International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 2 (2018), pp. 219-241

http://www.irphouse.com

Charging electrical vehicles on the Indian power grid: Analysis, challenges, and solutions

K L Mokariya[a,*], Dr V.A.Shah[b], Dr N.P. Patidar[c]

[a] *Department of Electrical Engineering S.V.N.I.T,Gujarat, India*

[b] *Department of Electrical Engineering S.V.N.I.T,Gujarat,India*

[c] *Department of Electrical Engineering,MANIT,Bhopal,India*

Abstract

Electrical vehicles (EVs) are a promising technology for reducing greenhouse gas emissions and other environmental impacts of road transport. India's future energy security is threatened by increasing oil prices and high import costs. The availability of charging power and charging infrastructure is one of the key reasons for the widespread adoption of EVs. Considering that up to 50% of vehicles are charged from supply mains, the amount of power required was analysed. Whether the Indian power grid is sufficiently capable of delivering the required charging power and fulfilling the Indian government's goal of increasing the use of EVs requires investigation. Energy losses were measured in 255 villages in Gujarat, India, and solutions were suggested as well as implemented to overcome these losses. The experimental test setup of a centrifugal pump was developed and implemented in villages and industry by using variable frequency drive, programmable logic controllers, and a supervisory control and data acquisition system with a cost-effective paddle-wheel flow meter. Similar energy-efficiency improvement scopes were determined and implemented in all the villages under study. Finally, challenges and barriers to the growth of electric vehicles in India with concrete solutions is suggested by authors with policy improvements needed is mentioned clearly.

Keywords: Mobility- mission, EV, PLC, SCADA, Energy conservation, Energy policy

Abbreviations

GHG: Greenhouse emisions
NEMMP: Nations Electric Mobility Mission Plan
LCV: Light commercial vehicle
BEV: Battery-operated EV
FAME: Faster adoption and manufacturing of EV
PEV: Plug-in EV
SOC: State of charge
AMI: Advanced metring infrastructure
SHP: Small hydro power plant
V2G: Vehicle-to-grid
PLC: Programmable logic controllers
SCADA: Supervisory control and data acquisition system
VFD: Variable frequency drive
HMI: Human machine interface
RTU: Remote terminal unit
BEP: Best efficiency point
PID: Proportional-integral-derivative control
ICS: Industrial control system
LED: Light-emitting diode
CFL: Compact fluorescent lamp
CDM: Clean development mechanism
OCPP: Open charge point protocol
EVSE: EV supply equipment
EV: Electrical vehicle

1. INTRODUCTION

The Indian automobile industry is growing rapidly. The demand for two-wheeler, commercial, and passenger vehicles is expected to become 34, 2.7, and 10 million vehicles per year, respectively, by 2020; thus India is the third largest vehicle market in the world. The increase in the number of vehicles will increase the demand for fossil fuels and adversely affect the environment (Nations Electric Mobility Mission Plan [NEMMP] India-2020, 2012).The Indian automotive industry has seen considerable growth because of economic liberalisation in the past two decades (Automotive Mission Plan India, 2016). As per international energy agency statistics, the transportation sector accounts for 30% of the global energy consumption and is the second largest source of CO_2 emissions, contributing 20% of global greenhouse gas (GHG) emission. Large quantities of oil need to be imported to meet energy needs in India. For economic development and GHG reduction, overcoming the problems associated with conventional vehicles is necessary. National energy security and growth of domestic manufacturing capabilities is the main objective of NEMMP 2020. According to an estimate of the NEMMP NEMMP India 2020 (2012) and CII market survey (2015), India’s objective is to deploy 400,000 passenger BEVs by 2020 for meeting a benchmark value to avoid the import of 120 million barrels of oil and emission of 4 million tonnes of CO_2 by 2020.

India’s oil imports are likely to reach 92% of the total demand by 2020 (CII market survey, 2015). This dependency and the increasing prices of oil possess serious threats to India’s future energy security. According to NEMMP India-2020 (2012), developing technologies that eliminate the adverse effects of conventional automotive technology is crucial for economic development in India. Concern regarding the environment is increasing globally, and pollution has become a major concern in India. India is the fourth largest consumer of energy in the world. Most energy requirements are met by crude oil and coal. However, these conventional sources of energy contribute to the high level of pollution in most Indian cities. The transport sector accounts for nearly 18% of the total energy consumed in India, and it is a major source of CO_2 emission in the country. According to India transport report prediction 2032 (2014), without corrective or remedial measures, the overall transport CO_2 emissions can reach 1000 MT by 2030. Therefore, both the central and state governments are now developing strategies to encourage the use of alternative energy sources. The EV segment is a thrust area for growth; hence, the Government of India is planning to make India 100% EV by 2030.If country has to overcome some obstacles for rapid adoption of electric mobility, namely the availability of required charging power, required infrastructure for charging, high cost of acquisition, existing vehicle battery technology challenges (price, range, and performance), acceptance by consumers, performance standards of EVs compared with conventional vehicles with internal combustion engines (e.g., range, speed, and acceleration), and lack of research and development in the country.

According to Executive summary power sector India, 2016, Load generation balance report India 2016 and Energy statistics India (2016), India's installed capacity as on August 2016 is 305.5 GW of which thermal power and renewable energy account is 212.5 GW (69%) and 44 GW (14.47%), respectively. Globally, India ranks ninth in terms of economic development. The country faces an energy deficit of 11% and a peak load deficit of 14%. The per capital energy consumption is 820 kWh, and more than 300 million homes remain unelectrified. The government aims to reduce transmission and distribution losses in the power sector from 22% to 15% by 2019 (Thakur and Chakrabarty, 2015). Energy consumption definetly results in economical growth (Shahbaz and Vanhoang, 2017). However, at present, generated power does not meet the demand in many parts of the country. Moreover, high transmission and distribution losses indicate that energy conservation practices should be adopted on a large scale for widespread EV use (EV penetration) in the country. Therefore, to boost the use of EVs on a large scale, generation capacity should be increased; however, this is not viable at present. Enhancing India's power generation capacity by using nonconventional energy sources, particularly using solar power to charge vehicles in the future, converting the existing power grid into a smart grid with smart meters, and improving infrastructure availability are few other options that can be explored. However, for an immediate effect, energy conservation is the most suitable solution because people in many parts of India are still not familiar with energy-efficient devices and energy conservation practices. If the challenges to the adoption and establishment of EVs in India are overcome, the automobile industry can provide employment to numerous people in future under the concept of Make-in-India. The government has started taking concrete steps in this direction as under the faster adoption and manufacturing of hybrid and EV (FAME) India scheme. The department of heavy industries has extended demand incentives at Rs. 127.77 crore for the purchase of 1,11,897 electric and hybrid EVs until February 2017. The period for implementation of the FAME India scheme is 6 years (till 2020). A report released by the government states that the country would become as a 100% EV (all-EV) nation by 2030 under a new financial scheme. Moreover, India is working on a new scheme to offer the all-electric cars with zero down payments to prevent expenditure on costly fossil fuels.

EV penetration can provide significant advantages to supply and demand-side authorities. Significant EV penetration will result in a high plant load factor and it will avoid losses due to improper renewable power evacuation. An increase in EV penetration will result in a high demand for batteries and eventually reduce the storage cost for consumers. However, an increase in EV penetration will also increase the building infrastructure requirements (Kumar and Dash, 2013). In India, which is a developing country, meeting infrastructure requirements for charging EVs is currently a major part of the effort for meeting energy demands.

An increase in the peak load due to EV charging significantly affects the existing power distribution system (Li and Tao, 2011) Penetration of EVs will also cause concerns regarding the effects on the transmission and distribution system (Clement and Hense, 2010; Copes and Soares, 2011; Dyke and Schofield, 2010; Fernandez and Roman, 2011; Melipoulos and Meisel, 2008). Current harmonics produced due to charging stations can cause abnormal operation in transformers, such as additional losses, reduced efficiency, temperature rise, and premature insulation and winding failure, and these abnormalities effect the reliability, security, efficiency, and economy of newly developing smart grids owing to possible transformer outages and loss of transformer life (Schneider and Gerkensmeyer, 2008; Yousuf and Kumar, 2011). The battery chargers for PEVs have high ratings and use nonlinear switching devices; the use of these chargers may result in the injection of high harmonic currents into the distribution system (Dyke and Schofield, 2010). Derating of transformers will become necessary due to harmonic losses generated by nonsinusoidal load currents (Schneider and Gerkensmeyer, 2008). To achieve efficient grid charging, the charging processes must be properly coordinated so that PEVs with higher ‘charging pressure’ (equivalently, lower SOC) can be charged first (Li and Tao, 2011). Smart-meter technology will play a key role in coordinated charging (Yousuf and Kumar, 2011). The advance metring infrastructure (AMI) architecture is for two-way communication between a utility company and a smart utility meter with an IP address. Real time data of power consumption are provided by the AMI, and it plays a key role in the functioning of the smart grid. Smart metring will create opportunities to run PHEVs with a controllable load (David hart et al., 2008; David and Stephanie, 2013; Richard Brown et al., 2008) to apply vehicle-to-grid (V2G) and to combine PHEVs and renewable energy in the network.

The investigation is required to determine whether the grid is feasible to overcome the challenges of EV penetration and to assess the economic benefits over conventional vehicles. Therefore, in this context, we determined the amount of charging power required if up to 50% total vehicles (cars, two wheelers, and three wheelers) are charged from the supply mains. A detailed analysis of the current power grid scenario, according to region, suggests that in some of the regions in India, the generation does not match the demand. Vehicle batteries should be charged during the off-peak period, and they should deliver power to the grid during the peak period. Annual load profiles were analysed from which off-peak periods for penetrating EVs can be determined. Energy conservation techniques should be adopted for enhancing energy security with penetration of EVs. Under the Vishvakarma yojna for rural electrification, energy losses were measured in some villages in Gujarat, and solutions were provided to mitigating the losses; moreover, the corresponding reports were submitted to authorities. Design and implementation of the variable frequency drive (VFD) discussed in this study and other energy-efficient devices have been implemented in the villages and industries (in this study) to reduce the energy deficit by a considerable amount and absorb a substantial number of vehicles in India.

This study is divided into the following four sections:

1. Assessment of charging power requirement from the grid while charging 50% of available vehicles in 2016.
2. Assessment of energy and power demand in the Indian context with load pattern study for determining off-peak periods for EV penetration.
3. Concrete steps implemented for energy conservation in villages and industry (presented as case studies) and enhancing EV penetration.
4. Challenges and barriers to the growth of EVs in India with probable solutions.

Many regions of the country are still facing power deficit, and most of the power generation is still from coal and oil. Hence, mass penetration of EV requires alternative options such as increasing power generation, utilisation of nonconventional energy sources, coordinated charging with present grid conditions, and implementing energy conservation practices. India primarily depends on coal and oil-based power generation and requires imported fuel for power generation. Hence, increasing power generation by using oil and coal-based fuels is not a feasible solution considering the global warming and economic effects of running these power plants. Solar energy can be a solution because India is targeting 100 GW solar installation capacity by 2019. However, at present, considering the payback period of solar technology, this is not an immediate solution. Because transmission and distribution losses play major role in power sector and very little care is taken in villages for conserving energy as people are not as much used to the energy-efficient technologies as comparing the population of the country and hence principles of energy conservation is the best option at the moment for conserving energy and penetrating more number of vehicles in India. We focused on energy conservation in industry and villages, and the conserved energy can be used for running vehicles. For energy conservation, VFDs with programmable logic controllers (PLCs) and a supervisory control and data acquisition (SCADA) system were implemented using a low-cost and effective paddle-wheel-type flow meter. The test setup was developed, made completely functional, and installed at numerous places. The saved energy can be used to increase the penetration of EVs in India.

Furthermore, energy-efficient lighting for houses and streets was installed in the villages, and power factor improvement was achieved using automatic power factor controllers. Similarly, other effective energy conservation practices were also implemented in villages and industries, and energy-efficient technologies were suggested and implemented in the villages. Finally, concrete suggestions for overcoming obstacles in the progress of EV development in the country were provided.Our results support the penetration of EVs into the grid.

2. CHARGING POWER ASSESSMENT OF EVs IN INDIA

2.1. Total number of vehicles in India

Table 1 (Automotive mission plan India, 2016) presents the total number of vehicles sold in India each year according to the Society of Indian Automobile Manufacturers data for the past five years.

Table 1. Total number of vehicles in India

Category (Vehicles)	2011–12	2012–13	2013–14	2014–15	2015–16
Passenger	2629839	2665015	2503509	2601236	2789678
Commercial	809499	793211	632851	614948	685704
Three-wheeler	513281	538290	480085	532626	538092
Two-wheeler	13409150	13797185	14806778	15975761	16455911
Total	17361769	17793701	18423223	19724371	20469385

As shown in Table 1, 20469385 vehicles were sold in India in 2016. Investigation and analysis were performed for determining the fuel saving and kWh capacity required when 5%, 10%, 15%, 20%, and 50% of the available vehicles in the country in 2016 were considered as EVs.

2.2. Energy required for EV penetration into the grid

Table 2 shows W-h capacity of EVs.

TABLE 2. EV W-h capacity

Light commercial vehicles (LVCs)	Two wheelers	Three wheelers
250 W-h/km	37 W-h/km	135 W-h/km

2.3. LCV energy calculations

The following assumptions were made while evaluating the power (kW-h) required from the Indian power grid:

1. LCVs constituted 10% of the available commercial vehicles in 2015–16.
2. Commercial vehicles ran 40 km/day.
3. The energy consumption (W-h/km) of 10% of the commercial vehicles can be used to calculate yearly energy consumption.

Similar calculations were used to determine the yearly energy consumption of two and three-wheeler vehicles travelling 16 and 80 km/day (Table 3).

Table 3. EV energy consumption (kW-h)

LCVs	Two wheelers	Three wheelers	Total
250281960	355579325	212115866	817977151

If the cost of electricity is considered Rs 6/unit, the total cost is Rs 4907862906.

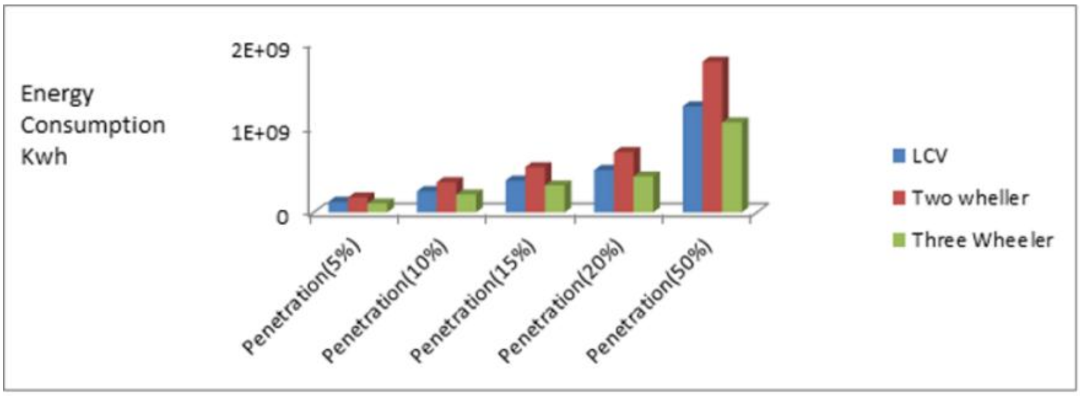


Figure 1. Energy required for EVs charging from supply mains.

Figure 1 depicts the charging power required per year when up to 50% of vehicles are considered EVs. It indicates that a large amount of charging power will be required to achieve the objective set for 2020. Energy conservation is more applicable than other long-term strategies as an immediate solution for widespread EV use.

3. INDIAN POWER GRID SCENARIO

The existing conditions and load pattern of the Indian power grid were carefully studied for EV penetration analysis.

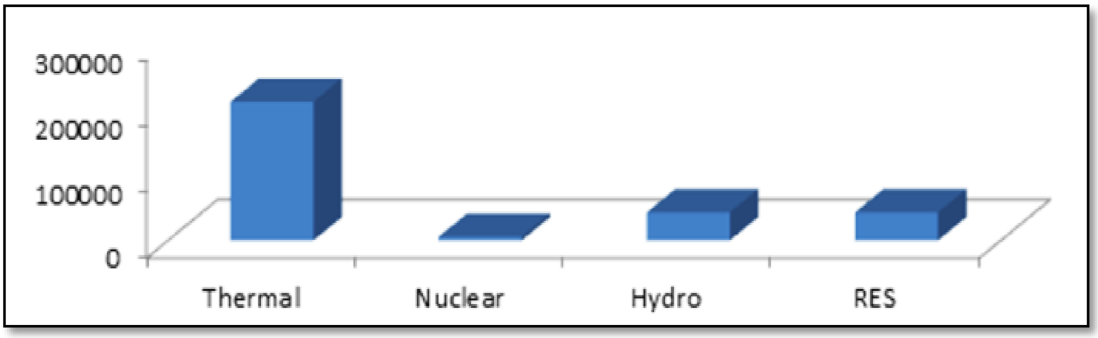


Figure 2. A graphical representation of installed capacity of India as on 31 March 2016.

Figure 2 (Energy statistics India, 2016) shows that thermal-based generation is dominant. Renewable energy sources (RES) are expected to increase in near future.The installed capacity of India in MW according to region as on March 2016 is shown in Table 4 (Executive summary power sector India, 2016).

Table 4. Region-wise distribution of installed capacity (MW) as on 31 March 2016

Region	Thermal				Nuclear	Hydro	RES	Grand Total
	Coal	Gas	Diesel	Total				
Northern	45644.50	5331.26	0.00	50975.76	1620	18246.77	8630.13	79472.66
Western	72153.01	10815.41	0.00	82968.42	1840	7447.50	15314.9	107570.84
Southern	36442.50	6473.66	917.48	43833.64	2320	11558.03	18154.12	75865.79
Eastern	30622.87	190	0.00	30812.87	0.00	4289.12	475.39	35577.38
Northeast	310	1698.30	36.00	2044.33	0.00	1242.00	263.72	3550.02
Islands	0.00	0.00	40.05	40.05	0.00	0.00	11.10	51.15
All India	185172.88	24508.63	993.53	210675.04	5780	42783.42	42849.38	302087.84

Table 5 (Executive summary power sector India,2016) shows details of region-wise demand of power, availability, and shortage in the year 2015–16. From the details, it can be seen that many regions of the country are facing power deficit. The energy shortage varied from 0.2% in the western region to 5.2% in the north-eastern region.

Table 5. Region wise power demand in 2016

Region	Energy				Peak			
	Requirement	Availability	Surplus/Deficit		Demand	Met	Surplus/Deficit	
	MU	MU	MU	%	(MW)	(MW)	(MW)	(%)
Northern	340475	324009	−16466	−4.8	54474	50622	−3852	−7.0
Western	346767	345967	−800	−0.2	48640	48199	−441	−0.9
Southern	288025	283494	−4531	−1.6	40030	39875	−155	−0.4
Eastern	124653	123646	−1007	−0.8	18169	18056	−113	−0.6
North-Eastern	14488	13735	−753	−5.2	2573	2367	−206	−8.0
All India	1114408	1090851	−23557	−2.11	163886	159119	−4767	−2.91

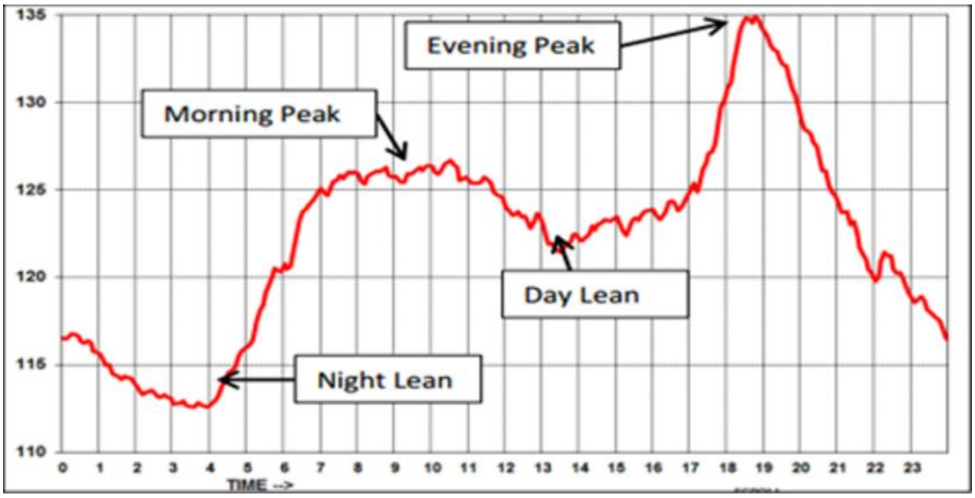


Figure 3. Daily load curve.

Typical load curve of India is shown in Figure 3 (Load factor in Indian power system 2016). A typical load curve has four important cardinal points, namely night lean, morning peak, day lean or afternoon trough, and evening peak. After sunrise, with the switching on of electrical appliances, the domestic load increases gradually. As the day progresses, commercial/office load increases and the domestic load reduced. After sunset, the overall lighting load increases again, thus causing the evening peak. During this time commercial/office load also starts decreasing. Thereafter, the domestic load also starts decreasing and reaches a minimum level at night. The typical load curve can be changed by human interventions such as load shedding, demand management, chipping the hills, and filling the valleys of the load curve. Once the off-peak and peak load periods are identified, periods of EV penetration can be identified, which will not overload the power grid. From the load curve, the number of vehicles that a distribution company can allow for charging for a specific period of time that can also be identified. The contribution of renewable energy to the total energy generation in India is extremely small; hence, India must adopt energy conservation techniques.Despite upcoming new generation and transmission projects, in the context of EV penetration, energy conservation is necessary to compensate the energy deficit. Sincere efforts are required to reduce the gap between supply and demand.

4. SOLUTION TO ACCELERATE EV PENETRATION ON INDIAN ROADS BY IMPLEMENTING ENERGY CONSERVATION

Many regions of the country are facing energy deficits and the major part of energy generation is still obtained using coal and oil-based methods, hence, for mass penetration of EV alternative options for increasing power generation, such as use of nonconventional energy sources, coordinated charging with present grid conditions, and implementing energy conservation, are necessary. Under FAME, India's government has sanctioned Rs. 795 crores (123 million USD) for developing and testing necessary infrastructure and for pilot projects for EV technology development; however, the availability of charging power is a major problem and requires an immediate solution for mass EV penetration. Solar power is an emerging technology for EVs. As per the Jawaharlal Nehru Solar Mission, India is targeting 20000 MW of grid connected solar power by 2022. However, as an immediate and effective solution, energy conservation practices must be implemented in villages, cities, industries, schools, and offices.We worked on a project under the Vishwakarma yojna for rural electrification in 255 villages in Gujarat. Under this project, opportunities for energy conservation were identified and energy-efficient devices were implemented. Apart from the energy conservation opportunities, this scheme also focuses on providing physical and social infrastructure in the villages and implementing renewable energy technologies in the villages, thereby improving the living standards of the rural population. The test setup was developed for energy conservation by using a VFD for a centrifugal pump; the setup was used both in the industry as well as in the villages.

4.1. Energy conservation by using a VFD for centrifugal pump

The total electrical energy usage in industrial facilities and electric motors is approximately 25%–50%. Pumping systems account for nearly 20% of the total energy used worldwide. Significant opportunities exist to reduce pumping system energy consumption through smart design, retrofitting, and operating practices (Gaudani et al., 2015; Radgen and Munchen, 2005). The application of variable duty has potential to enable energy conservation, improve performance, and to reduce life cycle cost. With the increase in energy demand, the energy efficiency of pump drives is also gaining importance. When a pump's speed is reduced, less energy is provided to the fluid; consequently, less energy needs to be throttled or bypassed. The speed can be controlled in numerous ways. The most popular type of variable speed drive is the device that comprises a centrifugal pump, an induction motor, and a frequency converter, which allows speed control of the pump drive (Gaudani et al., 2015). In many cases, varying the speed is the most energy-efficient flow control method (Radgen and Munchen, 2005).

4.2. Centrifugal pump flow control comparison of a VFD and throttling device

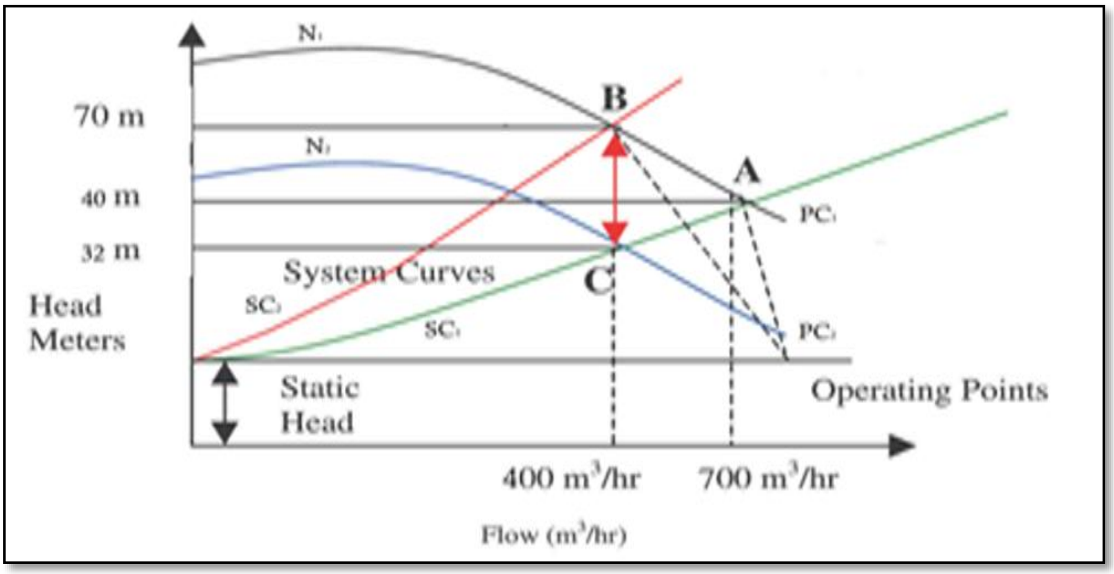


Figure 4. Comparison of flow control by using a VFD and a throttling valve

Suppose consider a system with a system curve represented in Figure 4 (Gaudani et al., 2015) by line SC1. The pump curve is line PC1 which intersects system curve at operating point A, where the flow rate is 700 m^3/h and the head is 40 m. However, the actual requirement of flow is 400 m^3/h. Hence, the flow rate can be reduced by closing the throttle valve, which inserts an artificial resistance to the system; consequently, the system curve is rises above the first one (in terms of head). The new operating point becomes B at which the desired flow rate 400 m^3/h is achieved but at a relatively high head. Therefore, the pump has to overcome additional head (BC); and pump consumes more electrical power than it did at a flow rate of 700 m^3/h. Thus, the use of a throttling valve is not an energy-efficient method (Gaudani et al., 2015) to control flow rates.

Another option is to reduce the speed from N1 to N2; thus, the pump curve shifts below the first and intersects the original system curve at point C, which is the best efficiency point for the pump, where the desired flow and head as well as overall efficiency are achieved.

4.3. System configuration

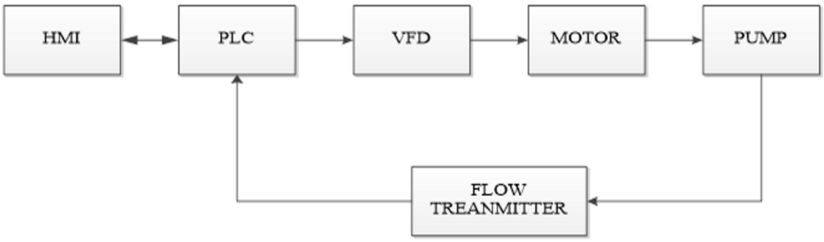


Figure 5. Components of a VFD.

System Configuration of the proposed scheme is shown in Figure 5. It contains HMI/SCADA, PLC, VFD, motor, centrifugal pump, and flow transmitter. SCADA is a centralised system that can monitor and control sites or complexes of systems spread over large areas. Most control actions are performed automatically by Remote Terminal Units (RTUs) or by PLCs. VFDs or ideally variable voltage and VFDs are extremely useful for centrifugal pump application because they provide maximum energy conservation when the speed changes according to the demand for flow. A VFD comprises a rectifier, DC bus, and a three-phase voltage source inverter that uses a carrier-based sinusoidal pulse-width modulation technique. Squirrel cage induction motors are used as they are robust and give highly precise speed control. In the proposed system, a paddle-wheel flow meter, with a sensor and a transmitter to sense the flow rate of the centrifugal pump, was used. The PLC received a signal, which is of 0–20 mA, from the flow transmitter. This signal was converted into 0–32000 count and sent to the PLC. A reference input is given from the SCADA system according to the flow requirement. An error signal was produced by the PID controller, which was finally converted into 0–10 V and sent to an inverter. In the inverter, the reference signal was compared with a carrier signal to produced required gate pulses.

4.4. Specification for proposed test setup

The proposed test setup is shown in Figure 6, which shows a centrifugal pump, motor, VFD, and PLC. The specifications of components are listed in Table 6.

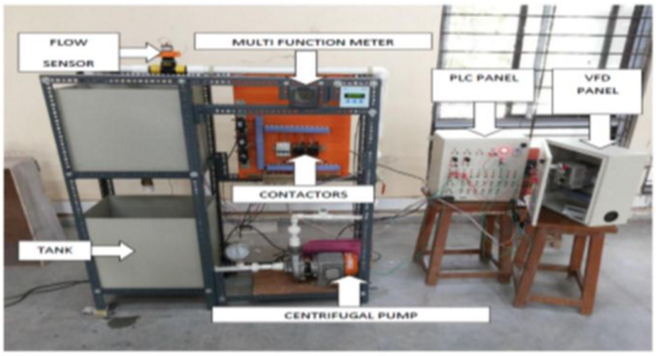


Figure 6. Proposed setup

Table 6. Specification of components

Sr. No.	Name of device	Specification	
1	Tank	Tank1	450X300X450 mm
		Tank2	430X280X430 mm
2	Centrifugal pump	Hp	0.5
		Duty	S1
		Power	0.37 kW
		Voltage	400/440 V
		Current	1.75 A
		Speed	2800
		Frequency	50HZ
3	Paddle-wheel flow meter	Flow rate change	0.5 m/sec to 5 m/sec
		Accuracy	+/− 1% of full scale deflection
		Input voltage	5 to 12 V DC
		Output voltage	Square wave (sinking) of 5–12 V open coil output amplitude, 15–17.5 Hz/metre/second
		Protecting rating	IP 65
4	PLC	Company name	SIEMENS S7-200 CPU 224
		Physical size	120.5X80X62
		Programme memory	1862 bytes
		Data memory	5120 bytes
		Local on board I/O	14 DI and 10 DO
		Communication Ports	RS 485

4.5. Construction working and Calibration of flow meter

The paddle-wheel flow meter comprises a paddle-wheel sensor, pipefitting, and display/controller. The sensor consists of rotating wheel or impeller with embedded magnets, which is perpendicular to the flow and rotates when inserted in a flowing medium. As the magnets in the blades spin past the sensor, the paddle wheel generates frequency and voltage signal proportional to flow rate.

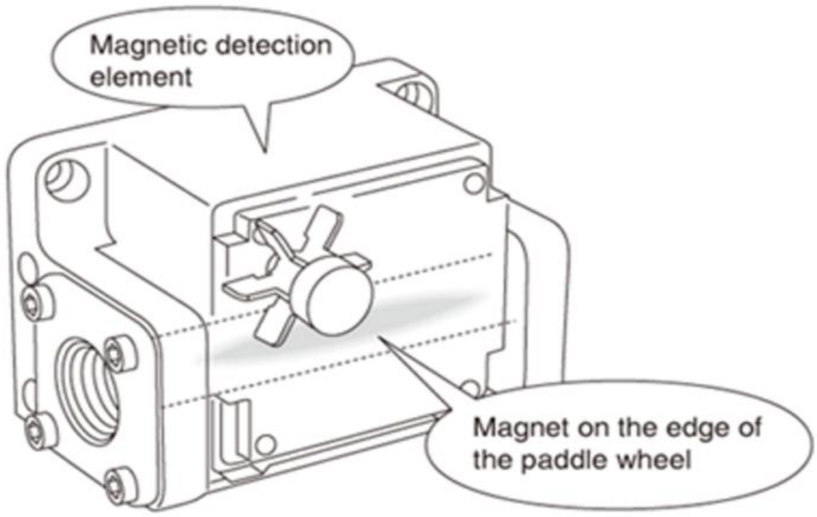


Figure 7. Structural diagram of paddle-wheel flow meter

To validate the measure indicated by a flow meter, we first manually calculated the flow rate for the duration of 30 s. For this, we first measured the volume of water filled in the tank during the 30 s of interest and thus obtained the flow rate as follows:

Volume of water filled in the tank during the duration of 30 s

= (Length of the tank) × (breadth of the tank) × (height of the tank filled by the water during 30 s)

= (430 ×280 ×125) mm3 = 15.05 L

Thus, the flow rate is 15.05 L/30 s.

Now, the flow rate obtained from flow meter is 1910 L/h. For duration of 30 s

Flow rate = (1910/3600) × 30 = 15 L/30 s.

Thus, the two values obtained were almost same; hence, the flow meter was properly calibrated. Paddle-wheel flow meter cost is moderately high. It is suitable for fluids with moderate velocity and steady rate with low viscosity. Thus, it is highly suitable for mass implementation at very moderate cost.

4.6. Flow chart for the proposed VFD setup

The PLC programme starts and immediately goes for initialization procedure in the first scan itself. During this initialization, various processes such as enabling and disabling some control bit, mode selection, and defining memory pointers, and high-speed counters were performed. The use of control bit enables selection of either the Direct or the VFD mode. From flow transmitter, the flow is achieved in L/h. Maximum flow is 4000 L/h. Using the flow transmitter, this signal is 0f 4–20 mA which is converted into 0-32000 count and then it is converted into 0-1 for PID controller, this signal is known as a process variable. The second value input to the PID controller is from the SCADA system and it is known as the set point. This process of converting the signal from actual flow to 0–1 is known as normalisation. The output of PID controller is from 0–1 and it is known as a control variable. This signal is converted again into 0–10 V and it is given to the VFD. This Process is known as de normalisation. For getting the precise flow reading averaging is done for 20 readings at a time for that a timer of 30 millis is used and 02 counter is used so after total $30X02 \times 20$ (readings) = 1200 ms = 1.2 s flow readings will be updated.

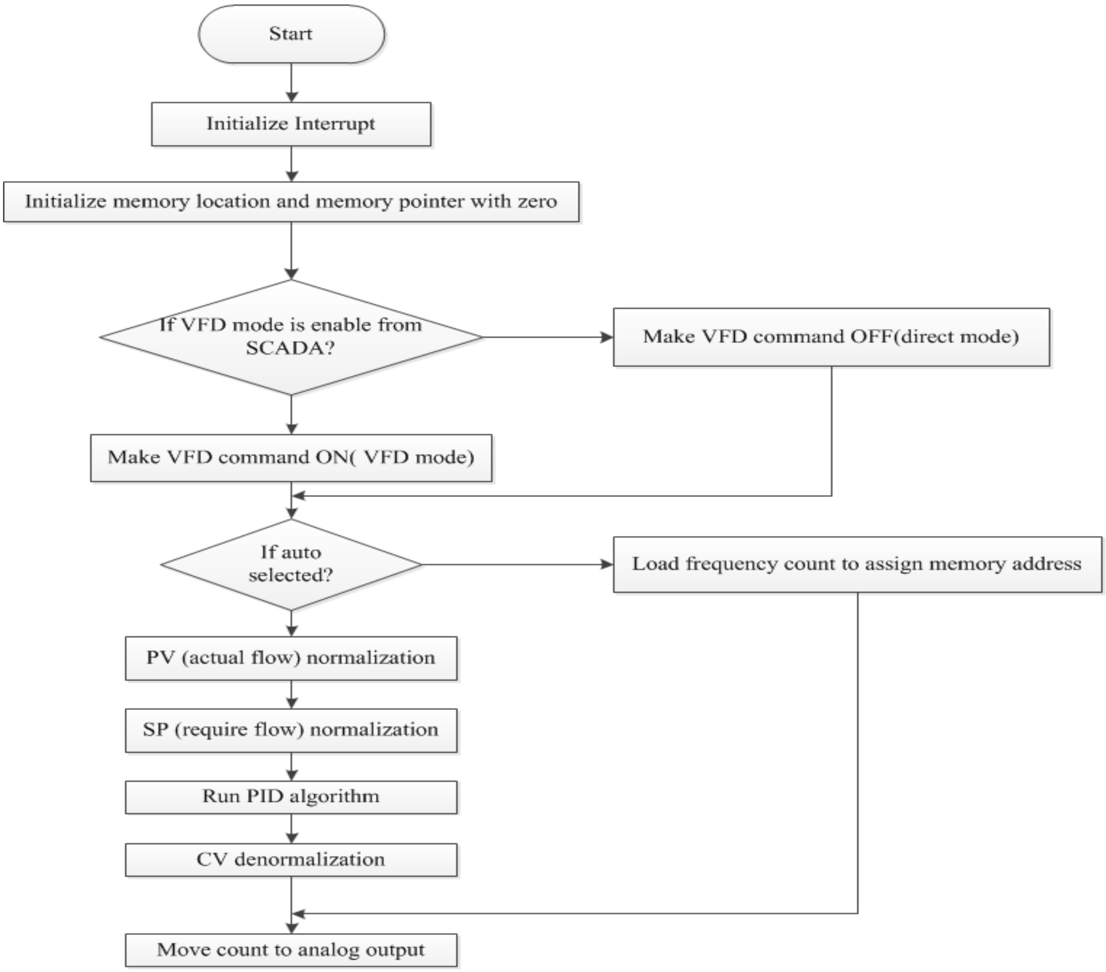


Figure 8. Proposed flowchart

The setup demonstrates a closed-loop control using a VFD with a PLC and SCADA system. Herein, the required flow rate is specified using SCADA in the form of set points. The Start/Stop command can be given from the SCADA system. SCADA also enables selection of either of two modes i.e. direct mode or VFD mode. Moreover, it also enables the selection of two sub modes of the VFD mode, namely auto mode and manual mode. In the auto mode, we fed the required flow as the set point and the PLC adjusted the frequency and speed to provide the required flow, whereas in the manual mode we fed frequency as the set point to obtain the required flow. In the auto mode, the current flow rate value was obtained from the flow sensor in the form of high-speed pulses in the range of 0–50 Hz. These high-speed pulses were received by the PLC, and then the average of 20 flow rate samples was assessed out to stabilize the fluctuations in the obtained flow rate value. This value was used as the process variable PV in the form of feedback by the PID block of the PLC which simultaneously received the required flow rate as a set point from the SCADA system. The PID block compares the measured flow rate with the set point and generates an error signal. By adjusting proper values of KP, Ti, and Td we obtained the desired type of response. The PID generated the control signal proportional to the error signal, which adjusted the frequency of motor through the VFD to obtain the desired output. The control signal from the PLC to VFD was in the form of 0–10 V signal available at the analogue output ports of PLC.In the Manual mode, we used the actual flow rate and given frequency as set points to obtain the flow rate as required. The required communication between the PLC and SCADA system occurred through the connection between RS485 (PLC side) and RS232 (PC side).

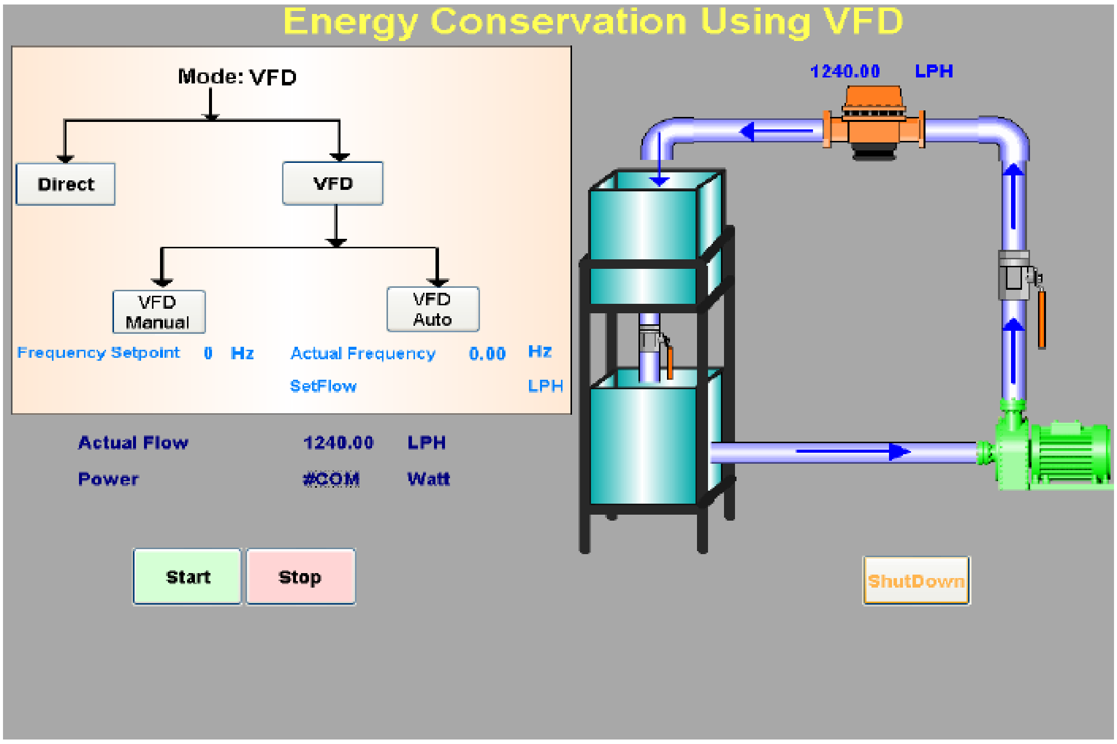


Figure 9. SCADA display of a pump with the VFD

Figure 9 shows the display obtained on the SCADA system. It is a type of industrial control system (ICS). ICSs are computer controlled systems that monitor and control industrial processes that exist in the physical world. The term SCADA usually refers to centralised systems, which monitor and control entire sites or complexes of systems spread out over large areas. Most control actions are performed automatically by RTUs or by PLCs.

4.7. Experimental results

Experimental results with direct and VFD mode are compared in the following section

4.7.1. Direct mode

The observation recorded with flow of centrifugal pump with direct mode is shown in Table7.

Table 7. Readings and observation in direct mode

f	Ps = 0.0136 * Ps1	Pd = 10 * Pd1	H = Ps−Pd	Q1	Pi	V	N
Hz	*m of H_2O*	*m of H_2O*	*m of H_2O*	*m^3/hr*	*W*	*Volt*	*RPM*
50	−2.9932	4.30	7.2932	3.610	620	410	2809
50	−1.6327	9.04	10.6727	2.402	560	410	2830
50	−0.8163	11.30	12.1163	1.489	516	410	2850
50	−0.5442	12.07	12.6142	1.025	496	410	2856
50	−0.2721	12.66	12.9321	0.618	472	410	2864
50	−0.2041	13.32	13.5241	0.042	456	410	2866

4.7.2. VFD mode

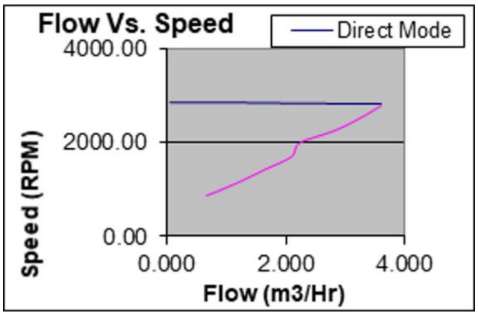
The observation recorded with the flow of centrifugal pump with VFD mode is shown in Table 8.

Table 8. Reading and observation VFD mode

f	Ps= 0.0136 * Ps1	Pd= 10 * Pd1	H=Ps−Pd	Q1	Pi	V	N
Hz	*m of H_2O*	*m of H_2O*	*m of H_2O*	*m^3/hr*	*W*	*Volt*	*RPM*
50	−3.2653	4.3700	7.6353	3.610	620	400	2797
45	−2.7211	3.4500	6.1711	3.287	500	392	2554
40	−2.1769	2.3400	4.5169	2.837	364	330	2269
35	−1.6327	1.3000	2.9327	2.233	264	287	2000
30	−1.0884	0.8500	1.9384	2.093	200	248	1704
25	−0.8163	0.2200	1.0363	1.657	148	209	1440
20	−0.5442	0.0010	0.5452	1.194	104	168	1155
15	−0.2721	0.0010	0.2731	0.660	80	128	872

The two tables of direct mode and VFD mode show that the input power consumption decreased considerably in the VFD mode. The head also decreases considerably in the VFD mode. Thus, VFDs provide suitable opportunities for saving energy. A large amount of energy can be saved if well-designed VFDs with cost-effective paddle-wheel-type flow meters are implemented in villages and industries.

4.7.3. Comparative graph



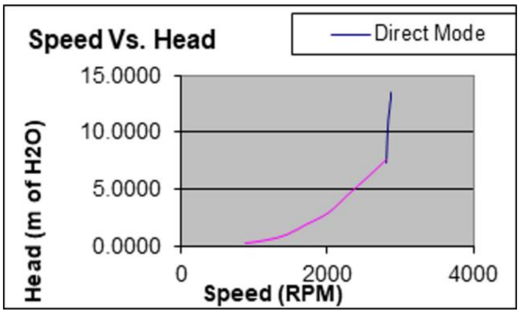


Figure 10(a). Flow vs speed and **Figure 10(b).** Speed vs head

From Figure 10(a), speed is almost constant in the direct mode, whereas it decreases with the flow in the VFD mode. Figure 10(b) shows that speed is almost constant in the direct mode, whereas in the VFD mode, it will decrease with the head.

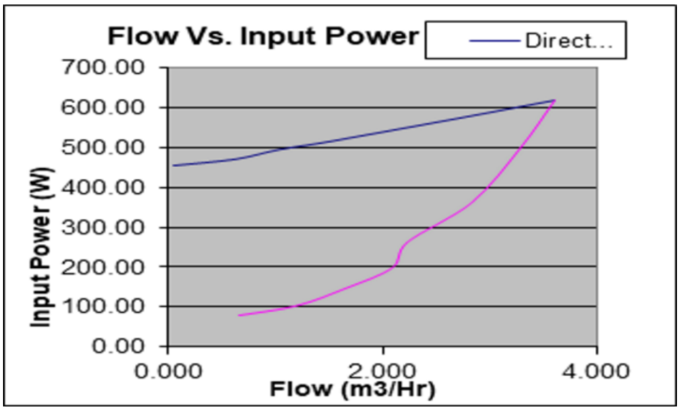


Figure 11. Flow vs input power

Figure 11 shows that for reducing the flow by the same amount, VFD provides a better solution for saving energy than does a throttling device.

Energy saved by means of intelligent energy efficient devices and by adopting, other energy conservation, practises can help in a massive way for EV penetration in Indian power grid.

5. CHALLENGES AND BARRIERS TO THE GROWTH OF EVS IN INDIA WITH A PROBABLE SOLUTION AND POLICY IMPROVEMENTS REQUIRED.

1. In India in 2016, the per capital energy consumption is 1075 kW-h/year (one-third of the world average) and 25% of the population does not have access to electricity. Transmission and distribution losses have reduced from 26.63% in 2011–12 to 21.81% in 2015–16. However, the losses are still high considering the population and demand of the country and energy conservation. Hence, the use of energy-efficient devices must be considered. Strong government policies supporting the cause are extremely necessary (Energy policy, Govt of India, 2017).
2. Wind and solar prices in terms of kW-h have declined from 60% in 2010 to 52% in 2015. However, in the next 3 years, energy conservation practices with concrete steps to reduce technical and nontechnical losses will play a significant role in generating the required amount of EV charging energy. (Energy policy, Govt of India, 2017).
3. Smart grid and grid infrastructure development are required in the country because the addition of RESs should not affect the grid adversely (**strong policy reforms required**).
4. India does not have Lithium ion reserves to support a large domestic market for EVs. There is also a **lack of clear policies** for supporting the growth of supply, manufacturing and safety concerns/perceptions around EVs.
5. Issues related to battery charging, battery life, and recycling of batteries, (**strong policy reforms required).**
6. India’s electricity production is dominated by fossil fuel-based methods with low carbon benefits. This contribution of fossil fuel-based methods to energy production needs to be reduced.
7. High local taxes and low initial costs of IC engine-based vehicles **(policy improvements required**).
8. Needs heavy duty power plug terminal (high current) everywhere: home, parking, and street with the metering device. Regulatory standards and codes need to be developed. Low consumer awareness leads to low rates of adoption of EVs. The majority of EVs use lead batteries, and their lifespan is short due to the use of unsuitable controller chargers. India dose not impose stringent norms for lead handling or recycling. Therefore, lead pollution is considerably hazardous compared with that caused by petrol/diesel. **Majority of the small EV owners, (E-rickshaw owners particularly in Delhi) are using domestic connections for charging their EVs; according to IE rules, this activity is considered as theft of power because the utility is paid at a domestic rate and the use is for commercial purpose (strong policy reforms required).**

Here, some recommendations have been given by ISGF to promote promotion of EVs that other states can also take for reference.

1. Transportation buses running on most congested routes should be converted into electric buses where traffic in areas is dense and speed is low resulting in high emission and fuel use.
2. By 2020, existing nonelectric three-wheeler vehicles should be phased out and existing nonelectric scooters, mopeds, and motor cycles shall be phased out by 2025.
3. In the capital of India, Delhi, 10% of the new cars registered (four-wheeler vehicles) shall be EVs from 2016 and to be increased to 100% by 2020, and all existing non-EVs to be phased out by 2025.
4. Level 2 charging stations and direct-current fast-charging stations should be installed at different locations of the city.
5. Standard EV charging units equipped with EVSEs should use for charging three-wheeler and four-wheeler vehicles.
6. As discussed in paper earlier precise tariff rates should be set for EVs. At 9 h, some concessional rates should be given for mass penetration of EVs, and that helps plant load factor of power stations.
7. Large organisations should allot half of their corporate social responsibility funds for the creation of EV charging facilities at least for next 5 years.
8. Battery swapping scheme and such charging stations should be installed at appropriate places like nearer to metro stations.
9. EV charging units in parking area should be mandatory for new commercial and multi-storeyed buildings.
10. Concessional taxes may be offered to EVs and its parts.
11. Recognisable number series should be given to all EVs **(policy improvement required).**
12. For government vehicles, duty free import of EVs might be allowed for a limited time (or limited numbers) **(policy improvement required).**
13. Customer education should be provided for EV technology and its use.

In addition to the aforementioned suggestions, the following points will also be very useful for EV development in India.

1. EVs must be designed with proper energy-storage devices.
2. EVs must use an intelligent controller and charging system so that the life of energy-storage devices is maximum.
3. RES must be used for charging.
4. Plantation of Beema bamboo and *Pongamia* (karanj) should be undertaken in surrounding areas. Gasification of bamboo can be used to produce biofuel, which can be bottled and brought to urban areas. Furthermore, the biodiesel

from karaj oil can be brought to city area to run DG sets to make the decentralised charging stations entirely grid autonomous.

5. Plantation can act as carbon sinks.
6. Measure 4 will offset the use of fossil fuel.
7. Measure 1 and 2 will prevent lead pollution and will drastically improve the EVs OPEX economics. The present trend discourages the use of EVs and the popular mind set does not favour the adoption of EVs.
8. All these measures would boost start-ups and generate numerous employment opportunities as per the vision of the honorable Prime Minister of India.
9. This will also meet with the compliance of India towards Kyoto Protocol and CDM.

6. CONCLUSION

Energy conservation is a crucial aspect for reducing the gap between the supply and demand of energy and for increasing the penetration of EVs in India. In India, to achieve mass penetration of EVs and economic development, large amounts of charging power and infrastructure development are required. We have implemented several energy-efficient devices and energy conservation practices in industries, cities, and especially in villages. VFDs have numerous applications. When operated in the variable voltage variable frequency mode, a VFD can facilitate considerably higher energy savings than a throttling device can in a centrifugal pump. The energy saved by using energy-efficient devices, such as VFDs with a low-cost paddle-wheel flow meter, can be utilised to enhance the grid strength for charging EVs. Suggestions and necessary policy improvements given by the author to remove barriers to the growth of EVs in India will be highly useful in the near future for EV development and use in India.

REFERENCES

[1] Report on National Electric mobility mission plan by 2020(NEMMP-2020),Department of heavy industry ministry of heavy industries and public enterprises government of India (dhi.nic.in/writereaddata/Content/NEMMP2020.pdf).

[2] Article on, Automotive mission plan 2006-2016, A mission for development of Indian automotive industry, the ministry of heavy Industries & public enterprises, Government of India (http://dhi.nic.in).

[3] CII GKAFC –Arya Market Research survey report 2015.Consumer's perspective towards E-mobility,(http://www.cii.in).

[4] INDIA transport report, Moving INDIA to 2032, First published 2014 in India by Routledge 912 Tolstoy House, 15–17 Tolstoy Marg, Connaught Place, New Delhi 110

001,(http://tripp.iitd.ernet.in/publications/NTDPC/Vol%20032/NTDPC%20Vol%2003_Part%202.pdf).

[5] Executive summary power sector August 2016, by Government of India ministry of power Central Electricity Authority New-Delhi, (www.cea.nic.in).

[6] Load Generation Balance report 2015-16, Government of India Ministry of power.(http://www.indiaenvironmentportal.org.in/files/file/lgbr_report.pdf).

[7] Energy statistics 2016, central statistics office, Ministry of stastics and program implmentation, Government of India, New delhi 23rd issue, available at www.mospi.gov.in.

[8] Jagruti thakur, Basab Chakraborty,2015, "Intellli-grid Moving towards automation of electric grid in India",Renewable and sustainable energy reviews 42(2015)16-25.

[9] Muhhamad shahbaz, Thi Hong Van Hoang, Mantukumar Mahalik, David Robaud,2017, "Energy consumption financial development and economic growth in India new evidence from a non linear and asymmetric analysis",Elsevier energy economics 63(2017)199-212.

[10] Kumar, Praveen and Kalyan Dash, 2013,"Potential Need for Electric Vehicles Charging Station Infrastructure and its Challenges for the Indian Market,"Advance in Electronicandelectricengineering,3(4):471476.(http://www.ripublication.com/aeee/61pp%20%20%20471-476.pdf).

[11] Qiao Li, Tao, cul, Rohit Negi, Franz Franchetti, Marija D,2011.Online decentralized charging of Plug in Electric vehicles on the power system. IEEE Nov2011(https://arxiv.org/pdf/1106.5063.pdf).

[12] S. Meliopoulos, J. Meisel, G. Cokkinides, and T Overbye,2008, "Power system level impacts of plug-in hybrid vehicles, "IEEE energy, Atlanta GA USA,17-18 November 2008.

[13] K. Clement-Nyns, E. Hansen, and J. Driessen,2010,"The impact of charging plug-in hybrid electric vehicles on a residential distribution grid, "IEEE Trans. Power Syst, vol. 25, no. 1, pp. 371–380, Feb. 2010.

[14] L. Fernandez, T. Roman, R. Cossent, C. Domingo, and P. Frias,2011, "Assessment of the impact of plug-in electric vehicles on distribution networks",IEEE Trans. Power Syst., vol. 26, no. 1, pp. 206–213, Feb.2011.

[15] J. Lopes, F. Soares, and P. Almeida,2011,"Integration of electric vehicles in the electric power system, "Proc. IEEE, vol. 99, no. 1, pp. 168–183, Jan. 2011.

[16] K. Dyke, N. Schofield, and M. Barnes,2010, "The impact of transport electrification on electrical networks, "IEEE Trans. Ind. Electronics, vol. 57, no. 12, pp. 3917–3926, Dec. 2010.

[17] K. Schneider, C. Gerkensmeyer, M. Kintner-Meyer, 2008, "Impact assessment

of plug-in hybrid vehicles on Pacific northwest distribution systems, "Power Energy Soc. Gen. Meet., Jul. 2008, pp. 1–6.

[18] Ahmed Yousuf Saber, and Ganesh Kumar Venayagamoorthy,2011, "Plug-in Vehicles and Renewable Energy Sources for Cost and Emission Reduction",IEEE transactions on industrial electronics, vol. 58, no. 4, April 2011 1229.

[19] David G Hart,"Using AMI to realize the smart grid.Power", and energy society general meeting-conversion and delivery of Electrical energy in the 21st century,2008. IEEE conference 20-24 July 2008.

[20] Dolezilek David J, Schweitzer Stephanie,2013, "Practical applications of smart grid technologies",Saudi Arabia smart grid, November 24-27 2013.

[21] RichardEBrown.Impactofsmartgridondistributionsystemdesign,2008.IEEEPowerandEnergySocietyGeneralMeetingConversionandDeliveryofElectricalEnergyinthe21stCentury;2008,1–4, http://dx.doi.org/10.1109/PES. 2008.4596843.

[22] Electricity load factor in Indian power system,2016.Power system operation corporation Ltd Jan 2016(www.posoco.in).

[23] V K Gaudani,2009,Energy Efficiency in Electrical system IECC press,NewDelhi.

[24] P. Radgen, Ed.München,2005,"Getting it right applying a systems approach to variable speed pumping,"In proceedings of the 4thInternational Conference on the Energy Efficiency in Motor Driven Systems (EEMODS 2005),: Fraunhofer IRB Verlag, pp.304–314. ISBN 3-8167-6904-7.

[25] NitiayogEnergypolicy,GovernmentofIndia,2017,http://niti.gov.in/writereaddata/files/new_initiatives/NEP-ID_27.06.2017.pdf.