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Application of Simulation and Dynamic Programming Tools and Techniques for the Charging Cost Optimization in a Plug – in Electric Vehicle

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ABSTRACT

Future success of Electric Vehicles depends mainly on the costs of charging the EV and their capabilities of charging without any interruptions to the traditional electricity distribution grids.
To reduce the costs of charging and to charge the electric vehicles at the planed sessions one has to know the process of time varying charging power which is very important in calculating the cost of charging an electric vehicle. This process is called charging profile of an electric vehicle. These charging profiles for an Ather S340 plug in electric vehicle has been documented with all the required details. This information is used together with the historical and present BESCOM electricity rates, to find the cost of EV for 2017 and 2018, and the savings are tabulated.
The charging is done throughout the night from 10:00 PM to 6:00 AM (next day), along with the condition that empty battery at 10:00 PM. In the first stage the charging is started at 10:00 PM, In the next stage by making a smaller change with the references from the various research papers, the charging is done at exactly 1:00 AM, and the results are taken. This is done using the COMSOL simulation software. The change in the timings is giving us the total reduced cost of charging an electric vehicle up to 7%-8% roughly for a year. Further the cost of charging is made to come down additionally using the dynamic programming algorithm model with SCILAB codes.
By doing so, at least 25% more Indian electric vehicles can be charged by the present electricity grids, without producing more electricity and without even creating more load on the national, local, industrial and commercial grids.
Keywords: Electric Vehicles, Optimization, Charging sessions, BESCOM tariffs, Ather "S340", simulation, Dynamic Programming.

1. INTRODUCTION

Plug-in electric vehicles are the pure electric vehicles which use electricity as the mode of fuel or energy to move unlike any other vehicles in the market. Electric vehicles need to be charged from an external source using the charging spots and cables provided. The are many research papers which have right to reduce the cost of charging of an electric vehicle in a better way, using various techniques such as game theory, master slave scheduling, linear programming, quadratic programming, additive increase of multiplicative decrease, sliding mode control, congestion pricing and MPC. The Game Theory mainly focuses on the mathematical model of decision making among the players. The Master Slave Scheduling of charging segments happens by the permission of a master process to the slave process without disturbing the intermediate processes. Linear Programming is the most used type of a technique in all most all of the research papers because of its simplest form of solving the minimization and optimization problems involving the linear variables such as cost, time, etc.

Quadratic Programming is similar like the technique of Linear Programming but is much more advance than the latter. It can solve more complex problems with one or more variables. This technique has been applied together with the linear programming to obtain the best possible results. The technique of additive increase and multiplicative decrease is not recommended due to problems which involve the optimization of cost and time. Sliding mode control technique is used in majority of the research papers which has an effective impact in controlling the cost variables. It can reduce the electric vehicle traffic in a charging station during peak hours. This can be the best match with the time of day tariff, which has been one of the best tariff plans of the BESCOM implemented till date. The congestion pricing work similarly like the sliding mode technique based on the current tariff. The MPC technique is a type of process control tool that satisfies a set of constraints by controlling the processes.

All the above techniques have provided their own way of solving the problem of minimization and optimization of the cost of charging an electric vehicle. In this thesis, bits of every research paper has been collected, analyzed to make a firm foundation for the future algorithm models. In this thesis, the charging is mainly done at the night as mentioned previously. Charging of an electric vehicle starts off from the night 10:00 PM to 6:00 AM the next day. This is simulated in the simulation software for the best possible results.

Product S-340 has a purge charging range of 80KM, assuming customer travel distance, 80KM per day for an year happens to be 29,200KM per year. Here the state of health and the state of charge both plays an important role. The state of health shows the battery conditions as is maintained as a constant. The state of charge is already fed into the algorithm. So the calculations and cost minimizations are done for a year. A year has 8700 hours, which is plotted on a graph along the X-axis. In the initial stage, electric prices for charging an electric vehicle is calculated using BESCOM electric prices with the Scilab codes for 2017 and 2018.

For this purpose, the different BESCOM electricity prices are taken from the Government of Karnataka's official website. The reason for calculating electricity prices for 2017 and 2018 are to know how much cost savings can be done comparatively, so that the necessary changes in the algorithm can be made immediately and also implemented.

The full battery capacity in Ather S340 is 2.166KWH. This is not utilized completely from the owner of the vehicle, only 80% can be utilized. This comes up to 1.73KWH

2. PRODUCT ATHER "S340"

Ather S340 has been completely built from the scratch with every product being manufactured here in India. This product stands in the top most position in comparison with other 2 wheeler electric vehicle segments, which are in the electric vehicle market and are yet to enter the market.

The name itself gives us the major specifications, where S stands for Scooter, 3 stands for 3 KW motor capacity and 40 stands for 40Amp Hour capacity of the battery. S340 is the first of its kind where the design is made sure to comfort the customer, where in the maintenance charges have also been reduced which would be periodically be required for every internal combustion engine. It is one of the smartest scooters ever built in the country making the best utilization of the available resources. The official launch of the vehicle was done at the Surge event which was held in Bengaluru.

The vehicle"S340" Specifications

System: PEV
Electric motor: 3 - 5 kW, 14 Nm
Battery: Lithium-ion, 51.1V, 2.166 kWh, 42.4 Ah
Battery weight: 90 kgs
Acceleration from 0 - 100 km/h: 12.11 s
Max speed: 100 km/h
Charging consumption: 30 Wh/km
Fully charged in 2.8 units of energy (0% - 100%)
One charge = 80 Km at 40 Kmph (ARAI)

Charging times (empty to full):

13 A: 25 min
10 A: 32 min
8 A: 43 min
6 A: 54 min

3. PROBLEM STATEMENT

3.1 Problem genesis

The charging of an electric vehicle can happen at both job locations at home environment. But nowadays the need for a public charging is rapidly increasing. The electric vehicle market is growing bigger day by day. These public charging segments can be both private as well as government supported. In this thesis, we are concentrating more on the public charging as well as home environment charging. One can save money as well as limit the power usage capacity with the electricity range provided by the government by implementing certain small changes also the proposed algorithm in this thesis. Here we are mainly concentrating on the two wheeler segment charging spots which are installed at the home environment as well as Ather Company charging spots. These are supported by the government of Karnataka with BESCOM tariff plans. In home environment other electrical appliances such as induction stoves, mixers, ovens, water heaters, geysers, etc. utilize electricity. So we need to manage all these appliances along with the two wheeler charging without any drastic change in the electric billing charges for the given tariff rates. We mainly concentrate on the redemption of cost of charging an electric vehicle without exceeding the power usage limitations. This thesis answers many future questions regarding the electric vehicle. One of the main question being, can we really reduce the cost of charging an electric vehicle in home environment, also how does the electric vehicle charging varies with the home electric power range. All the information gathered in this project will be useful for research and development of an electric vehicle industry and even expanding the electric vehicle market. Traditional electrical grid distribution.

3.2 Dynamic Programming

$$\min J = \sum_{k=0}^{N-1} gk(xk, uk) + gn(xn) \qquad (1)$$

$$s.to$$

$$xk + 1 = f(xk, uk)$$

$$k = 0, 1, \ldots.., N - 1$$

Where
J – Cost function
u – Control Action x – State
k – Discrete Time index. k = {0, 1, 2, 3, ..., N-1}
N – The time horizon
gk(xk, uk) – Instantaneous cost
gn(xn) – final or terminal cost
The SoC is the ‘x’ States:
SoC = {0, 1, 2, ..., 100} [%]
The Charging Power becomes the control action ‘u’
control signals are the charging powers
P = { 6, 8, 10, 13 } [A]
For example assuming you are in state ‘X’ at time ‘k’ and with control action ‘u’ gk(xk, uk)is the Instantaneous cost you pay and gn(xn) is the final or terminal cost for charging the vehicle.

3.2.1 Cost to go Matrix

Cost to go matrix has time scale in the X axis and the state of charge in Y axis. It has 101 rows for the 100% state of charge and 24 columns and for 24 hours of the day. The time scale increases as we move in the X-axis and we move up in the Y axis the state of charge increases. The state of grid is 24424 cells. The final state constraint column is the one which explains at the given time and at the present state of charge what optimized cost can be implemented. Cost to go is nothing but the price that the electric vehicle consumer pays for commuting from one state of charge to other state of charge or from one place to other place. The matrix is fully filled up with the previously calculated with the costs of the algorithm. The algorithm has the lowest possible cost for any given state of charge and for any given state of space. For example, if a consumer is at 40% charge at 9:00AM, the algorithm can calculate the lowest possible electric prices to reach 100% electric charge. The algorithm gives the best possible lowest rates through the cost to go matrix. The below graph which is a result of cost to go matrix gives the complete structure of charging an electric vehicle at any time phase in a day in a year from the graph we can conclude that the first and second hour of a day is given the lowest possible costs to charge and electric vehicle for both 2017 and 2018. In the same way charging can be very costlier for a consumer in the time phase between 7 to 10 hour of a day, that is when you start early in the morning.

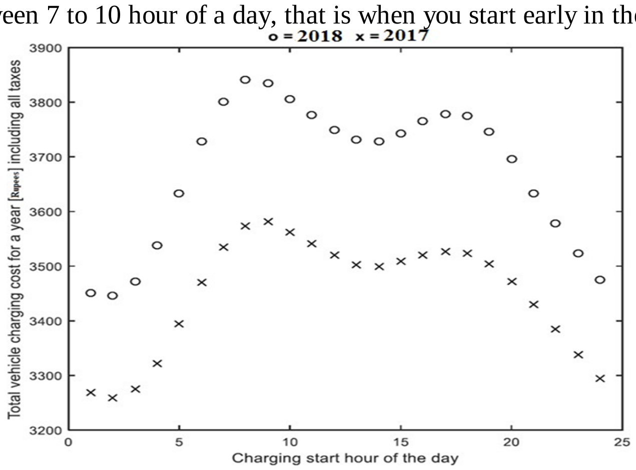

Figure 1 Costs of Charging

3.2.2 TOD and Charging sessions

Time of day tariff has been implemented by many countries other than India and all these countries are able to get huge benefits from these tariff plans. The flat tariff which had been implemented earlier had many disadvantages and was beneficial only for the consumers, but not utilities. In the time of day tariff the risk of both electricity utilizes and the consumers are balanced very well. Both can get benefits from this tariff. By the time of tariff the companies are able to shift the big time load to off big time and also reduce the cost for consumers. In the first stage, the time of day tariff has been implemented only in industrial sectors. But due to its huge benefits, government is trying to implement this tariff for all the sectors. The main intention of using time of day tariff is to ease out the problem of charging traffic occurring in charging stations and to also have a balanced distribution in all the hours of the day with the reduced cost of the consumers.

Table 1: Time of Day Tariff

Time of Day	Increase (+) / Reduction (-) in Energy Charges over the normal Tariff applicable	HOURS OF CHARGING
6 AM To 10 AM	(+) 100 Paise per unit	4 Hrs
10 AM To 6 PM	0	8 Hrs
6 PM To 10 PM	(+) 100 Paise per unit	4 Hrs
10 PM To 6 AM (NEXT DAY)	(-) 100 Paise per unit	8 Hrs

i. Collected DATA of Charging sessions

Table 2: Margin specifications

Charging session	Current [A]	Total energy consumption	Duration	Mean power
1	6	1.283	56	1364
2	6	1.285	55	1401
3	6	1.283	54	1425
4	8	1.227	42	1753
5	8	1.228	42	1754
6	8	1.228	43	1713
7	10	1.174	32	2175
8	10	1.173	33	2132
9	10	1.174	33	2134
10	13	1.173	25	2792
11	13	1.172	25	2812
12	13	1.173	26	2706

From the summary of the above charging sessions, we can infer that, As we move towards the lower charging powers the total energy consumed is more. For calculation purpose, the measured data from the charging sessions 7 to 9 were used. There are some important reasons for these particular charging sessions, they are:
1. Total energy consumed is more in the lower charging currents.
2. The total time consumed is more in the lower charging currents.
3. The computing of charging costs is done with Scilab and the results are stored.

4. Results

The Results from both the Simulation and dynamic Programming have been detailed here in the graphs and the table. The savings are very promising with respect to the electric vehicle market and industry are concerned. Shifting timings gave a very good leap towards the cost savings and the dynamic programming has extended the savings furthermore.

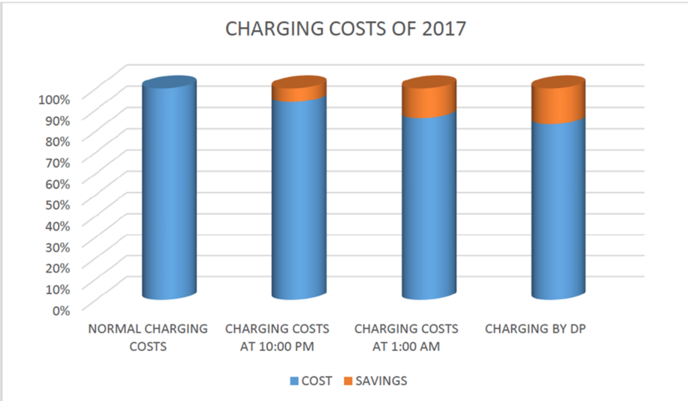

Figure 2 Charging costs for 2017

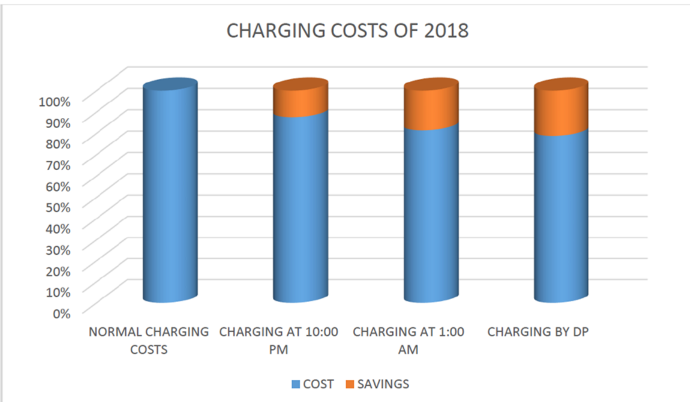

Figure 3 Charging costs for 2018

Table 3: Final Results

YEAR	Total yearly cost starting charging at different timings				
	10:00 PM	1:00 AM		Dynamic Programming	
	COST	COST	SAVINGS	COST	SAVINGS
2017	3746	3446	300	3328	418
2018	3504	3259	245	3153	351

5. Conclusion

This paper has applied the two main techniques, Simulation and Dynamic Programming for the charging cost optimization in an Electric vehicle. These have been compared and the results are tabulated. These techniques have been used to model the demand for EV charging, especially in the Product “S340”. A number of observations has been made regarding the state of the charge and the charging sessions of the “S340” Electric Vehicle and are used together with the 2017 BESCOM Prices to calculate the 2018 Prices. All the results are calculated and the savings are given in the table. From the table it is evident and proved that through simulations charging costs are lowered to 6 to 7 % just by shifting the timings from 10:00 PM to 1:00AM. And Dynamic Programming gives a major savings of 11% on the overall charging costs. The complete DP algorithm of Ather S340 is not introduced in detail in this thesis since the company’s rules and regulations are very strict regarding the company’s research and developments are concerned.

References

[1] Zhang, Fangzhu, and P. Cooke. "The green vehicle trend: electric, plug-in hybrid or hydrogen fuel cell." Dynamics of Institutions and Markets in Europe(2009).
[2] Mader, Jerry, and Transportation Energy Center TEC. "BATTERY POWERED VEHICLES: DON’T RULE THEM OUT." (2006).
[3] Study by KPMG “Emerging trends and technologies in the automotive sector- Supply chain challenges and opportunities” K- Klynveld, P- Peat, M- Marwick, G- Goerdeler (2015).
[4] Lutsey, N. "Transition to a global zero-emission vehicle fleet: a collaborative agenda for governments." (2015).
[5] Trends in vehicle concept for Journal of International Battery, Hybrid fuel cell Electric vehicle symposium on nov-2013, issue 1, volume 1.
[6] Problems in Electric Vehicle . International journal of applied research in Mechanical engineering. On 2012, Issue 1, volume 2.
[7] Contestabile, Marcello, Gregory Offer, and Robin North. "Electric vehicles: A synthesis of the current literature with a focus on economic and environmental viability." LCAworks. London (2012).
[8] Sanchez-Repila, Diego, and J. Poxon. "Hybrid electric vehicles: current concepts and future market trends." Rama de Estudiantes del IEEE de Barcelana 23 (2006).
[9] Andrea, D., 2010. Battery Management Systems for Large Lithium-Ion Battery Packs. Norwood: Artech House.
[10] Ashtari, A., Bibeau, E., Shahidinejad, S. and Molinski, T., 2012. PEV Charging Profile Prediction and Analysis Based on Vehicle Usage Data. IEEE TRANSACTIONS ON SMART GRID, 3(1), pp. 341-350.
[11] Bai, S. and Lukic, M., 2013. Unified Active Filter and Energy Storage System for an MW Electric Vehicle Charging Station. IEEE TRANSACTIONS ON POWER ELECTRONICS, 28(12), pp. 5793-5803.
[12] Batteryuniversity.com, n.d.. BU-410: Charging at High and Low Temperatures. [online] Available at: http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures [Accessed 2015-01-14T10:29].
[13] Bellman, R.E., 1957. Dynamic programming. Princeton: Princeton University Press.
[14] Bertsekas, D.P., 2005. Dynamic programming and optimal control, Volume 1. 3rd ed. Nashua, NH: Athena Scientific.
[15] Di Giorgio, A., Liberati, F. and Canale, S., 2013. Electric vehicles charging control in a smart grid: A model predictive control approach. Control Engineering Practice, 22, pp. 147-162.