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Abstract

Supervisory control for optimising phase load balancing in a system of multiple loads: a case study of a creep testing laboratory

In a system comprising numerous on–off electrical loads, the total power may vary over a wide range, which makes it impossible to supply such an installation from a low-power source. A solution is provided by algorithms that shape the energy demand according to its availability. The aim of this work was to develop and assess the quality of a supervisory control algorithm that limits instantaneous power peaks by filtering the load with a proportional–integral (PI) controller, to determine its computational complexity, and to implement it in a real object: the Creep Testing Laboratory of the Łukasiewicz Research Network – Upper-Silesian Institute of Technology in Gliwice.

The research was carried out in two stages. In the first stage, a model of the Laboratory was built in the MATLAB Simulink environment, preceded by the identification of the furnaces of the single- and multi-specimen machines. Two approaches were compared on the model: a heuristic one, based on task scheduling, and a filtering one, based on a simplified model of the Laboratory. As the heuristic approach led to unacceptable temperature fluctuations in the furnaces, the filtering solution was selected for implementation; it maintains a stable number of switched-on heaters and links the choice of heater to an admissible activation delay. The algorithm was divided into a supervisory control layer and a layer of subordinate controllers. By experimentally tuning the parameters of the supervisory controller, an approximately tenfold reduction in power peaks was achieved without affecting the operating parameters of the loads: the system follows changes in the average power by varying the number of activated loads and, when the change is smaller than the power of a single load, by frequency-modulating the signal.

In the second stage, the algorithm was implemented on the object. It was shown that the supervisory control itself does not require substantial computing power, whereas communication proved to be the bottleneck: neither the existing PROFIBUS network nor the purpose-built RS-485 network of dedicated controllers could transmit the required data within a 200 ms window. After increasing the transmission rate to about 1 Mb/s and doubling the sampling period to 400 ms, correct synchronization of heater activation was obtained while preserving the required creep-test parameters. The effectiveness of the stabilization was confirmed by tests on the object, both under mains supply and under emergency supply from a generator set.

This work demonstrated that the controlled delaying of the activation signals of electrical loads makes it possible to shape the total power waveform of the system without affecting their operating parameters. The proposed solution is characterized by low computational complexity, which enables its application in many installations.

Keywords: demand-side management, peak shaving, supervisory control, PI controller.