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An Improved Electronic Circuit for Tracing the I-V Characteristics of Photovoltaic Modules and Strings

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Abstract This paper presents an improved electronic circuit for testing photovoltaic (PV) modules or strings by tracing their I-V and P-V characteristics. It consists of an electronic fast varying load based on a power MOSFET controlled by means of an innovative sweeping gate-source voltage in order to improve the tracing of the I-V characteristics on an oscilloscope. In order to prevent damage of data acquisition systems and mainly for use with high voltage PV strings, galvanic isolation is introduced for the sweeping signal as well as current and voltage measurements. In spite of this improved characteristics, the developed electronic circuit keeps the advantages of low cost and simplicity. Experimental results obtained with the electronic circuit are presented.

A brief description

The electronic circuit utilizes a MOSFET as an electronic load to test PV modules. When the gate-source voltage (V_{GS}) is conveniently varied the operating point corresponds to the intersection of the PV module characteristic with the MOSFET one. Thus, by sweeping V_{GS} with a suitable signal the operating point of the MOSFET sweeps the I_{PV}-V_{PV} characteristic between V_{OC} and I_{SC}. While V_{GS} is less than the threshold voltage, V_{th}, the MOSFET will be OFF. When V_{GS} is increased above V_{th}, the device will operate in its active region where I_D rises approximately in a linear way with V_{GS}.
The scanning voltage (V_{GS}) is achieved in an innovative way in order to improve the I-V tracing on an oscilloscope. For this purpose a sweeping circuit consisting of a sinusoidal oscillator and a simple precision rectifier with a suitable gain and a variable positive DC offset voltage is used to generate a rectified sinusoid with amplitude regulation and the minimum value adjustable in order to be approximately the threshold voltage of the MOSFET. If a PV string is to be tested instead of a module an IGBT can be used instead of a MOSFET. The sweeping circuit is prepared to generate a voltage V_{GS} with a positive DC value that can be adjusted. Therefore, the circuit can be used with both power devices – MOSFETs and IGBTs.
The analogue sweeping signal generated by the sweeping block (a rectified sinusoid with variable amplitude and offset) is converted into a digital signal with a duty cycle proportional to its amplitude. This is done by using a PWM circuit built with a comparator and a simple sawtooth generator. Then the digital pulses are isolated and converted into an analogue signal corresponding to the voltage V_{GS} that will produce a proportional current I_D which is the same of the PV module (or string).
The electronic circuit includes isolation from the power device (MOSFET or IGBT) and PV module or string which is particularly important if the voltage across the PV module and the output current are to be measured with a digital acquisition system or when a PV string is to be tested instead of a module. The isolated PV module (or string) output voltage and current signals are used to trace the I-V characteristics. They are also multiplied by an analogue multiplier in order to trace the P-V characteristics. All the electronic circuit is based on simple, widely used and low cost components.

Conclusions

The I-V and P-V characteristics were captured and monitored with an oscilloscope and the experimental results obtained with a PV module demonstrate the operation of the electronic circuit developed in this work.
The proposed circuit is a simple and low cost solution suitable to be used for analysing the influence of field conditions like temperature, irradiance and partial shadowing on the PV module performance, as well as in identifying degradation and malfunction conditions.