



# **Adventures in Networked HVAC**

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# Internet Archive

570,000 TV Shows

1,600,000 Movies

128,000 Concerts

2,000,000 Audio Recordings

2,500,000 Books

412,000,000,000 Web Pages

47 PB Online Storage

3 Data Centers

# Knuth is my Homeboy Organist







# WTF?

- 500 guests in the house
  - Building is dark
  - Data center is offline
  - Web site is down
- 
- Cause: utility transformer delivered 320 A
  - Customer expected 800 A
  - Didn't see it coming

# What to do?



# Status Quo Ante

## Example: “Smart” Power Strip

- Will ask for a DHCP lease exactly once
- While the switch is still booting
- Will never ask for a DHCP lease again unless power-cycled
- US\$ 620

# Status Quo Ante

## Example: Embedded Fan Controller

- Speaks SNMP
- And only SNMP
- In an offensive way

```
snmpset -v1 -c password ip  
1.3.6.1.4.1.3854.1.2.2.1.18.1.8.7 i 0
```

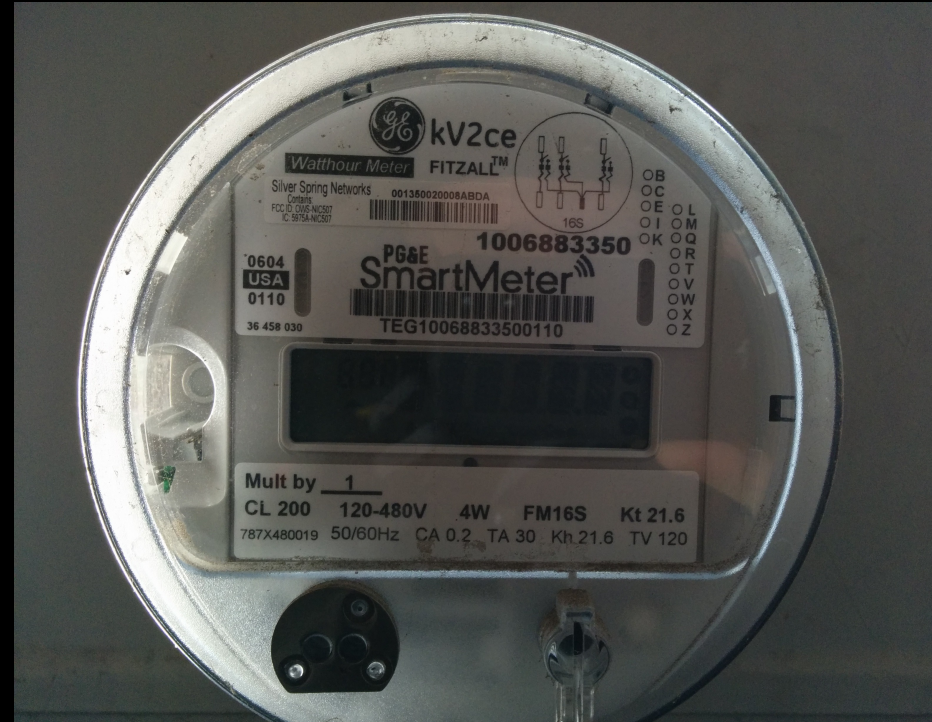
**Write 0 to turn on, 1 to turn off !**

# Status Quo Ante

## Example: Smart Meter

- Real-time
- Networked
- Probably accurate
- Installed by someone else

- No port
- No API



- Does blink an infrared LED per “energy unit”



[illegible]

# Consumer IoT to the Rescue?





# What's New?

- Cheap, networked boards
- Much easier to program and integrate
- WiFi is everywhere
- Lots of momentum: maker movement, crowd-funding
- Plenty of choices:
  - Range from soldering to cloud solution
  - Range from open to DRM infected
  - Pick what you are comfortable with
- Finally it's fun!



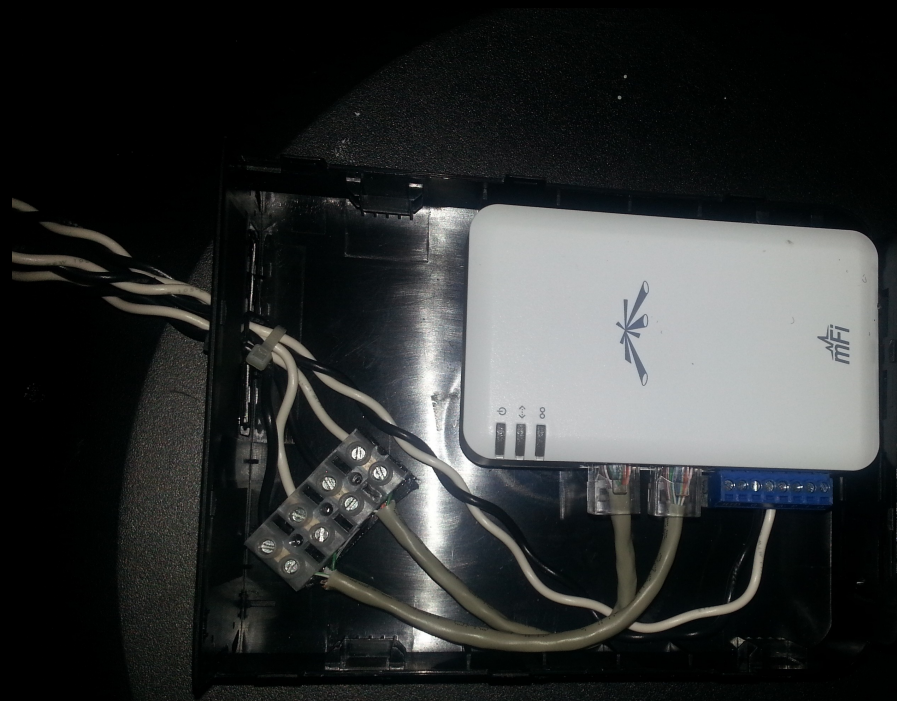
# Data Center Power Meter

## Requirements:

- Whole data center
- Real-time
- Networked
- Accurate enough
- Don't kill installer



# Data Center Power Meter



# Data Center Power Meter

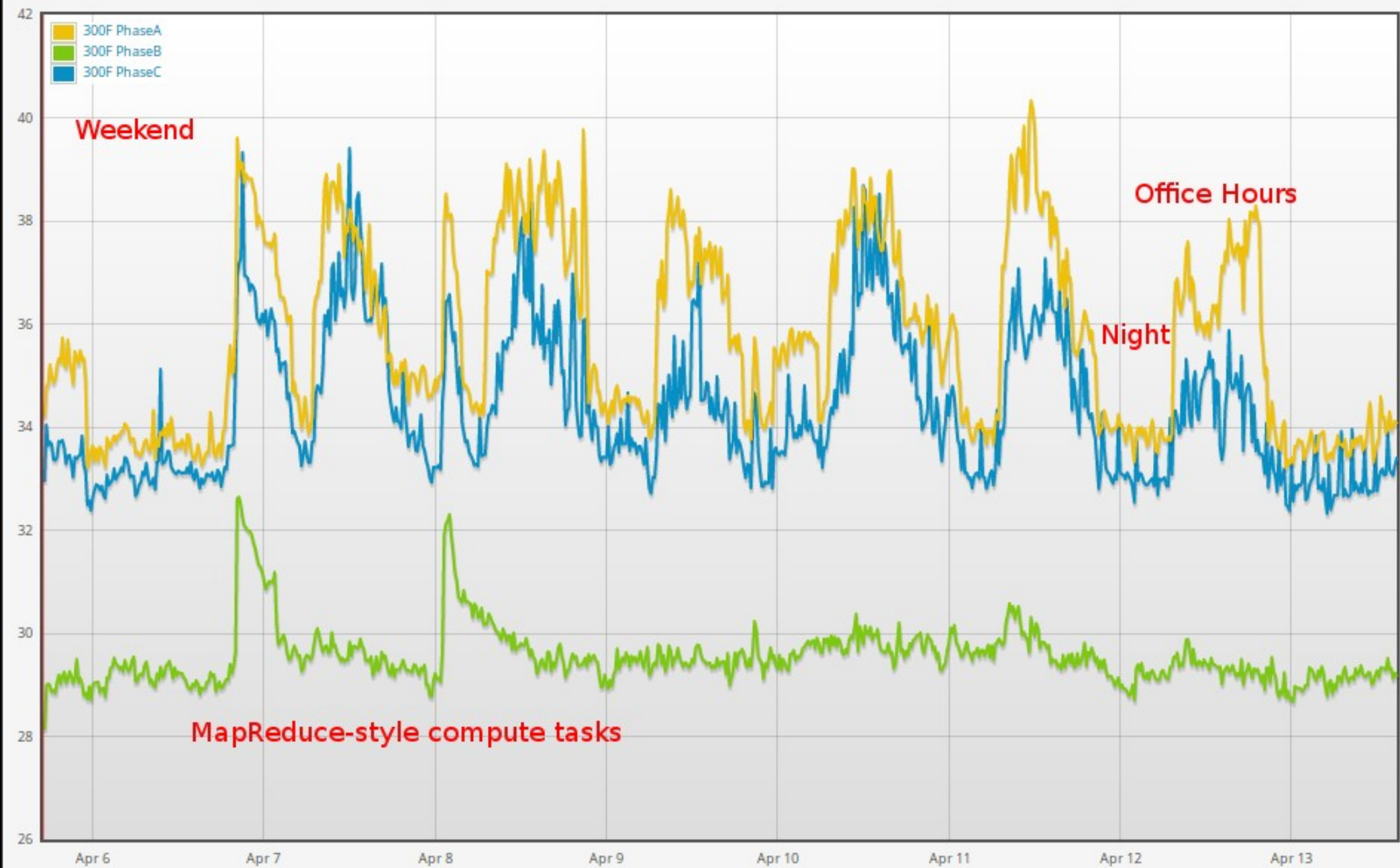
## Solution:

- Detachable ferrite core, utilizing induction
- Ubiquiti mPort sensor hub
- Does Root Mean Square in hardware
- No rectifier necessary
- No trigonometry needed
- Only arithmetic for calibration



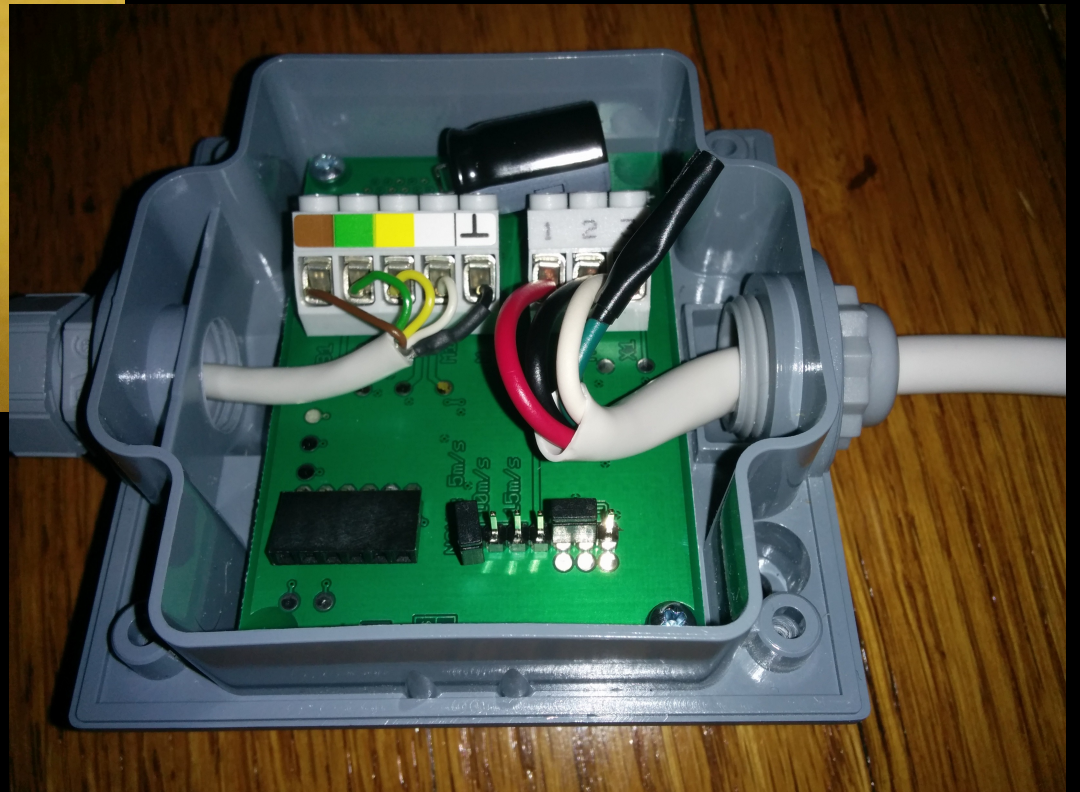
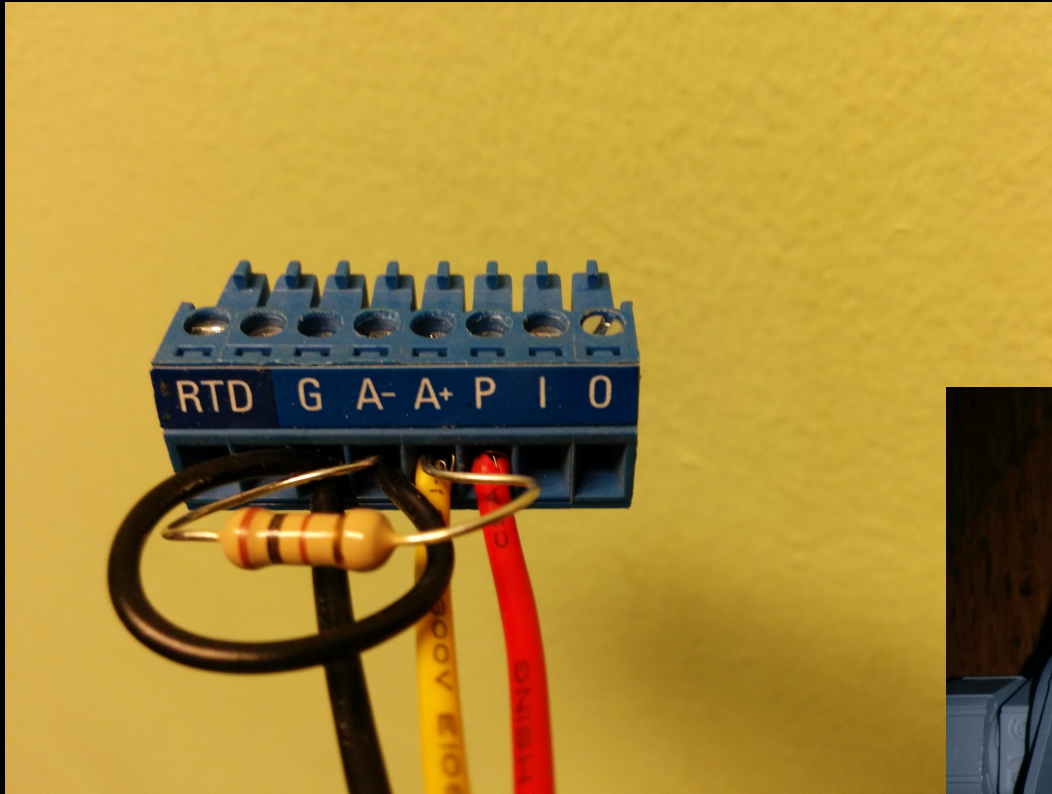
# Data Center Power Meter







# Airflow Meter



Die Philosophen haben die Welt  
nur verschieden interpretiert,  
es kommt aber darauf an,  
sie zu verändern.

Karl Marx

**“Philosophers have only interpreted  
the world differently,  
but the point is to change it.”**



# The Scary Step: Affecting the Real World





# Software Replacing Hardware

Rule Editor

Fan 6001 on

Conditions

**Power Furnace**  
less than 7.00 amps for more than 5 minute(s)

**Temp 6003-back**  
greater than 100.00 °F for more than 3 minute(s)

+ Add Condition

Any Condition

All Conditions

Edge Trigger

Level Trigger

Actions

Outputs

**Fan 6001** ☒ On

Notifications

☒ Send Email

**Tip:** Separate multiple emails with a comma.  
Hold additional email alerts for this event for  minute(s).

☒ Generate Event

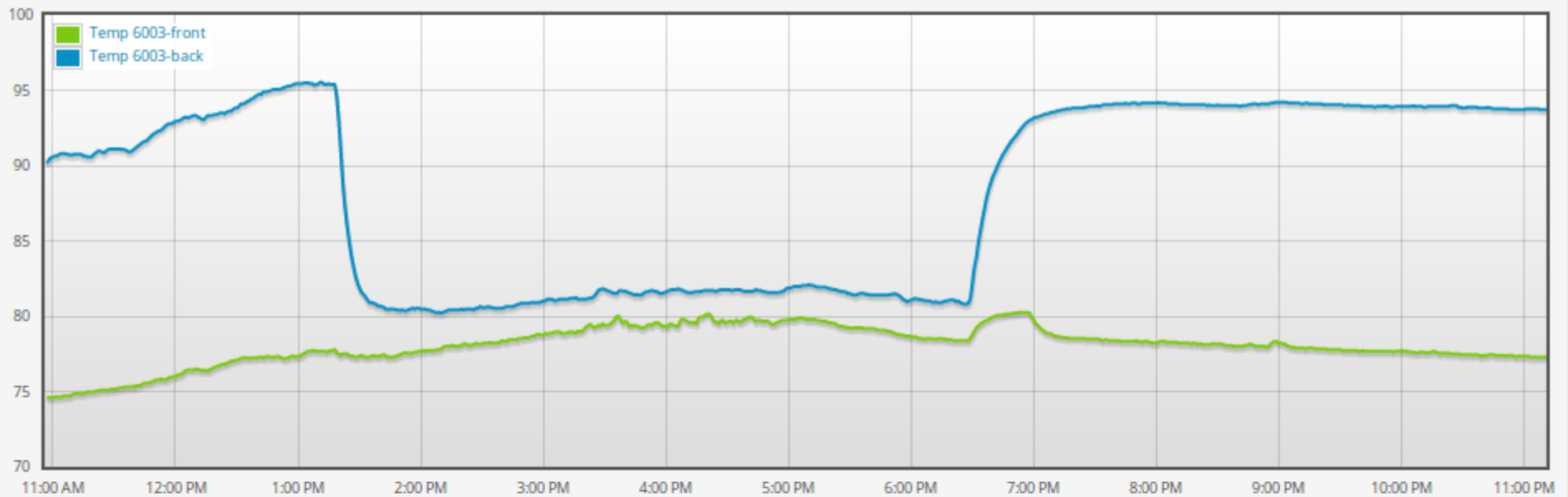
☐ Create System Alert

Don't create an event again for  minute(s).

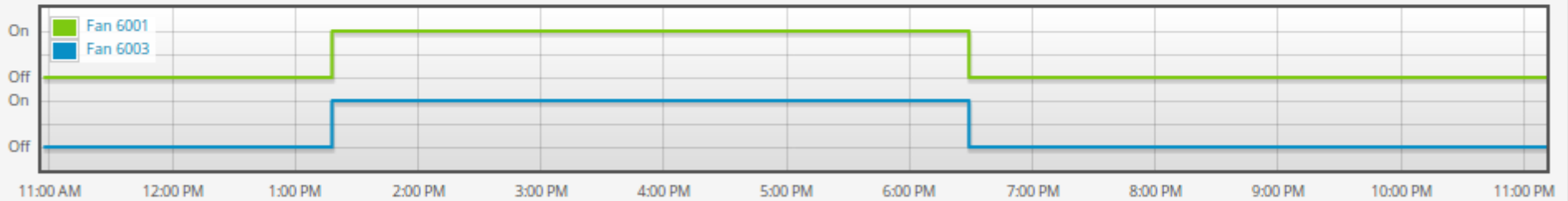
+ Add Action

# Insights through Correlation

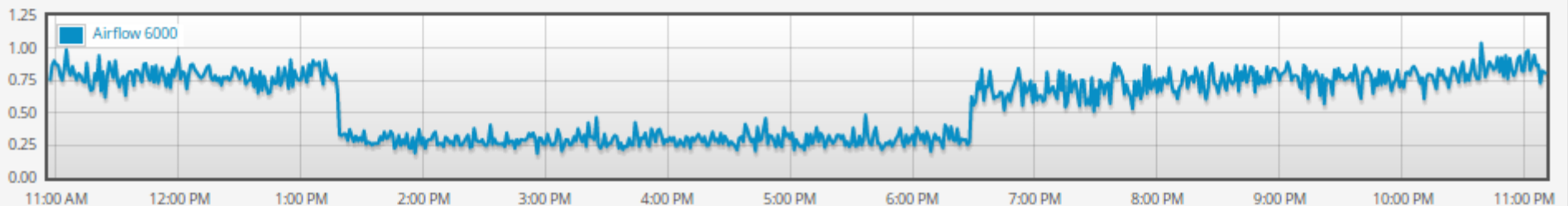
Temperature (° Fahrenheit)



Output



Airflow



# When not to Hack



# Results

- Situational awareness even when remote
  - Multi-input rules in software from diverse sensors
  - Retained manual overwrite
  - Balancing power use across phases
- 
- Two data centers without air conditioning
  - Excess used to heat building:  $PUE < 1$
  - 3.3 KW / PB



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