A Sustainable Campus with PEVs and Microgrid

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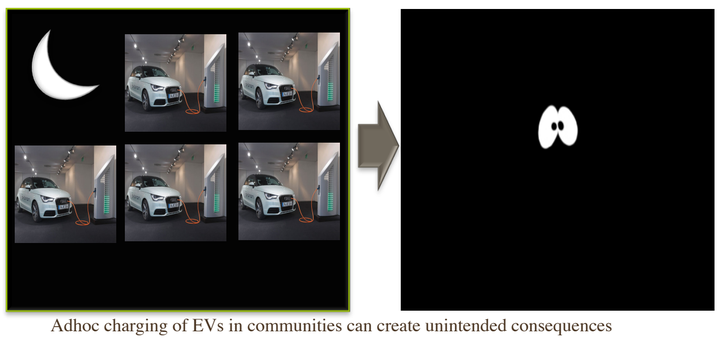
ABSTRACT

Twin goals for Buildings and Transportation



Adhoc charging of EVs in communities can create unintended consequences

Market penetration of plug-in electric vehicles (PEVs or 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. On the same and, buildings are aspiring to Net Zero status especially policies in several countries such as the 2030 US Buildings Challenge isn the US and natinal Climate Change Policy in Singapore. 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.

METHODOLOGY

Goal: Derive potential additional (vehicle charging) loads with given transformer capacity; with additional optimizations such as through microgrid and V2G charging.

NTU is one of the two main universities in Singapore. Campus photos show the hilly terrain and commuters waiting for their preferred mode of transport-- the shuttle bus.

Singapore at the macrolevel:

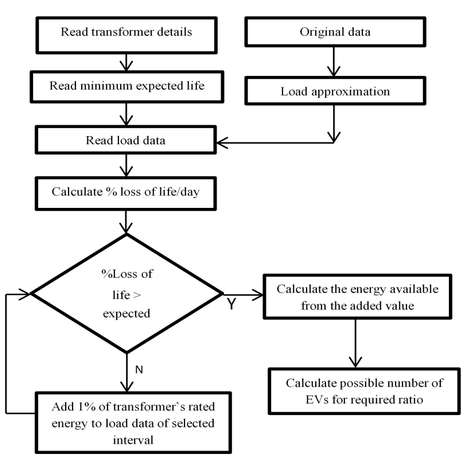
- An aggressive National Climate Change policy.
- A hot tropical climate, lack of natural resources and expanding economy pose interesting energy challenges.
- Launched EV test-bed program in June 2011 and incentives, making EVs 50-60% cheaper.
- Average travel distance 55 km(34 miles), within EV range.

Case study- NTU Green Campus initiative:

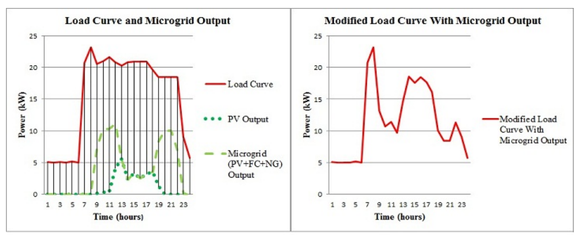
- Campus of 200 ha, 30,000 students; 6,000 staff.
- Intention to be a mini-city with EV fleet.
- Majority of Campus travel via shuttle buses
- Hilly terrain good for regenerative braking of PHEVs.
- Educational buildings such as LaCER (which has a microgrid demonstration) with load profiles similar to commercial buildings-attractive hosts for Distributed Energy Resources (DER).

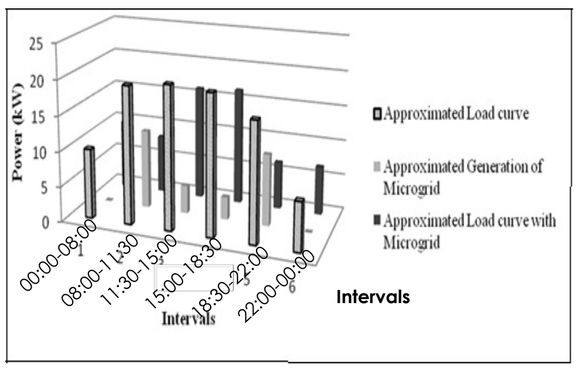
Route	Daily Average Bus km Travelled	Total Energy Consumption in kWh	Total Tail Pipe CO_2 emissions in kg	Total CO_2 emissions in kg
Shuttle Bus-A	208	595	125	144
Shuttle Bus-B	203	478	121	140
Shuttle Bus-C	430	1220	256	294

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



Flowchart of the algorithm for calculating the possible number of EVs.





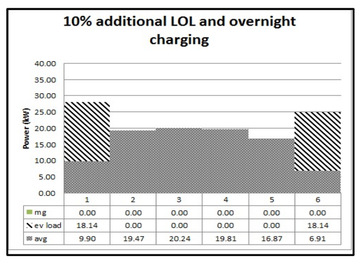
Load curve of typical day without and with impact of microgrid

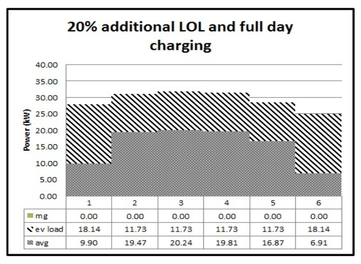
Steps taken:

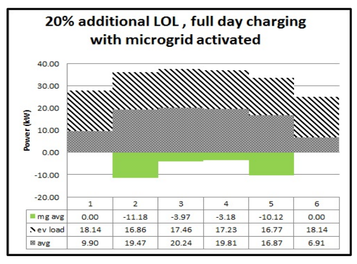
1. The transformer load data obtained for a period of 30 days spread over 3 months.
2. LOL of the transformer's insulation analyzed, based on critical factors such as winding hotspot temperature, expected insulation life and aging acceleration factor
3. Calculated energy used to estimate the possible number of EVs that can be charged using that transformer at any given time using three scenarios, using time intervals.
4. Considered additional supply from the LaCER microgrid onto the transformer capacity-- with the PV output as well as a combined 60 kWh output of the fuel cell and micro turbine. Recalculated 3 case scenarios based on microgrid supply.

FINDINGS

3 case scenarios were analyzed: using time intervals in a 24-hour period to ascertain daytime and nightime charging, and impact of microgrid and V2G charging.







Case 1:

- 10% additional LOL with only overnight charging at time intervals 1 and 6.
- Transformer can support up to 18.144 kW additional load in Time intervals 1 and 6

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.
- The transformer can support up to 18.144 kW during time intervals 1 and 6 while 11.726 kW additional EV loads can be supported during time intervals 2 to 5

Case 3:

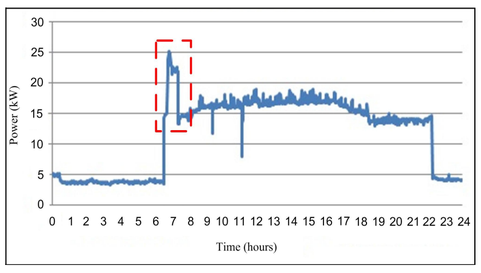
- 20% additional LOL with 24 hours charging including the impact of the microgrid where output from PV and 60 kWh from fuel cell and micro turbine is considered.
- Considering the impact of the microgrid, the transformer can support an average of 17.4 kW of additional EV loads throughout the day

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

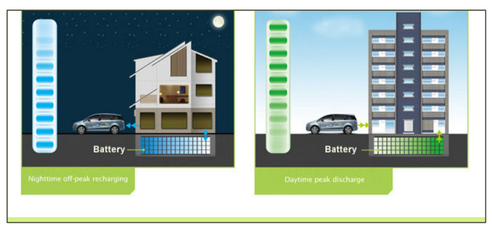
Estimated number EVs for different case scenarios

Additional Loads and Microgrid impact

i. The additional loads can be calculated using our algorithm to inform how many EVs can be charged in the daytime and nighttime without stressing the transformer.
ii. The impact of this particular microgrid is that it gives a 33% advantage in numbers of EVs that can be charged.



Load curve of a typical day at LaCER highlighting peak demand



Vehicle to Grid charging can have peak load shaving advantage

Additional Loads and V2G impact:

The peak demand occurs between 6:45 to 7:20 hours at the LaCER building. 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. This can help correct imbalances in the electric power grid and level the fluctuations inherent in DERs such as solar and wind energies. Batteries used in EVs usually have fast response that perform better than other current energy storage devices.

CONCLUSIONS

Charging of an EV Fleet can be optimized for efficiency of their operations in sustainable communities

- The methodology in this study can save xx amount of Co2 emissions in the case of NTU
- The methodology can save large infrastructure investment and replacement of burnt out transformers by optimizing fleets to current carrying capacity of building transformers
- This methodology proves the advantage of coupling a microgrid with the transformer and its impact on the number of EVs that can be supported.
- Methodology can be replicated for sustainable communities –especially valid for small communities with short driving distances, particularly where charging and discharging can be enabled without range anxiety.
- Strong potential in such a community to achieve demand response capability and intermittent PV output leveling through vehicle to grid (V2G) technology and building energy management systems

Photo: Dan Saelinger/ Getty Images

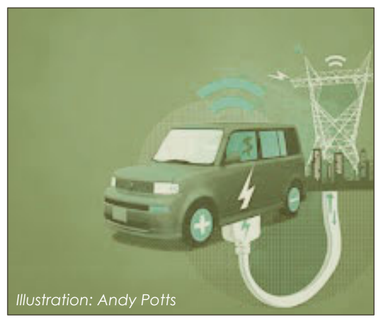


Illustration: Andy Potts

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