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Design and Implementation of Automated Residential Water Heating System using Sustainable Energy and PLC Techniques

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Abstract:

The study's goal is to design a control system that uses solar energy as a renewable and free energy source and water from wells to provide water and hot water around the clock to people residing in residential areas during difficult times and abnormal conditions. Research on this project was conducted during the devastating The electricity crisis in Mosul, Iraq, in the winter of 2014 was characterized by low temperatures (the city only received power for about two hours out of every seventy-two), a lack of other energy sources (oil, cooking gas, gasoline essentially disappeared), and the suspension of water delivery by the government's water purification plant. The most practical approach was to utilize solar water heating and individual generators (the Zone Generators, ZG) that serve multiple homes (3 h ON/3 h OFF) in the area. This system consists of 1) the primary electric water heater, 2) auxiliary electric water heaters, and 3) a programmable logic controller (PLC) from SIEMENS of Germany (LOGO!® V7.0). The 30 L emergency electric water heater is a backup system. The solar heater uses two flat panels to gather solar heat and a heat storage tank (Capacity 180 L). Valves for electrical regulation (12 VDC coil voltage).

INTRODUCTION

The key components of the control method are shown in Figure 1 below. Electricity may be drawn from either the National Electricity Act (NEA) or a generator through an automated transfer switch. To a ZG based on what is readily available. The programmable logic controller (PLC; Siemens, 2013; PT., 1989; Rashid, 2011; Hugh, 2010) has the following technical specifications' DC/DC/relay \sac Inputs: 8 digital or 6 digital Plus 2 analog C Inputs for 4 Relays C An add-on board having eight digital inputs and the same number of outputs Elements H1 and H2 of an electric heating system may only be

used when NEA is available. Supplying DC loads like the PLC, analog thermostat, solenoid valves, and H3 and H4 actuators with power is the backup battery charging system. The PLC has a number of outputs (Operating Voltages: 12 VDC) that it uses to power things like the solenoid Valves (V1-V6) (Va and Vb) and the actuators of the Electrical heater elements (H3 and H4). C the PLC receives data from a single analog temperature sensor (thermostat) (PT., 1989). C It is necessary to have a single analog thermometer of monitoring the hot water supply's final temperature before it leaves the unit. C In the case that neither NEA nor ZG are available, the system can be kept operational by charging its backup battery with the help of a photovoltaic solar cell (Thabet, 2014) (PV) (Current 2A, Voltage 12 V, safety factor 1.25).

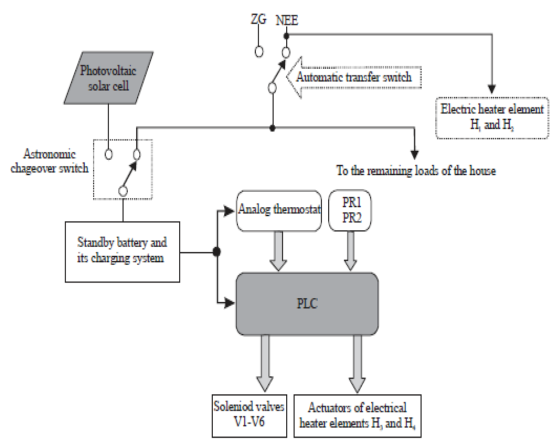

Fig. 1: Main parts of the electric scheme

MATERIALS AND METHODS

Hardware task

Installation works:

Specifically, our system operates as seen in Fig. 2. The primary storage tank that connects to the municipal water system through Val or Vibe, and the V1 Solenoid Valve is the main water supply for the whole system. The water temperature (the system's input temperature) is measured by an analog thermostat and sent to a PLC's analog input for regulation. Solenoid Valve V2 regulates the flow of water into a storage tank housing two flat plate solar collectors, while solenoids V3 and V5 regulate the flow of water out of the tank. The H4 element is an electrical heater that is submerged in the tank.

Two solenoid valves, V3 and V6, regulate the flow of water into the primary electric water heater, which has two electrical elements, H1 and H2. Solenoid Valve V4 regulates the input of a supplementary electric water heater equipped with an electrical element heater H3. There is a thermometer installed at the system's output so that users may monitor the temperature of the hot water they get.
Modifications to the electrical system: Automatic Transfer Switch (ATS) is shown in detail in Figure 3; it consists of two primary Contactors (C1 and C2) that provide the load from either NEA (C1) or ZG (C2), and two Pilot Relays (PR1 and PR2) that check the availability of NEA and ZG.

Two of the 3000 W electric heater elements (H1 and H2) of the primary electric water heater are wired in series with the NEA (L1 and N). The solar heating system had a 500-Watt electric heater element designated as "H4". Contactors C5 and C4 on the PLC allow for control by either NEA or ZG. ZG must use the PLC via Contactor C3 to turn on the 1000-W electric heating element H3. As can be seen in Fig. 4, a diode is connected in series with each heater element (H3 and H4) to minimize the current drawn from the ZG. This is a very simple and affordable method for reducing power to resistive loads (electric heater elements).The PLC, its expansion modules, actuators, and sensors all get their power from a battery (12 VDC/75 AH), which is charged by a battery charger that is likewise linked to the ATS's output and may be controlled by either NEA or ZG. In the absence of NEA and ZG throughout the day, the same battery is charged by a PV solar cell to provide continuous electrical power for our loads. At night and when neither NEA nor ZG are available, an inverter is powered by DC electricity to provide emergency AC loads like led lights. As can be seen in Fig. 5, the inverter may be controlled manually through a manual switch so that it can be adjusted to meet the specific requirements of the user.

To keep the electrical power flowing to the loads, the changeover relay and astronomical clock function as shown in Figures 5, 6, and 8. The primary function of this backup power source is to ensure that the PLC, its control system, and the emergency loads always have electricity when needed. In Fig. 5 we see the PLC and its control system.

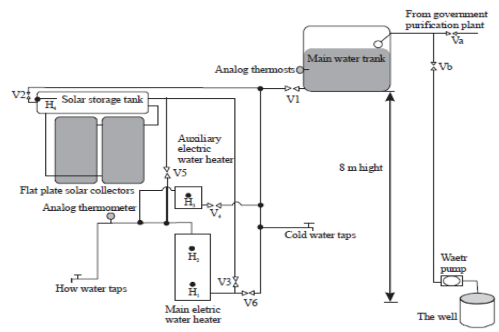

Fig. 2: Main construction of the system

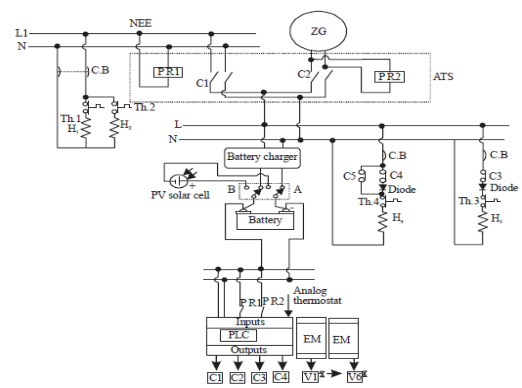

Fig. 3: All power sources (NEA, ZG, and PV) contribute to the system's primary electrical scheme, whereas only the emergency loads need constant power. Consumer-activated by means of a switch. The astronomical clock's workings are shown in Figures 6 and 8; these will be discussed in greater detail later in this study.

Table 1: The possible cases that could take place when the system is in operation

Cases	NEE	ZG	V1	V2	V3	V4	V5	V6	H1 and H2	H3	H4
Case one	1	0	1	0	0	0	0	1	1	0	0
20°C =< T_w > =30°C	0	1	1	1	0	0	1	0	0	0	(1)0
Case two	1	0	1	1	1	0	0	0	1	0	(1)0
10°C =< T_w <20°C	0	1	1	1	0	0	1	0	0	0	1
Case three	1	0	1	1	1	0	0	0	1	0	1
3°C =< T_w <10°C	0	1	1	0	0	1	0	0	0	1	0
Case four emergency	0	0	1	1	0	0	1	0	0	0	0

Software design:

Table 1 summarizes the potential instances that might occur while running the system, helping to provide context for how it is used. Cold water is supplied through valves labeled C V1, C V2, C V4, and C V6. The hot water supply valves are located at C V3 and V5. The C 1 code indicates that the valve is in the open position (ON state) If the valve indicator reads C 0, it is closed (OFF state) To the tenth power, water (C TW) When the sun goes down or clouds roll in, the main tank's temperature is set to C 1. To begin with an example: The first step in this scenario is completed when these prerequisites are met: C Power is provided by NEA. C Generally speaking, the primary water tank stores water at a temperature of 20-30 degrees Celsius.

Thus, two switches are activated. The internal thermostats of H1 and H2 as well as V1 and V6 should be adjusted to 50 and 65°C as seen in Fig. 2. This is the typical instance, and it may be used either during the day or at night. As for the second part, it is completed when there is no NEA and the water in the main water tank is between 20 and 30 degrees Celsius, and the ZG supplies the load; in this case, V6 is closed, V2 and V5 are opened, and hot water is supplied to consumers without using any electricity during the day, while the heater element H4 is activated during the night and on cloudy days to make up for the solar system's inefficiency. Subsequent Example: Case two is used in the following ways to increase system efficiency during daytime hours when the weather becomes cold and the water in the main water tank drops to below 20 degrees Celsius and energy is available from NEA.
Turn on the main electric water heater and the solar heating system by opening valves V1, V2, and V3.
When the sun is shining, the solar water heater will increase the temperature of the water going into the primary electric water heater, lowering the total amount of time needed for the water to heat up. The solar water heating system's storage tank includes a heater element, H4, with a power output of 500 watts, which is triggered when the sun isn't shining or when clouds cover the sky. This increases the temperature of the water before it is sent to the central electric water heater.

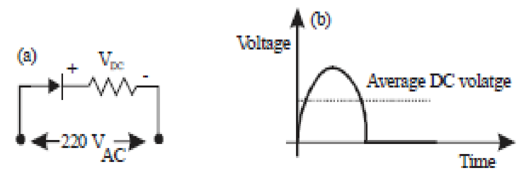

Fig. 4 (a-b): Diode rectification heating cuts down on wait times for the element to reach temperature and operate at half the frequency of a conventional heater. H4's heating element's built-in thermostat must be adjusted to 40 degrees Celsius. If there is no NEA and the main water tank's water temperature is also below 20 degrees Celsius and ZG is providing the load, then Valve 3 will be closed and Valves 2 and 5 will be opened to keep customers' taps full with hot water.

Three different scenarios: The solar heating system with H4 is activated during sunny or cloudy periods daily and also at night periods when NEA is available by opening V2 and V3. This case states that when the temperature drops to between two and three degrees Celsius, hot water is supplied to consumers from the main electric water heater tank. Since ZG will be supplying power to the home in the event that NEA is unable to do so, the solar heating system will continue to provide hot water to the residents by opening Valves V2 and V5 during daylight hours while H4 is turned on. Power diode will be used to provide energy to the heater element, reducing the heater's overall power usage. The auxiliary electric water heater's heating element H3 is rated at (1000 W), and its built-in thermostat is set at 65°C, so that when the valves V1 and V4 are opened, the auxiliary heater's heating element is energized via. A power diode to reduce energy consumption.

Situation four (emergency): when there is no electricity at all (neither NEA nor ZG is available), a photovoltaic solar cell is utilized to charge the battery throughout the day, turning on V1, V2, and V5. During the day, a solar system will provide customers with hot water directly (the charging effectiveness of this system will depend on the weather conditions).

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The water left in the solar system's storage tank will be used to supply customers at night. Changing the charging process from NEA or ZG to the photovoltaic solar cell is accomplished by a changeover relay with a unique function.

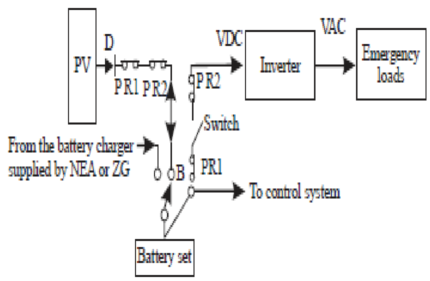

Fig. 5: A schematic diagram for a sustainable power supply

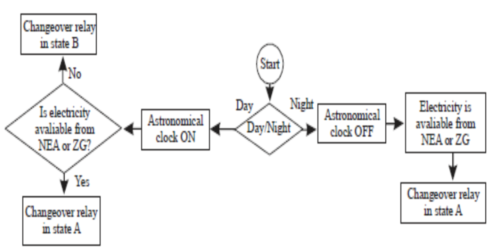

Fig. 6: Flowchart of the astronomical clock and the changeover relay

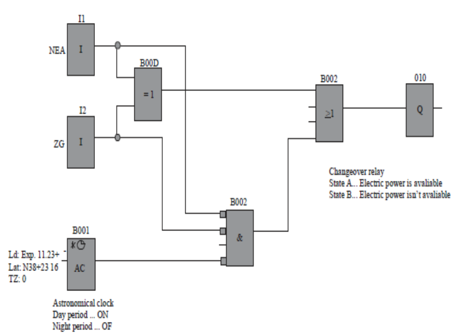

Figure 7: Using the astronomical clock as part of the study's control system, as implemented by the "Astronomical clock" program (Siemens, 2013) the purpose of this operation used to schedule peak brightness during the hours around the LOGO's geographic location's sunrise and sunset (Siemens, 2013). In Figure 8 we can see how this feature is implemented in our control software. In the event of an emergency, the control system will activate automatically, while consumers will manually activate emergency loads provided by the inverter through a switch based on their individual demands, as shown in Fig. 5.

Program Description: The core of our system, represented by the analog component of the FBD (Function Block Diagram) software shown and explained in Fig. 7, consists of an analog input that receives the temperature values of the main water tank from an analog temperature sensor. The analog input value is amplified and sent to an analog threshold trigger function block, which reads the value of the signal, evaluates it, and then outputs a set or reset value based on the threshold values.

Siemens (2013) this section of the code is in charge of keeping an eye on the main tank's water temperature and activating and deactivating the system's solenoid valves and heater contactors accordingly. To alert users that the load is not being supplied by electricity and that both NEA and ZG are turned off, a blinking light has been included into the system's architecture. For customers who have an immediate need for hot water in very cold weather at night when ZG is available (the hot water is provided by the auxiliary electric water heater), the emergency push button seen in Fig. 7 may be manually operated. As illustrated in the flowchart of Fig. 6, when both NEA and ZG are cutoff (day or night), our control system relies on the astronomical clock to establish the latitude and longitude of the site of our current experiment and to set the dawn and sunset timings of this place (Siemens, 2013).

RESULTS AND DISCUSSION

About 80-120 L of hot water (between 45 and 50°C) may be heated and supplied continuously by our water heating system. However, under uncommon circumstances, the hot water temperature might drop to around 30 degrees Celsius. With the availability of ZG, the auxiliary electric heater can provide around 20 L of hot water at a temperature of roughly 50°C within 40 minutes during times of emergency (at night and during very cold weather). The practical portion of our study is shown in the following figure: Fig. 9 depicts the main and auxiliary electric water heaters, as well as a few valves and the heater element H3. Figure 10 depicts the primary water storage tanks, solar heating system, and electrical heating element H4. The majority of the controlling system (the HMI is not used in this study) is external to the control panel, as shown in Figure 11. In order to demonstrate the operation of our system, we recorded the input and output temperatures of the main tank water and hot water taps twice daily throughout the month of December (1–31), at 12 a.m. and 2 p.m., respectively.

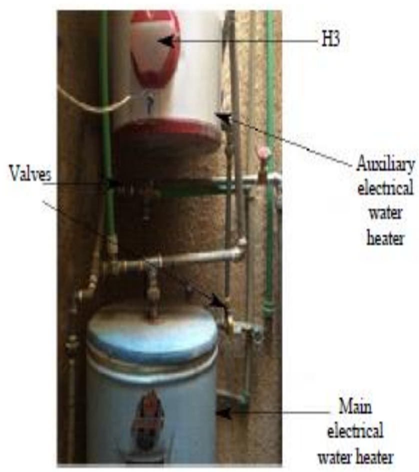

Fig. 9: Electric water heaters

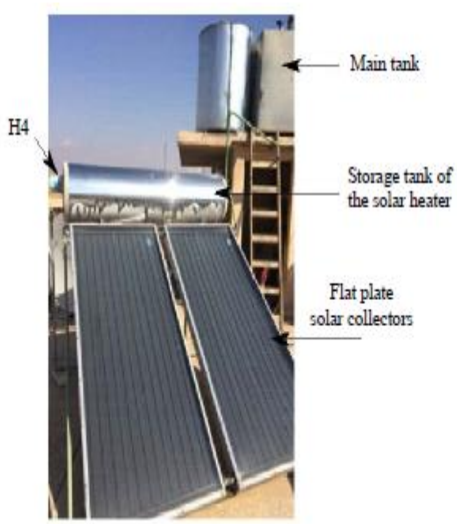

Fig. 10: Solar water heating system

Fig. 11The temperatures of the primary controller and the average of the two outputs were measured, calculated, and depicted as depicted in Figure 12. As can be seen in Fig. 12, the output water temperature dropped twice in December due to cloudy and rainy weather.

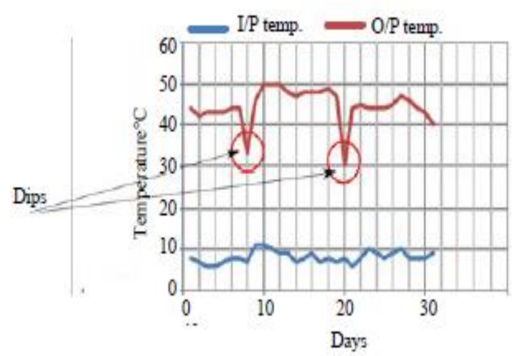

Fig. 12: I/O temperatures in December, 2014

CONCLUSION

When used between October 1 and April 30, the water heating system designed and implemented in this study achieves excellent results. In December, January, and February when the NEA is not in effect, because it ensures that residents have access to a constant supply of hot water. Considering its potential future applications, it is crucial to assess the efficiency of this heating system through a proper evaluation of its operation. Our automated system could also be made user-friendly by incorporating an HMI (Human Machine Interface

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