FUZZY LOGIC CONTROLLER DESIGN FOR PHOTOVOLTAIC SYSTEM

I. Elzein, Y. N. Petrenko
South-Lebaniz University, Lebanon
Belarus national technical university, Minsk, Belarus
imad.zein@liu.edu.lb, ypetrenko@bntu.by
E-mail:

Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation. In order to continuously harvest maximum power from the solar panels, they have to operate at their MPP despite the inevitable changes in the environment. This is why the controllers of all solar power electronic converters employ some method for maximum power point tracking (MPPT). Over the past years many MPPT techniques have been published and based on that the main paper's objective is to analyze one of the most promising MPPT control algorithms: fuzzy logic controller.

Introduction

According to the realization of high efficiency and low cost photovoltaic (PV) modules, interest in photovoltaic power generation system has increased over the past decade as a clean and infinite energy [1]. The PV modules have maximum operating points corresponding to the surrounding condition such as intensity of the sunlight, the temperature of the PV modules, cell area, and load. When solar energy is used as a power source, the output power has to be maximized by improving the efficiency of the power conditioning equipment used and implementing an adaptive power controller that automatically tracks the system to the point of maximum power delivered from the solar panel under all conditions.

Maximum Power Point Tracking (MPPT) is the newest concept which helps to extract the maximum possible power from a PV array. The MPPT methods are various in the complexity, convergence speed, popularity, cost, operating range, sensor dependence, capability of escaping from local optima and their applications [2-5].

One of the most significant issues in PV system and MPPT efficiency is DC-DC converter. In recent years, there has been increasing interest in the development of efficient control strategies to improve dynamic behavior of DC–DC converters by using traditional PID based controllers and fuzzy logic controller (FLC), neural networks (NN), and neuro-fuzzy controller or adaptive fuzzy logic controller (AFLC) which have been used to control buck, boost and buck–boost converter which were presented.

I. Fuzzy logic controller

In recent years, there has been increasing interest in the development of efficent control strategies to improve dynamic behavior of DC–DC converters by using fuzzy logic controller (FLC), neural networks (NN), and neuro-fuzzy controller to control buck, boost and buck–boost convertes.

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity. Microcontrollers have also helped in the popularization of fuzzy logic control [3].

The implementation of fuzzy logic is used to have a faster controller response and to increase system stability once reached the MPPT. Corresponding authors made their effort in design of Fuzzy Logic Controllers and demonstrated some difficulties in the selection of membership functions and fuzzy rule base, which is traditionally achieved by a tedious trial-and-error process.

II. The modified FLC (MFLC)

This controller optimizes membership functions and rule base of the FLC were obtained from training data in the pattern file. Shrinking-span membership functions algorithm is introduced to construct membership functions for FLC. In case when shrinking factor is chosen one membership functions have equal span. In fact, the shrinking-span membership functions is constructing membership functions method for FLC which, in compare to [3], [4] generates a series of orderly arranged membership functions for a linguistic variable across its universe of discourse.

If shrinking factors is chosen one (s = 1), the membership functions have equal span. By applying various shrinking factors to the same linguistic variable, deferent membership function obtained to examine which is the most suitable for a specific application process.

The inference result of each rule consists of two parts of weighting factor, w_i, of the individual rule, and degree of change in duty ratio C_i, according to the rule. The weighting factor w_ii is obtained by means of Mamdani's MIN fuzzy implication of membership degrees $\mu_e(e)$ and $\mu_{de}(de)$. C_i is retrieved from control rule table. As a result the inferred output of each rule using Mamdani's MIN fuzzy implication is given as:

$w_i = min\{\mu_e(e), \mu_{de}(de)\}$ $z_i = w_i \cdot C_i$ where $z =$ denotes the fuzzy representation of change in duty ratio inferred by the i-th rule.

The MFLC algorithm described above can be implemented on a number of devices. We will consider implementation on a ST52E420 microcontroller, which is an 8-bit microcontroller and the erasable EPROM version, which has 4 Kbytes program and data EPROM. This model has been chosen to perform, in an efficient way, both Boolean and fuzzy algorithms, in order to reach the best performances that the two methodologies allow. This microcontroller has another important role in allowing describing a problem using a linguistic model instead of mathematical model. The microcontroller includes an 8-bit sampling (A/D) converter with an 8 analog channel fast multiplexer and 2.5 reconfigurable digital ports in order to transfer data from/to the on-chip Register Files. A three independent PWM/Timers are included allows managing directly power devices and high frequency PWM controls.

The ST52T410/ST52x420 Decision Processor (DP) main features are: Up to 8 Inputs with 8-bit resolution; 1 Kbyte of Program/Data Memory available to store more than 300 to Membership Functions (Mbfs) for each Input; Up to 128 Outputs with 8-bit resolution; Possibility of processing fuzzy rules with an unlimited number of antecedents; unlimited number of Rules and Fuzzy Blocks.

The limits on the number of Fuzzy Rules and Fuzzy program blocks are only related to the Program/Data Memory size.The ST52T410/ST52x420 Core allows for the implementation of a Mamdani type fuzzy inference [5] with crisp consequents. Inputs for fuzzy inference are stored in 8 dedicated Fuzzy input registers. The LDFR instruction is used to set the Input Fuzzy registers with values stored in the Register File. The result of a Fuzzy inference is stored directly in a location of the Register File.

MFLC adapts membership functions and computes the consequent parts of rules in the rule base. The inputs of MFLC are model data in the pattern file that is created from some data for desired output. The outputs of MFLC are membership functions and the consequent parts for FLC. The MFLC can update its parameters which are membership function's shrinking factors according with the suggested algorythm. The simulation and the implementation of the MFLC for buck, boost and buck–boost converters results demonstrated that the converters are stable and can be regulated with a good performance under different input disturbance and load variation. The results also indicate that the MFLC is general and can be applied to any DC–DC converter topologies. Thus, the same microcontroller software can be used to control any switch-mode converters without any medications.

Conclusion

In this paper, a modernized fuzzy logic controller was introduced for DC–DC converter output voltage regulation in MPPT system in PhV station and have implemented on an 8-bit microcontroller. The MFLC is able to regulate the output voltage of buck, boost and buck–boost converters to desired value despite change in load. Since these converters, buck, boost and buck–boost, are controlled using the same MFLC algorithm without any modifications to microcontroller program. This shows that the proposed algorithm is general and can be applied to any DC–DC converter topologies practically.

1. Koutroulis, E.A. New technique for tracking global maximum power point of PV arrays operating under partial-sheding conditions / E.A. Koutroulis, F.Blaabjerg// IEEE Jornal of Photovoltaics.- 2012.-Vol. 2, №.2. -P. 343-350.
2. Esram, T. Comparison of photovoltaic array maximum power point tracking techniques / T. Esram, P.L. Chapman // IEEE Transactions on Energy Conversion.- 2007.- Vol. 22, №.2.-P. 439-449.
3. Implementation of a fuzzy logic controller for DC–DC convertersusing an inexpensive 8-b microcontroller / T. Gupta [et al.] // IEEE Transaction on Industrial Electronics.- 1997.- Vol.44. №5.-P. 661–668.
4. Rubai, A. Hardware Implementation of an adaptive network-based fuzzy controller for DC–DC converters./ A.Rubai, A.R.Ofoli, M.Garuba//IEEE Transactions on Industry Applications.-2005.-Vol. 41. №5.-P. 1557–1565.
5. Petrenko, Y.N. Fuzzy logic and genetic algorithm technique for non-liner system of overhead crane / Y.N. Petrenko, S.E. Alavi // Computational Technologies in Electrical and Electronics Engineering (SIBIRCON).- 2010 IEEE Region 8 International Conference.-P. 848 - 851.