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_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$_2$ capital cost at charging station s	\$/MW
p_s^{HC}	H$_2$ energy cost at charging station s	\$/MWh
p_{st}^{HE}	H$_2$ operating cost at charging station s at time t	\$/MWh
r_s^H	H$_2$ 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
$\bar{l}_{si}^W$	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

Parameter/Set	Definition	Unit
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, $\mathbb{Z}_2 = \{0, 1\}$	–

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

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

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:	$g_{st}^B + g_{st}^H + g_{st}^P + g_{st}^M + g_{st}^W \geq d_{st}^E + d_{st}^B + d_{st}^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(3)
Battery Constraints:	$0 \leq d_{st}^B \leq k_s^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(4)
	$0 \leq g_{st}^B \leq k_s^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(5)
	$0 \leq g_{st}^B \leq x_{st}^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(6)
	$0 \leq x_{st}^B \leq e_s^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(7)
	$x_{st}^B = x_{s(t-1)}^B + d_{st}^B - g_{st}^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(8)
	$\|g_{st}^B - g_{s(t-1)}^B\| \leq r_s^B,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(9)
	Need to add initial SOC conditions		(10)
Hydrogen Constraints:	$0 \leq d_{st}^H \leq k_s^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(11)
	$0 \leq g_{st}^H \leq k_s^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(12)
	$0 \leq g_{st}^H \leq x_{st}^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(13)
	$0 \leq x_{st}^H \leq e_s^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(14)
	$x_{st}^H = x_{s(t-1)}^H + d_{st}^H - g_{st}^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(15)
	$\|g_{st}^H - g_{s(t-1)}^H\| \leq r_s^H,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(16)
	Need to add initial SOC conditions		(17)
Solar PV Constraints:	$0 \leq g_{st}^P \leq f_{st}^P k_s^P,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(18)
SMR Constraints:	$0 \leq g_{st}^M \leq u_s^M \bar{k}_s^M,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(19)
	$u_s^M \in \mathbb{Z}_0^+,$	$\forall s \in \mathbb{S}$	(20)
	$\|g_{st}^M - g_{s(t-1)}^M\| \leq r_s^M,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(21)
Wholesale Power Constraints:	$0 \leq g_{st}^W \leq \sum_i u_{si}^W \bar{k}_i^W,$	$\forall s \in \mathbb{S}, \forall t \in \mathbb{T}$	(22)
	$u_{si}^W \in \mathbb{Z}_2,$	$\forall s \in \mathbb{S}, \forall i \in \mathbb{I}$	(23)
	$\sum_i u_{si}^W \leq 1,$	$\forall s \in \mathbb{S}, \forall i \in \mathbb{I}$	(24)