HIGH EFFICIENCY MAXIMUM POWER POINT TRACKING CONTROL IN PHOTOVOLTAIC-GRID CONNECTED PLANTS

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SUMMARY

This paper presents a high performance tracking of maximum power delivered from photovoltaic generators using adaptive neural fuzzy inference systems ANFIS. The non-precise and uncertain behaviour of the climate require stochastic modeling. This hard and hazardous task consumes more computation. Fuzzy logic is the powerful tool for modeling uncertainty and approximate reasoning, however, the presence of expert is the most important part of the design. Expertless design requires data which must cover all the possibilities of operation. Neural networks are the best learning machines in the field. ANFIS combines the advantages of fuzzy logic and neural networks in one package and gives an optimized fuzzy inference system embedding the whole knowledge of the system behaviour (tracking operation). Hysteresis current controller is implemented in order to shape the current to be interfaced to the public grid.

Simulation results carried out from MATLAB demonstrate the success of the technique giving thus high efficiency of the proposed controller.

Keywords: *ANFIS, MPPT, photovoltaic generators, hysteresis current control, pv-grid connection, PVG.*

1. INDRODUCTION

Solar energy is the most popular renewable today. Photovoltaic generators (PVG) are used to convert solar light to electrical current. They behave as a non linear sources depending on climatic parameters. Insolation level and temperature are the most important factors influencing the maximum power delivered from the PVG.

Maximum Power Point Trackers are used to extract maximum energy from photovoltaic generators. They exist as a controlled converter/inverter. The control is implemented in analog or digital computing system. Enhancements in microcontrollers technology and low cost considerations encourage the usage of digital control solutions. Such control is usually an executable program downloaded in the flash memory of the microcontroller.

Different algorithms have been covered in the literature. Fuzzy logic control [1] and neural networks [2][3] have been applied as a soft computing techniques.

In this paper a hybrid technique[4][5] that combines fuzzy logic and neural networks is applied to identify the maximum power point. Simulation results demonstrate the power of the ANFIS in the identification of the MPP and extracting the maximum power.

2. SYSTEM LAYOUT

Figure 1 shows the layout of the realized system.

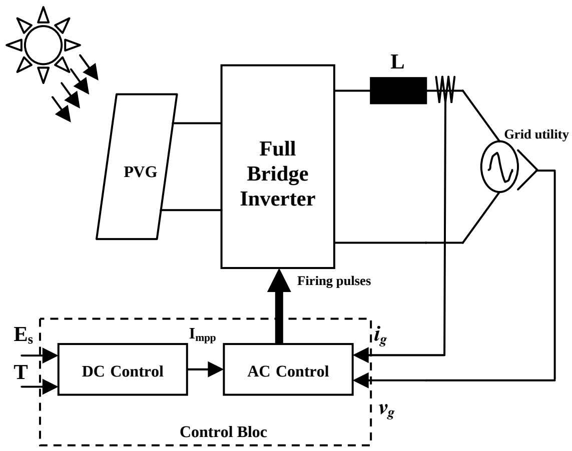


Fig. 1 System components.

The principal components of the system are:

2.1. Photovoltaic generator

The system is fed from a photovoltaic generator. The DC current is obtained directly from the sun light (insolation) conversion process. Figure 2 shows the P-V curves of the PVG for an increasing values of insolation. The MPP changes in a meaningful way versus the insolation level, and consequently as the insolation level rises, the maximum power rises proportionally.

Therefore, the capture of the insolation level reveals more information on the MPP position.

The short circuit current measurement from a pilot cell serves as an indication of the insolation level.

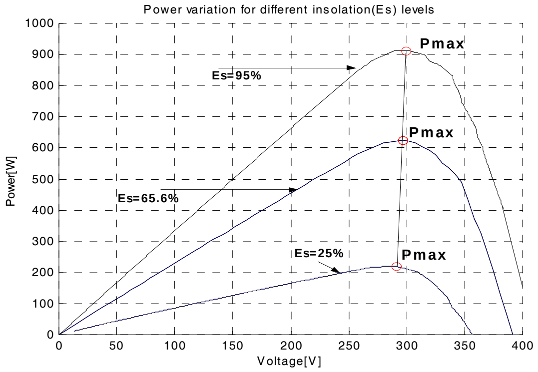


Fig. 2 MPP variation for three different values of insolation.

2.2. Full bridge inverter

Grid utility delivers AC current. In order to connect the PVG to the public grid, an inverter is inserted between the two sides to invert DC current to AC current in synchronism with the grid in order to achieve unity power factor.

2.3. Control bloc

This is the backbone of the whole system. It is composed of two main controllers as indicated in figure 1.

2.3.1. DC Control Side

In the DC control side, the parameters relative to the PVG (Insolation-E_s- through the short circuit current, and temperatute-T- through open voltage circuit measurements) are sensed and serve as inputs to the tracking controller which consists of an Adaptive Fuzzy Neural Inference System (ANFIS). Figure 3 depicts the configuration of the network.

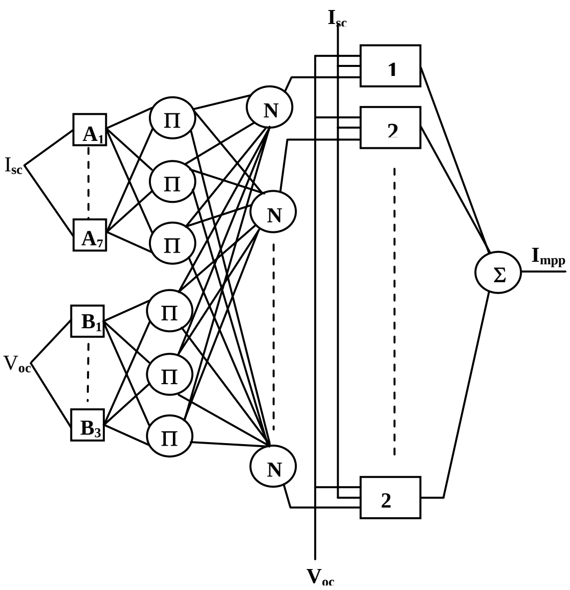
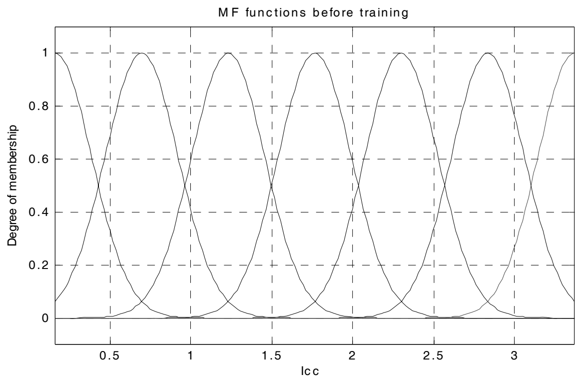


Fig. 3 MPP Identification implementation details.

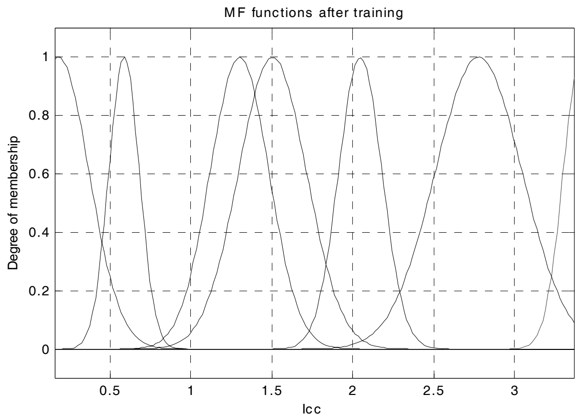
ANFIS network specifications:

- *Inputs* : short circuit current I_{sc} (insolation) and open circuit voltage V_{oc} (temperature).
- *Output* : optimal or maximal current available from the PVG.
- *Number of membership functions*: Seven(7) for I_{sc} and three(3) for $V_{oc.}$
- *Number of rules*: 21 (Sugeno FIS)

The membership functions for inputs are presented in the figure 4. It can be seen that the shapes vary before training (initial state figure 4-a) and after training (after learning the behaviour of the system figure 4-b), this variation reflects that the impact of the insolation is dominant on the maximum power delivered.



(a)



(b)

Fig. 4 Fuzzy membership function for inputs I_{sc} (a) before training, (b) after training .

The training procedure is based on an available database from the laboratory. The learning algorithm is hybrid combining LSE (Least Square Estimate) and backpropagation algorithm for adjusting the parameters of the output FIS.

The resulted FIS is capable of deciding which optimal current corresponding to the actual climatic conditions is to draw from the PVG.

2.3.2. AC Control Side

Once the optimal current is identified, the inverter is responsible for conducting it to the grid. Figure 5 gives a schematic diagram of the AC control side.

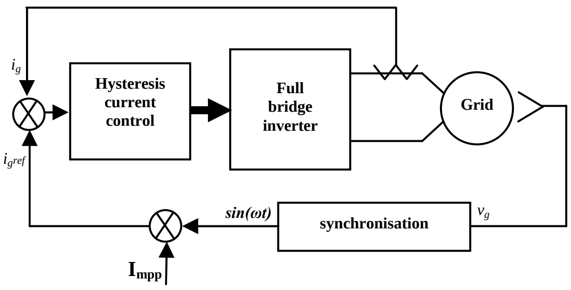


Fig. 5 AC Side Control details.

The synchronisation bloc generates a unity sine wave each zero crossing of the grid voltage. This sine is then multiplied by I_{mpp} to obtain the reference current to be delivered to the grid i_{gref}. The output current of the inveter i_g is sensed then compared to the reference current through a hysteresis current controller. Two hysteresis current control techniques have been applied in order to obtain satisfaction via standard IEEE Std 929-2000[6]: Fixed and sine band hysteresis current control [7][8].

1) Fixed-band hysteresis control

$i_{ref}(t) = I_{mpp} \sin(wt)$

upper band $\quad i_u = i_{ref}(t) + \Delta i$

lower band $\quad i_l = i_{ref}(t) - \Delta i$

where Δi = hysteresis band

if $i_g > i_u$, $V_{inv} = - V_{pvg}$

if $i_g < i_l$, $V_{inv} = +V_{pvg}$

2) Sinusoidal-band hysteresis control

The algorithm is

$i_{ref}(t) = I_{mpp} \sin(wt)$

upper band $\quad i_u = (i_{ref}(t) + \Delta i) \sin(wt)$

lower band $\quad i_u = (i_{ref}(t) - \Delta i) \sin(wt)$

for $i_{ref}(t) > 0$:

if $i_g > i_u$, $V_{inv} = - V_{pvg}$

if $i_g < i_l$, $V_{inv} = + V_{pvg}$

for $i_{ref}(t) < 0$:

if $i_g < i_u$, $V_{inv} = + V_{pvg}$

if $i_g > i_l$, $V_{inv} = - V_{pvg}$

where V_{inv} is the inverter output voltage.

Figure 6 gives the limits that shapes the inverter output current for the fixed and sine band hyteresis current control.

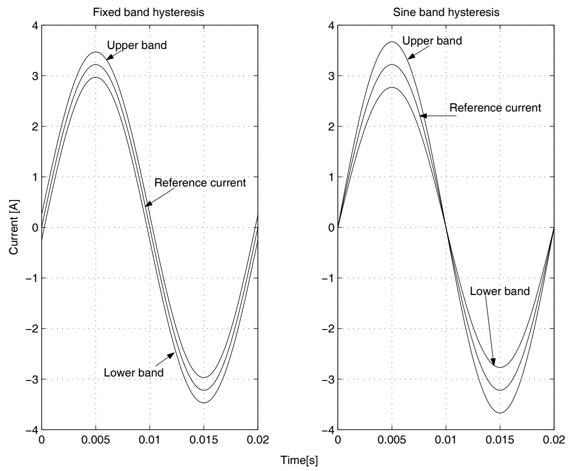


Fig. 6 Fixed and sine band hysteresis limits.

3. SIMULATION RESULTS AND DISCUSSION

Inveter output current in figure 7 represents the results of the applied techniques. It is observed that the sine band hysteresis current control gives a smooth current shape and a low total harmonic distortion (figure 8) comparing to the fixed band hysteresis current control. However the commutation number per cycle is small for fixed band hysteresis current control. This constraint is important in the choice of the commutator device. In both cases best performance as required by the standard IEEE 929-2000 (THD < 5%) is obtained.

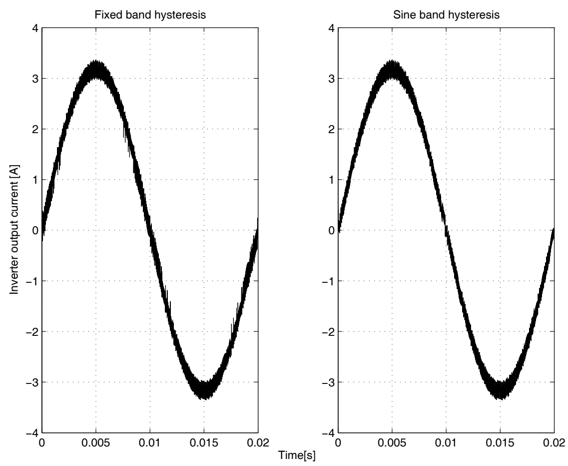


Fig. 7 Inverter output current for fixed and sine band hysteresis control.

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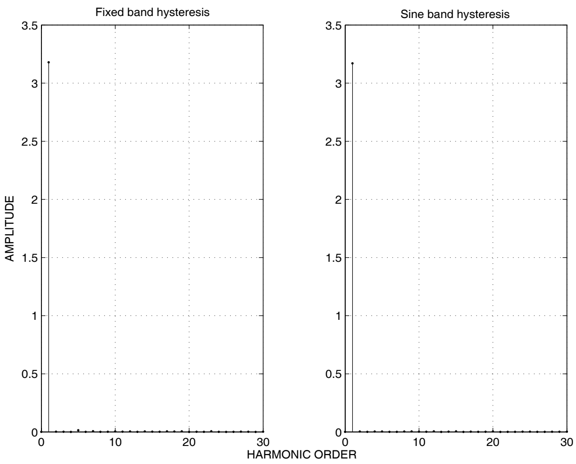

Fig. 8 Harmonic contents of Inverter output current for fixed(THD=1.71%) and sine band(THD=1.47%) hysteresis.

In order to test the performance of tracking the MPP, we have applied an insolation variation to the whole system. Figure 9 gives the inverter output current. It is observed that the proposed controller follows precisely the maximal current identified by the ANFIS.

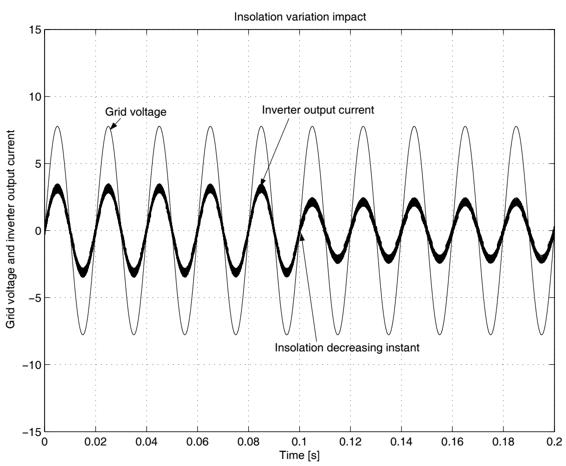

Fig. 9 Inverter output current for insolation variation (decreasing value).

4. CONCLUSION

Adaptive neural fuzzy inference systems have been applied successfuly in MPP tracking for PV-Grid connected plants. It is shown that high performance tracking is achieved, optimizing thus the efficiency of the whole system. Hysteresis current control of the voltage source inverter leads to standard requirements IEEE 929-2000 of the connection, respecting thus the current harmonic and DC component contents. Simulation results demonstrate the performance of the proposed controller.

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BIOGRAPHIES

DELLA KRACHAI Mohamed was born on 29.09.1973. In 2001 he graduated (MSc.) at the department of Electronics of the Faculty of Electrical Engineering at USTO-MB University in Algeria. He is currently persuing his PhD in the field of power electronics and solar energy. Since 2001 he is working as a lecturer with the Department of Electronics. His scientific research is focusing on renewable energies, neural networks, fuzzy logic and power electronics.

MIDOUN Abdelhamid is actually the Dean of the electrical engineering faculty in the university USTO-MB, he had obtained his PhD from Bristol UK university in 1986, his interest research fields are: renewable energies, power electronics, electrical storage systems, PWM strategies and softcomputing control.