day-ahead process of agreeing on schedules contains four steps of DM (DM1 - DM4) and one in GM:

1. **DM1:** DM optimizes schedules of local, conditional loads with new daily data.
2. **DM2:** As the solution schedule might not fulfill necessarily the limits of the grids yet, DM submits it (as "initial schedule") to GM for further controls.
3. **GM1:** In case of excess (yellow), GM curtails the "accepted power" in each customer involved, otherwise (green) it returns unchanged values to DM.
4. **DM3:** DM adapts the schedules of its aggregates when power was curtailed.
5. **DM4:** DM communicates with local devices and sends the last values of "accepted schedules" to the controller of each of its aggregates.

In the N-1 case (red light), the conditional loads are switched off in both branches until completion of reparation, whereas unconditional loads of the affected branch restart like up to now as soon as both branches get connected.

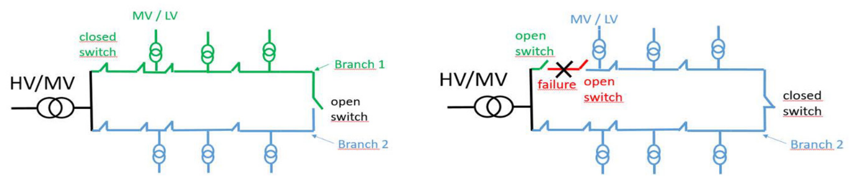

Figure 2 open ring grid structure (left) and supply (right) with closed switch in N-1 case

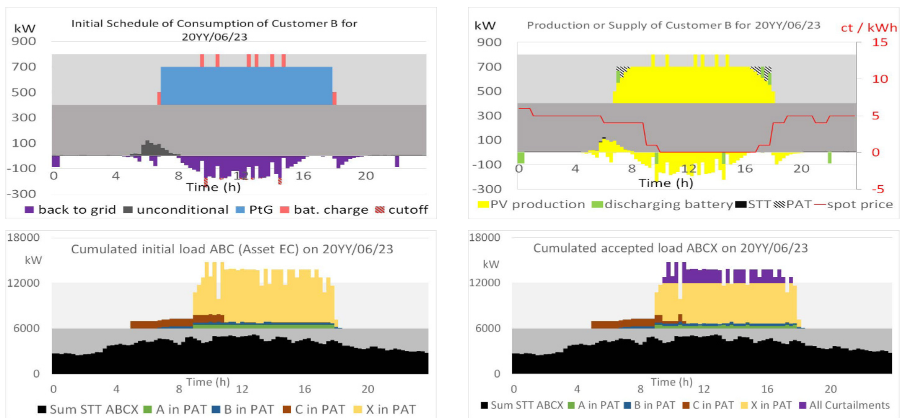

Figure 3 Initial schedules for B (top) and initial / accepted cumulative ones (bottom left / right)

Simulation settings and result

The daily simulation is based on data from real pilot industrial customers A, B and C and illustrated for B, with a planned extension of PV capacity to 700 kW, and a combination of new 100 kWh battery (with 100 kW) and an existing gas tank with a new Power-to-Gas (PtG) unit of 300 kW to increase the part of PV production consumed on site instead of feeding it back to the grid and reduce the import of fossil fuel. Figure 3 displays on top initial schedules i.e. the power value (consumption by usages left, production or supply right) of a full day. The consumption is split in the lower part, containing unconditional loads (dark grey), an upper part with conditional loads (blue for PtG, rose for battery charge) and a negative part (fed back to the grid). On the right graph, two sources of supply from the grid are displayed in black, standard tariff (STT, full) black and reduced conditional tariff (PAT, brindled). Production includes PV (yellow) and battery discharge (green).

To illustrate a grid congestion case, we assume that the three customers are located in the same branch of a middle voltage grid with 12 MW of capacity, out of them only 6 MW are reserved for unconditional loads. With its peak of cumulative unconditional at 5228 kW, and with timely coincidence between unconditional and conditional loads, the June 23^{rd} is selected. Without the concept of the conditional load, the asset at the entry of the branch have 6931 kW from at 11 a.m. The split in 5031 kW unconditional and 1900 kW conditional is possible. To verify also the handling of a congestion within the conditional loads, we assume an ad-hoc customer X without unconditional loads but with up to four PtG units of 1 MW resp. 2 MW. The bottom left side of Figure 3 displays the cumulative initial schedule of all four customers including X in yellow: from 9 to 11 a.m. all conditional loads reach 8.9 MW and exceed the grid limit of 6 MW by 2.9 MW: all customers will have a reduced "accepted schedule", as shown on the bottom right side of Figure 3. This reduction is split over each concerned customer according a point system (see poster). The curtailed part (of all customers) is displayed in violet color.

On average over all 365 days, the N-1 band is utilized at a rate of 1.5 % with values from 0.0 % on January, 23^{rd} to 8.7 % on May, 20^{th}. In absence of customer X, no conditional load is curtailed. With customer X, the average utilization of the N-1 band raises to 7.3 % with values from 0.4 % on November, 7^{th} to 80.7 % on May, 20^{th}. Conditional loads are cut on 72 different days, at most by 17.1 % of the N-1 band on the worst-case day December, 19^{th}, but with a yearly average of only 0.9 % of the band. As the connection of additional customers in the same branch of the grid is less probable, the curtailment does not significantly damage the end-customers nor increase their cost by load shifts to other time slots.

Discussion and Conclusion

The approach was evaluated in scenarios with provoked grid congestions. Daily schedules of new flexible load connected as conditional loads were simulated with cost minimization. If all three customers would be located in the same branch of a middle voltage grid with peaks already just under 50 % of the capacity, the grid would become congested with the addition of new loads if unconditional, but not if conditional. In worst case for the grid, we simulate the entry of an opportunistic new customer X with a large power for conditional loads and Figure 3 show a congestion of the full capacity band reserved for the N-1 case. The curtailment mechanism by the grid manager is the ultimate protection against this kind of grid congestion. In all simulated 365 days, the accepted schedules respect the constraints of the customers and the cumulative schedule of all customers respects the capacity limit of the grid. Future work will evaluate some economic aspects of the concept in the perspective of end customers, like the profitability of investing in these new loads.

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Availability of data and materials
Input data are only the tariff system, the installed capacities, and the timeseries of spot price, of PV production and of electrical consumption from our project partners. Data are stored in the internal repository of the project.

Author's contributions
Analysis, investigation and writing by author 1, review and supervision by author 2.

Competing interests
The authors declare that they have no competing interests.

References

1. Geidl, M., Andersson, G.: A modeling and optimization approach for multiple energy carrier power flow. In: 2005 IEEE Russia Power Tech, pp. 1–7 (2005)
2. Lu, J., Bernreuther, M., Volkwein, S.: Mathematical modeling and global optimization of hybrid energy supply networks. Technical Report 358 (2017)
3. Staudt, P., Schmidt, M., Gaerttner, J., Weinhardt, C.: A decentralized approach towards resolving transmission grid congestion in germany using vehicle-to-grid technology. Applied Energy **230**, 1435–1446 (2018)
4. Togeby, M., Brus, R., Bang, C., Holmberg Rasmussen, L.: Congestion in distribution grids, evaluation and analysis of dso options for congestion management in smart grids. Technical report, (September 2014)
5. Bagemihl, J., Boesner, F., et al. A market-based smart grid approach to increasing power grid capacity without physical grid expansion. Computer Science - Research and Development **33**(1-2), 177–183 (2018)