Project: Simulation of electric vehicle charging behaviour

A simulation is required of electric vehicle charging behaviour based upon the paper “A statistical analysis of EV charging behaviour in the UK”:

https://www.researchgate.net/profile/Luisnando_Ochoa/publication/283210919_A_statistical_analysis_of_EV_charging_behavior_in_the_UK/links/562e059708ae22b17034cf60/A-statistical-analysis-of-EV-charging-behavior-in-the-UK.pdf?origin=publication_detail

- The paper provides a method for simulating electric vehicle charging demand.
- The simulation should be for N electric vehicles – *N = 1000 initially, I should be able to amend.*
- Probability distribution functions (PDFs) are presented in the paper, these include:
    - Number of Connections per day %. **Note** to simplify things the simulation should be based upon 1 and 2+ connections per day, see **Table A** below: where the PDF for 2+ is an aggregation of the rest.

TABLE A: 1 AND 2+ CONNECTIONS PER DAY - From TABLE I: PDF OF THE NUMBER OF CONNECTIONS PER DAY (%)

No of Connections	1	2+	total
Weekday	71.26	28.74	100.00
Weekend	68.99	31.01	100.00

    - Table II. Initial and Final state of charge per connection (1st, 2nd connection). The simulation should use the PDFs from Table II. This is to simulate the charging behaviour which is different between Weekday and Weekend and dependant on whether the connection is the 1st or 2nd connection of the day.
    - Figure 1 & 2 shows the PDF of the start charging time per connection for Weekday and Weekends for the 1st or 2nd connection of the day. The PDFs are in graph format which have been reproduced in Appendix: **Table B** in these notes. Note these PDFs have been smoothed.
    - Assume a square waveform in charging behaviour – so when not charging Demand kW would be 0, when charging Demand kW would be 3.6kW for the electric vehicle.
    - Note: use of power factor in charging demand (i.e., a constant 3.6 kW demand with a 0.98 power factor) for each connection between the connection time and finishing time. (impacts length of charging).
    - If there are two connections, each charging process must not overlap with the other.
    - PDF used in the simulation should be easy to update.

Software to be used – as I have some familiarity with this.

- Python: SimPy package – including use of real time mode (RealtimeEnvironment)
- OS: Ubuntu 16.04 x64

Requirements

1. Simulation deployed onto 1 cloud instance (vultr.com) ***setup with the simulation running in real time*** and producing a data feed (using print output) every 60 secs for the N data simulations in the following comma delimited format:

Example print output:

ev.ev1, 3.6, 1556363345.384962

The print output will be sent to a timeseries database and viewed in real-time.

Data Item	Description	Sample
Ev_id, e.g. ev.ev1	Metric identifying the electric vehicle from 1 to N vehicles	ev.ev1 ev.ev256
Demand kW, e.g. 3.6	Electric vehicle demand (in kW), when charging this should be 3.6	3.6 – when charging 0 – when not charging
Time, e.g. 1556363345.384962	The python time time() method returns the time as a floating point number expressed in seconds since the epoch, in UTC.	1556363345.384962

2. Creation of EV profiles: A file containing for each minute for the year 2019 and for each of the N electric vehicles its kW demand. Therefore 60*24*365 – 525600 rows * N columns of data as output from the simulation in normal mode.

Expected results

- Individual EV profiles that agree with the PDFs.
- Diversified demand (aggregated demand/N) for the N electric vehicles agreeing with Figure 7 & 8 from the paper.

Appendix: **Table B** - PDF of the start charging time per connection – Weekday & Weekend 15 mins resolution

	Weekday		Weekend	
Time 15 mins starting	**First Connection**	**Second Connection**	**First Connection**	**Second Connection**
00:00	0.836	0.047	1.261	0.009
00:15	1.300	0.047	1.997	0.009
00:30	0.743	0.047	0.420	0.009
00:45	0.650	0.047	0.315	0.009
01:00	0.557	0.047	0.210	0.009
01:15	0.464	0.047	0.158	0.009
01:30	0.371	0.047	0.158	0.009
01:45	0.279	0.047	0.158	0.009
02:00	0.232	0.047	0.158	0.009
02:15	0.232	0.047	0.158	0.009
02:30	0.186	0.047	0.158	0.009
02:45	0.186	0.047	0.158	0.009
03:00	0.186	0.047	0.158	0.009
03:15	0.186	0.047	0.158	0.009
03:30	0.186	0.047	0.158	0.009
03:45	0.186	0.047	0.158	0.009
04:00	0.232	0.047	0.158	0.009

04:15	0.232	0.047	0.158	0.009
04:30	0.232	0.047	0.158	0.009
04:45	0.279	0.047	0.158	0.009
05:00	0.325	0.047	0.158	0.009
05:15	0.371	0.047	0.158	0.009
05:30	0.464	0.047	0.158	0.009
05:45	0.604	0.047	0.158	0.009
06:00	0.743	0.047	0.210	0.009
06:15	0.929	0.095	0.263	0.009
06:30	1.068	0.142	0.315	0.009
06:45	1.207	0.190	0.368	0.009
07:00	1.346	0.237	0.473	0.009
07:15	1.578	0.285	0.578	0.009
07:30	1.671	0.332	0.683	0.009
07:45	1.764	0.380	0.788	0.009
08:00	1.857	0.427	0.998	0.009
08:15	1.857	0.474	1.209	0.009
08:30	1.811	0.522	1.419	0.095
08:45	1.764	0.617	1.576	0.190
09:00	1.578	0.617	1.682	0.284
09:15	1.486	0.522	1.787	0.379
09:30	1.393	0.522	1.839	0.474
09:45	1.161	0.569	1.839	0.569
10:00	0.929	0.617	1.839	0.616
10:15	0.836	0.664	1.839	0.664
10:30	0.789	0.712	1.839	0.711
10:45	0.789	0.759	1.839	0.758
11:00	0.836	0.806	1.839	0.806
11:15	0.836	0.854	1.839	0.853
11:30	0.882	0.901	1.839	0.901
11:45	0.905	0.949	1.839	0.948
12:00	0.929	0.996	1.839	1.043
12:15	0.975	1.044	1.839	1.138
12:30	0.975	1.091	1.734	1.232
12:45	0.975	1.139	1.682	1.327
13:00	0.929	1.328	1.629	1.422
13:15	0.882	1.281	1.576	1.517
13:30	0.882	1.233	1.524	1.612
13:45	0.882	1.281	1.471	1.706
14:00	0.882	1.328	1.419	1.801
14:15	0.905	1.328	1.471	1.896
14:30	0.905	1.376	1.524	1.991
14:45	0.905	1.423	1.576	2.086
15:00	0.929	1.471	1.629	2.180
15:15	0.975	1.423	1.682	2.275
15:30	1.021	1.423	1.734	2.370
15:45	1.068	1.660	1.787	2.465
16:00	1.114	1.898	1.839	2.559

16:15	1.253	1.992	1.839	2.654
16:30	1.393	2.087	1.839	2.844
16:45	1.625	2.135	1.839	2.654
17:00	1.764	2.372	1.839	2.702
17:15	1.950	2.372	1.839	2.559
17:30	1.996	2.609	1.839	2.544
17:45	2.136	2.704	1.787	2.496
18:00	2.136	2.846	1.576	2.449
18:15	2.136	2.704	1.314	2.401
18:30	1.996	2.657	1.314	2.354
18:45	1.950	2.609	1.261	2.307
19:00	1.903	2.562	1.209	2.259
19:15	1.811	2.514	1.156	2.212
19:30	1.764	2.467	1.104	2.165
19:45	1.625	2.467	1.051	2.117
20:00	1.625	2.372	0.946	2.070
20:15	1.625	2.419	0.893	2.022
20:30	1.393	2.277	0.841	1.975
20:45	1.300	2.277	0.788	1.928
21:00	1.161	2.182	0.736	1.880
21:15	1.021	2.135	0.683	1.833
21:30	0.975	2.087	0.631	1.785
21:45	0.929	2.040	0.578	1.738
22:00	0.882	1.898	0.525	1.659
22:15	0.882	1.660	0.473	1.564
22:30	0.836	1.423	0.420	1.469
22:45	0.836	1.186	0.473	1.375
23:00	0.836	0.949	0.420	1.280
23:15	0.836	0.949	1.839	1.090
23:30	0.836	0.569	0.631	0.237
23:45	0.929	0.380	0.420	0.190

Source: Figure 1.
PDF of the start charging time per connection – Weekday.

Source: Figure 2.
PDF of the start charging time per connection – Weekend.