Accepted Manuscript

An intelligent real-time cyber-physical toolset for energy and process prediction and optimisation in the future industrial Internet of Things

Sarogini Grace Pease, Russell Trueman, Callum Davies, Jude Grosberg, Kai Hin Yau, Navjot Kaur, Paul Conway, Andrew West

PII: S0167-739X(16)30382-X
DOI: https://doi.org/10.1016/j.future.2017.09.026
Reference: FUTURE 3681

To appear in: *Future Generation Computer Systems*

Received date : 6 October 2016
Revised date : 10 June 2017
Accepted date : 10 September 2017

An Intelligent Real-time Cyber-Physical Toolset for Energy and Process Prediction and Optimisation in the Future Industrial Internet of Things

Sarogini Grace Pease, Russell Trueman, Callum Davies, Jude Grosberg, Kai Hin Yau, Navjot Kaur, Paul Conway, and Andrew West

Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU UK

Abstract

Energy waste significantly contributes to increased costs in the automotive manufacturing industry, which is subject to energy usage restrictions and taxation from national and international policy makers and restrictions and charges from national energy providers. For example, the UK Climate Change Levy, charged to businesses at 0.554p/kWh equates to 7.28% of a manufacturing business's energy bill based on an average total usage rate of 7.61p/kWh. Internet of Things (IoT) energy monitoring systems are being developed, however, there has been limited consideration of services for efficient energy-use and minimisation of production costs in industry. This paper presents the design, development and validation of a novel, adaptive Cyber-Physical Toolset to optimise cumulative plant energy consumption through characterisation and prediction of the active and reactive power of three-phase industrial machine processes. Extensive validation has been conducted in automotive manufacture production lines with industrial three-phase Hurco VM1 computer numerical control (CNC) machines.

Keywords:

1. Introduction

Consumption of energy resources on an industrial scale has a significant worldwide environmental impact, using around 54% of total energy production [1]. The automotive industry is subject to regulation and taxation from national and international policy makers [2] and restrictions and charges from national energy providers [3], thus a competitive economic advantage can be obtained by reducing unnecessary usage at a factory level [4]. For example, the UK Climate Change Levy (CCL) is charged to businesses at 0.554p/kWh. This equates to 7.28% of a manufacturing businesses energy bill based on an average total usage rate of 7.61p/kWh [2]. The European Commission targets on climate change [5] mandate that member states increase energy efficiency by 20% by 2020.

In the USA over 50% of energy produced is wasted, with energy-efficient technologies offering a 23% improvement (equivalent to 7% GDP) [6]. UK waste equates to £1.6bn annually and could potentially be reduced by 15-30% [7, 8]. Appropriate optimisation first depends on characterising wasteful consumption with accurate monitoring of processes, associating these with their unique energy signatures [9].

Monitoring the resource consumption of each process is a key factor in achieving improved efficiency in industrial applications. Extraction of the features responsible for energy waste can be used to instruct intelligent process scheduling. In the domain of energy management, advantages can then be obtained through adaptation of industrial processes to reduce unnecessary waste and tuning process scheduling in line with energy pricing and excess charges.

Systems and assets in this domain must comply with industrial safety and robustness standards, e.g. wall-mounting on DIN Rails and wiring enclosure [10]. Many proposed systems facilitate monitoring of low power ($< 240V$, $< 10A$) domestic and small business systems [11]-[12]. In a typical manufacturing plant various machines, distributed in production lines, will operate in excess of the nominal three-phase voltage ($> 400V$) to perform a range of assembly and machining operations. Three-phase, high voltage ($> 1kV_{RMS}$ [13]) Alternating Current (AC) supply systems are predominantly used to distribute electrical power and supply electricity directly around industrial sites in the UK. Three-phase, low voltage ($50V - 1kV_{RMS}$) AC wiring