Infrastructure and Resources for Transition to EVs As Main Mode of Transportation

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***Abstract*-India has taken a policy decision to move over to electric vehicles as the major mode of transportation in the country by the year 2030. This paper presents a review of the areas which the planning for introducing EVs on a large scale needs to cover. Specific aspects relating to the different areas like power generation, distribution, manufacturing, service, recycling, human resource training, financing is covered in brief. Possible initiatives to be taken bythe government to meet the planned objectives are also indicated.**

Keywords- Electric Vehicle, transportation, infrastructure, Internal Combustion

I. INTRODUCTION

Implementing the government's plan of making Electric Vehicles(EVs) as the main mode of transportation by the year 2030 seems increasingly feasible with the new technologies for supporting EVs becoming more commonly available. EVs to be a transport medium on a large scale, three major technologies which can be deployed effectively, deserve consideration. First is the technology for compact batteries with long expected life which can be carried on board the vehicle as energy carriers for an adequate range of kilometers per charge. The second notable technologies is the two renewable sources of energy- solar electric panels and wind mill systems which are now more economically viable [1]- [4]. The availability of high speed signal processors making compact motor controllers economical. One of the objectives of adopting EVs is to reduce the population caused by highly polluting IC engine based vehicles progressively and replace them with zero emission EVs. The related benefits will be i) better environment in the cities and resultant saving in health costs and ii) saving of precious foreign exchange by reduction of import of oil used for running IC engine vehicles [5].

Many countries have been successful in reducing dependence on oil to improve the environment and for reducing dependence on import of oil. India is presently heavily dependent on oil and 80 % of oil consumed is imported. Shift to EVs will minimize this dependence on oil to Avery great extent. Two-wheeler vehicles, cars, buses and rail trains on Indian roads can be EVs in future; however, the long-haul goods carriers or trucks, the Earth moving. The country like Denmark, Netherlands and Germany are examples of countries which have achieved notable success and reached a level of nearly 75 % of their energy requirements being met with means other than oil. equipment, the heavy Armed Forces vehicles, ships and commercial aircraft, in view of their very high-power rating, may have to continue to use oil or gas based fuels for quite sometime.

To meet this stated objective of the Indian government to introduce EVs as the main transport medium, a planned approach for implementation in different areas is called for [6], [7]. The more numbers of new electric power generating plants are required to be erected to meet the increased power demand from EVs. The increased power demand for charging of electric vehicles should ideally not be

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expected to be got from coal based thermal power generation plants, but some constructive efforts are required to achieve it progressively from renewable energy sources like solar electric power and wind mill driven generation. Distribution network and fast battery charging stations at multiple locations in cities, rural areas and along the highways are required to cater electric energy to EVs. It is required to install manufacturing plants for making battery assemblies on a mass scale. It is also required to build sources for supplying the raw material in large quantities for metals like Lithium, Copper and aluminum to support EV based industries. It is required to develop sources for supplying electronic control units and power electronics systems for fitment on electric vehicles as well as for battery charging. Reframing of technical education and training of manpower is required for supporting the activities of designing, assembling, testing and servicing the electric vehicles. Specific emphasis is to be given on education and research, for maximizing self-reliance in raw materials as well as in self manufacturing of electrical and electronics items for the industry. It is also required to take maximum efforts for increasing recycling and material recovery from old batteries and other items.

II. GENERATION OF ELECTRIC POWER FOR EVS

One major thrust area when EVs are sought to be introduced, is to provide adequate and reliable supply of electric energy for EVs through increased generation and reliable distribution. Power generation in India is mostly from thermal power plants using coal as fuel and only about 25 % of total generation at present is from Hydroelectric power, Nuclear power, Solar electric power and wind mill power. Dependence mainly on coal based thermal power plants as a main source of power in India would seem quite in order since coal is available abundantly in India. Coal based thermal power generation as a major source of electric power is expected to continue in India for a few decades to come, with the share from other renewable sources concurrently set to increase steadily. Solar powered plants and wind mill based power plants are becoming economically feasible with newer technologies and with expanding scales of production. However, the level of power generated by solar electric and wind mill sources tends to vary with the prevailing weather conditions like sunshine, cloud, wind speed etc., and the energy generated needs to be used up as it gets generated unlike in a coal based or a hydro

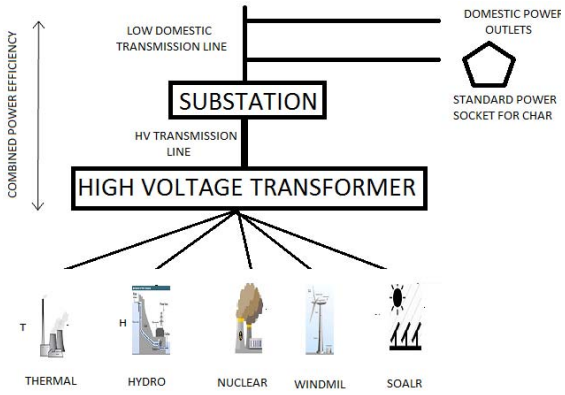

Fig 1 Sources of power for EVs

power plant where the level of generation can be controlled to match up to the demands by varying the input. Storing Solar or wind mill energy in batteries in a large scale is not only unwieldy but it is also not prudent economics-wise [8], [9]. Solar based power and wind mill based power will therefore act as only secondary sources of power feeding to the power grid but these sources will nevertheless help in reducing dependence on oil, gas or coal and in turn to reduce toxic emissions [10]. Fig 1 shows the sources of power for EVs as a first step in planning for providing adequate electric power, an approximate estimate of the power / energy needs for powering the EVs of all classes should be made. While seeking to work out a fairly accurate and representative estimate of the power demand for EVs some assumptions can be made. Some of them are (a) The population of EVs will only comprise two/ three wheelers, cars and buses (b) Growth of vehicle population will be sustained at the present rate.

Typical value of KW for EVs will range between about 3 to 100 as seen from Table 1.

Table No-1 Approximate Ratings for EVs:

Type of Vehicle	Power (kW)	Speed (RPM)	Torque (Nm)
Motor Cycle	3.3	3600	9.4
Car	52	4500	135
Bus	92	2400	400

The EV motor ratings here have been taken to be nearly the same as in a similar class of IC engine vehicle.

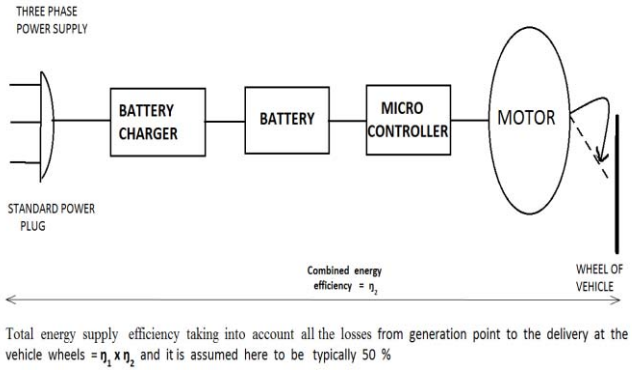

Fig 2 Basic power chain in EV

Estimate the power required to cater to the EVs the above KW ratings need to be combined with the efficiency of delivery of power from the generating stations up to the driven wheels of the vehicle. The power distribution losses, the AC to DC conversion and other losses in battery chargers, DC to AC inverter / motor controller losses and the losses in the motor are all combined to arrive at a figure of the overall energy efficiency. Based on the components of basic power flow chain in EV shown in Fig 2, a figure of 50 % could be taken as the approximate overall efficiency. While budgeting for installed power plant capacity other plausible assumptions will be i) that the vehicles will not need to run at the rated maximum power output level mall the time since maximum power is used only during acceleration and for climbing gradients and ii) not all vehicle batteries will be getting charged at the same time; some vehicles will also remain parked and be idle and therefore not be consuming any energy. Considering all these factors an overall usage factor of 10 % of maximum power as the actual consumption can be taken as a realistic figure. Power demand of different classes of vehicles estimated as Table 2.

Table 2 Rough estimate of power requirements for various electrically operated vehicles

	Current Population in Crores	Projected population in 2030in Crores	Estimated average power demand kW	Projected power requirement in 2030 at 10 % usage factor GW
Motor Cycles	10	25	6.6	150
Cars	2	3	100	300
Buses	0.2	0.3	184	55
Total power demand by EVs in 2030				505 GW

Thus, the total power requirement with consideration of consumption for EVs will be of the order of 505GW. The present installed power generation capacity in India by all means is only 330 GW. It can thus be seen that introduction of EVs in such a large scale by the year 2030 will require rapid increase in power supply infrastructure by close to 200 % of the present installed capacity. Increasing generation capacity therefore requires maximum attention while planning for the transition to EVs. In reality due to sheer paucity of space on the road and lack of parking areas the overall population of the vehicles may not rise as much. But this is unpredictable.

At present two wheelers are also a kind of life-line for the middle and lower middle-class people. Any draconian measure towards reducing pollution in cities like banning IC engine vehicles and replacing them with EVs will affect not only ~~on~~ the car owners but also the lower classes seriously. In this aspect, the planning for replacement of IC engine vehicles with EVs necessarily has to be at a measured pace and cover all the classes of vehicles and more importantly the two wheelers in a focused way without causing much disruption in the day to day life of people. The power supply for EVs must be made available easily, locally and reliably for all vehicle users.

Power generation in India will continue to come mainly from coal based thermal power plants for some years since India has operated coal deposits of the order of 300 billion metric tons and lignite deposits of 45 billion tons and the coal reserves will help support the extra power required for EVs. However, coal based power plants also have toxic emissions and increased power generation to supply EVs will also mean increased overall emissions from the coal based power plants and technologies like "clean coal technology" for power plants have to be introduced to offset the effect of pollution due to increase in the number of coal based thermal power plants. Clean coal, technology significantly minimizes the emissions of Sulphur dioxide (SO_2) and Nitrogen oxide (NO_x) from the power generating plants. Increasing coal based power plant capacity requires the corresponding related infrastructure development to be stepped up on a large scale in other areas like coal mining, clean coal technology, thermal power plants, and transmission and distribution networks.

The evident improvement with regard to environmental pollution will be seen in cities when the IC engine vehicles in cities are progressively eliminated and replaced by zero emission EVs. The share solar electric generation plants and windmill

generation units will also further help in the reduction of pollution levels.

III. SCENARIO OF RENEWABLE AND NON-RENEWABLE SOURCES OF ENERGY

India has been installing power plants using indigenous technology for coal based super thermal power stations using mostly indigenously mined coal. Increasing the capacity of coal based thermal power to cater to EVs is thus a case of scaling up the mining capacity to assure continuous reliable supply of coal. The thermal power plant equipment like boilers, water cooling systems, generators, transformers, transmission lines and towers etc. are already being made in India now. The manufacturing capacity for these items has to be expanded to match the expected increase in power plant capacity. It is inevitable that some parts of plants and raw materials may need to be imported to fill up the gaps that may arise in source capacity and this aspect should be also part of the capacity planning.

Nuclear power technology has been quite well absorbed in India and scaling up to higher levels is possible if the socio - political angles are well taken care of, the human safety concerns are well addressed and continued supply of nuclear fuels is assured. Solar electric panels and wind mill generators are imported and also partly made in India. The scale of production of these also has to be stepped up to meet the increasing electric power demand.

As indicated earlier the power plant capacity for providing electric power for EVs will be of the order of 505GWs. Table 3 gives the proposed estimates for capacity distribution, land requirements and capital investment to produce this additional power. The planning for capacity enhancement should be geared correspondingly.

Table 3 Proposed estimates for generating additional power for EVs

Type of power station	Capacity proposed	Land requirement in hectares	Capital investment required Rs
Coal	300GW	90000	35 lakh crores
Nuclear	45GW	2250	3 lakh crores
Solar	100GW	100000	9 lakh crores
Wind	60GW	57000	4 lakh crores

Installation of such large sizes of plants requires large of tracts lands which should be normally not usable for other productive purposes like agriculture. Such large-scale infrastructure development also involves huge expenditures on capital costs and as per the above estimate it comes to about Rupees 51 lakh crores spanning the years till 2030. There will be costs in addition to these to cover the installation of power distribution lines, transmission towers and substations which may add approximately 40 % to the cost of power stations. There will also be costs for human resources and technology development to support EVs and all these will need to be budgeted and the finance has to be adequately planned for. The rough estimates of land requirement and finances are indicated here to give an overall perspective and this data could be a basis for getting more precise data for detailed planning to move towards the objectives.

The running costs of the power plants other than the solar power plants and windmill power plants will be mainly the cost of fuel and water. The running costs will be partially offset by the savings in imported oil cost when the IC engine based vehicles are replaced by EVs.

The location of the power plants will depend i) on the logistics of fuel delivery and of safety in the case of Coal based and Nuclear power plants and ii) on the availability of shadow less sunshine areas for solar power plants and iii) wind rich areas for windmill power plants.

It cannot have denied that in the present situation, in India non-renewable generation has a higher percentage of generation in comparison to generation from renewable energy sources. The generation of electrical energy in non-renewable category is mainly from coal based thermal power plants and nuclear power plants. But there are some issues with generation from these sources. The issues of coal based thermal power plants are greenhouse gas emission, mining destructions, generation of millions of tons of waste, emission of harmful substances and the issues of nuclear power plants are nuclear radiation accidents, disposal of radioactive waste, requirement of high initial capital and fuel availability. So, looking at the drawbacks of these two types power plants, in coming years, it is very essential to increase generation from renewable energy sources and to progressively reduce generation from non-renewable energy sources for the following reasons, i) improved public health and environment quality, ii) inexhaustible energy supply, iii) little to no global warming emissions, and iv) a more durable and resilient energy system.

V. DISTRIBUTION AND DELIVERY OF ELECTRICAL POWER TO EVS

The generation of Electricity will be normally in locations remote from cities and highways. Making supply available conveniently to the public can be realized through a distribution network to ensure reliable 24 X 7 power supply for charging EVs; just similar to the case of the existing power supply networks for Electric locomotives used in Railways for reliably supplying the power 24X7 to a large number of Electric trains distributed over wide geographical regions of the country. New transmission lines and distributors will have to be placed along with highways and rail tracks to reduce the initial investment.

The EV power grid could have the power supplied from generators using any of the energy sources- Coal, Hydro, gas, oil, nuclear, solar panels or windmills. In addition, individual charging stations could themselves have smaller solar panels and / or wind mills installed locally which are connected to the mains supply lines from the local substations so that the net demand or load on the main supply grid can be minimized.

Electric vehicles usually are provided with an industry standard connector interface to charge the batteries from the domestic power supply points. The level and the rate of charging from domestic power outlet points will be limited to prevent local substations from getting over burdened with increased load in the nights. It is the experience in other countries that overnight charging at homes at a typical limit level of 15 amps over the night is adequate to pack enough energy in the batteries for normal range of distances the vehicle is needed to run over a day on an average. Roadside battery charging for catering to a large population of cars is an important need from a user point of view just like the location of many present-day fuel filling stations and to meet this need, separate energy distribution and delivery networks may have to be structured adequately. Figure 3, shows the grid support for the EV with renewable energy source.

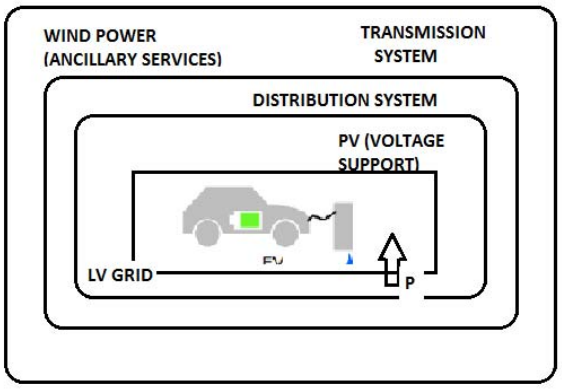

Fig 3 EV grid support structure

VI. MANUFACTURING, INFRASTRUCTURE AND HUMAN RESOURCES

Apart from the power infrastructure, the scale of the overall industry effort to introduce EVs is also huge. To meet this requirement, the experienced technical human resources and manufacturing capacity already available have to be leveraged and the installed capacities of the different industries both in the public and private sectors need to be expanded rapidly. The government budgetary allocations should include the areas of capacity enhancement and know- how development. Manufacturing infrastructure and capacity development should mainly cover the areas such as coal industry products, solar and wind energy related products, batteries, motors and controllers etc. Expansion in the usage of EVs will progressively result in underutilization or total non-utilization of existing capacities for manufacture of items for IC engine based vehicles. While planning for creation of new infrastructure for introducing EVs, the opportunities for re-engineering the available facilities to support EV based industries should be explored as part of planning. An example of this kind of revamping exercise is that of the original Toyota plant in California, USA which was acquired, modified and refurbished for making Tesla electric cars. The manufacturing units making engines can be re-engineered to make motors for EVs and wind mill turbines for wind mill power generators. Obviously, the re-engineering of manufacturing shops will require funds and the government should plan for this and provide adequate financial assistance and subsidies for the purpose.

Such large-scale efforts to change from IC engine based vehicles to EVs will throw up a lot of materials, equipment and machinery as obsolete and disposable. The possible waste materials are as shown in Table 3. Creating infrastructure for recycling of such obsolete material in large quantities is a very valuable industry initiative to save import costs in the long run. Recycling industries also have the potential to create employment opportunities in a big way and there should be right incentives from the government for such industries.

Table 3 Recycling items

Sr No.	Items for recycling	Type of waste
1	IC Engine parts	Mainly metals
2	Batteries	Lead/ carbon based material
3	Rubber/ Plastic parts of ICE based vehicles	Plastic/rubber material
4	Electronic and electrical parts	Obsolete materials

Shifting to EV based transportation from the ICE based vehicles induces changes in the required technical knowhow for vehicle engineering design, manufacturing and servicing. The new areas would entail fresh training of existing experienced manpower, changes in syllabus contents of courses and programmers in terms of technical education, re-orientation of training and skills development to support the new technology. Efforts in Research and Development should be directed towards increasing the level of indigenization of components and raw materials used in solar panels, wind mill power, batteries, motors and electronic controllers.

VII. CONCLUSIONS

Many developed and developing countries are shifting from oil based mode of transport to electrically operated mode of transport. India has set deadline as 2030. Last decade has seen rapid growth in wireless communications technology. EV technology may be game changer in the next decade. To usher in the envisaged change to EVs on a large scale, a planned strategy covering Power generation and distribution, land acquisition, raw materials, manufacturing capacity enhancement including re-engineering existing infrastructure, recycling plants, human resource development, research and development and steady flow finance is called for. Change is required from individual to institute level. Authors have tried to identify the changes which are expected to come about in the electrical energy sector, i.e. in generation, transmissions & distribution, materials and manufacturing, human resource development, technological issues, servicing of vehicles, battery charging stations and Priorities need to be changed from common man to bureaucrats to policy makers. Adoption to EVs will have huge impact on the environment.

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