Controlling the Pieces

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Abstract

The operation of the central plant at the University of North Florida is a 24 hour operation that is fully manned for only one shift per day and no weekends. In order to obtain optimal performance from the central plant, provide adequate capacity for campus demand, provide the ability to respond to continued campus growth and rising energy prices, the UNF central plant had to learn how to control the pieces. The plant evolved into the operation and facility that is now, due to a desire of Physical Facilities to survive. In the not distant past, the central plant in July of 1999 was operating in a state of near calamity or disaster on most days. The central plant equipment then consisted of 4 centrifugal chillers and two large Scotch Marine boilers in varying states of disrepair and poor efficiencies. All of the plant equipment was controlled via an Andover 256 control panel that only provided rudimentary on and off control for the plant systems. Essentially the central plant was controlled by HVAC Mechanics who functioned as human thermometers and Program Logic Controllers (PLC).

The University of North Florida central plant Building Automation System (BAS) controls is an on going project that continues to expand and evolve due to the universities continued phenomenal growth. The University of North Florida is a 35 year old campus consisting of over 50 structures of varying types and design encompassing over 3 million square feet situated on approximately 250 acres. Of the 3million square feet, 2.3 million square feet of the campus is supplied with chilled and heating hot water for temperature control by a central plant. The central plant consists of (4) 1000 ton Centrifugal Chillers, (1) 8 million and (2) 4 million BTU Boilers, (1) Plate and Frame Heat Exchanger, (6) 500 ton stainless steel, multiple fan, forced draft cooling towers and (2) 1000 ton, stainless steel, single fan, induced draft cooling towers, (3) 150 HP Chilled Water (CW) secondary pumps, (2) 50 HP Hot Water (HW) secondary pumps and Variable Frequency Drives (VFD) on all cooling tower fans, CW and HW secondary pumps.   .

During my first week of orientation with the University, I started asking questions as to how the plant was being controlled.   One of the Control Technicians working for the University provided the following answers to these questions. How do we switch the plant between heating and cooling? Answer: My work schedule is from 6 a.m. to 2 p.m. daily. When I arrive to work, I determine whether there is a need for heating or cooling. Question #2: How do the chillers and boilers respond to campus the load? Answer: When I get to work, if the water distribution temperature is to low or to high, I start or shut down chillers or boilers to get the desired temperature.

Within my first week working at the University, it was very clear that we could not continue to operate the campus central plant in the manner that that it had been operated in previous years. The challenges that we faced were daunting to say the least. These challenges included a campus that had lost faith in our ability to provide consistent air conditioning and heating to campus buildings. Additionally, we encountered sporadic humidity and temperature control in buildings due to fluctuating water temperatures, slow response to changing load conditions, equipment reliability, an inability to monitor plant operations and campus demand, very poor energy efficiency and requirement of additional man hours to operate the central plant. These issues provided a catalyst for the manner and method by which we designed and implemented the central Plant control and inter-related building control schemes that we employ today.

(The Pieces)

The first task that had to be addressed in an immediate fashion was equipment reliability. Of the four original chillers in the plant, only the Trane chiller operated in a reliable fashion. As a short term fix, all chillers and boilers in the plant were given a thorough inspection by OEM representatives and immediate repairs implemented to improve equipment reliability. The next task was to solicit and partner with an engineering firm to evaluate the present and future needs of the campus. Once the University partnered with the engineering firm, TLC Engineering for Architecture, over a period of four years, all of the original chillers and boilers with the exception of one Trane chiller were replaced.

Due to financial considerations, the vastness of the undertaking, the requirement to rebuild the central plant in the same facility and to continue providing chilled and hot water to campus, a utility master plan was created. The plan identified potential campus growth, location for growth and the requirements for future central plant growth to provide for the future needs of campus. Over the same four year period, the manner and method by which we “controlled the pieces” evolved into the manner by which we operate the central plant today. Early on in the process, we decided to consolidate the multiple plant on/off control lines into a comprehensive plant program. The following items became the basic tenant of how the plant would operate and provide a mandate on how UNF control technicians and the BAS controls company, WW Gay Facility Automation, would construct the finished plant program. (1) The central plant will stage chillers and boilers up and down based on campus load expressed in BTU and Tons. (2) Equipment will be staged up and down to produce 45 degree chilled water and variable heating hot water ranging between 100 to 180 degrees depending upon the (Outside Air Temperature) OAT. (3) Monitor status of essential pumps, cooling towers, chillers, boilers. (4) Provide a means to remove equipment from normal start sequences in order to perform maintenance. (5) Program sequence to place equipment in a maintenance mode if it fails to start, starts next available piece of like equipment and places equipment in an alarm status. (6) Vary condenser water temperature to chillers by using temperature, humidity and dew point to calculate optimal condenser water supply temperatures provided to chillers. (7) Provide appropriate sensors and program logic to control variable volume secondary campus pumping on chilled and hot water loops. (8) Install equipment and procedures to ensure long term equipment serviceability and operation.

(Controlling the Pieces)

In the paragraphs above, “the pieces”, the desired operational parameters were identified. In the following paragraphs the manner and method by which the central plant is controlled will be discussed in brief detail. For simplicity, the system sequence of operations will be broken down into heating and chilled water supply and distribution.

Heating Hot Water Sequence of Operation:

In the heating hot water program, once it has started it will not return to the line zero position again unless there is a power outage or a mandatory plant shutdown due to repairs or modifications to the plant. At line zero of the heating program the HW secondary and primary pumps and Boilers are in the off position. Upon a campus heating load being established, the BAS will sense current campus OAT and establish a secondary HW setpoint. Upon establishment of the HW setpoint, the Andover BAS commands the three-way control valve located on the secondary side of the HW heat exchanger to the full bypass position, upon confirmation of valve position, campus secondary HW pumps are started, system flow (GPM) is measured using a Vortex Shedding Meter located in the secondary HW distribution line down stream of the secondary pumps and the smallest available boiler is started. The campus Hot Water Return and Supply (HWR)/ (HWS) temperature is monitored by the campus BAS. Upon boiler enable and start, the boiler internal controls will modulate flame control to achieve and maintain 180 degree supply water temperature on the primary side of HW heat exchanger. The three way valve on the HW secondary side of the heat exchanger is then modulated to maintain the desired campus supply temperature along with monitoring the temperature of the primary HWR temperature to boiler to insure at no time the primary return temperature drops below 160 degrees to protect boilers from thermal shock. During the entire process, the BAS monitors OA temperature as a reference to establish a sliding campus HW supply setpoint. Essentially the HW supply temp is reset using a sliding temperature scale from 20 - 90 degrees. At 20 degrees HW is delivered to campus at 180 degrees whereas at 90 degrees and above HW is delivered to campus at 100 degrees. Campus HW secondary pumps are controlled via variable frequency drives and a Differential Pressure (DP) sensor located in a campus building that is hydraulically farthest away from campus secondary pumps. A user established campus HW DP setpoint is established. The BAS will then control the HW secondary pumping to maintain the established DP setpoint and stage available boilers to provide enough capacity via plant boilers to supply campus demand expressed in Million BTU. The BAS determines campus demand or load by calculating the difference between the campus HWS and HWR temperature X GPM X 500 (Δ *GPM*500= BTU).

Chilled Water Sequence of Operation:

Like the heating hot water program, once the chill water program is started it will not return to the line zero position again unless there is a power outage or a mandatory plant shutdown due to campus buildings being conditioned 24 hours a day. At line zero of the Chilled Water program the (CW) secondary, Chiller primary pumps and Chillers are in the off position. Upon a campus cooling load being established, the BAS will send an enable signal to the first of four 1000 ton centrifugal chillers. The BAS will then start the associated primary and condenser water (CCW) pumps, open the cooling tower automated basin valves and start cooling tower fans at minimum speed. The chiller

having been enabled by the BAS will perform its internal start up procedures and seek establishment of flow from a hardwired condenser water flow switch. Once Chiller starts, the chiller internal controls will modulate the chiller to deliver a constant 45 degree CW into the CW primary loop. Campus CW secondary pumps will draw water from the primary loop and distribute to campus buildings. The CW secondary pumps are controlled via variable frequency drives and a Differential Pressure (DP) sensor located in a campus building that is hydraulically farthest away from campus secondary pumps. A user established campus CW DP setpoint is established. The BAS will then control the CW secondary pumping to maintain the established DP setpoint and stage available chillers to provide enough capacity to supply campus demand expressed in Tons of Refrigeration. The demand or load is determined by the BAS calculating the difference between the campus CWS and CWR temperature X GPM /24
(Δ *GPM/24= Tons). Information to calculate tonnage is obtained via a Vortex Shedding Flow meter and two temperature sensors located down stream of the secondary pumps in the CW supply and return lines. The condenser water is supplied to the chillers via a constant volume pump sized for the chiller. Once the BAS starts a chiller and associated equipment, the BAS will stage the appropriate numbers of cooling towers required to support the online tonnage. The BAS will then set a condenser water supply setpoint based on a dew point sensor located near the central plant and modulate cooling tower fans to maintain the calculated supply temperature.

The Benefits of the “Pieces”

After the implementation and installation of the control systems, programs and some of the new equipment listed above, the University has garnered a number of benefits in many different areas. Over the last 5 years, the university has added over 300,000 square feet of new space to be conditioned by the central plant; equivalent to 10 % of the total campus square footage. Yet the central plant Kilowatt-hour (KWh) usage has only shown minimal increases. The decision to operate cooling tower fans and secondary pumping with Variable Frequency Drives (VFD) has resulted in greater energy efficiency across the board. During mild temperature days, the combination of plant programming and equipment allows the BAS to provide lower condenser water to the chillers thus requiring the chillers to expend less KWH in the production of chilled water. The VFD and cooling tower fan combination further conserves additionally energy by reducing the amount fan energy required to produce desired condenser water temperatures. Simply put, the fans only have to move the minimal required amount of air to achieve desired setpoints. Optimized chiller and boiler control have allowed the proper sequencing of chillers and boilers in a manner that meets heating and cooling demand without human intervention. These changes resulted in the plant KW/Ton being reduced from1.05 KW/Ton efficiency to a consistent .60 KW/Ton.   We completely eliminated the 6 am mechanic shift mentioned earlier and a weekend shift that came in to check the plant. With the plant upgrades, plant on call personnel has the ability to monitor the plant remotely and receive an email notification if a primary piece of equipment fails to start or breaks down while operating. The BAS will also place a failed piece of equipment into a maintenance status, enable the next available piece of like equipment and send out a notification of the problem condition. Finally over the previous 5 years, changes to the central plant and upgraded BAS in campus buildings have allowed Physical facilities to slash the sheer number of temperature complaints by greater than 70%. This was achieved with the ability to providing consistent pressure and temperature in both the hot and cold water distribution systems, better humidity control as a result of a consistent 45 degree supply cold water temperature and year round heating hot water to properly use the reheat systems.