Fuzzy Power Management for Automatic Monitoring Stations in the Arctic

Demian Pimentel and Petr Musilek
Electrical and Computer Engineering, University of Alberta
Edmonton, Alberta, Canada

ABSTRACT

Monitoring stations in the Arctic operate in harsh environments, with limited seasonal availability of solar energy. Using an energy simulator, we have developed intelligent power management strategies to overcome these difficulties. The simulator includes renewable energy production modules (wind and solar), and loads (station components). Guaranteeing constant energy availability requires an adequate sizing of the power sources, and their prudent usage. At the same time, system shut-downs have to be minimized to allow data collection at required intervals. To achieve such performance, we devised a fuzzy logic control strategy. Results presented in this paper confirm viability of this approach.

KEY WORDS: Arctic, monitoring station, power management, fuzzy logic, simulator, energy harvesting, solar panel, aeroelastic flutter generator.

INTRODUCTION

Monitoring stations in the Arctic are typically powered by solar panels and rechargeable batteries. During sunny seasons, the solar panels provide electricity to the station and keep the batteries charged. However, continuous operation of the station during the polar night requires a considerable amount of energy, usually supplied by a bulky and heavy bank of batteries. If the energy contained in the batteries is entirely consumed before the end of the dark season, the station becomes nonoperational, with the associated loss of valuable data.

During the polar night, harvesting energy from other sources (wind, thermal gradients) is an attractive option. We developed a simulator of Arctic monitoring stations that allows the study of power sources with multiple energy inputs, such as solar radiation and wind. The simulator is designed to model an Environment Canada’s reference weather station, but other systems and power sources can be modeled as well. The simulator can be used for two main purposes: sizing of power sources, and development and testing of power management algorithms. Because the availability of each energy source is dependent on the geographic location, data from specialized meteorological databases has been used to drive the simulator. Three locations in Canada (Resolute, Inuvik and Whitehorse) and one in the United States (Barrow) were selected for this study.

The simulated system consists of the reference station, a rechargeable lead-acid battery, a solar panel, and a wind flutter generator array. Simulation results show that an efficient management of the scarce energy resource is necessary (Pimentel, Musilek et al., 2010a). In particular, we have made the following important observations about the operation of the simulated station without a sophisticated power management: 1) Energy transducers and batteries must be appropriately sized; 2) Physical and economical constraints on battery size lead to undesirable intermittent operation of the station should during Winter; and 3) Excess energy is wasted during the summer, whenever the state of charge of the battery reaches 100%.

Because the energy sources (sun, wind) are weather-dependent, their availability is stochastic. For this reason, a simulation-based approach for power source sizing that uses intelligent techniques to efficiently manage the energy flows has been developed. In particular, we present a power management strategy based on fuzzy logic. The main objective of the fuzzy logic controller is to minimize energy losses and system shut-downs caused by the absence of solar radiation and wind in conjunction with a discharged battery. Results of simulations using real meteorological and climatological data are presented for the four Arctic locations across Canada and the USA.

AUTOMATIC ARCTIC MONITORING STATIONS

An automatic weather station is composed of a power source, a data logger, and several sensors. A mast is typically used to support the equipment. Fig. 1 shows a monitoring station installed in the Arctic.

Equipment operating in Arctic regions works under extreme weather conditions, and is subject to the following special considerations:

- Access to remote Arctic locations is seasonal, expensive and time consuming. It is required to install and maintain equipment, and to retrieve data.
- Equipment is subject to very low temperatures, high winds and riming.