

# Model Formulation

Table 1: List of Variables

Variable	Definition	Unit
$k_s^B$	Battery power rating at charging station $s$	MW
$e_s^B$	Energy capacity for battery at charging station $s$	MWh
$g_{st}^B$	Battery electricity generation at charging station $s$ at time $t$	MWh
$d_{st}^B$	Inflow demand for battery at charging station $s$ at time $t$	MWh
$x_{st}^B$	State of charge for battery at charging station $s$ at time $t$	MWh
$k_s^H$	H <sub>2</sub> power rating at charging station $s$	MW
$e_s^H$	Energy capacity for H <sub>2</sub> at charging station $s$	MWh
$g_{st}^H$	H <sub>2</sub> electricity generation at charging station $s$ at time $t$	MWh
$x_{st}^H$	State of charge for H <sub>2</sub> at charging station $s$ at time $t$	MWh
$d_{st}^H$	Inflow demand for H <sub>2</sub> at charging station $s$ at time $t$	MWh
$k_s^P$	Solar capacity at charging station $s$	MW
$g_{st}^P$	Solar electricity generation at charging station $s$ at time $t$	MWh
$g_{st}^M$	SMR electricity generation at charging station $s$ at time $t$	MWh
$u_s^M$	Number of SMR modules to build at charging station $s$	Whole number
$k_s^W$	Capacity of transmission line connecting wholesale markets to charging station $s$	MW
$g_{st}^W$	Electricity generation purchased from wholesale markets to charging station $s$ at time $t$	MWh

Table 2: List of Parameters and Sets

Parameter/Set	Definition	Unit
<i>Parameters:</i>		
$p_s^{BK}$	Battery capital cost at charging station $s$	\$/MW
$p_s^{BC}$	Battery energy cost at charging station $s$	\$/MWh
$p_{st}^{BE}$	Battery operating cost at charging station $s$ at time $t$	\$/MWh
$r_s^B$	Battery ramp rate at charging station $s$ at time $t$	MWh
$p_s^{HK}$	H <sub>2</sub> capital cost at charging station $s$	\$/MW
$p_s^{HC}$	H <sub>2</sub> energy cost at charging station $s$	\$/MWh
$p_{st}^{HE}$	H <sub>2</sub> operating cost at charging station $s$ at time $t$	\$/MWh
$r_s^H$	H <sub>2</sub> ramp rate at charging station $s$ at time $t$	MWh
$r_s^{HE}$	H <sub>2</sub> inflow ramp rate at charging station $s$ at time $t$	MWh
$p_s^{PK}$	Solar capital cost at charging station $s$	\$/MW
$p_{st}^{PE}$	Solar operating cost at charging station $s$ at time $t$	\$/MWh
$f_{st}^P$	Solar capacity factor at charging station $s$ at time $t$	%
$p_s^{MK}$	SMR capital cost at charging station $s$	\$/MW
$p_{st}^{ME}$	SMR operating cost at charging station $s$ at time $t$	\$/MWh
$\bar{k}_s^M$	SMR capacity at charging station $s$	MW
$l_s^W$	Length of transmission line built to connect to charging station $s$	Miles
$p_s^{WK}$	Transmission capital cost at charging station $s$	\$/MW
$p_s^{WI}$	Transmission infrastructure cost at charging station $s$	\$/mile
$p_s^{WC}$	Conductor cost at charging station $s$	\$/mile
$p_{st}^{WE}$	Wholesale electricity cost at charging station $s$ at time $t$	\$/MWh
$p_s^{WO}$	Other costs (including land costs and overhead costs)	\$
$d_{st}^E$	Electricity demand at charging station $s$ at time $t$	MWh
<i>Sets:</i>		
$\mathcal{S}$	Set of stations, index $s = \{1, 2, 3, \dots, 170\}$	–
$\mathcal{T}$	Set of hours, index $t = \{1, 2, 3, \dots, 24\}$	–
$\mathbb{Z}_0^+$	Set of whole number, $\mathbb{Z}_0^+ = \{0, 1, 2, 3, \dots\}$	–

$$\begin{aligned}
\min_{\substack{k_s^W, k_s^B, k_s^H, k_s^P, u_s^M, \\ e_s^B, e_s^H, \\ g_{st}^W, g_{st}^B, g_{st}^H, g_{st}^P, g_{st}^M, \\ d_{st}^B, d_{st}^H}} \quad & \sum_s \left\{ \underbrace{\left[ p_s^{BK} k_s^B + p_s^{BC} e_s^B + \sum_t p_{st}^{BE} g_{st}^B \right]}_{\text{Battery Expansion and Operating Costs}} + \underbrace{\left[ p_s^{HK} k_s^H + p_s^{HC} e_s^H + \sum_t p_{st}^{HE} g_{st}^H \right]}_{\text{H}_2 \text{ Expansion and Operating Costs}} + \underbrace{\left[ p_s^{PK} k_s^P + \sum_t p_{st}^{PE} g_{st}^P \right]}_{\text{Solar PV Expansion and Operating Costs}} \\
& + \underbrace{\left[ p_s^{MK} u_s^M k_s^M + \sum_t p_{st}^{ME} g_{st}^M \right]}_{\text{SMR Expansion and Operating Costs}} + \underbrace{\left[ p_s^{WK} k_s^W + \sum_t p_{st}^{WE} g_{st}^W + (p_s^{WI} + p_s^{WC}) l_s^W + p_s^{WO} \right]}_{\text{Transmission Expansion and Operating Costs}} \right\} \quad (1)
\end{aligned}$$

s.t.

$$\text{General Non-negativity: } k_s^B, k_s^H, k_s^P, k_s^W, e_s^B, e_s^H \geq 0, \quad \forall s \in \mathcal{S} \quad (2)$$

$$\text{Market Clearing Conditions: } g_{st}^B + g_{st}^H + g_{st}^P + g_{st}^M + g_{st}^W \geq d_{st}^E + d_{st}^B + d_{st}^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (3)$$

$$\text{Battery Constraints: } 0 \leq d_{st}^B \leq k_s^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (4)$$

$$0 \leq g_{st}^B \leq k_s^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (5)$$

$$0 \leq g_{st}^B \leq x_{st}^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (6)$$

$$0 \leq x_{st}^B \leq e_s^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (7)$$

$$x_{st}^B = x_{s(t-1)}^B + d_{st}^B - g_{st}^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (8)$$

$$\|g_{st}^B - g_{s(t-1)}^B\| \leq r_s^B, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (9)$$

$$\text{Need to add initial SOC conditions} \quad (10)$$

$$\text{Hydrogen Constraints: } 0 \leq d_{st}^H \leq k_s^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (11)$$

$$0 \leq g_{st}^H \leq k_s^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (12)$$

$$0 \leq g_{st}^H \leq x_{st}^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (13)$$

$$0 \leq x_{st}^H \leq e_s^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (14)$$

$$x_{st}^H = x_{s(t-1)}^H + d_{st}^H - g_{st}^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (15)$$

$$\|g_{st}^H - g_{s(t-1)}^H\| \leq r_s^H, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (16)$$

$$\|e_{st}^H - e_{s(t-1)}^H\| \leq r_s^{HE}, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (17)$$

$$\text{Need to add initial SOC conditions} \quad (18)$$

$$\text{Solar PV Constraints: } 0 \leq g_{st}^P \leq f_{st}^P k_s^P, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (19)$$

$$\text{SMR Constraints: } 0 \leq g_{st}^M \leq u_s^M k_s^M, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (20)$$

$$u_s^M \in \mathbb{Z}_0^+, \quad (21)$$

$$\|g_{st}^M - g_{s(t-1)}^M\| \leq r_s^M, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (22)$$

$$\text{Wholesale Power Constraints: } 0 \leq g_{st}^W \leq k_s^W, \quad \forall s \in \mathcal{S}, \forall t \in \mathbb{T} \quad (23)$$