Chapter 8
Multiobjective Optimization of Solar-Powered Irrigation System with Fuzzy Type-2 Noise Modelling

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ABSTRACT

Design optimization has been commonly practiced for many years across various engineering disciplines. Optimization per se is becoming 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 (e.g. solar insolation and ambient temperature fluctuations) when their system interacts with the environment. Therefore, successful modelling and optimization procedures would require a framework that encompasses all these uncertainty features and solves the problem at hand with reasonable accuracy. In this chapter, the sizing and design optimization of the solar powered irrigation system was considered. This problem is multivariate, noisy, nonlinear and multiobjective. This design problem was tackled by first using the Fuzzy Type II approach to model the noise factors. Consequently, the Bacterial Foraging Algorithm (BFA) (in the context of a weighted sum framework) was employed to solve this multiobjective fuzzy design problem. This method was then used to construct the approximate Pareto frontier as well as to identify the best solution option in a fuzzy setting. Comprehensive analyses and discussions were performed on the generated numerical results with respect to the implemented solution methods.

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INTRODUCTION

Diesel generators, gas turbines and other fossil-fuel based power systems have been widely employed for driving conventional irrigation systems. Currently, various issues related to the utilization of fossil fuel in power systems have surfaced (e.g. price fluctuations, environmental concerns and efficiency). Hence in recent studies, the harnessing of solar energy to power irrigation pumps have become popular (Helikson *et al*., 1991; Wong & Sumathy, 2001; Jasim *et al.*, 2014; Dhimmar *et al*., 2014). The design and sizing of solar power systems greatly impacts the system's reliability, emissions and efficiency (Al-Ali *et al*., 2001). Thus challenges in effective sizing of this system falls into the realm of optimization. Here the optimal sizing and design are obtained such that the following targets are achieved (Shivrath *et al*., 2012; Carroqino *et al*.,2009):

- Increased savings
- Low emissions
- Good system efficiency
- High power output

Efforts in the optimization of solar powered irrigation systems have been performed via the implementation of metaheuristics such as: genetic algorithms (GA) and particle swarm optimization (PSO) (Gouws & Lukhwareni, 2012). However, due to the complexity of the system, the design needs to be carried out in such a way that it takes into account multiple aims simultaneously (i.e. multiobjective optimization) (Chen *et al*., 1995).

Real-world optimization problems often contain large degrees of uncertainties. To effectively handle such problems, higher order fuzzy logic (FL) such type-2 FL approaches are often employed in tandem with optimization techniques (Castillo & Melin, 2012; Ontoseno *et al*., 2013; Sánchez *et al*., 2015). Most existing research works involving the application of type-2 FL systems revolve around control theory and control system design (Fayek *et al*., 2014; Martinez *et al*., 2011; Bahraminejad *et al*., 2014; Oh *et al*., 2011; Linda and Manic, 2011). For instance in Wu and Tan (2004), the authors investigated the effectiveness of evolutionary type-2 FL controllers for uncertainty modelling in liquid-level processes. In that work, the authors employed the genetic algorithm (GA) to evolve the type-2 FL controller. This approach was found to perform very well for modelling uncertainties in complex plants compared to conventional type-1 FL frameworks. In Bahraminejad *et al*., (2014), a type-2 FL controller was employed for pitch control in wind turbines. Pitch control in wind turbines are critical for power regulation and reduction of fatigue load in the components of the turbine. In Bahraminejad *et al*., (2014), the type-2 FL controller was shown to significantly improve the adjustment of the pitch angle, rotor speed and power output of the wind turbine generator. Similarly, in Allawi (2014), a type-2 FL controller was utilized for controlling robots involved in cooperation and target achieving tasks in multi-robot navigation systems. In that work, the controllers were optimized using the Particle Swarm Optimization (PSO) and the Hybrid Reciprocal Velocity Obstacles techniques. The author discovered that the optimized type-2 FL controller performed very well for controlling such robots.

Besides control theory and engineering, type-2 FL has also been employed for modelling systems endowed with high levels of uncertainty. For instance in Paricheh and Zare (2013), a type-2 FL system was used to predict long-term traffic flow volume. In Paricheh and Zare (2013), the traffic flow data was heavily influenced by various time-dependent uncertainties and nonlinearities. In that work, the authors