Energy storage for demand response vientiane

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Nowadays, a large proportion of the world"s energy production is based on fossil fuels. The use of these non-renewable resources contributes significantly to greenhouse gas emissions, adding to environmental pollution. Moreover, the accelerated depletion of these finite resources poses a serious threat to their availability for future generations. In light of recurring economic and oil crises, scientific efforts have increasingly turned towards renewable energy sources, which have emerged as a pivotal sector, gaining importance in both research and development initiatives1,2.

Wind energy has been used for at least 3,000 years. It was first used for navigation on the Nile at least 5,000 years ago and, at the same time, windmills were pumping water in China. Since then, wind sensor technology has continued to evolve. In 1891, the Dane Poul la Cour invented the first wind generator designed to produce electricity3,4. At the beginning of the 20th century, he designed the first vertical-axis wind turbine, with a relatively low power. It wasn"t until 1957 that the Danish manufacturer Gedser achieved an output power of 200 kW. But it was only after the first oil crisis in 1973, when oil-exporting countries reduced their exports and entered the wind energy market, that the first wind turbines were developed5,6.

By the end of 2019, the installed wind power capacity worldwide had reached 650.8GW, reflecting an annual addition of 59.667GW. This was well above the 50.252GW installed in 2018. 2019 represented the second highest growth period for the wind energy sector in terms of market size, achieving a growth rate of 10.1%, an improvement on the 9.3% growth seen in 2018, although still below the peak growth rates seen in 2016 and 2017. Collectively, wind turbines installed by the end of 2019 had the capacity to meet more than 6% of global electricity demand7,8.

Wind energy is commercially deployed in over half of the world"s nations9. In 2019, many countries saw significant penetration of wind power. China and the USA dominated the market with substantial new installations, adding 27.5GW and 9.1GW respectively10. These two countries have recorded their highest market volumes in the last five years11,12. Conversely, many european markets, particularly Germany, have slowed considerably as a result of inappropriate policies. Germany, once the world leader in wind power, has added just 2GW in 2019, down sharply from the 6.2GW added in 201713.

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All stakeholders agree that the corona virus crisis will have an impact on market development in 2020, leading to a general slowdown in the wind energy industry in most markets. In 2019, global wind power capacity grew by 59 GW, an increase of 10.1%14.

A variety of renewable energy sources are currently available, including hydroelectricity, geothermal energy, biomass, photovoltaic energy and wind power. One of the main advantages of these renewable energy sources is their minimal impact on the environment, as their use does not lead to air pollution or the emission of greenhouse gases such as carbon dioxide and nitrogen oxides, which are major contributors to global warming15.

Wind power has become one of the most sought-after renewable resources for electricity generation, used both in isolated locations and as an additional source of energy for interconnected grids16,17. It is a viable alternative that is helping to reduce the world"s growing demand for electricity. The continuing progress and widespread adoption of wind energy conversion systems has led to significant investment by the industrial and scientific communities, which are focusing on improving the technical efficiency, economic viability and overall quality of electricity generation18,19.

Many remote areas of the world rely on stand-alone power generation systems, using local renewable energy sources such as solar, wind, hydro and biomass. In these independent systems, the role of energy storage is crucial in maintaining reliability20. Given the intermittent nature of renewable resources, energy storage becomes essential to ensure continuous availability of electricity. In geographically remote areas without grid connection, renewable energy systems are integrated with storage solutions to maintain constant energy production, compensating for periods when renewable energy production is insufficient12.

Wind power has established itself as one of the leading sources of renewable energy, offering a sustainable alternative to fossil fuels. However, its inherent intermittency and variability pose major problems and challenges, particularly in isolated or off-grid systems where there is no grid stabilization. The fluctuating nature of wind can lead to unreliable energy production, making it difficult to maintain a consistent and stable energy supply in these systems. For stand-alone wind systems, it is essential to ensure continuity of energy supply, particularly in remote areas where the energy infrastructure is minimal.

To meet these challenges, the integration of energy storage systems into wind energy conversion systems (WECS) has been proposed as a solution. Among the various storage methods, pumped storage systems (PSS) are widely recognized for their efficiency and scalability in managing energy surpluses and deficits. Combining a WECS based on a permanent magnet synchronous generator (PMSG) with a PSS can provide a robust framework for reliable power supply in stand-alone systems. However, the integration of these two systems poses significant control and optimization challenges, particularly in terms of maximizing power extraction from the wind, maintaining voltage stability and ensuring a continuous flow of energy between the PMSG, the load and the storage system.

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