Title
Sustainable Campus with PEV and Microgrid

Permalink
https://escholarship.org/uc/item/0km3r882

Authors
Singh, Reshma
Kumar, K Nandha
Sivaneasan, B
et al.

Publication Date
2022-12-21

Sustainable Campus with PEV and Microgrid

K. Nandha Kumar, B. Sivaneasan, P. L. So, H. B. Gooi, Nilesh Jadhav,
Nanyang Technological University, Singapore
Reshma Singh and Chris Marnay, Lawrence Berkeley National Laboratory

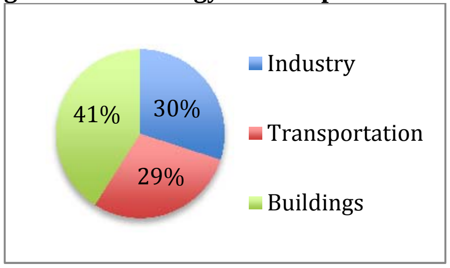
ABSTRACT

Market penetration of electric vehicles (EVs) is gaining momentum, as is the move towards increasingly distributed, clean and renewable electricity sources. EV charging shifts a significant portion of transportation energy use onto building electricity meters. Hence, integration strategies for energy-efficiency in buildings and transport sectors are of increasing importance. This paper focuses on a portion of that integration: the analysis of an optimal interaction of EVs with a building-serving transformer, and coupling it to a microgrid that includes PV, a fuel cell and a natural gas micro-turbine. The test-case is the Nanyang Technological University (NTU), Singapore campus. The system under study is the Laboratory of Clean Energy Research (LaCER) Lab that houses the award winning Microgrid Energy Management System (MG-EMS) project. The paper analyses three different case scenarios to estimate the number of EVs that can be supported by the building transformer serving LaCER. An approximation of the actual load data collected for the building into different time intervals is performed for a transformer loss of life (LOL) calculation. The additional EV loads that can be supported by the transformer with and without the microgrid are analyzed. The numbers of possible EVs that can be charged at any given time under the three scenarios are also determined. The possibility of using EV fleet at NTU campus to achieve demand response capability and intermittent PV output leveling through vehicle to grid (V2G) technology and building energy management systems is also explored.

Introduction

Improving energy efficiency in buildings and transportation, which together constitute two-thirds of energy end-use in the U.S., as shown in Figure 1, has traditionally followed parallel strategies; however, that situation needs to change.

Figure 1. U.S. energy end-use pie chart



Source: U.S. Department of Energy (DOE), *2012 Buildings Energy Data Book,* Section 1.1.1, 2012.

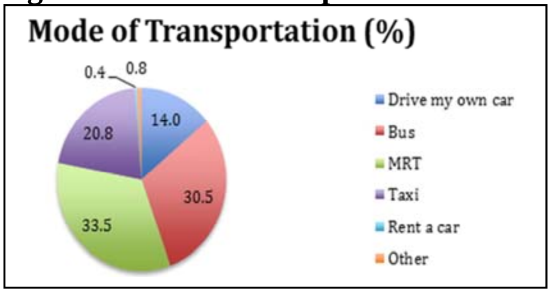
In California, for instance, transportation accounts for 40 percent of the state's greenhouse gas emissions. The California Air Resources Board’s Jan 2012 Advanced Clean Car Package now requires automakers to cut emissions from all new vehicles in half by 2025, and it anticipates a total of 1.4 million zero-emission and plug-in hybrid vehicles (PHEV) on the road in California by 2025. It also stipulates that by 2025, 15% of all new cars and trucks sold be powered by batteries, hydrogen fuel cells, or other technology that produces little or no air pollution. PHEVs and Electric Vehicles (EVs) have the greatest potential for widespread market penetration and the literature indicates that most PHEV charging will likely occur at buildings and homes during off-peak hours (Electric Power Research Institute 2007). Analysis shows that PHEV’s will increase residential building energy loads by 13% and electricity use by 55% for a 2010 vintage home (Rohloff, Roberts & Goldstein, 2010). The additional load implications will adversely affect building energy targets, especially the U.S. 2030 Buildings Challenge which sets goals at a 60% reduction in energy use by 2015, 90% reduction by 2030 and 100% (Zero Net Energy) by 2035. On the other hand, effective management of PHEVs in conjunction with the grid could have mutually beneficial impacts. It is estimated by the International Energy Agency (IEA) that electrified transport could reduce GHG emissions by 30% around the world by 2050.

Singapore has also set aggressive transport and buildings energy efficiency goals and has a targeted National Climate Change Policy. Its hot tropical climate, lack of natural resources and expanding economy pose interesting energy challenges. Transportation and buildings have been major sources of green-house-gases emissions (GHG), contributing 18% and 17% respectively. There were about 950,000 motorized vehicles in Singapore at the end of 2010, while the total population is just over 5 million. (Source: Land Transport Authority-Singapore). Singapore is actively considering deployment of EVs and launched its EV test-bed program in June 2011 to assess the benefits and feasibility of adopting EVs in Singapore. This program incentivizes purchase of EVs through the Enhanced Transport Technology Innovation and Development Scheme (TIDES+), which allows a waiver on all vehicular taxes for the test-bed participant, making the EV 50-60% cheaper. In return, the participant is obligated to log in key data such as number of passengers in the EV, weather conditions and air-conditioning status via a smart device located within the EV for every trip.

EVs have ranges usually between 90km to 160km (56 miles to 100 miles), which is well within limit of the average travel distances of 55km (34 miles) in Singapore (LTA), and therefore is less cause for ‘range anxiety’. Here, electricity is generated using predominantly imported natural gas; current well-to-wheel emissions estimates from automakers show about 66% reduction in carbon emissions when switching from a gasoline car to an equivalent-size EV (Source: Renault-Nissan). Singapore is actively looking at renewable energy resources such as solar energy to diversify its fuel mix and also reduce its environmental impact. This makes the future case for EVs even stronger. As part of the EV test-bed program, Bosch is tasked to design, develop and deploy up to 60 normal charging stations (full charge within 7-8 hours) and 3 quick charging stations (full charge within 30-45 minutes), and the charging infrastructure will be scaled up to match the take-up rate of EVs for the test-bed. However, the capability of the power distribution network to support the EVs has to be verified and the corresponding impacts of additional loads in the form on the distribution system are to be determined.

The Nanyang Technical University (NTU) is one of Singapore’s two largest public universities with the biggest campus, with 200 hectares area, with 30,000 students and 6,000 faculty and staff. NTU announced its Campus Master Plan in February 2011, whereby it established its intention to become a mini-city, with adoption of energy efficient and sustainable technologies, and possibly including provisions for EVs (electric buses, cars and bikes) for transportation. A recent survey[1] conducted on the campus revealed that the majority of the travel around the campus is already made using shuttle bus service. (Fig 2)

Figure 2. Mode of transportation to NTU



Two-thirds of respondents travel by public transport to NTU, and use three different shuttle routes within campus (Route-A, Route-B and Route-C) and one route (Route-D) connects the campus to Pioneer Mass Rapid Transport (MRT, Singapore's metro system) station. The energy consumption and CO_2 emissions of the shuttle buses on campus is tabulated in Table 1. The campus has a hilly terrain, making it more amenable to PHEVs, and suitable for harvesting energy through regenerative braking and hence the efficiency gain will be high. This scenario is also more favorable when compared to diesel-powered buses, which have high CO_2 emissions.

Figure 3. NTU campus photos showing the hilly terrain and commuters waiting for shuttle bus

Table 1. Energy consumption and CO_2 emissions of shuttle buses on campus (per day)

Route	Daily Average Bus km Travelled	Total Energy Consumption in kWh	Total Tail Pipe CO_2 emissions in kg	Total CO_2 emissions in kg
Shuttle Bus-A	208	595	125	144
Shuttle Bus-B	203	478	121	140
Shuttle Bus-C	430	1220	256	294

---

[1] Survey conducted by the Energy Research Institute @NTU in January 2012 with 108 respondents including staff and students on NTU campus

Proposed Methodology

There are numerous methods in the literature that can be used to determine the impact of electrification on transportation; however, few studies have estimated the number of EVs that can be deployed with current power generation capacity (Ipakchi & Albuyeh, 2009), or estimated the total power generation requirement for a stipulated EV fleet percentage (Shrestha & Ang, 2007). No proper methodology exists in the literature for estimating the capacity of distribution transformers to support the EV fleet. Each distribution transformer has different capacity and characteristics that determines the amount of EVs it can handle at any given time. The distribution transformers are the weakest links of a power system because of their relatively low capacity and low operating voltage. Due to the additional load created by EVs, the distribution transformers are relatively stressed more than any other equipment in the distribution system (Masoum, Moses & Smedley, 2011). Hence estimating the capability of distribution transformers to support EVs is important in order to determine the capability of whole system. The loss of life (LOL) of the distribution transformer is an important factor to consider as it is directly related to reliability and economics of the system (Gong et al. 2011). Any premature/unexpected failure of the distribution transformer is not only associated with replacement cost but also the revenue loss due to supply interruption. A study on the capacity of the transformer will provide the amount of additional EV loads that can be supported by the transformer such that the additional load has minimal effect on the transformer's life expectancy. The decision on the amount of LOL allowed will be taken by the power system operators, in the case of NTU it is the Office of Development and Facilities Management.

A methodology is now proposed for estimating the number of EVs that a transformer can support and also study the impact of penetration of a microgrid on the number of EVs. The 60kVA transformer serving NTU's Laboratory of Clean Energy Research (LaCER) is taken as the test case. LaCER houses an award winning[2] Microgrid Energy Management System (MG-EMS) project. The microgrid prototype incorporates software applications that manage sensing data and perform load and generation management. A number of traditional and renewable energy sources, namely synchronous generators, solar PVs, wind turbines, fuel cells and battery banks are installed in the microgrid setup (see Table 3). (Fuel cell and micro turbine are operated during morning and evening peak periods.) Control algorithms are implemented to allow both grid connection and islanded operations of the microgrid. A Low-Voltage (LV) Distribution panel is simulated as industrial/commercial and housing loads as part of the microgrid. The hardware components including On-Line Tap Changers (OLTCs), circuit breakers and relays of the whole system are controlled by MG-EMS in a server. The developed microgrid and the MG-EMS server system will be used in the future for test-bedding EV management and control schemes. It is therefore important to analyze the load capacity of the transformer serving LaCER and estimate the number of EVs it can support. Furthermore, using smart charging, the voltage regulation, power losses and harmonics can be maintained within required limits (Clement, Haesen & Driesen, 2010; Deilami et al. 2010 & 2011). Tables 2 and 3 describe the transformer and microgrid parameters.

---

[2] Best Innovation in Green Engineering Award, ASEAN Virtual Instrumentation Applications Contest Singapore, 20 October 2010.

Table 2. Transformer parameters

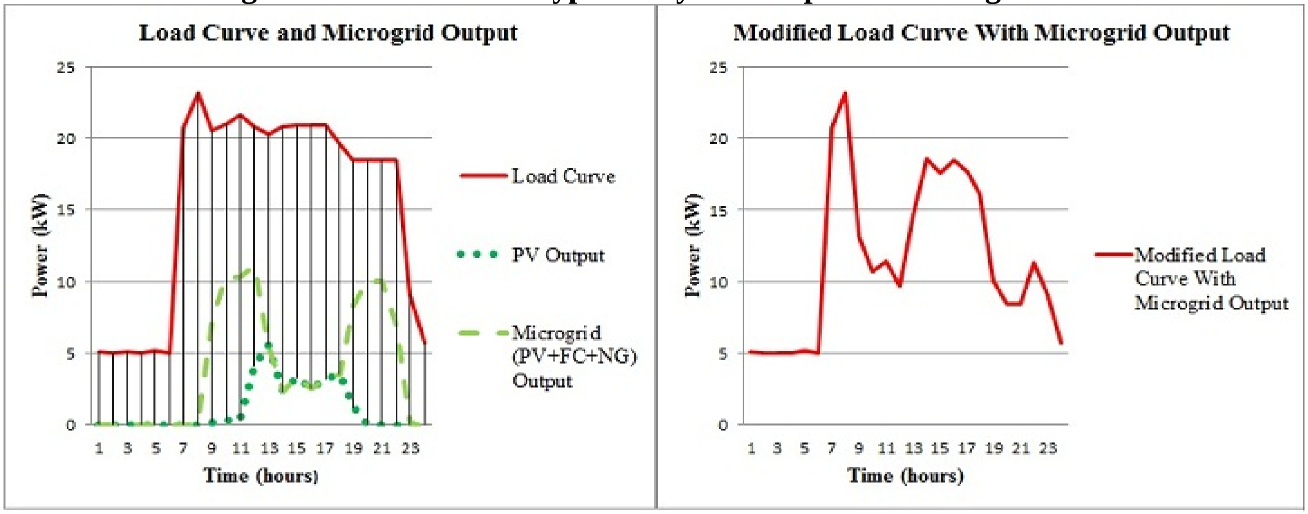
Life of transformer (Hours):	180000
Ambient temperature (°C):	30
Rated load (kVA):	60
Ratio of full load loss and no load loss:	4.5
Empirical constant M:	0.7
Empirical constant N:	0.7
Top oil temperature rise over ambient at rated load (°C):	45
Hotspot temperature rise over top oil, at rated load (°C):	35
Oil thermal time constant for rated load (Hours):	4.89

Table 3. Microgrid parameters

Source	Output Power	Operating Hours (based on Peak period)
Solar PV	10kW peak	Actual output based on solar radiation
Fuel cell (FC)	5kW continuous	8.00 to 11.30 hours and 18.30 to 21.30 hours
Natural Gas Micro Turbine	5kW continuous	8.00 to 11.30 hours and 18.30 to 21.30 hours

In order to obtain the maximum number of EVs, the LOL of the transformer's insulation is analyzed. The transformer load data obtained for a period of 30 days spread over 3 months is used for the analysis. Since the transformer is supplying power to a building used for educational purposes, its load profile is similar to a commercial building, significant since mid-sized commercial buildings are attractive hosts for Distributed Energy Resources (DER) adoption. Load curve for a typical day and impact of penetration of microgrid are shown in Figure 4.

Figure 4. Load curve of typical day with impact of microgrid



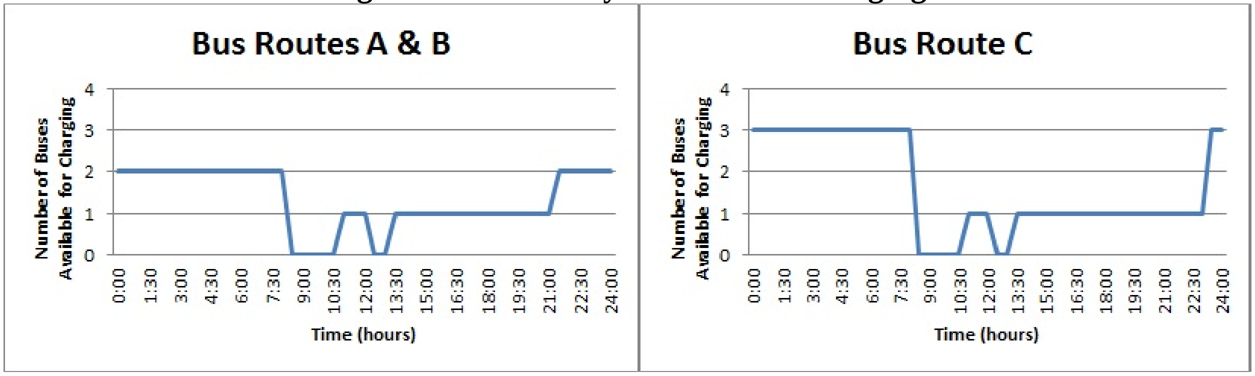
Since the life of the transformer's insulation depends on its average load during a particular period rather than the instantaneous load, approximation of the actual load curve into time intervals is needed. The approximation of the load curve is obtained by:

$$L = \sqrt{\frac{L_1^2 t_1 + L_2^2 t_2 + L_3^2 t_3 + \cdots + L_n^2 t_n}{t_1 + t_2 + t_3 + \cdots + t_n}} \qquad (1)$$

where L_1, L_2, etc. are the various load steps in percentage per unit ,in actual power (kVA) or in current (A), and N is the total number of loads considered. t1, t2, etc. are the respective durations of these loads in minutes.

The intervals for the load approximation are decided based on a number of factors. Firstly, the starting time of the off-peak period of the load curve, which is approximately 22:00 hours, is considered. Secondly, the approximate time required for the transformer insulation to cool down to the desired temperature is taken to be approximately 2 hours. Thirdly, the average charging time required for the electric vehicles is taken to be around 6-10 hours to reach 100% state of charge (SOC). Finally, the availability of the electric vehicles for charging is also considered. Currently, there are 2 buses in service each for routes A and B, and 3 buses for route C. Although there are multiple numbers of buses per route and varying schedules (see Fig 5), for the sake of analysis in this paper the estimation of the EV fleet considers only 1 route A bus to be charged at the charging station located at LaCER.

Figure 5. Availability of Buses for Charging



An approximated load curve is shown in Figure 6, where Interval 1 is from 00:00-08:00 hours, Interval 2 is 08:00-11:30 hours, Interval 3 is 11:30-15:00 hours, Interval 4 is 15:00-18:30 hours, Interval 5 is 18:30-22:00 hours and Interval 6 is 22:00-00:00 hours. The time duration during which the load is normal/medium (08:00-22:00 hours) is further divided into four intervals to clearly visualize the impact of the microgrid. Further, the energy that the transformer can supply with the allowed LOL can be calculated using the algorithm as shown in Figure 7.

Figure 6. Approximated load curves with and without microgrid

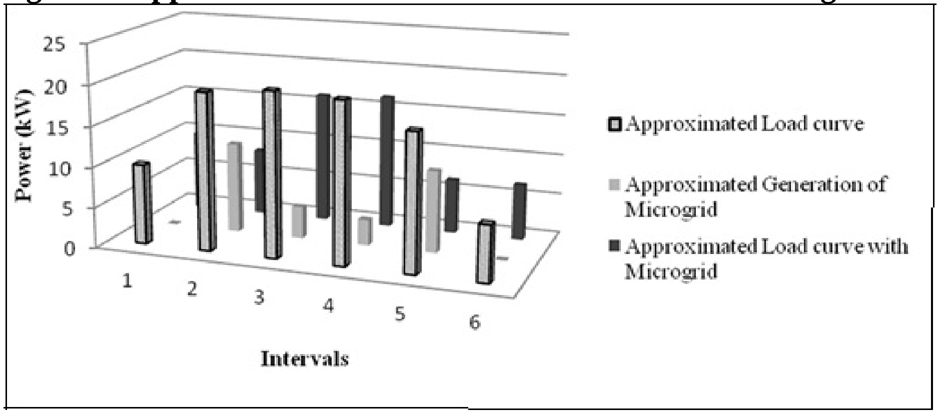
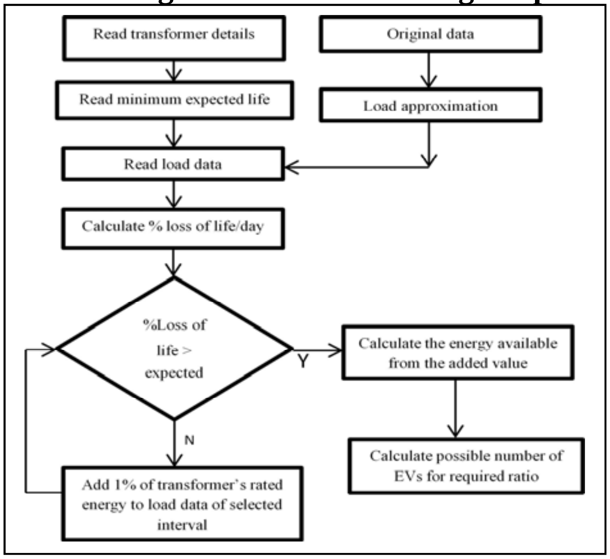


Figure 7. Flow chart of the algorithm for calculating the possible number of EVs



The calculated energy will be used to estimate the possible number of EVs that can be charged using that transformer at any given time. The transformer LOL is determined by

$$F_{AA} = \exp^{\left[\frac{1500}{383} - \frac{1500}{\Theta_H + 273}\right]} \quad (2)$$

$$F_{EQA} = \frac{\Sigma_{n=1}^{N} F_{AA} \cdot n \cdot \Delta t_n}{\Sigma_{n=1}^{N} \Delta t_n} \quad (3)$$

$$\%LOL = \frac{F_{EQA} \cdot 24 \cdot 100}{Expected\ Insulation\ Life} \quad (4)$$

F_{EQA} is the equivalent aging factor for the total time period,
n is index of the time interval, t,
N is total number of time intervals,
$F_{AA,n}$ is aging acceleration factor for the temperature which exists during the time intervalt_n,
t_n is time interval, hours,
Θ_H is the winding hotspot temperature, °C.

The winding hotspot temperature is calculated using the method explained in Annexure C of IEEE Std C57.91-1995. However, if some actual measurements are made using devices[3] then more accurate results can be obtained. While calculating the energy available, the LOL is calculated for every day (base LOL) and the average for 30 days of the calculated LOL is verified in order to ensure that the added energy is within the limits of the expected value.

EV Fleet Estimation based on Transformer LOL Calculation

Maximum possible number of EVs is analyzed for:

1. Case 1: 10% additional LOL with only overnight charging at time intervals 1 and 6.

---

[3] Devices such as mentioned at (http://www.bplglobal.net/eng/knowledgecenter/download.aspx?id=393)

2. Case 2: 20% additional LOL with 24 hour charging, where during the night only one shuttle bus and a few other vehicles can be charged; during the day a few vehicles can be charged.
3. Case 3: 20% additional LOL with 24 hours charging including the impact of the microgrid where output from PV and 60 kWh from fuel cell and micro turbine is considered.

All the calculations made for finding the maximum possible number of EVs are based on the conservative approach rather than the optimized approach. Only an energy-based calculation is performed where the rating, number, and type of chargers are not considered in the simulation model.

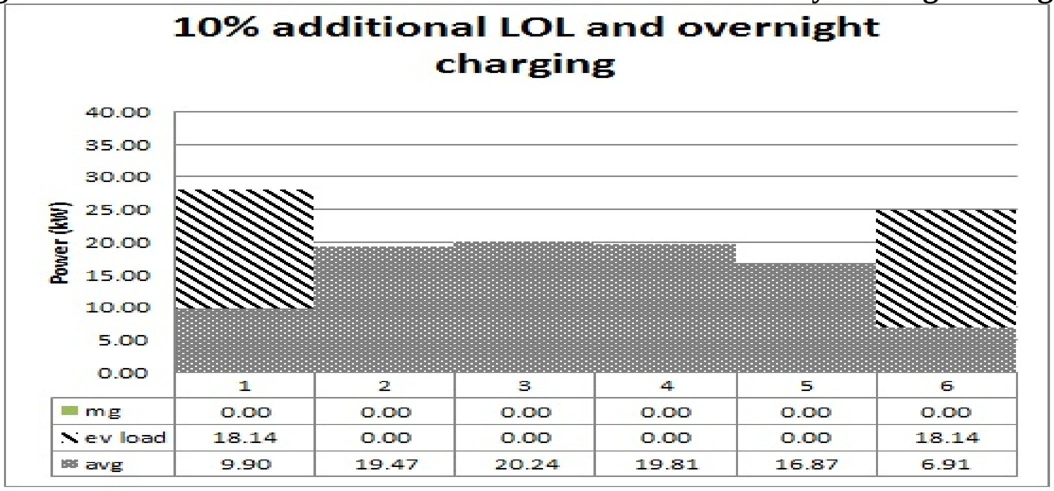
Figure 8 shows the additional EV loads that can be supported by the transformer in Case 1. The transformer can support up to 18.144 kW additional loads during this time interval.

Figure 9 shows the additional EV loads that can be supported by the transformer in Case 2. The transformer can support up to 18.144 kW additional EV loads during time intervals 1 and 6 while 11.726 kW additional EV loads can be supported during time intervals 2 to 5.

Figure 10 shows the additional EV loads that can be supported by the transformer in Case 3. This analysis takes into consideration the impact of the microgrid on the transformer capacity--with the PV output as well as a combined 60 kWh output of the fuel cell and micro turbine. The fuel cell and micro turbine are operated only during intervals morning and evening peak periods, i.e. time intervals 2 and 5. The output of the PV supports the grid during intervals 2 to 4 based on actual solar radiation data[4]. The microgrid output totals approximately 11 kW, 4 kW, 3 kW and 10 kW during intervals 2, 3, 4, and 5 respectively. Considering the impact of the microgrid, the transformer can support an average of 17.4 kW of additional EV loads throughout the day.

The number of EVs that can be charged under each case is shown in Table 4. It can be clearly seen that the microgrid has significant impact on the number of EVs that can be supported with an increase of approximately 33% (considering EV cars) compared to without the microgrid coming online. Note that a specific fleet was not chosen for this analysis; instead the number of each type of vehicle was analyzed.

Figure 8. Load curve for Case 1: 10% additional LOL and only overnight charging



	1	2	3	4	5	6
🟩 mg	0.00	0.00	0.00	0.00	0.00	0.00
▨ ev load	18.14	0.00	0.00	0.00	0.00	18.14
▦ avg	9.90	19.47	20.24	19.81	16.87	6.91

---

[4] (http://nwsp.ntu.edu.sg/weather/portal_download.php)

Figure 9. Load curve for Case 2: 20% additional LOL and 24 hours charging

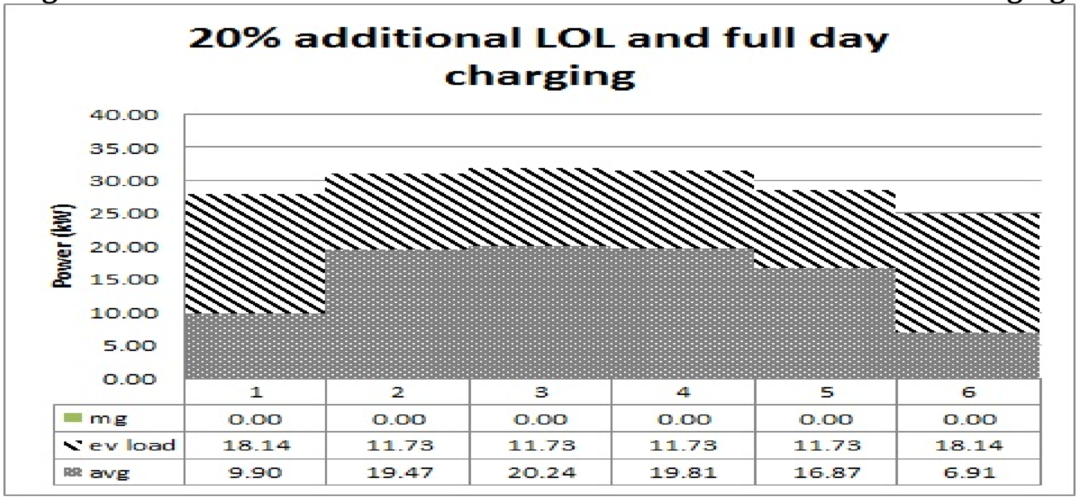


Figure 10. Load curve for Case 3: 20% additional LOL, 24 hours charging with microgrid

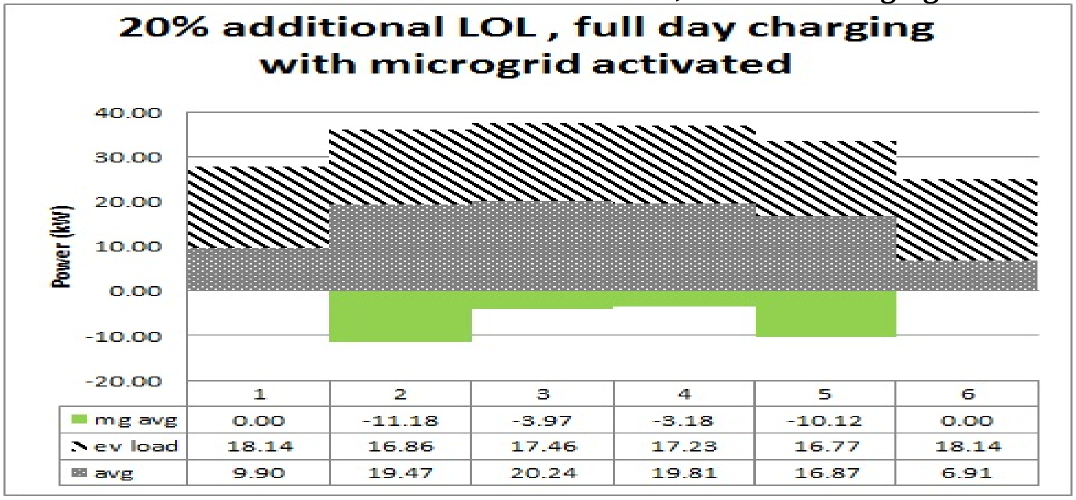


Table 4. Estimated number EVs for different case scenario

Scenario		Cars	Motorcycles	Quad/tricycle	E-moped	Bicycle
Case 1	Total EVs	13	68	33	119	318
	Total EVs with 1 A-bus	3	16	8	29	76
Case 2	Total EVs	25	130	63	227	606
	Total EVs with 1 A-bus	15	78	38	137	364
Case 3	Total EVs	30	156	76	274	730
	Total EVs with 1 A-bus	20	105	51	183	488

The numbers shown in Table 4 are estimation for the number of each type of vehicle where no combination of vehicles (fleet) is considered. For example in Case 1, either 13 cars or 68 motorcycles or 33 quad/tricycles or 119 e-mopeds or 318 bicycles can be charged. When one route-A shuttle bus is charged then the change in numbers are indicated in second row of Case 1. The difference between Case 1 and Case 2 gives the number of vehicles that can be charged during daytime. The difference between case 2 and case 3 will give the impact of microgrid.

Vehicle to Grid Technology

Electrification of transportation not only improves efficiency over an internal combustion engine, it also decreases the carbon footprint of the transportation sector. When parked, EV batteries could be used to let electricity flow from the car back to the power lines, adding value to the utilities. This Vehicle-to-Grid (V2G) technology can provide the short bursts of power used to correct imbalances in the electric power grid and can also be used to level the fluctuations inherent in DERs such as solar and wind energies.

All major industrial and commercial consumers in Singapore, including large buildings purchase power from the utility or gencos/retailers on a 30-minute maximum demand interval, with a contracted capacity to meet maximum demand. The contracted capacity is the declared purchasing capacity of the consumer. The consumer will be charged 50% more if the declared contracted capacity is exceeded. On the other hand, if actual usage is less, the consumer will still be billed according to the contracted capacity. The tariff details for High Tension Small (HTS) Supplies usage charges are given in Table 5.

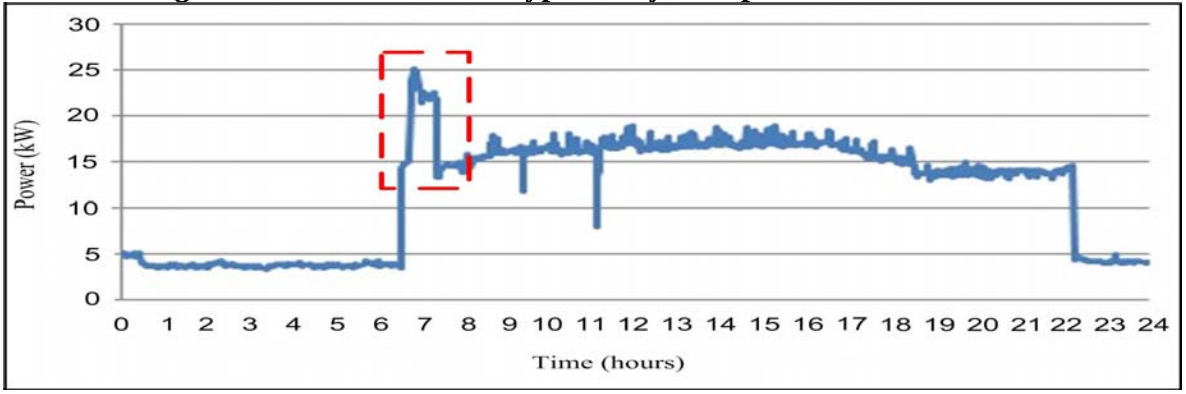
Table 5. Average Peak Period Charge for HTS Supplies

Usage charge	With effect from April 2011 (with 7% GST)
Contracted capacity charge	S$7.45/kW (Monthly rachet)
Un-contracted capacity charge	S$11.17/kW (Monthly rachet)
Peak period charge (0700-2300 hours)	S$0.2578/kWh
Off-peak period charge (2300-0700 hours)	S$0.1581/kWh
Reactive power charge	S$0.0063/kVArh

Various Building Energy Management Systems (BEMS) are being implemented in buildings to ensure that contracted capacity is not exceeded and to reduce energy consumption through energy efficiency measures. One potential function of the EVs is to provide load shifting/leveling capability by storing extra energy at times of low load demand and supplying the stored energy during periods of heavy load demand. Moreover with the presence of DERs as a part of BEMS, the storage devices become inevitable to counter the intermittent nature of DERs. The availability of EVs, which represents a huge energy storage device, that sits parked and unused for long periods of time is an added advantage for BEMS. Furthermore, the batteries used in EVs usually have fast response that performs better than other current energy storage devices. EVs and BEMS can work to reap the benefit of lower cost off-peak power and counter the disadvantage of high energy storage cost. This can also result in improving the utilization factor/load factor of the transformer while the whole system can be more dynamic and efficient.

Taking the typical LaCER's load curve, the microgrid advantage for EVs can be clearly explained. It is assumed that one shuttle bus (Route-A) with battery capacity of 120 kWh is charged overnight during intervals 6 and 1, while 3 cars with battery capacity of 16 kWh and 5 motorcycles with battery capacity of 2 kWh are charged during intervals 2, 3 and 4. Figure 11 shows the load curve of a typical day. The peak demand occurs between 6:45 to 7:20 hours. During this period, the shuttle bus is available for discharging to level the peak load. Energy demand during this interval is around 3 kWh, but on some days it can reach 7-8 kWh. Nonetheless, this energy demand is less than 10% of total energy of the shuttle bus battery capacity. Therefore, discharging the battery at a rate of C/10 or less will not affect its performance and a charge-discharge cycle 10% of DOD (if at all used) will not affect the life the of battery to a great extent. Therefore, the peak demand can be decreased considerably, which reduces the cost of operation of the buildings and improves energy efficiency. During daytime, it would not be wise to level the peak demand using the battery as the penetration of solar power will have much higher savings. EVs as an energy storage device can also be used to level the intermittent output of the PV system.

Figure 11. Load curve of a typical day with peak demand marked



Conclusion

In this paper, a method for estimating the number EVs that a transformer can support based on the important factor of insulation loss of life (LOL) calculation was developed. An algorithm for finding the maximum number of EVs was presented that can be used for other studies. The advantage of coupling a microgrid with the transformer and its impact on the number of EVs that can be supported was also presented. Using the microgrid prototype at LaCER Labs as a test case, it was observed that the transformer can support an average of 17.4 kW of additional EV loads throughout a typical day. This equates to the capacity of charging 30 EV cars, or 20 EV cars plus one bus per 24-hour period. The microgrid has a significant impact on the number of EVs that can be supported with an increase of approximately 33% (considering EV cars) compared to without the microgrid. The possibility of using EVs at the NTU campus to achieve demand response capability and intermittent PV output leveling through vehicle to grid (V2G) technology and building energy management systems was also discussed. In order to optimally deploy an EV fleet, additional research needs to be conducted specifically on reduction of utility costs via load shifting by using the EV as the mobile energy storage in the microgrid. Additionally, business models must be developed wherein a rental EV company can receive reimbursement for helping arbitrage the buildings' operations cost, and for car battery degradation, that can partially offset their mobile storage investment.

References

Adam Rohloff, Jon Roberts, Noah Goldstein. "Impacts of Incorporating Electric Vehicle Charging into Zero Net Energy (ZNE) Buildings and Communities", ACEEE 2010

Clement-Nyns, K.; Haesen, E.; Driesen, J. “The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid”, IEEE Transaction on Power systems, Vol. 25, no. 1, Feb-2010.

Deilami, S.; Masoum, A.S.; Moses, P.S.; Masoum, M.A.S.; "Voltage profile and THD distortion of residential network with high penetration of Plug-in Electrical Vehicles," Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES.

Deilami, S.; Masoum, A.S.; Moses, P.S.; Masoum, M.A.S.; "Real-Time Coordination of Plug-In Electric Vehicle Charging in Smart Grids to Minimize Power Losses and Improve Voltage Profile," Smart Grid, IEEE Transactions on, vol.2, no.3, pp.456-467, Sept. 2011.

G.B. Shrestha, S G Ang, “A study of electric vehicle battery charging demand in the context of Singapore, ” IEEE Power Engineering Conference, 2007.

Gong, Q.; Midlam-Mohler, S.; Marano, V.; Rizzoni, G., “PEV charging impact on Residential distribution transformer life,” Energytech, 2011 IEEE

http://www.arb.ca.gov/msprog/zevprog/factsheets/advanced_clean_cars_eng.pdf.

http://www.bplglobal.net/eng/knowledgecenter/download.aspx?id=393.

http://www.ema.gov.sg/media/files/publications/soo/EMA_SOO_2010_web-2.pdf

http://www.iea.org/papers/2011/EV_PHEV_Roadmap.pdf

http://www.lta.gov.sg/content/lta/en/corporate/facts_figures/statistics.html

http://www.mitsubishimotors.com/corporate/about_us/technology/review/e/pdf/2008/20e.pdf.

http://nwsp.ntu.edu.sg/weather/portal_download.php.

Ipakchi, A.; Albuyeh, F.; “Grid of the future”, Power and Energy Magazine, IEEE-April 2009.

“IEEE Guide for Loading Mineral-Oil-Immersed Transformers”, IEEE Std C57.91-1995.

Masoum, M.A.S.; Moses, P.S.; Smedley, K.M., "Distribution transformer losses and performance in smart grids with residential Plug-In Electric Vehicles," Innovative Smart Grid Technologies (ISGT), 2011

Schremp, Gordon, Jim Page, and Malachi Weng-Gutierrez. 2009. "Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report." CA.: California Energy Commission.

Stadler Michael, Marnay Chris, Sharma Ratnesh, Mendes Goncalo, Kloess Maximillian, Cardoso **Goncalo, Megel Olivier, Siddiqui Afzal. “Modeling Electric VehicleBenefits Connected to Smart** Grids”, 7th IEEE Vehicle and Power Propulsion Conference (Chicago) Sep 2011.

U.S. Department of Energy (DOE), 2008 Buildings Energy Data Book, Section 1.1.1, 2008.