Putting Smart Meters to Work – Beyond the Usual

Kartik Palani, Nabeel Nasir, Vivek Chil Prakash, Amandeep Chugh, Rohit Gupta, Krithi Ramamritham*
Department of Computer Science, Indian Institute of Technology, Bombay
{kartik, nabeel, vivekcp, amandeepchugh, rohitg, krithi}@cse.iitb.ac.in

ABSTRACT

The paper shows how smart meters can be put to work, beyond their traditional use, towards explaining abnormal and unexpected patterns in the behavior of electrical appliances. We describe two kinds of uses, by visualizing and analyzing smart meter data for an academic building. The first gives us the ability to find anomalous appliance behaviors and the other helps to discover sub-optimal energy consumption patterns. The goal is to stress the fact that the ubiquitous smart meter can act as a sensor not only for monitoring consumption but also for detecting interesting energy usage patterns.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

Keywords

Smart Meter; Smart Buildings; Anomaly Detection

1. ANOMALY DETECTION

In a large building, quite often malfunctioning devices go unnoticed. Sometimes, these anomalous devices draw large current, thereby adding to the building's consumption, unnecessarily. The ability to analyze the power consumption of a building at various levels of granularity aids in detecting such usage patterns. To observe anomalous behavior we propose a setup that measures data at a macro-level (one smart meter per building) as well as at a micro-level (smart meters in every room of the building).

1.1 Macro Analysis

In this section we describe a fault that we detected by analyzing the building's smart meter data.

*The authors would like to thank DeitY, Govt. of India and TCS for their generous support of this work.

e-Energy'14, June 11–13, 2014, Cambridge, UK.
ACM 978-1-4503-2819-7/14/06.
http://dx.doi.org/10.1145/2602044.2602084.

When an inductive load turns on, it is characterized with a spike in the current drawn. However, one commonly detected anomaly is a spike of unexpectedly high amplitude that occurs periodically. Figure 1 shows one such occurrence that we noticed in our academic building. Thirty to sixty Ampere spikes occurring every three minutes and lasting two hours were observed on the second phase. Our previous experiments had helped create profiles of appliances typically used in the building. However, none of the appliance signatures contained spikes with these characteristics!

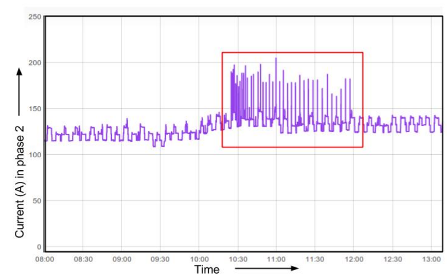

Figure 1: Periodic spikes with unexpectedly high amplitudes

On a non-working day, these spikes were observed again. Taking advantage of the low building occupancy, we were able to isolate the anomalous device: using the room occupancy log for the building, we inferred the list of occupied rooms. Further inspection showed that only one of them had heavy-duty inductive loads (in this case air conditioners), which might have caused the anomaly. We operated the sixteen ACs in the room sequentially until we identified the malfunctioning AC. (It is worth noting that our building is not centrally air-conditioned; each room/hall has one or more AC units, each operating independently.)

We found that the anomalous behavior was due to compressor overload trip, caused by compressor malfunction or non-function. One of the reasons for this is the locked rotor state of compressor. In a single phase compressor a capacitor is required to move the compressor from locked rotor state to running state. If the capacitor is faulty this doesn't happen and a huge current is drawn (about 4-6 times the norm). This causes the overload relay to trip. Following this, we replaced the capacitor in the AC and the spikes stopped occurring.

1.2 Micro Analysis

To reduce peak power consumption, we have deployed the Thermal Comfort Band Maintaining algorithm [1] to control the execution of the several ACs in our lab; this algorithm al-

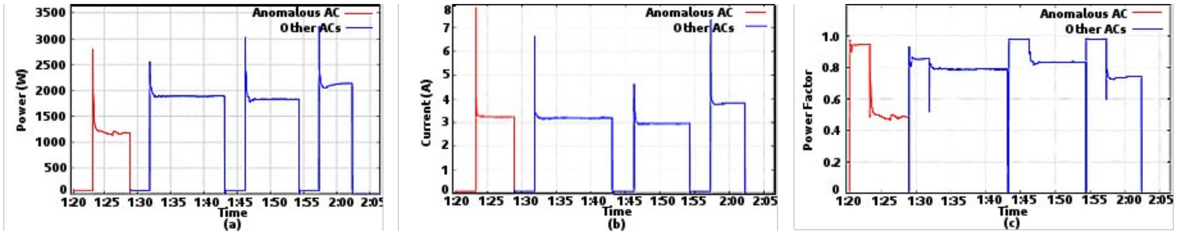

Figure 2: The power (a), current (b) and power factor (c) plots of the anomalous AC

lows only a subset of the ACs to operate at a time while still maintaining the thermal comfort level. Figure 2 (a) presents one instance of this execution where ACs run one after another. But we were surprised by the behavior of AC1, which showed a power consumption profile that is different from the others!

In order to find the cause of the anomaly, we plotted the current profiles for each of the ACs, as shown in Figure 2 (b) and were surprised to see that they were similar. This meant that for the ACs, either the supplied voltage or the power factor was different, inferred from the following relation:

$$ActualPower = V \cdot I \cdot \cos\phi$$

where V *= voltage ,* I *= current, cos* ϕ *= power factor*

ACs powered by the same power source, receive the same supply voltage. However, a comparison of the power factors, as shown in Figure 2 (c), revealed that the misbehaving AC had a sub-optimal power factor.

We found that the anomalous AC had a coolant leak. The compressor in an AC converts the coolant from low pressure to high pressure, and moves the coolant through its refrigeration cycle. Lower amount of coolant implies lesser work for the compressor. Thus, the current drawn was not being efficiently converted to useful work, leading to a drop in the power factor.

This exercise led us to the following findings:

- To detect anomalies such as the one presented, *knowing parameters like voltage and power factor, in addition to knowing the current, is vital.* These can only be measured by smart meters, in contrast to other metering devices like clamp-on meters, which measure only current. This strengthens our choice of using a smart meter as a sensor to identify anomalies.
- Although macro-analysis can give us significant insights into the electrical consumption patterns and also help detect anomalies, its major drawback is that smaller changes in consumption patterns remain inconspicuous. For such cases, micro-analysis, at the sub-building level becomes essential.

2. SUB-OPTIMAL BEHAVIOR DETECTION

In a building, it is noticed that the base load, i.e., the load at zero occupancy, is not zero. This generally arises due to server rooms, since the servers and the air conditioners that maintain the right operating conditions for them run all the time. However, it is noticed that rooms other than server rooms show such behavior.

An analysis of our lab's electricity consumption data showed that at zero occupancy multiple computers were still running. Since all the computers in the lab are of the same make, we know the average consumption of a single computer (∼45W). For our lab, we had three computers running because they either host applications or act as database servers. Thus the average consumption at zero occupancy should have been around 135W (as shown in Figure 3). However, we were surprised to find that the average consumption at night, when the lab was unoccupied, was around 380W.

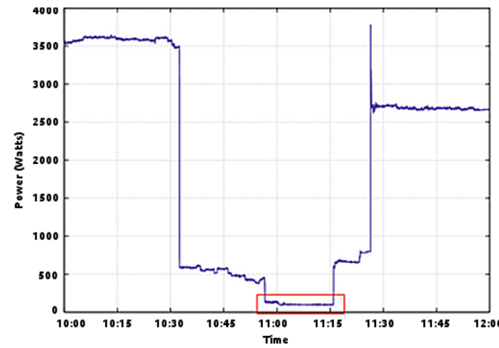

Figure 3: The aggregate usage data when three computers are running has been marked

A survey revealed that many users were leaving their computers on through the night. Further probing showed that the users, occasionally, access their computers remotely. However, given the low frequency of such occurrences, the excess energy usage is worth avoiding.

Having a common computer in the lab with a separate login for each of the users would drastically reduce power consumption while preserving user privacy. This way a user may remotely login to this centralized machine and perform necessary computations. Also, any other computer that is left on at zero occupancy can be queried and turned off.

3. CONCLUSION

We believe that the work described here is just the beginning in terms of exploiting the many facets of smart meter data analytics. We are currently working on algorithms to automatically detect anomalies and optimize usage using the smart meter data. We believe that in the presence of both tangible as well as virtual sensors in smart buildings, this data can be mined for extracting insights that will be useful not only for achieving energy usage optimization but also for fault isolation and identification and services optimization and consolidation among many others.

4. REFERENCES

[1] Karmakar, G., Kabra, A., and Ramamritham, K. Coordinated scheduling of thermostatically controlled real-time systems under peak power constraint. In *Real-Time and Embedded Technology and Applications Symposium (RTAS), 2013 IEEE 19th* (2013), pp. 33–42.