Data Integration and EMS Upgrades for "Factor IV Area" Building Metering

Project Final Report *July 19, 2012*

BCIT Group for Advanced Information Technology (GAIT)

Scope of Work

The Factor IV Project's goal is to reduce energy consumption by 75% in a group of buildings in the Northeast area of BCIT's Burnaby campus. In order to do this, there is a need to be able to measure the real-time Energy consumption of each building in the "Factor IV Area", to gather building energy baselines, and to monitor improvements.

In order to do this a number of items of work needed to be completed:

- Install 4 new meters (SDC-NE23, PDC-NE23, SDC-6, SDC-8).
- Bring online a multitude of other BCIT-Facilities-installed ION meters.
- Integrate all these new meters into GAIT's Microgrid EMS.
- Apply meter math (subtractions and additions of the real-time power and energy readings from meters on contributing power feeds to the buildings) to create a virtual real-time meter reading for each individual building in the Factor IV Sustainability Precinct:
  - NE01
  - NE02
  - NE03 AFRESH
  - NE03 Centre for Architectural Ecology
  - NE04
  - NE06
  - NE08
- Develop a new EMS User Interface clearly showing the Factor IV area as a map with colour-coded and labeled buildings, with click-through to meter data for the building.
- Display in the EMS user interface an energy consumption chart for each building with actual consumption of the building plotted against a predictive curve based on a regression-model baseline (baseline model parameters to be supplied by Andrea Linsky, BCIT Energy Specialist, and Alex Hebert, BCIT Energy Manager).

Work Completed

Meters were sourced by SOCE and installed by BCIT Facilities department, as per specifications developed by GAIT. EMS software development and meter data integration work, meeting the above requirements, was completed by GAIT and demonstrated to the client on March 21, 2012 and in a final review meeting on May 7, 2012. The EMS can be viewed at ems.bcit.ca/factor4

Validation

User Interface

Correct functioning of the EMS user interface for the Factor IV application was confirmed with the client in the final review meeting on May 7, 2012.

The following additions to the EMS were demonstrated:

- Meter data imported into EMS database.
- Meter data transformed into per-building virtual-meter data.
- EMS UI showing clickable map of all buildings in the Factor IV Phase 1 area.
- Chart of energy consumption, outside air temperature, and baseline, with exportable data, and user-settable power-consumption-level notifications.

Meter Data Validation

Meter data validation was conducted by examining and validating the "chain of assumptions" about the Factor IV meter data acquisition, processing, and display.

1. The meters we are reading are installed and configured correctly.

This is a Facilities department responsibility. However, when the new meters were set up, as they came online, the data coming in was carefully checked by GAIT and found to be "reasonable" (considering the nature of the buildings metered) as far as could be determined, except that a few problems were caught, such as missing, duplicate, and abnormal readings, as well as mislabelled meters. These were communicated to Facilities and rectified as installation and configuration work was completed in a second contracted work period. All such problems then appeared to GAIT to have been resolved.

The meters of interest are (EMS database names):

AFRESH_ION7650.meter
Sub_C PDC-C.meter
Sub_C PDC-NE23.meter
Sub_C SDC-NE23.meter

Sub_C SDC-NW3.meter
Sub_D PDC-D.meter
Sub_D SDC-6.meter
Sub_D SDC-8.meter
Sub_N PDC-N/1/2.meter
Sub_N SDC-NE3.meter
Sub_N SDC-NE9.meter
Sub_W PDC-W.meter
Sub_W SDC-NE10.meter

The AFRESH meter is one of the meters that GAIT installed. All the other meters were installed by Facilities and are part of their ION Enterprise system.

2. The meter communications is properly set up and installed and configured correctly.

All the Facilities meters, and GAIT's AFRESH meter are wired in with Ethernet data connections. The GAIT EMS system automatically notifies its operators if data communications is lost to any meter. Data has been flowing reliably from all meters.

3. The meter aggregations are done correctly to properly sub-meter the buildings in question.

NE1.meter = Sub_N PDC-N/1/2.meter - Sub_N SDC-NE9.meter - Sub_N SDC-NE3.meter
NE2.meter = Sub_C PDC-C.meter - Sub_C SDC-NW3.meter - Sub_C PDC-NE23.meter - Sub_C SDC-NE23.meter
NE3.meter = Sub_N SDC-NE3.meter - AFRESH_ION7650.meter
NE4.meter = Sub_D PDC-D.meter - Sub_D SDC-8.meter - Sub_D SDC-6.meter
NE8.meter = Sub_W PDC-W.meter - Sub_W SDC-NE10.meter

AFRESH is read directly from our AFRESH_ION7650.meter.

NE6 is read directly from the Sub_D SDC-6.meter.

These are all correctly set up, corresponding to meter math specified on the BCIT Substation Metering Plan (BCIT Facilities) and consistent with GAIT's repeated inspection of the single-line diagrams for the power feeds to the buildings.

One sanity check that can be done is to see if any of the buildings ever get negative readings which technically shouldn't happen, but is possible due to rounding errors and line losses.

There are in fact some for NE2, but they were all back in March. Since the NE2 calculations involve subtracting out three other meters there is plenty of room for slight errors to accumulate and result in some slightly off errors.

2012-03-13 14:30 -0.33886719 kWh
2012-03-13 15:00 -0.14874267
2012-03-13 15:15 -0.30548097

2012-03-13 15:30	-0.28424071
2012-03-13 15:45	-0.07763672
2012-03-13 16:15	-0.12207031
2012-03-13 16:30	-0.14642334
2012-03-13 17:00	-0.20996093
2012-03-15 17:00	-0.01318359
2012-03-19 15:30	-0.03100586
2012-03-19 15:45	-0.13635254
2012-03-19 17:30	-0.08068847
2012-03-19 17:45	-0.12609863
2012-03-20 17:15	-0.08105469

It is interesting that these are all in the afternoon. It should be noted that this was around the time that meters were still being installed and configured and that no negative readings have been seen since.

4. The GAIT EMS Data Replicator is getting the correct readings from the ION databases and properly putting them into the EMS database.

The ION database readings have been compared to the EMS readings and the numbers match.

5. The interval readings are correctly calculated from the accumulated readings.

Fortunately, because the meters we are reading are not using wireless, the readings are very reliable and so the interval readings are also 100% present so the interval-energy charting do does not have gaps in it anywhere.

The interval readings have been summed and match the kWh consumption values.

6. Sanity checks.

The last step is looking at the data and determining if it is "reasonable". This is highly subjective and requires extensive knowledge of the buildings in question and how they are used and what the internal workings are.

- NE1 - Follows a very standard Mon-Fri pattern, with a reduced (by about 25%) but also similar pattern for Sat/Sun.

- NE2 - Mon-Fri patterns are similar, although there are some consistent ups and downs during the day that are puzzling. They may be linked to when the students are using the equipment in the shop. Sat/Sun patterns are VERY different. Daytime usage is reduced so much during the weekends that it becomes noticeable that NE2 apparently controls outside parking lights somewhere, about 4 kW worth.

- NE3 - Is a fairly consistent 3.5 kW/h throughout the entire week with the occasional peaky bits. That's about right for a small office building.

- AFRESH - There is not one consistent day there. EVERY day is different in some way. I suspect this largely due to the PV supplying a fair amount of power during the nicer days.

- NE4 - Somewhat consistent Mon-Fri. Weekends are a little bit different. There are some unusual spots though that might bear some investigation as to what's going on.

- NE6 - Quite consistent through the week. Sat/Sun are almost both the same and looking like the building is shut down on both days. There's not a lot of additional consumption above the baseline which surprises me. It also looks like NE6 controls about 2.5 kW of night-time parking lights.

- NE8 - Consistent weekday usage. There is flatline weekend usage of about half the daytime weekday loads.

Appendix A: Building Energy Baseline Models

To fulfill the requirements of the map UI and building baseline extension of the Factor IV project, GAIT developed baseline energy models that could be displayed in the energy consumption chart for each building in the Factor IV area.

The building energy models are simple currently; based on averaging of each building's historical consumption data on a given day of the week. The historical data is only available for the several months that the per-building virtual meters have been in operation. As a refinement, the historical data considered for the average is taken only from "comparable" seasons/semester periods, depending on whether the particular building is expected to be affected by seasonal temperature and/or occupancy changes.

Specifically, the energy consumption baseline for a building is an average of historical data that takes into consideration the day of the week, the week of year, the occupancy rating of the week of year for the building, the season assignment of the week of year, whether the building's electrical consumption is affected by outside air temperatures (i.e. heating/cooling seasons) and whether the building is affected by occupancy changes (i.e. high occupancy during regular school semesters, low occupancy during the summer).

The EMS baseline software has been developed in a general, configuration-driven manner, so that updated building energy models, with parameters based on regression-models, can be readily substituted in for the simple historical average models, with no additional programming required – just model parameter configuration in a database.

The following is an anecdotal description of the current baseline calculation algorithm by the programmer. It can be considered as reference comments for use in interpreting the code.

Baselines

There are two steps to making baselines for the Factor IV buildings. The first step is to calculate the estimated daily building energy consumption, followed by breaking down the daily consumption into hourly approximations.

Daily Baselines

Daily baselines are calculated through a formula that takes into account multiple factors driving energy consumption in a campus building, including which day-of-the-week it is (or just weekday vs. weekend), outside air temperature, predicted outside air temperatures, occupancy levels (relative, approximate, or measured), and values calculated from historical data.

At the moment, the models that are being used are simply average weekday consumption values and average weekend consumption values. This works quite well for some buildings (NE1), but not at all for other buildings (AFRESH). There are also instances were Saturday and Sunday values are quite different.

Baselines have an effective as-of date. This allows baseline formulas for each building to change (be refined) over time but still keeps track of what formula was used in the past. With this we can store baseline values and also know which formula was used to calculate that baseline value. Present-day baselines are always calculated using the most recently defined baseline formula for the building.

Hourly Baselines

Hourly baselines are a lot more complicated than daily baselines as they involve calculating hourly averages for each day-of-the-week where the weeks used to calculate these averages have to (roughly) approximate similar conditions to the target day.

Each week of the year is classified into two dimensions.

What is the approximate occupancy of the building?

High occupancy (regular school year term)
Low occupancy (summer semester)

What effect is the outside air temperature having on the building?

Heating season (it’s too cold outside)
Cooling season (it’s too hot outside)
Just right (no heating or cooling needed)

High occupancy weeks are ones defined where Maquinna Residence had 1,970 students or more for that week.

Heating weeks are defined as having a weekly average temperature of 18°C or more. Cooling weeks have a weekly average temperature of 15°C or less. “Just right” weeks are > 15°C and < 18°C.

Hourly baselines also have as-of dates that are separate from the daily baseline function as-of dates.

The next step is to categorize each week for each building based on the occupancy and season. This is for all weeks since the building meter was activated, not just a “typical” year. This allows us to mark certain weeks as “weird” so that they will not be used for calculating hourly baselines. Examples of “weird” weeks would be Maquinna Residence competitions, the two weeks of the 2010 Olympics, spring break and Christmas holiday periods, BCIT Open House events, or any time where readings may be suspect (missing readings, meters offline for an extended period of time, abnormal weekend usage, etc.).

Note that there are some buildings where occupancy does not factor in very much because the buildings are always occupied by roughly the same number of people (staff) all year round. NE3 and AFRESH are two buildings in the Factor IV area where this is the case. These buildings *always* have a “high” occupancy.

Likewise, there are some buildings which are hot water heated and so seasonal changes do not have much of an effect on them. The Factor IV buildings to which this applies are: NE2, NE4, NE6, and NE8. These buildings’ weeks are classified as always “just right” season.

NE1 is the only building that is likely to be affected by *both* occupancy and the season.

Once all that is in place it’s time to pull everything together. This is also done in a number of steps. The first is to figure out how many distinct occupancy/season combinations there are for a building. Then, for each combination, find out the weeks where we have good readings (i.e. aren’t weird) and break those weeks down by each hour for each day-of-the-week. Group all the hours together for each day-of-the-week, sum them for each day, then divide by each hour to get each hour’s percentage and store that, for each occupancy/season combination.

The last step in this process is to get a daily baseline value, look up the hourly baseline percentages based on the occupancy and season (which in turn are based on the week-of-the-year) and the most current as-of date, multiply each hourly percentage by the day’s baseline value, and write everything out to the database so that we can chart it.