121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #10696

TRNSYS as an Education Tool to Predict Indoor Environment Temperature for Undergraduate Students

Dr. Ahmed Cherif Megri, North Carolina A&T State University

Dr. Ahmed Cherif Megri, Associate Professor of Architectural Engineering (AE). He teaches capstone, lighting, electrical, HVAC and energy design courses. He is the ABET Coordinator for the AE Program. His research areas include airflow modeling, zonal modeling, energy modeling, and artificial intelligence modeling using the support vector machine learning approach. Dr. Megri holds a PhD degree from INSA at Lyon (France) in the area of Thermal Engineering and "Habilitation" (HDR) degree from Pierre and Marie Curie University - Paris VI, Sorbonne Universities (2011) in the area of Engineering Sciences. Prior to his actual position, he was an Associate Professor at University of Wyoming (UW) and prior to that he was an Assistant Professor and the Director of the AE Program at Illinois Institute of Technology (IIT). He participated significantly to the development of the current architectural engineering undergraduate and master's programs at IIT. During his stay at IIT, he taught thermal and fluids engineering (thermodynamics, heat transfer, and fluid mechanics), building sciences, physical performance of buildings, building enclosure, as well as design courses, such as HVAC, energy, plumbing, fire protection and lighting. Also, he supervises many courses in the frame of interprofessional projects (IPRO) program.

Areas of Interests: - Zonal modeling approach, - Integration zonal models/building energy simulation models, - Zero Net Energy (ZNE) building, - Airflow in Multizone Buildings & Smoke Control, - Thermal Comfort & Indoor Air Quality, - Predictive modeling and forecasting: Support Vector Machine (SVM) tools, - Energy, HVAC, Plumbing & Fire Protection Systems Design, - Computational Fluid Dynamic (CFD) Application in Building, - BIM & REVIT: application to Architecture and Electrical/Lighting Design systems.

AC 2014 - 10696: TRNSYS as an Education Tool to Predict Indoor Environment Temperature for Undergraduate Students

Ahmed Cherif Megri, North Carolina A&T State University

Dr. Ahmed Cherif Megri, Associate Professor of Architectural Engineering (AE). He teaches capstone, lighting, electrical, HVAC and energy design courses. He is the ABET Coordinator for the AE Program. His research areas include airflow modeling, zonal modeling, energy modeling, and artificial intelligence modeling using the support vector machine learning approach. Dr. Megri holds a PhD degree from INSA at Lyon (France) in the area of Thermal Engineering and ”Habilitation” (HDR) degree from Pierre and Marie Curie University - Paris VI, Sorbonne Universities (2011) in the area of Engineering Sciences. Prior to his actual position, he was an Associate Professor at University of Wyoming (UW) and prior to that he was an Assistant Professor and the Director of the AE Program at Illinois Institute of Technology (IIT). He participated significantly to the development of the current architectural engineering undergraduate and master’s programs at IIT. During his stay at IIT, he taught thermal and fluids engineering (thermodynamics, heat transfer, and fluid mechanics), building sciences, physical performance of buildings, building enclosure, as well as design courses, such as HVAC, energy, plumbing, fire protection and lighting. Also, he supervises many courses in the frame of interprofessional projects (IPRO) program.

Areas of Interests:
- Zonal modeling approach,
- Integration zonal models/building energy simulation models,
- Zero Net Energy (ZNE) building,
- Airflow in Multizone Buildings & Smoke Control,
- Thermal Comfort & Indoor Air Quality,
- Predictive modeling and forecasting: Support Vector Machine (SVM) tools,
- Energy, HVAC, Plumbing & Fire Protection Systems Design,
- Computational Fluid Dynamic (CFD) Application in Building,
- BIM & REVIT: application to Architecture and Electrical/Lighting Design systems.

TRNSYS as an Education Tool to Predict Indoor Environment Temperature for Undergraduate Students

Ahmed Cherif Megri
North Carolina A&T State University
Civil, Architectural and Environmental Engineering Department
Email: ac_megri@hotmail.com

Abstract:

TRNSYS (TRaNsient SYStem) is an extremely flexible graphically based software environment with a modular structure that can be used to model and simulate the behavior of any transient systems. While the vast majority of works done are focused on analyzing the performance and thermal behavior of thermal solar systems, mechanical and electrical energy building systems, TRNSYS has been used for other applications such as biological processes and so on.

Due to its modular structure and the high flexibility, TRNSYS can be used as an effective tool for teaching engineering and architecture students the thermal behavior of building components, as well as building thermal envelope at an early stage. At the same time, they can experience integral planning processes firsthand.

In this paper, we propose a methodology where students can build their own system, perform numerical experimentation and evaluate the results using TRNSYS environment. One comprehensive case study will be introduced and demonstrated.

We discuss the process from students' point of view, and the experience earned in modeling, design, experimentation, and also in written and oral communication skills. Future plans to evaluate the effectiveness of this capstone in term of learning outcomes.

1. Introduction:

The 1973 oil embargo was the propulser for the creation of the first generation of multiple energy simulation programs, such as DOE and TRNSYS in USA, ESP-r in UK, CODYBA in France. These programs are still in use until today, even if multiple versions have been developed, because of their flexibility and their reliability.

Among all these programs, only TRNSYS (Klein, 1976), (Klein, 1977), (Klein, 2006) reach the international scientific community, since it benefits from the modularity structure that makes it one of the most appropriate software for education and research. Hundreds of papers, projects, and collaborations have been developed using this computer program over the world.

In this paper, we propose a methodology where students can build their own system, perform numerical experimentation and evaluate the results using TRNSYS environment. One comprehensive case study will be introduced and demonstrated.

We discuss the process from students' point of view, and the experience earned in modeling, design, experimentation, and also in written and oral communication skills. Future plans to evaluate the effectiveness of this capstone in term of learning outcomes.

2. Modeling using TRNSYS environment:

TRNSYS is an environment, where a model is represented by a number of modules connected to each other using constant parameters, and input/output variables. The modules may be very simple, such as a pump, fan or a simple duct or a much more complex models, such as a thermal building, an airflow building, a heat pump, and VAV HVAC system. TNSYS itself includes a number of modules (library). Other modules may also be prepared by the user or bought from a third party.

Usually, each module is a representation with an equation or more to predict specific values (output). The inputs are the variables and the constant are the parameters. Among the most used modules, weather reader, and the output plotter. Understanding the systems, models and the simulation steps are necessary to make the linkage between the modules together to solve a specific problem (see figure 1). The procedure may be:

- Define the objective of the simulation
- Draw the system
- Decompose the model into modules
- Check the availability of the modules
- Prepare the missing ones
- Linkage between the modules
- Simulation

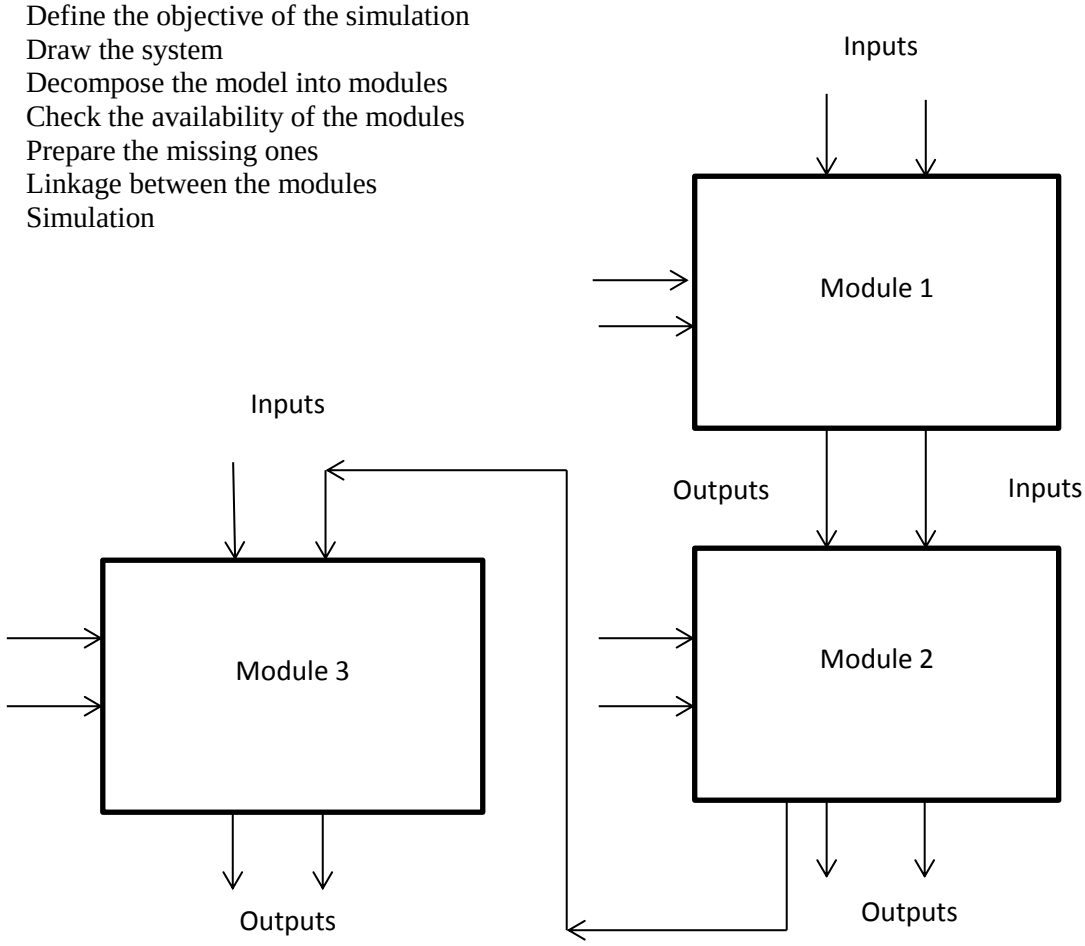

Figure 1: TRNSYS representation

3. Case studies:

In this case study, the integration building/systems is studied. The systems selected are: solar and geothermal systems. As well, an air HAVC system using heat pump is associated with the building. The main objective of this system is to heat and cool the building using a heat pump system that uses one or both of the two existing systems: the solar and the geothermal systems. In case these two systems are not available, an auxiliary system is used. The whole system is described in the figure 2. The figure 3 shows the major components composing the system and the water flow within the system.

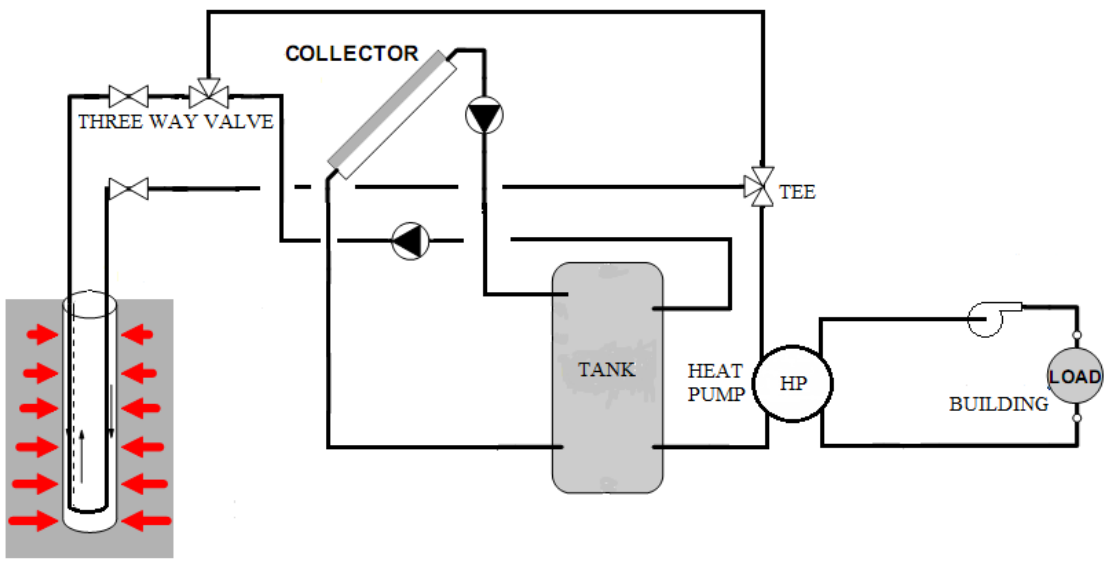

Figure 2: Building/geo-solar/HVAC integrated System

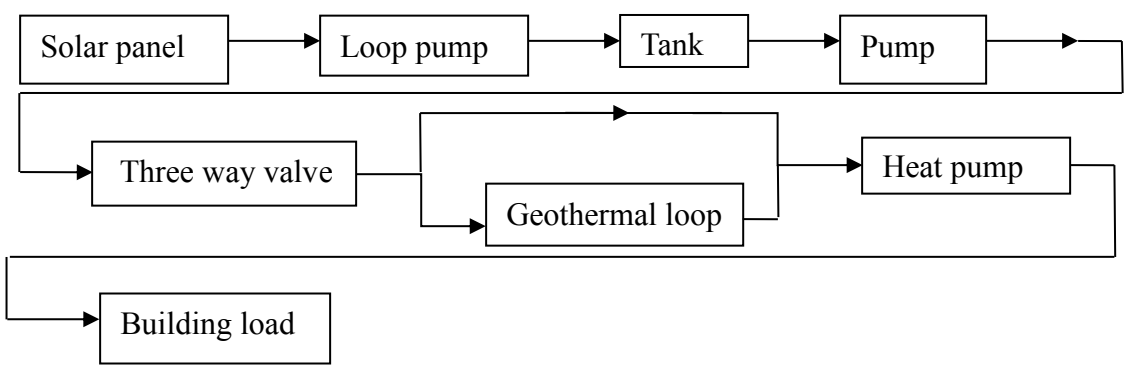

Figure 3: System I sketch of modeled hybrid geothermal/solar system

The students start to familiarize themselves with the software going through the whole process using preexisting simple examples. As soon as, the students understand the process, we move to the other level, where students are supposed to compose their own system, with the guidance and the help of the instructor.

The students are given the description of simple system (composed of only of one single system, such as building, or HVAC system). The students will go through the process described below to perform the simulation, with the guidance of the instructor. The level of help depends on the quality of the students. Usually, students need some level of help.

The process used is described as:

Step 1: General information, such as weather condition, numerical methods, and the numerical simulation parameters are selected.

Step 2: Identify the system components, called modules. Each module is associated to a Type number. In our case the components are: solar panel, tank, pipe, pump, three way valve, tee, geothermal heat exchanger, heat pump, and building.

All these module need to have a model. These models can be taken from TRNSYS library, made by the user or bought from a third party.

Step 3: A comprehensive building description is performed. This description includes, building dimensions, number of zones, walls compositions, windows, doors, heating/cooling and ventilation parameters and schedules, and so on. This part is very important and requires a significant time to be completed. The students need to have multiples lectures to be familiar with building energy simulation programs.

Step 4: Decide about the control levels that need to be used. In our case, three level of control:

- Indoor temperature control, using thermostat
- Control to decide what system need to be used (solar only, solar + geothermal, solar + geothermal + auxiliary system)
- Control to avoid over-heat from solar panel

Step 5: The modules (Types) need to be connected to each other (Figure 4), through input/output variables, following the system configuration and functionality (see the figures 2 and 3).

Step 6: All inputs and parameters (constant input) are identified and checked.

Step 7: Decide about how we can see the output from the simulation results.

Step 8: Create the deck file and run the simulation

Step 9: check and analyze the results.

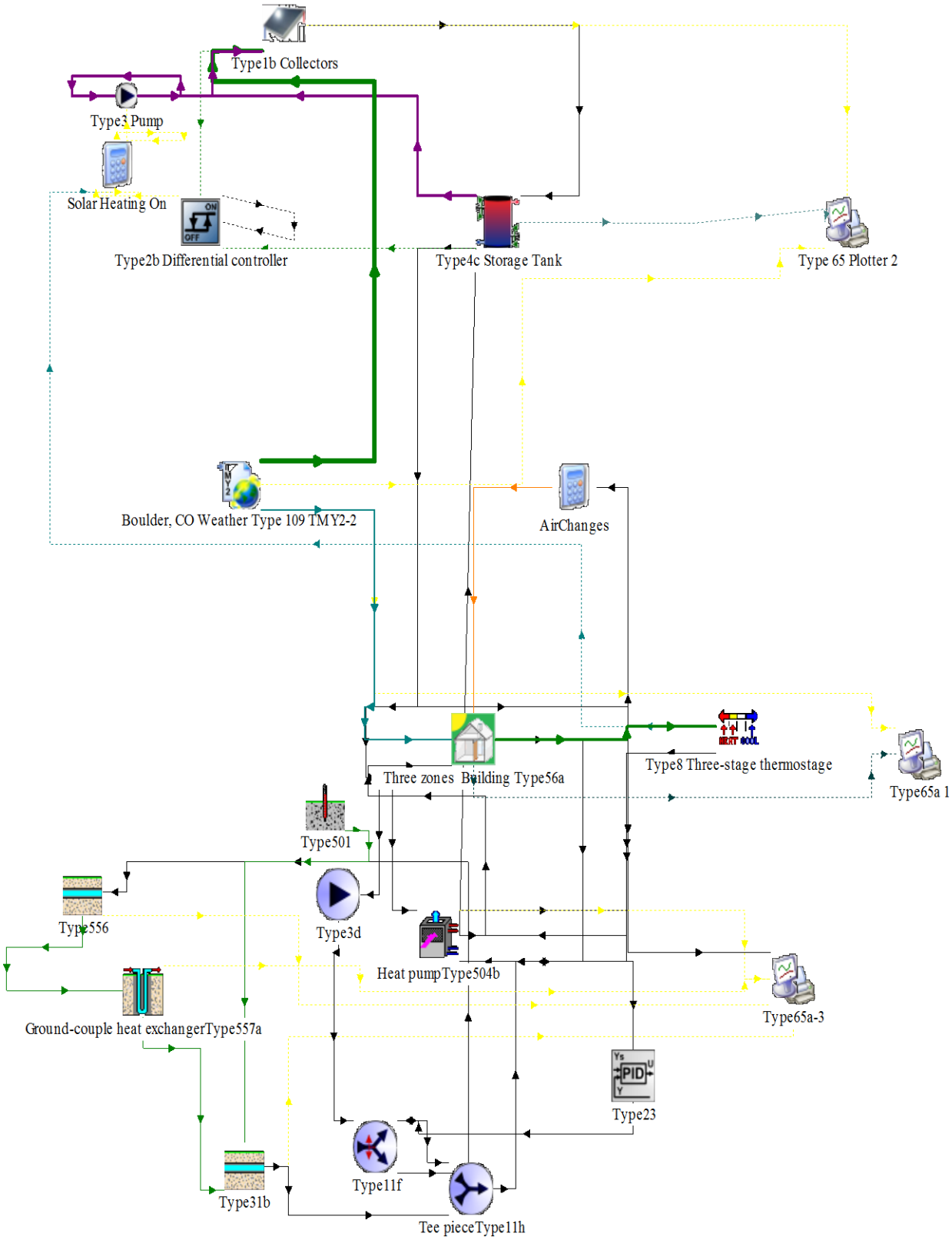

Figure 4: TRNSYS studio hybrid building/geo-solar/HVAC system

3.1. Simulation results:

A multi-zone building is selected for this study. Usually, we select a few zones building to limit the number of inputs. The simulation period is selected from January 27 to February 3. The running results are focused on February 1-3, the first half part of simulation time is only for initialization purpose. The limitation of the study to only 3 days is necessary to be able to analyze the results and give interpretation to different behaviors.

In the system, the diverter type is performing the function of the three way valve. When the three way valve diverter input control signal is 1 (according to the internal control function of diverter), the geothermal loop is bypassed and only the solar loop deliver heat to the building. When the diverter control signal is 0, the geothermal loop is included into the heating system. In a situation of an extremely cold weather, the thermostat sends a 2nd heating stage signal to the auxiliary heater, and the heater will be turned on to increase the room temperature.

The key control element of this system is the three way valve. It controls whether the geothermal loop need to be included or not in the system. In our configuration (Figures 2 and 3), it can create three operation modes based on the heat source from solar loop, the geothermal loop or the auxiliary heater. The figure 5 shows the tank load side temperature versus the ambient temperature values. The figure 6 shows the indoor temperature for different operation modes.

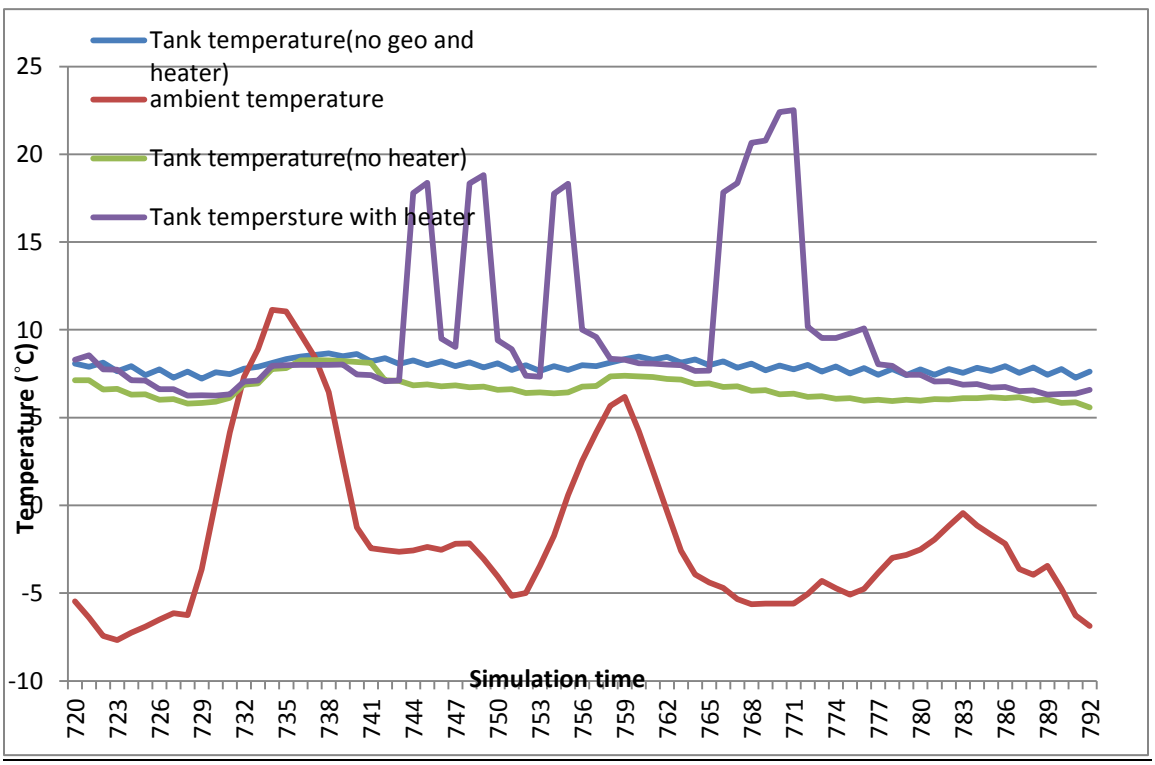

Figure 5: tank load side temperatures for different operation modes

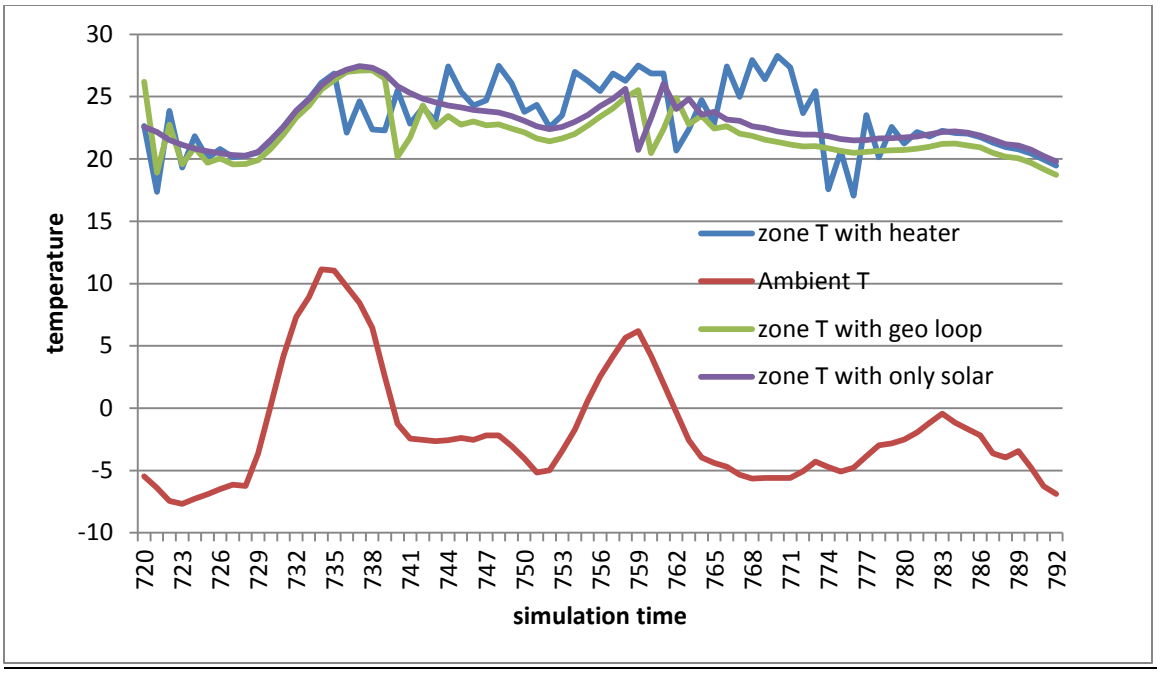

Figure 6: zone temperatures for different operation modes

Three modes are simulated. These modes are: (1) mode 1, where only the solar recirculating loop is included in the heating system, the geothermal loop is bypassed by the three way valve; mode 2, where both solar and geothermal loops are included in the heating system; mode 3, where the temperature of the zone cannot reach the set point temperature, the thermostat send a signal to turn on the auxiliary electrical heater, located within the hot-water tank. The figure 7 represents the indoor temperature when geothermal is used or not.

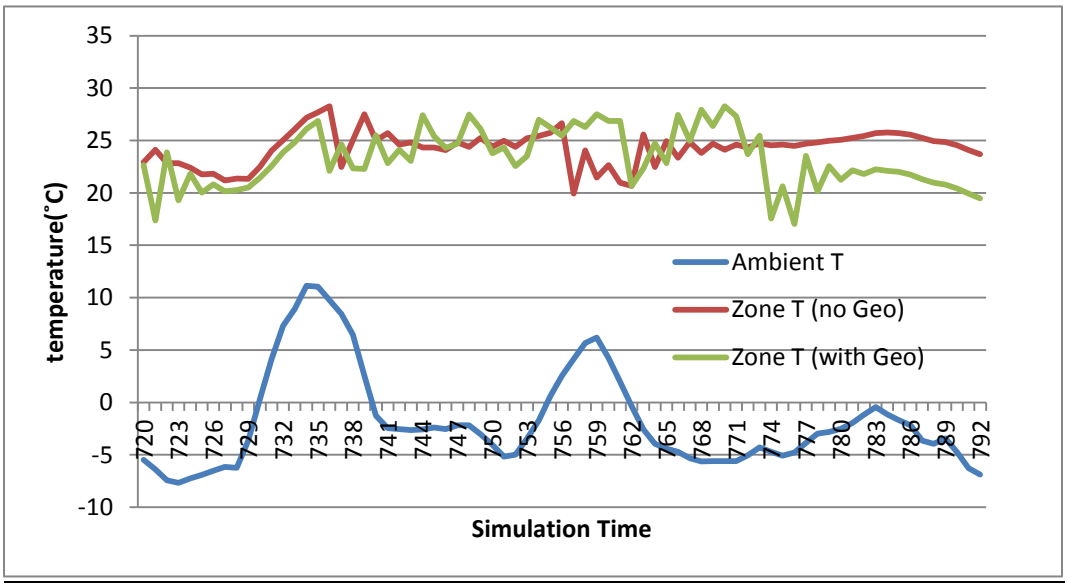

Figure 7: zone temperature with or without geothermal system

A second investigation inside the geothermal loop is conducted: the outlet fluid temperatures comparisons of horizontal ground-coupled heat exchanger, vertical U-tube ground heat exchanger and buried pipe heat exchanger at different status of three way valve (Figures 8 and 9).

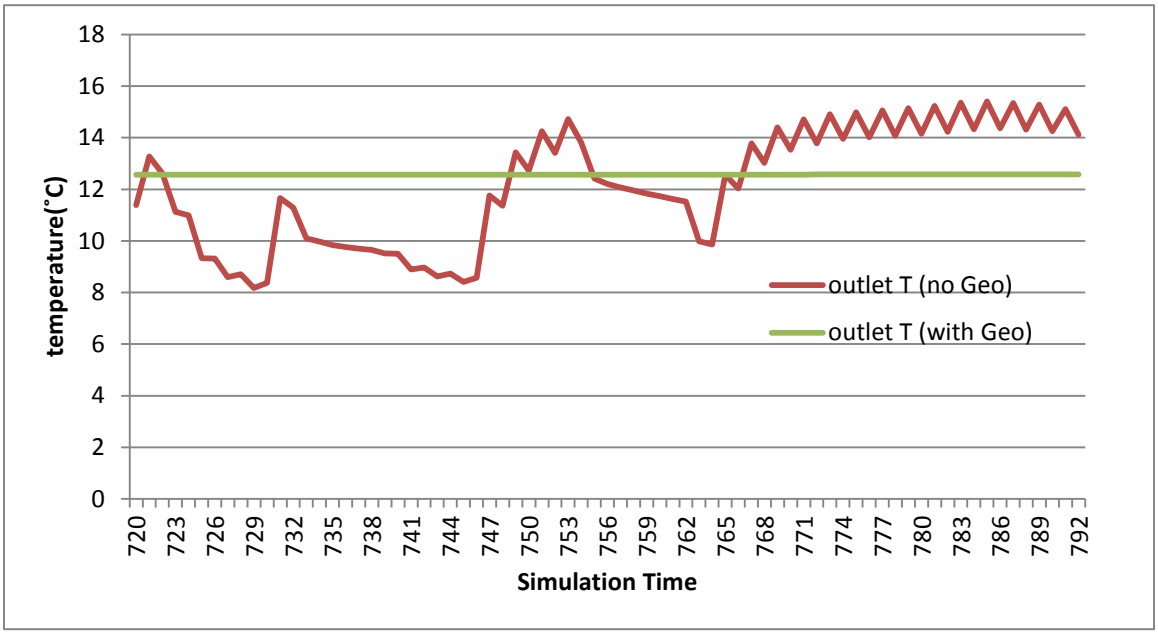

Figure 8: horizontal ground-coupled heat exchanger temperature with or without geothermal

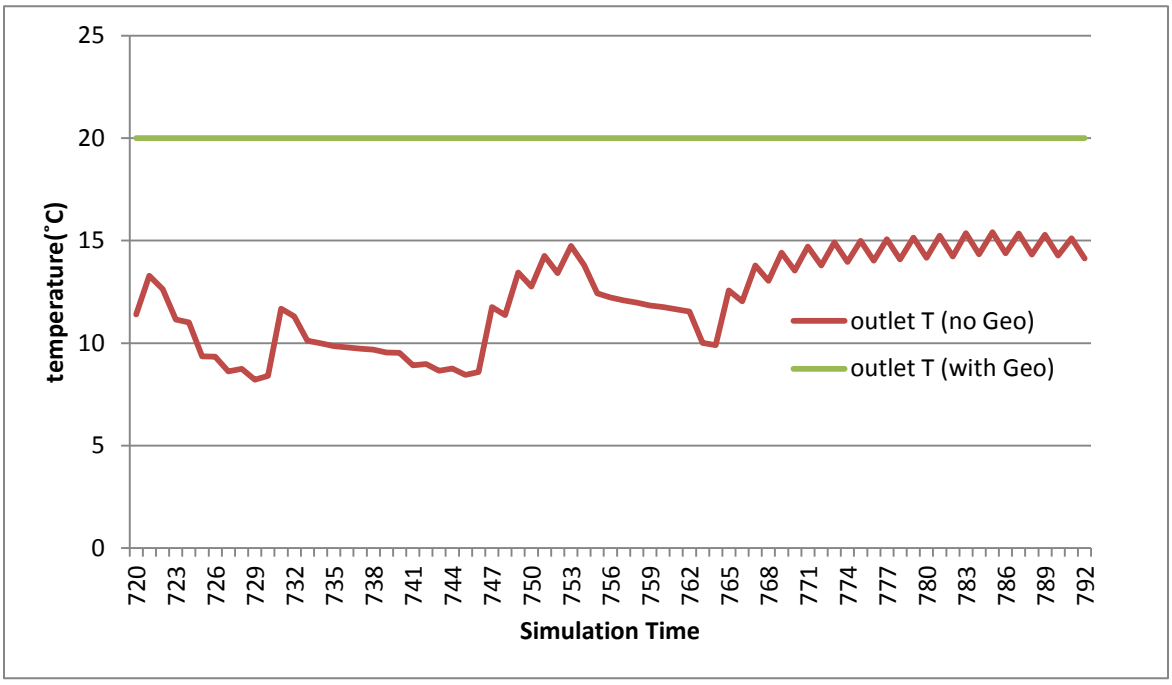

Figure 9: vertical U-tube heat exchanger temperature with or without geothermal

4. Course evaluation:

In parallel with the self-evaluation of each course by the instructor, we also conduct a course evaluation by students. This topic is a part of the HVAC laboratory course. The course objectives introduced earlier in the course are again provided to the students at the end of the semester. The students' input on whether the materials offered have met the objectives is then complied and used in the program outcome assessment process. Results of instructor course evaluations (conducted by students) are reviewed by the Department Chair and the Dean and shared with the faculty.

Each faculty member also conducts an evaluation of performance of students in his/her courses as part of the Program objectives and outcome assessment process. A summary report on the performance of students (to meet the Program objectives) and compliance with the Program outcomes is prepared and submitted to the Department Chair for the assessment purposes.

Future plans to evaluate the effectiveness of the capstone in term of learning outcomes: Actions that will be implemented to improve the effectiveness of the curriculum in term of learning outcomes:

- We expanded on the instructors' self-evaluation such that more direct assessment of students' learning outcomes is obtained. A set of standards for instructor's self-evaluation will be prepared by the faculty and the Board of Advisors and will be implemented with the annual assessment cycle. The main point of these standards is that the evaluation of students' performance will based on samples of work in three categories of students: those in the upper 75 percentile, those in the 50 – 75 percentile and those below the 50 percentile populations. Thus the assessment results compiled are based on course performances and grades, exams, projects, presentations of students, and writings as required in some courses. Furthermore, each course specifically addresses the learning outcomes and relation between the course and the Program outcomes, the methods used for the evaluation of students' performance and the relevance of the course materials to the Program outcomes following the standards adopted for the assessment process.
- Students will be provided with the course descriptions including learning objectives and outcomes. Students also will provide their input on the Program outcomes. The results from this instrument are used along with those from the instructors' self-assessment of courses as a means to ensuring compatibility in results obtained.
- A more rigorous process in assessing the learning outcomes of this lab course will be implemented, which are in parallel with the Program outcomes. The following outlines process will be used for this capstone course assessment.
    - Individual instructor evaluation of the degree of learning achievement of individual students on a capstone team, which includes consideration of the collective achievements of the team.
    - Peer evaluation (optional by instructor).
    - Grading of deliverables by the instructors.
    - Teamwork survey.
    - Self-assessment.

5. Conclusions:

Teaching TRNSYS to undergraduate students is not an easy task. Usually students prefer to use software like eQUEST and EnegyPlus with an existing interface, where they need only to manipulate a driven menu, and the number of input/output is limited. The main problem with these software are their limitation to specific tasks. This restriction limits the application field of the existing energy simulation programs.

The teaching of TRNSYS needs a long and tedious preparation that concerns multiple subjects, starting from numerical methods, to weather data analysis, to the understanding of several models and systems. The instructor's mastering of the software and expertise in the energy area, thermal systems are absolutely important and necessary.

In this paper, we proposed a methodology where students can build their own system, perform numerical experimentation and evaluate the results using TRNSYS environment. One comprehensive case study have been introduced and demonstrated.

The flexibility and modular structure of TRNSYS allows the integration of multiple systems, such as building, solar panel, geothermal, control and perform a comprehensive analysis. The students learn how to perform a simulation, to select and analyze the effect of the weather data, the effect of each parameter on indoor temperature and more importantly how to perform control, energy and economic analysis.

6. References:

Klein, S.A., Beckman, W.A., Duffie, J.A. 1976. A Design Procedure for Solar Heating Systems. Solar Energy, Vol. 18, pp. 113-127.

Klein, S.A., Beckman, W.A., Duffie, J.A. 1977. A Design Procedure for Solar Air Heating Systems. Solar Energy, Vol. 19, No. 5, p. 509.

Klein, S.A. et al. 2006. TRNSYS 16: A Transient System Simulation Program, SEL, University of Wisconsin, Madison USA.

Mathworks, Inc., MATLAB and SIMULINK are registered trademarks, 2009.

Google, Inc., Google SketchUp is a registered trademark, 2009.

Ellis, P. 2009, OpenStudio plugin for Google SketchUp3D, Version 1.0, January 2009, http://sourceforge.net/projects/openstudio.

Weber, A. 2006. TRNFLOW: A module of an air flow network for coupled simulation with the multizone building model of TRNSYS.