Photovoltaic Tracking System Solar Radiation Measurement: Data Validation Using MPPT

A. LAY-EKUAKILLE, G. VENDRAMIN, A. FEDELE, A. TROTTA
[1]Dipartimento d'Ingegneria dell'Innovazione, [2]Dipartimento di Elettrotecnica ed Elettronica
[1]University of Salento, [2]Polytechnic of Bari
Via Monteroni, 73100 Lecce, Via Orabona, 70100 Bari
ITALY

Abstract: - The operating mode of a common PV (Photovoltaic) generator envisages the installation of panels so that they must be oriented towards south direction and slanted according to a determined magnitude that varies depending upon latitude of chosen location. The value of the tilt angle of the PV panel is usually equals to the value of the latitude more or less 10°, according as one wants a great throughput of the PV facility during winter or summer time. In order to increase PV system throughput, different solar tracking plants have been implementing, that is, automatic systems capable of orienting panels (thanks to brightness and/or radiation sensors) so that solar rays must always be perpendicular to them. Consequently, a yield increasing can be noticed in terms of performances of the all PV plant. This research presents the outcomes of a tracking system, validated by means of a MPPT (Maximum Power Point Tracker) apparatus

Key-Words: - PV system, Tracking system, Pyranometer, Radiation measurement, electrical throughput, sensors

1 Rationale

The position of the sun can be found by specifying three coordinates. However, if one assumes the distance from the sun to the Earth to be constant, the position of the sun can be indicated using two coordinates, that is, the solar altitude and the azimuth [1]. The complement of the zenith angle, θ_z, is called the solar altitude, α, and represents the angle between the horizon and the incident solar beam in a plane determined by zenith and the sun, as shown in fig 1. It has already been noted that the air mass is proportional to sec θ_z. Thus,

$$AM = AM(90°)\csc\alpha \qquad (1)$$

The angular deviation of the sun from directly south can be described by the azimuth angle, ψ, which measures the sun's angular position east or west of the south. Another angle, the hour angle is the difference between noon in the plane of apparent travel of the sun. The hour angle is the difference between noon and the desired time of day in terms of a 360° rotation in 24 hours, In clear terms,

$$\omega = \frac{12-T}{24} x360° = 15(12-T)° \qquad (2)$$

where T is the time of day expressed with respect to solar midnight, on a 24-hour clock. By relating ω to the other angles previously envisaged, it is possible to show [1] that the sunrise angle is given by

$$\omega_s = \cos^{-1}(-\tan\phi\tan\delta). \qquad (3)$$

which, in turn, implies that the sunset angle is given by $-\omega_s$. This relationship is very useful since it enables one to determine the number of hours on a specific day at specific latitude that the sun is above the horizon; while the number of hours of daylight is

$$DH = \frac{48}{360} x\omega_s = \frac{\cos^{-1}(-\tan\phi\tan\delta)}{7.5} hr \qquad (4)$$

Two very important relationships among α and ψ can be determined by anyone who enjoys trigonometry. If δ, φ and ω are known, then the position of the sun, in terms of α and ψ at this location at this date and time, can be determined from [2]:

$$\sin\alpha = \sin\delta\sin\phi + \cos\delta\cos\phi\cos\omega \qquad (5)$$

and

$$\cos\psi = \frac{\sin\alpha\sin\phi - \sin\delta}{\cos\alpha\cos\phi} \qquad (6)$$

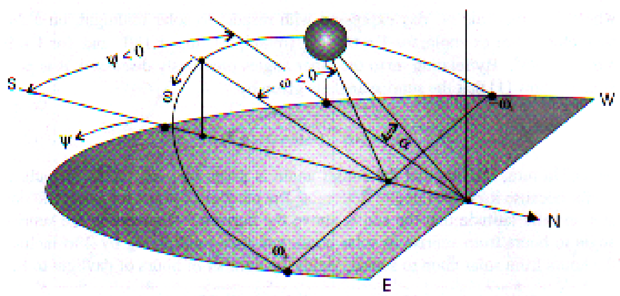

Fig. 1 Sun angles

2 Facility description

The experimental facility contains mechanical and electronic devices that allow the system to track solar trajectory as indicated in fig. 2 (only for MPPT) and in fig. 3. The structural basement is capable of hosting 6 traditional FV panels and operates as a strong infrastructure (see fig. 4).

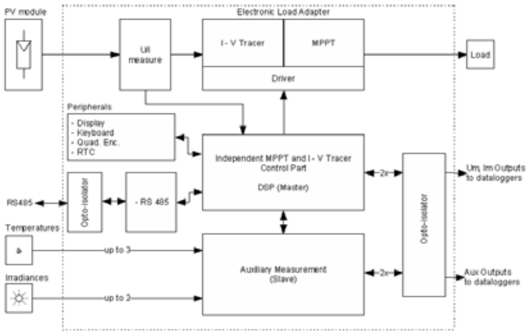

Fig. 2 MPPT 3000 Architecture

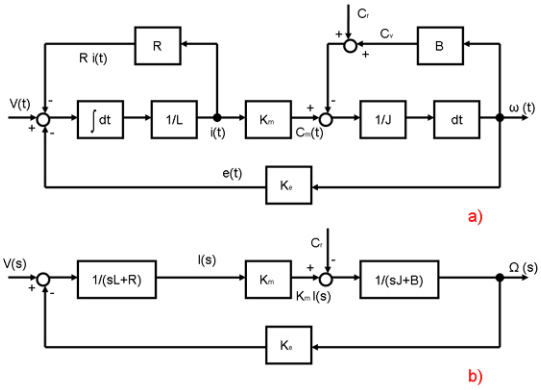

Fig.3 Block diagrams in time and frequency domains

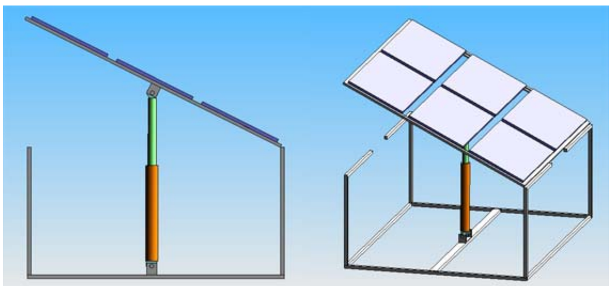

Fig. 4 Solid works system representation

Once build, for accelerating and proving the operating mode of the plant, just one FV panel has been mounted on the infrastructure according to fig. 5, by using a CM11 pyronameter. The facility has been mounted on the roof of the Department compound. So the PV system will use an MPPT in order to operate near the maximum power points. This system does not use a solar sensor but a recording of coordinates and sun trajectory for different locations.

Fig. 5 One panel tracking plant

3 Data acquisition

As recalled in the previous paragraph MPPT plays a key role. Maximum power operation is a challenging issue, sine it requires that the system load be capable of all power available from PV system at all times. Not only does this mean that the system load needs to be maximum when PV system output is maximum, but its means the system load must adjust itself rather quickly at the onset or dispersion of cloud cover.

In any case, the I-V characteristic of the ideal load will intersect the locus of maximum power points on the I-V characteristics of the PV array for varying illumination levels. The I-V characteristic for this ideal load is shown in fig.6, while fig. 7 depicts the software that allows to manage the MPPT operating mode during data acquisition session in Lab.

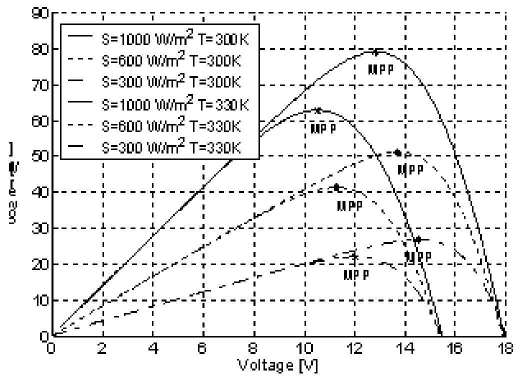

Fig. 6 MPPT behaviour

ISBN: 978-960-6766-71-8 ISSN: 1790-5095

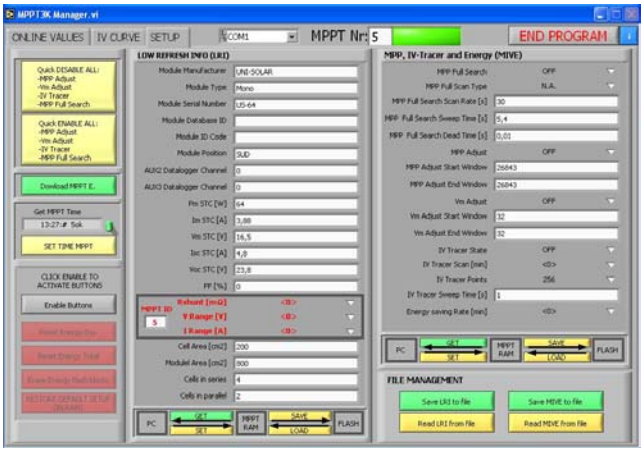

Fig. 7 MPPT Setup program

For data acquisition, a comparison has been performed between a fixed FV plant and a tracking one by using 4 MPPT modules as illustrated in fig. 8 and whose fig. 9 relates the inner part. The modules are located in a specific cabinet in order to avoid the contact with dust, rain, hot and cold conditions [3].

Fig. 8 MPPT cabinet

Consequently, a program has been traced out in the effort to detect the sun position day by day for all the year as seen in fig. 10. The program makes a correlation between altitude (vertical axe) and azimuth (horizontal axe) from east to west at any instant.

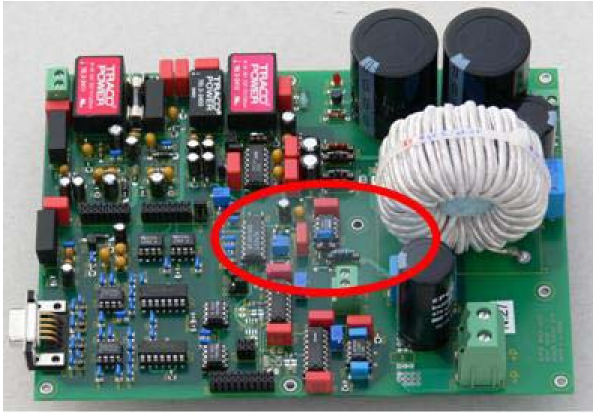

Fig. 9 MPPT inner

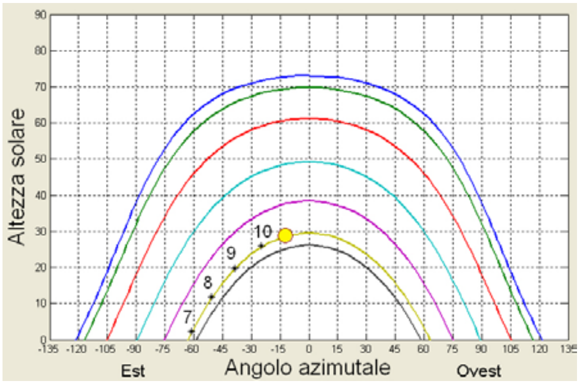

Fig. 10 Sun orbit description program

4 Summary and conclusion

Two experimental systems have been mounted on the floor of the dept laboratory, that is, a fixed arrays and a mobile ones. The comparison has been made between one fixed panel and a mobile one, managed by a solar tracking plant.
Fig. 11 and fig. 12 depicts the power vs time and radiation vs time respectively. They show, as expected, a significant difference, in terms of throughput between the two plants. The fixed plant has a small yield with respect to the tracking system. The mobile system remains stable in presence of sun from 9 a.m. up to 15 p.m., while the fixed system releases the maximum yield at noon.

As a correct and appropriate indicator, a performance ratio (PR) has been computed. This parameter takes into account all losses apart from nominal efficiency of PV conversion of modules [4]:

$$PR = \frac{\eta_{PV}(real)}{\eta(@\,STC)}$$

that is, the ratio between the global throughput of the system in real conditions and that of modules measured at STC ones. So the PR for the tracking is nearly 93% while it

ISBN: 978-960-6766-71-8

ISSN: 1790-5095

is in general around 90%. That is a good result and indicates the design has been correctly performed.

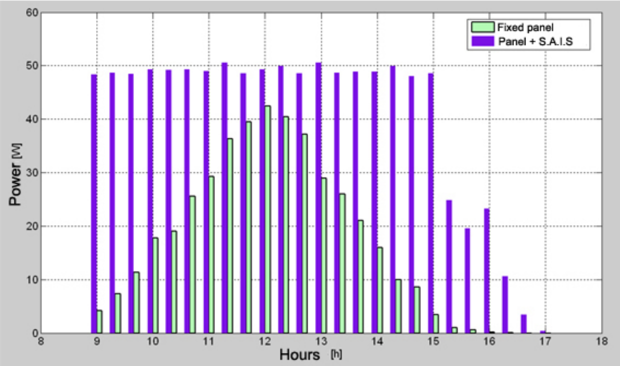

Fig. 11 Compared power vs time

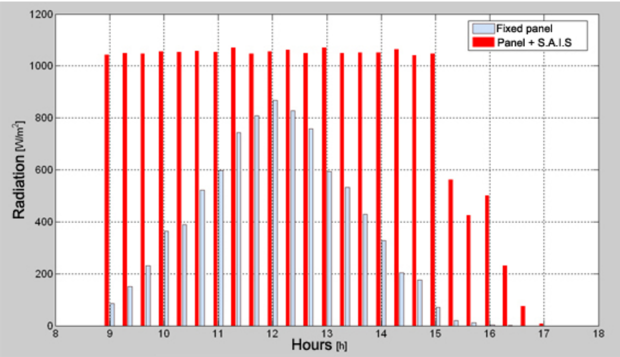

Fig. 12 Compared radiation vs time

References:

[1] Markvart,T, *Solar Electricity*, John Wiley & Sons, Chichester, U.K., 1994.

[2] *Maintenance and Operation of Stand-Alone Photovoltaic Systems*, Sandia National Laboratories, Albuquerque, NM, 1991.

[3] IEEE 929-2000, "*IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems*", IEEE Standards Coordinating Committee 21, Photovoltaics, 2000.

[4] Miller, R.D. and Zimmerman, D.K., *Wind Loads on Flat Plate Photovoltaic Array Fields, Phase III and Phase IV Final Reports*, prepared for Jet Propulsion Laboratory, Contract No. NAS-7-100-954833, Boeing Engineering and Construction Company, Seattle, WA, April 1981.