Basic Optimizing of Vehicle Charge

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March 25, 2013

Estimatating the energy requirement for fleet vehicles with the goal to minimize the charge costs.

0.1 Battery Charge:

- Maximum charge of Battery is 1.00 unit, which requires 6.00 hours.
- Battery capacity : 15 kWh
- Maximum charge speed per minute $u_c = \dfrac{1}{6 \times 60}\ kWh/min$
- Maximum discharge speed per minute $u_d\ = \dfrac{0.04}{15}\ kWh/min$
- State of battery charge, soc: $0 \leq soc \leq 1.0$

0.2 Price Series:

- Number of Price dates $= n_p\ , where\ price\ dates\ represents\ for\ each\ hour\ for\ all\ dates\ of\ p = 1....i$
- Buying price $(p - n)$ Euro/MWh, $where\ p = price\ and\ n = ask\,mid\,spread$
- Selling price $(p + m)$ Euro/MWh, $where\ p = price\ and\ m = mid\,bid\,spread$

0.3 Connection Series:

- Number of trips per week $= n_t$
- Connection template:
  1. $n_t in\,range\,(Mon\,00:00 - Sun\,23:00) \Rightarrow shift = 0$
  2. $n_t cross\,the\,weekend\,(eg.\,Sun\,09:00 - Mon\,01:00) \Rightarrow shift = 1$
- Total number of weeks $= w$
- Total number of Connection dates $= n_c = (n_t \times 2) \times w$
- Total number of Consumption $= n_c$

0.4 Charge Optimizer:

- w =window = optimization hours, $1 < w < j\ where\ j\ is\ number\ of\ hour\ to\ optimize(e.g.\ 48\ hour)$
- t =index of price dates, $where\ \ 0 \leq t \leq w$
- $tend = t + w - 1,\ \ where\ \ 1 < tend < n_p$
- s =index of connection dates,$0 \leq s < n_c$
- In all case, $connection\_dates[s] \geq price\_dates[t]$, so when:

Case-I: $when\ \ 1 < tend < n_p \quad where,\ \ 0 \leq t \leq w\ \ and\ \ 0 \leq s < n_c$

$$s_{01} = s,\ \ s_1 = s,\ \ t_1 = t$$

Case-1: $where,\ \ 0 \leq t_1 \leq w\ \ and\ \ 0 \leq s_1 < n_c$

$if\ \ connection\_dates[s_1] < price\_dates[t_1]\ \ \rightarrow break,$

$since,\ \ connection\_dates[s_1] \geq price\_dates[t_1]$

Case-2: $when\ \ t_1 \leq tend\ \ or\ \ t_1 \geq 0\ \ and\ \ 0 \leq s_1 < n_c :$

$s_2 = s_1$

$t_1 = t_1 + 1$

Case-3: $if\ \ soc < 0 \longrightarrow break$

$s = s_{01},\ \ t = t + w$

Case-2: $when\ \ t_1 \leq tend\ \ or\ \ t_1 \geq 0\ \ and\ \ 0 \leq s_1 < n_c :$

$s_2 = s_1$

$t_1 = t_1 + 1$

Case-2.a: $where\ \ 0 \leq s_1 < n_c\ \ when\ \ n_c > connection\_dates[s_2] < price\_dates[t_1 + 1]$

$s_2 = s_2 + 1$

Case-2.b: $if\ \ connection\_dates[s_2] < price\_dates[t_1 + 1]$

$s_{01} = s_1 = s_2 \rightarrow break,$

$because,\ \ connection\_dates[s_2]\quad last\_connection\_dates < price\_dates[t_1 + 1]$

Case-2.c: $s_1 \leq k < s_2 + 1 :$ loop followed

Case-2.d: $if\ \ t_1 \leq tend\quad and\ \ 0 \leq s_2 < n_c :$

$s_{01} = s_2$

Case-2.e: $if\ \ tend \leq t_1 \leq n_p - 1\quad and\ \ k\%2! = shift\quad and\ s_2 > t_1 + 1 :$

$extend = True$

Case-2.f: $else :$

$extend = False$

Case-2.c: $s_1 \leq k < s_2 + 1 :$

Case-2.c-(i) $dstart = \begin{cases} connection\_dates[k-1], & if\ \ s_1 < k < s_2 + 1 \\ price\_dates[t] & for\, k = s_1\ \ and\ \ k < s_2 + 1 \end{cases}$

Case-2.c(ii) $dend = \begin{cases} price\_dates[t+1] & if\ \ s_1 < k < s_2 + 1 \\ connection\_dates[k], & for\, k = s_1\ \ and\ \ k < s_2 + 1 \end{cases}$

Case-2.c(ii)-A: $if\ \ dstart \leq k\%2 < dend\ \ and\ \ k\%2! = shift :$

$$duration = (dend - dstart)\ \ hours\ \ = (dend - dstart)\ \times 60\ \ minutes$$

$$v_{in}\epsilon[0, x]\ \ v_{out} = 0.0\ \ where,\, 0 \leq x \leq \frac{1}{6 \times 60}\ \ kWh/min$$

Case-2.c(ii)A-1: $if\ \ u_d > 0 :$

$$v_{out}\epsilon[0, y]\ \ ,where\ \ v_{in}\epsilon[0, x]\ \ 0 \leq y \leq \frac{0.04}{15}\ \ kWh/min$$

Case-2.c(ii)-A-2: $consumption = \begin{cases} consumption[k] & if\ \ dend = connection\_dates[k] \\ 0 & else \end{cases}$

Case-2.c(ii)-B: $if\ \ k\%2 == shift\quad and\ \ False\quad \longrightarrow break$

Mathematical formulation:

0.1 *Variable definition:*

$$Charge\ of\ Battery\ v_{in}\epsilon[0,x]\ where,\ 0 \leq x \leq \frac{1}{6\times 60}\ kWh/min$$
$$Discharge\ of\ Battery\ \ v_{out}\epsilon[0,y], where\ 0 \leq y \leq \frac{0.04}{15}\ kWh/min$$

0.2 *Parameter:*

$Charge\ duration,\ t_d$	$Price\ p$
$Charge\ of\ Battery\ V_{in}$	$Mid\ bid\ spread,\ m\ (Euro/Mwh)$
$Discharge\ of\ Battery\ V_{out}$	$Ask\ mid\ spread,\ n\ (Euro/Mwh)$
$Charge\ of\ Battery\ without\ optimization\ V_{in_{nop}}$	$Buying\ price\ of\ charge,\ (p+m)\ (Euro/Mwh)$
$State\ of\ Charge\ V_{in}$	
$State\ of\ charge\ without\ optimization,\ S_{nop}$	$Selling\ price\ of\ charge,\ (p-n)\ (Euro/Mwh)$
$New\ state\ of\ charge\ without\ optimization,\ S_n$	$Initial\ state\ of\ charge\ S_0$
	$State\ of\ charge\ at\ time\ t,\ S_t$
$Charge\ cost\ prob$	$Minimum\ charge\ of\ battery,\ C_{min}$
$Charge\ cost\ without\ optimization,\ prob_{nop}$	$Charge\ capacity,\ C$
	$Consumtion\ of\ charge,\ k$

0.3 *Formulate the Objective Function:*

The Objective Function becomes,

1. **Minimise Charge costs** $= \mathbf{min}\,\{\mathbf{V_{in} * (p+m)\ - V_{out} * (p-n)}\}$
   (a) $\mathbf{prob} = \mathbf{min}\,[\{\mathbf{V_{in} * (p+m)\ - V_{out} * (p-n)}\} \times \mathbf{C}]\,/\mathbf{1000}$ (Euro/Mwh)
   (b) $S_n\ \epsilon\ [1.0,\ S_{nop} + V_{in}]$
   (c) $V_{in\_nop}\ = (S_n - S_{nop}) \times C$
   (d) $prob_{nop} = (V_{in_{nop}} \times C \times p)/1000$
   (e) $Vol = (V_{in} - V_{out}) \times C\ and\ Vol_{plus}\ \epsilon[0,\ Vol]$
   (f) $S_t\ = [S_0 + (V_{in} - V_{out})] \times C$
   (g) $S_{nop} = (S_t + V_{nop})$

0.4 *The Contraints:*

State of charge in Battery at running time t ,

$$\mathrm{S_t = (S_0 + x - y - k)}\quad \text{where, } 0 < \mathrm{S_t} \leq 1.0$$

Minmium charge of Battery, $\mathrm{C_{min}}$:

$$0 < (\mathrm{C_{min}} + 1\mathrm{e}^{-5}) \leq \mathrm{S_t}$$

$$Consumtion\ of\ charge,\ k \neq 0$$