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ELECTRIC VEHICLES **Midterm Project**

As a new type of end-user appliance/load, electric vehicles (EVs) have recently gained more importance as the electrification of the transport sector, which traditionally is a major fossil fuel consumer, is promoted. EVs are different than traditional loads posing challenges and offering opportunities that should be examined in detail.

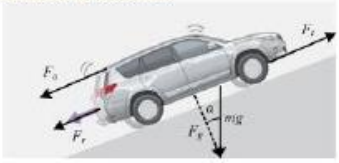
The State-of-Energy (SoE) dynamics of an EV can basically be formulated as:

$$SOE_t^{EV} = SOE_{t-1}^{EV} + CE_{EV} \cdot P_t^{EV,ch} \cdot \Delta T, \quad \forall t > T_a$$
$$SOE_t^{EV} = SOE^{EV,ini}, \qquad if\ t = T_a$$

where

$SOE^{EV,ini}$	initial state-of-energy of the EV [kWh].
CE_{EV}	charging efficiency of the EV.
$P_t^{EV,ch}$	EV charging power [kW].
SOE_t^{EV}	state-of-energy of the EV [kWh].
T_a	EV arrival time.
ΔT	Time granularity

A sample modeling concept for EVs can be described as follows:



$$P(t) = \frac{P_v(t)}{\eta_d}$$
$$P_v(t) = v(t) \cdot F_t(t)$$
$$F_t(t) = m_v \frac{dv(t)}{dt} + F_a(t) + F_r(t) + F_g(t) + F_d(t)$$
$$F_a(t) = \frac{1}{2} \cdot \rho \cdot A \cdot C_x \cdot v(t)^2$$
$$F_r(t) = m_v \cdot C_r \cdot g \cdot \cos(\alpha)$$
$$F_g(t) = m_v \cdot g \cdot \sin(\alpha)$$

where

$P(t)$	Electrical power demand in period t [W]
$P_v(t)$	Mechanical power demand in period t [W]
η_d	Drive train efficiency
$F_t(t)$	Total tractive effort (traction force) in period t [N]
$F_a(t)$	Aerodynamic drug force in period t [N]
$F_r(t)$	Rolling friction (resistance) force in period t [N]
$F_g(t)$	The force caused by the gravity when driving on non-horizontal roads (hill climbing force in period t [N]
$F_d(t)$	The disturbance force that summarizes all other effects in period t [N]
A	Front surface [m^2]
C_x	Drag coefficient
C_r	Rolling resistance coefficient
m_v	Vehicle mass [kg]
α	Road slope [rad]
g	Gravity of earth [m/s^2]
ρ	Density of air [kg/m^3]
$v(t)$	Vehicle speed in period t [m/s]

Here it should be noted that:

- $m_v \frac{dv(t)}{dt}$ (Acceleration force) will be negative if the vehicle is slowing down.
- $F_g(t)$ will be negative if the vehicle is going downhill
- A typical value for the drag coefficient is 0.3, but there are some designs that have achieved a lower value of 0.19. For motorcycles and buses, this goes up to 0.7-0.8.
- The main factors affecting the rolling resistance coefficient are the type of tyre and the tyre pressure. If the tyres are pumped up to a higher pressure, the performance of the vehicle becomes better, but the driving becomes less comfortable (0.015 for a radial ply tyre, can be down to 0.005 for specific tyres developed for vehicles).
- The density of air surely varies with temperature, attitude and humidity. However, the use of standard 1.25 value is reasonable for most cases.
- The numerical expression of $\frac{dv(t)}{dt}$ is simply the difference between consecutive values of $v(t)$ divided by the time step as:

$$\frac{dv(t)}{dt} = \frac{v(t) - v(t-1)}{\Delta T}$$

where ΔT is the time granularity **which must be defined in or converted to seconds specifically for this equation.**

The vehicle specifications are summarized as follows:

Drag coefficient=0.19	Front surface=1.8 m^2
Rolling resistance coefficient=0.0048	Drive train efficiency=0.85
Vehicle mass=1580 kg (1400 kg vehicle plus 2 passenger of each 90 kg)	Gravity of earth=9.81 m/s^2
EV battery capacity=22 kWh EV charging power=6.6 kW	Density of air=1.25 kg/m^3

Assume that there is no slope for the road the vehicle travels ($\alpha = 0$) and no disturbance force. There are three separate identical vehicles (EV-1, EV-2 and EV-3) departing from different destinations and reaching a common place for parking. EV-1 departs from destination A at 2:10 with an initial SoE of 11 kWh and reaches to the parking lot D in 15 minutes with the speed variation given in the following table. Besides, EV-2 departs from destination B at 2:35 with the initial SoE of 13.6 kWh and reaches to the parking lot D in 11 minutes with the speed variation also given in the following table. Moreover, EV-3 departs from destination C at 2:50 with the initial SoE of 12 kWh and reaches to the parking lot D in 16 minutes with the speed variation also given in the following table.

EV-1	
Time [min]	**Speed [km/h]**
0	0
1	3
2	5
3	6
4	8
5	9
6	14
7	14
8	12
9	11
10	11
11	10
12	10
13	6
14	2
15	0

EV-2	
Time [min]	**Speed [km/h]**
0	0
1	5
2	8
3	8
4	12
5	10
6	9
7	8
8	7
9	3
10	2
11	0

EV-3	
Time [min]	**Speed [km/h]**
0	0
1	5
2	8
3	8
4	15
5	12
6	10
7	8
8	8
9	7
10	7
11	7
12	7
13	6
14	4
15	2
16	0

a) Find the SoE value of each vehicle when reaching the parking lot in D after the usage periods given in the aforementioned table (time granularity to be used here is 1min for SoE calculation) **(25p hand solution+25p code/model based verification=50p)**

b) Consider that parking lot D has sufficient number of EV charging stations. Assuming that each EV types arrives to this parking lot with the SoE values calculated in (a), find the power variation regarding the total EV charging from the mentioned parking lot till the end of maximizing the last EV's SoE. (time granularity to be used here is 5min) **(25p hand solution+25p code/model based verification=50p)** (Assume the charging efficiency as 0.95 for the overall question.)

Hints:

- First of all, (a) and (b) should be solved by hand mathematically, then the results should be verified by a Simulink model or m-file code in MATLAB.
- mn is the last two digits of your student number. For example if the last two digits of your student number is 40, then m is equal to 4 and n is uqual to 0. Therefore, as an example, the vehicle speed of EV-2 at time 1 becomes 5*4.0=20 km/h.
  - Specific condition: If the last two digits of your student number is 00, then please assume it as 10.
- Each project depends on a single person, and if the last two digits of the student numbers of two separate students are the same, then their projects will be analyzed in further details in order to be sure about any copy issue!
- Solving each question by hand correctly is **mandatory**! For the students who cannot solve the problems by hand correctly, the solutions in MATLAB will be **neglected** in order to be fully sure about the copy of the code or the simulation diagram!
- You should provide a report for the project. You can use this file as a cover page (**fulfilled with a pen that cannot be erased!**) or you can also provide a separate cover page including the course name, student name, group of the course and student number and a signature.
  - For the part of solving the questions by hand, it is mandatory to use the Equations format in Microsoft Word software. **No handwriting will be accepted!** You can also use LATEX in this manner.
  - Each student will also provide a rar or zip file including the Word (or LATEX) version of the report, and the MATLAB Simulink file(s) or m-file(s). Any missing attachment will result in loss of project points.
- **Any copy issue will result in zero points for the project and further disciplinary actions will be taken!**
- The projects should be delivered via onlinekampus system till August 26, 2019 8am **with signature**. The projects delivered later **with any reason** will be neglected and will therefore be given zero points.

Good luck.

Assoc. Prof. Dr. Ozan ERDİNÇ

a)

Calculations For EV-1:

Converting km/s to m/s: $v(t) = v_t \times 1000/3600$

$v(0) = 0 \times \frac{1000}{3600} = 0\ m/s$

$v(1) = 3 \times \frac{1000}{3600} = 0.8333\ m/s$

$v(2) = 5 \times \frac{1000}{3600} = 1.3889\ m/s$

$v(3) = 6 \times \frac{1000}{3600} = 1.6667\ m/s$

$v(4) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(5) = 9 \times \frac{1000}{3600} = 2.5000\ m/s$

$v(6) = 14 \times \frac{1000}{3600} = 3.8889\ m/s$

$v(7) = 14 \times \frac{1000}{3600} = 3.8889\ m/s$

$v(8) = 12 \times \frac{1000}{3600} = 3.3333\ m/s$

$v(9) = 11 \times \frac{1000}{3600} = 3.0556\ m/s$

$v(10) = 11 \times \frac{1000}{3600} = 3.0556\ m/s$

$v(11) = 10 \times \frac{1000}{3600} = \ 2.7778\ m/s$

$v(12) = 10 \times \frac{1000}{3600} = 2.7778\ m/s$

$v(13) = 6 \times \frac{1000}{3600} = 1.6667\ m/s$

$v(14) = 2 \times \frac{1000}{3600} = 0.5556\ \ m/s$

$v(15) = 0 \times \frac{1000}{3600} = 0\ m/s$

$F(t) = m_v \frac{dv(t)}{dt}$

$F(0) = 1580 \times \frac{0-0}{0-0} = 0\ N$

$F(1) = 1580 \times \frac{0.8333-0}{60-0} = 21.9444\ N$

$F(2) = 1580 \times \frac{1.3889-0.8333}{120-60} = 14.629\ N$

$F(3) = 1580 \times \frac{1.6667-1.3889}{180-120} = 7.3148\ N$

$F(4) = 1580 \times \frac{2.2222-1.6667}{240-180} = 14.6296\ N$

$F(5) = 1580 \times \frac{2.5-2.2222}{300-240} = 7.3148\ N$

$$F(6) = 1580 \times \frac{3.8889-2.5}{360-300} = 36.5741\ N$$

$$F(7) = 1580 \times \frac{3.8889-3.8889}{420-360} = 0\ N$$

$$F(8) = 1580 \times \frac{3.3333-3.8889}{480-420} = -14.6296\ N$$

$$F(9) = 1580 \times \frac{3.0556-3.3333}{540-480} = -7.3148\ N$$

$$F(10) = 1580 \times \frac{3.0556-3.0556}{600-540} = 0\ N$$

$$F(11) = 1580 \times \frac{2.7778-3.0556}{660-600} = -7.3148\ N$$

$$F(12) = 1580 \times \frac{2.7778-2.7778}{720-660} = 0\ N$$

$$F(13) = 1580 \times \frac{1.6667-2.7778}{780-720} = -29.2593\ N$$

$$F(14) = 1580 \times \frac{0.5556-1.6667}{840-720} = -29.2593\ N$$

$$F(15) = 1580 \times \frac{0-0.5556}{900-840} = -14.6296\ N$$

$$F_a(t) = \frac{1}{2}\rho.A.C_x.v_t^2$$

$$F_a(0) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = 0\ N$$

$$F_a(1) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0.8333^2 = 0.1484\ N$$

$$F_a(2) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.3889^2 = 0.4123\ N$$

$$F_a(3) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.6667^2 = 0.5938\ N$$

$$F_a(4) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(5) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.5000^2 = 1.3359\ N$$

$$F_a(6) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.8889^2 = 3.2326\ N$$

$$F_a(7) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.8889^2 = 3.2326\ N$$

$$F_a(8) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.3333^2 = 2.3750\ N$$

$$F_a(9) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.0556^2 = 1.9957\ N$$

$$F_a(10) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.0556^2 = 1.9957\ N$$

$$F_a(11) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.7778^2 = 1.6493\ N$$

$$F_a(12) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.7778^2 = 1.6493\ N$$

$$F_a(13) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.6667^2 = 0.5938\ N$$

$$F_a(14) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0.5556^2 = 0.0660\ N$$

$$F_a(15) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = \ 0\ N$$

$$F_r(t) = m_v . C_r . g . \cos(\alpha)$$

$$F_r = 1580 \times 0.0048 \times 9.81 \times \cos 0 = 74.399\ N$$

$$F_g(t) = m_v . g . \sin(\alpha)$$

$$F_g(t) = 1540 \times 9.81 \times \sin 0 = 0\ N$$

$$F_d(t) = 0$$

$$F_t(t) = F(t) + F_a(t) + F_r(t) + F_g(t) + F_d(t)$$

$$F_t(0) = 0 + 0 + 74.399\ 0 + 0 = 74.399\ N$$

$$F_t(1) = 21.9444 + 0.1484 + 74.399\ + 0 + 0 = 96.4919\ N$$

$$F_t(2) = 14.6296 + 0.4123 + 74.399\ + 0 + 0 = 89.4410\ N$$

$$F_t(3) = 7.31481 + 0.5938 + 74.399\ + 0 + 0 = 82.3076\ N$$

$$F_t(4) = 14.6296 + 1.0556 + 74.399\ + 0 + 0 = 90.08422\ N$$

$$F_t(5) = 7.3148 + 1.3359 + 74.399\ + 0 + 0 = 83.0498\ N$$

$$F_t(6) = 36.5741 + 3.2326 + 74.399\ + 0 + 0 = 114.2058\ N$$

$$F_t(7) = 0 + 3.2326 + 74.399\ + 0 + 0 = 77.6317\ N$$

$$F_t(8) = -14.6296 + 2.3750 + 74.399\ + 0 + 0 = 62.1444\ N$$

$$F_t(9) = -7.3148 + 1.9957 + 74.399\ + 0 + 0 = 69.0799\ N$$

$$F_t(10) = 0 + 1.9957 + 74.399\ + 0 + 0 = 76.3947\ N$$

$$F_t(11) = -7.3148 + 1.6493 + 74.399\ + 0 + 0 = 68.7335\ N$$

$$F_t(12) = 0 + 1.6493 + 74.399\ + 0 + 0 = 76.0483\ N$$

$$F_t(13) = -29.2593 + 0.5938 + 74.399\ + 0 + 0 = 45.7335\ N$$

$$F_t(14) = -29.2593 + 0.0660 + 74.399\ + 0 + 0 = 45.2058\ N$$

$$F_t(15) = -14.6296 + 0 + 74.39 + 0 + 0 = 59.7694\ N$$

$P_v(t) = v(t).F_t(t)$

$P_v(0) = 0 \times 74.3990 = 0\ W$

$P_v(1) = 0.8333 \times 96.4919 = 80.4099\ W$

$P_v(2) = 1.3889 \times 89.4410 = \ 124.2236\ W$

$P_v(3) = 1.6667 \times 82.3076 = 137.1793\ W$

$P_v(4) = 2.2222 \times 90.0842 = 200.1872\ W$

$P_v(5) = 2.5 \times 83.0498 \ = 207.6245\ W$

$P_v(6) = 3.8889 \times 114.2058 = 444.1335\ W$

$P_v(7) = 3.8889 \times 77.6317 = 301.9010\ W$

$P_v(8) = 3.3333 \times 62.1444 = 207.1480\ W$

$P_v(9) = 3.0556 \times 69.0799 = 211.0774\ W$

$P_v(10) = 3.0556 \times 76.3947 = 233.4282\ W$

$P_v(11) = 2.7778 \times 68.7335 = 190.9265W$

$P_v(12) = 2.7778 \times 76.0483 = 211.2454\ W$

$P_v(13) = 1.6667 \times 45.7335 = 76.2226\ W$

$P_v(14) = 0.5556 \times 45.2056 = 25.1143\ W$

$P_v(15) = 0 \times 59.7694 = 0\ W$

$P(t) = \frac{P_v(t)/1000}{\eta_d}$

$P(0) = \frac{0/1000}{0.85} = 0\ kW$

$P(1) = \frac{80.4099/1000}{0.85} = 0.0946\ kW$

$P(2) = \frac{124.2236/1000}{0.85} = 0.1461\ kW$

$P(3) = \frac{137.1793/1000}{0.85} = 0.1614\ kW$

$P(4) = \frac{200.1877/1000}{0.85} = 0.2355\ kW$

$P(5) = \frac{207.6245/1000}{0.85} = 0.2442\ kW$

$P(6) = \frac{444.1335/1000}{0.85} = 0.5225\ kW$

$P(7) = \frac{301.9010/1000}{0.85} = 0.3551\ kW$

$P(8) = \frac{207.1480/1000}{0.85} = 0.2437\ kW$

$P(9) = \frac{211.0774/1000}{0.85} = 0.2483\ kW$

$$P(10) = \frac{233.4282/1000}{0.85} = 0.2746\ kW$$

$$P(11) = \frac{190.9265/1000}{0.85} = 0.2246\ kW$$

$$P(12) = \frac{211.2454/1000}{0.85} = 0.2485\ kW$$

$$P(13) = \frac{76.2226/1000}{0.85} = 0.0897 kW$$

$$P(14) = \frac{25.1143/1000}{0.85} = 0.0295\ kW$$

$$P(15) = \frac{0/1000}{0.85} = 0\ kW$$

v (m/s)	Accel. Fo	Fr	Fg	Fd	Fa	Ftotal	Pv (W)	P (kW)
0	0	74,399	0	0	0	74,399	0	0
0,8333	21,9444	74,399	0	0	0,1484	96,4919	80,4099	0,0946
1,3889	14,6296	74,399	0	0	0,4123	89,441	124,2236	0,1461
1,6667	7,3148	74,399	0	0	0,5938	82,3076	137,1793	0,1614
2,2222	14,6296	74,399	0	0	1,0556	90,0842	200,1872	0,2355
2,5	7,3148	74,399	0	0	1,3359	83,0498	207,6245	0,2443
3,8889	36,5741	74,399	0	0	3,2326	114,2058	444,1335	0,5225
3,8889	0	74,399	0	0	3,2326	77,6317	301,901	0,3552
3,3333	-146.296	74,399	0	0	2,375	62,1444	207,148	0,2437
3,0556	-7,3148	74,399	0	0	1,9957	69,0799	211,0772	0,2483
3,0556	0	74,399	0	0	1,9957	76,3947	233,4282	0,2746
2,7778	-7,3148	74,399	0	0	1,6493	68,7335	190,9265	0,2246
2,7778	0	74,399	0	0	16.493	76,0483	211,2454	0,2485
1,6667	-29,2593	74,399	0	0	0,5938	45,7335	76,2226	0,0897
0,5556	-29,2593	74,399	0	0	0,066	45,2058	25,1143	0,0295
0	-14,6296	74,399	0	0	0	59,7694	0	0

$$SOE_t^{EV} = SOE_{t-1}^{EV} + CE_{EV}.P_t^{EV,ch}.\Delta T$$

Not: $\Delta T = \frac{1}{60}$ because we converting minute to hour for right calculation.

$$SOE_0^{EV} = 11 - 0.95 \times 0 \times 1/60 = 11\ kWh$$

$$SOE_1^{EV} = 11 - 0.95 \times 0.0946 \times 1/60 = 10.9985\ kWh$$

$$SOE_2^{EV} = 10.9985 - 0.95 \times 0.1461 \times 1/60 = 10.9962\ kWh$$

$$SOE_3^{EV} = 10.9962 - 0.95 \times 0.1614 \times 1/60 = 10.9936\ kWh$$

$$SOE_4^{EV} = 10.9936 - 0.95 \times 0.2355 \times 1/60 = 10.9899\ kWh$$

$$SOE_5^{EV} = 10.9899 - 0.95 \times 0.2442 \times 1/60 = 10.9860\ kWh$$

$$SOE_6^{EV} = 10.9860 - 0.95 \times 0.5225 \times 1/60 = 10.9778\ kWh$$

$$SOE_7^{EV} = 10.9778 - 0.95 \times 0.3551 \times 1/60 = 10.9721\ kWh$$

$$SOE_8^{EV} = 10.9721 - 0.95 \times 0.2437 \times 1/60 = 10.9683\ kWh$$

$$SOE_9^{EV} = 10.9683 - 0.95 \times 0.2483 \times 1/60 = 10.9643\ kWh$$

$SOE_{10}^{EV} = 10.9643 - 0.95 \times 0.2746 \times 1/60 = 10.9600\ kWh$

$SOE_{11}^{EV} = 10.9600 - 0.95 \times 0.2246 \times 1/60 = 10.9564\ kWh$

$SOE_{12}^{EV} = 10.9564 - 0.95 \times 0.2485 \times 1/60 = 10.9525\ kWh$

$SOE_{13}^{EV} = 10.9525 - 0.95 \times 0.0897 \times 1/60 = 10.9511\ kWh$

$SOE_{14}^{EV} = 10.9511 - 0.95 \times 0.0295 \times 1/60 = 10.9506\ kWh$

$SOE_{15}^{EV} = 10.9506 - 0.95 \times 0 \times 1/60 = 10.9506\ kWh$

EV-1 comes to D charging spot with $SOE = 10.9506\ kWh$

Calculations For EV-2:

Converting km/s to m/s: $v(t) = v_t \times 1000/3600$

$v(0) = 0 \times \frac{1000}{3600} = 0\ m/s$

$v(1) = 5 \times \frac{1000}{3600} = 1.3889\ m/s$

$v(2) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(3) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(4) = 12 \times \frac{1000}{3600} = 3.3333\ m/s$

$v(5) = 10 \times \frac{1000}{3600} = 2.7778\ m/s$

$v(6) = 9 \times \frac{1000}{3600} = 2.5000\ m/s$

$v(7) = 8 \times \frac{1000}{3600} = 2.2222 m/s$

$v(8) = 7 \times \frac{1000}{3600} = 1.9444\ m/s$

$v(9) = 3 \times \frac{1000}{3600} = 0.8333\ m/s$

$v(10) = 2 \times \frac{1000}{3600} = 0.5556\ m/s$

$v(11) = 0 \times \frac{1000}{3600} = 0\ m/s$

$F(t) = m_v \frac{dv(t)}{dt}$

$F(0) = 1580 \times \frac{0-0}{0-0} = 0\ N$

$F(1) = 1580 \times \frac{1.3889-0}{60-0} = 36.5741\ N$

$F(2) = 1580 \times \frac{2.2222-1.3889}{120-60} = 21.9445\ N$

$F(3) = 1580 \times \frac{2.2222-2.2222}{180-120} = 0\ N$

$$F(4) = 1580 \times \frac{3.3333-2.2222}{240-180} = 29.2593\ N$$

$$F(5) = 1580 \times \frac{2.7778-3.3333}{300-240} = -14.6296\ N$$

$$F(6) = 1580 \times \frac{2.5000-2.7778}{360-300} = -7.31481\ N$$

$$F(7) = 1580 \times \frac{2.2222-2.5000}{420-360} = -7.3148N$$

$$F(8) = 1580 \times \frac{1.9444-2.2222}{480-420} = -7.3148\ N$$

$$F(9) = 1580 \times \frac{0.8333-1.9444}{540-480} = -29.2593\ N$$

$$F(10) = 1580 \times \frac{0.5556-0.8333}{600-540} = -7.3148\ N$$

$$F(11) = 1580 \times \frac{0-0.5556}{660-600} = -14.6296\ N$$

$$F_a(t) = \frac{1}{2}\rho.A.C_x.v_t^2$$

$$F_a(0) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = 0\ N$$

$$F_a(1) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.3889^2 = 0.4123\ N$$

$$F_a(2) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(3) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(4) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.3333^2 = 2.3750\ N$$

$$F_a(5) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.7778^2 = 1.6493\ N$$

$$F_a(6) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.5^2 = 1.3359\ N$$

$$F_a(7) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(8) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.9444^2 = 0.8082\ N$$

$$F_a(9) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0.8333^2 = 0.1484\ N$$

$$F_a(10) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0.5556^2 = 0.0660N$$

$$F_a(11) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = 0\ N$$

$$F_r(t) = m_v.C_r.g.\cos(\alpha)$$

$$F_r = 1580 \times 0.0048 \times 9.81 \times \cos 0 = 74.399\ N$$

$$F_g(t) = m_v . g . \sin(\alpha)$$

$$F_g(t) = 1540 \times 9.81 \times \sin 0 = 0\ N$$

$$F_d(t) = 0$$

$$F_t(t) = F(t) + F_a(t) + F_r(t) + F_g(t) + F_d(t)$$

$$F_t(0) = 0 + 0 + 74.399 + 0 + 0 = 74.399\ N$$

$$F_t(1) = 36.5741 + 0.4123 + 74.399 + 0 + 0 = 111.3854\ N$$

$$F_t(2) = 21.9445 + 1.0556 + 74.399 + 0 + 0 = 97.3990\ N$$

$$F_t(3) = 0 + 1.0556 + 74.399 + 0 + 0 = 75.4546\ N$$

$$F_t(4) = 29.2593 + 2.375 + 74.399 + 0 + 0 = 106.0333\ N$$

$$F_t(5) = -14.6296 + 1.6493 + 74.399 + 0 + 0 = 61.4187\ N$$

$$F_t(6) = -7.3148 + 1.3359 + 74.399 + 0 + 0 = 68.4202\ N$$

$$F_t(7) = -7.3148 + 1.0556 + 74.399 + 0 + 0 = 68.1398\ N$$

$$F_t(8) = -7.3148 + 0.8082 + 74.399 + 0 + 0 = 67.8924\ N$$

$$F_t(9) = -29.2593 + 0.1484 + 74.399 + 0 + 0 = 45.2882\ N$$

$$F_t(10) = -7.3148 + 0.0660 + 74.399 + 0 + 0 = 67.1502\ N$$

$$F_t(11) = -14.6296 + 0 + 74.399 + 0 + 0 = 59.7694\ N$$

$$P_v(t) = v(t) . F_t(t)$$

$$P_v(0) = 0 \times 74.3990 = 0\ W$$

$$P_v(1) = 1.3889 \times 111.3854 = 154.7020\ W$$

$$P_v(2) = 2.2222 \times 97.3990 = 216.4423\ W$$

$$P_v(3) = 2.2222 \times 75.4546 = 167.6769\ W$$

$$P_v(4) = 3.3333 \times 106.0333 = 353.4443\ W$$

$$P_v(5) = 2.7778 \times 61.4187 = 170.6075\ W$$

$$P_v(6) = 2.5 \times 68.4202 = 171.0504\ W$$

$$P_v(7) = 2.2222 \times 67.8924 = 151.4217\ W$$

$$P_v(8) = 1.9444 \times 67.8924 = 132.0130\ W$$

$$P_v(9) = 0.8333 \times 45.2882 = 37.7402\ W$$

$$P_v(10) = 0.5556 \times 67.1502 = 37.3057\ W$$

$$P_v(11) = 0 \times 59.7694 = 0\ W$$

$$P(t) = \frac{P_v(t)/1000}{\eta_d}$$

$$P(0) = \frac{0/1000}{0.85} = 0\ kW$$

$$P(1) = \frac{154.7020\ /1000}{0.85} = 0.1820\ kW$$

$$P(2) = \frac{216.4423/1000}{0.85} = 0.2546\ kW$$

$$P(3) = \frac{167.6769/1000}{0.85} = 0.1973\ kW$$

$$P(4) = \frac{353.4443/1000}{0.85} = 0.4158\ kW$$

$$P(5) = \frac{170.6075/1000}{0.85} = 0.2007\ kW$$

$$P(6) = \frac{171.0504/1000}{0.85} = 0.2012\ kW$$

$$P(7) = \frac{151.4217/1000}{0.85} = 0.1781\ kW$$

$$P(8) = \frac{132.0130/1000}{0.85} = 0.1553\ kW$$

$$P(9) = \frac{37.7402/1000}{0.85} = 0.0444\ kW$$

$$P(10) = \frac{37.3057/1000}{0.85} = 0.0439\ kW$$

$$P(11) = \frac{0/1000}{0.85} = 0\ kW$$

v (m/s)	Accel. F	Fr	Fg	Fd	Fa	Ftotal	P (W)	P (kW)
0	0	74,399	0	0	0	74,399	0	0
1,3889	36,574	74,399	0	0	0,4123	111,3854	154,702	0,182
2,2222	21,945	74,399	0	0	1,0556	97,399	216,4423	0,2546
2,2222	0	74,399	0	0	1,0556	75,4546	167,6769	0,1973
3,3333	29,259	74,399	0	0	2,375	106,0333	353,4443	0,4158
2,7778	-14,63	74,399	0	0	1,6493	61,4187	170,6075	0,2007
2,5	-7,3148	74,399	0	0	1,3359	68,4202	171,0504	0,2012
2,2222	-7,3148	74,399	0	0	1,0556	68,1398	151,4217	0,1781
1,9444	-7,3148	74,399	0	0	0,8082	67,8924	132,0123	0,1553
0,8333	-29,259	74,399	0	0	0,1484	45,2882	37,7402	0,0444
0,5556	-7,3148	74,399	0	0	0,066	67,1502	37,3057	0,0439
0	-14,63	74,399	0	0	0	59,7694	0	0

$$SOE_t^{EV} = SOE_{t-1}^{EV} - CE_{EV}.P_t^{EV,ch}.\Delta T$$

Not: $\Delta T = \frac{1}{60}$ because we converting minute to hour for right calculation.

$$SOE_0^{EV} = 13.6 - 0.95 \times 0 \times 1/60 = 13.6\ kWh$$

$$SOE_1^{EV} = 13.6 - 0.95 \times 0.1820 \times 1/60 = 13.5971\ kWh$$

$$SOE_2^{EV} = 13.5971 - 0.95 \times 0.2546 \times 1/60 = 13.5931\ kWh$$

$SOE_3^{EV} = 13.5931 - 0.95 \times 0.1973 \times 1/60 = 13.5900\ kWh$

$SOE_4^{EV} = 13.5900 - 0.95 \times 0.4158 \times 1/60 = 13.5834\ kWh$

$SOE_5^{EV} = 13.5834\ - 0.95 \times 0.2007 \times 1/60 = 13.5802\ kWh$

$SOE_6^{EV} = 13.5802 - 0.95 \times 0.2012 \times 1/60 = 13.5770\ kWh$

$SOE_7^{EV} = 13.5770 - 0.95 \times 0.1781 \times 1/60 = 13.5742\ kWh$

$SOE_8^{EV} = 13.5742 - 0.95 \times 0.1553 \times 1/60 = 13.5717\ kWh$

$SOE_9^{EV} = 13.5717 - 0.95 \times 0.0444 \times 1/60 = 13.5710\ kWh$

$SOE_{10}^{EV} = 13.5710 - 0.95 \times 0.0439 \times 1/60 = 13.5703\ kWh$

$SOE_{11}^{EV} = 13.5703\ - 0.95 \times 0 \times 1/60 = 13.5703\ kWh$

EV-2 comes to D charging spot with $SOE = 13.5703\ kWh$

Calculations For EV-3:

Converting km/s to m/s: $v(t) = v_t \times 1000/3600$

$v(0) = 0 \times \frac{1000}{3600} = 0\ m/s$

$v(1) = 5 \times \frac{1000}{3600} = 1.3889\ m/s$

$v(2) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(3) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(4) = 15 \times \frac{1000}{3600} = 4.1667\ m/s$

$v(5) = 12 \times \frac{1000}{3600} = 3.3333\ m/s$

$v(6) = 10 \times \frac{1000}{3600} = 2.7778\ m/s$

$v(7) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(8) = 8 \times \frac{1000}{3600} = 2.2222\ m/s$

$v(9) = 7 \times \frac{1000}{3600} = 1.9444\ m/s$

$v(10) = 7 \times \frac{1000}{3600} = 1.9444\ m/s$

$v(11) = 7 \times \frac{1000}{3600} = 1.9444\ m/s$

$v(12) = 7 \times \frac{1000}{3600} = 1.9444\ m/s$

$v(13) = 6 \times \frac{1000}{3600} = 1.6667\ m/s$

$v(14) = 4 \times \frac{1000}{3600} = 1.1111\ m/s$

$v(15) = 2 \times \frac{1000}{3600} = 0.5556\ \ m/s$

$v(16) = 0 \times \frac{1000}{3600} = 0\ m/s$

$$F(t) = m_v \frac{dv(t)}{dt}$$

$$F(0) = 1580 \times \frac{0-0}{0-0} = 0\ N$$

$$F(1) = 1580 \times \frac{1.3889-0}{60-0} = 36.5741\ N$$

$$F(2) = 1580 \times \frac{2.2222-1.3889}{120-60} = 21.9445\ N$$

$$F(3) = 1580 \times \frac{2.2222-2.2222}{180-120} = 0\ N$$

$$F(4) = 1580 \times \frac{4.1667-2.2222}{240-180} = 51.2037\ N$$

$$F(5) = 1580 \times \frac{3.3333-4.1667}{300-240} = -21.9445\ N$$

$$F(6) = 1580 \times \frac{2.7778-3.3333}{360-300} = -14.6296\ N$$

$$F(7) = 1580 \times \frac{2.2222-2.7778}{420-360} = -14.6296\ N$$

$$F(8) = 1580 \times \frac{2.2222-2.2222}{480-420} = 0\ N$$

$$F(9) = 1580 \times \frac{1.9444-2.2222}{540-480} = -7.3148\ N$$

$$F(10) = 1580 \times \frac{1.9444\ -1.9444}{600-540} = 0\ N$$

$$F(11) = 1580 \times \frac{1.9444\ -1.9444}{660-600} = 0\ N$$

$$F(12) = 1580 \times \frac{1.9444\ -1.9444}{720-660} = 0\ N$$

$$F(13) = 1580 \times \frac{1.6667-1.9444}{780-720} = -7.3148\ N$$

$$F(14) = 1580 \times \frac{1.1111\ -1.6667}{840-780} = -14.62962\ N$$

$$F(15) = 1580 \times \frac{0.5556-1.1111}{900-840} = -14.6296\ N$$

$$F(16) = 1580 \times \frac{0-0.5556}{960-900} = -14.6296\ N$$

$$F_a(t) = \frac{1}{2}\rho.A.C_x.v_t^2$$

$$F_a(0) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = 0\ N$$

$$F_a(1) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.3889^2 = 0.4123\ N$$

$$F_a(2) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(3) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(4) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 4.1667^2 = 3.7109\ N$$

$$F_a(5) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 3.3333^2 = 2.3750\ N$$

$$F_a(6) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.7778^2 = 1.6493\ N$$

$$F_a(7) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(8) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 2.2222^2 = 1.0556\ N$$

$$F_a(9) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.9444^2 = 0.8082\ N$$

$$F_a(10) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.9444^2 = 0.8082\ N$$

$$F_a(11) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.9444^2 = 0.8082\ N$$

$$F_a(12) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.9444^2 = 0.8082\ N$$

$$F_a(13) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.6667^2 = 0.5937\ N$$

$$F_a(14) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 1.1111^2 = 0.2639\ N$$

$$F_a(15) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0.5556^2 = 0.0660\ N$$

$$F_a(16) = \frac{1}{2} \times 1.25 \times 1.8 \times 0.19 \times 0^2 = \ 0\ N$$

$$F_r(t) = m_v . C_r . g . \cos(\alpha)$$

$$F_r = 1580 \times 0.0048 \times 9.81 \times \cos 0 = 74.399\ N$$

$$F_g(t) = m_v . g . \sin(\alpha)$$

$$F_g(t) = 1540 \times 9.81 \times \sin 0 = 0\ N$$

$$F_d(t) = 0$$

$$F_t(t) = F(t) + F_a(t) + F_r(t) + F_g(t) + F_d(t)$$

$$F_t(0) = 0 + 0 + 74.399\ 0 + 0 = 74.399\ N$$

$$F_t(1) = 36.5741 + 0.4123 + 74.399\ + 0 + 0 = 111.3854N$$

$$F_t(2) = 21.9445 + 1.0556 + 74.399\ + 0 + 0 = 97.3990\ N$$

$$F_t(3) = 0 + 1.0556 + 74.399\ + 0 + 0 = 75.4546\ N$$

$$F_t(4) = 51.2037 + 3.7109\ + 74.399\ + 0 + 0 = 129.3137\ N$$

$$F_t(5) = -21.9445 + 2.3750 + 74.399\ + 0 + 0 = 54.8296\ N$$

$$F_t(6) = -14.6296 + 1.6493 + 74.399\ + 0 + 0 = 61.4187\ N$$

$$F_t(7) = -14.6296 + 1.0556 + 74.399\ + 0 + 0 = 60.8250\ N$$

$$F_t(8) = 0 + 1.0556 + 74.399\ + 0 + 0 = 75.4546\ N$$

$F_t(9) = -7.3148 + 0.8082 + 74.399 + 0 + 0 = 67.8924\ N$

$F_t(10) = 0 + 0.8082 + 74.399 + 0 + 0 = 75.2072\ N$

$F_t(11) = 0 + 0.8082 + 74.399 + 0 + 0 = 75.2072\ N$

$F_t(12) = 0 + 0.8082 + 74.399 + 0 + 0 = 75.2072\ N$

$F_t(13) = -7.3148 + 0.5838 + 74.399 + 0 + 0 = 67.6780\ N$

$F_t(14) = -14.6296 + 0.2639 + 74.399 + 0 + 0 = 60.0333\ N$

$F_t(15) = -14.6296 + 0.0660 + 74.399 + 0 + 0 = 59.8354\ N$

$F_t(16) = -14.6296 + 0 + 74.39 + 0 + 0 = 59.7694\ N$

$P_v(t) = v(t).F_t(t)$

$P_v(0) = 0 \times 74.3990 = 0\ W$

$P_v(1) = 1.3889 \times 111.3854 = 154.7020\ W$

$P_v(2) = 2.2222 \times 97.3990 = 216.4423\ W$

$P_v(3) = 2.2222 \times 75.4546 = 167.6768\ W$

$P_v(4) = 4.1667 \times 129.3136 = 538.8070\ W$

$P_v(5) = 3.3333 \times 54.8296 = 182.7653\ W$

$P_v(6) = 2.7778 \times 61.4187 = 170.6075\ W$

$P_v(7) = 2.2222 \times 60.8250 = 135.1666\ W$

$P_v(8) = 2.2222 \times 75.4546 = 167.6769\ W$

$P_v(9) = 1.9444 \times 67.8924 = 132.0130\ W$

$P_v(10) = 1.9444 \times 75.2072 = 146.2362\ W$

$P_v(11) = 1.9444 \times 75.2072 = 146.2362\ W$

$P_v(12) = 1.9444 \times 75.2072 = 146.2362\ W$

$P_v(13) = 1.6667 \times 67.6780 = 112.7966\ W$

$P_v(14) = 1.1111 \times 60.0333 = 66.7037\ W$

$P_v(15) = 0.5556 \times 59.8354 = 33.2419\ W$

$P_v(16) = 0 \times 59.7694 = 0\ W$

$If\ Pv\ positive: P(t) = \frac{P_v(t)}{\eta_d},\ If\ Pv\ Negative\ P_v(t).\eta_d$

$P(0) = \frac{0/1000}{0.85} = 0\ kW$

$P(1) = \frac{154.7020/1000}{0.85} = 0.1820\ kW$

$$P(2) = \frac{216.4423/1000}{0.85} = 0.2546\ kW$$

$$P(3) = \frac{167.6768/1000}{0.85} = 0.1973\ kW$$

$$P(4) = \frac{538.8070/1000}{0.85} = 0.6339\ kW$$

$$P(5) = \frac{182.7653/1000}{0.85} = 0.2150\ kW$$

$$P(6) = \frac{170.6075/1000}{0.85} = 0.2007\ kW$$

$$P(7) = \frac{135.1666/1000}{0.85} = 0.1590\ kW$$

$$P(8) = \frac{167.6769/1000}{0.85} = 0.1972\ kW$$

$$P(9) = \frac{132.0130/1000}{0.85} = 0.1553\ kW$$

$$P(10) = \frac{146.2362/1000}{0.85} = 0.1720\ kW$$

$$P(11) = \frac{146.2362/1000}{0.85} = 0.1720\ kW$$

$$P(12) = \frac{146.2362\ /1000}{0.85} = 0.1720\ kW$$

$$P(13) = \frac{112.7966/1000}{0.85} = 0.1327\ kW$$

$$P(14) = \frac{66.7037/1000}{0.85} = 0.0785\ kW$$

$$P(15) = \frac{33.2419/1000}{0.85} = 0.0391\ kW$$

$$P(16) = \frac{0/1000}{0.85} = 0\ kW$$

v (m/s)	Accel. F	Fr	Fg	Fd	Fa	Ftotal	Pv (W)	P (kW)
0	0	0	0	0	0	74,399	0	0
1,3889	36,5741	74,399	0	0	0,4123	111,3854	154,702	0,182
2,2222	21,9445	74,399	0	0	1,0556	97,399	216,4423	0,2546
2,2222	0	74,399	0	0	1,0556	75,4546	167,6769	0,1973
4,1667	51,2037	74,399	0	0	3,7109	129,3137	53,8807	0,6339
3,3333	-21,9445	74,399	0	0	2,375	54,8296	182,7653	0,215
2,7778	-14,6296	74,399	0	0	1,649	61,4187	170,6075	0,2007
2,2222	-14,6296	74,399	0	0	1,0556	60,825	135,1666	0,159
2,2222	0	74,399	0	0	1,0556	75,4546	167,6769	0,1973
1,9444	-73,1481	74,399	0	0	0,8082	67,8924	132,013	0,1553
1,9444	0	74,399	0	0	0,8082	75,2072	146,2362	0,172
1,9444	0	74,399	0	0	0,8082	75,2072	146,2362	0,172
1,9444	0	74,399	0	0	0,8082	75,2072	146,2362	0,172
1,6667	-73,1481	74,399	0	0	0,5938	67,678	112,7966	0,1327
1,1111	-14,6296	74,399	0	0	0,2639	60,0333	66,7037	0,0785
0,5556	-14,6296	74,399	0	0	0,066	59,8354	33,2419	0,0391
0	-14,6296	74,399	0	0	0	59,7694	0	0

$$SOE_t^{EV} = SOE_{t-1}^{EV} - CE_{EV}.P_t^{EV,ch}.\Delta T$$

$$SOE_t^{EV} = SOE_{t-1}^{EV}$$

Not: $\Delta T = \frac{1}{60}$ because we converting minute to hour for right calculation.

$$SOE_0^{EV} = 12 - 0.95 \times 0 \times 1/60 = 12\ kWh$$

$$SOE_1^{EV} = 12 - 0.95 \times 3.7079 \times 1/60 = 11.9971\ kWh$$

$$SOE_2^{EV} = 11.9971 - 0.95 \times 3.6395 \times 1/60 = 11.9931\ kWh$$

$$SOE_3^{EV} = 11.9931 - 0.95 \times 0.1972 \times 1/60 = 11.9900 kWh$$

$$SOE_4^{EV} = 11.9900 - 0.95 \times 15.4428 \times 1/60 = 11.9799\ kWh$$

$$SOE_5^{EV} = 11.9799\ - 0.95 \times -3.5130 \times 1/60 = 11.9765\ kWh$$

$$SOE_6^{EV} = 11.9765 - 0.95 \times -1.8930 \times 1/60 = 11.9733\ kWh$$

$$SOE_7^{EV} = 11.9733 - 0.95 \times -1.5155 \times 1/60 = 11.9708\ kWh$$

$$SOE_8^{EV} = 11.9708\ - 0.95 \times 0.1973 \times 1/60 = 11.9677\ kWh$$

$$SOE_9^{EV} = 11.9677\ - 0.95 \times -0.6011 \times 1/60 = 11.9652\ kWh$$

$$SOE_{10}^{EV} = 11.9652 - 0.95 \times 0.1720 \times 1/60 = 11.9625\ kWh$$

$$SOE_{11}^{EV} = 11.9625 - 0.95 \times 0.1720 \times 1/60 = 11.9598\ kWh$$

$$SOE_{12}^{EV} = 11.9598 - 0.95 \times 0.1720 \times \frac{1}{60} = 11.9571\ kWh$$

$$SOE_{13}^{EV} = 11.9571\ - 0.95 \times -0.5155 \times 1/60 = 11.9550\ kWh$$

$$SOE_{14}^{EV} = 11.9550 - 0.95 \times -0.7738 \times 1/60 = 11.9537\ kWh$$

$$SOE_{15}^{EV} = 11.9537 - 0.95 \times -0.3793 \times 1/60 = 11.9531\ kWh$$

$$SOE_{16}^{EV} = 11.9531 - 0.95 \times 0 \times 1/60 = 11.9531\ kWh$$

EV-3 comes to D charging spot with $SOE = 11.9531\ kWh$

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b)

For EV-1 charging mode:

$$SOE_t^{EV} = SOE_{t-1}^{EV} + CE_{EV}.P_t^{EV,ch}.\Delta T$$

$$SOE_t^{EV} = SOE_{t-1}^{EV}$$

At 2.25 o'clock is start time to charge the EV-1:

$$SOE_5^{EV} = 10.9506 + 0.95 \times 6.6 \times 5/60 = 11.4731\ kWh$$

$$SOE_{10}^{EV} = 11.4731 + 0.95 \times 6.6 \times 5/60 = 11.9956\ kWh$$

$$SOE_{15}^{EV} = 11.9956 + 0.95 \times 6.6 \times 5/60 = 12.5181\ kWh$$

$$SOE_{20}^{EV} = 12.5181 + 0.95 \times 6.6 \times 5/60 = 13.0406\ kWh$$

$SOE_{25}^{EV} = 13.0406 + 0.95 \times 6.6 \times 5/60 = 13.5631\ kWh$

$SOE_{30}^{EV} = 13.4231 + 0.95 \times 6.6 \times 5/60 = 14.0856\ kWh$

$SOE_{35}^{EV} = 14.0856 + 0.95 \times 6.6 \times 5/60 = 14.6081\ kWh$

$SOE_{40}^{EV} = 14.6081 + 0.95 \times 6.6 \times 5/60 = 15.1306 kWh$

$SOE_{45}^{EV} = 15.1306 + 0.95 \times 6.6 \times 5/60 = 15.6531\ kWh$

$SOE_{50}^{EV} = 15.6531 + 0.95 \times 6.6 \times 5/60 = 16.1756\ kWh$

$SOE_{55}^{EV} = 16.1756 + 0.95 \times 6.6 \times 5/60 = 16.6981\ kWh$

$SOE_{60}^{EV} = 16.6981 + 0.95 \times 6.6 \times 5/60 = 17.2206\ kWh$

$SOE_{65}^{EV} = 17.2206 + 0.95 \times 6.6 \times 5/60 = 17.7431 kWh$

$SOE_{70}^{EV} = 17.7431 + 0.95 \times 6.6 \times 5/60 = 18.2656\ kWh$

$SOE_{75}^{EV} = 18.2656 + 0.95 \times 6.6 \times 5/60 = 18.7881\ kWh$

$SOE_{80}^{EV} = 18.7881 + 0.95 \times 6.6 \times 5/60 = 19.3106\ kWh$

$SOE_{85}^{EV} = 19.3106 + 0.95 \times 6.6 \times 5/60 = 19.8331\ kWh$

$SOE_{90}^{EV} = 19.8331 + 0.95 \times 6.6 \times 5/60 = 20.3556\ kWh$

$SOE_{95}^{EV} = 20.3556 + 0.95 \times 6.6 \times 5/60 = 20.8781\ kWh$

$SOE_{100}^{EV} = 20.8781 + 0.95 \times 6.6 \times 5/60 = 21.4006\ kWh$

$SOE_{105}^{EV} = 21.4006 + 0.95 \times 6.6 \times 5/60 = 21.9231\ kWh$

$SOE_{110}^{EV} = 21.9231 + 0.95 \times 6.6 \times 5/60 \ = 22.4456\ kWh$

EV-1 charged fully after $110\ minutes\ =\ 1.50$ hours

$2.25\ +\ 1.50 = 4.15\ o'clock$

But exact charged time is can be found from this calculation:

$22.4456 = 22 + 0.95 \times 6.6 \times \Delta T$

$\Delta T = 0.0711\ hour = 4.2641\ minute$

$4.15 - 0.0711 \cong 4.08$

For EV-2 charging mode:

$SOE_t^{EV} = SOE_{t-1}^{EV} + CE_{EV}.P_t^{EV,ch}.\Delta T$

$SOE_t^{EV} = SOE_{t-1}^{EV}$

At 2.46 o'clock is start time to charge the EV-2:

$SOE_5^{EV} = 13.5703 + 0.95 \times 6.6 \times 5/60 = 14.0928\ kWh$

$SOE_{10}^{EV} = 14.0928 + 0.95 \times 6.6 \times 5/60 = 14.6153\ kWh$

$SOE_{15}^{EV} = 14.6153 + 0.95 \times 6.6 \times 5/60 = 15.1378\ kWh$

$SOE_{20}^{EV} = 15.1378 + 0.95 \times 6.6 \times 5/60 = 15.6603\ kWh$

$SOE_{25}^{EV} = 15.6603 + 0.95 \times 6.6 \times 5/60 = 16.1828\ kWh$

$SOE_{30}^{EV} = 16.1828 + 0.95 \times 6.6 \times 5/60 = 16.7053\ kWh$

$SOE_{35}^{EV} = 16.7053 + 0.95 \times 6.6 \times 5/60 = 17.2278\ kWh$

$SOE_{40}^{EV} = 17.2278 + 0.95 \times 6.6 \times 5/60 = 17.7503\ kWh$

$SOE_{45}^{EV} = 17.7503 + 0.95 \times 6.6 \times 5/60 = 18.2728\ kWh$

$SOE_{50}^{EV} = 18.2728 + 0.95 \times 6.6 \times 5/60 = 18.7953\ kWh$

$SOE_{55}^{EV} = 18.7953 + 0.95 \times 6.6 \times 5/60 = 19.3178\ kWh$

$SOE_{60}^{EV} = 19.3178 + 0.95 \times 6.6 \times 5/60 = 19.8403\ kWh$

$SOE_{65}^{EV} = 19.8403 + 0.95 \times 6.6 \times 5/60 = 20.3628\ kWh$

$SOE_{70}^{EV} = 20.3628 + 0.95 \times 6.6 \times 5/60 = 20.8853\ kWh$

$SOE_{75}^{EV} = 20.8853 + 0.95 \times 6.6 \times 5/60 = 21.4078\ kWh$

$SOE_{80}^{EV} = 21.4078 + 0.95 \times 6.6 \times 5/60 = 21.9303\ kWh$

$SOE_{85}^{EV} = 21.9303 + 0.95 \times 6.6 \times 5/60 = 22.4528\ kWh$

EV-2 charged fully after $85\ minutes\ =\ 1.25$ hours

$2.46\ +\ 1.25 = 4.11\ o'clock$

But exact charged time is can be found from this calculation:

$22.4528 = 22 + 0.95 \times 6.6 \times \Delta T$

$\Delta T = 0.0722\ hour = 4.333\ minute$

$4.11 - 0.0433 \cong 4.07$

For EV-3 charging mode:

$SOE_t^{EV} = SOE_{t-1}^{EV} + CE_{EV}.P_t^{EV,ch}.\Delta T$

$SOE_t^{EV} = SOE_{t-1}^{EV}$

At 3.06 o'clock is start time to charge the EV-3:

$SOE_5^{EV} = 11.9531 + 0.95 \times 6.6 \times 5/60 = 12.4756\ kWh$

$SOE_{10}^{EV} = 12.4756 + 0.95 \times 6.6 \times 5/60 = 12.9981\ kWh$

$SOE_{15}^{EV} = 12.9981 + 0.95 \times 6.6 \times 5/60 = 13.5206\ kWh$

$SOE_{20}^{EV} = 13.5206 + 0.95 \times 6.6 \times 5/60 = 14.0431\ kWh$

$SOE_{25}^{EV} = 14.0431 + 0.95 \times 6.6 \times 5/60 = 14.5656\ kWh$

$SOE_{30}^{EV} = 14.5656 + 0.95 \times 6.6 \times 5/60 = 15.0881\ kWh$

$SOE_{35}^{EV} = 15.0881 + 0.95 \times 6.6 \times 5/60 = 15.6106\ kWh$

$SOE_{40}^{EV} = 15.6106 + 0.95 \times 6.6 \times 5/60 = 16.1331\ kWh$

$SOE_{45}^{EV} = 16.1331 + 0.95 \times 6.6 \times 5/60 = 16.6556\ kWh$

$SOE_{50}^{EV} = 16.6556 + 0.95 \times 6.6 \times 5/60 = 17.1781\ kWh$

$SOE_{55}^{EV} = 17.1781 + 0.95 \times 6.6 \times 5/60 = 17.7006\ kWh$

$SOE_{60}^{EV} = 17.7006 + 0.95 \times 6.6 \times 5/60 = 18.2231\ kWh$

$SOE_{65}^{EV} = 18.2231 + 0.95 \times 6.6 \times 5/60 = 18.7456\ kWh$

$SOE_{70}^{EV} = 18.7456 + 0.95 \times 6.6 \times 5/60 = 19.2681\ kWh$

$SOE_{75}^{EV} = 19.2681 + 0.95 \times 6.6 \times 5/60 = 19.7906\ kWh$

$SOE_{80}^{EV} = 19.7906 + 0.95 \times 6.6 \times 5/60 = 20.3131\ kWh$

$SOE_{85}^{EV} = 20.3131 + 0.95 \times 6.6 \times 5/60 = 20.8356\ kWh$

$SOE_{90}^{EV} = 20.8356 + 0.95 \times 6.6 \times 5/60 = 21.3581\ kWh$

$SOE_{95}^{EV} = 21.3581 + 0.95 \times 6.6 \times 5/60 = 21.8806\ kWh$

$SOE_{100}^{EV} = 21.8806 + 0.95 \times 6.6 \times 5/60 = 22.4031\ kWh$

EV-1 charged fully after $100\ minutes\ =\ 1.40$ hours

$3.06\ +\ 1.40 = 4.46\ o'clock$

But exact charged time is can be found from this calculation:

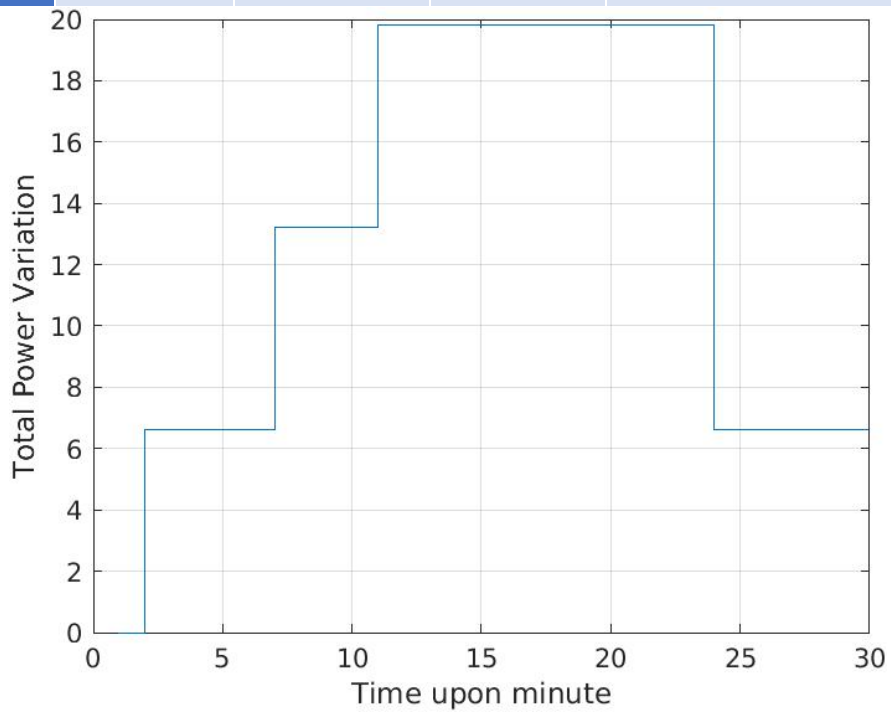
$22.4031 = 22 + 0.95 \times 6.6 \times \Delta T$

$\Delta T = 0.0643\ hour = 3.8574\ minute$

$4.46 - 0.0643 \cong 4.40$

Time	EV-1	EV-2	EV-3	Total Power
2.25pm	6.6	0	0	6.6
2.30pm	6.6	0	0	6.6
2.35pm	6.6	0	0	6.6
2.40pm	6.6	0	0	6.6
2.45pm	6.6	0	0	6.6
2.50pm	6.6	6.6	0	13.2
2.55pm	6.6	6.6	0	13.2
3.00pm	6.6	6.6	0	13.2
3.05pm	6.6	6.6	0	13.2
3.10pm	6.6	6.6	6.6	19.8
3.15pm	6.6	6.6	6.6	19.8
3.20pm	6.6	6.6	6.6	19.8
3.25pm	6.6	6.6	6.6	19.8
3.30pm	6.6	6.6	6.6	19.8
3.35pm	6.6	6.6	6.6	19.8
3.40pm	6.6	6.6	6.6	19.8

3.45pm	6.6	6.6	6.6	19.8
3.50pm	6.6	6.6	6.6	19.8
3.55pm	6.6	6.6	6.6	19.8
4.00pm	6.6	6.6	6.6	19.8
4.05pm	6.6	6.6	6.6	19.8
4.10pm	6.6	6.6	6.6	19.8
4.15pm	6.6	6.6	6.6	19.8
4.20pm	0	0	6.6	6.6
4.25pm	0	0	6.6	6.6
4.30pm	0	0	6.6	6.6
4.35pm	0	0	6.6	6.6
4.40pm	0	0	6.6	6.6
4.45pm	0	0	6.6	6.6
4.50pm	0	0	6.6	6.6



Matlab Code:

```
Cx = 0.19; %Drag coefficient
Cr = 0.0048; %Rolling coefficient
m = 1580; %vehicle mass with 2 person
A = 1.8; %front surface
eff = 0.85; %drivetrain efficiency
g = 9.81; %gravity
alpha = 0; %slope of road
dens = 1.25; %air density

bat_cap = 22; %battery capacity
charge = 6.6; %charging power rate
ch_eff = 0.95; %charging efficiency
fd=0; %other forces
SoE = [11; 13.6; 12]; %SoE of each car
speedEV1 = [0 3 5 6 8 9 14 14 12 11 11 10 10 6 2 0]; %EV-1's speed
speedEV2 = [0 5 8 8 12 10 9 8 7 3 2 0 ]; %EV-2's speed
speedEV3 = [0 5 8 8 15 12 10 8 8 7 7 7 7 6 4 2 0]; %EV-3's speed

%-----------------------------------------------------------------%
```

```
disp("EV-1");

v1 = speedEV1.*(1000/3600); %km/h to m/s
dt=60 %Accel Force deltaT is 60sec
deltaT = 1; %delta ts = s.*(1000/3600); %velocity m/s
square1 = v1.^2; %for Fa velocity needed squared
vel1 = diff(v1); %acceleration
zero = [0]; %after diff one var is empty so
dv1 =[zero vel1]; %first integer is must be = 0

f1 = m.*dv1./deltaT; %Newton law of motion
fa1 = 0.5*dens*A*Cx*square1; %Aerodynamic Drag Force
fr1 = m*Cr*g*cos(alpha); %Rolling Friction
fg1 = m*g*sin(alpha); %hill climbing force
ft1 = f1+fa1+fr1+fg1+fd; %Total Force
Pv1 = v1.*ft1; %Instantaneous vehicle power needed in watts
P1 = zeros(size(Pv1));  %Instantaneous Power
for i = 1:length(Pv1)
    if Pv1(i)>0 %if positive divide 0.85
        P1(i) = Pv1(i)./(eff*1000); %Instanteneous Power in kWs
    elseif Pv1(i)<0 %if negative multiple 0.85
        P1(i) = Pv1(i).*eff./1000; %Instanteneous Power in kWs
    end
end

%discharge mode for EV
disp("Discharge rates");
for ii = 1:length(P1)
    SoE(1) = SoE(1) - ch_eff*P1(ii)*deltaT/60; %formula
    disp(SoE(1));
end
table1 = [v1; dv1; f1; fa1; ft1; Pv1; P1];

disp("Charging rates");
i=1; %counter
pout1(i)=0; %power consumption counter
t1 = 0; %2.25pm, EV-3 comes to D point
deltaT = 5/60; %delta is changing by 5 min. We need hour so divide 60
while SoE(1)<bat_cap
    if t1>=0 %2.25, EV-1 arives D
        SoE(1) = SoE(1) + ch_eff*charge*deltaT;
        t1=t1+5; %timer
        i=i+1; %ordinary counter
        pout1(i)=charge; %6.6kW power used
        disp(t1);
        disp(SoE(1));
        t_list1(i,:)=[SoE;t1];
    else
        t_list1(i,:)=[SoE; t1];
        SoE(1) = SoE(1);
        t1=t1+5; %timer
        i=i+1; %ordinary counter
        pout1(i)=0; %0 power used
    end
end
fprintf("EV-1 charged at %.2f o'clock\n", 2.25+t1*0.0166667); %0.0166667 is min to
hour

%-------------------------------------------------------------%
disp("EV-2");

v2 = speedEV2.*(1000/3600);
dt = 60; %Accel Force deltaT is 60sec
deltaT = 1; %delta ts = s.*(1000/3600); %velocity m/s
square2 = v2.^2; %for Fa velocity needed squared
ve2 = diff(v2); %acceleration
zero = [0]; %after diff one var is empty so
```

```
dv2 =[zero ve2]; %first integer is needed = 0

f2 = m.*dv2./deltaT; %Newton law of motion
fa2 = 0.5*dens*A*Cx*square2; %Aerodynamic Drag Force
fr2 = m*Cr*g*cos(alpha); %Rolling Friction
fg2 = m*g*sin(alpha); %hill climbing force
ft2 = f2+fa2+fr2+fg2+fd; %Total Force
Pv2 = v2.*ft2; %Instantaneous vehicle power needed in watts
P2= zeros(size(Pv2));  %Instantaneous Power
for i = 1:length(Pv2)
    if Pv2(i)>0 %if positive divide 0.85
        P2(i) = Pv2(i)./(eff*1000); %Instanteneous Power in kWs
    elseif Pv2(i)<0 %if negative multiple 0.85
        P2(i) = Pv2(i).*eff./1000; %Instanteneous Power in kWs
    end
end

%discharge mode for EV
disp("Discharge rates");
for ii = 1:length(P2)
    SoE(2) = SoE(2) - ch_eff*P2(ii)*deltaT/60; %formula
    disp(SoE(2));
end
table2 = [v2; dv2; f2; fa2; ft2; Pv2; P2]; %

disp("Charging rates");
i=1; %ordinary counter
pout2=0; %power consumption counter
t2=0; %3.16pm, EV-3 comes to D point
deltaT = 5/60;
while SoE(2)<bat_cap
    if t2>=21 %2.25+21 = 2.46, EV-2 arives D.
        SoE(2) = SoE(2) + ch_eff*charge*deltaT;
        t2=t2+5; %timer
        i=i+1; %ordinary counter
        pout2(i)=charge; %6.6kW power used
        disp(t2);
        disp(SoE(2));
        t_list2(i,:)=[SoE;t2];
    else
        t_list2(i,:)=[SoE;t2];
        SoE(2) = SoE(2);
        t2=t2+5; %timer
        i=i+1; %ordinary counter
        pout2(i)=0; %0kW power used
    end
end
fprintf("EV-2 charged at %.2f o'clock\n", 2.25+t2*0.0166667); %0.0166667 is min to
hour

%-----------------------------------------------------------------%
disp("EV-3");

v3 = speedEV3.*(1000/3600); %km/h to m/s
dt = 60 %Accel Force deltaT is 60sec
deltaT = 1; %delta ts = s.*(1000/3600); %velocity m/s
square3 = v3.^2; %for Fa velocity needed squared
vel3 = diff(v3); %acceleration
zero = [0]; %after diff one var is empty so
dv3 =[zero vel3]; %first integer is needed = 0

f3 = m.*dv3./deltaT; %Newton law of motion
fa3 = 0.5*dens*A*Cx*square3; %Aerodynamic Drag Force
fr3 = m*Cr*g*cos(alpha); %Rolling Friction
fg3 = m*g*sin(alpha); %hill climbing force
ft3 = f3+fa3+fr3+fg3+fd; %Total Force
Pv3 = v3.*ft3; %Instantaneous vehicle power needed in watts
```

```
P3 = zeros(size(Pv3));  %Instantaneous Power
for i = 1:length(Pv3)
    if Pv3(i)>0 %if positive divide 0.85
        P3(i) = Pv3(i)./(eff*1000); %Instanteneous Power in kWs
    elseif Pv3(i)<0 %if negative multiple 0.85
        P3(i) = Pv3(i).*eff./1000; %Instanteneous Power in kWs
    end
end

%discharge mode for EV
disp("Discharge rates");
for ii = 1:length(P3)
    SoE(3)= SoE(3) - ch_eff*P3(ii)*deltaT/60;
    disp(SoE(3));
end
table3 = [v3; dv3; f3; fa3; ft3; Pv3; P3];

disp("Charging rates");
i=1; %ordinary counter
pout3=0; %power consumption counter
t3=0; %timer
deltaT=5/60; %delta is 5 min. we need hour so divided by 60
while SoE(3)<bat_cap
    if t3>=41 %2.25+41 = 3.06, EV-2 arives D
        SoE(3) = SoE(3) + ch_eff*charge*deltaT; %formula
        t3=t3+5; %timer
        i=i+1; %ordinary counter
        pout3(i)=charge; %6.6kW power used
        disp(t3);
        disp(SoE(3));
        t_list3(i,:)=[SoE;t3];
    else
        t_list3(i,:)=[SoE;t3];
        SoE(3) = SoE(3);
        t3=t3+5; %time timer
        i=i+1; %ordinary counter
        pout3(i)=0; %power variation timer for EV-3
    end
end
fprintf("EV-3 charged at %.2f o'clock\n", 2.25+t3*0.0166667); %0.0166667 is min to
hour

pout1(length(pout1)+1:length(pout3))=0; %the lengths was not equal to add each
other
pout2(length(pout2)+1:length(pout3))=0; %the lengths was not equal to add each
other
pout=pout1+pout2+pout3; %power variation
stairs(pout); %graph
xlabel("Time, 2.25 is 0, min");
ylabel("Total Power Consumption");
```