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	kg
g_{st}^H	H$_2$ electricity generation at charging station s at time t	kg
x_{st}^H	State of charge for H$_2$ at charging station s at time t	kg
d_{st}^H	Inflow demand for H$_2$ at charging station s at time t	kg
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 cost	$/MW
p^{BC}	Battery energy cost	$/MWh
p^{BE}	Battery hours (= 4)	hour
p^{HK}	H$_2$ capital cost	$/MW
p^{HC}	H$_2$ energy cost	$/kg
p^{HE}	H$_2$ operating cost	$/kg
$\bar{d}^{H}_{st}$	H$_2$ demand at charging station s at time t	kg
c^{H}	Conversion factor from 1 MWh to kg of H$_2$ (= 49.3)	—
p^{PK}	Solar capital cost	$/MW
p^{PE}	Solar operating cost	$/MWh
f^{P}_{st}	Solar capacity factor at charging station s at time t	%
g^{M}_{min}	SMR minimum stable load	MWh
p^{MK}	SMR capital cost	$/MW
p^{ME}	SMR operating cost	$/MWh
$\bar{k}^{M}$	SMR module capacity	MW
$\bar{k}^{W}_{si}$	Effective capacity of transmission line at charging station s in group i	MW
p^{WK}_{si}	Annualized capital cost for transmission capacity group i at charging station s	$/MW
p^{WE}_{st}	Wholesale electricity cost at charging station s at time t	$/MWh
p^{WO}_{s}	Overhead add-ons at charging station s	%
d^{E}_{st}	Electricity demand at charging station s at time t	MWh

Parameter/Set	Definition	Unit
Sets:		
$\mathbb{I}$	Set of transmission line capacity levels, index $i = \{1, 2, 3, ..., 10\}$	–
$\mathbb{S}$	Set of stations, index $s = \{1, 2, 3, ..., 170/161/152\}$	–
$\mathbb{T}$	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, $\mathbb{Z}_{2} = \{0, 1\}$	–

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

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

s.t.

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

Market Clearing Conditions: $\quad g_{st}^B + g_{st}^P + g_{st}^M + g_{st}^W \geq d_{st}^E + d_{st}^B + \left(\dfrac{1}{c^H} \right) d_{st}^H, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \qquad (3)$

Battery Constraints:

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

Hydrogen Constraints:

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

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

SMR Constraints:

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

Wholesale Power Constraints:

$$0 \leq g_{st}^W \leq \sum_i u_{si}^W \bar{k}_{si}^W, \qquad \forall s \in \mathbb{S}, \forall t \in \mathbb{T} \qquad (23)$$
$$u_{si}^W \in \mathbb{Z}_2, \qquad \forall s \in \mathbb{S}, \forall i \in \mathbb{I} \qquad (24)$$
$$\sum_i u_{si}^W \leq 1, \qquad \forall s \in \mathbb{S}, \forall i \in \mathbb{I} \qquad (25)$$