Data

Table 1: Parameters of Entities

Entity	Static Parameter Configuration
PDN	**Nodes**: 33 (IEEE 33-bus system) **Voltage Limits**: $0.9 \sim 1.1$ p.u. ($V_{min}^2 = 0.81, V_{max}^2 = 1.21$) **Substation**: Bus 1, $V_0 = 1.0$ p.u., $P_g^{min} = 0$, $P_g^{max} = 10$ MW, $Q_g^{max} = 3.86$ MVar
DG (ICE)	**Location**: Buses 5, 18, 25, 28 **Capacity**: $P \in [0, 4.5]$ MW, $Q \in [-2, 2]$ MVar
TN	**Time Value (w)**: 0.083 \$/min **Charging Price (c_e)**: 0.15 \$/kWh ($t_1 - t_3$), 0.20 \$/kWh ($t_4 - t_5$) **Avg Charging Demand (E)**: 10 kWh **Charging Parameter (J)**: 0.05

Table 2: Parameters of the PDN (Standard IEEE 33-Bus System)

Line (Bus i – Bus j)	**r (p.u.)**	**x (p.u.)**	**Note**
1 – 2	0.000575	0.000293	Connects CS1 (Bus 2)
2 – 3	0.003076	0.001567	
3 – 4	0.002284	0.001163	
4 – 5	0.002378	0.001211	Connects ICE1 (Bus 5)
5 – 6	0.005110	0.004411	
6 – 7	0.001168	0.003861	
7 – 8	0.004443	0.001467	
8 – 9	0.006426	0.004617	
9 – 10	0.006514	0.004617	Connects CS2 (Bus 10)
10 – 11	0.001227	0.000406	
11 – 12	0.002336	0.000772	
12 – 13	0.009159	0.007206	
13 – 14	0.003379	0.004448	
14 – 15	0.003687	0.003282	
15 – 16	0.004656	0.003400	
16 – 17	0.008042	0.010738	
17 – 18	0.004567	0.003581	Connects CS3 & ICE2 (Bus 18)
18 – 19	0.001023	0.000976	
19 – 20	0.009385	0.008457	
20 – 21	0.004083	0.004795	
21 – 22	0.004423	0.005848	
22 – 23	0.004547	0.005389	
23 – 24	0.008850	0.007963	
24 – 25	0.005603	0.004427	Connects CS4 & ICE3 (Bus 25)
25 – 26	0.003087	0.003184	
26 – 27	0.006413	0.005175	

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Line (Bus i – Bus j)	r **(p.u.)**	x **(p.u.)**	**Note**
27 – 28	0.006766	0.005374	Connects CS5 & ICE4 (Bus 28)
28 – 29	0.002595	0.002271	
29 – 30	0.005059	0.002511	
30 – 31	0.009744	0.009630	
31 – 32	0.003105	0.003619	
32 – 33	0.003410	0.005362	

Table 3: Parameters of the Transportation Network (TN)

Link ID	**Type**	**Free Flow Time (min)**	**Capacity (veh/h)**
1	Regular	7	800
2	Regular	9	400
3	Regular	9	200
4	Regular	12	800
5	Regular	7	350
6	Regular	9	400
7	Regular	5	800
8	Regular	9	350
9	Regular	5	250
10	Regular	9	300
11	Regular	9	550
12	Regular	10	550
13	Regular	9	600
14	Regular	6	700
15	Regular	9	500
16	Regular	8	300
17	Regular	7	200
18	Regular	14	400
19	Regular	11	600
CS1 (at Bus 2)	Charging	20	300
CS2 (at Bus 10)	Charging	20	300
CS3 (at Bus 18)	Charging	20	300
CS4 (at Bus 25)	Charging	20	300
CS5 (at Bus 28)	Charging	20	300

Table 4: Complete Traffic Demand (OD Demand) over Time Periods

OD Pair	**Nodes** ($r \to s$)	**Traffic Demand (veh)**				
		t_1	t_2	t_3	t_4	t_5
1	$1 \to 2$	150	250	350	250	150
2	$4 \to 2$	250	450	700	450	350
3	$1 \to 3$	250	300	550	250	200
4	$4 \to 3$	150	150	200	100	100

The derivation process of the objective function is as follows:

$$
\begin{aligned}
&\sum_{t\in T(T)}\sum_{a\in T_A^{rg}}(\omega t_{a,t}^{rg}+Toll_{a,t})x_{a,t}^{rg}+\sum_{t\in T(T)}\sum_{a\in T_A^{ch}}(\omega t_{a,t}^{ch}+\lambda_a^e E_e+Fee_{a,t}^e)x_{a,t}^{ch}\\
&=\sum_{t\in T(T)}\sum_{rs\in T(RS)}\sum_{k\in K_{rs}^e}\Bigg[\sum_{a\in T_A^{rg}}(\omega t_{a,t}^{rg}+Toll_{a,t})f_{k,rs,t}^e\delta_{a,k,rs}^e\\
&\quad+\sum_{a\in T_A^{ch}}(\omega t_{a,t}^{ch}+\lambda_a^e E_e+Fee_{a,t}^e)f_{k,rs,t}^e\delta_{a,k,rs}^e\Bigg]\\
&=\sum_{t\in T(T)}\sum_{rs\in T(RS)}\sum_{k\in K_{rs}^e}\Bigg[\sum_{a\in T_A^{rg}}(\dots)\delta_{a,k,rs}^e+\sum_{a\in T_A^{ch}}(\dots)\delta_{a,k,rs}^e\Bigg]f_{k,rs,t}^e \qquad (1)\\
&=\sum_{t\in T(T)}\sum_{rs\in T(RS)}\sum_{k\in K_{rs}^e}c_{rs,k,t}^e f_{k,rs,t}^e\\
&=\sum_{t\in T(T)}\sum_{rs\in T(RS)}u_{rs,k,t}^e\sum_{k\in K_{rs}^e}f_{k,rs,t}^e\\
&=\sum_{t\in T(T)}\sum_{rs\in T(RS)}u_{rs,k,t}^e q_{rs,t}^{e,mod}
\end{aligned}
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