Equipment Designed to Control a Heating Hybrid System with Solid Fuel Boiler and Solar Panels

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Abstract: - This paper deals with identifying and solving the problems that occur in gasification heating stations work. The control equipment is a simple, reliable solution, meant for out-of-way houses, where it can increase the level of heating and the heating station efficiency. Our solutions turned out to be convenient both from economic and safety point of view. In order to keep the equipment working when the electric energy supply brakes down, a non-interruptible power source is necessary. We used a hybrid system that consists of a solid fuel boiler and solar panels. During the first year of operating, we identified the problems and improved the original system. The paper describes the components and the running mode of the heating station control equipment. Using such a device turned out to be convenient both from economic and safety point of view.

Key-Words: - Control, gasification, hybrid heating system

1 Introduction

One of the main goals of the energy global policy is reducing the fossil fuel consumption. From this point of view, using the regenerative energy resources for heating homes is an interesting target which aims, in a sustainable development context, the energy supply safety appreciation, environment protection and reliable energy technology trade development.

Comfort basic elements perception and appreciation by a human being are influenced by certain psychological factors and, in the same time, human evolution and poise are highly connected to environment [8]. So, there is a mutual interface between the psychological comfort and the thermal one.

Technical comfort assumes all the parameters which are achieved and controlled using different kind of installations, influencing human nature and acting on human senses. This includes thermal, acoustic, olfactory and visual comfort.

Inside a building, the microclimate has to be the result of a multi-criteria optimization, taking into account the thermal comfort and the energy saving as well.

Heating equipment can work using classical fuel (wood, coal, gas, oil, waste) or renewable sources of power (sun, wind or geothermal energy).

It is very important to pay attention to the heating equipment we want to use, taking into account several factors as: housing unit location, its solitude coefficient, climate, available power sources.

One of the most often used kinds of fuel, especially in villages, is wood (even industrial wooden leavings). Wood is the oldest fuel that mankind has used for heating homes, as it has always been available [1].

Using the wood remaining is an attractive solution for heating, as in Romania there is plenty of it, at much lower cost comparing to tree stems. The main inconvenience of the remaining use is that we need large and dry depositing spaces. Also, the heat resulted at the beginning of the combustion process is much higher than later on, which can be explained by the fact that, during the incipient phase of the combustion, the empty spaces inside the leftings mass are much larger, favouring the feeding of the flame with oxygen.

2 Heating hybrid system

The hybrid heating system using wood and solar energy that we designed consists in:
- boiler using wooden fuel and its infrastructure (fuel deposit, supplying system etc.);
- solar thermal system;
- thermal energy storage;
- heating control system

The hybrid heating system (solar – wood) allows an economy of almost 30% of the wooden fuel requirement for heating and hot water.

This system was achieved in an out-of-way house placed at 15 km far from the nearest town, where the junction to the gas, water or any heating network is practically impossible. Water is supplied from a nearby spring, stocked in a basin. The water flows from the basin to the house, through a pipe line, using gravity. The only available energy sources are solar energy and the energy provided by the solid fuel combustion.

The clime is specific for a hilly and mountainous area. The temperature registers a considerable variation along the year, between -22,9 °C in the winter and 36,8 °C in summer, which were the lowest and the highest temperatures ever measured [7].

During the first year, the house heating was made using a gasification boiler, circulation pump, by-pass pump and related radiators, for each room. That first solution and the problems we met, are presented further on in the paper.

The heating system is made of three solar panels (fig. 1), a solid fuel boiler [4] that can work with pallets, bricks or logs cracked to the appropriate size, stocking boiler, circulation and by-pass pumps and the pump meant to ensure circulation of the thermal agent heated by the solar panels.


Fig.1 Disposition of solar panels

Even if a single solar panel was enough to satisfy the hot water demand [2], we chose to use three of them in order to aid the boiler in heating the house, mostly during spring and autumn months, when the thermal energy need is not considerable and the sun can still provide enough energy.

We considered also the perspective of having more hot water during the summer, for example for warming up the water of a pool.

We used solar collectors, because of their price, easy installation and good weather-fastness, but we are awarded of the fact that they are not the best.

3 Solid Fuel Boiler Control System - Components, Run Mode and Shortcomings.

A gasification boiler is standard equipped with its own control system consisting of an electronic block that controls the two fans (the variable speed one and the warm air flow one, for automate ignition) [1], [9].

Beside this inbuilt control system, it is necessary to achieve another one to command the recirculation and the by-pass pumps depending on the fuel temperature and the heating need of the house [3], [5], [9].

This control equipment must be made of components with very low power consumption, as we intend to use it for thermal power plants heating out-of-the-way houses, where electric energy supply is often broken, sometimes for a long time, especially during wintertime [8]. Meanwhile all equipment must keep functioning with electric energy provided by an independent non-interruptible power source.

The automation electric circuit includes gauges, indicators, contactors, controllers, indication lights, time relay, sensors and alarm horn. The main component is a digital indicator with standard signal 4-20 mA, with two alarm contacts [10].

The device is meant for measuring temperatures. The input is from K, J, T, S types thermocouples or thermally sensitive resistance elements (Pt 100, Pt 46, Pt 50, Cu 53) or standard signal (4-20 mA, 0-20 mA, 0-10 V) [5], [6].

The device can work in two modes: measuring mode and setting mode. The alarm values can be set within the equipment measuring range, depending on the input type.

In installations which include power circuits, it is necessary to supply the equipment through a separator element (transformer).

In gauging, we have to consider the kind of input: standard, coming from a thermally sensitive resistance or coming from a thermocouple.

Also, the temperature influence can be adjusted, by the current injected in the temperature diode.

If the output is standard (4-20mA), the scale can be gauged, within the output range.

3.1 The Control Circuit Diagram and Panel

When designing the heating station control equipment, we took into account the building and functioning characteristics of the station and failure possible causes which we tried to prevent. Also, we had to design a circuit as simple and reliable as possible, with an optimum rate quality – reliability – price (Fig. 2).

The significance of the notations in the diagram is: d_0 – time relay; d_1, d_1', d_2, d_2' – supplementary relays; C_1, C_2, C_3 – contactors; e_1, e_2, e_3, e_4 – tremblers; A300 – inverter; RS485 – standard signal indicator; L, R, L, V – indicating lamps, BP, BO – buttons on/off; b – regime switch

The control panel is shown in fig. 3.

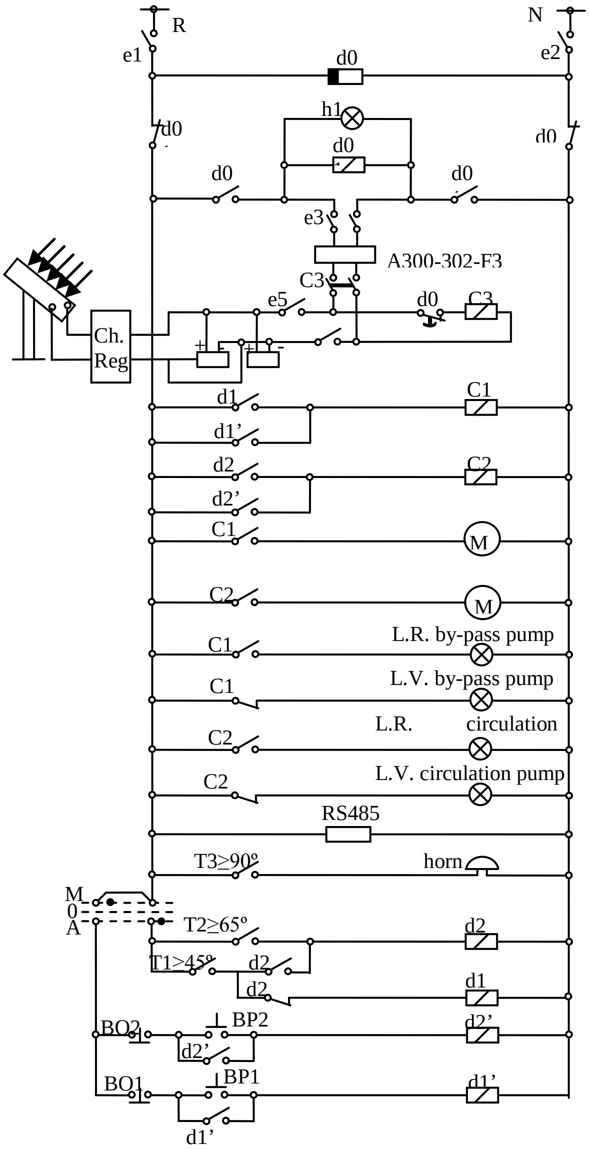

Fig.2 Control circuit diagram

3.2 The Control Equipment Running Mode

Before we start the thermal station, we have to check the electric and the control equipment to be supplied and the valves to be in normal functioning position [12]. We switch the regime using the key *b*, first to the MANUAL position; we run the functioning tests for each pump with the on/off buttons. This allows checking whether signalizers fit to the pumps state. Afterwards, we start the heating station.

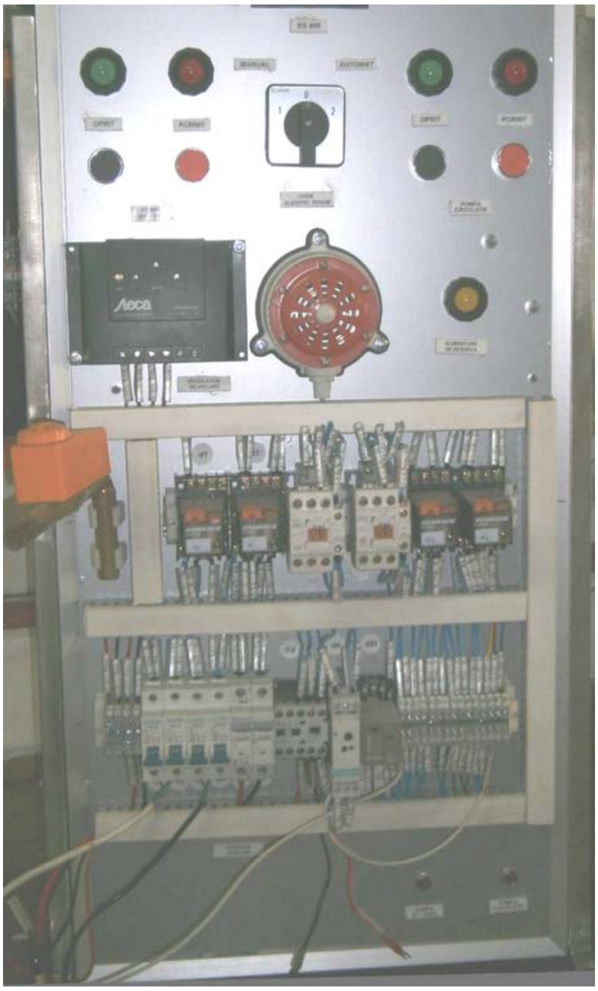

Fig. 3 Heating station control panel

Once the fire is on in the boiler, the heating medium temperature starts increasing and the thermally sensitive resistance, mounted on the turn pipe [11], delivers information to RS485 which processes it and displays the temperature value. The real time temperature value is indicated no matter which is the switch position.

The regime choosing key is switched to the AUTOMAT position. Now, the pumps are controlled by RS485 [9]. When the temperature reaches $T_1 = 45.1$ °C, the relay d_1 is energized and it commands the C_1 contactor which turns on the by-pass pump. So, the temperature gets increasing faster, as the by-pass pump circulates the water into the boiler.

At a temperature of $T_2 = 65.1$ °C, by energizing the d_2 relay, the circulation pump is turned on 10]. From this moment on the temperature keeps

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increasing a few tenths of degree and next, it starts decreasing, as the cold water from the radiators flows into the boiler.

If the water quantity in the installation is comparatively equal to that in the boiler and the radiators are properly equilibrated (the return valves are more and more opened as we get farther from the boiler, till the farthest one, which is completely opened), then the temperature should not decrease under 40 °C and the temperature in the boiler should not reach the dew-point.

In order to avoid such a situation, we equipped the installation with a by-pass pump [10]. When the temperature gets to 44.9 ° C, the circulation pump shuts down and cold agent doesn't enter the boiler any more. Still, the temperature goes down a couple of degrees, until the fire succeeds to increase the temperature again. About now, the temperature in the burning place is maximum, as all wood burns. From now on, the temperature keeps increasing, the pumps turning on cycle is restarted and the temperature stabilizes at about 73-75 °C. The difference between the water temperature in turn and return is of about 15°.

It is possible that the control system breakdown occurs and it is not noticed by the human operator. For such situation, the equipment has a distinct temperature sensor, on the turn pipe. When the water temperature gets to 90 °C, its contact commands an alarm horn, avoiding out of control situations.

An opposite break down situation can be water freezing and pipes or radiators cracking. This is a problem we have to work on to avoid it. For the time being, it is recommended that, when nobody is at home, the pumps should be left in manual mode.

Overheating can be caused by oversupplying the boiler with solid fuel of high caloric power or power supply break down. In out-of-way areas, this often happens, especially in cold season, when the snow weight can break the electric lines. That's why we thought about supplying the control equipment from an independent power source.

Switching from one supply source to the other is made spontaneously, by the time relay d_0 and the contactor C_3. We took into account that, in such isolated locations, the power voltage can go up and down several times during a short period of time. That's why we considered a temporization in the action of switching sources.

We designed the equipment not to permit both sources to work in the same time. When the network power supply recovers, the surveying relay interrupts the circuits to the batteries and re-establishes the connection to the main power supply.

4 Identified Problems and Solutions

Because the house is not insulated, a huge amount of fuel (wood) and frequent boiler charging cycles were needed, especially when the temperature was very low. At the same time, the control system that we used first presented working difficulties due to external factors that we couldn't anticipate. This fact caused lack of safety in the boiler operation and the plant efficiency decline bye incomplete fuel burning, frequent tar sediments in the fireplace and on the breech.

One of the major problems that we had to face was that the voltage decreases below 180 V when grater consumers than usual are used up the supply network (blowpipe, high power motors). In such situation, the installation stopped (because of the automatic release of the spare time of 4 seconds) and the pumps restarted. In the „MANUAL" regime, the pump in use stopped and it did not restart even if the voltage got back to its rated value, unless it was commanded with the start button.

The solution was to replace the automatic release of the spare with an uninterruptible source of 650 VA which is also a voltage stabilizer with a dead time of 6 ms.

Another problem was the too low capacity of the accumulators to maintain the wiring live when the supply is interrupted, which was a design mistake. Primarily, the recirculation pump was of 0.035 kW which was all right when we first operated the plant, but subsequently we installed a three speed steps pump of 0.06, 0.08 respectively 0.1 kW. When the control system worked in back-up, the accumulators could ensure the necessary energy for 10 – 15 minutes, after which the battery voltage decreased below 11 volts, and the whole system broke down. Bigger problem was when we noticed that there was not the possibility of alarming any more when the temperature raised, because the alarm horn got unsupplied.

The solution we found and built-in was to replace the initial accumulators with DEEPCYCLE ones. These have a very different functioning regime comparing with the ordinary ones, meaning that they can inject a 20 – 25 A current into the system, for a long time (minimum 48 hours). So, the automation kept working. Their charging cycle is slow, with very low current, so they are suited to be charged by the solar panels. In addition, the uninterruptible source helps the accumulators recharge as long as there is an electric energy supply.

The raise of the heat carrier temperature and the boiler overheating are very serious problems, no matter the reason. The causes can be: the circulation pump locking, the motor breakdown, and failure of the measuring device, interruption of the thermal resistance or automation lack of supply. We had to replace the alarm horn (which had a supply voltage of 220 V) with another one, supplied at 12 V. This one has an incorporated accumulator, used when the main accumulator doesn't supply the right voltage.

To prevent the temperature raise because of the lack of energy supply of the automation system (braking down of the source, defective contact at the accumulator lugs, dead battery) we added a voltage surveying relay subsequent to the uninterruptible source (timing relay d_{01} with normally closed contact, delayed by 5 s) and an accumulator voltage surveying relay (supplementary relay d_{02} supplied at 12 V, normally closed contact, instantaneous basic time). They would alarm when a breakdown occurs.

Also, for protecting the boiler we conditioned the pumps start when the control system works using the spare supply. In such case, no matter the temperature value (beyond 45.1 °C) only the circulation pump gets working.

A heating system performance is given by its efficiency, endurance and reliability. Improving the control system performance leads to a higher work safety and ease of operation.

It is well known that the thermal plants, functioning with solid fuel, require a strict monitoring. It is not comfortable for the user because the boiler is in another room. We looked for solutions for the surveillance and the operation of a thermal plant, in an easy and economic way, with low fuel consumption.

The first improvement was to use a hybrid system: solid fuel boiler and solar panels. Even if, at the beginning, the panel solar cost was quite high, this was compensated by the free of charge energy provided by the sun, longer working life of the boiler and the diminution of the solid fuel consumed during the spring and autumn months. So, the investment is paid off within 2 to 4 years.

The solar thermal circuit control is simple and it does not require a permanent survey, as the temperature and pressure cannot reach emergency values. It has an only one pump, commanded by two thermostat sensors, on turn and return. These sensors contacts are in series with the normally closed contacts of the C1 and C2 contactors, such as this pump would not work simultaneously with none of the boiler pumps.

In order to improve the measurement precision and the temperature presetting possibilities, we replaced the RS485 indicator with a SHINKO one.

The modified control system diagram is presented in fig. 4.

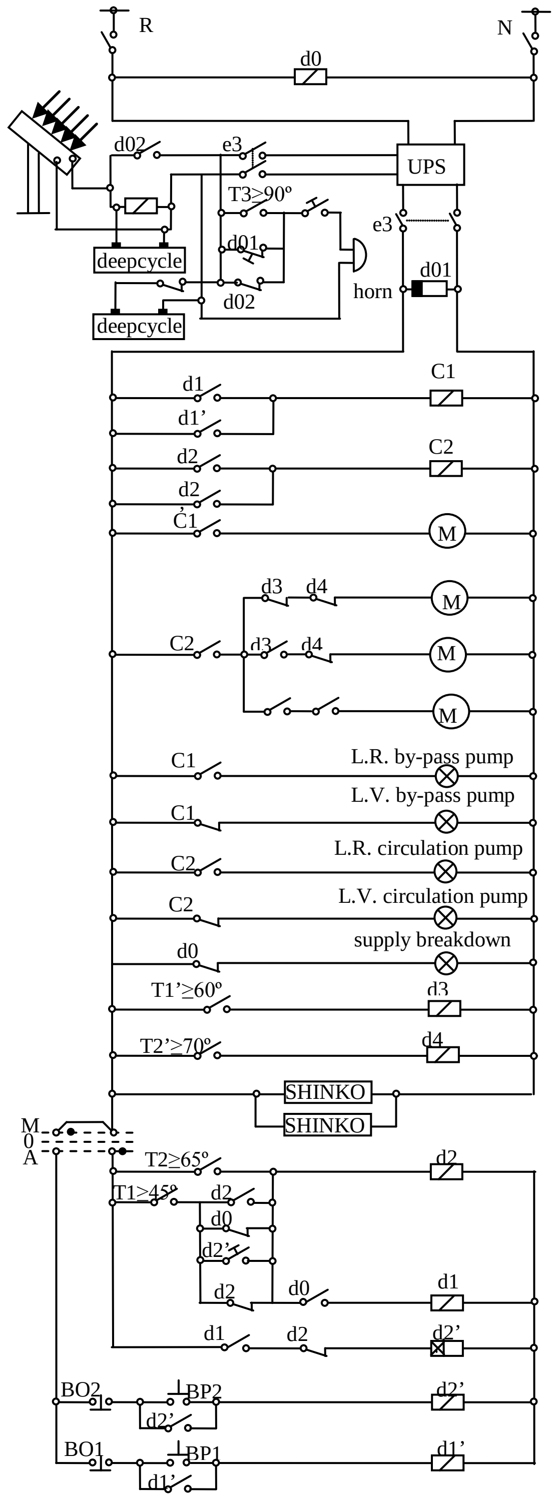

Fig. 4 Modified control circuit diagram

To better survey the heating system, in one room we mounted a box (fig. 5) with several devices, which:

- signal the pumps estate (operative or repose);
- indicate the temperature in different points (the thermal carrier temperature when living the boiler, the hot water temperature inside

the boiler, the temperature in different rooms of the house);
- signal optically and acoustically the different kind of failure;
- signal optically when the spare supply is activated (lack of supply from the energy network)

Fig. 5 Measurement and signal device

Thanks to these signals, one can know precisely when the fuel burning cycle is accomplished and the boiler needs to be reloaded, which pumps are operative and, mainly, if the control system is working correctly.

We noticed that, close to the burning cycle end, the temperature decreases until the value that actuates the circulation pump. After a short while it starts rising, so that the by-pass pump starts, but it does not reach 65.1 °C, because there is not enough fuel to burn. The water in the boiler stays hot but the temperature of the water in radiators goes down. When the boiler is reloaded and the circulation pump is started, the chilled water gets into the boiler and the heater can get to the condensation point temperature.

In order to avoid such situation and to use the entire energy produced by the boiler, in the circulation pump control circuit we introduced a time-delay contact (t = 5 min, how long it takes that the temperature increases from 45.1 °C to 65.1 °C), so that, whatever the temperature is (between the two values), the circulation pump starts working.

5 Conclusion

The efficiency of a boiler can be estimated starting from 100% and subtracting all the heat losses.

We noticed that, for a common boiler, a large amount of the efficiency decrement is caused by the heat lost in the furnace gases. The higher is the temperature, the waste of heat is higher and the efficiency is lower.

For increasing the efficiency of a boiler, it is necessary to find a solution to increase the return temperature. That can be accomplished by using a by-pass pump or an equipment meant to keep the thermal agent temperature within normal functioning limits (50 – 60 ºC), with minimum fuel consumption.

We designed this control equipment and run tests to check whether it works properly. The results were more than satisfactory. All rooms were heated and the thermal agent temperature and pressure stood within normal limits. For the same heating parameters, the solid fuel quantity was low, which turned to be a significant economic advantage.

The automation equipment presented in this paper could be a simple, reliable solution, and first of all achievable. It already works in an out-of-way house, with results beyond expectations.

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