IOT integrated PV-Grid expedient EV Charging Station for Confronting Duck Curve

Ann Rufus A[1] **Ravi T[2]** **Pon Nirmal C[3]** **Ferminus Raj A[4]** **Rajesh A[5]**

Assistant Professor
Department of Electrical and Electronics Engineering
SCAD College of Engineering & Technology, Cheranmahadevi, Tamil Nadu.
annrufus@gmail.com[1], mrraveee@gmail.com[2], cpnnir@gmail.com[3], ferminus.raj@gmail.com[4], arajesh20@gmail.com[5]

***Abstract*—In this paper, we study the effects of electricity production from a solar power plant on the load curve also known as duck curve and provide an alternative by charging electric vehicles in the IOT integrated multi-level charging stations. An effort is made to improvise the load curve by neutralizing the dip and sudden rise in the duck curve by creating alternative loading on the powergrid. It also supports for the promotion of EV utilization by improvising the charging technologies with the help of IOT interface and providing incentives to customers to utilize EVCS at the workplace. It also talks about an idea of replacing fossil fuel-based revenue system with centralized EV charging taxation that would boost the idea of green mobility.**

***Keywords*—duck curve, electric vehicle(EV), electric vehicle charging station(EVCS), pricing strategy, charging strategy, powergrid, photovoltaic effect.**

I. INTRODUCTION

National Electric Mobility Plan (NEMMP) 2020 targets to deploy 5 to 7 million electric vehicles by 2020 and further to replace all the IC engine enabled vehicles by EV's. The installed solar power capacity as of 30th June 2018 was 23GW, which is again increasing rapidly. Though this is reducing our dependability on fossil fuels, the excess generation of electricity from solar plants at noon is increasing the dip of the duck curve and causing an imbalance in the power system. The increase in EV's will increase the power demand for charging, although it is expected that majority of EV charging will occur at home during light load conditions of the power system but due to office schedules, the charging of EV's is occurring at high load conditions during the evening. Hence increasing the ramp of the duck curve. This will increase the stress on the grid infrastructure and hence increasing the cost.

In this paper, we introduce a new system for centralized EV charging stations with a commercial blend at multi-level parking buildings of the IT companies. The purpose is to charge the EV's using solar energy during the afternoon and creating alternative loading conditions on the power system to compensate the decrease in demand during off-peak hours. We propose an IOT based charging system that will provide incentives to the EV owners for charging during off-peak hours. The IOT based parking system will guide customer in finding his parking space based on uniform loading in all the parts of charging station and also notify him on the complition of charging. The IOT enabled plug-in charger, control center, bi-directional inverter, dc-dc converter are the components that with the proper cordination with the grid forms the entire system. In collaboration with the IT companies, we aim to promote the use of EV using a card-based payment system that will profit both the charging station and the IT Company.

This system aims to replace the pollution-based fossil fuel used revenue system with centralized EV charging taxation. It can also help to reduce the burden on the powergrid by confronting the duck curve through alternative loading during the peak power generation of the solar power plant.

II. SOLAR POWER

Ever since the discovery of the photovoltaic effect, solar technology is being improvised every day. The generation of solar energy reaches its peak from 10 AM to 3 PM. The output for a 100kW solar power plant for a day is as shown in figure 1.

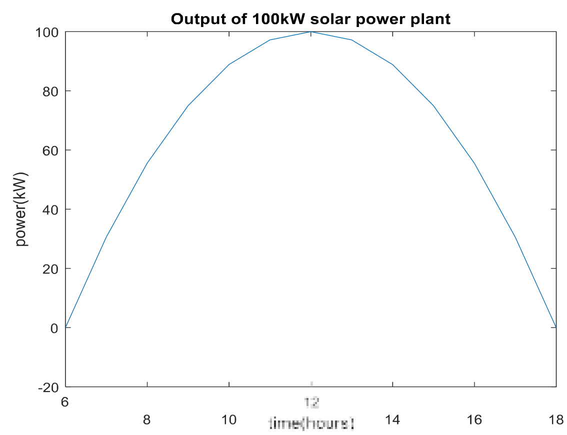

Figure 1. Matlab simulation for 100kW solar power plant.

It can be seen that the peak occurs during noon when there is low load condition. We can utilize this excess generated power for charging EV batteries using the constant current method. The losses associated with the conversion of power will be eliminated in this solar based system.

III. DUCK CURVE

The demand for electricity is at its lowest during the night. The demand rises with the start of the day and remains almost constant till evening. There is a sudden rise in the demand as sun sets. Over the years this curve was predictable but due to an increase in production from solar, the load curve observes a dip in the afternoon which is increasing every year. This results in instability in the power system infrastructure. The power generators have to rush their production in the evening and almost shutdown in the afternoon which is not desired to maintain the profit of the company. Figure 2 shows the variation of the duck curve over the years.

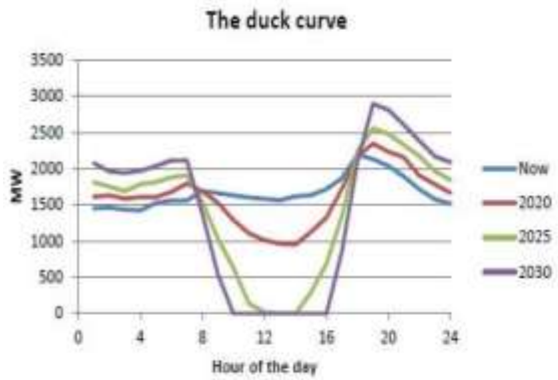

Figure 2. Forecast of duck curve according to Prof. William Grace's modeling

The power plant has to ramp up their production quickly in the evening when the PV production is minimum. Such large-scale operation has trouble turning on a dime, such load profile appearing like a duck's neck presents a problem.

IV. EV BATTERIES

The criteria on which battery selection process depends are the type, weight, size (energy density), life cycle, availability, cost, and efficiency. Various researches are in progress over this, but at the moment, Lithium-ion batteries are considered as the best rechargeable batteries for EV's. They are capable of rapid charging and are light weight with very low heating. For our reference, w have considered a battery of Nissan Leaf that has the following specifications

No.	*W (kWh)*	*Pmax (KW)*	*Pavg (kW)*	*Tcycle Hrs:Min*	*Vehicle*
1	20.23	2.17	2.08	9:44	N. Leaf
2	18.20	2.15	2.07	8:47	N. Leaf
3	17.17	2.27	2.05	9:00	N.eNV200

Table 1: Parameters of registered slow AC charging cycles[2]

V. CHARGING

A). Charging Techniques

1). Power rectifier- the power from the grid is converted from ac to dc using SCR controlled rectifier with efficiency more than 90% and power factor less than 3% total harmonic distortion. These power rectifiers are approximately 36 sq feet with 3 feet deep and resemble the fuel pumps found in petrol stations. .[3]
This consumes a lot of areas and these must also be provided with cooling systems

2). Dc charging- In our solar charging station, as the production and utilization both occur in dc, there is no need of conversion circuits and this space which is saved can be utilized to implement IOT integrated chargers with digital payment methods. The efficiency of such a system will be more than 99%.

3). Lithium-Ion Battery Charging- The charging process of Lithium-Ion battery is done either by a constant current, constant voltage or constant current-constant voltage(CC-CV). The typical charging characteristics over time as shown in figure 3.

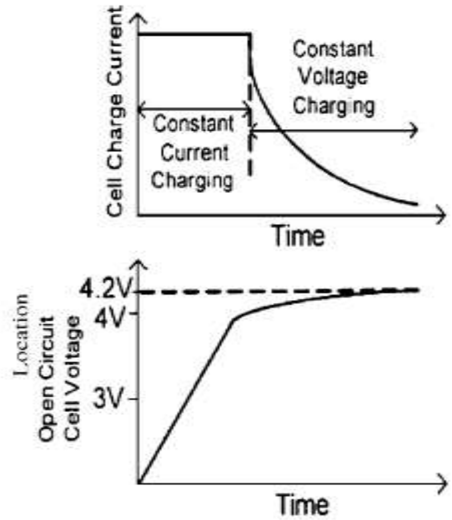

Figure 3. Typical Lithium Ion charging characteristics [4]

B). Charging Strategy

Taking reference of Nissan Leaf EV as shown in table 1, for slow charging, 2,17kW power is applied.
Case study- consider the average distance of 25km between workplace and home. The distance covered by EV between 2 successive charging would be 50km.
The range of Nissan Leaf= 200km [2]
Thus the state of charge(SOC) when the vehicle enters the charging station can be assumed to be 75%.

SOC=SOC(i)-IZ*t(j) -------- (1)

Where SOC(i) is last complete charge of EV and is assumed to be 100%.
I is the rated current drawn from the battery
Z is total circuit impedance
t(j) is the time taken by the EV to travel distance j.

V(SOC(i))- V(SOC)= ΔV ------(2)

Where V(SOC(i)) is the voltage level of battery at end of last charging.
V(SOC) is voltage after traveling for t(j)
ΔV is the drop in battery terminal voltage.

the output power of 100kW solar power plant is simulated in MATLAB as shown in figure 1. It can be seen that the power reaches the peak during 10-15 hrs. Consequently at this time, the duck curve reaches its maximum dip(figure2). This excess generation is utilized to charge the EV under the constant current curve of figure3.

The area under the curve from 10-15 hrs of figure 1 gives the excess power generation. This can be found using Integration,

$Pe=\int Power*dt$

Where dt varies from 10 to 15 and Pe is excess power generated.

Pe=467.625kWh.

As when the vehicle enters EVCS, SOC=75%.

$\Delta Q=5.25kWh$.

Therefore $n=pe/\Delta Q\sim 90$.

For a 100kW solar power plant, 90 EV can be charged simultaneously under constant current terminology. Once $\Delta V=0$ then the charging can be shifted to a constant voltage which can be provided from the grid as to maintain the load curve of a power system constant.

C). Pricing Strategy- Let r be the rate of electricity per kW.

A1=r1*P

Where r1 is the price of electricity supplied by the power board.

A2=r2*P

Where r2 is the price by EVCS ad P is power consumed by EV.

It is essential in customers point of view that r2 is less than r1, otherwise, he will not be interested in charging his vehicle at EVCS. If W is the wholesale price at which power grid purchases power from the solar plant, it is necessary that r2>W, otherwise EVCS will not make a profit. For comparison by the consumer over a time, he should observe that A2(m)<A1(m), where m is the number of times the EV was charged in EVCS.

To convince the customer to use EVCS, A2(m) can be further decreased by providing incentives as explained in section VI.

VI. IOT BASED CHARGING SYSTEM

A typical charging system (EVCS) in an IT park is as shown in figure 4.

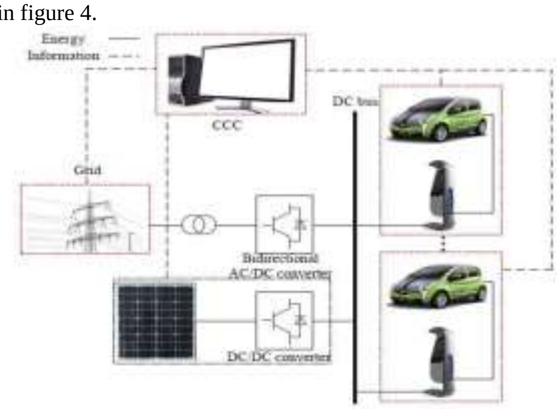

Figure 4. Structure of EVCS

The output of a solar power plant situated on the roof of charging station is controlled using a dc-dc converter(chopper circuit) and fed to dc bus. The bidirectional ac-dc converter consists of a rectifier circuit and an inverter with a common switch that is controlled using a microcontroller and a GSM module.

Referring to figure 4, from t=10 to t=15, it acts as an inverter to convert excess power from dc to ac and rest of the time as a rectifier. As the EV enters the EVCS, it is guided to the parking spot by the LED’s on the floor, care is taken that the loading in various parts of EVCS is uniform. This action is controlled in the control center CCC using IOT. After charging is completed, overcharge protection as shown in figure.5 disconnects the EV and sends the message to CCC and the owner of EV through the GSM module. The payment process can be done using credit/debit cards or the cards issued by EVCS.

For the cards issued by EVCS, the IT company will deposit 50% of travel allowance(TA) allocated to the employee every month. For this, 5% extra credit is credited to the card by the EVCS as an incentive to the customer while the EVCS will have (k*50%*TA) as a deposit for 1 month from which it will earn revenue and also pay IT company fixed percent of amount negotiated at the beginning to adopt EVCS in their parking premises. The IT company will get revenue and also it would not have to pay for security associated with parking. Thus this system would favour both customers as well as the IT company for the adoption of EVCS. A typical charging circuit along with the protection levels is shown in figure 5.

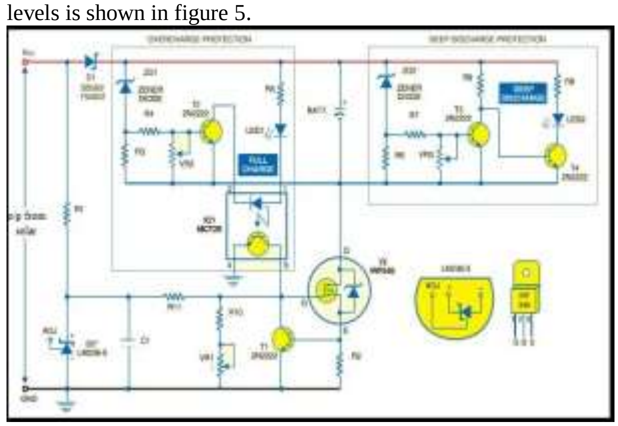

Figure 5- Typical constant current charging circuit [6]

VII. CONCLUSION

The IOT based EVCS will provide a boost to use EVs without the burden of adopting charging infrastructure individually. Due to the absence of converter circuits, this system will utilize power more efficiently and use less space. The ever-increasing dip observed in the duck curve can be finally neutralized and the burden from power system infrastructure and the power generating companies during peak hours can be reduced substantially. It will also help to achieve the goal of green mobility as even the power generated for electric vehicles will cause zero carbon emission. This system holds the potential to provide jobs and also taxation strategy can be implemented more conveniently than the tax that is being collected on fossil fuels today to run the economy of the country. This system will replace the pollution-based fossil fuel run vehicles by eco-friendly technology without affecting the economical growth of the country.

APPENDIX

Figure 1 shows the power production of a 100kW solar power plant. It is the curve generated in MATLAB.
The parabolic equation:
Y= -2.778x^2+66.667x-300
Is the curve represented power output. This equation is also used in section V(B) to find the excess power generated by the given power plant by integrating between time 10:00 to 15:00 of the day.

REFERENCES

[1] https://www.abc.net.au/news/2017-02-08/forecast-consumer-demand-on-south-west-interconnected-system/8249822

[2] Experimental Analysis of DC Electric Vehicles Charging Station Operation and its Impact on the Supplying Grid, Ryszard Pawełek, Paweł Kelm, Irena Wasiak, Institute of Electrical Power Engineering, Lodz University of Technology.

[3] Power Process. Syst., “AV-900 heavy duty cycling stations,”2007. [Online].Available:http://www.avinc.com/downloads/AV-900_WS_Specs.pdf

[4] A. M. Rahimi, “Lithium-ion battery charger for charging up to eight cells,” in Proc. Vehicle Power and Propulsion Conf., 2005, pp.131-136

[5] Pricing Strategy and Charging Management for PV assisted Electric Vehicle Charging Station Jisheng Tao, Debao Huang,Deling Li, Xian Yang, and Chanhui Ling

[6] https://www.slideshare.net/mobile/viv3ksharma/constant-current-battery-charger

[7] Research on Electric Vehicle Fast Charging Station Billing and Settlement System, Juan Liu, Beijing SG-EPRI UHV Transmission Technology Company

[8] Rapid-Charge Electric-Vehicle Stations, Mehdi Etezadi-Amoli, Senior Member, IEEE, Kent Choma, Member, IEEE, and Jason Stefani, Student Member, IEEE

[9] Research and Implementation of Electric Vehicle Fast Charging Station Parking, Guidance System based on Mobile Terminal, Juan Liu, Beijing SG-EPRI UHV Transmission Technology Company State Grid Electric Power Research Institute, Beijing, China

[10] economic incentives for reducing peak power utilization in electric vehicle charging stations, Jonathan Marty, Stanley Pietrowicz, Vincore labs, NJ,USA.