Modeling of Thermal Storage Tank for Heat Recovery Applications

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**INTRODUCTION**

The goal of this research was to develop a mathematical model of a stratified thermal storage tank containing stationary fluid with hot and cold heat exchangers. The model could be used as a screening tool to allow building designers and owners to determine size and configuration of a storage tank for operation with a distributed generation system, which will enable improved energy savings and reduced greenhouse emissions.

**DESCRIPTION OF SYSTEM**

The thermal storage tank considered contains two heat exchangers and stationary water inside the tank as storage medium. Heat is supplied by hot water entering the heat exchanger at the top of the tank and is withdrawn by cold water in the reverse direction.

![Schematic diagram of thermal storage](image)

The tank is assumed to be completely insulated such that no heat loss through the tank wall occurs, and the fluids were assumed to be at sufficiently high pressure such that no change in phase occurs.

**MATHEMATICAL MODEL**

Energy balance for stored water for generic node ‘n’:

\[
m_c c_p \frac{dT_i}{dt} = U A_h (T_{h,i} - T_i) + k A_s \frac{T_{i+1} - T_i}{\Delta x} + k A_s \frac{T_{i-1} - T_i}{\Delta x} + U A_c (T_{c,i} - T_i)
\]

\(m_c \) is the mass flow rate, \(c_p\) is the specific heat capacity, \(T\) is the temperature, \(A_h\) is the heat transfer area, and \(k\) is the thermal conductivity. The tank is assumed to be completely insulated such that no heat loss through the tank wall occurs.

Similarly for heat transfer fluids, the energy equations are:

\[
m_{h,i} c_{p,h} \frac{dT_{h,i}}{dt} = -U A_h (T_{h,i} - T_i) - h_{i,i-1} (T_{h,i-1} - T_{h,i})
\]

\(m_{h,i} \) is the mass flow rate, \(c_{p,h}\) is the specific heat capacity, \(T\) is the temperature, \(A_h\) is the heat transfer area, and \(h_{i,i-1}\) is the heat transfer coefficient.

\[
m_{c,i} c_{p,c} \frac{dT_{c,i}}{dt} = h_{i,i+1} (T_{c,i} - T_{c,i+1}) + U A_c (T_{c,i} - T_i)
\]

\(m_{c,i} \) is the mass flow rate, \(c_{p,c}\) is the specific heat capacity, \(T\) is the temperature, \(A_c\) is the heat transfer area, and \(h_{i,i+1}\) is the heat transfer coefficient.

The heat transfer coefficients are obtained by considering turbulent flow inside the heat exchangers.

**RESULTS**

The simplified model with 10 nodes can predict differentials in stored energy with 98% accuracy, while reducing model complexity and computational time.

**CONCLUSION**

The simplified model with 10 nodes can predict differentials in stored energy with 98% accuracy, while reducing model complexity and computational time.

**REFERENCES**


**FUTURE RESEARCH**

The thermal storage model can be integrated with energy modeling packages to estimate reductions in energy savings and emissions. Future work will focus on using machine learning algorithms to predict building heating loads and emissions, and subsequently investigating the benefits of integrating thermal storage in a building energy system.

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