Economic appraisal of hybrid-VPP use cases:
Substantial savings possible for new generators

HYBRID VPP4DSO

The project **hybrid-VPP4DSO** investigates the concept of a hybrid virtual power plant to provide services for distribution **grid operators, grid customers** and **balancing markets** in parallel. The analyses of the technical and economic feasibility focus on selected grid sections in the Austrian province of Styria and in Slovenia. Special emphasis is given on regulatory questions and suitable business models.

Key issues:

- Identification of **suitable applications** for the hybrid-VPP concept and of **new services** for grid customers
- Evaluation of **business models** for hybrid-VPPs
- Investigation of **benefits and impacts** on all relevant stakeholders
- Legal and **regulatory framework**
- Coupled **simulations of hybrid-VPP operations** in the distribution grid
- **Technical Proof-of-Concept** in laboratory environment

Simulation approach

In a first step, relevant grid sections were investigated by load flow analyses, showing future issues and suitable countermeasures. Several use cases for the hybrid-VPP were assessed by qualitative stakeholder analyses, and suitable business models were designed. The most relevant use case identified was the **customer-driven hybrid-VPP** operation (Fig. 1), where new grid customers can significantly save on grid connection costs if they agree to curtail feed-in (or load) by request of the DSO. Following a simple break-even analysis indicating economic feasibility for customers and VPP service, a detailed analysis was performed by means of a coupled simulation of load flow and VPP operation (Fig. 2) for each 15 min interval of a year in several scenarios for 2015 and 2030. Initially, load flow calculations simulated the expected generation and load of connected customers, the grid operation and potential issues, and defined the restrictions for VPP operation as well as required curtailment of the customers. The VPP algorithms simulated the participation of a pool of 34 flexible units (providing up to +6MW/-15MW secured flexible capacity) in the Austrian tertiary control market and additional active power adjustments (activation) of relevant units to support distribution grid operation. The results of the hybrid-VPP algorithms were sent back to the load flow simulation to evaluate the impact of the VPP operation on the distribution grid. In a final step, the results of both simulation models were used for economic appraisals of the hybrid-VPP operation and of the impact on the pooled grid customers. The simulations proved that the hybrid-VPP can **support distribution grid operation** and solve grid issues when sufficient flexible units are available. In the **customer use case**, new capacities in three wind parks in different grid sections with dominant feed-in from run-of-river hydro power were investigated. Simulations showed that the **required curtailment was only 1 - 4%** of annual generation from wind power. The feed-in profile of the wind parks is complementary to the hydropower generation, which enables shared use of existing infrastructure during most hours of the year. Since all results depend on local grid topology and conditions of feed-in and load, the concept's applicability must be evaluated individually.

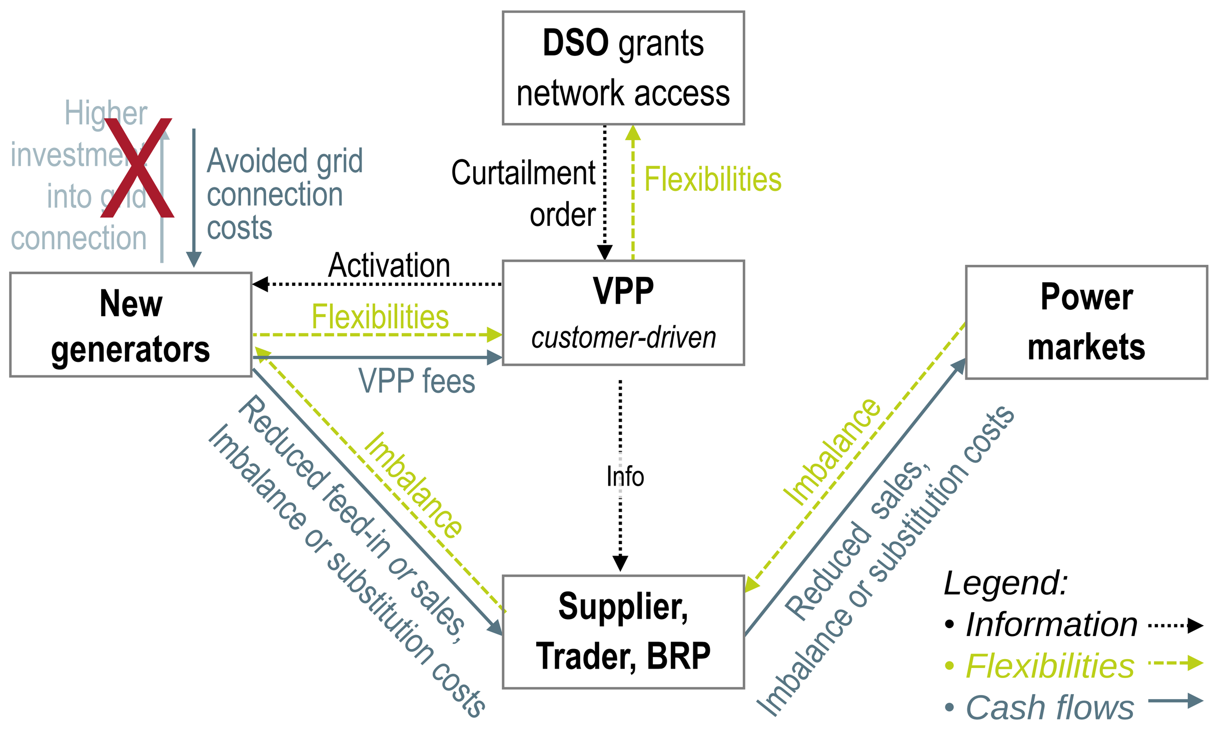

Figure 1 - Main relations between involved stakeholders in the use case of DSO-driven curtailment of new generators to reduce connection costs.

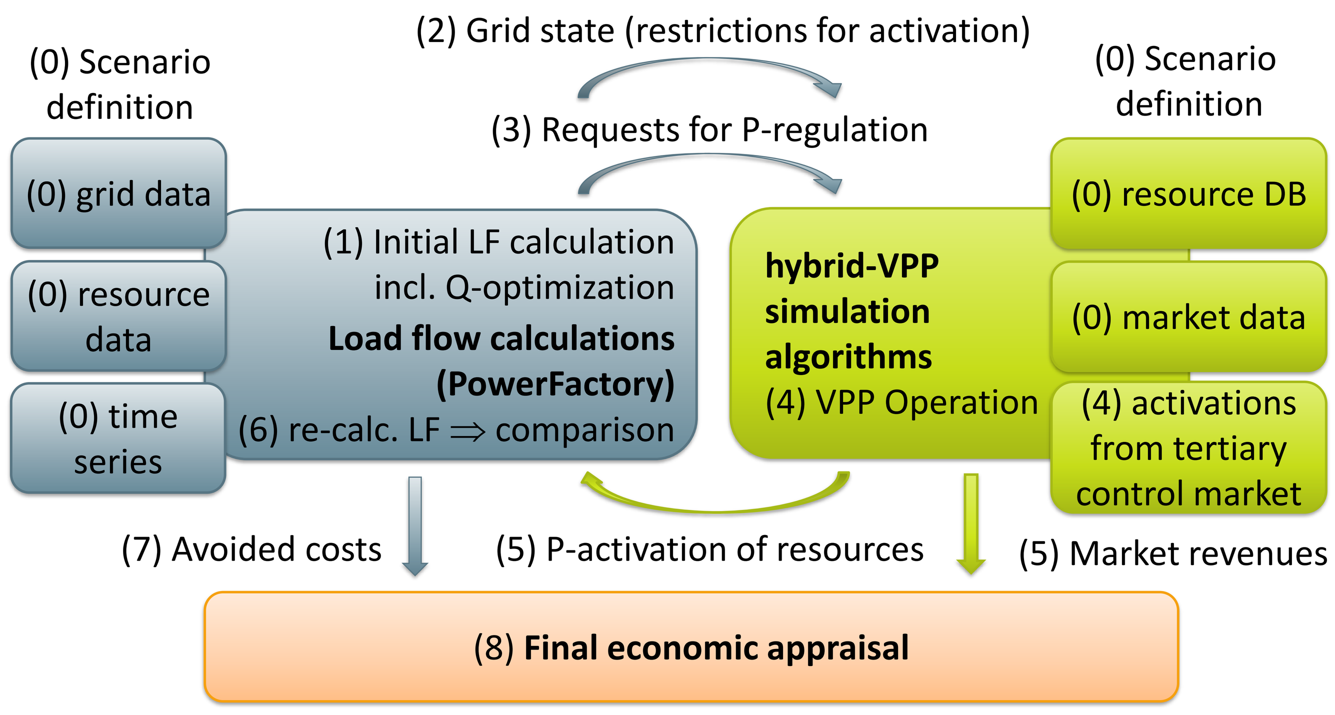

Figure 2 - Overview of procedure to perform coupled simulations of hybrid-VPP operation in the distribution grid for technical and economic evaluation.

Economic appraisal

The **qualitative stakeholder analysis** indicated that the customer use case can be realised in a business model satisfying all relevant stakeholders (DSO, grid customers, VPP, balance responsible party). There is no significant disadvantage for any stakeholder, which could become a barrier for the implementation of the hybrid-VPP. Imbalance is an issue but can be minimized if curtailment is announced by the DSO or VPP on the day before. The **case study** for new capacities in three wind parks (Fig. 3) showed that substantial savings are possible if investments into a new grid connection or reinforcement of existing connection can be minimized. In this use case, the **customer has the main benefit**, but depending on grid topology and value of curtailed feed-in. The operation of the hybrid-VPP to communicate and control customers' curtailment requires **about 20 MW** of controllable customers in order to be able to offer an acceptable service fee to the curtailed customers (Fig. 4). The VPP operator cannot expect substantial direct revenues from the curtailment service, but connected customers can be added to the market pool and generate additional revenues from the balancing markets during non-critical hours. The TSO will accept ancillary service provision from units curtailed by DSO if backup is available in other grid sections. The combined operation of the hybrid-VPP for balancing energy provision and support of grid operator (or customer) can be **highly profitable** (Fig. 5). Investment in a hybrid-VPP with approx. 20 MW of flexible capacity can result in a dynamic pay-back time of 1,6 years and an internal rate of return of ca. 170% over five years. Profitability is very sensitive to market revenues and personnel costs. The VPP can be designed to operate autonomously as to minimize personnel costs. Thus, the main risk is uncertainty regarding short term market development.

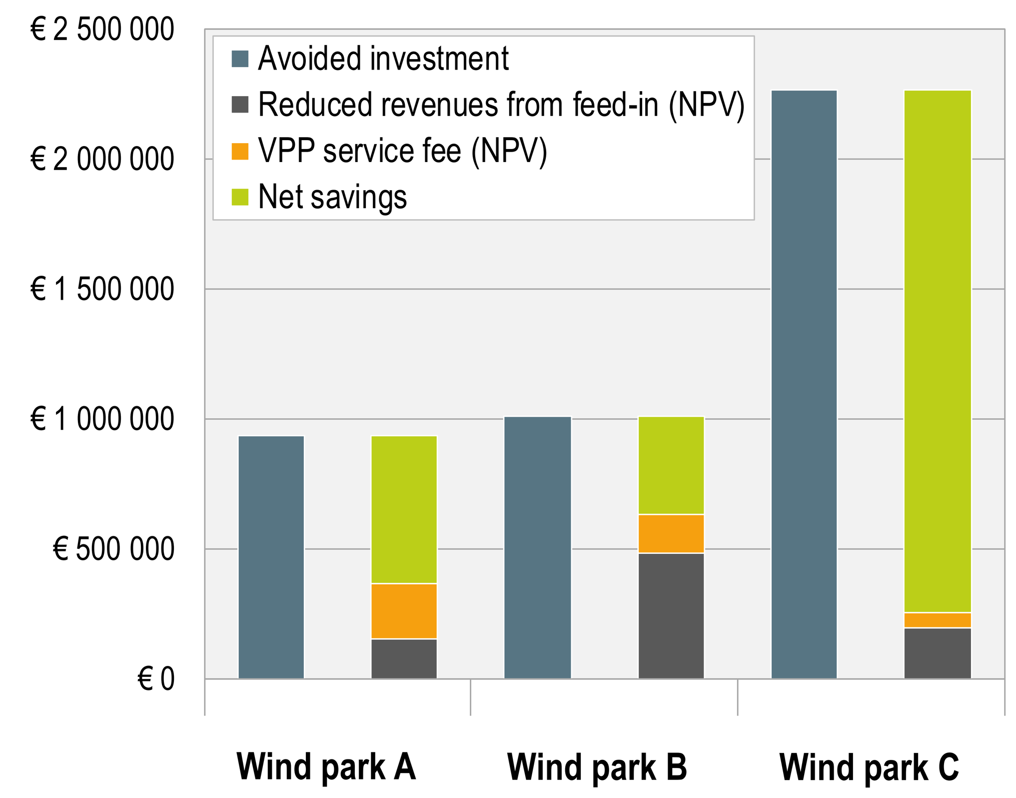

Figure 3 - Economic assessment from customers' perspective for new capacities in three assumed wind parks in different grid sections: Profitability increase possible if curtailment orders of DSO are accepted. (20 years life cycle of wind park, 5% interest rate)

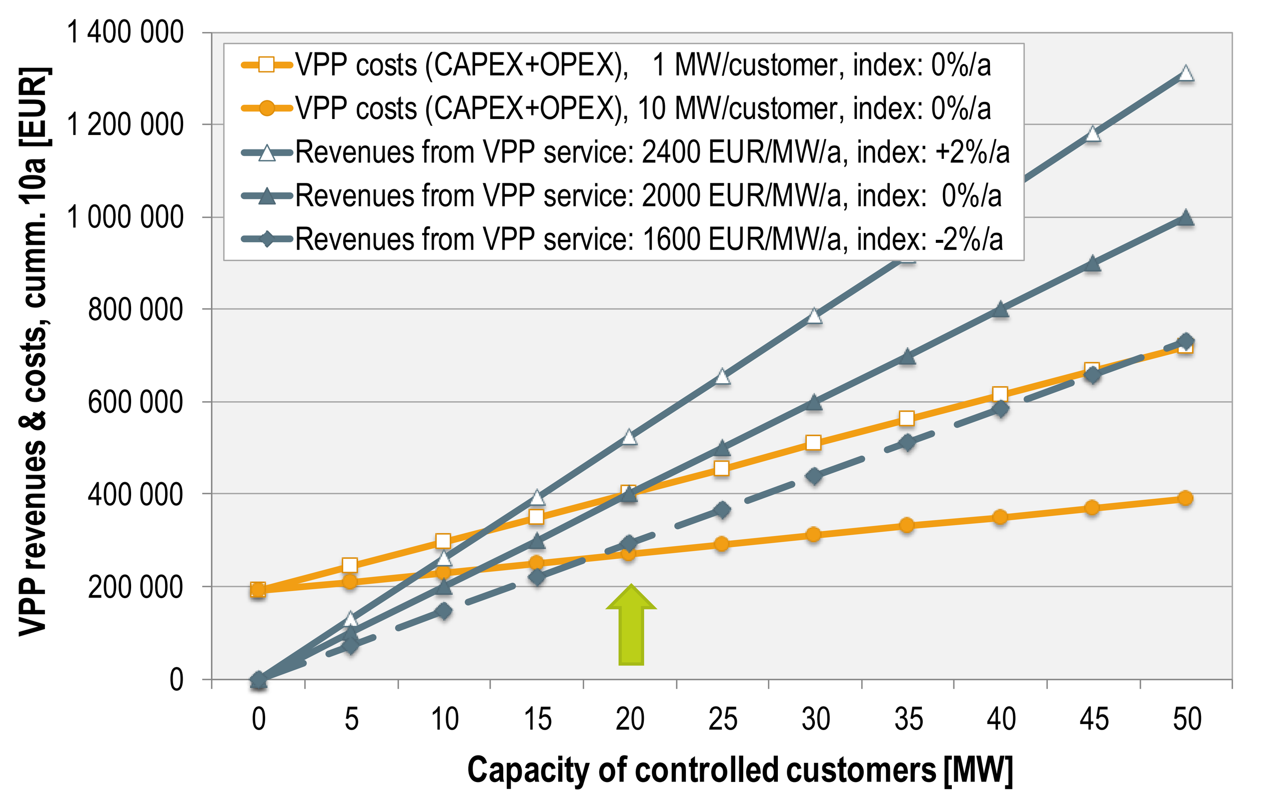

Figure 4 - Break-even analysis for customer-driven VPP service: About 20 MW capacity of controlled customers are required to reach break-even of the VPP service after 10 years, charging a service fee of 1500 to 2000 EUR/MW/a from curtailed customers. VPP operation by the DSO could reduce the required fee.

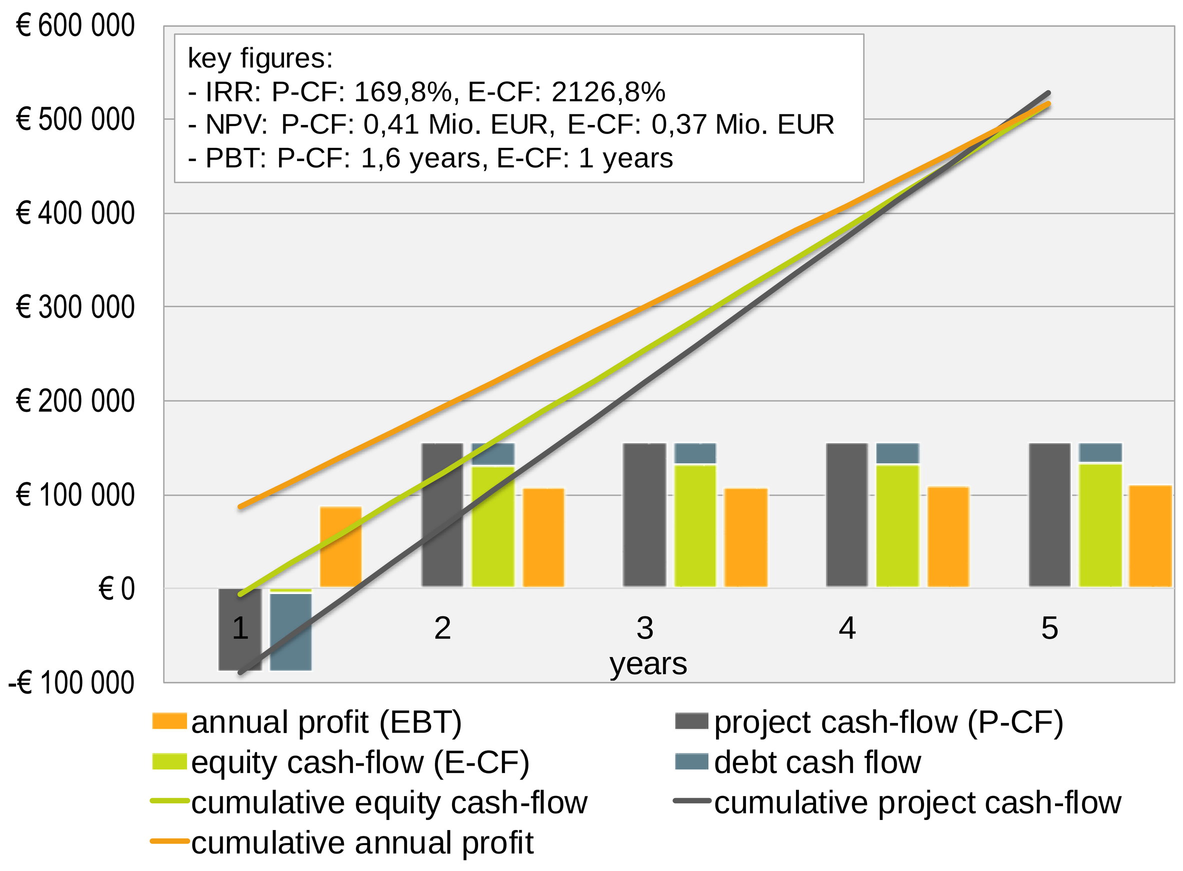

Figure 5 - Economic appraisal of hybrid-VPP operation on tertiary control market: Net cash flows (annual and cumulative) and annual profit (price level of Austrian market in 2015, 65% hit rate, 7,3% WACC)

Conclusions

- **The hybrid-VPP can be operated economically** if about **20 MW of flexible capacity** can be offered to Austrian balancing markets.
- The potential of the hybrid-VPP concept to **support distribution grid operation** was proven by means of coupled load flow simulations.
- The most promising use case for the hybrid-VPP is **customer-driven**, where (new) grid customers can save connection costs in by accepting temporary curtailment.
- In certain topologies wind parks can share grid infrastructure with existing run-off-river hydro plants requiring less than 5 % curtailment of feed-in.
- The **customer-driven use case requires about 20 MW** of controlled capacity in order to cover the costs of the VPP operator.
- Analyses of regulatory framework and practical experience showed that **hybrid-VPP infrastructure operated by a DSO could use synergies** and reduce costs of service.
- Practical applications of customer-driven hybrid-VPPs: Repowering of existing wind parks, efficient grid development for renewables, deferral of grid development.

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