DOI: 10.1049/stg2.12039

The Institution of Engineering and Technology WILEY

EDITORIAL

Guest Editorial: On the role of energy storage systems in the grid of the future: Selected papers from the 2019 UK Energy Storage Conference

1 | INTRODUCTION

This Special Issue is a collection of selected papers originating from the 2019 UK Energy Storage Conference (UKES) taken place on the 3rd–5th September 2019 in the Frederick Douglass Building at Newcastle Helix, Newcastle University and supported by the Supergen Energy Storage Network+, the Supergen Energy Networks Hub, the EPSRC National Centre for Energy Systems Integration, the Energy Storage Research Network (ESRN), and the STFC Network in Battery Science and Technology. The papers have been selected based on their quality and relevance to the areas covered in this journal, and include contributions from the Supergen Energy Storage Network + Early Career Researcher community. UKES is a bi-annual international conference, bringing together researchers from academia, industry, and policymakers across the whole field of energy storage and relevant themes, offering a unique opportunity for dissemination and collaboration through presentations, expert talks, and poster sessions to inspire future research. All papers in this Special Issue have been expanded and further developed from their original form to meet the criteria and high standards for inclusion in this journal.

In the last few years, the UKES conference has seen an increased number of papers that discuss Energy Storage in the context of grid applications. This is mainly due to the fact that energy storage, in its many forms, sizes, and locations, is seen by a wide range of stakeholders having a key role in future energy networks, by providing flexibility, enhancing affordability, security, and resilience against supply uncertainties, and addressing challenges related to climate change. Submitted papers evidence that over a small period of time, significant progress has been made in the research and development of models, tools, methods, and approaches that help to promote the role of storage in future networks; but also reveal that there are still significant challenges across a wide number of research areas that necessitate interactions between interplaying disciplines.

More particularly and in this Special Issue, we have gathered a selection of papers of the highest quality including academic and industrial contributions, in areas of technological breakthroughs in energy storage, network integration challenges, and management and control. These encompass a number of disciplines, from electrochemistry to power systems and from data sciences to economics.

2 | TECHNOLOGY-RELATED ASPECTS OF ENERGY STORAGE SYSTEMS

Technological breakthroughs in Energy Storage at a component level can accelerate adoption through more cost-effective and higher performing solutions. In this section, papers address issues of State of Charge (SoC) and lifetime calculation. The analyses include both thermal and electrochemical storage systems, and establish connections with real-world smart grid applications.

Papers [1–3] of this Special Issue are in this category. Paper [1] by Daniel Morales et al., introduces a model-based observer for the calculation of the SoC of water-based Thermal Energy Storage system for district heating and cooling systems (DHCS) that acts as a buffer between supply and demand schedules. A dynamic model of a one-dimensional stratified water tank is adopted to develop the observer. Its effectiveness is assessed through 'model-in-the-loop' co-simulations. Simulation results considering three different system configurations demonstrate that the model-based observer accurately estimates the temperature distribution within the tank, leading to an effective SoC computation and control—even in the case of sensor failure or upon limited sensor availability.

Paper [2] by M. Javadipour, et al., provides a monitoring solution that can be used in the ageing estimation of EV batteries. The proposed model analyses the current density in electrode and electrolyte of an EV lithium-ion cell using a simulation-assisted method that leads to improvement in SoH estimation accuracy. The multi-physics model of the cell is developed in COMSOL modelling software and the real-time data fusion process is implemented on dSPACE Microlabbox real-time simulator.

Paper [3] by El-Dalahmeh, et al., proposes a new and interesting method on estimating the Remaining Useful Life of Lithium-Ion Batteries based on a Smooth Particle Filter. This method appears to be more effective than traditional methods like Particle Filter Unscented Particle Filter. Comparison of various methods are performed based on datasets from the Prognostics Centre of Excellence NASA using non-linear characteristics degradation properties.

2.1 | Network integration of energy storage systems

Energy storage systems (ESSs) are among the promising technology developments that can facilitate did rapid growth in the integration of renewable energy resources and support the global efforts towards a decarbonised economy. With the integration of the ESSs the operators in different energy systems are able to enhance the efficiency of the operation and improve the security of supply.

There are a number of challenging directions regarding the integration of ESSs that need to be more investigated, which are listed as follows.

- Storage as a Service is an evolving area that needs to be further investigated and their potentials need to be analysed.
- Control and management of a population of storage devices to harvest network's services.
- Governmental incentives, policy, and regulation and their impact on the energy storage integration.
- Mobile storage systems (e.g. EVs, E-Bus, and E-Truck) and their usage in the energy networks.
- Smart charging and control of the ESSs.

Papers [4–6] of this Special Issue are in this category. Paper [4] by M. Habibi, et al., proposes the usage of energy storage in order to mitigate the uncertainties imposed by the usage of renewable energy sources. Key to this is the observation that previous stochastic models may result in large deviations due to the fact that they do not take into account corrective dispatches. An IEEE 24-Bus network was used to demonstrate that the proposed method can significantly the performance of the overall system.

The Paper by A. Saatloo, et al., in [5] is focussed on a multivector energy system that employs hydrogen. The key to this work is the uncertainty that is imposed on the system by wind fluctuations, electricity prices, and load demand. This combined uncertainty is addressed by using a hybrid robust stochastic method and the overall system is modelled as a mixed-integer linear programing problem. Numerical results demonstrate that the proposed method can be addressed the aforementioned uncertainty.

Authors in paper [6] present the results of an experimental evaluation of a 1.5 MJ/25 kW ESS that is connected directly to a medium voltage grid in order to provide fast and flexible grid control capabilities. The demonstrator consists of a cascaded modular multilevel converter able to interface directly to the medium voltage grid, fed by dual active bridge converters with isolation provided by medium frequency transformers whilst in the low voltage side DC bus, a low-voltage inverter, and a supercapacitor stack are connected via interleaved converters. The concept on which the demonstrator was designed can also facilitate the implementation of a solid-state substation with an integrated energy storage concept that can further increase the flexibility and reliability of future grids.

2.2 | Management and control of ESSs

Multivector energy systems offer great advantages to the operators of future energy grids as different energy carriers can complement each other and offer a viable solution to the energy trilemma requirement. Having said that different energy networks (like gas and electricity) have completely different operating conditions. This includes variability, time constants, and size. For example, heat and electricity demand fluctuate between seasons, but their absolute values and their variability diverge significantly.

Therefore, it is crucial that proper energy management methods are employed that utilise the potential that each energy carrier can offer. These strategies depend on the assets of the networks that are integrated, on the task(s) of the system, and on the interaction that the operators want to have between the energy carriers.

In this Special Issue, several such methods and studies are presented and useful results are obtained for a number of multivector energy systems ranging from purely electrical systems to cases that employ thermal storage or hydrogen.

Papers [7–9] of this Special Issue are in this category. Multivector energy systems using geothermal energy storage are presented in [7] by H. Hosseini, et al., high and low-temperature geothermal storage systems are studied combined with renewable energy sources such as wind and solar to meet local heat demands. Through a Techno-Economic-Environmental, it is proved that the high-temperature option is a better solution as it helps meet the heating demands of a local system while at the same time offer the least carbon-intensive configuration.

Paper [8] by P. Akaber, et al., investigates a Mixed Integer Linear Programing based solution for operating a fleet of E-mobile assets (e.g. E-buses, E-trucks, E-taxis, and E-ferries) considering technical and operational characteristics of different fleet elements. It takes into account customer (i.e. E-fleet operator) goals, such as load balancing and charging cost minimisation. Moreover, it is shown that through integrating ESSs, the E-depot charging capacity would be increased, which has a positive impact on the operation of the E-depot by a peak reduction of up to 50% and total charging cost reduction of 27% in the studied system.

Missing data analysis in charging/discharging ESSs that provide ancillary services to the grid are tackled in [9] by Pazhoohesh et al. In this work, the authors analyse the impact of missing information due to the sensor and/or network malfunctioning problems on the storage energy management system. Eight different imputation techniques are applied on data taken from a real 6 MW/10 MWh lithium-ion battery used at the distribution level at Leighton Buzzard, UK. The paper studies the results derived from each imputation method and useful remarks are made depending on the percentage and pattern of the missing data.

3 | SUMMARY

Although the key role of energy storage in the decarbonisation of future networks is undisputed, the papers in this Special Issue have revealed the complexity in trying to optimise relevant solutions end-to-end: from component to system. When assessing the potential of storage an end-to-end understanding from component properties to system needs is required: one that is cognisant not only of technical aspects but also social, economical, and environmental factors and related uncertainties.

The papers in this issue have provided evidence of original contributions that enhance the role of storage in networks, and achieved through collaborations and synergies such as between component modelling and application, between energy systems research and energy storage technologies, between industrial practice and demonstration with modelling, and between control methodologies and data sciences. It is, therefore, evident that the community in this area would benefit from more interactions between disciplines and even across sectors including academia, industry, and policy-making in order to achieve the societal impacts expected, especially in light of new challenges such as the COVID pandemic.

Vahid Vahidinasab[1]
Charalampos (Haris) Patsios[2]
Damian Giaouris[2]
Phil Taylor[3]

[1]*Department of EngineeringSchool of Science and Technology, Nottingham Trent University, Nottingham, UK*
[2]*School of Engineering, Newcastle University, Newcastle upon Tyne, UK*
[3]*School of Engineering, The University of Bristol, Bristol, UK*

Correspondence
Charalampos (Haris) Patsios, School of Engineering, Newcastle University, Newcastle upon Tyne, NE1 7RU UK.
Email: haris.patsios@ncl.ac.uk

ORCID

Vahid Vahidinasab https://orcid.org/0000-0002-0779-8727

REFERENCES

1. Morales Sandoval, D.A., et al.: Design and verification of an effective state-of-charge estimator for thermal energy storage estimator for thermal energy storage. (2021)
2. Javadipour, M., et al.: Analysis of current density in the electrode and electrolyte of lithium-ion cells for ageing estimation applications. (2021)
3. El-Dalahmeh, et al.: Smooth particle filter based likelihood approximations for remaining useful life prediction of lithium-ion batteries
4. Habibi, M., et al.: Assessment of energy storage systems as a reserve provider in stochastic network constrained unit commitment. (2021)
5. Saatloo, A., et al.: A Hybrid robust-stochastic approach for optimal scheduling of interconnected hydrogen-based energy hubs
6. Klumpner, C., et al.: Experimental evaluation of an energy storage system for medium voltage distribution grids enabling solid state substation functionality. (2021)
7. Hosseini, H., et al.: Techno-economic-environmental analysis of a smart multi energy grid utilising geothermal energy storage for meeting heat demand. (2021)
8. Akaber, P., et al.: An MILP-based customer-oriented E-fleet charging scheduling platform
9. Pajoohesh, M., et al.: Investigating the impact of missing data imputation techniques on battery energy management system. (2021)

AUTHOR BIOGRAPHIES

Vahid Vahidinasab (Senior Member, IEEE) received the PhD degree (Hons.) in electrical engineering from the Iran University of Science and Technology, Tehran, Iran, in 2010. Since 2010, he has been with the Department of Electrical Engineering, Shahid Beheshti University (SBU), as an Assistant Professor. He has also founded and managed the Soha Smart Energy Systems Laboratory, SBU. He has demonstrated a consistent track record of attracting external funds and managed industrial projects and closely worked with 12 large and complex national/international projects. From 2011 to 2018, he held a number of leadership roles at SBU and the Niroo Research Institute. In 2018, he moved to Newcastle University, where he worked as a Senior Research Associate and managed the inteGRIDy as an EU Horizon 2020 Project and also worked with the EPSRC Active Building Centre (ABC). Most recently, in 2021, he moved to Nottingham Trent University where he is currently a Senior Lecturer and lead teaching and research in the area of power and energy systems. His work is funded by the U.K.-EPSRC, EU-H2020, and industry partners and local utilities of Iran and the UK. He is a member of the IEEE Power and Energy Society (PES) and the IEEE Smart Grid Community. He is also a member of the Editorial Board and a Subject Editor of the *IET Generation, Transmission & Distribution,* and an Associate Editor of the *IET Smart Grid* and *IEEE Access*. He is also the Guest Editor-in-Chief of the Special Issue on "Power and Energy Systems Operation in Time of Pandemics: Lessons Learnt from COVID-19 Lockdown" of the *International Journal of Electrical Power & Energy Systems*. He was considered as one of the outstanding reviewers of the IEEE Transactions on Sustainable Energy, in 2018, and the IEEE Transactions on Power Systems, in 2020.

Damian Giaouris received the BSc degree in mathematics from Open University, Milton Keynes, UK, in 2009, the BEng degree in automation engineering from

Technological Educational Institute of Thessaloniki, Sindos, Greece, in 2000, a Postgraduate Certificate in mathematics from Open University, in 2011, and the PhD and MSc degrees in the area of control of electrical systems from Newcastle University, Newcastle upon Tyne, UK, in 2004 and 2001, respectively. He was a Lecturer in Control Systems with Newcastle University since 2004, before moving to the Centre for Research and Technology Hellas, Greece, in 2011 until 2015. Since August 2019, he has been a Reader in Control of Energy Systems with Newcastle University. His research interests include control of power converters, power systems, smart grids, electric vehicles, and nonlinear dynamics of electrical systems. He has more than 150 publications (with more than 3000 citations) and he has served as an Associate Editor at IET and IEEE journals.

Haris Patsios (HP) is a Senior Lecturer in power systems with a significant experience in the design, modelling, and control of power systems including renewables. He is a Co-Director and WP leader for the Supergen Energy Storage Network+, and Work Package Leader for the £5m EPSRC's National Centre for Energy Systems Integration (CESI). His research focuses on the development of integrated models and control techniques for flexibility resources such as energy storage in modern networks, working closely with UK industry and academia on a number of research projects and initiatives.

Phil Taylor (Senior Member, IEEE) received the Ph.D. (Eng.) degree in intelligent demand side management techniques from the University of Manchester Institute of Science and Technology (UMIST), Manchester, UK, in 2001. He previously held the DONG Energy Chair in Renewable Energy and was the Director of the Durham Energy Institute. He joined Newcastle University, Newcastle upon Tyne, UK, in April 2013, where he was the Head of the School of Engineering and held the Siemens Chair of Energy Systems. He joined the University of Bristol in July 2020, where he is the Pro Vice-Chancellor for Research and Enterprise. He is currently a Visiting Professor with Nanyang Technological University, Singapore.