Electric Vehicle Charging and Load Shedding

By William Mollenkopf

Electric Vehicle Charging and Load Shedding

- Fueling: The gas station right? (Reality is typically at home)

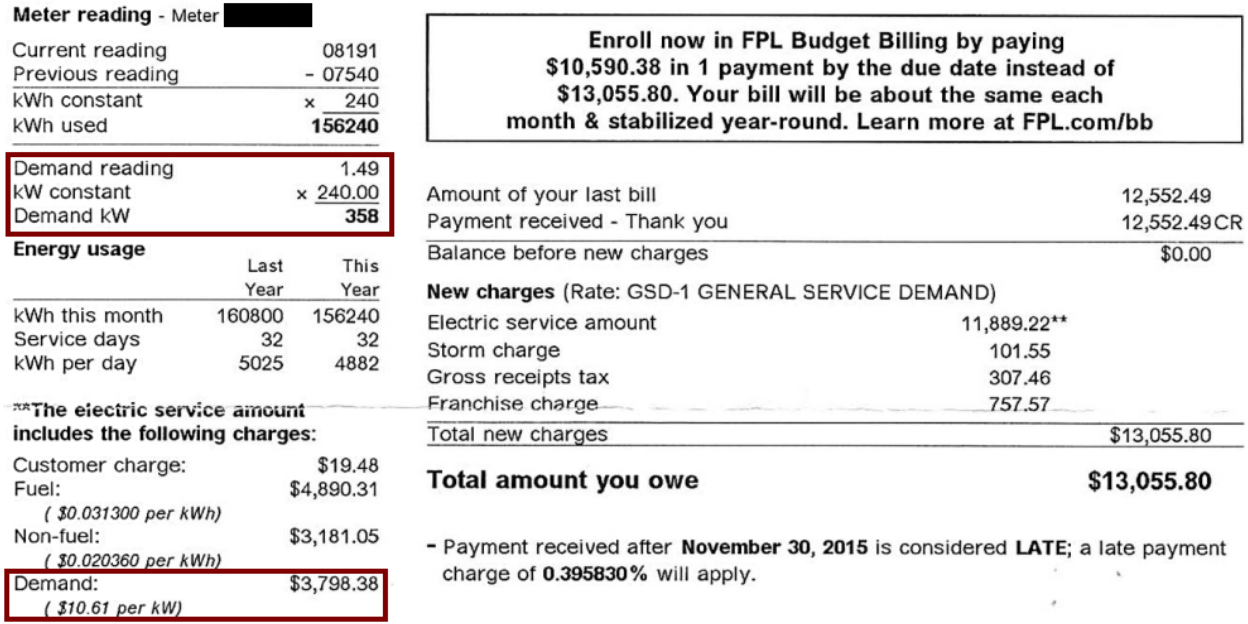
What if…

- You could fuel your car for free (or for very little) while out on the go, without being inconvenienced?

Image Sources: (Left):http://www.pluginrecharge.com/2010/05/ucfs-new-solar-powered-charging-station.html
(Right):http://www.simon.com/mall/waterford-lakes-town-center

(Background): Electric Bills

- Consumers are charged (more or less) a flat rate for how much power they consumed.
- Businesses are charged this way as well, but with an expensive peak demand fees as well.
- Example: $10.61 * 358 kW = $3,798.38 Demand Fee per month (In addition to typical consumption rate charges)



Meter reading - Meter [redacted]

Current reading	08191
Previous reading	- 07540
kWh constant	x 240
kWh used	**156240**
Demand reading	1.49
kW constant	x 240.00
Demand kW	**358**

Energy usage

	Last Year	This Year
kWh this month	160800	156240
Service days	32	32
kWh per day	5025	4882

****The electric service amount includes the following charges:**

Customer charge:	$19.48
Fuel:	$4,890.31
($0.031300 per kWh)	
Non-fuel:	$3,181.05
($0.020360 per kWh)	
Demand:	$3,798.38
($10.61 per kW)	

Enroll now in FPL Budget Billing by paying $10,590.38 in 1 payment by the due date instead of $13,055.80. Your bill will be about the same each month & stabilized year-round. Learn more at FPL.com/bb

Amount of your last bill	12,552.49
Payment received - Thank you	12,552.49CR
Balance before new charges	$0.00

New charges (Rate: GSD-1 GENERAL SERVICE DEMAND)

Electric service amount	11,889.22**
Storm charge	101.55
Gross receipts tax	307.46
Franchise charge	757.57
Total new charges	$13,055.80

Total amount you owe **$13,055.80**

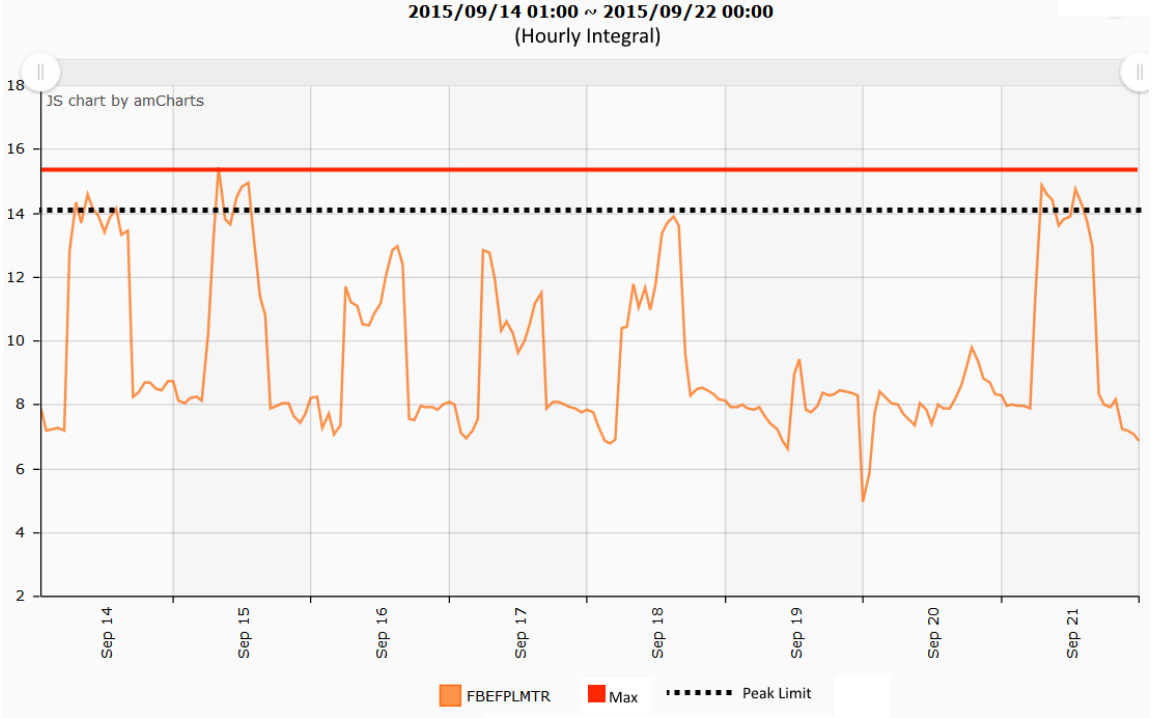
- Payment received after **November 30, 2015** is considered **LATE**; a late payment charge of **0.395830%** will apply.

(Background): Electric Bills-> Peak Demands

- Why? - Complex reasons, but *my* basic understanding is due to how power is generated.
- How are they calculated?
  - Several ways, but one in particular is the:
    - The Sliding Window
      (Example Sliding Window: 30 minutes, with 15 second slides)

(Background): Load Shedding

- Staying below the peak!
- How to perform shedding?: Controlling (on/off/partial consumption) of devices consuming power.



(Background): PID Controller Algorithm (Proportional-Integral-Derivative)

- What is this?: *Cruise Control*

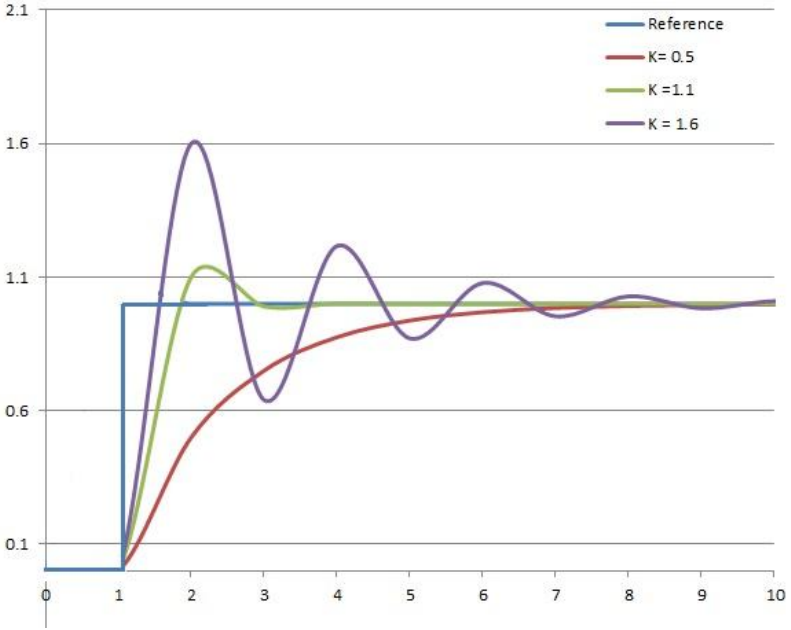


Image Sources: https://en.wikipedia.org/wiki/PID_controller

PID controller theory

$$\mathrm{u}(t) = \mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{d}{dt} e(t)$$

where

K_p: Proportional gain, a tuning parameter

K_i: Integral gain, a tuning parameter

K_d: Derivative gain, a tuning parameter

e: Error $= SP - PV$

t: Time or instantaneous time (the present)

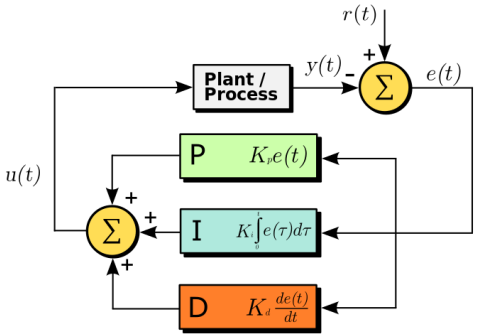
τ: Variable of integration; takes on values from time 0 to the present t.

Equivalently, the transfer function i

$$L(s) = K_p + K_i/s + K_d s$$

where

s: complex number frequency



(Main Focus): The Great Horizon

“An Optomized EV Charging Algorithm Using Control Horizon Method”

Abstract.
“In this paper, the optimized charging algorithm in electric vehicle (EV) is proposed using control horizon method. A model predictive control (MPC) with linear programming (LP) is used for optimal control, and the time-of-use (TOU) price is included to calculate the energy costs. Simulation results show that the reductions of energy cost and peak power can be obtained using proposed algorithms.”

Source: http://onlinepresent.org/proceedings/vol58_2014/24.pdf

(Main Focus): The Great Horizon (Cont.)

- We both have peaks? (Well kind of?)
  - Based on: Stepwise Power tariffs and TOU (Time of Use)

Graph Explanation

- 15 minute switching
- 9 hour range
- Starts at 11am
- Prior to Window = historical values
- After Window = future predicted values
- Each vertical axis = 15 minutes window where predictions are made and discarded every 15 minutes.

(1) On/off control algorithm ($u_i(k) = 0$ or 1, $k = 1, \cdots, N$).

(2) MPC control algorithm with LP ($0 \le u_i(k) \le 1$, $k = 1, \cdots, N$).

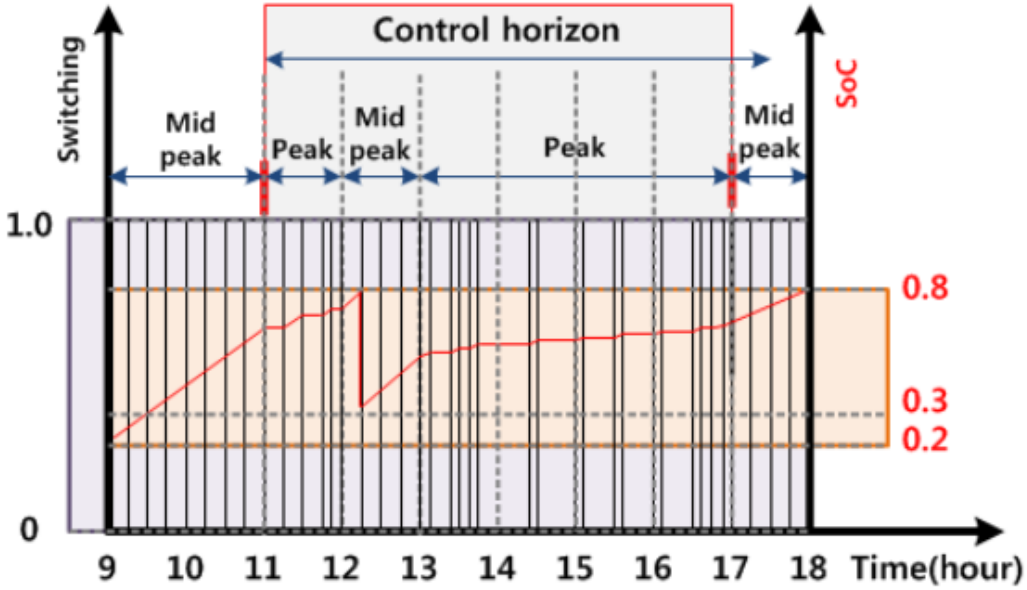


Fig. 1. Control horizon switching strategy

Source: http://onlinepresent.org/proceedings/vol58_2014/24.pdf

(Main Focus): The Great Horizon (Cont.)

Comparison:

- On/Off Method Versus Model Predictive Control (MPC) and Linear Programming (LP)
- 4.7% energy savings with MPC and LP over On/Off Method

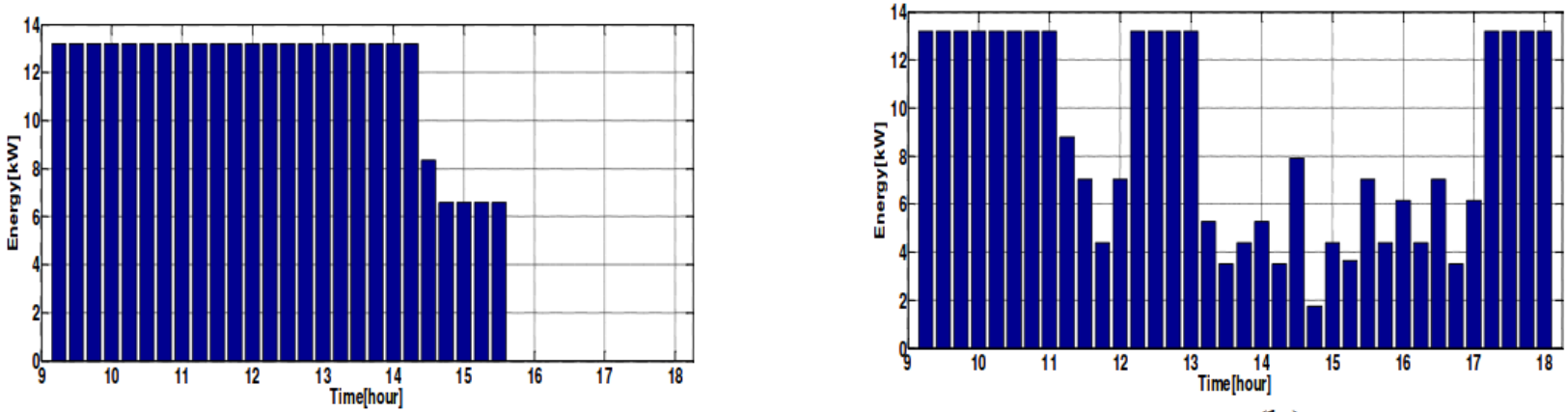


Fig. 2. Energy rate for temperature control: (a) On/off, (b) MPC with LP

Source: http://onlinepresent.org/proceedings/vol58_2014/24.pdf

(Future Focus): Moving Forward

- Paper states: more research and a more mature computer simulation is necessary to make improvements.
- How do we apply their algorithm, or at least the MPC and LP to:
  - Our 30 minute, 15 second sliding window
  - Instead of their one continuous flat peak they wish to avoid.
  - Allow businesses to offer EV charging without taking much of a hit to their power consumption?

Think about it… (Possible discussion points)

- What if we could have a system where we can both implement EV chargers AND perform load shedding?
- Ideas to obtain this: (For details, ask me later!)
  - Incorporate solar panels
  - MPC and LP
  - Possibly a network of EV cars that discharge based on advanced/agreed ruleset
- Consider:
  - How can people exploit EV Charging Stations?
  - A future where we shop, and explore the city based on what places have the best/cheapest EV chargers.

(End): Main Sources

- Chang-Jin Boo, Bong-Woon Ko, Ho-Chan Kim. "An Optimized EV Charging Algorithm Using Control Horizon Method." in *Advanced Science and Technology Letters* Vol.58 (Electrical Engineering 2014), pp.113-116 <http://onlinepresent.org/proceedings/vol58_2014/24.pdf>
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(End): Image Sources

- Plugin Recharge. “Plugin...Recharge!: UCF's New Solar…” <http://www.pluginrecharge.com/2010/05/ucfs-new-solar-powered-charging-station.html>
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(End): Questions?

Image Sources: http://www.govtech.com/transportation/Minnesota-Cities-Plan-for-Electric-Vehicles.html