Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
DAAAM Symposium

EMULATION WITH NEURAL NETWORKS FOR OPTIMIZATION ALGORITHMS FINDING

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Abstract: *The paper describes using the artificial neural network for array of solar panels emulation for finding optimization algorithms. This emulation is done in Matlab/Simulink with using Neural Networks Toolbox. It is emulation of real plant. Real plant is small solar plant. This plant is laboratory model for students. Laboratory model is used for control and optimization algorithms testing. Neural network emulation is used for developing optimal algorithms before usage on real plant. These control algorithms are then used for changing of solar panels array angle to light source. Main idea of that is maximize get power from solar panels array. Developed control algorithms are implemented to B&R Program Logic Controller (PLC). Some parts of implementation are done through automatically code generation from Matlab/Simulink.*
Key words: *Neural Networks, emulation, solar cells, optimizations*

1. INTRODUCTION

We developed model of small solar plant in our laboratory. Main idea of this model is student training and testing control and optimization algorithms in practice. We integrate classic control algorithms and modern control and optimization algorithms by this way in one model. Neural network is used for emulation of solar plant for creating computer model of real laboratory model. Some data are measured on this model for neural network training. This data are about actual voltage from solar cells and actual angle to light source. Intensity changing of light source is one parameter too. Analytical description of the solar cells behavior is not so easy for description and this is main reason for using neural network. It is function more variables from analytical point of view. In this case is number of variables two. We can develop and simulate this plant on computer only by this way. Motors parameters and models are known and can be implemented without problem to the complete model.

2. REAL MODEL DESCRIPTION

The main idea of the model is if solar cells angle to light source is changed then the output voltage from solar cells is changed too. This is described by very simplified equation (1)

$$U = \frac{U_{max}}{\alpha_{max}} \alpha \cdot \cos \varphi \qquad (1)$$

where U is output voltage from solar cells, U_{max} is maximal voltage from solar cells, α_{max} is maximal luminescence intensity for maximal voltage from solar cells, α is actual luminescence intensity and φ is actual angle solar cells to light source (Lorenzo, 1994), (Luque & Hegedus, 2003), (Habel, 2009), (Camacho et al., 1997), (Rektorys, 2003). As we can see in equation (1) maximal voltage is if angle φ zero. But this equation is for ideal system without many disturbances.

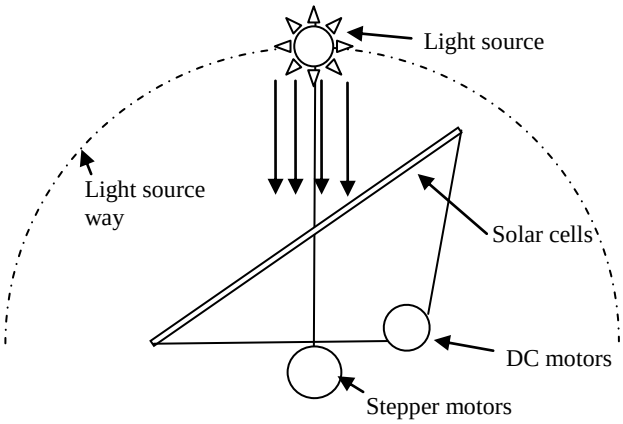

Fig. 1. Main scheme of laboratory model construction

Disturbance in this system is for example light from other light sources. Elimination of this disturbance can be close the system in the some black box without any holes or if another light source is stable we can abandon this disturbance.
Basic model scheme is on Fig.1. Model has two main parts. These parts are light source and solar cells. Motion of light source is done by two stepper motors for x and y axis. Motion of solar cells is done by two DC motors with incremental encoders. Two motor types are used because better training of students. DC motors are used because more accurately position control then with stepper motors and easy control. Motors have to be homed before starting model on end switches. End switches are for safety reason too. All motors are connected to PLC Bernecker&Rainer through special control cards for stepper motor and DC motor with full-bridge. Motors can be control direct by algorithms in PLC or through PLCopen ï motion control library. If we want to control motors direct we have to setup registers on control cards. This solution is little bit complicated. PLCopen is standard in industry (2010). It is easiest way for motion control in PLC B&R. Angle of solar cells to light source is changed by DC motors. We can change luminous intensity of light source. Twelve yellow LED diodes are used as light source. One LED diode has luminous intensity 6000mcd.

3. NEURAL NETWORK

One of basic using of neural networks is ability to model unknown systems. Problem is that after this modeling we donôt know what is inside. We have another black box which model another black box (Dreyfus, 2005), (Janczak, 2005). We don´t have mathematical model as from some classical identification method for example ARX or other (Ljung, 2006). But we are trying used neural network for solar cells emulation. We have

very simplified equation (1) and real process has many disturbances and deviations from this equation. These deviations we donôt know every. Next reason is student training for showing them real application for neural networks using.

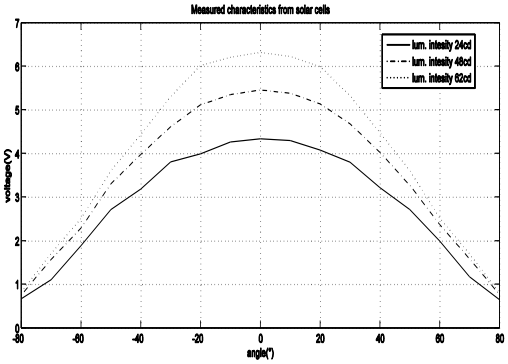

Fig. 2. Measured data from real model for neural network training

Training data are obtained by measurement on real model. Data are voltage from solar cells, angle of solar cells to light source and power of light source. Samples of training data are on Fig. 2. from real measurement on laboratory model. Three layer neural network is using for testing in our case. Levenberg-Marquardt training method is used for neural network learning (Nelles, 2001), (Veleba & PivoŇka, 2005), (Janczak, 2005). It used one input layer, one output layer and one hidden layer. Two input neurons are used, first for luminescence intensity and second for angle of solar cells to light source. Output is voltage from solar cells. Neurons in hidden layer are usually 20 in our case. We tested less than 20 neurons but in this case the result was not satisfied. When we tested more than 50 neurons then we lose ability of generalization. Sum of data is 51. It measured voltage from -80° to 80° with 10° step and for 3 levels of luminescence intensity. Levels are 24, 48 and 62cd. These first data and tests are in one axis. Angle was changed only in axis x. This is reason that only one input for angle is used and Fig. 2. is only 2D not 3D. One more input will be used in future for adding next angle in y axis and the problematic will be function of more variables.

4. CONCLUSION

Described real model is complete construct. Developing of the computer model and optimization algorithms are still in process. We have some problems with neural network. Main problem is that we lose generalize ability in some cases. We tried change number of neurons in hidden layer but without behaviour improving. It can be problem with data. Ten degrees step can be too big but we thing that bigger problem is in luminescence changing. We donôt have possibility change luminescence intensity then 24, 48 or 62cd now. It can be main reason why the neural network doesnôt have too big generalized ability. If change of luminescence is close to training luminescence intensity then output data are expected. Problem occurs if is setup luminescence intensity far from trained it means more than ±10. Next step of emulator development will upgrading training data. We will improve model for bigger scale luminescence intensity change. Using of PWM is easiest way for new luminescence step. Finally step wills development optimization algorithms for obtaining maximum voltage from solar cells. Basic algorithm will be gradient algorithm. It is possible find maximum by this way. But all area has to be scan for minimum finding. Other algorithms will test later and can be found for example in (Russel&Norving, 2010), (Kaplan, 1999). All developed algorithms will be implemented to PLC. We suppose that implementation of algorithms will be done by automatic code generation from Matlab/Simulink to PLC. PLC B&R support this automatic code generation without problems. We can implement algorithms from Matlab and its toolboxes which are supported by Real Time Embedded Workshop and Real Time Embedded Coder. Neural networks toolbox is not supported. In this case we have to programme our own neural network. We are using Ethernet Powerlink for connection between modules for remote control of motor modules. The main reason of using Ethernet Powerlink is for students only. Showing students practical using of Ethernet based communication bus. We donôt have problem used Ethernet Powerlink in motion control. Ethernet Powerlink was developed for motion control and sample time can be 400ɛs without problem.

5. ACKNOWLEDGEMENTS

This work was supported as a part of the solution of Czech Science Foundation GAĻR project No. 102/09/1680 Control Algorithm Design by Means of Evolutionary Approach and by the FRVĠ 532/G1.

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