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_2 power rating at charging station s	MW
e_s^H	Energy capacity for H_2 at charging station s	MWh
g_{st}^H	H_2 electricity generation at charging station s at time t	MWh
x_{st}^H	State of charge for H_2 at charging station s at time t	MWh
d_{st}^H	Inflow demand for H_2 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
u_{si}^W	Whether to build (1) or not build (0) transmission line of capacity group i at station s	Binary
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
Parameters:		
p^{BK}	Battery annual capital cos	\$/MW
p^{BC}	Battery energy cost	\$/MWh
p^{BE}	Battery operating cost	\$/MWh
r_s^B	Battery ramp rate at charging station s at time t	MWh
h^B	Battery hour	hour
p^{HK}	H_2 capital cost	\$/MW
p^{HC}	H_2 energy cost	\$/MWh
p^{HE}	H_2 operating cost	\$/MWh
$\bar{d}_{st}^H$	H_2 demand at charging station s at time t	MWh
r_s^H	H_2 ramp rate at charging station s at time t	MWh
p^{PK}	Solar capital cost	\$/MW
p^{PE}	Solar operating cost	\$/MWh
f_{st}^P	Solar capacity factor at charging station s at time t	%
g_{min}^M	SMR minimum stable load	MWh
p^{MK}	SMR capital cost	\$/MW
p^{ME}	SMR operating cost	\$/MWh
$\bar{k}^M$	SMR module capacity s	MW
$\bar{l}_{si}^W$	Length of transmission line of capacity group i built to connect to charging station s	Miles
$\bar{k}_i^W$	Effective capacity of transmission line in group i	MW
p_{si}^{WK}	Transmission capital cost for transmission capacity group i at charging station s	\$/MW
p_{si}^{WI}	Transmission infrastructure cost for transmission capacity group i at charging station s	\$/mile
p_{si}^{WC}	Conductor cost for transmission capacity group i at charging station s	\$/mile
p_{si}^{WL}	Land cost for transmission capacity group i at charging station s	\$/mile
p_{st}^{WE}	Wholesale electricity cost at charging station s at time t	\$/MWh
p_s^{WO}	Overhead add-ons at charging station s	%
d_{st}^E	Electricity demand at charging station s at time t	MWh
Sets:		
$\mathbb{I}$	Set of transmission line capacity levels, index $i = \{1, 2, 3, ..., 7\}$	–
$\mathbb{S}$	Set of stations, index $s = \{1, 2, 3, ..., 170\}$	–
$\mathbb{T}$	Set of hours, index $t = \{1, 2, 3, ..., 24\}$	–
$\mathbb{Z}_0^+$	Set of whole numbers, $\mathbb{Z}_0^+ = \{0, 1, 2, 3, ...\}$	–
$\mathbb{Z}_2$	Set of binary numbers, $\mathbb{Z}_2 = \{0, 1\}$	–

$$\min_{\substack{u_{si}^W, k_s^B, k_s^H, k_s^P, u_s^M, \\ e_s^B, e_s^H, \\ g_{st}^W, g_{st}^B, g_{st}^H, g_{st}^P, g_{st}^M, \\ d_{st}^B, d_{st}^H}} \sum_s \Bigg\{ \underbrace{\left[p^{BK} k_s^B + p^{BC} e_s^B + \sum_t p^{BE} g_{st}^B \right]}_{\text{Battery Expansion and Operating Costs}} + \underbrace{\left[p^{HK} k_s^H + p^{HC} e_s^H + \sum_t p^{HE} g_{st}^H \right]}_{\text{H}_2 \text{ Expansion and Operating Costs}} + \underbrace{\left[p^{PK} k_s^P + \sum_t p^{PE} g_{st}^P \right]}_{\text{Solar PV Expansion and Operating Costs}} \tag{1}$$

$$+ \underbrace{\left[p^{MK} u_s^M \bar{k}^M + \sum_t p^{ME} g_{st}^M \right]}_{\text{SMR Expansion and Operating Costs}} + \underbrace{\left[\sum_i \left(p_{si}^{WK} \bar{k}_i^W + \left(1 + p^{WO}\right) \left(p_{si}^{WI} + p_{si}^{WC} + p_{si}^{WL} \right) \bar{l}_{si}^W \right) u_{si}^W + \sum_t p_{st}^{WE} g_{st}^W \right]}_{\text{Transmission Expansion and Operating Costs}} \Bigg\}$$

s.t.

General Non-negativity:
$$k_s^B, k_s^H, k_s^P, k_s^W, e_s^B, e_s^H \geq 0, \qquad \forall s \in \mathbb{S} \tag{2}$$

Market Clearing Conditions:
$$g_{st}^B + g_{st}^H + g_{st}^P + g_{st}^M + g_{st}^W \geq d_{st}^E - \bar{d}_{st}^H + d_{st}^B + d_{st}^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{3}$$

Battery Constraints:
$$0 \leq d_{st}^B \leq k_s^B, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{4}$$
$$0 \leq g_{st}^B \leq k_s^B, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{5}$$
$$0 \leq g_{st}^B \leq x_{st}^B, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{6}$$
$$e_s^B = h^B k_s^B, \qquad \forall s \in \mathbb{S} \tag{7}$$
$$0 \leq x_{st}^B \leq e_s^B, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{8}$$
$$x_{st}^B = x_{s(t-1)}^B + d_{st}^B - g_{st}^B, \qquad \forall s \in \mathbb{S}, \forall t > 1 \in \mathbb{T} \tag{9}$$
$$x_{s(t=1)}^B = 0.5 \times e_s^B, \qquad \forall s \in \mathbb{S} \tag{10}$$

Hydrogen Constraints:
$$0 \leq d_{st}^H \leq k_s^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{11}$$
$$0 \leq g_{st}^H \leq k_s^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{12}$$
$$0 \leq g_{st}^H \leq x_{st}^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{13}$$
$$0 \leq x_{st}^H \leq e_s^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{14}$$
$$x_{st}^H = x_{s(t-1)}^H + d_{st}^H - g_{st}^H, \qquad \forall s \in \mathbb{S}, \forall t > 1 \in \mathbb{T} \tag{15}$$
$$x_{s(t=1)}^H = 0.5 \times e_s^H, \qquad \forall s \in \mathbb{S} \tag{16}$$
$$g_{st}^H \geq \bar{d}_{st}^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{17}$$

Solar PV Constraints:
$$0 \leq g_{st}^P \leq f_{st}^P k_s^P, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{18}$$

SMR Constraints:
$$0 \leq g_{st}^M \leq u_s^M \bar{k}^M, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{19}$$
$$u_s^M \in \mathbb{Z}_0^+, \qquad \forall s \in \mathbb{S} \tag{20}$$
$$g_{st}^M \geq g_{min}^M, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{21}$$
$$\| g_{st}^M - g_{s(t-1)}^M \| \leq r_s^M u_s^M \bar{k}^M, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{22}$$

Wholesale Power Constraints:
$$0 \leq g_{st}^W \leq \sum_i u_{si}^W \bar{k}_i^W, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \tag{23}$$
$$u_{si}^W \in \mathbb{Z}_2, \qquad \forall s \in \mathbb{S}, \forall i \in \mathbb{I} \tag{24}$$
$$\sum_i u_{si}^W \leq 1, \qquad \forall s \in \mathbb{S}, \forall i \in \mathbb{I} \tag{25}$$