Chapter 2

Optimization of a Solar–powered Irrigation System

ABSTRACT

Optimization is now a crucial element in industrial applications involving sustainable alternative energy systems. During the design of such systems, the engineer/decision maker would often encounter noise factors when their system interacts with the environment (e.g., solar insolation and ambient temperature fluctuations). In this chapter, the sizing and design optimization of the solar powered irrigation system is considered. This problem is multivariate, noisy, nonlinear, and multiobjective (MO). This chapter is divided into two parts where two situations are considered during the optimization of the solar powered irrigation system. Part 1 is the MO design optimization of the mentioned system under constant weather conditions. Part 2 involves optimizing a more general form of the design problem by accounting for varying weather conditions, insolation, and ambient temperature. The details of the optimization procedures of the two cases are presented and discussed in this chapter.

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PART 1: DESIGN OF SOLAR POWERED IRRIGATION SYSTEM UNDER CONSTANT WEATHER CONDITIONS

Overview

Currently, optimization problems are frequently encountered by engineers and scientists working on systems related to alternative energy and sustainable technologies (Elamvazuthi et al. 2011; Ganesan et al. 2012). Standard irrigation systems are usually powered by diesel generators or other fossil-fuel based power sources. However, issues such as the diminishing of fossil fuel resources and stricter environmental regulations have caused a surge in efforts to search for cost effective, eco-friendly and efficient alternative power sources. Hence, the idea of the utilization of solar energy to supply power to irrigation pumps has recently surfaced (Helikson et al., 1991; Wong & Sumathy, 2001). In solar powered irrigation systems, design and sizing plays a critical role in reducing greenhouse emissions while ensuring the systems reliability and efficiency (Al-Ali et al., 2001). Hence, this problem enters into the optimization domain where optimal design and sizing is done in a way that issues like cost saving, emissions, system efficiency as well power output are ensured or improved (Shivrath et al., 2012; Carroqino et al., 2009). Optimization of solar powered irrigation systems has been carried out with various metaheuristic techniques such as: genetic algorithms (GA) (Holland, 1992) and particle swarm optimization (PSO) (Carroqino et al., 2009; Gouws & Lukhwareni, 2012). However when a system is designed such that it respects multiple aims, the need to carry out multi-objective (MO) optimization arises (Chen et al., 1995).

In MO optimization, one approach that has been effectively used to measure the quality of solution sets (which construct the Pareto-frontier) is the Hypervolume Indicator (HVI) (Zitzler & Thiele, 1998). The HVI is specifically useful in cases where the Pareto frontier is unknown. Recently, this indicator has been frequently applied in many works involving MO problems (Beume et al., 2007; Igel et al., 2007; Knowles & Corne, 2003). The HVI is the only indicator which is strictly Pareto-compliant that can be used to measure the quality of solution sets (degree of dominance) in MO optimization problems (Beume et al., 2007; Zitzler & Thiele, 1999).

The main approach presented in this work involves an evolutionary symbolic regression approach called Analytical Programming (AP) (Zelinka, 2002; Zelinka & Oplatkova, 2003). AP algorithm fuses the concepts of evolution
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