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THE ECONOMIC IMPACT AND SIGNIFFICANCE OF IMPLEMENTING NEW TECHNOLOGIES IN THE POWER STORAGE SEGMENT

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Abstract

In the present article will be considered the economic aspects in the implementation of new technologies in energy storage and energy transportation. After reduction of the carbon footprint in power generation process, it's also very important that the flexible transfer and storage of the produced energy that is not immediately consumed. For the last 15 years the industrial storage of electricity is technically realistic, but it's still a matter of discussion how economically justified it is. Some economic risks can be identified and some security measures can be taken. There is possible optimization of energy storage that can make it adjustable to the demand and energy market prices. There are some implications to the Industry 4.0 and increase of e-mobility generated energy consumption.

Keywords: storage, energy, renewables, capacity, profitability, solar, wind, grids, transmission, distribution

JEL: O33

Introduction

The plans and goals for decarbonization of energy production require intensive implementation of green and renewable energy. This renewable energy is generated by sources which are inconsistent and unreliable in terms of time of energy production versus highest energy consumption. With traditional understanding and energy system the generated energy which is not immediately consumed can be considered as finally wasted. The energy storage for large scale industrial consumption is a relatively new technical and innovation concept that allows the electric energy to be stored for mid- and long-term period and its consumption to be delayed for the moment when the energy demand is higher. Recent capital and operational costs of such energy storage devices were not economically justified,

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at least for the last 10 years. The situation is changing and the recent technology development makes the prices and the costs of such electric storage equipment much more attractive and competitive. That's valid for the energy supply during periods when the energy production is not active or the demand is very high.

Energy demand

In general, the most electrical energy consuming industries are steel production, metal processing, chemical industry, petroleum refining, construction, mining, pulp and paper production and food industry. According to the McKinsey report (Krishnan, Hamid, Woetzel, Smit, Pacthod, 2022), the highest increase of energy costs will be observed in the sectors of steel and cement production. Following that scenario, before their decrease they will reach a peak of 30% to 45% compared to the present levels. This is the cost of the delivered electricity along with its generation, transfer, distribution and storage. The finance impact will be anticipated. All costs, including OPEX, CAPEX and depreciation of new and existing assets, will increase by 25% by 2040 compared to the levels of 2020. The main reason comes from the necessary investment for building renewables, grid and storage capacity. Despite the increased electricity consumption of energy intensive industries, the demand of ecologically produced energy will increase too. The production of hydrogen and bio fuels will rise 10 times from 2021 to 2050, and respectively along with this an increase of the number of installations for energy storage is expected. According to the same forecast, it is expected that by 2050 the investments in physical assets, including electric power storages, will reach 275 trillion USD. That makes about 9,2 trillion dollars per year.

Energy storage

The storage of electricity can be considered also in different ways where the energy is being transformed from one kind into another. It's available not only in a battery form (Topalovic, Haas, Ajanovic, Hiesl, 2022). The energy storage was used in different ways long years ago. The main methods include:

- Pumping Hydro Power Stations, where the kinetic hydro energy is stored through its pumping to the upper part of the dam during the generation of cheapest electric power;
- Energy storage through compressed air;
- In an electrochemical way, e. g. Vanadium Redox Flow Batteries (VRFBs) and Reversible Solid Oxide Cells (rSOC)
- Electromechanical;
- Liquidization of air;

- With batteries of electric power storage (main types are: Li-ion, NiCd, NaS, Lead-Acid)
- Thermal power storage;
- Storage through producing hydrogen.

As a result of this study that compares the economic effectiveness of different of energy storage methods and transformation in the West Balkans region, it's proven that the Pumped Hydro Storage (PHS) is still economically most effective.

Indeed, the estimations for the upcoming and more intensively implemented energy storage as a separate economic activity, are very optimistic. Let's consider the option where the energy storage is separated as an independent economic subject. Such research has been presented by Giorgio Locatelli (Locatelli, Palerma, Mancini, 2015). Here, along with the Electric Power Stations, generating electricity, entities called Electricity Storage Plants (ESP) are considered. Their main purpose is to balance the intermittent power generation from renewable sources (RES). The profitability of each entity has been analyzed and the focus is put on entities in the UK and the EU. The generated electric power from RES increases, but along with it we have an increase of the costs for its production. The conclusions have been made in the context that such entities are still not capable of offering competitive enough electricity prices. Therefore, they need to be subsidized as they still cannot have their own independent economic existence. Even from an economic perspective they are able to provide additional capacity of already generated electricity in the particular moment of electric power deficit and in highest demand, even at a higher price.

In another study, the same research team investigates the trade-off "reserve capacity vs. profitability" of large ESP and how to reach the "optimum size capacity". According to Locatelli et al (2015), the optimal size of the storage capacity maximizing the Net Present Value (NPV) is lower than the optimal size capacity. There is no economic sustainability for any of ESP technologies that is not subsidized. ESP can exist only as an operating energy storage and as a plant following the load that shifts electrical energy from periods of low peaks to periods with high peaks.

The inconsistency and unpredictability of the renewable energy sources as well as the discrepancy between the power generation and energy demand by consumers are the main issues to resolve, especially for micro-grids that are supplied by 100% renewable sources. The technologies for energy storage (ES) could be such possible solution (Baldinelli, Barelli, Bidini, Discepoli, 2020). A possible split between capacity and power along with the adaptation of energy storage is based on Vanadium Redox Flow Batteries and Reversible Solid Oxide Cells. For micro-grids with a low level of interconnection the separate scaling of power and capacity is a very significant characteristic for achieving higher cost-effectiveness.

The current economic metrics of energy storage from renewable sources are not very successful in assessing the value of stored energy, especially if the energy source intensity is not quite predictable. According to the authors of the research it is possible for the technical and economic indicators for ES to improve their performance and capacity within micro-grids.

Renewable energy sources like solar and wind can be more reliable if they are added to bigger grids and therefore costs of ES can be reduced significantly. Another team of researchers (Tong, Yuan, Lewis, Davis, Caldeira, 2020) use 36 years (1980 – 2015) periodic data and assess the impact of low-cost energy storage on highly reliable electricity systems that use renewable energy only. The status of ES can vary and transform from high-cost storage to inexpensive storage if it can serve as seasonal storage and can fill short-term gaps between variable renewable energy generation (VRE) and hourly demand. The capital costs of energy storage technologies are also decreasing significantly and improve their technical performance. Energy storage technologies bring benefits to the grid operations like energy balancing, price arbitrage, and provision of additional services. This increases the value proposition of energy storage for electric power grids.

Energy storage at a good price can prove the renewable electricity as competitive enough to the energy from fossil fuels, when it comes to the costs. According to Prachi Patel (2019) the energy storage is recommended to cost 20 USD per kWh for the grid in order to be 100% powered by an energy mix by solar and wind. That sounds not optimistic when it comes to the Li-Ion batteries which cost is around 175 USD per kWh. Energy storage needs to reach a cost of 10 to 20 USD per kWh from solar/wind mix to be competitive with a baseload by a nuclear power plant or natural gas plant providing to 5 USD per kWh. These scenarios are theoretically valid if the energy storage needs to meet the demand for 100% of the time. If that storage meets the demand for 5% of the time, it could work at a price of 150 USD per kWh. And Li-Ion batteries can reach that price of 150 USD per kWh with a growing share in the utility scale. PHS and Compressed air storage (CAS) that use extra power to elevate water up or to compress air, can both be used to power a turbine and generate electricity at a necessary time have a low energy cost of 20 USD per kWh. The negatives of those systems are that they use enormous space and special geological circumstances and therefore they are not suitable for use everywhere.

Here are some prospective battery/storage technologies and their costs:

- Sodium nickel chloride batteries – 315 USD – 490 USD per kWh
- Vanadium redox flow batteries – 100 USD per kWh
- Sulphur flow batteries – 10 USD per kWh

- High temperature sodium-sulphur batteries – 500 USD per kWh (IRENA, n.d.).

It seems that there is a significant low price for one type – the Sulphur flow batteries compared to the other. It meets the formal criteria for acceptable cost, but actually there are still problems with the battery size and the temperature range it works.

Between energy sources and end energy consumers the transport of energy or the energy infrastructure is positioned. Making the energy supply more sustainable, saving energy and making different sectors and forms of energy (electricity, gas, heat) more interconnected will change the demand on existing and new energy infrastructure. That energy infrastructure is rapidly evolving to smart grids and their management is being constantly transferred from human employee control to automated control.

Energy transport typically is meant as moving energy from one location to another. Under energy transfer we understand moving energy out of something (solid, liquid or gas) thereby reducing its energy, into something else (another solid, liquid or gas) thereby increasing its energy. The energy transport typically is pipeline transport.

Optimal management of the energy storage

Till now we have reviewed the energy storage systems and plants, but they are existing not alone. Their optimal storage control is critical for the proper interaction with the smart grid.

Along with the economic impact there are some risks arising with the mass implementation of energy storage technologies. These devices are supposed to play a leading role in the demand management and the load planning. For the utility operations it's a primary goal to control and plan the storage. The operator gets a demand request to assure a power with different requirements and durations. The controller needs to manage a device with storage capacity that has a limited capacity. The goal is to develop an algorithm for control of the energy storage that will minimize the long-term operational costs of the grid (Koutsopoulos, Hatzi, Tassiulas, 2011). The price is a function of the instant energy consumption that is being supplied from by the grid. Each additional quantity of power that meets the demand, is more expensive with the increase of the power demand. The algorithm adaptively performs cycles of charging and discharging of the storage device. We consider that the algorithm is optimal if the capacity of charge and discharge is getting bigger. The assumption is that a specific amount of energy should be satisfied at all times and that is resolved through a dynamic programming. The optimal model can be extended and a renewable source can be included to charge the energy storage device.

The demand of energy storage devices.

Usage of ES devices makes it easier to vary the energy mix from several sources. Some of these key sources are: wind, biogas, solar, geothermal and wave. Many of big energy consuming businesses and households can possibly benefit from the implementation of energy storages – transportation, manufacturing and agriculture. In transportation businesses the usage of hybrid electric vehicles is rapidly growing. Plug-in electric vehicles and railways can make the role of energy storage solutions more and more critical. The key aspects for the grid configurations (Alahakoon, 2016) are defining the scale and the size of energy storage, choosing the type of energy storage and controlling the aspects of energy storages. In Australia a significant number of the energy storage equipment implemented in micro grids consists of hybrid systems. They usually combine at least two types of energy storages.

The hybrid energy storage is a concept that combines two different energy storages together, e.g. a combination of a super capacitor and a battery. The transport is a typical large energy consumer and therefore is an area accelerating the implementation of hybrid energy storage systems (HESS).

There are two main characteristics of HESS – specific energy and specific power. Specific energy is related to the amount of stored energy and emittance of that energy over a long period of time. Specific power means the loading ability with regard to device capacity for delivering energy to a consumer.

Table 1: Comparison of batteries and super capacitors.

Parameter	Battery	Supercapacitor
Service life	Limited	Very high
Energy density	High	Low
Power density	Low	High
Charging time	Long	Short

Source: Capacitech Energy

HESS fully utilizes the stability of ES devices and the speed of power storage equipment. It could be an efficient way for the combination of energy and power for symmetric use. Research on these systems is drawing more attention with substantial findings on technologies of battery management system (BMS), power conversion system (PCS), energy management system (EMS), predictive control techniques (Dong et al., 2022). That reflects with strong system stability and provides guidelines for application of a HESS.

The Fourth industrial revolution is characterized by the adoption of computers and automation in cooperation with intelligent, autonomous systems powered by data and machine learning. It increases the significance of reliable, flexible and clean energy. Speaking of the Industry 4.0 and putting the emphasis on the digital technologies and interconnectivity of Internet of things (IoT), we have to admit the increasing importance of transportation industry with more than 5% of the GDP of the EU countries. They plan a modal shift from road and air to rail transport that will improve the environment with less CO2 emissions and will generate a number of additional benefits such as reduced dependency on foreign energy suppliers, or reduced congestion and health issues (Parpulova-Ashworth, 2021). That digitalization, innovation as well as the intense usage of e-mobility will confirm that energy storages that can support more efficient energy management at all three major stages of a power network: energy generation, transmission and distribution.

Conclusion

There is a rise of industrial and consumer electricity demand, initiated by traditional industries and raising Industry 4.0. The industrial and power generation decarbonization requires acceleration in the invented renewable energy sources. They seem to be still very inconsistent and unreliable and that's why the management mix and management of power smart-grids is more and more important. The flexible and optimized energy storage becomes a possible resolution for the demand planning, energy supply and balance of the grid. The economic impact of the storage will be more significant in the next years with the optimization of the existing and newly developed storages.

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