Wind turbine generator controller

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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.

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.

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.

Facilitate energy storage and recovery in the PSS, dynamically switching between the motor (storage) and the generator (power) according to energy demand and wind conditions.

The process of converting wind energy into electrical energy involves several stages. As shown in Fig. 1, the wind energy conversion system under study includes a pumped water storage station, which plays a key role in managing the flow and storage of energy within the system.

Firstly, the horizontal wind turbine converts the kinetic energy of the wind into mechanical energy available on the generator shaft. The generator consists of a PMSG with a high number of pole pairs. This structure makes it possible to operate at low speeds without a gearbox, and offers another advantage as less volume (space), less maintenance and less weight.

When available energy exceeds the load requirements, a hydraulic storage mode stores the excess energy in as a potential energy form, by pumping water from the lower basin to the upper basin. In this case, the pump is driven by a PMSM which operates in motor mode.

When there is a shortage of wind energy, PMSM operates in generator mode by transforming the potential energy of the stored water gravity into mechanical energy available on the PMSG shaft, then into electrical energy.