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Safeguarding the integrity of Liquefied Natural Gas infrastructure assets with digitization: Case of a domestic gas metering upgrade project

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ABSTRACT

Low productivity levels have contributed to the cost and schedule overruns that have plagued the construction of Liquefied Natural Gas (LNG) processing facilities in Australia. Traditional paper based methods such as Computer-Aided-Design have been relied upon to create, manage, store and retrieve information throughout each phase of a project's lifecycle for Electrical, Instrumentation and Control Systems (EICS). As a result of utilizing CAD to document (e.g., specifications, and 'as-builts') ECIS, the propensity for errors, omissions and information redundancy to occur, significantly increases. Attending to issues of this nature during the construction of a facility can result in scope changes, losses in productivity, and increases in project costs. Using a case study, this paper examines the nature of the documentation produced to up-grade a domestic gas metering system that formed an integral part of a LNG plant's production process. Issues hindering productivity during the production of the documentation, communication and information exchanges, and change management involved with the deliver of the EICS are presented. In addressing problems identified in the case study, it is suggested that EICS for an LNG plant should be digitized (i.e process of converting information into a digital format) using a Systems Information Model to ensure effective and efficient production and management of information throughout its lifecycle, and contribute towards safeguarding the assets integrity.

1. Introduction

The State of Western Australia (WA) produces approximately 90% of the nation's estimated recoverable conventional gas reserves, which are located in the Carnarvon and Browse basins in the State's North West. These gas fields support the Liquefied Natural Gas (LNG) export industry of WA, as well as its domestic gas market. Domestic gas is provided by Chevron's Gorgon and Wheatstone, and Woodside's Karratha Gas Plant. In fact the State Government policy aims to ensure that 15% of the gas produced from offshore developments are made available for domestic use (Government of WA, 2015). Having in place reliable and robust infrastructure that is able to supply gas for industrial processing, manufacturing, residential use and electricity generation within the State is critical to supporting its economic and social well-being. It is, therefore, a necessity that the supply of gas is not adversely impacted. However, maintenance and upgrading of the infrastructure has the potential to hinder this supply, especially, if works are not effectively planned and regular inspections and maintenance are inadequately undertaken.

In 2008, for example, WA experienced a significant disruption to its supply of natural gas as a result of a rupture in a pipeline that had been subjected to corrosion, which lead to an explosion at the processing plant on Varanus Island. The plant supplied a third of WA's gas and subquently needed to be shut down for almost two months while detailed engineering investigation and major repairs were undertaken. The WA Chamber of Commerce estimated the overall economic impact of this disruption to be in the magnitude of AU$6.7 billion (SMH, 2008). According to NOPSA (2008), the main causal factors that contributed to this event were:

- ineffective anti-corrosion coating at the beach crossing section of the sales gas pipeline;

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- ineffective cathodic protection of the wet-dry transition zone of the beach crossing section of the pipeline; and
- inadequate inspection and monitoring by the operator of the beach crossing and shallow water section of the pipeline.

With the benefit of hindsight, it suggested that events of this nature could have been mitigated if real-time condition monitoring and sensing technologies had been employed and integrated with a Systems Information Model (SIM). Yet, there has been a tendency for inspection and monitoring of asset information to be manually recorded using paper based systems. As a result of recording information in this format, it can be misinterpreted due to illegible handwriting and incomplete information that is often difficult to retrieve as it tends to be stored in a variety of disparate locations. An inability to instantly obtain access to the correct information from a reliable consolidated 'point of truth' (POT) can result in ineffectual decision-making, adversely impact productivity levels and jeopardize safety (e.g., Hossain et al., 2015; Zhou et al., 2015a,b; Choi et al., 2016). LNG operators have recognized the significance of this problem and as a result have begun to embrace a wide range of innovative technologies (e.g., Internet of Things, Radio Frequency Identification (RFID), Sensors, Geographical Information Systems (GIS) and Quick Response (QR) codes) to ameliorate process safety and the management of information during operations and maintenance (Zhao, 2015; Tanabe et al., 2016).

Despite the widespread support of operators to adopt technology to maintain their assets' integrity and ensure that their production levels meet their contractual obligations supplying gas for overseas purchasers (e.g., China and Japan), a fundamental problem prevails and has been eschewed. The design and documentation of Electrical Instrumentation and Control System (EICS), for example that are required to operate an LNG plant and its associated infrastructure, are generated using Computer-Aided-Design (CAD). They are then issued in a paper format for contractors to prepare and submit a tender price for specific EICS workpackages.

A reliance on the use of CAD to produce documentation can result in errors, omissions and considerable information redundancy, which can hinder the ability of those who are contracted to deliver specific workpackages (Love et al., 2016a). As a result of errors, omissions and inconsistencies that may arise in the documentation created for construction, requests for information (RFI) are raised by contractors. A response to a RFI often requires amendments to documents, which are then re-issued to the contractor. In essence, this process continues until construction is completed and 'as-built' documentation is provided to the operator at hand-over. Seldom, however, does 'as-built' documentation reflect what has been actually installed. Moreover, the 'as-built' may be stored at locations that are inaccessible during operations (Gallaher et al., 2004; Love et al., 2013). This poses significant risks to operations and maintenance activities and may unnecessarily compromise the asset's integrity.

To address this problem, it is suggested that the traditional CAD process used to design and document EICS should be changed throughout a project's lifecycle by adopting an object oriented approach based upon a SIM. In this paper a case study is used to highlight the problems that materialized with the documentation that was produced and issued as the basis to upgrade the metering system of a domestic gas pipeline. The potential application of a SIM based upon the experiences from previous empirical studies in other sectors such as mining are drawn upon to demonstrate its effectiveness for use within the LNG sector. It is suggested that the digitization of EICS projects throughout their lifecycle, which can be enabled by using a SIM, will make a significant contribution to safeguarding assest integrity and process safety. It is particularly important to have access to reliable and accurate information for EICS as in they can represent 29% of the world's capital expenditure on plant within the hydrocarbon industry (Aveva, 2012). In addition, during operations, EICS typically account for 60% of maintainable items and are critical to safe and efficient operations.

There is limited research that has examined the nature of poor quality documentation and its impact on operations and maintenance within the process industries, particularly in the LNG sector (Love et al., 2016a). Additionally, there has been a tendency for operators to integrate and synchronize 'as-built' documentation with their asset management systems and inspection technologies. However, those who are charged with inspecting, repairing and maintaining assets are invariably confronted with incomplete and/or inappropriate information. Before decisions and sign-offs can be undertaken, the information must be sought, which, as noted above, can take a significant amount of time and therefore impact productivity and costs. For a detailed review of the issues surrounding the production of documentation, the management of information and creation of 'as-builts' in process related industries refer to Love et al. (2013, 2016a).

2. Research approach

To better understand the issues that confront the LNG sector, an exploratory case study approach was undertaken to analyze existing 'practice' and how digitization may lead to process improvement and ensure an asset's performance over its lifecycle (Yin, 1984). Research of this nature is dependent upon a variety of data sources, which is referred to as *triangulation* (Love et al., 2002).

Documentation provided by an EICS organization who adopted the role of 'off-site project management and technical support' afforded the researchers with documentary data juxtaposed with informal interviews and discussions, which were used to develop a narrative for the case study, as well as clarify issues raised by researchers. Data was collected and analyzed in the offices of the participating organization for reasons of commercial confidentiality. Data was extracted from numerous contractual documents such as the project's scope of work (SoW), Bills of Materials (BoMs), schedules, drawings, and Inspection Test Reports (ITR). A total of 12 unstructured interviews with EICS engineers ranging from 30 to 60 min and daily informal discussions over a two month period were also undertaken to provide a context to the documentation that was made available to the researchers.

3. Gas metering upgrade

The case study gas plant forms an integral part of Australia's largest oil and gas development. The gas plant produces LNG, domestic gas, condensate and Liquefied Petroleum Gas (LPG). The metering system for one of the pipelines, installed in the 1990s had four metering runs (i.e. utilizing ultrasonic flow meters), but only two were utilized for tariff metering. Of the two remaining metering runs, the piping of one metering run had been demolished between its isolation valves and thus required a new one to be installed, while the other had been permanently removed. Considering the condition of the existing metering station, the new project required all metering facilities to be upgraded, which included replacing the Ultrasonic Flow Meter (UFM) spools as well as the associated instrumentation (e.g. pressure and temperature sensors).

The new metering system also required the supervisory and mass flow computers to be replaced, which were comprised of its own standalone metering network with connectivity to the site wide Distributed Control System (DCS) and remote customer Supervisory Control and Data Acquisition (SCADA) systems. In addition, the metering system's moisture (H_2O) and hydrogen sulphide