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POTENTIALS OF LOAD-SHIFTING WITH RENEWABLE ENERGY STORAGE: AN ENVIRONMENTAL AND ECONOMIC ASSESSMENT FOR THE UK

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Overview

The Paris Agreement set targets to limit global warming to less than 2°C above the pre-industrial level to significantly reduce the risks and impacts associated with climate change [1]. Globally, the energy supply sector is responsible for 25% of greenhouse gas (GHG) emissions [2]. In addition to ratifying Paris Agreement, the UK government has adopted legally binding 80% emissions reduction target from 1990 levels by 2050 as outlined in Climate Change Act. The decarbonisation of power supply, along with electrification of heat and transport, are highlighted as key elements of this transition by both policy and academic research [3]–[5]. Storage systems, via the multiple services they offer across the electricity supply chain [6] at different operational scales stand to create system-wide benefits, enhanced flexibility and reliability for effective management of the grid [7]. The potential contributions storage systems can make towards minimizing the carbon intensity of UK grid with high levels of renewables is recognised by the government as well [8]. This study aims i) to determine the amount of load shifting that can be achieved by the combination of current renewable energy mainly wind and solar and UK grid level storage, ii) analyse the amount of renewable energy generation and storage (RES) needed to phase out programmable gas power generation during the periods of peak demand and iii) assess their economic and environmental implications. The environmental impacts considered are the life cycle emissions associated with electricity generation from the UK mix and the production, installation and use of batteries. The analysis will be extended to cover the future energy scenarios.

Methods

This study investigates the load shifting potentials with the integration of RES batteries in two sizes: a limited storage capacity and an infinitely large storage capacity. The limited size storage device considered was a 6 MW/ 10MWh lithium-ion (Li-ion) battery module, as used in a trial from 2013 to 2016 [9]. Li-ion battery is considered as a promising electrical energy storage option, offering high energy density and high output voltage, high round-trip efficiency, and better than all other batteries currently available in the market [10]. The number of storage modules was increased gradually until the maximum charging capacity (or excess power) provided by the combined baseload, solar and wind power model was reached. The aim of integrating more storage into the national power system is to decouple the timing of renewable energy generation and the peak electricity demand, in order to capture the energy generated at a particular time and use it later [11]. This decoupling allows the peak load to be supplied from low cost RES and storage, thereby reducing the need to run expensive peak load power generation plants [12]. Actual data of the UK electricity supply and demand profile from 1st June 2016 to 31st May 2017 were used in this assessment, which include data on different types of generation on half-hourly basis [13]. A code to schedule the charging and discharging of the storage was developed and run against the daily base load generation combined with wind and solar power, and the national demand profile. SimaPro 7.2 life cycle assessment (LCA) data was used to account for inputs and impacts related to the electricity generation and storage facility production, transport and use. The SimaPro data was combined with the IPCC's fifth assessment report 100-year global warming potential (GWP) impact factors to calculate environmental savings [2]. The GWP savings were calculated based on the overall peak demand offset by increasing storage capacity, which was otherwise be supplied by the peaking power plants.

Results

Over the investigated period, the emerging results from the limited size storage analysis show that up to 1561 GWh of peak demand could be shifted currently by implementing various combinations of storage capacity, delivering up to 2.27 $MtCO_2e$ reduction in emissions. Furthermore, it is expected that this figure can reach up to 1887 GWh and

2224 GWh in the future under different scenarios by 2020 and 2035, respectively. These growths are due to the predicted increase of renewable generation capacity, increase in overall electricity demand based on population growth, fossil fuel prices and GDP forecasts. Therefore, the more renewable generation that is integrated into the system, the more scope there is for increased storage capacity under the model of daily base load met by conventional and programmable sources plants, and peak load met by storage with combination of renewable energy, especially solar and wind. On the other hand, the emerging results from the model under the infinitely large storage capacity show that a maximum of 4760 GWh of peak demand could be offset over the selected period. The emerging results show that the infinitely large storage model has much higher potential for load shifting than that of the limited storage model. The reasons are that the limited storage model was constrained by the number of batteriesallowed in the system, maximum charging and discharging capacity per hour, and discharge taking place once the device is fully charged and there is excess demand at the grid. In contrast, the infinitely large storage model does not have these limitations and can store energy as much as the excess power available and can put back to the grid once there is a demand even if the storage is partially charged. However, the results presented in this paper are emerging rather than conclusive and further investigations are currently underway. Also, there are still many technical and economic challenges facing the widespread utilisation of RES storage and its large-scale applications, such as lack of market frameworks to extract the value of storage systems for alternative services [14], a lack of provision in the grid code for new entrants to the market, and a lack of full-scale trials [15]. Despite all these barriers, the study reveals that with rapidly dropping costs and improving technology options, RES storage will become crucial to increasing integration of intermittent renewable sources, the progress towards a low carbon economy, and reduction of greenhouse gases.

Conclusions

The RES storage, especially battery, is vital to increasing the integration of renewable sources into the energy generation mix by reducing the inherent issues of intermittency and variability. There are some obstacles to overcome before it becomes widespread, including some regulatory and policy issues, but also high unit cost and few proven, mature, large-scale battery storage options. The emerging results from this study has shown that conventional fossil fuel generation has the potential to be offset or replaced by renewable powered battery storage, and this leads to small but not insignificant savings in terms of GWP offsetting. With falling costs and rapidly maturing technology the GWP savings can only increase.

References

[1] UNFCCC, “Paris Agreement,” Paris, 2015.

[2] IPCC, “Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of teh IPCC,” IPCC, Geneva, Switzerland, 2014.

[3] DECC, “The Carbon Plan: Delivering our low carbon future,” London, 2011.

[4] G. Anandarajah and N. Strachan, “Interactions and implications of renewable and climate change policy on UK energy scenarios,” *Energy Policy*, vol. 38, pp. 6724–6735, 2010.

[5] F. G. N. Li, E. Trutnevyte, and N. Strachan, “A review of socio-technical energy transition (STET) models,” *Technol. Forecast. Soc. Change*, vol. 100, pp. 290–315, 2015.

[6] M. Y. Suberu, M. Wazir Mustafa, and N. Bashir, “Energy storage systems for renewable energy power sector integration and mitigation of intermittency,” *Renew. Sustain. Energy Rev.*, vol. 35, pp. 499–514, Jul. 2014.

[7] S. Weitemeyer, D. Kleinhans, T. Vogt, and C. Agert, “Integration of Renewable Energy Sources in future power systems : The role of storage,” *Renew. Energy*, vol. 75, pp. 14–20, 2015.

[8] M. Bell, A. Gault, and M. Thompson, “Meeting Carbon Budgets: Closing the policy gap: 2017 Report to Parliament,” 2017.

[9] UK Power Networks, “Smarter Network Storage: design and planning considerations for large-scale distribution-connected energy storage (SNS1.2),” 2013.

[10] B. Dunn, B. Dunn, H. Kamath, and J. Tarascon, “Electrical energy storage for the grid : A Battery of choices,” *Science (80-.).*, vol. 334, pp. 928–936, 2011.

[11] M. Aneke and M. Wang, “Energy storage technologies and real life applications - A state of the art review,” *Appl. Energy*, vol. 179, pp. 350–377, 2016.

[12] J. Eyer and G. Corey, “Energy Storage for the Electricity Grid : Benefits and Market Potential Assessment Guide,” California, 2010.

[13] Gridwatch, “G.B. National Grid Status,” 2017. .

[14] D. Pudjianto, M. Aunedi, P. Djapic, and G. Strbac, “Whole-Systems Assessment of the Value of Energy Storage in Low-Carbon Electricity Systems,” *IEEE Trans. Smart Grid*, vol. 5, no. 2, pp. 1098–1109, 2014.

[15] O. H. Anuta, P. Taylor, D. Jones, T. McEntee, and N. Wade, “An international review of the implications of regulatory and electricity market structures on the emergence of grid scale electricity storage,” *Renew. Sustain. Energy Rev.*, vol. 38, pp. 489–508, Oct. 2014.