Microcontroller based adaptive system for solar collector parameters management

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Abstract. The solar collectors belong to the most widespread renewable energy production tools. Still, the following problem has been faced when using these collectors in temperate climatic zone – insufficient heat production during autumn-winter-spring season and excessive heat generation in summer time. However, this problem could be solved through utilization of multi-layered collector with automatic management which ensures liquid flow channeling to layers with different heat absorption and emission parameters.

1 Introduction

Solar collectors represent themselves an efficient way to utilize renewable free energy resources; easy operation, middle-term recoupment, state support for purchase of equipment strongly facilitate broad exploitation of these heat exchanger devices [1-7]. At the same time, solar collector’s application possess a substantial problem for temperate climatic zone energy consumers – and this problem is related to insufficient heat production during winter season and excessive heat generation in the course of summer time [8-12]. The latter phenomenon causes overheating of the device and bringing heat carrier to the boil – temperature can reach 200 and above Celsius degrees [1, 4, 5, 12]. Majority of household consumers are not able to utilize this excessive heat produced and are forced to invest in insulation projects; various shields and roller-blinds are not protective enough due to influence of external factors like wind, precipitation, birds. Unfortunately, other solutions usually are not available for consumers since they are comparatively expensive and complicated [2, 12-14].

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Fig. 1. Solar collector partially covered by roller-blind
2 The new method, experimental results and discussion

In order to solve the problem identified, recent study proposes relevantly modified construction of solar collector, especially flat-plate collector [2] – concretely, 1) a multi-layered design of collector’s shell where heat carrier can circulate at several levels, and 2) on programmed microcontroller based management system for appropriate distribution of heat carrier flow. Internal layer (i.e. channel located nearby the absorbent) receives maximal solar energy and have been used during the highest consumption of heat energy. In the case of overheating flow is switched to the external layer which is divided by air gap from the absorbent – here is the lowest absorption and also highest heat emission through convection and infra-red radiation. This process mathematically is described by the following equation:

\[ Q_{total} = Q_{accumulated} - Q_{lost} \]  

(1)

were \( Q_{lost} \) – heat lost due to radiation and convection.

Heat loss from the external layer is a function of several parameters – like difference between environmental and heat carrier’s temperature, heat carrier’s temperature itself as well as thermal conductivity of solar panel material:

\[ Q_{lost} = f (\Delta t^{in-out}, t^{in}, \lambda_{solar\ panel\ material}). \]  

(2)

Such a choice (i.e. constructions with dynamic regimes) is particularly important for collector systems without heat accumulator. The following main technical considerations have been taken into account when designing modified solar collector:

- circulation within outer layer (located near collector shell’s external surface) is particularly disadvantageous since considerable part of generated heat has been lost through outward emission of heat;
- circulation performed in internal layers / channels is more efficient since external channel (i.e. layer with air gap) serves as a heat insulation covering;
- 6-8 and more layers could be fit within solar collector’s device which has been made from easily available transparent and semi-transparent polycarbonate materials.

![Solar collector’s management](image)

Fig. 2. Solar collector’s management
Microcontroller’s capacities (WiFi, Bluetooth communication channels, memory volume) allow both automatic (algorithmic) and manual operations for collector’s management.

Field experiments have been carried out in Latvia, during autumn time, with ambient air temperature +15°C, wind velocity ≤ 3m/s, natural illuminance ~ 1000 lx. Main parts of experimental device are depicted in Fig. 3-5. Easily available motorized three-way valve, multilayer cellular polycarbonate, processed aluminium tubes (for heat carrier connection) have been used.

In Figure 6 demonstrates temperature decrease in external (outer) layers: one can see that difference is small, just about 5 ºC; however, within 80-120 ºC range it can grow considerably 20 ºC and more.

Collector system’s management is implemented in accordance with an appropriate algorithm focused on actuators (electromagnetic valves) which channel heat carrier flow to proper layers.

Collector’s input/output thermal sensors provide data (both temperature difference and absolute temperature values have been taken into account) for outlet signal – such an information is sufficient to fix heat consumption increase, system overheating and the beginning of evening when circulation should be stopped.
3 Conclusions

Construction of new solar collector is comparatively simple, easily programmable, suitable for remote control. It could be switched out during autumn, winter and spring seasons by channelizing flow through inner layer. Electric energy consumption is low, operation is performed silently, device does not require regular maintenance. The main benefit – proposed device does not include any external elements which could be damaged by atmospheric factors or birds.

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