Measurement 125 (2018) 284–293

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Recording and analysing measurements from an RTG crane

I. Harrison[a,*], S. Pietrosanti[a], A. Luque[a], R. Mayer[b], W. Holderbaum[c]

[a] Dept. of Biomedical Engineering, University Of Reading, Reading RG6 6AY, United Kingdom
[b] 9 Heathwood Close, Yateley, Hampshire GU46 7TP, United Kingdom
[c] School of Engineering, Manchester Metropolitan University, Manchester M1 5QD, United Kingdom

ARTICLE INFO

Keywords:
Energy reduction
Beckhoff
MATLAB
Graphical user interface
RTG cranes
Power measurement system
Energy storage
Simulations

ABSTRACT

The paper presents a bespoke power measurement system that has been designed and implemented on a Rubber Tyre Gantry, RTG crane at the Port of Felixstowe, PoF. The design of a novel system topology which is centred around a Beckhoff computer, as well as the specifications of the various transducers used, is detailed. To complement the hardware installation, a bespoke data analysis tool has also been developed in MATLAB, an overview of its operation and use are presented. The system allows for the characterisation of the cranes' various motors during operational hours; furthermore, the data collected has been used to verify simulations of RTGs developed as part of the overall PoF project. The measurement system was installed on RTG1 at the port in March 2016.

1. Introduction

Transshipment is crucial to international commerce. Shipping ports such as the Port of Felixstowe, play a vital role in this process, allowing goods to be transferred off and on ships and facilitate the travel of goods onwards to the rest of the country. The issue that most ports face is their large energy consumption, and carbon emissions, from the various machines that enable their operation. The energy consumption and carbon emissions of ports in the EU are being targeted by European Commission as part of "Reducing emissions from the shipping sector" initiative [1]. This has forced numerous ports to investigate options for carbon emission reduction. The owner of the PoF and numerous other shipping ports, Hutchison Port Holdings Limited, have set up their own green policy called Go Green [2] to help combat this ever-growing issue. The PoF have also decided to electrify their entire fleet of Rubber Tyre Gantry, cranes (Fig. 1). Investigations carried out by Yang and Chang in 2013 suggest this electrification has dramatic impacts and is able to "achieve 86.60% energy savings and a 67.79% reduction in CO2 emissions" [3]. A multitude of methods for optimising port operations have been researched globally, as reviewed by Stahlbock and Vo [4].

RTGs allow containers to be manoeuvred off and on container stacks from trucks, tugs or straddle carriers. RTGs are typically powered via an on-board diesel generator; the electrification process enables the RTGs to be connected to the local electrical network. In the case of PoF, this is achieved using a VALHE conductor bar which runs the length of the container stack. This can be seen in Fig. 1, the bar resembles a metal fence along the left-hand side of the empty container stack. With this electrification an obvious issue arises, that is the increase in the power demand on the port's local grid. An RTG can consume up to 350 kW during the initial phase of a lift, and 250 kW in steady state (based upon a standard lift test with a 30 T container); it is clear that if multiple RTGs were lifting containers simultaneously, the cumulative power load could significantly increase the demand on the incoming grid supplies.

Port operators can gain benefit from examining the power consumptions of their cranes as they then are able to understand how energy demand directly affects their running costs. Carbon emissions also need to be established to ensure that operators comply with policies like the aforementioned "Reducing emissions from the shipping sector" initiative [1].

Metering and measurement is an important in a number of industries in order to establish where energy can be saved [6]. For instance, many new smart metering devices for the home environment are being developed [7–9]. When examining industrial power and energy metering, O'Driscoll and O'Donnell have published a comprehensive review of the state-of-the-art technologies [6]. To our knowledge, power metering at shipping ports has been examined by a number of authors for examination of carbon reduction [10], for energy reducing technologies [11] and for port infrastructure [12].

Acciaro and Wilmsmeier [13] have stated the following with regards to shipping ports. "Numerous technological solutions are available to reduce energy consumption. However, the uptake of these technologies is often hampered by economic, regulatory, managerial or technical barriers and in general by a lack of financial incentives or of

* Corresponding author.
E-mail address: i.harrison@reading.ac.uk (I. Harrison).

https://doi.org/10.1016/j.measurement.2018.04.089
Received 8 August 2017; Received in revised form 24 April 2018; Accepted 25 April 2018
Available online 26 April 2018
0263-2241/

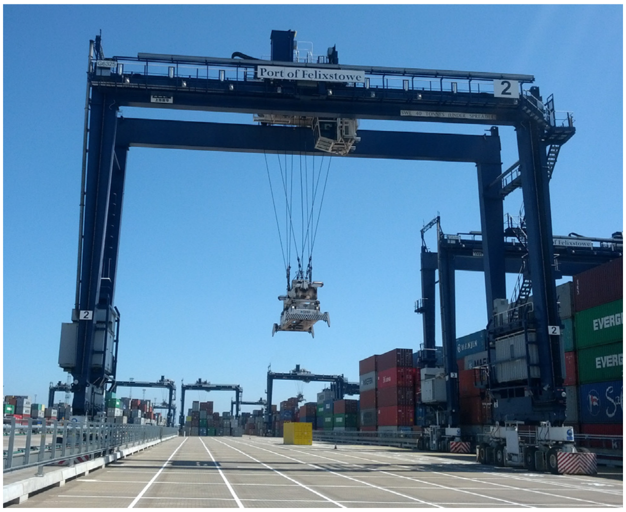

Fig. 1. An RTG crane at the Port of Felixstowe [5].

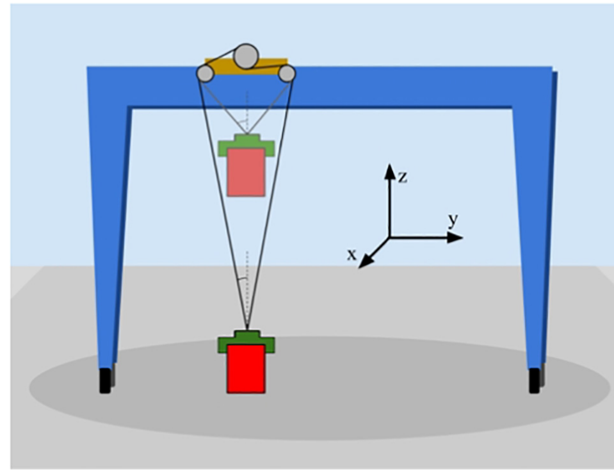

Fig. 2. Diagram of an RTG [14].

knowledge. An important issue is the limited availability of high quality data and the lack of information sharing between actors." This was one of PoF's motivations for acquiring data with high precision and high sampling rate.

Previous RTG power measurements made by our group, which led to our previous analysis [14] were all made from data extracted from the crane's on-board PLC. Unfortunately, this method posed a number of issues:

- The power dissipated by the dump resistors was not measured.
- The data for each motor was measured by the motor drives which only recorded the current and voltage. Unfortunately the power factor wasn't recorded hence the active to reactive power ratio was unknown.
- As additional diagnostic equipment from the PoF was used to record this data, the overall dataset was only recorded over 6 days, of which only 4 of the days were usable.

For these reasons a new system was required, and hence this paper describes a bespoke measurement system that has been developed. This novel system not only stores measured power information from the RTGs' various motors, but also interfaces with the RTG's PLC in order to obtain operational information. In conjunction with this measurement system, custom software, which facilitates the analysis of the vast quantity of data, is also presented in this paper.

This paper presents a complete measurement system that will enable researchers and port operators to measure power flows. Furthermore, a data analysis tool interfaces with the measurement system and extracts key indicators from all the metered data. The paper is presented as follows: Section 2 briefly describes the topology of an RTG; Section 3 describes the hardware and installation of the bespoke system; Section 4 introduces the software developed to perform the analysis of the vast quantity of data; Section 5 provides a number of examples of the graphical user interface, GUI's output.

2. RTG topology

The RTG on which the measurement system has been deployed at PoF, was manufactured by Shanghai Zhenhua Heavy Industries, ZPMC. The image of an identical model RTG is presented in Fig. 1 and a simplified overview is given in Fig. 2. An RTG has three main groups of motors, hoist, trolley, and gantry, with reference to Fig. 2 these provide movement in Z, Y and X directions respectively. The hoist motor is used to lift the containers, and the trolley motor allows the container to be traversed, i.e. horizontally moved with respect to crane. Typically, an RTG has four gantry motors, which provide power to each of the RTGs' wheels and thus allows the entire crane to be driven to its required location within the port. In terms of power consumption, the motors can be ranked in the following order, hoist (largest), gantry and trolley (smallest), where the hoist accounts for over a quarter of the overall power consumption of the crane [14]. An electrical overview of how these motors are powered is presented in the following section alongside the metering points for the measurement system (see Fig. 3).

As described earlier, RTGs use their hoist motor to lift containers, using power to perform work against gravity. However, during lowering that same motor acts as a generator to provide electrical braking. This power is typically dissipated as heat through dump resistors, via a fast-acting switch known as a chopper. Technologies such as energy storage systems, ESSs are now under development to reduce the losses in RTGs and are further discussed in Section 7.

In order to manoeuvre the shipping container, a device called a spreader is used, which is attached to the crane and can lock onto the container to allow it to be repositioned. The spreader is aptly named as it can expand and contract in length to accommodate various standard sizes of shipping container, ranging from 20 ft to 45 ft in length. The spreader itself is connected to the RTG with eight cables that are attached to drums on the trolley, which can be seen in Figs. 1 and 2. The trolley is typically where the drivers cabin in situated, providing them with a top down view of the container which can also be seen in Fig. 1.

3. RTG measurement system

The RTG measurement system described in this paper has been devised in order to collect a number of variables that are used to validate simulations of RTGs and understand power flows.

Fig. 3 presents a line overview of the system topology. The measurements were recorded via a Beckhoff CX2020 Programmable Logic Computer, PLC [15]. The Beckhoff PLC is linked (via Ethernet cable) to a Westermo MRD-455 4G router [16], which allows data to be collected remotely. This PLC takes input from the following: