Chapter 20
Performance Evaluation of a Dynamic Model of a Photovoltaic Module for Real-Time Maximum Power Tracking

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ABSTRACT

This case study deals with the modeling and maximum power tracking of a stand-alone photovoltaic (PV) power generator. A dynamic model of a solar cell has been developed, simulated, and validated using experimental data. Effects of parameter variations have been accounted for in the dynamic model. The dynamic model developed in MATLAB®/Simulink® environment is embedded in the LabVIEW® environment for real time hardware in the loop verification of the simulation results. It was found that the actual real-time maximum power that a PV can produce is significantly different from the average power provided by the manufacturer. Preliminary experimental testing showed that one can extract as much as 20% more power from the PV than what is suggested by the manufacturer. The three week long experiment is documented, and the model is then validated through the design of experiment. Finally, the conclusions of the case study are outlined and the future work is proposed.

INTRODUCTION

Energy is extremely important to human beings in today's world. We rely on energy to the point that our lives will be entirely interrupted if energy became unavailable. Energy is used to power our homes with light and daily use appliances; our cars, planes, and trains for transportation; our computers for education, product development, business records; and so many other things which we take for granted.

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In today's world there are plentiful renewable resources, and an excellent potential to enhance the ability to handle the further development of technology in the generation, storage, and distribution of power and energy, and to realize large-scale application of these systems. The rise in the cost of petroleum and the effects of coal on the environment force the issue of seeking alternative sources of energy that are renewable and environmentally friendly. One such source is solar energy. Solar energy is extracted via photovoltaic (PV) modules. The problem with this alternative form of energy is the poor efficiency of solar cells. The inability to guarantee reliable, uninterrupted output at a cost that can be comparable to conventionally produced energy has been the drawback of photovoltaic systems.

BACKGROUND

The term "photovoltaic," PV, is derived from two Greek words: phos meaning "light," and voltaic meaning "electrical." In turn, voltaic is named after the Italian physicist Volta, which is the same origin of the measurement "volts" (Smee, 1849). "Photovoltaic" has been used in English vocabulary since 1849 (Smee, 1849); however, the PV effect was first announced by Bequerel in 1839 and commercial use of this form of power production did not come until much later during the mid-1950's (Shushnar, 1985). The cost of PV power production has been much too high to effectively compete with the other forms of conventional power sources. However, the concern of cost is becoming less of a problem as we have seen a dramatic drop in price from \$100/kWh in 1962 (Vera, 1992) to as little as \$0.30/kWh in 2008 (Photovoltaic Industry Statistics, 2008).

Photovoltaic (PV) energy conversion is the process of converting light energy directly into electric energy. PV energy is generated only when specific conditions are met, including proper absorption of solar radiation, creation of movable electron/hole pairs, collection of charges, and connection of oppositely charged contacts. Conceptually, a solar cell is an electrical current source, driven by a flux of radiation. There are other light sources available which can also produce photovoltaic electricity (Khan, 2005); however, only solar radiation-based PV cells are analyzed in this chapter.

In a PV panel, semiconductors account for nearly 60% of overall expenses. Commercially available PV's are generally only 10-20% efficient, producing energy in normal sunlight at the rate of 1-2 kWh per sq. m each day. On average, complete solar radiation of 1 kW per sq. meter will generate a potential difference of approximately 0.5 V and a current density of 200 A per sq. m. of cell area. Therefore, a standard industrial cell of 100 sq cm area will generate approximately 2 A of current. The cell has a typical life span of little more than twenty years (Khan, 2005). Also, because the system is stationery, it can be left in isolated locations without maintenance (Bigge & Kumar, 1993).There are many advantages of using PV systems over other common power sources. Some of these benefits include (Bigge & Kumar, 1993):

1. PV systems have long life spans with duration of 20+ years.
2. PV systems perform in nearly any weather condition and have an instantaneous response to solar radiations.
3. PV systems are dependable, modular, sturdy, and require little maintenance.
4. PV systems operate silently.

Some disadvantages of the PV system are: (Bigge & Kumar, 1993):

1. PV systems have high initial cost and a large investment is required for the setup.
2. As this is a weather-dependent device, energy storage in the form of batteries is required as

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