Research Assessment Exercise 2020
Impact Case Study

University: The Hong Kong Polytechnic University
Unit of Assessment (UoA): Electrical & Electronic Engineering (12)

Title of case study: Energy Infrastructure Devices for Electric Vehicle Adoption

(1) Summary of the impact

The Electric Vehicle and Energy Storage (EV-ES) team in UoA12 engages in research, development, and technology transfer of power electronics that handle bi-directional heavy currents and integrated energy storage with a focus on electric vehicle (EV)–related applications. These activities have led directly to the adoption of electric vehicles in a range of organizations and facilities to reduce roadside pollution, enhance the quality of life, and enable further economic growth downstream. Since 2013, the activities of this group have led to direct benefits for the wider community through activities such as:

- The licensing of battery management system designs
- The installation of EV-ES developed Smart-EV chargers at the HK International Airport
- Adoption of new charging infrastructure for a public company (CLP, 0002:HK)
- Tangible results in other unanticipated areas

(2) Underpinning research

The research group has started from basic research in all aspects of power electronics and later on power conversion in vehicle design. Inspired by the ex-Vice President of PolyU (Dr. Lui), a number of research projects were initiated by the University for industry partners and the HK Innovation and Technology Commission's ITF scheme starting in the early 2000s. From then on, we have developed an active research portfolio covering a range of topics for the past 15 years:

Battery Research: As the essential device for energy storage in EVs, the EV-ES team makes use of the power conversion research to further explore the battery charging systems, battery management systems and wireless charging strategies. The EV-ES team also considers super-capacitor pairing for the integration of the battery which paves the way for the new energy unit for EV. [Refs 2, 3]

Motor and Drive Research: Instead of the conventional research in induction motor and permanent magnet motor, the EV-ES team concentrates on the fault tolerance switched-reluctance motor (SRM) which is believed by many to be the best motor for future EV. Research in this direction has been spun off from the areas of linear active suspension, in-wheel motor, and motor torque control. [Refs 1, 6]

EV Design: A number of new comprehensive EV designs have been developed. The most promising one is "MyCar" which has already been transferred to industry. Also, marine transport options are an important class of EV considered by the team as traditional marine engines are a tremendous source of pollution.

EV charger: Initial charger research started in 1997 when Cheng started to investigate the phase-shifted power converter and a PhD student started to use this technology in EV charger designs. It is a fundamental concept that enables EV power circuitry. The application includes the first

EV charger network in Hong Kong and the region, and then high power charger with smart power-sharing in Hong Kong airport, and will extend the installation overall the whole city. [Refs 4, 5]

(3) References to the research

1. [X. D. Xue, K. W. E. Cheng, T. W. Ng, and N. C. Cheung, "Multi-Objective Optimization Design of In-Wheel Switched Reluctance Motors in Electric Vehicles", IEEE Trans Industrial Electronics, Vol. 57, Issue: 9, 2010, pp. 2980 – 2987. DOI: 10.1109/TIE.2010.2051390

2. Cheng, K.W.E., Divakar, B.P., Hongjie Wu, Kai Ding, Ho Fai Ho; "Battery-Management System (BMS) and SOC Development for Electrical Vehicles", IEEE Transactions on Vehicular Technology, Vol. 60, Issue: 1, 2011, pp. 76 – 88. DOI: 10.1109/TVT.2010.2089647

3. Ye Yuanmao and K.W.E. Cheng, "Zero-Current Switching Switched-Capacitor Zero-Voltage-Gap Automatic Equalization System for Series Battery String", IEEE Transactions on Power Electronics, Jul 2012, Vol 27, No. 7, Jul 2012, pp. 3234-3242. DOI: 10.1109/TPEL.2011.2181868

4. Ye, Y. ; Cheng, K.W.E., "Modeling and Analysis of Series-Parallel Switched-Capacitor Voltage Equalizer for Battery/Supercapacitor Strings", IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol.3, Issue: 4, Dec 2015, pp. 977 – 983. DOI: 10.1109/JESTPE.2015.2418339

5. Yuanmao Ye; Ka Wai Eric Cheng, "Analysis and Design of Zero-Current Switching Switched-Capacitor Cell Balancing Circuit for Series-Connected Battery/Supercapacitor", IEEE Transactions on Vehicular Technology, 2018, Volume: 67, Issue: 2 , pp. 948 – 955. DOI: 10.1109/TVT.2017.2749238

6. XD Xue, K.W.E. Cheng, SL Ho, "Optimization and Evaluation of Torque Sharing Functions for Torque Ripple Minimization in Switched Reluctance Motor Drives", IEEE Trans Power Electronics, Vol. 24, Issue: 9, 2009, pp. 2076 – 2090. DOI: 10.1109/TPEL.2009.2019581]

(4) Details of the impact

Below, highlights of impact are presented:

- **Since 2012: Launch of 'MyCar' in US market in Mississippi (Economic, Societal and Cultural Impact)**
  The pioneering work on EV power supply systems (Ref 2 and 6) would be realized in the development of the MyCar electric vehicle, prior to the period of assessment. However, in 2012, the MyCar would make its way through legal disputes to be realized in the US market through a licensing and manufacturing agreement. As noted in Im1, the MyCar production would lead to 426 jobs created in the US state of Mississippi when the low-speed vehicle was planned for production. With a price-tag of $15,500 USD and a range of 115 miles, the EV is important as it signifies **"the revolutionary strategy of creating an affordable electric car that will reshape how Americans think about meeting our daily transportation needs"** [Im1].

Figure 1: Ceremony to celebrate the MyCar electric vehicle as Hong Kong's **"First home-grown EV"** (left). Former President of the USA, Bill Clinton and former PolyU President, Prof. Timothy Tong, with a MyCar Electric Vehicle in at the US production site (right).

- **2012-2019+: Licensing and technology transfer of the "solar air conditioning for vehicles" to Green-Power Industrial Ltd (Economic Impact)**
  Although the underlying work to enable solar air conditioning for vehicles (SAV) was performed prior to the assessment period, a licensing agreement was announced in 2010/2011 and later realized in 2012. As noted by the Associated Press in Im2, air-conditioning usually accounts for one-third of the energy consumption of vehicles, but since they are only used for a few hours each day, a combination of batteries and solar panels could be ideal to handle such functions. This technology would eventually make its way to Swire Coca Cola Hong Kong where it was adopted for some of their delivery vehicle fleet. Every year since 2012, the technology has been licensed by Green-Power Industrial Ltd, and as noted by Mr. Eric Mak, the EV-ES team **"provides essential guidance and assistance for the research, technology transfer and production"** of SAVs. This help is "critical as the company sought to enter the market of the SAV". [Test. 2]

- **2015-2019+: Develop the battery management system and start licensing procedure to industry (Economic Impact)**
  Staff in the ES-EV team of UoA12 have licensed the BMS and wireless power transfer for energy storage and mobility application to industry partners [Im3] Vicwood Ltd (in 2018), Smart Mobility Ltd (in 2019), and China Dynamics. Smart Mobility LTD intends to use these charging systems to move towards electrified marine transport, giving rise to improved significant environmental impact as the marine pollution is often considered to be more hazardous than roadside pollution. Smart Mobility Ltd specifically mentions [Test. 3] that the technology of UoA12 in **"electric mobility are excellent and re the best in the region and the world."** As noted in the testimonial by Vicwood [Test. 1], the UoA12 **"have devoted excellent support to the technology and this technology is critical is critical as we have determined to enter the market of wireless power transfer and battery management."** Furthermore, as mentioned by China Dynamics in [Test. 5] **"the technology derived from PolyU is excellent and is one of the best of electric vehicles, electric vessels, and battery management systems in the word."** They go on to mention **the "indispensable and important role"** of the UoA12.

- **2009-2016 CLP (Environmental Impact, Quality of Life, Economic Impact)**
  China Light and Power Hong Kong (CLP) commissioned PolyU to implement highly scalable standard EV charging systems with integrated Octopus payment processing. These stations were then deployed around the SAR territory. As noted by the former Managing Director [Test. 4.1], **"We chose to work with them because of their world-class expertise in the area of energy infrastructure."** This cooperation is set to continue in the years ahead as CLP

looks to help the local government achieve its goals with EV charging infrastructure. Also noted by another CLP manager in [Test. 4.2], **"Eventually, the air quality of the society would be improved and the efficiency of energy use would be greatly enhanced."**

- **2017: The installation of EV-ES developed Smart-EV chargers at the HK International Airport (Public Policy and Services, Quality of Life)**
  With input from the Airport Authority in Hong Kong, the EV-ES team in UoA12 was able to deploy a locally made EV Quick Charger solution for the fleet of electric vehicles that are used by ground staff at the HK International Airport, one of the busiest airports in the world. This "Smart-To-Charge" system smartly distributes electricity to chargers, minimizes electrical infrastructure cost and allows for flexible future expansion of the charging network depending on demand and capacity. The project was such a success for the Airport Authority that it gained the attention of local policy makers and the ability for PolyU's charging stations to quickly charge EVs meant that definitive guidelines could be set for the strategy regarding the future balance of electric vehicles in Hong Kong (as noted in Im4 and Im5).

Figure 2: Electric Vehicle DC Fast Charger at the HK Airport Authority (left). Members of UoA12 and representatives from the HK Legislative Council and Airport Authority (right) [Im5].

(5) Sources to corroborate the impact

References:

Im1 https://www.autoblog.com/2012/07/14/mississippi-automaker-unveils-15k-mycar-electric-car-gets-visi/
Im2 https://www.youtube.com/watch?v=OxaVP-zAOjE
Im3 Licensing agreement between PolyU and various companies
Im4 Wen Wei Po 26th December 2016
Im5 HKIE Engineer Magazine May 2018 & HKIE Engineer Magazine March 2018

Testimonials

[1] Mr Calvin Cheng, Director, Vicwood Prosperity Technology Limited
[2] Mr. Eric Mak, CEO of Green Power Industrial Limited (Licensing of SAV)
[3] Ms. Nora Chiang, Director of Smart Mobility Ltd (Licensing of BISC)
[4] Mr. Paul Poon, Former Managing Director CLP Power (Collaborator of Charging network for EV) [4.1] and Mr. Yun Pui Chu, Senior Logistics & Transport Manager, CLP Power [4.2]
[5] Mr. Simon Cheung, Head of Project Development, China Dynamic Ltd (Collaborator of BMS)