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Optimum Operation of Virtual Power Plant

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Abstract

The electric grid is the largest and most complex machine ever built. It's an amazing feat of engineering providing reliable, safe and on-demand power. This grid is built on 20th century technology with large, centralized generation, mostly fossil fuel-based and only a few points of control. There's an urgent call to transition off of fossil fuels in order to prevent the worst effects of climate change. Clean power generation like wind, solar and hydro play vital role in facing the mentioned challenge. This hardware is not on its own enough to replace fossil fuels while maintaining our current standard of on-demand and reliable power.

Keywords: Renewable energy • Resource • Power plant • Solar energy

Introduction

The tricky thing about the power grid is that supply and demand have to match in real-time or else frequency and voltage can deviate and this can damage devices and lead to blackouts [1]. The grid itself has no ability to store power, so the incoming power supply and outgoing power consumption need to be controlled in a way that it maintains the balance. To point blank this concern, renewable energy sources like solar, hydro, wind energy posses an alternative to fossil fuel with clean and green energy generation. These sources comes with another concern of variable output nature, with integration with grid, there are few controlling points. Integration of such REs with energy storage system and maximum control proves to be liable solution [2]. Virtual power plant can be defined in many ways, one of which is that it is a cloud-based distributed power plant that aggregates the capacities of heterogeneous Distributed Energy Resources (DER) for the purposes of enhancing power generation, as well as trading or selling power on the electricity market. DG technologies (including RES) have undergone many enhancement, to facilitate these enhancements and outweigh the injected challenges, VPP stands as a solution [3]. It makes use of information collected from its entities and uses that information to form a stable, technically feasible, economically viable, environment friendly power grid. As the name suggests, VPP is digital and not a physical entity like the actual grid but works in tandem with the existing electric grid. VPP maximizes the energy harvesting process from the renewable resource.

New technologies were created and research was done in order to increase the overall effectiveness of RES. The majority of DG units are deployed in distribution networks today at low and medium voltage levels [4]. New issues are emerging, such as a shift in the power flow, as a result of the stochastic nature of RES and the large number of installed DG. Assistants at the Otto-Von Guericke university in Magdeburg, Germany, are Pio Lombardi, Michal Powalko and Krzysztof Rudion. These tasks include power system balancing, frequency control and overvoltages prevention. The introduction of innovative solutions, including as Energy Storage Systems (ESS), Network Security Management systems (NSM), and virtual power plants, was made in an effort to balance the production and consumption of energy [5].

In this project, VPP is constructed using solar, wind, fossil fuel and battery integrated to agrid operating in multiple modes based on the l oad profile.

Literature Review

The idea of VPPs was initiated in 2003 by K. Dielmann and Alwin van der Velden in 2003 and through about 16 years from 2003 to 2019, a lot of ideas discussed the perspective of VPPs as a future energy generation source. K. Dielmann et al. started their VPP idea from the point of view of the electric international market, energy must be provided so that it is as low priced and reliable as possible [6]. The most important factor to the success of a VPP is its use in the open energy market; adaptation must be made for the electric coupling of the VPP and above all the voltage and frequency performance, as well as the reliability aspects must be examined further. Integrated distributed energy resources include all renewable energy systems, intermittent renewables, photovoltaic systems, wind systems, power small and micro-units, hydro and small hydro power plants, some of thermal systems and Combined Heat and Power plants (CHP). Also, Energy Storage Systems (ESSs) and special loads can be integrated with DERs to form VPPs. ESSs include: Embedded energy storage, pumped storage power plant, and battery switch stations [7].

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The special loads like: Electric vehicles, aggregated thermostatically controlled loads etc. VPPs comprise of four basic components: Generation technology (dispatchable power plants, and stochastic generating units), energy storage technologies, dispatchable and flexible loads and information communication technology. Modelling of VPPs and its components take different approaches and scenario.

Virtual Power Plant (VPP) is a term used for aggregation of Distributed Energy Resources (DERs) in order to make them appear as a single, larger power plant. When the VPP also includes storage and demand response capabilities, it allows variable renewable energy sources, such as wind and solar Photovoltaic (PV) power, to act as a large dispatchable power plant. Amongst other REs Wind power stands as an immeasurable power in the world intensely attracts the attention of planners of power distribution networks [8]. WT technologies are extremely promoting to better and better technologies so that they are able to alter the wind power to electricity power with higher efficiency. ESSs are utilized to preserve the excess energy and to release it in order to supply the energy demands of customers in the moments when the demand is high. Studies in solar energy have upscaled REs contribution to the system one of which is presented by S.A. Keshuov et al. in 2018 where he studied voltage stability while integration of solar power plant while integrating it with distribution network [9]. The added value of solar energy and wind energy is been discussed by Despina Koraki et al. in 2018. Energy storage technologies like Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES), Battery Energy Storage System (BESS), Flow Battery Energy Storage System (FBES) enhances the integration of REs with grid. These systems are flexible and can be designed for various applications like EMS for high altitude and pumping stations as described.

The rapid growth of large-scale renewables and Distributed Energy Resources (DER) leads to increased uncertainty and reduced controllability of energy generation. Thus, control of demand is becomes more necessary to maintain network energy balancing. Individually these devices are often too small to operate in the electrical markets and operated individually can have negative impact on the local network [10]. The fast growing penetration of Distributed Energy Resources (DER) and the continuing trend towards a more liberalized electricity market requires more efficient energy management strategies to handle both emerging technical and economic issues [11]. Thus for energy manage ment, VPP is designed by using stochastic programming and stochastic robust models followed by other mathematical models for control, hydraulics etc by Yu.V. Monakov et al. in 2018. From economical point of view various market trends, characteristics and demands from the Medium Term Market (MTM) to the Real Time Market (RTM) with different target of VPP in the Energy Market (EM) and Ancillary Service Market (ASM) are discussed by Xue Jin et al. in 2018. In 2010, K. El Bakari et al. highlighted the advantages of the VPP taking major technical, economical and regulatory aspects in an adaptive power system which stands true even after a decade [12].

Discussion

Problem identification

From the above literature review, two main challenges can be revealed. These are discussed in the following. From a carbon offset point of view, more and more renewables need to be merge into the grid, which are intermittent and variable in nature Integration of REs is inevitable for transition to clean affordable sustainable energy. As more renewable generation comes onto the grid, a few things happen [13]. Reduced control: Generation can't be as easily turned up to follow demand and its ill advised to turn down the energy generated or else this clean energy generated will be lost framing a setback for the transition towards clean energy. Uncertainty: Generation can't be forecast precisely, and it can change quickly. This rapid change is hard to predict and it takes a heavy toll on the grid contributing Intermittency: Due to its intermittency, renewables can’t be considered as a dispatchable power source and never can be a base load as well, unless there is a massive energy storage option. As a result, the practice adopted by the grid operator is to give priority to renewable sources whenever it is available and regulate the production of dispatchable sources.

As more and more renewables, especially solar PV systems, are getting installed, the grid operators find it difficult for its integration [14]. To a greater extent the energy storage systems will overcome the challenges mentioned above. But the grid integration for the energy storage systems particularly for the decentralized systems (for business units and households) have got its own practical difficulties to implement. Due to the same, there is a good chance that the system can waste the generated power during low demand (Table 1) [15].

Mode	Operating conditions
Mode 1	The output power of PV is more than the load power (Ppv>PL)
Mode 2	The output power of WT is enough to supply the power to demand load (Pwt>PL)
Mode 3	The PV output power is less than load demand and sum of PV and WT power is higher than requested power (Ppv+Pwt>PL)
Mode 4	The fuel cell and battery supplies remaining power when the load demands more power than generation
Mode 5	The VPP needs power to fulfill the demand in case of more consumption than generation (PVPP<PL)

Table 1. Sustainable solutions for these challenges thus became crucial.

Conclusion

Energy Storage technologies like Pumped Hydro Storage (PHS), Compressed air energy storage (CAES), Battery Energy Storage System (BESS), Flow Battery Energy Storage system (FBES) enhances the integration of REs with grid. These systems are flexible and can be designed for various applications like EMS for high altitude and pumping stations as described. As more and more renewables, especially Solar PV systems, are getting installed, the grid operators find it difficult for its integration. To a greater extent the energy storage systems will overcome the challenges mentioned above. But the grid integration for the energy storage systems particularly for the decentralized systems (for business units and households) have got its own practical difficulties to implement.

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