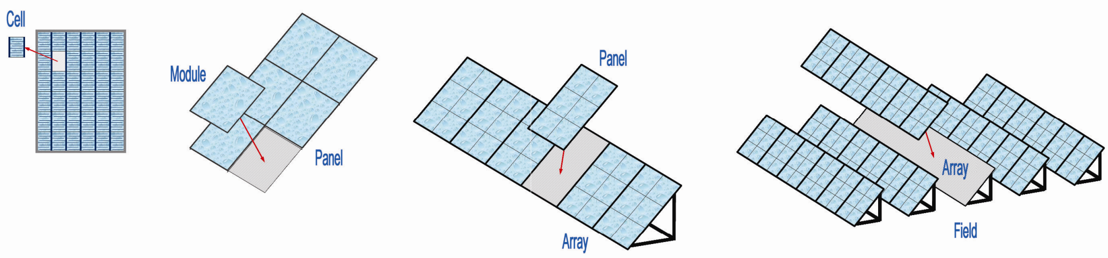
Solar Energy
How to improve power efficiency levels

Abstract
The ongoing deployment of large-scale solar energy fields across Europe ensures that efficiency in photovoltaic technologies continues to increase so that those who do decide to invest in a field maximise their profits and make a quicker return on investment. Giacomo Mazzullo of TDK-Lambda Italy suggests the greatest margin for improvement in efficiency is in the photovoltaic panel.

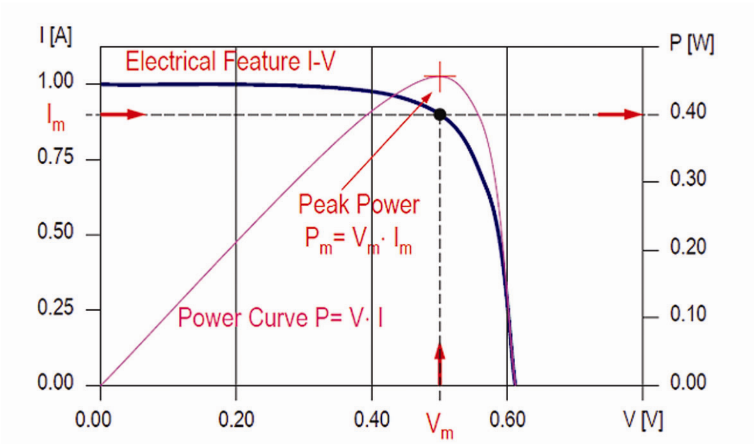
Introduction
Generally speaking a photovoltaic field is a collection of PV panels properly connected in series and in parallel to achieve the desired operating conditions. When designing a PV field certain decisions must be made early on in the process that can greatly affect operation. These include the panel's series-parallel configuration: in a series system power is limited by the panel that delivers the lowest current and in a parallel configuration voltage is the limiting factor. The choice of operating voltage also affects the final operation, not to mention the choice of support structures and the minimum distance between rows of panels to avoid shadows.



Cell to Field – the power from light.

From the point of view of the support structures of the panels, there are two types of systems. Fixed frame systems are, as the name suggests, designed with a fixed inclination. However, to improve the amount of solar energy radiation that hits the solar panel as the sun changes angle during the day and throughout the year, systems with single / double axis tracking were developed utilising stepper motors and electronic control. In a decentralised double-axis tracking system, for example, the main advantage is that the control box can be positioned in close proximity to the panel's structure, thus avoiding long and expensive cabling that, in a large facility, can affect the total cost of the plant significantly. This is because the isolated high-voltage input DC-DC converters, such as the PH series from TDK-Lambda, enable the controls and the stepping motors to be powered directly by the solar panel's output.

To improve the electrical performance of the individual cells in the panel's modules still further, a technique has been developed that optimises the panel's operation by ensuring it works at the point of maximum power for as long a period as possible. This technique is called MPPT (Maximum Power Point Tracker). To better understand how a photovoltaic panel works, the figure illustrates the exponential relationship between current (I) and voltage (V) of a PV cell. In this example, it has been assumed that the irradiation is constant. It shows that the maximum power point (MPP) occurs at the drop-off (or knee) of the curve, where the resistance is equal to the negative of the differential resistance (V/I = - d V/d I).



Electrical Feature (I-V) and power curve for a single photovoltaic cell.

As you can see from the chart, it is a low probability that the panel operates at that point, which would imply that it does not ever provide its maximum power (which, in turn, means an inherently lower energy efficiency conversion). To be able to work at the point of maximum power (MPP), systems are used for active tracking of MPP called MPPT (Maximum Power Point Tracker). Not to be confused with panel trackers, which track the position of the sun for maximum irradiation, the MPPT adapts to a voltage or current level that is more suitable to whatever load the panel is designed to drive.

Maximum power point trackers utilise some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell. The working concept of an MPPT tracker is simple: a cell works at its max power (for a certain radiation) if it works at its Vm and Im. The MPPT circuit adapts the impedance that the panel views at its output, so that all the cells can work at their maximum power point (MPP).

At present, MPPT systems are integrated within the inverter and check that the PV field works at the point of maximum power. Unfortunately, this type of solution does not consider the state of each panel and, in very large plants, may be subjected to irradiation levels that differ significantly. Areas of shade on the array, caused by trees or clouds, the accumulation of dust on the surface of the array and the fluctuation of temperatures across the array will all have an affect on the array output – in these circumstances the central inverter cannot compensate for one or more panels with a low output.

An alternative MPPT solution is to adopt a more distributed approach. This technique uses a DC-DC converter in between the panel and inverter – the control logic is the input point (V-I) from the immediate photovoltaic panel. The concept is simple: if the panel delivers a voltage and a current different from the values of MPP then the control logic guides the DC-DC in such a way as to return the panel in its MPP.

Although simple in concept, the control algorithm is very complex; there is a curve and a point of MPP for each value of irradiation and the control system does not know the value of irradiation of the single panel, so it must be fully independent and stable even during rapid changes in brightness.

MPP systems can either by analogue or digital, each with its pros and its cons. Certainly, the digital MPP system has the characteristics of flexibility and adaptability, however, the analogue system is considerably faster.

How to make an MPPT system cost-effective? Current research is focused on lowering the cost of the panel and improving the coupling between the panel and inverters. In the future, if reductions in the cost of DC-DC converter and control logic are met, the MPPT circuitry will be integrated into each panel and thus obtain maximum draw of power from the panel automatically.

For further information

N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Perturb and Observe MPPT Technique Robustness Improved," IEEE International Symposium on Industrial Electronics, vol. 2, May 2004, pp. 845-850.

N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of Perturb and Observe Maximum Power Point Tracking Method," IEEE Transactions On Power Electron., vol. 20, July 2005, pp. 963-973.

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