Automation system for solar heat supply system

Murat Kunelbayev

Institute of Information and Computer Technologies, Almaty, Kazakhstan

Abstract: In this article development and research of an automation system for a two-circuit solar installation with thermosiphon circulation. Automation systems of two-circuit solar installations with thermosiphon circulation have a complex character for the development and technological processes during operation. According to experimental and theoretical results, the change in the amount of heat in storage tanks supplied from flat solar collectors also has a significant complex character. An automated control system based on the concept of SCADA (Supervisory Control nd Data Acquisition) was used to monitor and control the operation of an experimental two-circuit solar installation with thermosiphon circulation. With the help of SCADA, the average tank temperature was calculated on the first day of operation of the system, they agree well and give a discrepancy of 2-3%, and on the second day of operation the discrepancy is 15-20%. The high discrepancy is due to the thermal insulation condition of the tank and is due to reversible thermosiphon cooling. The highest intensity of solar radiation reaches from 12:00 to 16:00 in both circuits, which indicates that the intensity in summer is higher than in winter.
Keywords: flat solar collector, heat pump, two-circuit solar installation with thermosiphon circulation, automation system, SCADA, solar heat supply system, PLC, control system,

Introduction

Sustainable development, an increase in energy demand and a reduction in the use of fossil energy sources are the three most important factors that have made renewable energy the first studied, evaluated and promoted science in the world today [1]. Solar, wind, hydro, biomass, etc. resources have been used recently to go hand in hand with fuel, and basically overcome the problem of working well for a long period of time. However, solar energy is the most diverse among others, since it exists anywhere in the world [1]. Therefore, scientists have developed many systems useful for collecting energy extracted from solar radiation and converting it into electricity, heat, or both [1, 2]. Among these systems, photothermal conversion technology remains the most diverse in all, however, depending on the classical form of radiation conversion, it is not enough to ensure good operation of heated systems [2]. Therefore, optimization approaches are used [3,4]. Several works on various methods of optimization of solar heating systems have been published in the literature [3]. The authors began by determining the optimal strategy for controlling the modulation of water flow in solar thermal applications, using as a starting differential algorithm based on the on-off principle (from 0 to the maximum flow value) [1.5], thus, the controller either starts or turns off the water flow pump in accordance with the on-off temperature difference. There are several control strategies that are used along with the differential approach, such as Proportional-Integral-Differential (PID) controllers, Proportional-Derived Sums (PSD) controllers and fuzzy logic controllers [6]. These methods can certainly be more practical in programming than others, and more useful considering several aspects. Microcontroller-based systems are widely used for monitoring physical parameters (temperature, pressure, humidity, etc.) and, in particular, parameters related to the use of solar energy [6]. According to the literature of past studies, implemented management strategies have contributed to improving the energy efficiency of solar thermal facilities [6-8]. However, the developed electronic devices differ from one job to another according to the specific requirements of each specific application [9]. In this article, we decided to study two different types of controllers and apply the most suitable one for the heating system in order to maintain the temperature in the desired range (from 30 °C to 40°C).In this article [10], the control of the integral derivative (PID) of voltage for a DC motor (DC) is developed and implemented. This controller was chosen because of the possibility of building flowcharts that can be built in the Matrix Laboratory (MATLAB) Simulink. A simulation analysis of the PID control voltage for an open loop and a closed loop is carried out. The results show that the voltage measurement error for a closed loop is lower compared to an open loop. In addition, the hardware was configured to test the MATLAB Simulink model. This article [11] is devoted to the development of a PID controller for monitoring and controlling the speed of a DC motor, and the MATLAB program is used for calculation and modeling. PID controllers are widely used in industrial enterprises because of their simplicity and reliability. Industrial processes are subject to parameter changes and parameter perturbations. This article [12] presents a comparison between some well-known control schemes, such as feedback, feedback plus direct communication, cascade and cascade plus direct communication for controlling a third-order process. The simulation results show that the RA method provides excellent performance in the case of feedback plus direct and cascade control schemes. On the other hand, the ZN method turns out to be the best in the case of a cascade circuit plus direct control.

Method of research

Automation systems of two-circuit solar installations with thermosiphon circulation have a complex character for the development and technological processes during operation.

According to experimental and theoretical results, the change in the amount of heat in storage tanks supplied from flat solar collectors also has a significant complex character.

The water temperature in the accumulator tank maintains a balance between the amounts of heat coming from solar collectors, as well as supports the thermal performance of the heat pump with the help of an automatic heat pump control system. The thermal balance between the supply and consumption of thermal energy is controlled by the flow of water supplied from the cold water supply line to the solar heat supply system. This balance is also maintained by an automatic heat pump control system. To increase the operational efficiency of the solar heat supply system, an automated process control system is used. In order to solve this problem, the following steps are used:

a) Elimination of emergency situations and assessment of the condition of individual nodes of the solar heat supply system according to sensor readings;

b) Ensuring the autonomous operation of the installation.

With the help of these two stages, this technological process makes it possible to reduce operating costs and reduce the influence of the human factor on the reliability of the solar heat supply system.

One of the main ways to automate the solar heat supply system is the use of specialized software and hardware complexes, which allowed us to solve the following tasks:

a) To obtain data on the state of the system and changes in technological processes on the control controller;

b) To process data on changes in the technological parameters of the solar heat supply system in real time;

c) To improve algorithms for managing technological processes in the solar heat supply system;

d) Monitor in real time the technological state of the installation.

Results

An automated control system based on the concept of SCADA (Supervisory Control and Data Acquisition) was used to monitor and control the operation of an experimental two-circuit solar installation with thermosiphon circulation.

All measuring components are integrated into one measuring system based on a Programmable Logic Controller (PLC), where an algorithm for controlling the operation of the installation is implemented. The PLC is connected via Ethernet protocol to the Dispatch Control Data acquisition system (SCADA) with visualization and collection of measured data. Programmable logic controller (PLC) performing the following functions–

- collecting and processing information from temperature sensors, flow meters, incoming solar radiation sensors, etc.;

- providing communication with the server for processing and storing information under the control of the "Master SCADA" system.

To implement the development and research of the automation system of a two-contour solar installation with thermosiphon circulation, "Master SCADA" was used.

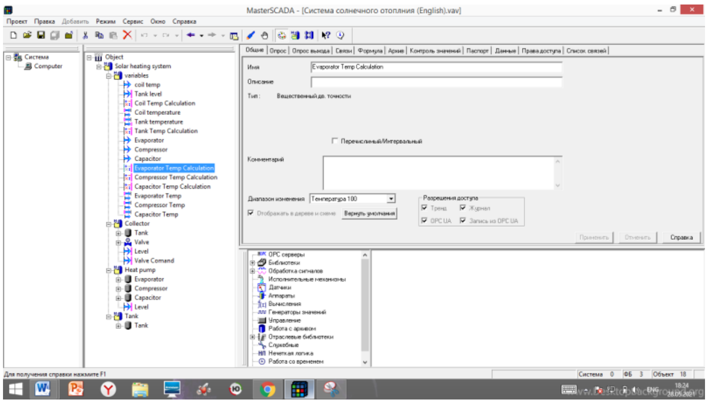

Fig.1. – The "Master SCADA" program

Figure 2 shows the dispersion control of a 2-contour solar installation with thermosiphon circulation in the "Master SCADA".

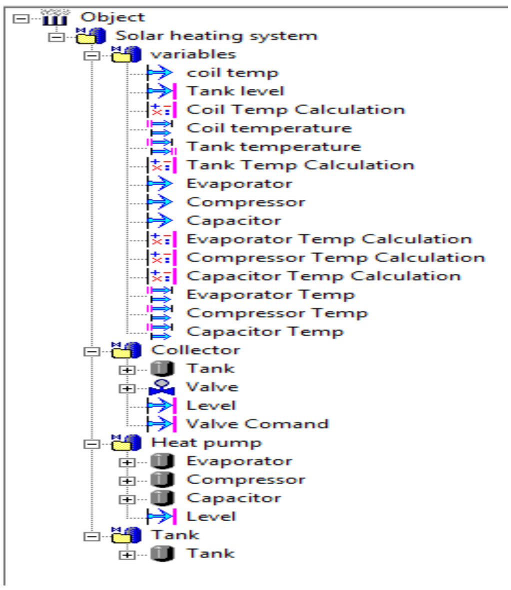

Fig.3. - Objects and variables in "Master SCADA"

Figure 3 shows objects and variables in the "Master SCADA" for a 2-contour solar installation with thermosiphon circulation.

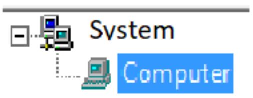

Fig.4. - Control computer

Figure 4 shows the control computer, one of the main components for managing the entire system.

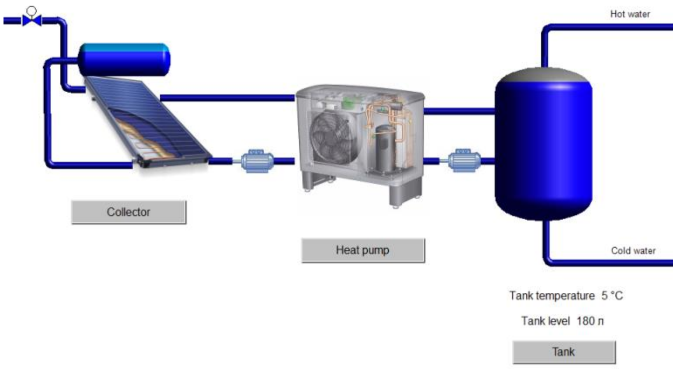

Fig.5. - Automation system of a two-contour solar installation with thermosiphon circulation in "Master SCADA".

Figure 5 shows the automation system of a two-contour solar installation with thermosiphon circulation in "MasterSCADA". This system is made in the MasterSCADA program. That is, in the MasterSCADA program, we can see the automation of this project. The purpose of this project is to heat the water in the tank using solar energy. The main elements of this project are: a flat solar collector, a heat pump, a storage tank. Let's focus on the principle of operation of this system. First, consider a flat solar collector. Inside the flat solar collector there are coils.

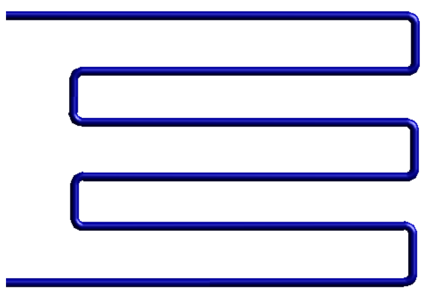

Fig.6. - Coil of a flat solar collector in "MasterSCADA"

Figure 6 shows the coil of a flat solar collector in "MasterSCADA". Solar energy heats the water in the coils. The warm water in the coils is replaced through the valve with cold water, and the heated water accumulates in a small tank. After that, the heated water enters the heat pump. After the heat pump, cold water already comes to the collector.

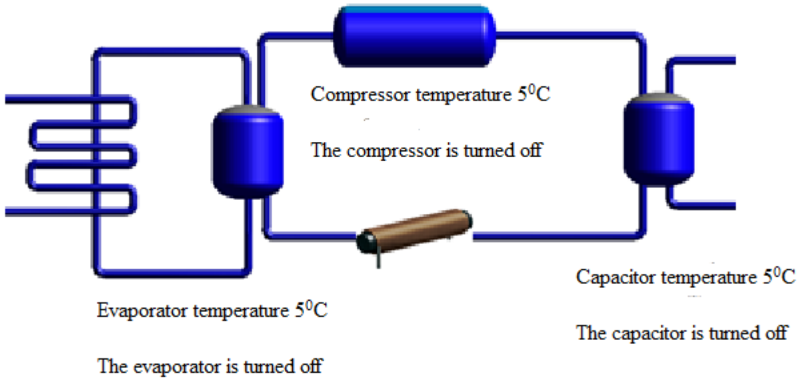

Fig.7. - Diagram of the heat pump in "MasterSCADA"

Figure 7 shows the diagram of the heat pump in "MasterSCADA". As we can see, the heat pump takes heated water from the coils of a flat solar collector.

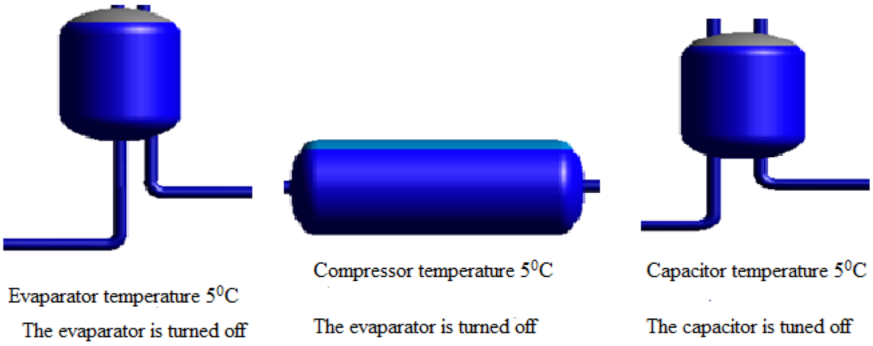

Fig.8. - Diagram of the evaporator, condenser and compressor of the heat pump in "MasterSCADA"

Figure 8 shows the diagram of the evaporator, condenser and compressor of the heat pump in "MasterSCADA". In "MasterSCADA" the whole process takes place through the buttons (on/off). Namely, we turn on and off the evaporator and condenser. And steam is compressed in the compressor.

After turning on the evaporator in the heat pump, the temperature in the collector decreases, namely in the coils and all the heat accumulates in the correctional room.

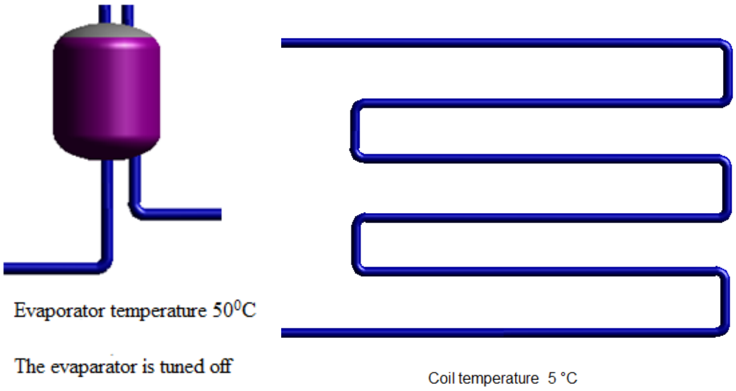

Fig. 9. - Heat accumulation in the evaporator

After this operation of the heat pump, our mnemonic circuit changes:

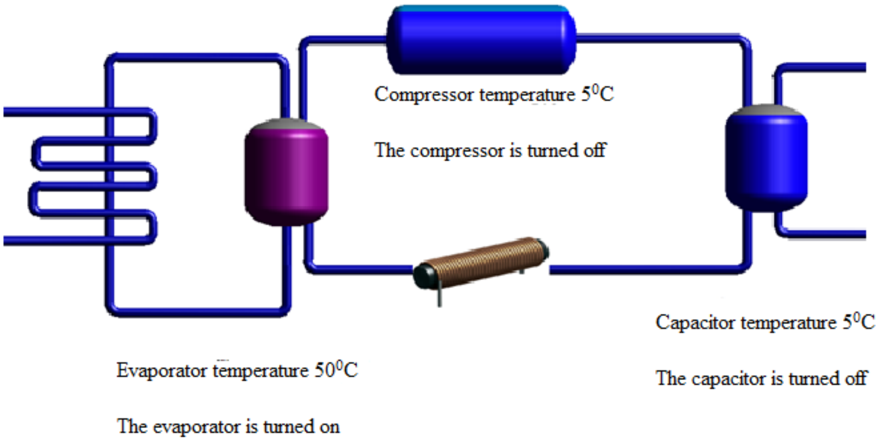

Fig.10. - Mnemonic diagram after switching on the heat pump evaporator in "MasterSCADA"

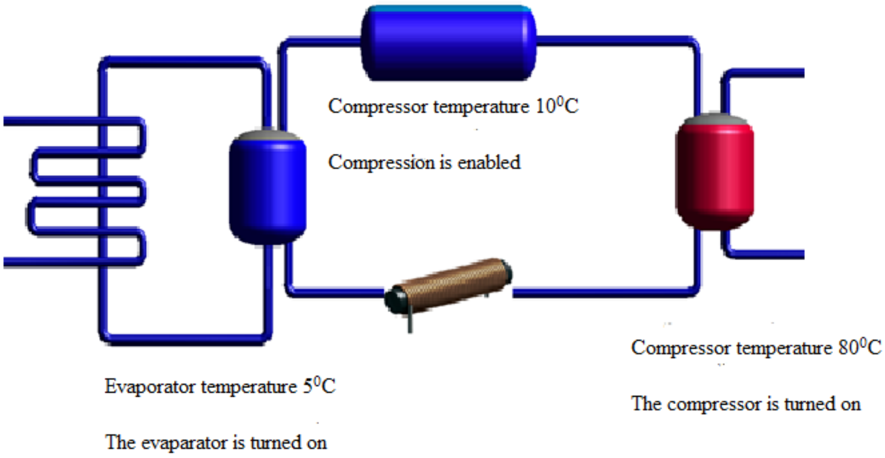

Fig.11. - Mnemonic diagram after switching on the heat pump condenser in "MasterSCADA"

Thus, the solar heating cycle passes through the heat pump. Namely, now we have looked in detail at the principle of operation of the heat pump. After such a cycle, you may notice that the battery tank that is in the house has warmed up.

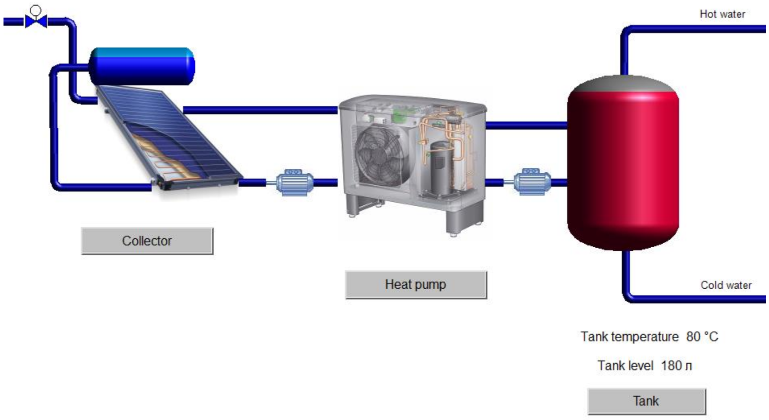

Fig.12. - The final mnemonic diagram of the automation system of a two-contour solar installation with thermosiphon circulation in the "Master SCADA".

Conclusion

By receiving data from a Programmable Logic Controller (PLC), the SCADA system is able to evaluate the technological parameters of processes occurring in various units of the installation, namely:

- receives data on the temperature and volume of coolant circulation in each circuit by a two-circuit solar installation with thermosiphon circulation;

- calculates the amount of transferred thermal energy in various circulation circuits based on the readings of temperature sensors and flow meters;

- receives information about the performance coefficient of the heat pump;

-evaluates the efficiency of a two-circuit solar system with thermosiphon circulation.

In order to increase reliability, backup circulation pumps are provided in two-circuit solar installations with thermosiphon circulation with a heat pump. To increase the working life of the circulation pumps of the first and second circuits, the pumps are alternately switched on in accordance with the corresponding algorithms. The SCADA system in automatic mode, without operator involvement, supports the operation of the heat supply system in a given mode under various external influences.

References

1. Kalogirou S.A., Karellas S., Braimakis K., Stanciu C., Badescu V. Prog. Energy Combust. Sci. 2016. №56. pp. 106–137.

2. Slimani M.E A., Amirat M., Bahria S., Kurucz I., Aouli M., Sellami R. Energy Convers. Manag. 2015. №25. pp.209-221.

3. Assaf J., Shabani B. Appl. Energy.2016. №178(41). pp.66– 77.

4. Serir C., Rekioua D., Mezzai N., Bacha S. Int. J. Hydrogen Energy. 2016. №41 (45). pp.20974–20986.

5. Beschi M., Padula F., Visioli A. Control Eng. Pract. 2016. №56. pp.190–199.

6. Gürel A.E., Ceylan İ. Case Stud. Therm. Eng. 2014. №2. pp.42–49.

7. Isaksson J., Nilsson D., Kjäll P., Robinson N.D, Richter-Dahlfors A., Berggren M. Org. Electron. Physics, Mater. Appl. 2008. №9 (3). pp.303–309.

8. Fatehnia M., Paran S., Kish S., Tawfiq K. Geoderma. 2016. №262. pp.133–139.

9. Benammar S., Khellaf A., Mohammedi K. Energy Convers. Manag.2014. №78. pp. 923–930.

10. Aizam S., et al. J. Appl. Environ. Biol. Sci. 2015. №5 (9), pp. 661 – 731.

11. Singh A.P. Innovative Systems Design and Engineering.2013. №4 (6). pp.22–28.

12. Kumar R., Singla S.K., Chopra V. Journal of Applied Research and Technology. 2015. № 3. pp. 409-415.