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Retrospective future proofing of a copper mine: Quantification of errors and omissions in 'As-built' documentation

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ABSTRACT

The electrical instrumentation control systems (EICS) 'As-built' documentations of a copper mine were found to possess a significant errors and omissions, which hindered the asset owner's ability to undertake effective and efficient operations and maintenance. A Systems Information Model (SIM) was used to retrospectively create a connected system to ensure all physical equipment and the associated connections that were constructed are modelled in an object-orientated database. In creating the SIM, the existing errors and omissions in the 'As-built' documentation were quantified, and cost savings that could be achieved for a future planned copper mine, with a similar design, were identified. The limitations of using conventional computer-aided-design (CAD) to design and document EICS are discussed. It is recommended that retrospectively creating a SIM can provide owners and operators with significant productivity benefits as well as ensure the asset's integrity. The case study presented provides asset owners and operators with the empirical evidence to challenge conventional thinking surrounding the design, engineering and documentation of EICS using CAD and alternatively consider the use of SIM.

1. Introduction

"An error doesn't become a mistake until you refuse to correct it".

(Orlando Aloysius Battista)

'Future Proofing' ensures that an asset continues to be of value into the future (Love et al., 2015). As environmental aspects continue to change with increasing speed, the requirements that assets must meet in terms of health and safety, flexibility and cost-effectiveness are becoming ever more demanding. An innate feature of 'Future Proofing' assets is determining the 'best option' that provides optimum value so as to ensure an asset can be built at minimum expense in consideration of a project's life cycle.

While obtaining optimum value will invariably be a key business driver for asset owners, existing technology (e.g., computer-aided-design (CAD)) and processes used to engineer and document a new mining project, for example, may stymied this goal. This is due, in part, to the engineering and documentation produced by Engineering Procurement Construction (EPC) and EPC Management (EPCM) contractors and their consultants, which often contains errors, omissions and redundant information (Love et al., 2014). In the mining industry, electrical instrumentation and control systems (EICS) account for 29% of the world's capital expenditure on plant. In plant operations, EICS typically accounts for 60% of maintainable items as well as being critical to safe and efficient operations. Thus, it is imperative that 'As-built' documentation is error-free and reflects precisely what has been installed. If EICS are ineffectively and inefficiently designed and documented, then an asset owners' plant, equipment and facilities may fail to operate and meet production targets, which can result in considerable economic loss and jeopardise safety and adversely impact their share price.

This paper presents a case study of a copper mine whose owner was dissatisfied with the EICS 'As-built' documentation which was provided on completion and hand-over of their mine. Essentially, errors and omissions were prevalent within the documentation provided, which impacted their ability to effectively and efficiently manage operations and maintenance as well ensure the assets

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integrity. A Systems Information Model (SIM) is used to retrospectively create an object-orientated database to ensure all physical equipment and associated connections are modelled as constructed. In creating the SIM, errors and omissions in the existing 'As-built' documentation were quantified, and potential cost savings that could be achieved for a future anticipated copper mine, based upon a similar design, and are identified. Research examining the benefits of using an objected-orientated approach for the processes of designing, engineering and documenting EICS's has been limited (e.g., Love et al., 2013a,b; Hanna et al., 2013; Hanna et al., 2014). Though, initial research has estimated that the use of a SIM applied to the processes of EICS in mining can provide a 94% cost saving and a substantial improvement in productivity (Love et al., 2013a,b).

2. Handover of 'As-Built' documentation

A considerable amount of documentation is needed to maintain and operate of a mine. Yet, most existing mining facilities have this information stored in paper documents (e.g., rolls of drawings, folders of equipment information, file folders of maintenance record (Love et al., 2013a,b). The documentation is contractually requested by the owner and handed over after the mine is already in use, often months later, and placed in storage where is difficult to access. According to Gallaher et al. (2004) "an inordinate amount of time is spent locating and verifying facility and project information from previous activities. For example, 'As-built' drawings (from both construction and operations) are not routinely provided and the corresponding records of drawings are not up-dated. Similarly, information on facility condition, repair parts status, or a project's contract or financial situation is difficult to locate and maintain" (p.121). Moreover, information is often contained on several documents (e.g., drawings, data sheets, and test sheets), which can render the search for information during maintenance and operations an arduous task and adversely impact productivity.

Many mine owners use various forms of computer maintenance management systems (CMMS) and computer asset management systems (CAMS) to manage information contained within test sheets, vendor information, maintenance (Mtce) data and the like. Such information is often transferred manually into these systems, which is costly and time consuming process. CMMS/CAMS are often not used until they contain all the necessary data that has been checked for accuracy and completeness (Teicholz, 2013). The cost and time associated with entering, verifying, and up-dating information in these systems can be phenomenal for mine owners and operators. Gallaher et al. (2004) revealed that eighty percent of owners and operators incur significant interoperability costs during maintenance and operations. In addition, legacy data issues are often a problem, as information is often stored in a variety of different media. Such information does not always reflect the true configurations of an asset as the 'As-built' documents are often not maintained or were poorly communicated (Gallaher et al., 2004). This problem arises due to the way that the design, engineering and documentation is conventionally produced, particularly in the case of EICS. In the next section of this paper, the conventional method of producing EICS documentation within mining is described.

3. Electrical instrumentation and control systems

With the advent of CAD, electrical and system engineers have been able to efficiently and effectively experiment with various alternative design solutions. Circuits can be validated more readily and the accuracy of the design improved. The advantages offered by CAD in electrical engineering are that it (Love et al., 2015):

- provides an understandable representation of the numerical results (e.g. through graphs and other graphic devices);
- reduces the tediousness of solving common and complex equations;
- provides the ability to use simple numerical methods to solve complex problems that would be time-consuming to undertake; and
- enables the testing of the design (such as the maximum value of load resistance the design can support).

Typical types of drawings created within CAD for EICS systems are: (1) block, (2) schematic, (3) termination and (4) layout. In addition cable schedules and 'Cause and Effect' (C&E) diagrams will be provided within the documentation produced, though this is dependent upon the nature of the system that is being designed and documented. Despite the benefits that CAD has provided to the field of EICS, engineers are prone to making errors and omissions, especially as objects are often replicated on several different types of drawing as noted in Fig. 1.

Concepts and requirements from several sources are translated on to documents and drawings in varying patterns. As noted above, the same information is placed on several documents to form relationships between them (Fig. 1). Different information about the same component will regularly be placed in various places and so equipment and cable tags are often repeated. As a documentation package evolves, it is difficult to ascertain which particular documents contain the same information or show related information. Checking the accuracy of the information contained within the documentation therefore forms a critical component of the engineering process. Yet, the extant literature consistently demonstrates that effective checking is rarely undertaken due to time and financial constraints imposed on engineering firms (e.g., Lopez and Love, 2012). When meticulous checking is undertaken, errors and omissions are invariably found and consequently several iterations of the documentation may be required (Palaneeswaran et al., 2014). Unfortunately, due to the time constraints imposed upon the engineers, incomplete or inaccurate documentation is often distributed to contractors, which results in them generating requests for information (RFI) during construction. An RFI essentially seeks to identify and resolve issues on-site to avoid potential contract disputes and claims at a later date (Tadt et al., 2012).

Depending on the scale and nature of the RFI, site work may have to be temporarily suspended, which may result in non-productive time (e.g., waiting, idle time) being experienced. In fact, the contractor may also experience considerable non-productive time, as they aim to understand the nature of the

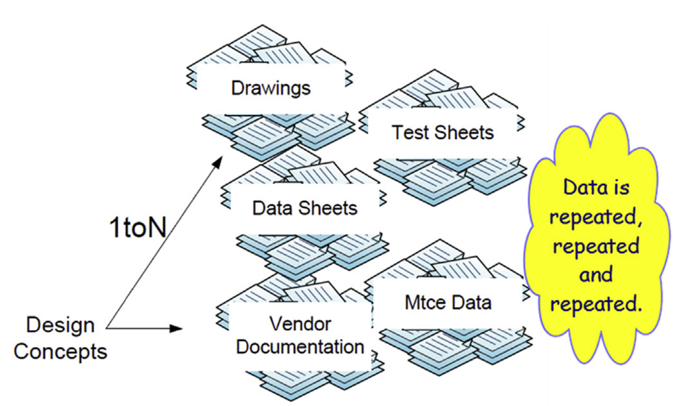

Fig. 1. Replication of objects.