Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
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Annals & Proceedings of DAAAM International 2011

POSSIBILITIES OF REPLACEMENT OF ABSORPTION COOLING UNIT BY SYSTEM OF PELTIER MODULES IN PROCESS OPTIMIZATION OF TRIGENERATION SYSTEM CONTROL

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Abstract: *Article describes the analysis and experimental measurings of cooling system equivalent to absorption cooling unit, which could be used as cooling system of trigeneration unit. Replacement of this system is created by laboratory model of Peltier module working in ratio 1:130. Peltier module is not replacement of real system, which would ensure production of cold usable in practice. However it is suitable means for aplication of simulation and experiments control of trigeneration unit.*
Key words: *trigeneration, Peltier module, measuring of cooling system, control of system*

1. INTRODUCTION

Thermal system of trigeneration unit is system, which has thermal energy as input and cold as output. This system is economically challenging for purpose of research of control. There was an effort to find such system, which would replace it and be sufficient as laboratory model for creation of trigeneration control algorithms. Peltier module was selected for this purpose. It works on a different principle and its input is not thermal energy but electricity. However similarity between absorption cooling unit and Peltier module was confirmed in (Kocur & Suriansky, 2010). On the bases of this knowledge measurements of cooling system were performed, which are described in article in more detail. Article aims to show the possibility of Peltier module as appropriate regulation element.

2. EXPERIMENTAL MEASUREMENTS

2.1 Laboratory model of cooling system

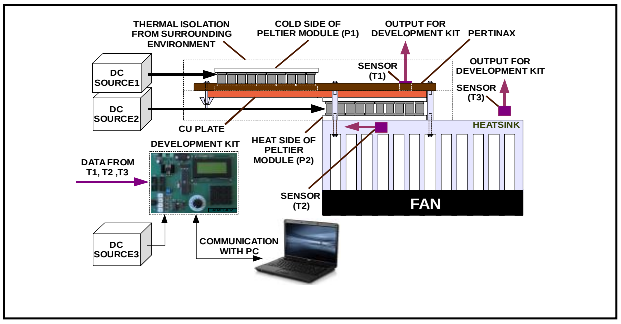

Fig. 1. Equivalent laboratory model of cooling system of trigeneration unit

Model is created by Peltier modules P1 /I_{max}=8.5A, U_{max}=15.4V and Q_{max}=71W/ (HB Corporation-a) and P2 /I_{max}=30.5A, U_{max}=15.6V and Q_{max}=257W/ (HB Corporation -b). Modul P2 is used in cooling mode and P1 in thermal load mode. Modul P2 needs to ensure dissipation of heat from its hot side for right operation. Although cooling mode on one side is increasing by enlarging of modul input power but it causes proportional increasing of heating on the other side. Heatsink with fan is used for this purpose. Cold side of module P2 is connected to Cu plate, which represents measuring environment. On the Cu plate is placed digital temperature sensor (T1) ADT7301 which works with accuracy of 13-bits and with temperature resolution of 0,03125 °C (Analog Device, 2004). Plate with sensor is fully isolated from surrounding environment with isolated material. For simulation of cooling load Peltier module P1 is used, which heats environment by costant heat. Communication between sensors is performed through SPI bus and operation is controlled by processor ATMEGA32. Next sensor is installed on the heatsink (T2). This serves to measure thermal side temperature of module P2. Third temperature sensor (T3) measures ambient temperature.

2.2 Characteristics of thermal load

Function of heating is ensured by module P1. In this case temperature of hot side was measured. As pattern, temperature characteristic for heating to temperature 30°C is shown on the Fig.2. Measured characteristics, which are necessary for measuring of system coolling are more specified in Tab.2. For indication in table applies: $\mathbf{I_1}$, $\mathbf{U_1}$ and $\mathbf{P_1}$ => supply current, voltage and input power of module P1, **t** => temperature stabilization time of Cu plate heated by module P1, $\mathbf{T_h}$ => temperature of Cu plate after stabilization time, which is heated by module P1.

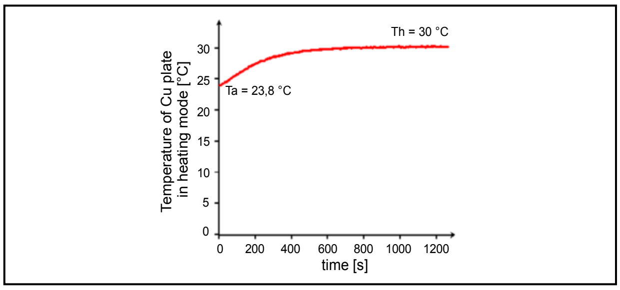

Fig. 2. Characteristic of measured Cu plate to Th = 30°C by module P1 at ambient temperature Ta = 23,8 °C

T_h [°C]	I_1[A]	U_1 [V]	P_1 [W]	t [s]
27	1,65	4,05	6,68	669
30	2,33	5,7	13,28	690
35	3,22	8	25,76	1014
40	3,7	9,5	35,15	1588

Tab. 2. Table of measured values by Peltier module P1

2.3 Cooling system with load

System represented by module P2, which cools Cu plate was loaded through heating of Cu plate by module P1 in different time intervals by different thermal powers, which corresponds to temperatures in following order: 40, 30, 35 and 27°C. Modul itself was connected just at the time 100 seconds, until that time ambient temperature was measured, which had 24,5°C. The first load for cooling system was actually ambient temperature. Change of load was performed always after stabilization of previous state. On the Fig.3 courses of measured temperature of researched Cu plate are shown. For better clarity of individual time intervals of graph these intervals are separated by white and grey color. Results of measurement are summarized in Tab.3, wherein: $\mathbf{t_{0\text{-}4}}$ => time of made change of cooling system, $\mathbf{T_{cu}}$ => temperature of Cu plate after stabilization of state.

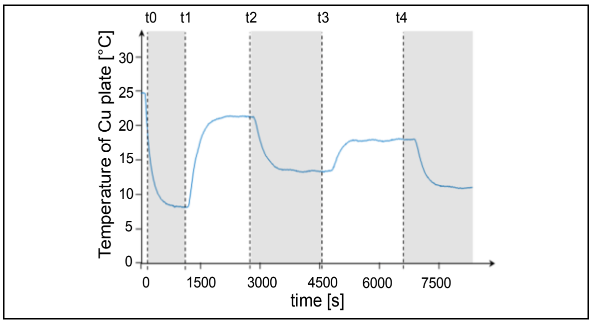

Fig. 3. Temperature of Cu plate coolled by module P2 (I2 = 10A, U2 = 5.5 V [P2= 55W]) with change of load P1.

state	$t_{0\text{-}4}$ [s]	T_h [°C]	T_{cu} [°C]	note
$\mathbf{t_0}$	100	24,5	8,2	connection of module P2*
$\mathbf{t_1}$	1120	40	21,2	connection of load P1
t_2	2740	30	13,4	1. change of load P1
t_3	4580	35	18	2. change of load P1
t_4	6580	27	11	3. change of load P1

Tab. 3. Table of measured values of cooling system with change of load by module P1 (*state corresponding to load of ambient temperature)

Next measurement (Fig.4) was also performed for cooling with load but with difference, that load was constant during the whole measurement (corresponding to temperature of heating to 30°C) and cooling power was changed.

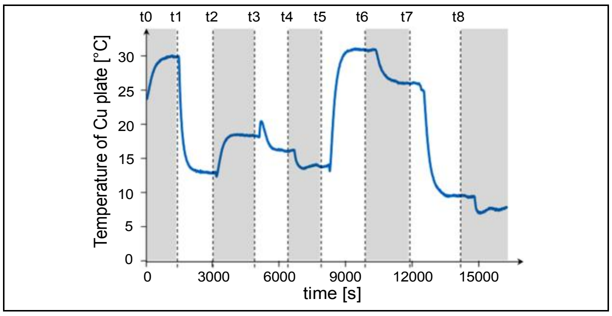

Fig. 4. Temperature of Cu plate with constant load by module P1 and change of cooling power of module P2.

Results of measurement are in Tab.4, where $\mathbf{I_2}$ => supply current of module P2.

state	$t_{0\text{-}4}$ [s]	I_2 [A]	T_{cu} [°C]	note
$\mathbf{t_0}$	0	–	30	connection of load P1 (30 °C)
$\mathbf{t_1}$	1410	10	12,9	connection of module P2
t_2	3000	15	18,3	1. change of P2 cooling power
t_3	4900	5	16,0	2. change of P2 cooling power
t_4	6400	8	13,8	3. change of P2 cooling power
t_5	7900	20	30,8	4. change of P2 cooling power
$\mathbf{t_6}$	9900	20	26,0	disconnection of load P1
t_7	11890	5	9,6	1. change of P2 cooling power
t_8	14200	10	7,9	2. change of P2 cooling power

Tab. 4. Table of measured values of cooling system with constant load and with change of cooling power.

2.4 Evaluation and results of experiments

Results of measurements shown in graphs on the Fig.3 and Fig.4 and summarized in tables show onto conduct of Peltier module in load mode. It is necessary to note, that achieved results are valid only for the given cooling system using this concrete used system of heat dissipation. With other system results will be different in various ways. By connection of module P1 working in heating mode to module P2 working in cooling mode, it is possible to observe conduct of cooling in individual phases of system load. From these graphs can be clearly seen, that given system is possible to regulate with no problems by means of regulator. From Tab.4 is clear, that the most effective cooling (on bases of stabilization speed and cooling ability) by module P2 on such conditions will be achieved by supply current 10A. Therefore, for Peltier module P2 working in described conditions and supplied by current 10A parameters of system were calculated, which can be used by design of system regulation. Transient characteristic (Nascak & Suriansky, 2004) of this system after calculation has form:

$$S(s) = \frac{0{,}2208}{1 + 146 \cdot s} \tag{1}$$

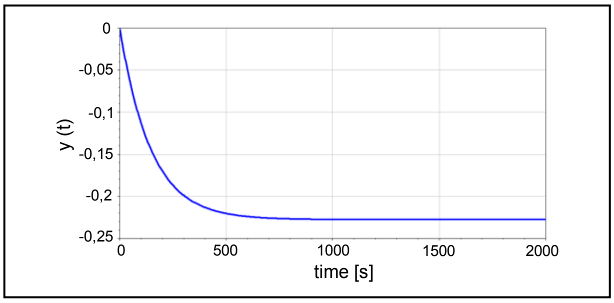

Fig. 6. Simulated transient characteristic in Programe CC correponding to equation 1.

3. CONCLUSION

From graphs can be clearly seen, that given system is possible to be regulated with no problems by means of regulator. Desribed experimental measurements of system are key step to creating of control algorithms of trigeneration unit with using of described laboratory equivalent model of cooling system. Created algorithms can be applied for needs of simulations and experiments of trigeneration control, based on which it is possible to know better conduct of this system and so optimize operation of control. In the next time of research will be designed regulatory circuit and then created simulation model of trigeration system with using equivalent cooling unit based on Peltier module.

4. REFERENCES

Analog Device (2004). ADT7301, Preliminary Technical Data, *Available from:* http://pdf1.alldatasheet.com/datasheet-pdf/view/85924/AD/ADT7301.html *Accessed:* 2011-03-31

HB Corporation-a. Thermoelectric Cooler TEC1-12708, *Available from:* http://pdf1.alldatasheet.com/datasheet-pdf/view/227421/ETC2/TEC1-12708.html *Accessed:* 2011-03-31

HB Corporation-b. Thermoelectric Cooler TEC1-12730, *Available from:* http://pdf1.alldatasheet.com/datasheet-pdf/view/164396/ETC/TEC1-12730.html *Accessed:* 2011-03-31

Kocur, V. & Suriansky, J. (2010). Similarity of simulation models of absorption cooling unit and Peltier module, In: *Acta Facultatis Technicae*, Vol. XV., No. 1 /2010, pg. 95-105, Technical University in Zvolen, Slovakia, ISSN 1336-4472

Nascak, L. & Suriansky, J. (2004). *Basics of automation and process control*, Technical University in Zvolen, Slovakia, ISBN 80-228-1430-X, Zvolen