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Uncertainty 19 - 22 JUNE 2016 Bergen, Norway

Intermittent Renewable Electricity Generation

Thomas Leautier, Presiding TSE Persearcher, Toulouse School of Economics

Comparative Scenarios in Islanded Systems: Energy Supply-storage Sizing Problem Applied to Electricity and Mobility Devensité de Nantes, IEMN-IAE

Solar, Wind and Market Power in a Hydro Based Grid Stephen Poletti

Impact of Variable Renewable Energy Production on Electricity Prices Through a Modeling Approach Cyril Martin de Lagarde

Université Paris-Dauphine Christophe Bonnery

Electricity Storage and Flexibility Requirements on the Road to Decarbonization in European Electricity

Estimating Emissions Offsets of Intermittent Renewable Energy

Patrick Narbel, Presiding Partner, ADAPT Consulting AS

Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets

John E Patsons MIT Sloan School of Management

Zero-Variable Cost Power Systems: Implications for Bectricity Market Design and Capacity Investments Anton D Jankins Anton Sepulveda Argence National Laboratory

Pick Exposure in Electricity Markets: The Need for Intra-day Hedging Rectine Homeyown Boroumand Autocate Professor of Economics, PSB Paris School

Market and Policy Risks for VRE Investment and their Impacts on Effectiveness and Efficiency of RES-E Policy Targets - An Agent-Based Modelling Approach Matthias Reeg

German Aerospace Center (DLR) - Systems Analysis and Technology Assessment

The Corporate Social Responsibility of Hydropower Companies in Alpine Regions - A Welfare-economic Approach

8. Innovations and Technologies (Aud. Terje Hansen)

Roger Fouquet, Presiding Professor, Grantham Research Inst LSE

Life Cycle Analyses of End-User Electricity Generation in Ten Major European Countries Gorkem F Uctug

The Welfare Effects of Energy Services and Technologies (1700-2010)

Technology Implications for an Integrated European Bioeconomy

Lukas Kranzl Energy Economics Group

Structuring Public Support for Radical Low-Carbon Innovation in the Materials Sector: Bridging the Valley of Death Karsten Neuhoff University of Wisconsin-Madison

Multinational Innovation, Product Life Cycles and Intellectual Property Rights Protection: Which is the Best Place to Invent Something?

9. IAEE Best Student Paper Award Session (Aud. 24)

Knut Einar Rosendahl, Presiding Professor, Norwegian Univ. of Life Science

Carbon Taxes, Oil Monopoly and Petrodollar Recycling

Waldemar Marz Johannes Pfeiffer IFO Institute for Economic Research at the University

Estimating the Potential for Electricity Savings in Households ETH Zurich, Center of Economic Research

Reliability, Congestion and Investment in Electricity Transmission Marten Ovaere KU Leuven, Department of Economics

How to Sell Renewable Electricity - Interactions of the Intraday and Day-Ahead Market Under Uncertainty Frank Obermüller Andreas Knaut Institute of Energy Economics, University of Cologne

10. Heat and Electricity (Aud. 23)

Benjamin Schlesinger, Presiding President, Benjamin Schlesinger & Assoc LLC

CHP Plant Operation and Electricity Market Prices - Analytical Insights and Large-Scale Model Application Research Associate, University of Duisburg-Essen

Residential Energy Efficiency and European Carbon Policies: A CGE-analysis with Bottom-up Information on Energy Efficiency Technologies Brita Bye Taran Fæhn Statistics Norway

Endogenous Power and Heat Generation Modelling in various CHP Plant Types DIW Berlin

Status-quo Bias and Consumers' Willingness to Pay for Green Electricity: A Discrete Choice Experiment With Real Economic Incentives Roland Menges Clausthal University of Technology

Technical-Economic Potential of PV Systems on Colombian Residential Sector Ferreira Paula

11. Prospects for Nuclear Power (Aud. 22)

Christian von Hirschhausen, Presiding Professor, TU Berlin

Phasing Out Nuclear Power in Europe Rolf Golombek Frisch Centre Finn R Aune

Ambiguity Aversion and the Expected Cost of Rare Energy Disasters: An Application to Nuclear Power Accidents François Lévêque Mines ParisTech - CERNA Centre for Industrial

Logistics of Dismantling Nuclear Power Plants A Model-Based Analysis of Low- and Intermediate-Level Waste Management in Germany Tim Scherwath German Institute for Economic Research (DIW Berlin) Roman Mendelevitch Technische Universität Berlin (TU Berlin)

TECHNO-ECONOMIC EFFECTS OF DECENTRALISED BATTERY SUPPORTED PHOTOVOLTAIC SYSTEMS CONSIDERING DIFFERENT TYPES OF TARIFFS

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Overview

The social and economic acceptance of photovoltaics has increased significantly in recent years. Decreasing costs for photovoltaic systems let it become a competitive energy source for decentralized use. In the last years, one can observe increasing self-consumption of photovoltaic electricity. Responsible for this trend is the increasing spread of retail electricity prices and feed-in remuneration. Therefore, the profitability of photovoltaic systems mainly depends on self consumed PV-electricity. Besides this fact another trend arised: Stationary battery systems. Subsidies and technological learning led to decreasing costs and to affordable systems which can increase self consumption and self sufficiency significantly.

This paper focuses on the techno-economic impact of battery supported photovoltaic systems from an household and a system perspective. Therefore, we analyze the effects on the "residual" load of households as well as the economic implications due to battery storage systems. We consider different scenarios for household electricity tariffs and feed-in remunerations and furthermore different operation scenarios of the battery storage.

Methods

Based on measured data of horizontal irradiation and ambient temperature, the PV-output is calculated following the approach suggested by Huld (Huld et al., 2010). The PV-output can be calculated depending on the direction and installation angle of the PV-modules. The electricity consumption of households are implemented as standardized load profiles but can also be replaced with measured load profiles. In this study, the battery is modeled as lithium battery with a typical loading gauge. The PV-output, the load profile as well as the parameters of the battery are input parameters for the linear optimization model. The optimization model, which is based on the YALMIP toolbox and the GUROBI solver, controls the operation of the battery, decides when to purchase electricity from the electricity grid and when to feed in the PV-surplus, depending on the (time variable) tariff and the operation mode of the battery. The objective function of the model is to minimize the costs of electricity purchase and the calculation is done for 25 years with different PV- and battery capacities. We differentiate between two operation strategies of the battery: Covering mainly peak load and covering total load. With assumptions on the future developement of household electricity prices and feed-in tariffs, the internal rate of return (IRR) is calculated.

$$NPV = -(I_{PV}) + \sum_{t=1}^{25} \frac{C_t}{(1 + IRR)^t} = 0$$

where the cash-flow (C_t) strongly depends on self-consumption, electricity tariffs and feed-in remuneration.

Results

Battery supported photovoltaic systems can increase self-consumption and self-sufficiency of households significantly. When we look at a standardized household load profile with a consumption of 4000 kWh/a, a 5 kWp PV-system and a 5 kWh battery storage, the rate of self consumption increases from about 31% to 48% and the rate of self sufficiency increases from 42% to 66% considering a battery storage system.

Figure 1 shows two charging strategies of the battery, whereas the left figure displays the results for the total load coverage strategy and the right the peak load coverage strategy. In peak load mode the battery mainly covers a fixed peak load (e.g. 50% of the maximum load [kw]) but is also able to cover total load if battery capacity is left. When we compare these two charging strategies in terms of self consumption and self sufficiency we can observe that there is almost no difference as a result of the optimally use of the batterie's capacity. This implicates, that there is also no difference in terms of economic parameters when most common electricity tariffs and feed-in remunerations (fixed kilowatthourly based rate) are considered. When we look at time variable tariffs (ToU tariff, Peak load Pricing) there is a difference in the economic parameters.



Figure 1: Charging Strategies of the battery for a standardized household load profile: left: total load coverage, right: peak load coverage

Figure 2 points out the residual load of a household without a PV-System and with PV-System and battery. It can be seen, that there is almost no difference in peak load when we look at the electricity which has to be purchased from the electricity grid ("residual load" if PV is installed). This indicates, that users of PV-Systems and batteries operated in total coverage mode need the same power rate as users without these systems, but pay less network access charges. We thereby anticipate that through a shift of the network access charges from energy-related consumption to capacity, the true costs of individual customer groups can be better reflected and may also change the economic profitability of battery storages significantly.

Not only alternative tariff-options, which influence the operation mode of the battery, but also technological learning has a big impact on the economic profitability of decentralized battery storages. In 2013 a 5 kWh lithium battery storage accounts for about 2560 €kWh, in 2015 it declined to about 2000 €kWh and the world wide trend of declining battery costs continues unabated. Even if the economic profitability is not reached yet, a break even point can be reached in the next years and thus can influence an enhanced rollout of these systems with impacts on the whole electricity system.



Figure 2: Classified residual load of a standardized household load profile

Conclusions

Due to technological learning and alternative tariffs, battery storages can become an economic attractive solution for decentralized use. In a future energy system, they can change the load profile of households significantly and they need to react on price signals (charge the battery when electricity prices are low, discharge when prices are high) if time variable tariffs are implemented. Besides their role of increasing self-consumption and self-sufficiency, a "system friendly" operation mode is necessary to be a flexibility option to match electricity demand and suppy.

References

Huld, T., Gottschalg, R., Beyer, H.G., and Topič, M. (2010). Mapping the performance of PV modules, effects of module type and data averaging. Sol. Energy *84*, 324–338.