Neural Fuzzy Networks for Optimal MPPT Control in PV Powered AC Loads

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ABSTRACT
Renewable energies are being more popular and viewed in some cases as a viable alternative to conventional sources of energy. A great number of renewable based applications have been developed to satisfy energy demand in different fields. This paper deals with the application of artificial intelligence in photovoltaic powered AC loads. Neural fuzzy networks are applied in order to optimize the energy produced by photovoltaic generators (PVG) and successfully improving the maximum power point tracking (MPPT) control. Simulation and experimental results will be given to demonstrate the efficiency and performance of the proposed control system.

KEY WORDS: Photovoltaic generators (PVG), Neural networks, Fuzzy logic, MPPT.

INTRODUCTION

Photovoltaic generators belong to a non linear electrical sources family where the output power is related to weather conditions such as insolation and temperature. Naturally, these parameters change imprecisely in time and consequently affect the power delivered to the load. Figure 1-a gives the nonlinear relationship between the output current and the output voltage of the photovoltaic generator. In practice the power versus voltage curve is commonly used to determine the maximum power point (Figure 1-b). The maximum power increases according to the elevation of insolation (Figure 1-c), however a less important influence is observed when the temperature varies (Figure 1-d). It is therefore necessary to track in real time the maximum power (MPP) from the photovoltaic generator (Hiyama et al., 1995). Several techniques have been proposed in order to drive AC loads at the MPP (Yao et al., 1994),(Muljadi, 1997). These techniques are based on analytical models. A linguistic attributes represent a good mean to describe the variation of the output power versus weather parameters. Such description is well done by fuzzy logic. Towards this goal, MPP tracking controller based on fuzzy identifier cascaded with a fuzzy regulator is developed.

SYSTEM LAY-OUT

The proposed structure of the realized system is proposed in Figure 2. As shown in this figure, the system consists of a photovoltaic generator which presents the supply source. A pulse width modulated (PWM) inverter is used to convert the DC power to an AC power in order to feed the three phase loaded induction motor.

The modulation index of the PWM inverter is obtained from a fuzzy logic based tracker, the key bloc in our system. This index is varied in the way that the inverter

keeps driving maximum power from the photovoltaic generator. This leads to increase the reliability of the system and improves its efficiency.

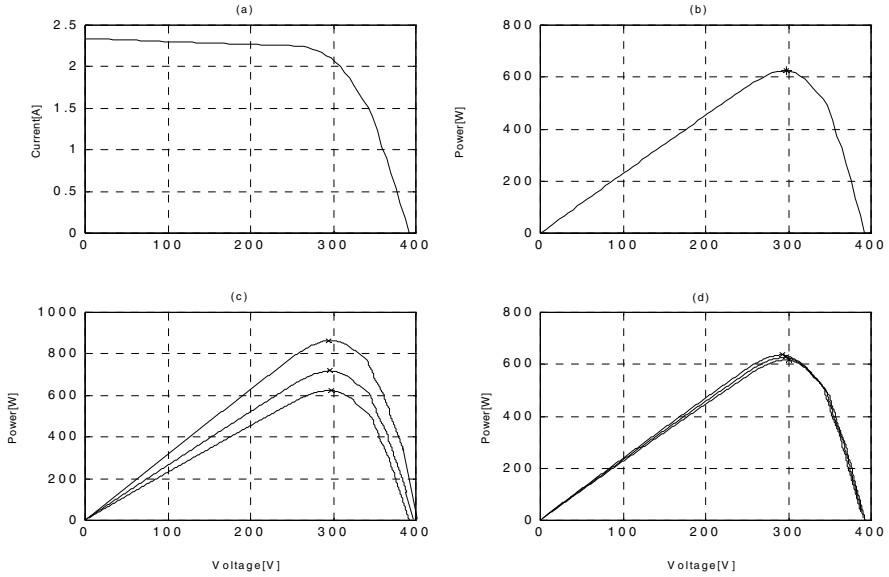

Figure 1. Current-Voltage(a) and Power-Voltage(b) characteristics of the PVG under 65.6% of insolation and 25°C of temperature, P-V characteristic for different insolation levels (c) and for different temperatures(d) (cross sign marks the maximum power point).

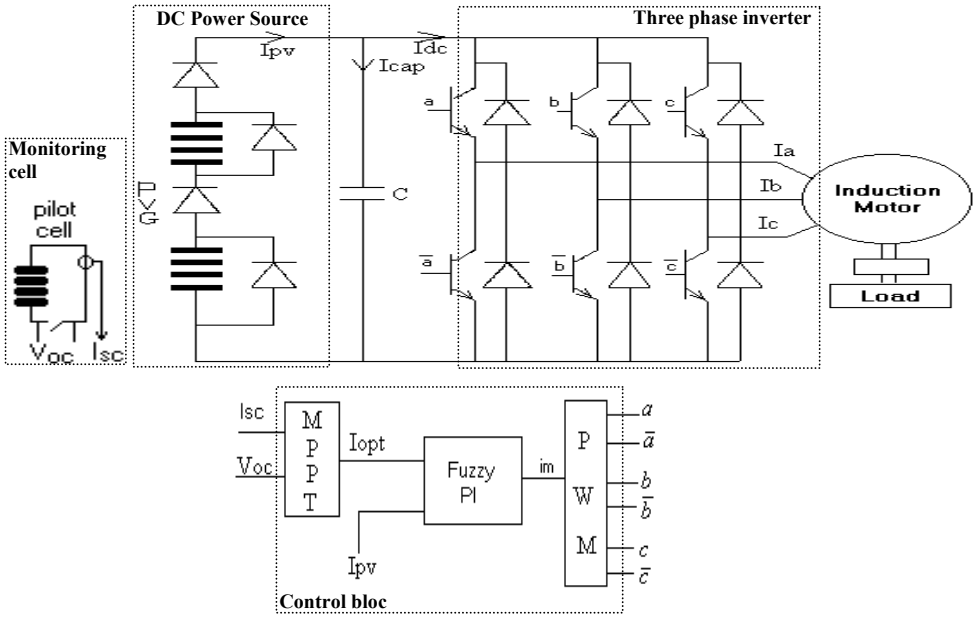

Figure 2. System lay-out

MAXIMUM POWER POINT TRACKING

The maximum power tracking is the most important task in photovoltaic based systems. In order to achieve this task accurately, this operation is decomposed into two subtasks: The MPP identification and the fuzzy tuning regulator.

MAXIMUM POWER POINT IDENTIFICATION

An experimental data collected from monitoring cell (obtained from various insolation (short circuit current - I_{sc}) and temperature (open circuit voltage - V_{oc}) levels) have served as a learning data for the adaptive neural fuzzy network (Jang, 1993), (Jang and Sun, 1995) presented in Figure 3. The network is composed of two kinds of nodes: circular nodes are static (no parameters are modified during the learning operation) and square nodes which are adaptive (integer fuzzy system parameters that might be optimized during the training operation). The network was trained for seven(7) membership functions for I_{sc} (due to the high correlation between the MPP and insolation) and three(3) membership functions for V_{oc}, their final shapes (after training process completed) are shown in Figure 4. A set of optimised rules describing the identifier behaviour is also carried out from the training process.

FUZZY PROPORTIONAL INTEGRAL REGULATOR

The fuzzy PI regulator is used to generate the optimal PWM signal in order to drive the load to the maximum available power. The reference I_{opt} (optimal current) provided by the fuzzy identifier is compared to the actual PVG output current, a control signal (modulation index variation) is delivered to keep tracking the reference. The design of this regulator is done in a phase plan space (Bose 1986).

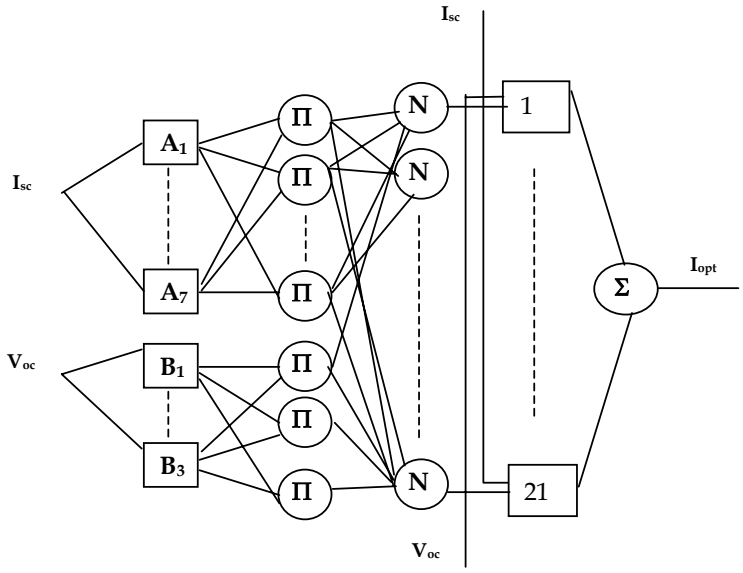

Figure 3. Neural Fuzzy network configuration

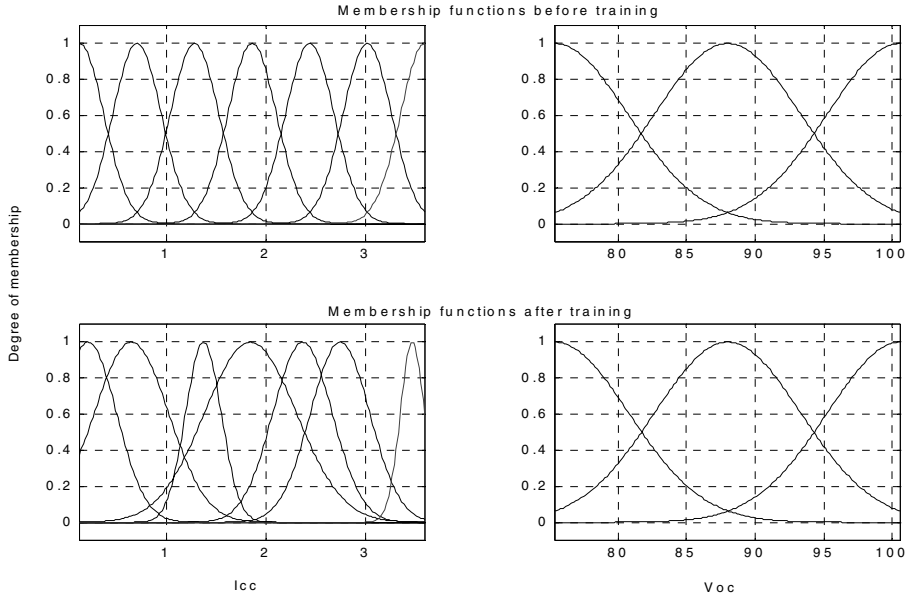

Figure 4. Membership functions shapes before and after the training process.

SIMULATION AND EXPERIMENTAL RESULTS

To illustrate the performance of the proposed a system, a simulation program has been developed and tested under MATLAB™ software. Figure 5 gives the response of the system when the insolation changes from 65% to 80%. As we can see from figure 5.a, the plugged load consumes a certain amount of current that is not the optimal one, decreasing in fact the efficiency of the system. Otherwise, when applying the proposed tracker, best and accurate results are obtained (figure 5.b).

Figure 6 gives the practical results issued from the soft starting procedure and the tracking tests. It is shown that the power drawn from the photovoltaic generator is at its maximum, hence improving the efficiency of the entire system.

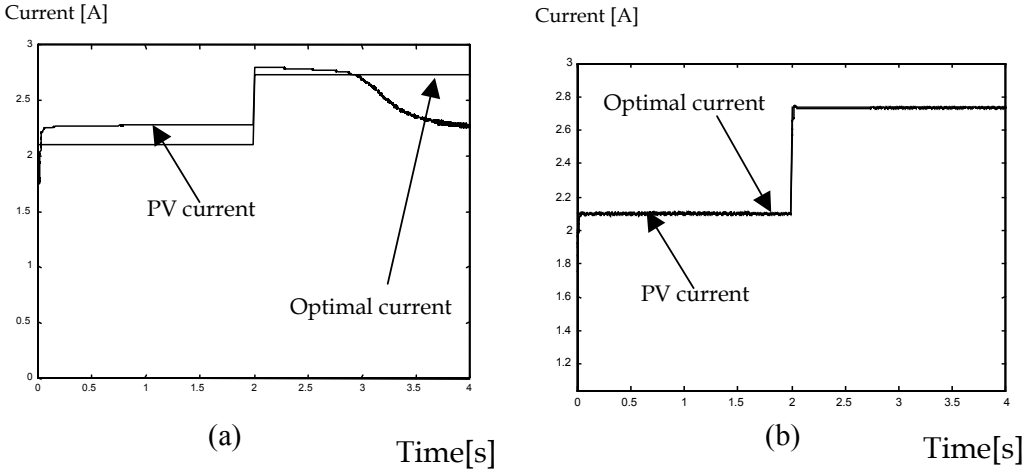

Figure 5. Output currents for insolation variation from 65% to 80%. (a) without (b) with tracking.

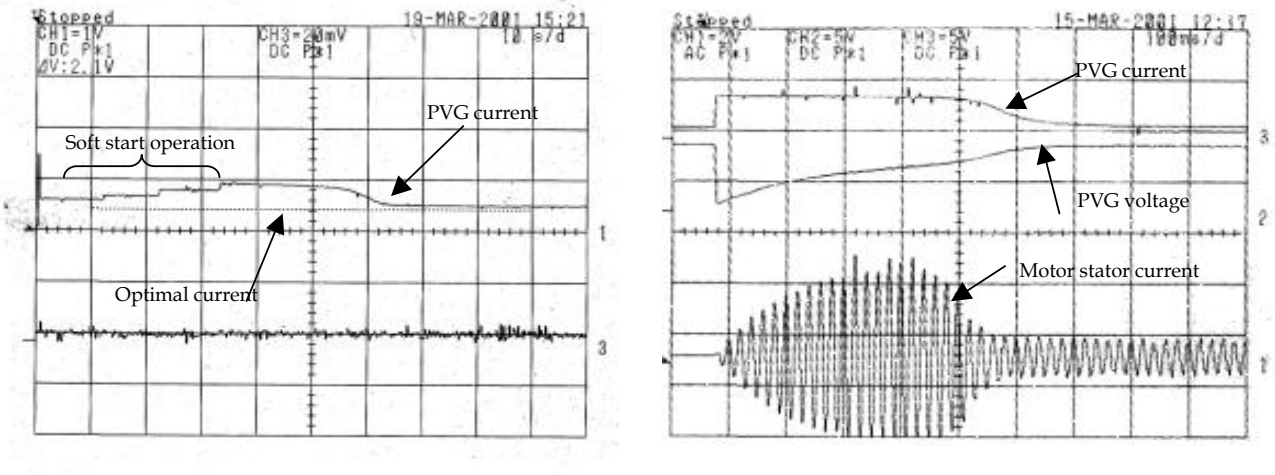

Figure 6. Experimental results (a) soft starting of the motor and tracking the maximum power, (b) DC current, voltage of the PVG and stator current of the motor.

CONCLUSION

A high performance maximum power point tracker based on neural fuzzy identification and fuzzy control has been investigated in this paper. Optimal efficiency operation and robustness against climatic parameters variation are demonstrated through the simulation and experimental results.

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الشبكات العصبية الذكية للتحكم الأمثل في توجيه أسطح الخلايا الكهروضوئية لتيار الحمل التردد

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ملخص
تعتبر الطاقات المتجددة في تطور مستمر من الناحية التقنية و الاقتصادية، و يمكنها في بعض الأحيان تعويض مصادر الطاقات الأخرى. انعكس هذا التطور في الحياة العملية من خلال العدد الهائل من التطبيقات لأجل تلبية الطلبات الطاقوية. في هذا البحث تم استعمال تقنية جديدة من تقنيات الذكاء الاصطناعي من أجل رفع مردود نظام طاقوي مصدره الطاقة الشمسية. هذه التقنية ضمت الشبكات العصبية المعروفة بسعة التعميم و المنطق الغامض الذي يترجم ذكاء الإنسان في حل المسائل. لقد قدمت هذه التقنية نتائج ناجحة جدا في استخلاص الطاقة القصوى التي يمكن إنتاجها من خلال مولد الطاقة الشمسية و لقد تم صنع النظام التجريبي (في مختبر الالكترونيات الطاقوية و الطاقة الشمسية بجامعة محمد بوضياف بوهران) من أجل تأكيد النتائج النظرية المتحصل عليها من خلال الكمبيوتر.