

Forecourt Electric Vehicles Charging Hubs – UK and Saudi Research and Education Collaboration

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Abstract— This paper covers how a successful model of electric vehicles (EV) forecourts in the UK can be implemented into Kingdom of Saudi Arabia (KSA) for supporting research, knowledge, and innovation in emerging EV technologies. The paper also addresses the challenges of implementation of EV technologies via research, training and curriculum development.

Keywords—EV Forecourt, Electric Vehicle, Research and Education Collaboration, UK & Saudi Arabia.

I. INTRODUCTION

The UK-Saudi Electric Vehicles Education and Research Network is a game-changing partnership among higher institutions in the UK and Kingdom of Saudi Arabia (KSA). The focus of the network is on the next generation of EV technologies. The network shall promote multidisciplinary collaborations from different engineering and non-engineering departments. The acceleration of transition to this new green smart technology would require collaboration in preparing new graduates with knowledge and research skills in the fields of enhanced energy management (advanced modelling, monitoring, and control of electric vehicle subsystems), energy storage (comprehensive lifecycle deployment of electric vehicle batteries), advanced power modules (advanced integrated power modules for ultra-compact chargers), next-generation powertrain (innovative system topologies to increase efficiency of EV powertrains), ubiquitous charging (fast, on-board, and wireless charging solutions to reduce range anxiety), and EV opportunities (e.g., expand the utilisation of EV and batteries).

Brunel University London (UK) and King Abdulaziz University (KSA) are working together through a British Council grant to identify key challenges and constraints for the development and implementation of EV technologies in KSA. The project will propose a successful model for collaboration between universities and industry to prepare young graduates and researchers capable of addressing the challenges of EV technologies. This paper presents a vision of how a forecourt EV charging hub technology can be disseminated and implemented, not just KSA but also in other countries in the middle east.

II. FORECOURT EV CHARGING HUBS

A forecourt EV charging hub is mainly an ‘electric’ filling station designed to meet the demands of the emerging EV market. Usually the forecourt offers services (in addition to charging EV) like dining facilities, meeting space and Wi-Fi hotspots, groceries, EV sales, valet services, etc. In the UK, there are over 100 electric forecourts powered by net zero carbon energy. The aim is to solve EV charging concerns and

lead the way to large EV adoption well before the 2030 petrol and diesel ban.



Fig. 1: A typical forecourt EV charging hub [1]

Fig. 1 illustrates a typical forecourt EV charging hub in the UK. There are four main components: The solar panel (main source of energy), the battery bank (usually 2nd life battery packs stored in a well-ventilated building), the charging units and the retail section within the station. The forecourt could be just powered by the solar panel via the batteries or could also be connected to the grid. If connected to the grid then the off-peak electricity rate is used to either charge or trickle charge the batteries. The solar panels could be connected in centralised configuration (string diodes and central inverter), PV strings with individual inverters, or strings with individual converters and a common inverter, or an AC module configuration. Each configuration has some advantages and some limitations. Fig. 2 illustrates how a solar panel system can be connected with the charging unit. The maximum power point tracking (MPPT) is carried out within the string converter and then a DC link is used for the battery as well as for charging EVs via appropriate battery chargers. An inverter is used to link the whole system to a smart grid where other renewable energy sources could also be used. In order to be able to design, build and use such forecourts; a good educational programme based on relevant curriculum is essential and this is discussed in the following section.

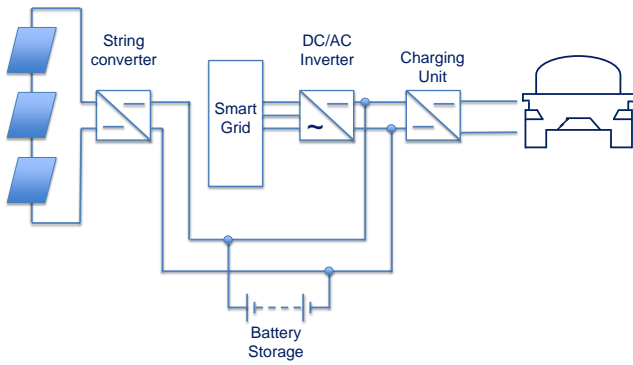


Fig. 2: Layout of a typical charging station

III. EV- CURRICULUM DEVELOPMENT

EV is an interdisciplinary topic which could be a rich area for teaching undergraduate (UG) and postgraduate (PG) students as well as for carrying out research topics. Fig. 3 illustrates how various departments/colleges can collaborate in the education of EV systems.

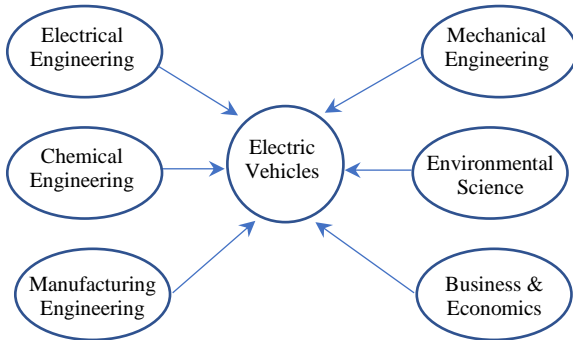


Fig. 3: Interdisciplinarity of EV Systems

Since EV is becoming a booming industry and is expected to expand further in the future, the authors feel that perhaps it is the time to move ahead and to suggest a 4/5 year curriculum. The curriculum can be specific for EV education and provide the industry with the needed, focused, and skilled manpower. The proposed programme is based on a 5 year university MEng degree if adopted in the middle east (following 12 years of primary preparatory and secondary education) or 4 years university MEng degree (following 13 years of primary and secondary education as the case in the UK). The proposed curriculum can start by combining relative modules from different departments, and it could grow in the future and be hosted within an independent department of EV engineering. The proposed curriculum is based on 8 (or 6) modules per year where each module has 15 (or 30) credit. So, the total number of credits per year is 120 credits (600 credits for the 5 years degree or 480 credits for the 4 years MEng degree). Tables 1 to 5 present the suggested topics in each of the 4 or 5 year programme based on the experience of the authors in designing several engineering UG and PG courses.

Table 1: Proposed UG degree courses for year 1

Year 1 (not included in the 4 years MEng programme)
Mathematics for Engineering
Physics
Chemistry
Applied Mechanics
Electronic and Electrical Fundamentals
Health Issues and Ethics
Simulation Workshop (PSPICE)
Practical Workshop (could link to the practical parts in other modules)

Table 2: Proposed UG degree courses for year 2

Year 2
Mathematics for Engineering (2)
Electric Machines
Machine Elements
Digital Systems
Computer Aided Design (CAD)
Health issues and ethics (2)
Simulation Workshop (MATLAB)
Practical Workshop (could link to the practical parts in other modules)

Table 3: Proposed UG degree courses for year 3

Year 3
Renewable Energy Technology Fundamentals
Design of Electric Machines
Integrated Electronics
Sensors and Transducers
Mechatronics
Business for Engineers
Introduction to Energy Storage / Battery Technology
Practical Workshop (could link to the practical parts in other modules)

Table 4: Proposed UG degree courses for year 4

Year 4
Power Electronics and Drives
Dynamics and Control
Mechanics and Materials
Design and Manufacturing
Communication Systems
Innovation in Sustainable Engineering Design
Independent Project (40 credits)

Table 5: Proposed UG degree courses for year 5

Year 5
Advanced Vehicular Technology
Battery Management Systems
Plug-in and Wireless Charging
Power System Stability and Control
RF & Optical Communication Systems
Autonomous EV Technology
Group Project (40 credits)

It can be seen that the curriculum starts with generic modules and then goes into more details in relevant modules in the later years. The year 4 independent project could be within the area of EV charging mechanism, in the communication area, in the electric drives or in the mechanics/material or manufacturing. The year 5 group project should be carried out by a group of students (minimum 4) to produce a near final product which contain power electronics / communication / design / and manufacturing elements. It is important to link this educational programme to a government vision of the EV charging infrastructure.

IV. FUTURE EV CHARGING INFRASTRUCTURE IN SAUDI ARABIA

Vision 2030 is a strategy set by Saudi Arabia which is aimed at diversifying and de-carbonising the Saudi economy. The economy is at present heavily reliant on oil and the country has a target of Zero Carbon emission by 2060. A part of this strategy is gearing up to make a shift to EV over the next 10 years as it moves to attract more local EV investment and production companies. Saudi Arabia has also seen a fast-growing interest in developing the local EV battery supply chain. They have also announced that at least 30% of cars in its capital (Riyadh City) would be electric by 2030. The main aim is to reduce planet-warming emissions. Of course, in order to achieve the target of low carbon emissions, the electricity which is used to charge EVs should come from renewable energy sources otherwise we will be shifting the pollution from one place to another. Forecourt EV charging hubs are an excellent investment where renewable energy sources and clean energy storage combined with EV charging points are all come together with retail-entertainments provision. Such facilities do not exist in Saudi Arabia at present but there are individual charging stations located at different parts of the Kingdom as shown in Fig. 4. There are 15 connectors scattered in 14 locations (10 Schuku-EU Plug, 3 TYPE 2 Plug and 2 Tesla chargers) [2]. The latest station was opened in Al Faisaliyah, Az Zilfi. This information based on figures recorded up to May 2022. This figure needs to increase in the near future as there is a plan to produce 150,000 EV by 2026 in KSA [3].



Fig. 4: EV charging connectors in KSA [2]

In the UK, there are 45,000 connectors in 25,000 charging devices scattered in 16,000 different locations/charging stations as shown in Fig. 5 [4]. It must be noticed that this figure is changing almost daily. Also, this number does not include private residential connectors and they are also changing daily. The UK-wide network has over 100 electric forecourts powered by net zero carbon energy. Transferring the electric forecourt technology to KSA will provide a strong pulling force toward net zero carbon energy. This technology requires good foundation in terms of education & research.



Fig. 5: EV charging connectors in the UK [4]

V. RESEARCH COLLABORATION

Research ‘in general’ is an important tool for building knowledge and facilitating learning which should lead to the understanding of many issues and increasing public awareness. Research collaboration ‘in specific’ can result of higher impact publications, greater creativity, less work for everyone without compromising on results, ability to bring more experience, better chance of funding, less risk, etc. In this paper, the authors are suggesting some PhD research topics for a jointly/collaborative supervision:

A. Projects related to the EV Forecourt

- Optimisation of energy storage devices within the forecourt for maximum efficiency. This includes the study of the site temperature throughout the year and the required ventilation/cooling/heating required.
- Distribution of the charging connectors within the forecourt. This involves the optimisation of the connector locations for maximum power transfer.
- Grid connection of the forecourt. This is to look at the peak shaving of the loads at certain times and distribute this load at low demand times.
- Business modelling of EV forecourt. This involves students from business background to set up a plan for the successful operation of EV forecourt, identifying sources of revenue, the intended customer base, payback time, subsidise products, and details of financing.
- Battery swapping can be an effective way to recharge EV but with challenges such as high capital investment, high operating costs, and low economic benefits. Enabling battery swap stations (BSSs) clusters to contribute in the frequency regulation (FR) service can better utilise idle batteries to enhance the operating economy of BSSs [5]
- Methodologies for an effective charging stations deployment has been a key research area to reduce investment costs as well as deliver better EV driving range and experience [6].

B. Projects Related to the EV Industry

- Battery management system. This is a very important and booming research area where the EV battery needs proper monitoring, protection, state estimation, performance optimisation and fast reporting operational status to external devices.
- End of life electric motors. EVs use different types of electric motors; the most popular one is the permanent magnet motor due to its high-power density in comparison with other types of motors. However, research is required for the end-of-life treatment for these motors as they contain rare earth magnets (REM).
- Wireless charging of EVs. Wireless power transfer (WPT) methods, including microwave power transmission, inductive-coupling-power transmission, laser power transmission methods, magnetic resonance coupling are some of the topics which require in-depth research.
- Mitigating three-phase power imbalance with EV and grid battery. Three-phase power imbalances could happen in distribution networks as a result of high EV charging demand. The imbalances become problematic with the rising number of EVs in the future and could be alleviated with coordinated charging strategies [7].
- As power systems are restructuring, the energy transaction between EV (via charging stations) and distribution network has become a key development. However, privacy and anonymity are a difficult problem to be addressed in energy transactions [8].
- Aramco, Hyundai Motor Group, and King Abdullah University of Science and Technology (KAUST) have recently agreed to jointly research and develop an advanced fuel for use in combination with a novel combustion system coupled with an electrified hybrid vehicle [9]. There are excellent opportunities for

students across the whole KSA to join such research project.

C. Projects Related to Information and Data Exchange

- Transmission System Operator (TSO)-Distribution System Operator (DSO)-electricity retailer data and information exchange. Grid to Vehicle (G2V) and Vehicle to Grid (V2G) bi-directional charging will hugely impact on the distribution and transmission network operation. The real-time power flow optimization with exchange of electricity price and power flow data within different entities should be standardised.
- EV data analytics. A prolific amount of data is generated for EV driving energy consumption and EV charging demand. For EV energy management systems, the use of high-quality energy consumption data will enhance EV powertrain performance and efficiency. For DSO and electricity retailers, it is crucial to understand the charging demand patterns to plan and operate in the most economic manner.

VI. RECOMMENDATIONS

The following are some recommended tasks which can be set in order to achieve a net zero carbon energy powered forecourts:

- A good awareness campaign of zero carbon energy powered forecourts for EV. British Council in the UK and Saudi Arabia are active in promoting collaboration work in this area by sponsoring several projects, including the one under the investigation in this paper.
- Encourage the deviation and diversity from the traditional engineering degree courses, which are taught at universities and technical colleges. Some degree courses can be adapted which can integrate modules from different engineering departments as well as to create up-to-date modules like advanced vehicular technology, battery management systems, etc. as discussed in section III.
- Organise specialised conferences in KSA where renewable energy industry, EV industry, universities, and research centres are invited from across the world to present the latest technology in the field.
- Subsidise EV zero carbon energy powered Forecourts for a period of 5 years where they provide free charging and perhaps free or subsidised catering.
- A well-planned study of the locations of the EV forecourts to prevent range anxiety (range anxiety is the driver 's fear that a vehicle has insufficient energy storage).

VII. CONCLUSIONS

This paper deals with the exchange of successful model of electric vehicles (EV) forecourts in the UK to Kingdom of Saudi Arabia (KSA) for supporting research, knowledge, and innovation in emerging EV technologies. The paper started by examining the main components in a typical EV charging hub and then the authors suggested an outline of undergraduate level EV technology curriculum. Some recommendations are provided in order to achieve net zero carbon energy powered forecourts. Possible research topics in this multidisciplinary area are also suggested.

Acknowledgments

The authors would like to thank the British Council for the funding of the project on “UK-Saudi Electric Vehicles Enhanced Education and Research Network”. This paper is based on the ongoing dissemination results.

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