This paper has been developed to outline an HVAC optimization and retro commissioning program that was implemented by BLDG Services Group Inc (BSG) in 2011 and 2012. The optimization and retro commissioning program objectives, implementation and results are discussed herein.

Introduction

The facility and its mechanical systems were designed and implemented with energy efficiency and automation as a primary focus. The building is heated with a hybrid ground source (aka geothermal) Robur gas absorption heat pumps (GAHP) and natural gas fired boiler. Cooling is provided with an combination of GAHPs and chillers.

The GAHP devices are natural gas fired devices that, in conjunction with the GSHE, provide the ability to develop 1.8 times the heat energy output per unit energy input or stated in terms of efficiency 180%. This technology provides a unique opportunity in the region in which it is installed as, in Alberta, the cost and method of electricity generation (primarily coal fired plants) make natural gas fired system as clean in terms of emissions and significantly less expensive to operate in terms of fuel cost. In 2012 the average cost per unit energy of electricity in Alberta was 6 times that of natural gas.

The system control is accomplished by local unit controllers and a supervisory building management system that provides a web based interface for local and remote monitoring. This optimization and retro commissioning program was developed based upon an HVAC system audit that was performed in 2011, after approximately 1 year of operation of the facility.

The Facility

The facility in question is an ACTO facility located in Edmonton Alberta, Canada. This facility houses an office and shop in a single structure. The facilities construction was completed in March of 2010 and was based upon a sustainable building design.

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The Initial Design

The system includes 11 – 10 ton Robur GAHP W-LB units that act as the primary heating system and secondary cooling system. The GAHP system is direct coupled to a 50 ton ground source heat exchanger (GSHE) that is comprised of 110 wells that have an average depth of 100 feet. The GAHP system is currently the largest of its kind installed in a commercial building in Canada.

Two - 30 ton chiller stacks provide the primary cooling source. These chillers are electric motor driven vapour compression units with economizers.

The space heating in the facility is accomplish primarily through the heating water system with some supplemental heat being provide via radiant tube heaters in the shop areas. The heating water is generated by the GAHPs and in the event of a GAHP failure to meet demand a back up gas fired boiler. The heating water is stored in 2 large buffer tanks and distributed to the hydronic heating manifold in the perimeter of floor of the office area and to fan coils located in the ceiling of the office space. The heating water system and boiler are isolated from the GAHP system by a thin plate heat exchanger.

Space cooling is provided via a chilled water system and is provided to the office areas only. The chilled water is generated by the rooftop chillers and in the event of a chiller failure to meet demand the GAHPs were plumbed to enable secondary and emergency cooling. The chillers chilled water is stored in 2 chilled water buffer tanks. The cooling water is stored in 2 buffer tanks and distributed to the office area fan coils located in the ceiling of the office space. The cooling water system is a closed system and the chilled water interface occurs at thin plate heat exchangers for both the chiller system and the GAHPs.

All primary pumping system are controlled by means of variable frequency drives with differential pressure inputs and all primary pumps have redundancy.

The building control system provides unit level control through dedicated controllers located in proximity to the controlled devices and a supervisory building management system (BMS) is layered over the unit control to provide an interface to monitor and control for the building operator. The BMS provides the graphic interface for real time monitoring along with the ability to provide; access to set points, trending, alarms, operating schedules and a custom software control to that provides for the development of control algorithms outside of the unit controllers.

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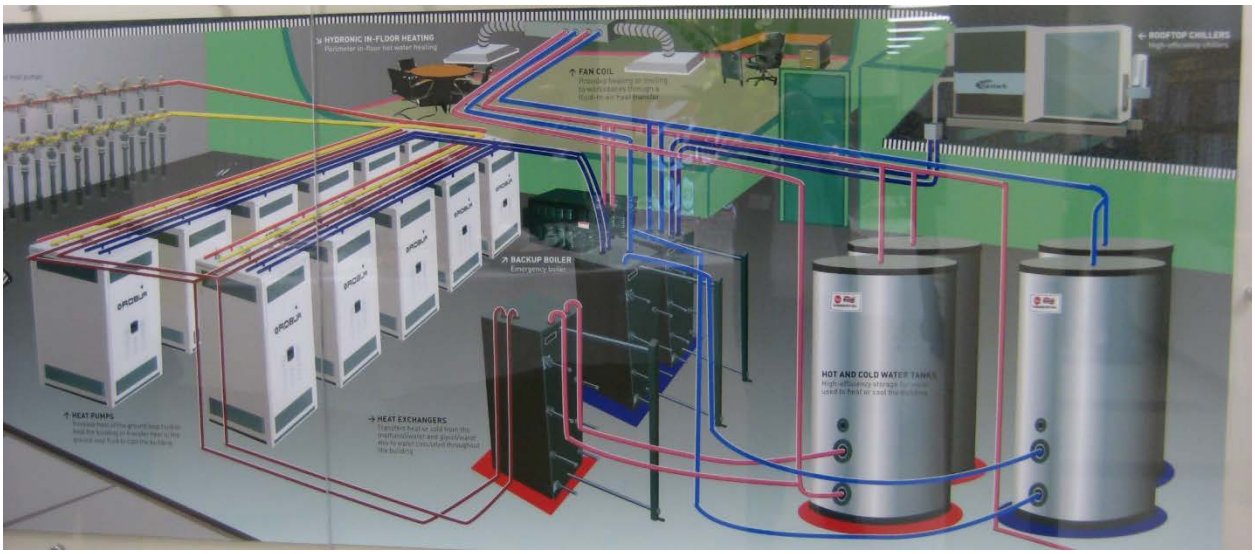

Figure 1 - System Design Schematic

Design Implementation

The implementation of the original design was completed by the mechanical and controls contractors during construction. The design intent was pursued, but due to incorrect design assumptions, limited understanding of the GAHP by the on-site contractors and no formal commissioning program a number of the features of the system were not successfully implemented and operational issues due to installation and design parameters specific to the GAHPs lead to limited reliability and functionality.

More specifically the GAHPs were not able to meet the design set points configured in the control system which lead to GAHP units regularly locking out of service and not being available when called by the control system. This lead to problems with meeting heating and cooling requirements, not meeting the domestic water set point requirements and no secondary or emergency cooling being available from the GAHPs.

System Audit

BLDG Services Group (BSG) was contracted to make repairs to the GAHP relating to their limited heating capacity and to review the operation of the units. During inspection and subsequent repairs it was discovered that more than half the unit were failing intermittently and 1 unit was not functioning. Based on this and subsequent failures after this repair and review a system audit was performed by BSG and the following issues with the system configuration and operations.

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- The systems was not flushed or improperly flushed after construction and large amounts of debris was found in the fluid loops connected to the GAHPs. This resulted in flow restriction at the circulating pumps due to clogged strainers (and in one case a clogged heat exchanger in a GAHP) and resulted in locking out of units due to low flow conditions.
- The system hot water supply temperature was specified in the design to require operations of the GAHP at their design limits continuously to meet heating water set points.
- The integral controllers supplied with the GAHP systems were not used in the integration, but instead additionally controllers were installed on each unit which provided limited information and control of the units relative to the integral controls capabilities.
- The domestic hot water system was served exclusively by the GAHP and the set point requirement caused the units to run continuously in an attempt to meet the set point even during cooling months. Additionally, the domestic hot water supply temperature was well below the recommended domestic hot water set point required to ensure that water borne bacteria could not survive in the storage tanks.
- The circulating pumps on the hot water side of the GAHP were found to be undersized.
- The GAHP controls were not correctly implemented to allow for secondary or emergency cooling.
- No time based staging of the units resulted in the same units being called instead units being alternately called to distribute operating hours between units.
- An erratic outdoor air measurement resulted in the heating system being shut down on hot weather when there was still a heating requirement in the facility.
- A number of set points were incorrect and some points were mislabeled in the building management system which resulted in incorrect readings on the user interface and in some cases incorrect operation of heating system.
- Alarms were limited in scope and the remote notification function of the system had not been implemented.
- No summary trend had been developed to review and asses the systems operation.
- The user interface was in some cases limited in providing a supervisory overview and the navigation was cumbersome.

Retro Commissioning

Based on the number of issues that were found during the system audit retro commissioning was performed on the control system and the GAHP system. The control system commissioning entailed end to end verification of the control systems inputs, a review of all point names, a review of all system links, and a calibration check of the systems transducers. The GAHP system included completion of the manufacturers start up commissioning for all heat pumps, confirmation of the function and configuration of system circulating pumps and their associated VFDs and all operation of all system control valves.

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Retro Commissioning Results

This retro commissioning process uncovered an number of issues with the configuration of the control system and its associated devices that had previously lead to limited system reliability and unpredictable operation and control. These included a lack of calibration of some transducers, incorrect point assignment and mislabeling in the control system both on the configuration and wiring sides. By removing the systemic problems related to the GAHP and control system it allowed the focus to move from repair to optimization of the system and restored operator confidence in the control system and devices.

System Optimization

The system optimization program was dived into 3 categories:

1. Mechanical Devices
2. Control System
3. User Interface

Mechanical System

The mechanical systems optimization including revising flow rates to the GAHP to reduce the lock out issues due to low flow that had plagued the system, performance of combustion analysis and tuning of all gas fired device to achieve maximum combustion efficiencies and re-plumbing and reconfiguration of the domestic hot water system.

The simplest and one that provided the ability to immediately resolve the issue of low flow rates for the GAHP was to revise the VFD configuration and allow the VFDs to increase motor speed to 120% of the name plate rating. Running the pump motors at 20% overs peed increased the pumps flow rate to more acceptable levels and continued to operate the motor within the manufactures operating limits. Although the flow limits are still below acceptable levels the system is now able to operate without regularly locking out on low flow and the customer is able to defer the upgrade of the motors and pumps while still maintaining a comfortable environment in the building.

The combustion analysis results indicated that all units tested were out of range of the manufactures specification and tuning was performed which brought all units back into range of the manufactures recommendation and therefore increasing their efficiencies.

The reconfiguration of the domestic hot water system enabled the domestic hot water storage tank to maintain recommended temperatures and ended the continuous heating calls to the GAHP.

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Control System

The control system optimization included revising the control schema to meet the original design intent of allowing the GAHP to provide cooling, to stage alternately, to allow GAHPs to provide free cooling to the cooling water system when in heating mode, and to allow for individual and manual control of GAHPs as well as to revise system set points.

The control system was reprogrammed and the chiller interlock reconfigured to allow the GAHP to provide primary cooling to the cooling water system when there was a heating occurring along with a cooling requirement in the facility. This result in free cooling during those period and reduces the load on the GSHE which results in higher GAHP efficiencies when the GSHE is used as the GAHP heat source.

Allowing manual control of the GAHP provides the operator and technicians the ability to perform tests on individual units and for operators to remove individual units from service or to dedicate individual units to a specific service as required.

Revision of system set points included exposing set points to operator so that they can adjust them to accommodate building operational modes and conditions. The implementation of reset curves that link outdoor air temperature to heating and cooling set points which in turn reduces the unit run times and loads on the GAHPs and chillers.

User Interface

The user interface revisions included modifications to provide summary displays of systems, the development of summary trends, the implementation of remote alarming capabilities, and the linking of trend data and operational mode information within summary displays.

Summary displays specific to the GAHP systems were developed to provide a single view that provides a summary of all 11 GSHP and their related systems. The single view display incorporates information found on 14 individual displays enabling the operator to see the entire systems operation rather than only individual devices and sub systems.

Enhanced alarms and instructions along with remote alarming were configured and implemented. Now email alarms are provided to both the ATCO building operations personnel and the BSG technicians. Prior to implementation operator were required to review the system alarm list to be advised of system anomalies. This method of alarm notification lead to significant latency between events and notification, as well as limited profile of events to building operations. The addition of instruction with alarms operator and technicians are specific and automatically direct operators and technicians to the

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method of alarm resolution. This has greatly increased timeliness for repair and resolution and therefore building comfort.

By integration of trend data and operational status to summary display building operators and technicians are able to quickly correlate and drill down into data to more easily and quickly understand the operation of the system and quickly resolve problems as a result.

Optimization Results

The most significant results specific to the optimization program were the reduced energy consumption and improvement of unit and system reliability. The GAHP energy consumption was reduced by 51% year over year for the comparative period available (May to September) at time this paper was prepared. The system reliability increased from less than 95% To 99% for the comparative period and unit reliability specific to the GAHP increased from less than 60% to over 95%.

Additional energy savings have been also been seen from the reduced run times and loads of the chillers as a result of the free cooling provided by the GAHPs.

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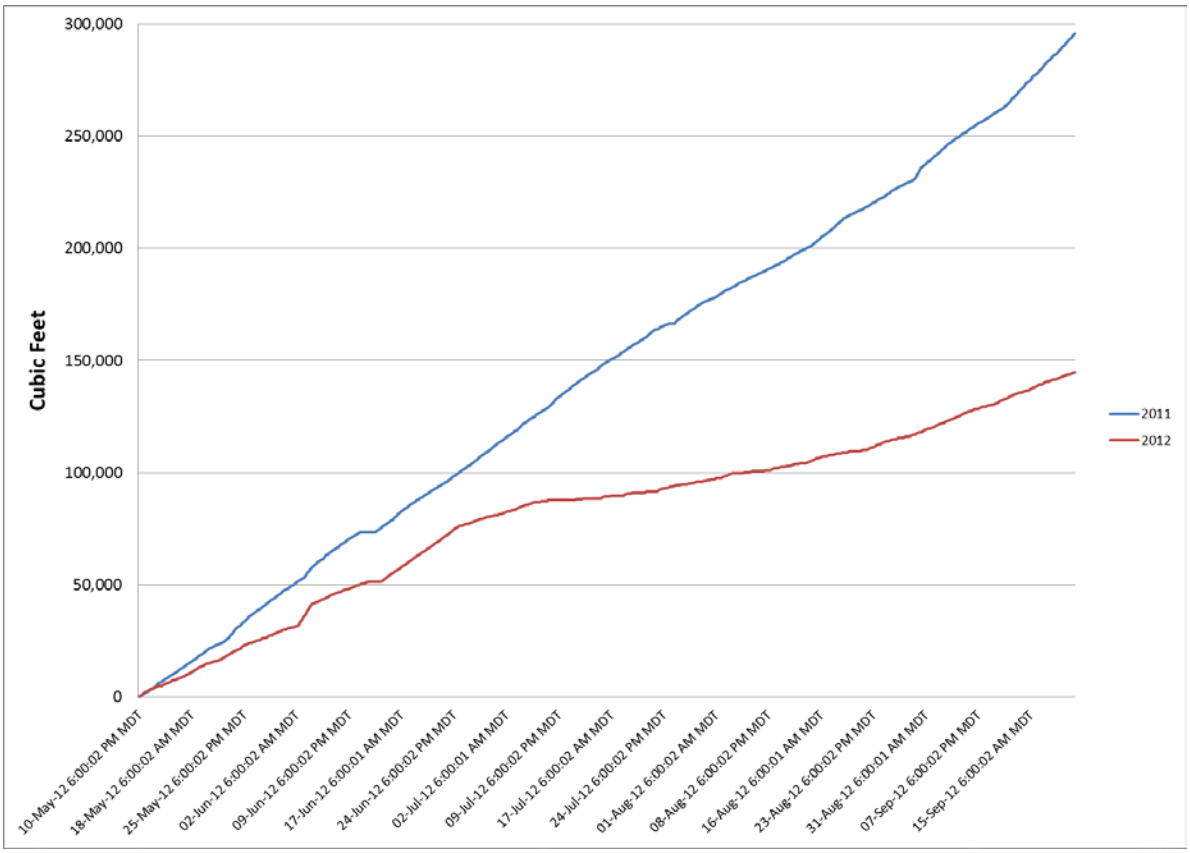

Figure 2 – Comparative NG Fuel Consumption

Conclusions

The most obvious conclusion to be drawn from the situation encountered at this facility is that a formal commissioning should be performed post construction to ensure that the systems and equipment function per the manufacturers specifications and that the design intent is met. In this case the first year of operation proved problematic for building operations, lead to comfort issues for the occupants and increased fuel consumption and cost.

From an economic stand point the results of the retro commissioning had a very large impact on energy consumption and efficiency on a facility that was already considered to be efficient in terms of its recent construction, modern design and energy saving systems and devices installed. The fuel consumption reduction will result in significant long term operating cost savings for the facility along with equally reduced greenhouse gas emissions.

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