MAXIMUM POWER TRACING FOR PHOTOVOLTAIC POWER SYSTEM

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Abstract: Global warming and energy policies have become a hot topic on the international Agenda in the last years. Developed countries are trying to reduce their greenhouse gas Emissions. For example, the eu has committed to reduce the emissions of greenhouse Gas to at least 20% below 1990 levels and to produce no less than 20% of its energy Consumption from renewable sources by 2020 [1]. In this context, photovoltaic (pv) Power generation has an important role to play due to the fact that it is a green source. The only emissions associated with pv power generation are those from the production of its components. After their installation they generate electricity from the solar Irradiation without emitting greenhouse gases. Maximum power point tracking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices.
Index Terms: Green house, PV, MPPT, MOSFET.

I. INTRODUCTION

Most of the PV power generation comes from grid-connected installations, where the power is fed in the electricity network. In fact, it is a growing business in developed countries such as Germany which in 2010 is by far the world leader in PV power generation followed by Spain, Japan, USA and Italy [3]. On the other hand, due to the equipment required, PV power generation is more expensive than other resources. Governments are promoting it with subsidies or feed-in tariffs, expecting the development of the technology so that in the near future it will become competitive [3]-[4]. Increasing the efficiency in PV plants so the power generated increases is a key aspect, as it will increase the incomes, reducing consequently the cost of the power generated so it will approach the cost of the power produced from other sources. Maximum power point tracking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. In electronics, the relationship between the direct current(DC) through an electronic device and the DC voltage across its terminals is called a current–voltage characteristic of the device. Electronic engineers use these charts to determine basic parameters of a device and to model its behavior in an electrical circuit. A more general form of current–voltage characteristic is one that describes the dependence of a terminal current on more than one terminal voltage difference; electronic devices such as vacuum tubes and transistors are described by such characteristics. The figure to the right shows a family of IV curves for a MOSFET as a function of drain voltage with overvoltage ($V_{GS} - V_{th}$) as a parameter.

These characteristics are also known as IV curves, referring to the standard symbols for current and voltage.

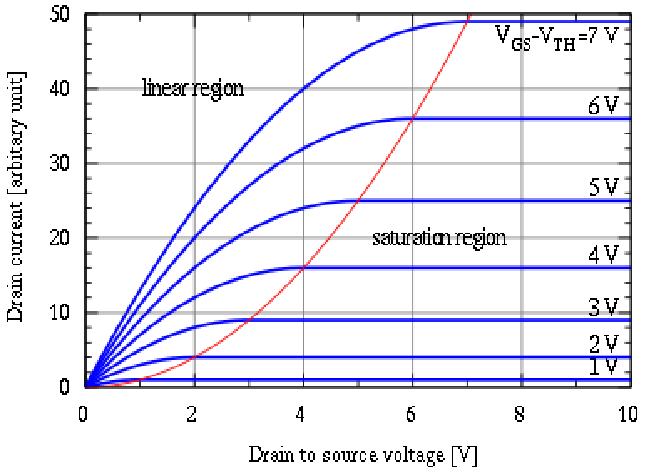

Figure: 1 MOSFET drain current vs. drain-to-source voltage for several values of the overdrive voltage, $V_{GS} - V_{th}$; the boundary between linear(Ohmic) and saturation (active) modes is indicated by the upward curving parabola.

The simplest IV characteristic involves a resistor, which according to Ohm's Law exhibits a linear relationship between the applied voltage and the resulting electric current. However, even in this case environmental factors such as temperature or material characteristics of the resistor can produce a non-linear curve.

The transconductance and Early voltage of a transistor are examples of parameters traditionally measured with the assistance of an I–V chart, or laboratory equipment that traces the charts in real time on an oscilloscope.

While I–V curves are applicable to any electrical system, they find wide use in the field of biological electricity, particularly in the sub-field of electrophysiology. In this case, the voltage refers to the voltage across a biological membrane, a membrane potential, and the current is the flow of charged ions through channels in this membrane. The current is determined by the conductances of these channels.

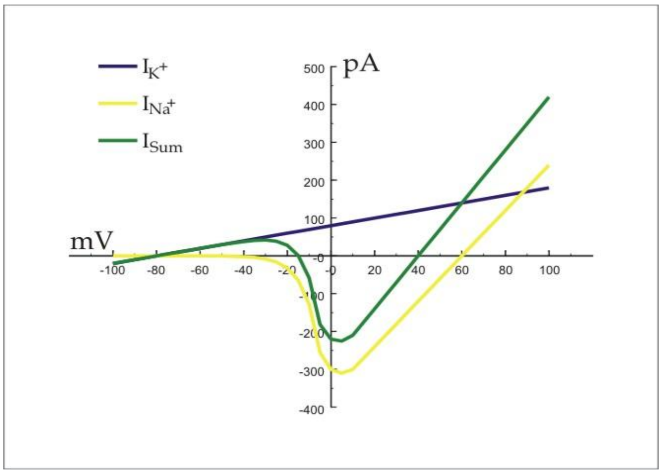

Figure 2: I – V characteristics

In the case of ionic current across biological membranes, currents are measured from inside to outside. That is, positive currents, known as "outward current", corresponding to positively charged ions crossing a cell membrane from the inside to the outside, or a negatively charged ion crossing from the outside to the inside. Similarly, currents with a negative value are referred to as "inward current", corresponding to positively charged ions crossing a cell membrane from the outside to the inside, or a negatively charged ion crossing from inside to outside.

The electric power supplied by a photovoltaic power generation system depends on the solar radiation and temperature. Designing efficient PV systems heavily emphasizes tracking the maximum power operating point. This work develops a novel three-point weight comparison method that avoids the oscillation problem of the perturbation and observation algorithm which is often employed to track the maximum power point. Furthermore, a low cost control unit is developed, based on a single chip to adjust the output voltage of the solar cell array.

II. SOLAR CELL

Operating principle

Solar cells are the basic components of photovoltaic panels. Most are made from silicon even though other materials are also used. Solar cells take advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to create an electrical current by an appropriate design of the structure of the solar cell, as will be explained in brief below. For further details, the reader can consult references [4] and [10].

A solar cell is basically a p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms: in the case of the n-layer, atoms with one more valence electron, called donors, and in the case of the p-layer, with one less valence electron, known as acceptors. When the two layers are joined together, near the interface the free electrons of the n-layer are diffused in the p-side, leaving behind an area positively charged by the donors. Similarly, the free holes in the p-layer are diffused in the n-side, leaving behind a region negatively charged by the acceptors. This creates an electrical field between the two sides that is a potential barrier to further flow. The equilibrium is reached in the junction when the electrons and holes cannot surpass that potential barrier and consequently they cannot move. This electric field pulls the electrons and holes in opposite directions so the current can flow in one way only: electrons can move from the p-side to the n-side and the holes in the opposite direction.

A diagram of the p-n junction showing the effect of the mentioned electric field is illustrated in Figure 3.

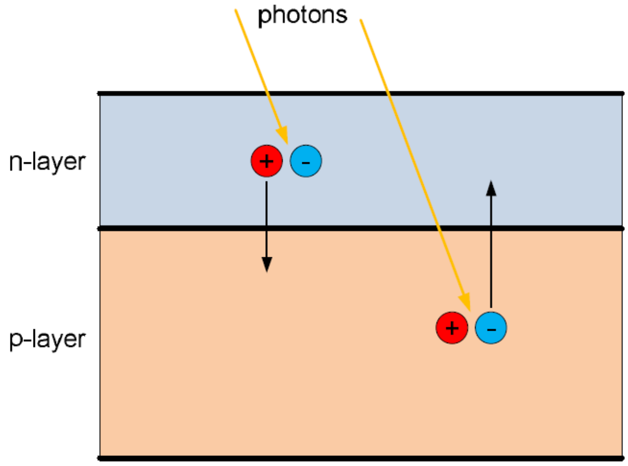

Figure 3 - Solar cell.

Metallic contacts are added at both sides to collect the electrons and holes so the current can flow. In the case of the n-layer, which is facing the solar irradiance, the contacts are several metallic strips, as they must allow the light to pass to the solar cell, called fingers. The structure of the solar cell has been described so far and the operating principle is next. The photons of the solar radiation shine on the cell. Three different cases can happen: some of the photons are reflected from the top surface of the cell and metal fingers. Those that are not reflected penetrate in the substrate. Some of them, usually the ones with less energy, pass through the cell without causing any effect. Only those with energy level above the band gap of the silicon can create an electron-hole pair. These pairs are generated at both sides of the p-n junction. The minority charges (electrons in the p-side, holes in the n-side) are diffused to the junction and swept away in opposite directions (electrons towards the n-side, holes towards the p-side) by the electric field, generating a current in the cell, which is collected by the metal contacts at both sides.

This can be seen in the figure above, Figure 1. This is the light-generated current which depends directly on the irradiation: if it is higher, then it contains more photons with enough energy to create more electron-hole pairs and consequently more current is generated by the solar cell.

Equivalent circuit of a solar cell

The solar cell can be represented by the electrical model shown in Figure 2. Its current voltage characteristic is expressed by the following equation:

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$$I = I_L - I_0\left(e^{\frac{q(V-IR_S)}{AkT}} - 1\right) - \frac{V - IR_S}{R_{SH}}$$

where I and V are the solar cell output current and voltage respectively, I0 is the dark saturation current, q is the charge of an electron, A is the diode quality (ideality) factor, k is the Boltzmann constant, T is the absolute temperature and RS and RSH are the series and shunt resistances of the solar cell. RS is the resistance offered by the contacts and the bulk semiconductor material of the solar cell. The origin of the shunt resistance RSH is more difficult to explain. It is related to the non ideal nature of the p–n junction and the presence of impurities near the edges of the cell that provide a short-circuit path around the junction [4]. In an ideal case RS would be zero and RSH infinite. However, this ideal scenario is not possible and manufacturers try to minimize the effect of both resistances to improve their products.

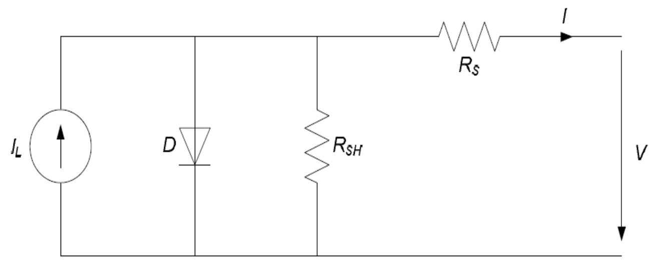

Figure 4 - Equivalent circuit of a solar cell.

A PV panel is composed of many solar cells, which are connected in series and parallel so the output current and voltage of the PV panel are high enough to the requirements of the grid or equipment. Taking into account the simplification mentioned above, the output current-voltage characteristic of a PV panel is expressed by equation below,

Where
np and ns are the number of solar cells in parallel and series respectively [11].

$$I \approx n_p I_L - n_p I_0\left(e^{\frac{q(V-IR_S)}{AkTn_s}} - 1\right)$$

Figure 5 shows the system configuration of the proposed PV system. This system consists of a solar array (75 W) with an open voltage of 21 V and a short circuit current of 4.6 A, an A/D and D/A converter, a $20^0/100$ Wresistor as the load, and a control unit on a single-chip.

Figure 5 depicts the circuits of the boost converter connected from the output of the solar cell. The power flow is controlled by varying the on/off duty cycle of the switching.

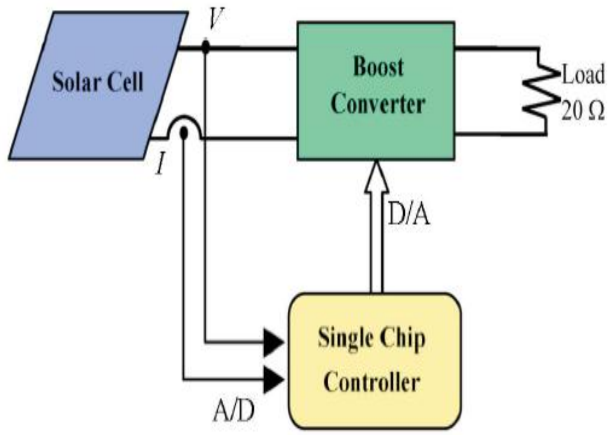

Figure 5. Configuration of the PV system.

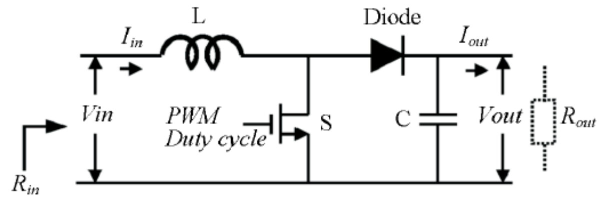

Figure 6. Circuits of the boost converter.

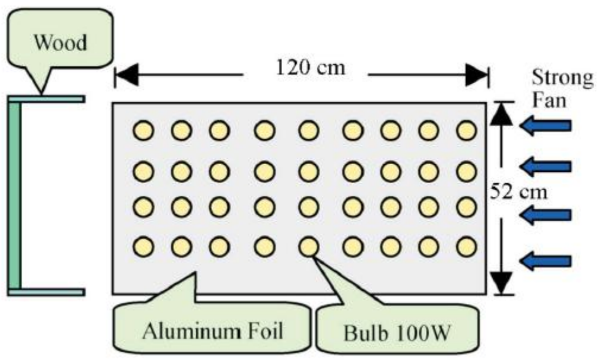

Figure 7. Configuration of the simulated solar source.

III. DISTRIBUTED SOLAR POWER GENERATION

Distributed solar generating systems are sited at the point of use, typically on or near residential or commercial buildings, and serve some or all of the energy needs of the building. Distributed systems may utilize solar thermal or photovoltaic technologies. When used to produce electricity, utility interconnection and net metering policies greatly influence a customer’s ability to install systems and lower their energy bills, respectively.

IV. Distributed Thermal Applications

There are many energy applications for which the load is purely thermal, such as water heating, space heating, swimming pool heating, cooking, industrial process heating and drying, and many of these energy needs can be supplied by solar energy. The most difficult thermal applications to achieve are cooking and high-temperature industrial heat applications. Since it is generally not cost-effective to transport thermal energy over long distances (more than a mile), these applications are invariably distributed, with energy being collected near the point of demand. Any of these applications could be met by electricity, so if they are met by solar thermal they may be considered "distributed,", since electricity does not need to be transported and distributed to meet them. A common example is water heating, which is normally accomplished with electricity or gas, but can also be readily accomplished by solar.

Solar thermal collectors may be of either flat plate or concentrating design. Flat plate thermal collectors consist of a dark absorber panel with incorporated fluid passages housed in an insulated box with a transparent glazing on the front. The heat-absorbing energy transfer medium may be either a liquid or air. For a low temperature application like swimming pool heating, the only thing that is necessary is an absorber panel with integrated fluid passages; however, glazing and insulation are needed to achieve higher temperatures for domestic water heating. Evacuated tube collectors, which house the absorber in an evacuated glass tube, permit even higher temperature collection with flat plate collectors.

The highest temperatures are achieved with concentrating collectors. These come in a number of designs, but in general consist of either a reflector or lens which concentrates solar radiation onto a smaller absorber surface including passages for the transfer fluid. There is a wide variety of industrial heat applications requiring temperatures up to and more than 1,000 degrees Fahrenheit and for most of these applications concentrating solar thermal collectors are required.

In addition to heating, cooling can be achieved by a number of solar thermal means, one being absorption cooling. Solar absorption chillers use a heat source, such as natural gas or hot water from solar collectors, to evaporate pressurized refrigerant from an absorbent/refrigerant mixture. Condensation of vapors provides the same cooling effect as that provided by mechanical cooling systems. Although absorption chillers require electricity for pumping the refrigerant, the amount is very small compared to that consumed by a compressor in a conventional electric air conditioner or refrigerator. Solar absorption cooling systems are typically sized to carry the full air conditioning load during sunny periods. Because absorption cooling equipment requires input temperatures of approximately 200 to 250 degrees Fahrenheit or greater, concentrating or possibly evacuated tube collectors are needed. While technically feasible, these technologies are not currently cost effective.

V. CONCLUSION

The main factor limiting utilization of the state's solar resource at a large scale today is its cost. However, solar costs are declining with the introduction of new technology types and improvements in manufacturing processes. As costs decline, larger projects may leverage economies of scale and become cost-effective within the next few years. In fact, two of the state's utilities have solicited proposals for central station solar power facilities within the past 18 months. Finally, expanding use of solar energy requires new thinking about the role of customer-sited generation in the electricity marketplace. The concept of customer choice must be expanded to include not just choice among utilities or retail electric providers, but also the choice to generate or offset some or all of one's own energy through solar or other on-site renewable distributed generation. Clear and consistent interconnection and net metering policies and processes statewide would further enable solar industry development and foster a cleaner, more diverse energy supply for all Texans.

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[7] The National Solar Radiation Database (NSRDB, http://rredc.nrel.gov/solar/old_data/nsrdb/) provides hourly solar radiation and meteorological data for sites throughout the United States for 1961–1990 (http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/) and 1991–2005 (http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/).

