Electric Bus Revolution of Shenzhen City in China

Report by India Smart Grid Forum (ISGF)

Shenzhen is the only city in the world where all the public buses are electric. During the period from 2011 to 2017, they replaced all the diesel buses with electric buses. There are 16359 electric buses in operation in Shenzhen City. Significance of this number is to be viewed from the perspective that in 2017, there were only 956 electric buses in entire Europe and less than 500 in entire United States. (*Please see table at Appendix –A for the number of electric buses in China and rest of the World*).

Brief History of Shenzhen City

In 1979 the Chinese Government under President Deng Xiaoping established Special Economic Zones (SEZs) in the Pearl River Delta region, with **Shenzhen** being the first SEZ allowing foreign direct investments under the open economic policies. It was a small fishing village called Bao'an County with a population of 30,000 which was renamed as **Shenzhen** City in 1979. Shenzhen's official population was 12 million in 2005, making the demographic 99% migrants. Present population is estimated at 22 million *(by 2010, there were 22 million registered SIM cards in Shenzhen).*Fastest growth in human history. In the same period, the economic growth has also been unprecedented in history - GDP grew from 1.96 million RMB in 1979, to 500 billion RMB in 2005. In 2016, Shenzhen's GDP totaled US$303.37 billion - higher than that of countries like Portugal, the Republic of Ireland, and Vietnam. Its ppp per-capita GDP was $49,185 (unregistered migrant population not counted) as of 2016, on par with developed countries such as Australia and Germany.

Majority of the consumer appliances sold around the world are made in Shenzhen and adjoining areas. It is also a magnet of technology entrepreneurs and high tech manufacturing. Shenzhen is home to many internationally successful high-tech companies, including Huawei, Tencent, BYD, Konka, Skyworth, Coolpad, ZTE, Gionee, TP-Link, DJI, BGI (Beijing Genomics Institute), OnePlus, etc. Taiwan's largest company, Hon Hai Group, has a large manufacturing plant based in Shenzhen as well as Foxconn which manufactures iPhones and iPads is also present here. Many foreign high-tech companies have their China operations centres located in the Science and Technology Park of the Nanshan District in Shenzhen.

In 2017, Shenzhen's economic output exceeded $338 billion, surpassing that of Hong Kong for the first time and ranked No.3 in China, only behind Shanghai and Beijing.

Electric Bus Revolution of Shenzhen

Public transportation in Shenzhen is very well planned and efficient. Buses used to be operated by Shenzhen City Government owned Shenzhen Bus Group and several private operators. In 2007, the City Government decided to move from diesel buses to electric buses and electric taxis. First move was to consolidate the bus operators in to three companies:

1. ***Shenzhen Eastern Bus Company Ltd***: 16 private bus operators were integrated and made Shenzhen Eastern Bus Company Ltd which is fully owned by the Shenzhen City Government. Today they operate 5805 electric buses.

2. ***Shenzhen Bus Group***: This Company was owned by Shenzhen City Government. Today they operate 5600 electric buses.

3. ***Shenzhen Western Bus Company Ltd***: This is still privately owned and they operate about 4000+ electric buses.

ISGF visited Shenzhen Eastern Bus Company Ltd on 16th April 2018 along with senior officers from BYD. All the electric buses operating in Shenzhen Eastern Bus Company are BYD's buses. Majority of the buses in other two bus companies are also from BYD which is head quartered in Shenzhen. BYD has one of their lithium ion battery plant (18 GWh annual capacity) in Shenzhen.

The President, General Manager and CTO of Shenzhen Eastern Bus Company hosted ISGF at one of their bus depots which support about 700 electric buses.

Key points noted during the visit are captured here:

1. Electric buses are mostly 10.5 meter in length with seating capacity of 32 plus 20-30 passengers standing. At peak hours >80+ people board the buses in certain routes. All buses have similar specifications and bought from same manufacturer. This has greatly helped in better maintenance and optimization of spares parts and maintenance tools.
2. Buses have LFP battery of 252 kWh which ensure minimum 200 km driving range per full charge.
3. Buses are charged with BYD supplied 80kW (415 Volt) AC chargers installed in the bus depots. Shenzhen Eastern Bus Company has 86 Depots that support 5805 buses.
4. Buses are usually charged during night when electricity tariff is lowest. In Shenzhen City the industrial tariff for electricity is:
    a. Normal Tariff: RMB 0.7234/kWh (7- 9 hrs, 11.30-14 hrs, 16.30-19 hrs, 21-23 hrs)
    b. Peak Tariff: RMB 1.0759/kWh (9-11.30 hrs, 14-16.30 hrs and 19-21 hrs)
    c. Off-Peak Tariff: RMB 0.2794/kWh (23 to 07 hrs)

    Bus charging in the depots are classified under industrial tariff; and during the 8 hours of off-peak tariff (11pm to 07 am), all buses are fully charged. Charging time is 3 to 4 hours depending on the state of charge (SOC) of the bus when it returns to the depot.
5. Shenzhen Eastern Bus Company has about 2200 chargers which supports their 5805 buses. All these charges are installed in their bus depots.

6. Buses are maintained by the Bus Company themselves with technical support and training from BYD.
7. The Bus Company has entered in to Annual Maintenance Contract (AMC) with BYD for each batch of buses they purchased. Buses have 8 years warranty period. During warranty period, main parts including battery and motors, electronics are guaranteed and repairs/replacements done by BYD.

8. The Bus Companies have undertaken extensive training programs for their entire staff and retained thousands of workers who became redundant. Reskilling and redeployment was a key priority. There were no job losses. Today they all are proud of this transition to electric buses which are much more comfortable to drive and maintain.
9. Shenzhen Eastern Bus Company invested in developing new technologies, equipment and processes which are patented and received several national and international awards.

Some of the facilities and ISGF interaction with the team can be viewed in this video: https://goo.gl/sGuG9S.

Other key questions posed by ISGF and the answers provided by the Bus Company are given below:

1. ***What were the key drivers for the transition to electric buses?*:** Being established as a leader in IT and hi-tech industry and a global city, Shenzhen decided to transform to a Green City and to be a role model for other cities in China and overseas. Electrification of public transportation was central theme of this green city transition which they have very successfully achieved in ten years.
2. ***When was this policy adopted/decision taken? How many years it took to rollout 16000+ electric buses?*:** It was decided in 2007. Started integration of several private bus operators in two three large bus companies which was completed by 2009. Then started with extensive planning and first batch of electric buses were introduced in 2011. Large rollouts took place during 2015 to 2017. By Dec 2017 all buses (16359) were replaced with new electric buses.
3. ***Was it a City Government decision or a National Government decision to change all buses in Shenzhen to electric?*:** It was the decision of the City Government which was supported by Provincial and National Governments.
4. ***What was the fare per kilometer (RMB/km) with diesel buses before and now what is the fare/km for electric buses?:*** Bus fare in the city is regulated and fixed by the City Government. It is same for diesel buses and electric buses. No changes in the fare after full fleet was replaced with electric buses.
5. ***The electric buses have been purchased on Capex by the Bus Operator (s) OR leased from Bus Manufacturers/Third Parties?:*** New Buses were bought by the three Bus Companies

under capex model. Approximate cost per bus is RMB 2 million. Out of this RMB 0.5 million is given as grant by National Government and another RMB 0.5 million grant given by Shenzhen City Government.

6. ***What are the Bus Specifications - seating capacity, driving range, battery capacity etc?:*** Air conditioned electric buses of 10.5 meter length with 32 passenger seats + space for 20-30 people to stand (peak times up to 80 people commute); 252 kWh LFP battery; 200 km minimum driving range per full charge; GPS, air purifier and pollution monitor, automatic ticketing machines etc are in-built in the buses.
7. ***Who is responsible for Operation and Maintenance of the electric buses?*:** Bus Company is maintaining the buses with training and technical support from BYD.
8. ***What are the warranties from the Bus Manufacturers for both Bus as well as Batteries?*:** 8 years warranty during which all defective parts including batteries are replaced/repaired.
9. ***Who invested and created the charging infrastructure for buses? Bus Operators or Electricity Company?*:** Bus Company set up their own charging stations in the bus depots; it is maintained by them. Electricity Distribution Company supplies electricity to these depots. Charging stations are bought from the same bus manufacturer (BYD).
10. ***What is the electricity Tariff for Bus Charging? Is it a subsidized electricity tariff or regular commercial tariff?:*** Industrial tariff is applied for bus charging which is explained in the previous page.
11. ***What was the total investment in this transition to electric buses? Any subsidies by City Government or National Government on Capital Investment on buses and charging infrastructure or electricity tariff?*:** Almost 50% of the cost of the buses was given as subsidy from National and City Governments. The life of diesel buses were 8 years in Shenzhen and replacement of buses after 8 years is part of the business plan of the Bus Companies.
12. ***What is the improvement in air quality after elimination of diesel buses?*:** The air quality improved a lot, Shenzhen has became one of the best city with good air quality in China and always listed top ten for its good air quality.
13. ***Has introduction of electric buses increased shared mobility (meaning private car owners who used to drive earlier are now using electric buses)?*:** Over 5000 private car owners in the city have already moved to electric buses.
14. ***What were the significant challenges faced in the transition stages from Diesel Buses to Electric Buses?*:** Technology transition was the main challenge. Extensive training and re-skilling was undertaken in partnership with the bus manufacturer. Been conducting weekly training programs for different groups of employees for years.
15. ***Brief details of training and capacity building measures taken for skill development of Drivers and Maintenance Crew*:** Ready to share in future meetings/interactions.
16. *Brief details on the public outreach programs undertaken to get support from the general public for the electric bus program*: Public outreach program was undertaken by City Government and Bus Companies.

17. ***Lessons learned and recommendations to other cities embarking on introduction of electric buses:*** Shenzhen Eastern Bus Company is already helping other cities in China in the transition to electric buses; every week they host delegations from overseas. They are willing to help cities in India. Overall O&M cost reduced by 60-70%. First batch of buses bought in 2011 are still in good condition. So far only very few buses had battery issues that were attended by BYD.

Discussions of the meeting with senior management of the Shenzhen Eastern Bus Company is captured in the video here: https://goo.gl/NyVfrf .

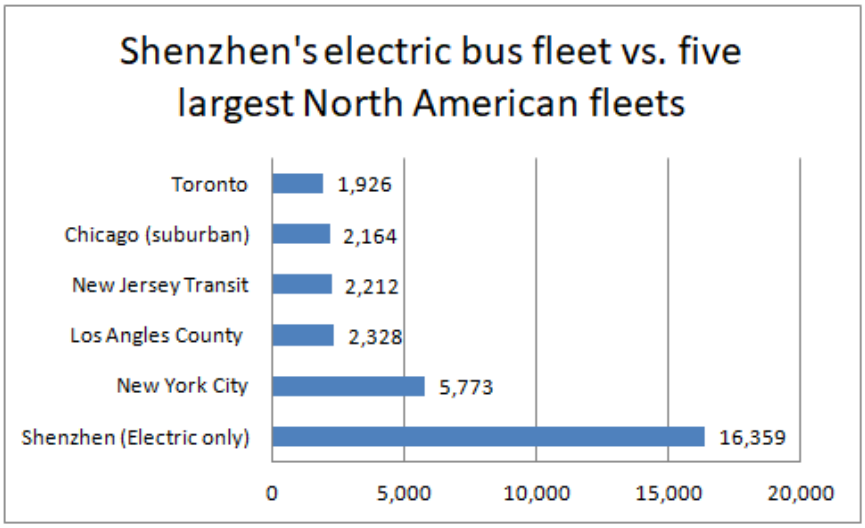
The video of the Shenzhen Eastern Bus Company describing the transition to Green City can be viewed here:
http://mail.qq.com/cgi-bin/ftnExs_download?k=69363935aee5d7f91d4aba261f6607180d015d530854055518535f040d4b01520d07140c0050071a0c5009575f5e5005000058073941357 56c7219724b0350591575565854134 15e5b511943500250581d0409040e560306071f17584952350a&t=exs_ftn_download&code=56959f57

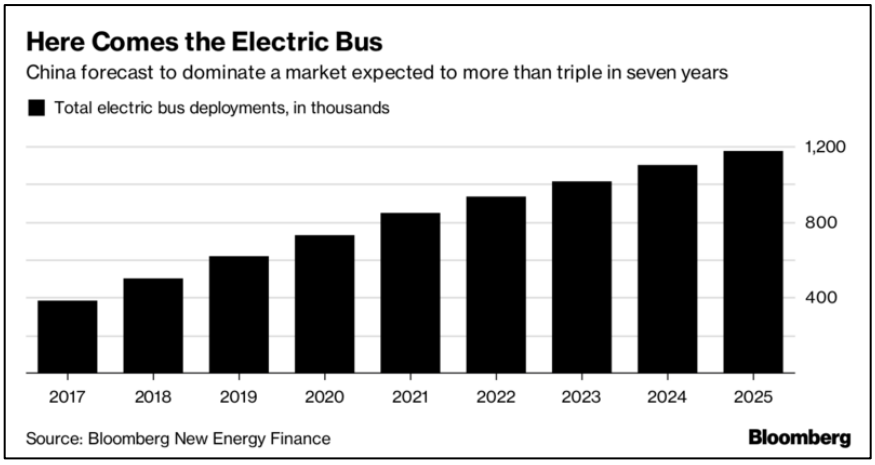
Key Recommendations for Bus Operators in India:

1. Detailed planning is required before mass roll out of electric buses.
2. Extensive training and re-skilling to be undertaken for the employees of bus operators.
3. Standardizing the bus specifications is very important – have one (or max two) type of buses from One Manufacturer in one bus transport company which will help in training, maintenance operations, spares and tools.
4. Send technical teams on study tours to large operators of electric buses in China for learning; and partner with them for experience sharing and knowledge transfer. Shenzhen Eastern Bus Company expressed interest in collaboration with bus operators in India.
5. It is pertinent to mention here that the highest temperature in Shenzhen is 32-33 degree Celsius in July-August and minimum temperature is 12-13 degrees during December-January months. Behaviour of the battery may be different in high temperature regions in northern India which require detailed studies of buses with different battery chemistries in cities with 40-45 degree Celsius temperature.

APPENDIX –A: Electric Bus statistics in China and rest of the world

Year	China Electric Bus Sales
2011	1136
2012	1904
2013	1672
2014	12,760
2015	94,260
2016	115,700
2017	89,546
TOTAL	**316,978**





Source Bloomberg

If Chicago, New York, New Jersey, Los Angles and Toronto electrify their entire bus fleet it will add up to 14460 only – still less than what Shenzhen already operates.

Total number of electric buses in the World at end of 2017 was 386,000 out of which 316,978 are in China (69,022 in rest of the world outside China). Per Bloomberg New Energy Finance (BNEF) report in February 2018, the total number of electric buses in the world is expected to triple to over 1.2 million by 2025.