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SIMULATION AND MODEL CALIBRATION OF A LARGE-SCALE SOLAR SEASONAL STORAGE SYSTEM

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ABSTRACT

The Drake Landing Solar Community (DLSC) is a master planned neighborhood in the Town of Okotoks, Alberta, Canada that has successfully integrated energy efficient technologies with a renewable energy source. The 52-house subdivision has space and water heating supplied by an innovative system which includes solar energy captured by an 800-panel garage mounted array, a borehole thermal energy storage system (BTES) for seasonal energy storage, and short-term thermal storage (STTS) tanks acting as a central hub for heat movement between collectors, district loop, and BTES. The system was designed to achieve a 90% annual solar fraction after 5 years of operation. A computer simulation was completed during the design phase to determine the appropriate sizes of the different components and the expected solar fraction for the project. Since completion of the construction of the subdivision, monitoring data has been collected for the entire system and this data is being used to calibrate the model constructed during the design period. This paper will discuss the original modeling of the solar district system and the calibration of the model with the measured data.

INTRODUCTION

The Drake Landing Solar Community (DLSC) is located in Okotoks, Canada; outside of Calgary. This new community is North America's first major implementation of seasonal solar thermal energy storage. In this community, solar thermal energy is collected throughout the year, delivered to the homes when there is a call for heating, and stored in the ground during periods when the collection outweighs the heating load. During periods of the year when the heating load outweighs the collected energy, the energy is retrieved from the ground and sent to the homes.

There are five main components of the DLSC project: the solar collection system, the Energy Centre housing two large short-term energy storage tanks, the Borehole Thermal Energy Storage (BTES) system, the district heating supply system, and the 52 single-detached energy efficient homes. See Figure 1 for a system schematic.

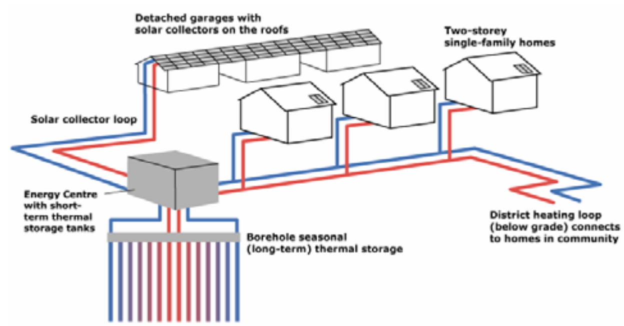

Figure 1: System Schematic

Solar energy is collected during the year by 800 flat-plate solar collectors (approximately 25,000 total square feet) mounted on garages located throughout the community. During a typical summer day, the collectors can generate 1.5 megawatts of thermal power. An innovative method utilizing both short-term, fluid-filled storage tanks and long-term ground thermal storage is employed to store the excess energy in such a way that it may be quickly and effectively retrieved from storage and supplied to the homes without losing too much of the energy to the environment while still retaining high enough temperatures to meet the heating loads. Two large water thermal storage tanks are located at the edge of the community in the Energy Centre; a building constructed to house the tanks, pumps, heat exchangers and controls for the project. Each of these tanks is approximately twelve and a half feet in diameter, 35 feet long, and contains approximately 33,000 gallons of water (125 cubic meters each). The tanks were sized to keep approximately one day's worth of solar energy available for use by the homes.

In this project, the ground underneath a park near the Energy Centre is used as the long-term storage device.

One hundred and forty four boreholes were drilled into the ground to a depth of approximately 115 feet to form the BTES. The holes are connected in series in such a way as to promote radial stratification in the ground; thereby allowing the core of the ground volume to be at higher temperatures than the edges (desired for lower losses to the surrounding ground). This critical radial stratification is maintained by reversing the flow during periods of charging and discharging.

The water-filled storage tanks act as a thermal buffer between the solar collectors and the building heating loads. During the summer months, the collectors charge the thermal storage tank with heated water by circulating water from the tanks through the solar collectors. When the tank temperatures rise beyond a pre-determined setpoint (based on the ambient temperature and time of day), water is circulated from the tanks and through the BTES, heating the ground and cooling the storage tanks (which allows more solar energy to be collected).

During the heating season, hot water is circulated from the large storage tanks to each house through a district heating loop. The hot water passes through specially designed heat exchangers in each home and a high efficiency fan blows air across the heat exchangers. On most days during the winter months, the solar collectors are not able to provide enough energy to the water storage tanks to heat the homes so energy is removed from the long term storage when needed. A backup gas boiler is provided to insure that heat is available to each and every home at all times. During the spring and fall months, most of the solar energy collected during the day is stored in the water tanks and circulation pumps provide each of the homes with a supply of hot water to meet the heating load. Some charging and discharging of the long term storage does occur on particularly warm sunny or cool cloudy days.

During the project design phase, a detailed TRNSYS (Klein 2007) model was built in order to simulate each component of the complex energy collection, storage, and distribution systems. The building heating loads were calculated by a third party detailed simulation analysis of the typical construction practices used in the neighborhood and this load data was used in the TRNSYS system simulation. The simulation model, when driven with ambient conditions and a control strategy, was then capable of predicting the temperatures and energy flows in each component of the system. Using a powerful optimization routine, and keeping in mind the economic and project constraints (available funds, available land area, area available for solar collectors, etc.), the distribution of the number of solar collectors, the size of the short-term storage tanks, and the number and depth of the boreholes for the ground storage was varied to find the combination that maximized the economic performance of the system. Using 50 years of historical weather data as a basis, the simulation model predicted that the current design will provide an average of 90+% of the heating energy to the homes with solar.

Once construction was completed, detailed monitoring of the system began and this monitored data was used to calibrate the simulation model to the data. Once calibrated or "tuned", the model will be able to more accurately predict the performance of the system in upcoming years and allow the designers to study a host of "What If" questions that surround the installation. Variations in controls (setpoints, flow rates, operation etc.) can then also be made using the simulation models first; with promising changes then carried out in the real system.

CALIBRATION

Measured temperature, flow rate and status data from the project for the period of July 1st 2007 through October 31st 2007 was used to tune the individual components of the detailed model of the system. The TRNSYS model of the "as-designed" system predicted an annual solar fraction above 90% for the heating system for the community after a few years (it takes several years to charge the ground). The goal of this exercise was to use the available data to tune the models of the major components to better match the measured data; with the idea that with "calibrated" models more accurate annual predictions can be made. The tuning of the models consisted of comparing the outlet temperatures or relevant energy flows between the measured data and the model when the model was driven with the measured inlet temperatures and flow rates: adjusting several pre-defined model parameters to achieve the best-fit to the measured data. In this paper, only the calibration of the major components in the model is described. Other calibration exercises were performed for many of the lesser components (pumps, pipes etc.). Where plots are provided in this paper showing the comparison between model and measurement, these plots should be considered as typical of the entire operating period and not just the week/day that provides the best looking fit to the measured data.

Tank Calibration

To calibrate the STTS storage tank heat loss factor, data periods where all tank flows were off (collector, district loop, BTES) were analyzed. The analysis reveals that the tank losses are greater than originally anticipated (by about a factor of 2) and it seems to be changing with time. Early analysis shows near steady temperature for a 4 hour window of time with no flow rates through the tank. Later periods show significant heat loss; especially in the lower section of the tanks with no flow through the tank.

The original TRNSYS model, which was based solely on the insulation properties provided by the manufacturer, under-predicted the heat transfer – especially in the lower section of the tanks. The base tank heat loss coefficients were then adjusted to better match the measured data with the top node heat loss coefficient halved in both tanks and the bottom node heat loss coefficient doubled in the cold tank. The top node loss coefficient may be smaller than originally predicted due to the tank not being completely full (less wetted area). The bottom node of the cold tank may be higher than predicted due to thermal shorts and possible thermosiphoning in the tank lines.

The model was not tuned specifically for unique charge and discharge conditions – although it is possible with the storage tank model and a solid data set with isolated flows through the storage tank. Instead, establishing the number of isothermal "nodes" in the model that resulted in the best match between the tank temperatures in the measured data and the corresponding simulated tank locations was the chosen approach. The original model assumed two 2-node storage tanks, a conservative approach that mimics the worst-case stratification levels that will likely be found for large storage tanks with a horizontal baffle used to promote thermal stratification.
The best fit to the data was found to have two 12-node tanks, significantly more stratification in the model than the original worst-case scenario. The tank model was calibrated by comparing the outlet temperatures from the tank (measured versus simulated) for the district loop outlet port, the collector loop outlet port, and the BTES loop outlet port (with each of the ports located at different heights and in different tanks) and not the measured tank temperatures themselves which were thought to be unduly influenced by the inlet flows. This provided the best methodology to reproduce the impact of the storage tanks on the performance of the entire system.

The results are shown in Figures 2 through 4 and show excellent agreement between measurement and simulation – even in both modes of BTES operation.

The measured data also revealed that there are large portions, located in the uppermost sections of the storage tanks, that are not influenced by the inlet and outlet flow rates to/from the tanks. These undisturbed sections are almost certainly caused by the locations of the hot-side inlet and outlet ports being too low on the tank – located near the mid-points of the tank and not near the tops of the tanks. These upper sections likely get heated by convective flow from the hot collector flows and hot BTES inlet flows into the tank and then stagnate, slowly losing energy back to the environment. This "feature" will significantly impact the performance of the DLSC system as the hottest water is not being distributed to heat the homes or charge the BTES during the summer months. Work is under way as of the writing of this paper to fix this problem.

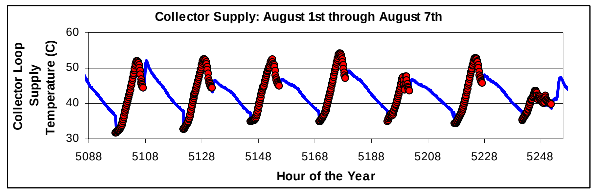

Figure 2: Storage Tank Calibration: Collector Loop Outlet Temperature for a Long Charging Period

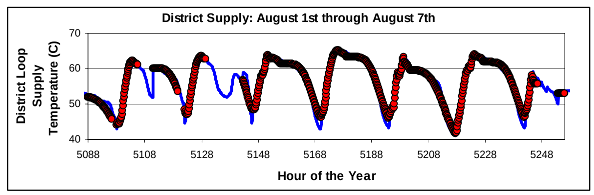

Figure 3: Storage Tank Calibration: District Loop Outlet Temperature for a Long Charging Period

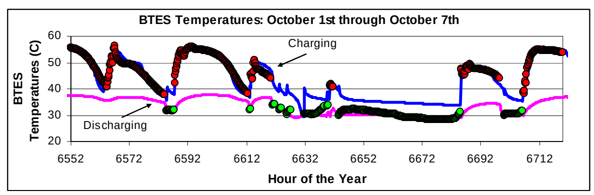

Figure 4: Storage Tank Calibration: BTES Outlet Temperature for a Period of Charging & Discharging

Collector Calibration

The measured data revealed that there was an energy balance problem across the collector heat exchanger, with more energy supposedly being collected than was transferred across the collector heat exchanger. An earlier analysis showed that the TRNSYS solar collector model, with the efficiency equation parameters derived from a rigorous collector test, significantly under-predicted the useful energy gain by the collectors. Knowing that the collectors were performing much better than anticipated, and with no other method available to determine which side of the collector heat exchanger had the measurement problem, it was assumed that the flow rate on the collector side of the heat exchanger was the culprit. To better balance energy across the heat exchanger, a flow reduction factor was introduced that simply scales back the measured collector-side flow rate by a constant value. The flow factor was varied to minimize the heat transfer error and a reduction of 7% was found to best-fit the measured data.

Using the measured inlet temperatures to each row, the measured collector pump flow rate (reduced by 7% and distributed to each row by area fraction), the measured ambient temperature and measured solar radiation, and the collector performance factors provided to us (collector efficiency equation and incidence angle modifiers), the outlet temperature from the model can be compared to the outlet temperature measured for each row.

In order to tune the model to measured data, the collector gain factor (transmission absorption product: $F_R\tau\alpha$) and/or the collector losses (F_RU_L) need to be adjusted to better match the measured data. Without many periods of near steady-state operation, it wasn't possible to plot the collector efficiency as a function of the inlet to ambient temperature difference divided by the incident solar radiation in order to derive the collector efficiency equation slope and intercept. Instead, the optical gain term ($F_R\tau\alpha$) and the thermal loss term (F_RU_L) were optimized to try and find the best combination that minimized the error between measured and simulated data. The optimization revealed that a large range of optical gain terms (with their corresponding loss terms) provided near-optimal results. The collector efficiency test provides a better estimate of the solar absorption term than it does for the losses (as the collectors in the test were not packed together as they are in the real installation) so the $F_R\tau\alpha$ term was fixed to the value specified in the collector test ($F_R\tau\alpha$=0.6926) and the loss coefficient was varied in the model using an optimization process. The minimum error between measured and simulated outlet temperatures was found at a value of F_RU_L of 2.17 $W/m^2.K$ which is ~40% lower than that found from the collector efficiency test. When run with this adjusted collector loss coefficient, the results from the simulation closely match those measured at the site and are shown in Figure 5.

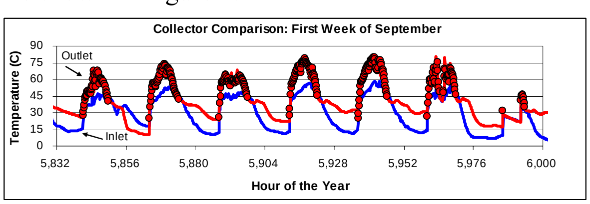

Figure 5: Comparison of Collector Outlet Temperatures with Adjusted Collector Loss Coefficients

District Loop Piping Calibration

Using the blueprints, as-built drawings, and manufacturer-supplied pipe specifications, the entire district loop sub-system was re-created in the TRNSYS model. The detailed model was driven with the as-measured district loop supply temperature and the as-measured flow rate. Looking at periods during the summer, when it is reasonably certain that there is little or no home heating going on (to avoid any discrepancies between modeled and measured heating loads), the simulated data and the measured data can be plotted to see if any tuning needs to be done for the district piping losses. Figure 6 is a plot showing the second week of July 2007 to demonstrate the agreement between the measured data and the simulation – without any tuning of the simulation models.

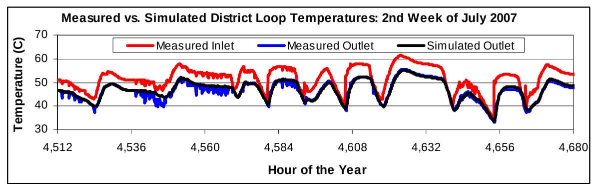

Figure 6 Comparison of District Loop Temperatures for the 2nd Week of July, 2007

However, one week of data does not adequately demonstrate that the district loop simulation accurately predicts the losses from the district loop. Ultimately it is the amount of energy lost through the pipes that will affect the annual predictions. The energy delivered to the district loop system (for both the measured data and the simulation) can be integrated on a daily basis for the entire period of analysis and plotted versus the average daily ambient temperature. For this analysis, the critical periods are when there is little or no home heating going on (as the simulated district loop models for this calibration do not contain the energy delivery devices to the homes). The analysis showed that the simulation slightly under-predicts the measured data for these periods.

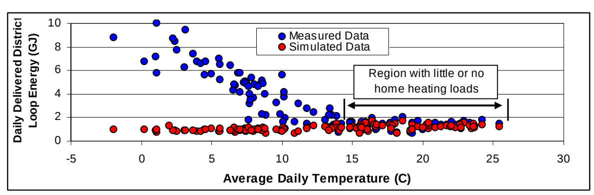

Figure 7: Comparison of Integrated District Loop Delivered Energy with Adjusted Pipe Losses

An error function (the sum of the differences between the daily measured pipe losses and the daily simulated pipe losses for every day with an average temperature above 15 C) was introduced, with the pipe insulation conductivity varied in order to minimize the error. The thermal conductivity of the pipe insulation needed to be increased by 20% to best match the measured and integrated data as shown in Figure 7.

An interesting observation was uncovered during the calibration of the Okotoks models. It turns out that the very detailed simulation models of the district loop system can be replaced with a very simple simulation that greatly increases the simulation speed without sacrificing accuracy. If all of the individual pipes, valves, and individual home heating loads on a street are replaced with one pipe leading to one house (representing all of the house heating loads on the street) and one pipe returning from this house, there are nearly identical results as from the detailed simulations of all components on that loop. The pipes leading to and from the aggregate house should be sized such that they account for the same total surface area as the collection of all the pipes for all the homes. This works out to be the distance from the energy center to the furthest house on each street plus the total distance from the district line to each individual house on the street (adjusted for length as these pipes are smaller in diameter than the main district lines). Figure 8 shows a comparison of the results from the two approaches. For reasons of simulation speed, the simpler approach will be used in the predictions of the annual performance.

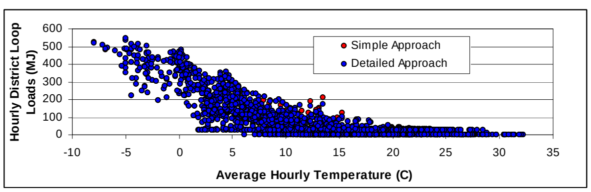

Figure 8 Comparison of Simple vs. Detailed District Loop Simulations

BTES Calibration

Calibration of a borehole ground heat exchanger system is typically done with an optimization algorithm (Wetter 2004); tuning the ground properties and borehole parameters until the outlet temperatures closely match the measured outlet temperatures when driven with the inlet temperature and flow rate. For this project, the ground thermal conductivity, ground heat capacitance (density x specific heat product) and the day of the year in which the ground heat exchanger began accepting energy from storage were varied. The last term (day of the year) was required as the ground heat exchanger began operation before the measured data collection began and the thermal history of the ground heat exchanger is an important consideration. Where available, the as-built borehole properties were used in the ground heat exchanger model with engineering estimates used to supply the remaining ground heat exchanger parameters.

Where measured data was not available for the tuning process, the inlet temperature and flow rate to the ground heat exchanger were provided by a detailed TRNSYS simulation of the entire system. This is only for periods prior to the measured data and is used solely to inject energy into the ground heat exchanger system.

The optimization error function was defined as the sum of squares of the difference between the measured outlet temperature and the simulated outlet temperature for all periods where the ground heat exchanger was receiving flow, in both charge and discharge modes.

The best fit values, along with the original estimates are thermal conductivity (1.373 W/m.K best fit, 2.110 original estimate), storage heat capacitance (3203 kJ/m^3K best fit, 2500 original estimate), and day of first GHX operation (153 best fit, 181 original estimate).

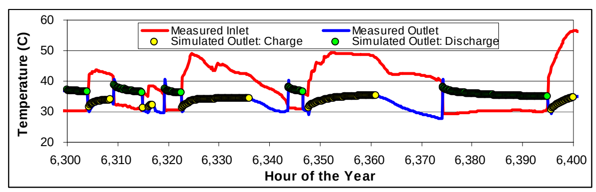

Figure 9: Measured and Simulated Temperature for a Week with Both Charging and Discharging Operation

With these properties, the match between the measured outlet ground heat exchanger temperature and the simulated value (estimated when the model is driven with the measured flow rate and inlet temperature) is excellent for both charging and discharging operation. Figure 9 is provided with a plot for a week with both charging and discharging of the ground heat exchanger. Only points with ground heat exchanger flow are provided for the simulation as the measured temperature decays to a different environment (ambient temperature or energy center temperature) then does the simulation (local soil temperature).

Collector Loop HX Calibration

As mentioned earlier in this paper, the measured data revealed an energy imbalance issue across the collector heat exchanger. The error was assumed to be on the collector side of the heat exchanger and a collector-side flow rate reduction factor was used to better balance the energy across the heat exchanger. With the collector flow rate reduction factor in place, the effectiveness of the collector heat exchanger (assumed to be constant during the year) in the simulation model was adjusted in order to minimize the error between the measured and simulated heat exchanger outlet temperatures. The error was the sum of the squares of the difference between the collector-side outlet temperatures plus the sum of the squares of the difference between the tank-side outlet temperatures for periods when the pumps were operating. At "best-fit" conditions, the collector heat exchanger effectiveness was found to be 0.74; less than the original 0.80 value assumed in earlier analyses. Figure 10 shows a plot of the first week in July and is representative of the remaining weeks in the measurement period.

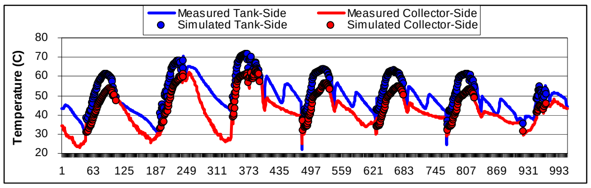

Figure 10: Collector Heat Exchanger Temperatures for the First Week of July, 2007

Pump Calibrations

By looking at the measured flow rates through the different flow loops, it was possible to determine the maximum flow rate and minimum turn down ratios for the various pumps. From the data, the collector loop and collector heat exchanger pumps were found to have a maximum flow rate of 14.4 liters per second with a minimum turn-down ration of 20%. The district loop heat exchanger pump was found to have a maximum flow rate of 5.35 liters per second with a minimum turn-down ratio of 10%. The district HX pump was found to have a maximum flow rate of 5.75 liters per second with a minimum turn-down ratio of 10%. These values were then used in the corresponding simulation models.

District Loop HX Calibration

The measured data also revealed an energy imbalance issue across the district loop heat exchanger. With no reason to suspect either flow rate to be more likely wrong than the other, the error was assumed to be on both sides of the heat exchanger (in opposite directions). A house-side flow rate reduction factor was used to better balance the energy across the heat exchanger. This 17% reduction in measured district loop flow rate (with a corresponding increase of 17% on the tank side of the HX) was used only in the district heat exchanger calibration.

With the district loop flow rate reduction factor in place, the effectiveness of the district heat exchanger in the simulation model was adjusted in order to minimize the error between the measured and simulated heat exchanger outlet temperatures. At "best-fit" conditions, the collector heat exchanger effectiveness was found to be 0.88; better than the original 0.80 value assumed in earlier analyses. A plot of a week late in October is shown in Figure 11.

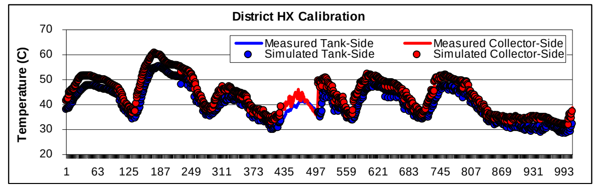

Figure 11: District HX Outlet Temperatures for a Week in October, 2007

Heating Load Calibration

Using the measured data, the daily heating load for the subdivision as a function of the average daily temperature can be derived. The data shows the typical pattern expected in residential construction, however, the heating load does not go to zero at warm ambient temperaturess. This is due to the circulation of hot fluid through the district loop during the warm summer months. The district loop pump is now controlled to shut down during warm ambient temperature periods but this control was not implemented until late August 2007. Using this warm-weather operation period, the heat loss through the district piping was estimated at about 1.4 GJ/day as described in the district loop piping calibration section found earlier in this paper.

If the portion of the load that is attributed to pipe losses (~1.4 GJ/day) is removed from the daily measured heating loads, and then these daily measured heating loads are overlaid on the daily heating load from the simulation as a function of average daily temperature, the simulated loads are found to closely match the measured loads for the data collection period (July 1st through October 31st 2007) and is shown in Figure 12. With these similar load patterns, no tuning of the simulated home heating loads was deemed necessary.

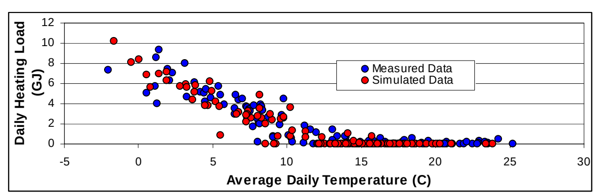

Figure 12: Comparison of Measured versus Simulated House Heating Loads

Control Calibration

The temperature difference between the average of the four collector temperature sensors and the bottom of the cool storage tank is used in the real system to initiate the collector pumps. According to the control specifications, a 10 degree temperature difference is used. A review of the September 2007 measured data shows that the collector-to-tank temperature used to initiate the collector pump was slightly greater than the 10 degrees specified (average around 12 C). However, the measurements are on a 10-minute basis and it is very likely that the temperature measurements are skewed slightly low as the collector temperature will drop when cold fluid begins to flow through the collectors. For this reason, a 15 degree C deadband was used in the model. This parameter will have little impact on the annual predictions.

Once the collector pumps are initiated, the control sequence calls for a 15 degree C temperature rise across the collector loop that is maintained by varying the collector loop pump flow rate. From a plot of measured data for the period of July 1st through October 31st 2007, it looks like the system is attempting to keep the 15 degree differential across the collector loop. The 15 C setpoint will continue to be used in the simulation model.

The collector heat exchange pump is controlled to provide the same capacitance rate through the collector heat exchanger as the collector pump. A review of the data confirms that this is happening. A review of the temperature delivered to the district loop system reveals that the system is doing a poor job of keeping the temperature at the district loop setpoint; often rising 30 to 40 degrees C above the setpoint during low-load conditions (shown in Figure 13). This is a critical design parameter as the higher the district loop temperature, the greater the thermal losses from the district loop

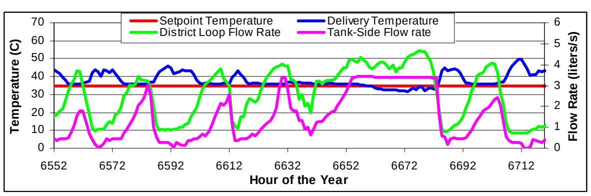

Figure 13: Delivery Temperature to the District System for the 1st Week of October, 2007

The inability of the control system to keep the delivery temperature at the setpoint occurs primarily during times when the district HX pump and the district loop pump are operating near their minimum speed. During times when the pumps are both operating above minimum speed the system seems to follow the setpoint fairly well.

According to field notes and specified control sequences, the system controls the district heat exchanger pump speed and the 3-way valves that send flow to, or around, the district heat exchanger to control the delivery temperature. The heat exchanger pump should begin to slow down when the delivery temperature rises above the setpoint until the pump reaches its minimum speed setting. At this point, flow from the storage tank should begin to be directed around the heat exchanger using the modulating three way valves to keep the delivery temperature near the setpoint. It is believed that the 3-way valves are not modulating flow around the heat exchanger on the tank-side as originally intended. To somewhat check this theory, the heat exchanger model developed for this project was changed to not allow the valves to modulate the flow. When simulating the "non-modulating" control the temperature of the district heat exchanger outlet temperature rises above the delivery temperature indicating that the system is overheating the delivery temperature. This happens at times when the district HX pump is operating at minimum flow conditions. The recommendation is to check (then fix) the 3-way valves or add a small district HX pump (tank side of the loop) that operates at the low flow conditions; with the larger (and current) pump used when the system requires more flow. The smaller pump will also aid in tank stratification as less hot water will be removed from the top of the hot storage tank and sent to the bottom of the cold storage tank.

In the real system, the pressure of the district loop sets the speed of the variable speed pump system. In the model, the district loop flow rate is set by a function which maintains a district loop temperature drop (supply-return) where the temperature drop is a linear function of the district loop supply temperature. Estimates by other project engineers set the temperature drop at 35 C delivery temperature at 10 degrees C and the temperature drop at 60 C delivery temperature at 28 degrees C.

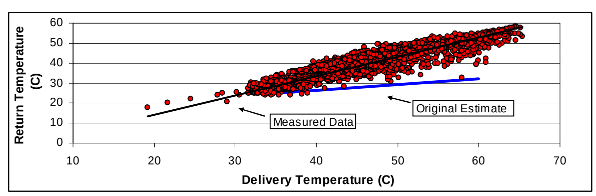

Figure 14: District Loop Return Temperature as a Function of the Delivery Temperature

A plot of the measured return temperature versus the measured supply temperature (Figure 14) shows that the real system is operating with a much different temperature profile. Using a linear regression technique, the return temperature is found to be 0.9588 times the supply temperature minus 4.79 C. So at 35 C delivery temperature the temperature difference is 6.23 degrees C and at 60 C delivery temperature the temperature difference is 7.26 degrees C. The parameters have been adjusted in the model to match the measured data.

CONCLUSIONS

The results from the calibration exercise are summarized below.

Short Term Thermal Storage (STTS): The losses from the storage tanks are greater than anticipated and show a somewhat disturbing trend of increasing with time. The stratification in the storage tanks was greater than originally modeled. As suspected from earlier analyses, the location of the inlet and outlet ports in the storage tanks is leading to large volumes of "unused" energy in the upper sections of the tanks.

Solar Collectors: The solar thermal collectors are performing substantially better than anticipated given the tested efficiency data. Assuming the transmission-absorptance product was correct from the collector test the "best-fit" loss term of the collector was found to be approximately 40% lower than that predicted by the collector test. The collector loss coefficient was adjusted accordingly in the model.

Borehole Thermal Energy System (BTES): The results from the calibration suggest that the ground has a lower "blended" thermal conductivity and a higher thermal capacitance than originally estimated from the bore test conducted at the site. The soil properties were changed in the model.

House Heating Loads: The as-modeled house heating loads match closely to those found from the measured data and no adjustments were made to the model.

Collector Heat Exchanger: An energy balance problem across the collector heat exchanger in the measured data was noted. The effectiveness of the collector heat exchanger was best-fit to a value of 0.74 in the model; slightly lower than the 0.80 value used in the model originally.

District Loop Heat Exchanger: An energy balance problem across the district loop heat exchanger in the measured data was noted. The effectiveness of the district loop heat exchanger was best-fit to a value of 0.88 in the model; slightly higher than the 0.80 value used in the model originally.

District Loop Piping: The measured heat loss from the district loop piping was approximately 20% higher than that predicted by the model. The pipe insulation was adjusted accordingly in the model.

Pumps: The measured data was used to determine the full-load pumping capacity as well as the minimum turn-down ratio for the variable speed drives.

Collector Controller: The upper dead band temperature difference for the controller was raised to 15 degrees C, a change from the 10 C dead band used in earlier analyses.

District Loop Controller: The measured data was used to update the temperature difference across the district loop which is used to set the loop flow rate as a function of the heating load in the model. An earlier estimate had predicted a much larger temperature difference across the loop at higher supply temperatures than is actually being observed. An issue with the district heat exchanger controls was also noted and is be investigated further. The 3-way valves that set the flow through the tank side of the district loop are not modulating at low tank-side pump speeds; resulting in a significant overheating of the district loop fluid above the setpoint during periods when the district loop pump is operating at low speed.

Annual Predictions

After performing the calibration exercises and making the changes to the TRNSYS models to better match the "as built" condition, the simulated performance of the Drake Landing Solar Community system (in its entirety) was estimated to produce 90+ % of the heating needs of the community with solar energy during a typical weather year. If the storage tank inlet/outlet problem is fixed in the model by assuming that the upper ports into and out of the tanks are located in the uppermost node (and not in the node nearest the baffle), and the 3-way valve modulation problem in the district loop is changed to better maintain the loop setpoint, then the performance prediction is that the system will meet an unprecedented 100% of the heating needs of the community with solar energy during a typical weather year.

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