FEASIBILITY STUDY OF INSTALLING ONLINE VIBRATION MONITORING AND ANALYSIS SYSTEM IN AN LNG PLANT (GE SYSTEM1)

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ABSTRACT

The report hereinafter presents a feasibility research study on the implementation of online vibration monitoring systems using GE system 1 within the premise of gas plant. Vibration monitoring is the most effective condition monitoring technique to determine the existence, cause, and severity of excessive equipment vibration. The technique gathers vibration data from the transducers mounted on rotating equipment. This data is further analysed to detect and identify the causes of any abnormal vibration. This enables corrective maintenance to be executed in a planned fashion before any functional failure is realized. System 1 is GE Energy's original software platform for the real-time optimization of the condition monitoring tools, as well as occurrence diagnostics. It facilitates a predictive maintenance strategy by linking portable data collection instruments and permanent monitoring by vibration rack BN3500 and BN1701 systems in an integrated condition monitoring environment.

The gas plant utilizes a comprehensive data network to facilitate intercommunication between sub-systems, such as field measurement devices, control systems, and central monitoring equipment. The sensors and data acquisition system are installed on the chosen machine to collect the data remotely. It also enables the detection of damages as well as minimizes human interference. In the case of gas plant, the software elements or modules, communicate with each other over a Local Area Network (LAN), although Wide Area Network (WAN) and internet connections are also possible. The selected research is based on quantitative primary data collected from source. Based on the online survey, this data is analysed and the conclusion is that most of the respondents are satisfied with the proposed system in a gas plant.

CHAPTER 1 INTRODUCTION

1.1 Introduction

The study is aimed at conducting a thorough exploration of the critical aspects of implementing the online vibration monitoring system hence the focus of the study will be on the effectiveness of the GE system 1 continuous condition monitoring software in a gas plant. Principally, the study will underscore comparative performance of the offline and online condition monitoring system. It should be noted, at the earliest opportunity, that the study is purely meant for feasibility of implementing the said system by measuring its operational effectiveness. Notably, the BN (3500 & 1701) system provides online monitoring suitable for machinery protection applications and it is designed to meet the requirement of the gas plant. Suryadevara and Mukhopadhyay [20] commented that Bently Nevada is intended to give a cost-effective improved path for a legacy monitoring system. The target of this project is to scope the requirements of connecting the Bently Nevada racks to the online System 1 Framework to enable centralised continuous vibration monitoring and analysis of all Bently Nevada modules at the gas plant.. It is a condition monitoring solution that comprises the protection of heavy machinery and complete access to vibration, temperature, and procedural data required for efficient machine condition monitoring within the System 1 software.

After accessing the data, the software provides the required navigation and scheming tools that a system analyst needs to identify any suspicious machine condition [17]. The 3500 system provides complex vibration waveform information to the condition monitoring software, which enables the system 1 decision support software to identify faults in the machinery in the real time for vital consumer assets. The degree to which acquired data is analysed at the gas plant depends on the criticality and type of monitored equipment [43]. It is envisaged that criticality level-A and level-B machines on the gas plant will be continuously monitored for vibration data using an online condition monitoring system.

1.2 Acronyms and definitions

ACRONYM	DEFINITION
BN	Bently Nevada
BOG	Boil-Off Gas
CAR	Central Auxiliary Room
CCA	Central Control & Administration Building
DAQ	System 1 Data Acquisition Software
CMMS	Computerised Maintenance Management System
DCS	Distributed Control System
FAR	Field Auxiliary Room
FOBOT	Fibre Optic Break-Out Tray
GTG	Gas Turbine Generator
HMI	Human Machine Interface
IS	Information Services
LAN	Local Area Network
MRP	Media Redundancy Protocol
OF	Optical Fibre
PDU	Power Distribution Unit
PMS	Power Management System
TIAC	Turbine Inlet Air Chilling

TCP/IP	Transmission Control Protocol/Internet Protocol
VLAN	Virtual Local Area Network

1.3 Background of the research

The research reflects on connecting Bently Nevada vibration racks with the GE System 1 monitoring software to enable continuous monitoring. The System 1 software designed to help in the optimization of equipment, condition monitoring, and event diagnostics [18]. The client-based architecture is scalable and flexible. The System 1 software is integrated into a single system with a common database structure. Notably, the connection of Bently Nevada with the System 1 platform enables the mechanical reliability and process engineers, operators, and other plant personnel to identify and respond to events in order to optimize the business impact [27]. The existing Bently Nevada 3500 system is represented over 50 years of the Bently Nevada machinery protection [45]. Best practice machinery is built on highly flexible as well as scalable rack based platform. Furthermore, the current 3500 systems were unrestricted as it includes a little subset of observe versions, which subsists today [19]. The initial release is focused on giving advanced, stretchy, and dependable vibration data based on the machines' protection obtainable at the time. It also provides simple and critical protection to machinery from catastrophic failure, which results in environmental safety concerns and significant loss of production.

1.3.1 Common major safety issues in an LNG Plant

The cost of downtimes due to unprecedented shutdowns and poorly scheduled maintenance program are among the leading causes of cost overshoots in the gas plant. Notably, compressor failures, for instance, can lead to production loss up to

AUD5 million/day. Yun [39] argues that extraordinary operating conditions of the compressor are to blame for the operational disruption. Predisposing conditions such as blocked heat exchanger surfaces may pose great safety risk to the system and the operators at large; normally, it will translate into systemic heat overload and thereafter pressure overloads. Besides, uncontrolled release of pressure energy (due to internal overbearing pressure) can result in punctures, lacerations, crushing and even death. Furthermore, parts of the equipment could also be propelled over great distances, causing injury and damage to people, the environment, and buildings hundreds of metres away. In a nutshell, should the due safety procedure not be followed to the letter, certainly, the following Specific HSE hazards associated with turbine/compressor area could result:

- High pressure feed gas and liquid streams jetting to the furthest distances thus causing injuries not only to the plant operators but the neighbouring buildings
- Low temperature streams and equipment – Cryogenic Processes
- High temperature streams and equipment mainly due to heat exchanger failure can cause unprecedented explosions and ultimately fires
- Noise leading to permanent hearing damage to the gas plant operators
- Rotating equipment under catastrophic failure conditions implicitly may eject high kinetic energy shrapnel
- Nitrogen liquid leaks due to the cracked vessels causing harm
- Mineral and synthetic lubrication oils leaking and causing harm
- Leak of flammable gases from piping and joints causing fires

1.3.2 Current site issues without online condition monitoring (CM)

There are frequent Emergency Shutdown System (ESD) trips caused by package heavy equipment failures. Further, inadequate failure analyses are conducted. (Offline vibration data collection only ever gives a snapshot in time of machinery performance)

The largest cost of continuing with an offline vibration data collection program is labour. Contractor charge-out rates depend on the experience of technical and engineering personnel performing data collection.

Offline data collection also demands a quantifiable amount of operator time, due to permit approval and facilitating unit changeovers. Indeed, a Permit to Work is required for each data collection route undertaken by an engineering technician. As well as consuming the technician’s paid time, this also consumes the resources of the permit authority

High site occupancy rate due to the manual data collection. The amount of time taken to collect data from BN racks for the various equipment types is estimated as too high. Regardless of equipment type, data collection occurs on a two-monthly cycle.

1.4 Research aims and objectives

The aim of the research study is to provide the gas plant leadership with a detailed overview of the available options and technical considerations for end-to-end connection of all currently installed BN racks to System 1 condition monitoring software. This research looks at Virtual LAN (VLAN) approach as one possible implementation of a gas plant BN condition-monitoring network. The configuration uses a partitioned VLAN over the existing Ethernet and optical fibre network. It catalogues the quantity and configuration of Bentley Nevada units on the gas plant, and the equipment they are monitoring. It also blueprints the location of all BN units on gas plant such as main substations, compressor substations, loading substation and correlating them with the major fibre links on the plant. The analyst designs an optimized network topology to connect BN units to the System 1 servers, which minimizes cost and maximizes redundancy. It determines the hardware requirements of interfacing Ethernet/IP communications with fibre protocols, including switches; patch panels, and jumper cables.

According to the aim of the research study, research objectives are recognized so that further incursion of the study topic is taken into consideration. After analysing the research objectives, the study topic is enabled and allows categorizing the broad topic into suitable forms. The list of research objectives are as follows:

- To analyse the Benifits of integrating the Bentley Nevada vibration racks to the GE system 1 condition monitoring software to enhance continuous date collection and vibration analysis.
- To establish the underlying cost benefits as a result of the implementation of the said system
- To quantitatively determine the cost of downtime in both events when the said monitoring system is fully operational and when it is offline.
- To estimate the mean-time between failures for both events (mentioned above).
- Improve safety by reducing unnecessary occupancy rate (This is to avoid fatality due to any unpredictable event on site)
- Survey of employees regarding the change in the system

1.5 Research questions

The research questions are approved to understand the research topic in a detailed manner. The research questions are helpful to collect relevant data on the selected topic. The following are the list of questions:

1. How can the integration of the GE System 1 online condition monitoring system will help to mitigate catastrophic compressor failure in the plant operation?

2. What are the options available to implement centralized continues monitoring system across the gas plant?
3. What are the perception and attitude of the plant operators, technicians and engineers for the change in the monitoring architecture?
4. What are the likely benefits to be realized as a result of the integration?
5. What critical components will ensure successful implementation of the upgraded system?
6. What parameters will dominate the reliability performance of the plant as far as the proposed monitoring system is concerned?

1.6 Research problem

Rotation of the equipment in a gas plant is critical due to the very high stored energy, and also the high capital and operating cost of the machines themselves. This requires monitoring to detect excessive vibration and before safety factors within the gas plant are compromised. Therefore, Bently Nevada (3500 and 1701) condition monitoring systems are used to detect and analyse the vibration of the machinery and equipment. As the system enables continuous vibration monitoring and analysing of all Bently Nevada modules, some commissioning and ongoing equipment failures occur in the system. Sometimes, the process of implementing such a condition monitoring system is expensive, and it raises the total budget and time of the research study. Therefore, this particular research conducts cost-benefit analysis to ascertain whether the capital and operational expenditure required for implementing an online condition-monitoring network would save money over the gas plant's operational life. In other considerations, the existing system was registering some systemic ambiguity during operations, hence there was need to propose a solution that would offer real-time monitoring and analysis support to be accompanied by timely preventive maintenance schedules. For example, the bearings (that are beyond reach) may overheat and become misaligned hence causing vibrations that can go undetected but ultimately could prove costlier if no system to offer real-time detection were integrated.

1.7 Justification for the research

This research is part of the concerted efforts to bring onboard the real-time solutions to the plant monitoring and analysis problems as registered earlier. It provides an opportunity to competently interrogate, in a scientific fashion, the effectiveness of the existing system and therefore seek alternative ways and means to close the systemic gaps. It should be noted that in a gas plant, safety is top priority; any lapse in safety systems will not only cause irreparable damages but may lead to fatal injuries to personnel. In order to support effective maintenance strategies in such a set-up, it is imperative to integrate state-of-the-art monitoring and detection facilities.

The research study is conducted to familiarize readers with the benefits of connecting the Bently Nevada vibration racks to the GE System 1 condition monitoring software. The benefits and advantages of this condition monitoring system are identified by doing a feasibility study on the gas plant. It enables a predictive maintenance strategy by linking portable data collection instruments and permanent monitoring by BN3500 and BN1701 systems in an integrated condition monitoring environment.

1.8 Methodology

The Methodology chapter provides detailed procedures and techniques used to choose and examine the information applied for understanding the subject of this study. It allows the reader to assess a study on the entire validity and dependability.

The Methodology chapter consists of two main sections: Data Collection and Analysis. For this research paper, the data was collected using the primary data collection method. Additionally, secondary sources were considered. The research methodology helps in comprehending the strategy adopted in identifying the benefits of connecting the Bently Nevada vibration racks to the GE system 1condition monitoring software in a gas plant.

1.9 Research outline

The research topic is divided into various sub-divisions and different chapters. In the Introduction chapter, the basic details related to research topic is discussed so that the reader can recognize the main argument of the thesis. The research study is then continued by aims and objectives, which assists in improved acceptance of the topic. In the Literature Review chapter, theories, as well as thoughts, are used to assist the analyst to appreciate the area of this research study. The author's arguments are critically analysed in own words to observe the pros as well as cons of the research topic. The Methodology chapter describes the rationale of the application for specific procedures and techniques used to choose and examine the information applied to appreciate the research related problem. In the data analysis and findings, the data is collected using the primary technique to generate accurate result based on the research topic. Finally, the Conclusion chapter gives an entire view of the study as well as its results.

1.10 Summary

The research study is reflected in a feasibility study on measuring the effectiveness of GE System 1 online condition monitoring software in the gas plant. It also summarizes the benefits of implementing such a system within the gas plant to reduce the maintenance cost and safety issues. The entire thesis report is to be divided into six different chapters namely Introduction, Literature Review, Methodology, Data Analysis, Findings and Conclusion and Recommendations.

CHAPTER 2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

Vibration-based analysis techniques can be widely used for condition based maintenance because vibration spectrum can be collected for all machinery which consists of rotating or moving elements. Vibration analysis is one among a number of techniques in condition based maintenance employed to monitor and analyze certain machines, equipment, and systems in a plant. Nevertheless, the prime notion behind the use of vibration analysis is to monitor rotating machinery to detect growing problems and to eradicate the possibility catastrophic failure. This is the most commonly used maintenance practice applied in strategic maintenance systems.

Spectral and time domain features are the main vibration signal analysis methods. Vibrations of machines usually result from dynamic forces due to moving structures and parts. Different machine conditions can be detected by identifying their corresponding fault symptoms, for example, mechanical vibration, changes in process parameters such as temperature, efficiency and air borne noise [40]. Detections in vibration analysis show a repetitive motion of the surfaces on rotating or oscillating machines. This repetitive motion may be caused by an unbalance, a misalignment, a resonance, electrical effects, rolling element bearing faults, or any number of other causes. To determine the current and future operating condition of the machine, it is vitally important to know the previous degradation pattern and the history of the machine. The major vibration characteristics of rotating equipment are displacement, velocity acceleration, Frequency, and phase angle [40]. In vibration spectra, “low” and “high” frequency ranges can be observed. The various types of vibration frequencies in a rotating machine are directly related to the geometry and the operating speed of the machine. By knowing the relationship between the frequencies and the type of defect, vibration analysts can define the cause and severity of faults or problem conditions. The low vibration range contains component frequencies produced by rotational motion (harmonics). While the high vibration range contains component frequencies resulting from the interaction between fluid-flow system and medium flow. In a power steam turbine, blade frequency range (the latter case above) is typically from a few hundred hertz to about 10–20 kHz, depending on the turbine design [40]

The 3500 System provides continuous, online monitoring suitable for machinery protection applications, and is designed to fully meet the requirements of the American Petroleum Institute’s API 670 standard for such systems. Due to stringent requirement in Oil and Gas industry especially in LNG, API standard is mandatory in term of Safety requirement.

Notably, this chapter serves to reinforce the adopted approach for research by identifying the existential gaps in the previous researches hence providing a fact-led architectural platform that was used to build on the study.

2.2 Conceptual framework for the research study

From the conceptual framework of this research study, it is seen that recent advancements within vibration monitoring and data analysis leads to the System 1 Condition monitoring software, which can accurately detect the problem before machine failure. It will reduce the number of shutdowns of costly machinery and maximize the production output in business operations of the any gas plant [13]. This type of system is installed on monitored equipment. It is networked back to a fundamental computer for breakdown of data with alarm management [1]. This set up is adopted for the gas plant. It will help to prolong machine life and optimize maintenance frequencies Wireless communication is one of the networking alternatives that reduces cost of installation, quicker deployment, and improved reliability.

The following figure displays the conceptual framework of the research study:

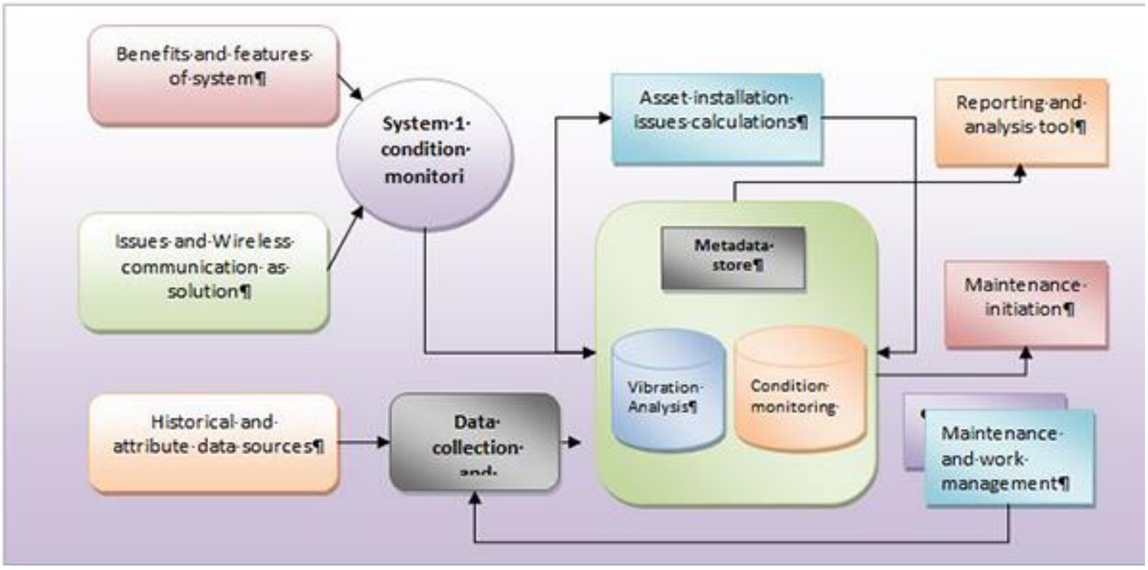


Figure 1 Conceptual framework of the research study.

(Source: [41], pp-1267)

2.3 Overview of the proposed system

2.3.1 Bently Nevada 3500

The GE Bently Nevada (BN) 3500 is a rack-based system that provides continuous online condition monitoring and protection of rotating equipment [4]. The system is highly modular, enabling customized functionality and integration with the gas plant equipment. Specifically, a BN unit can be configured with any combination of purpose-designed monitors, which plug into the rack's backplane, to record parameters such as radial and seismic vibration, eccentricity and differential expansion. Each module consists of a main module and an I/O module, which installs at the rear of the rack. The BN modules accept analogue signals from transducers mounted on the monitored equipment [24]. These signals are carried to their respective sensor units (which typically reside in a junction box near the monitored equipment) via coaxial cable. [21] discussed that from the sensor unit, the conditioned signal is carried to the input/output (I/O) module via a wire, which terminates either at the rack itself or at an external termination block, as shown in Figure 2.

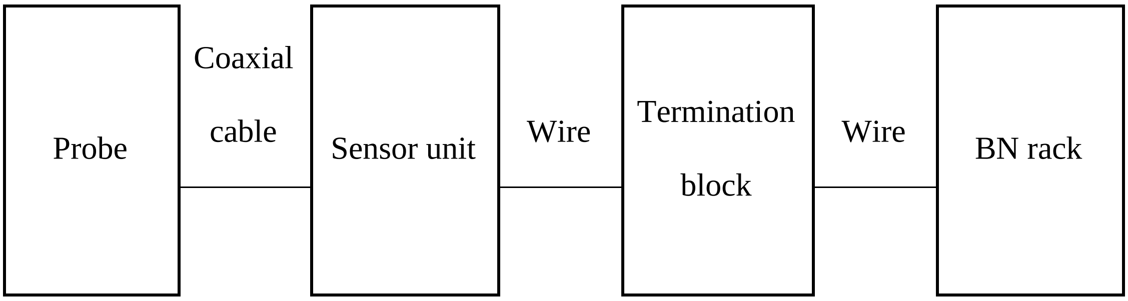


Figure 2 Data flow from BN probe to BN rack.

(Source: Created by the author)

2.3.2 Bently Nevada 1701

The Bently Nevada 1701 'Field Monitor' is a machinery protection system capable of measuring shaft radial vibration, axial thrust position, and seismic vibration using either acceleration or velocity transducers [15]. At the gas plant, the BN1701 units are used solely to monitor the vibration of the six gas Turbine Generators (GTGs). Specifically, there are two BN1701 units per GTG located in the main substations. BN1701 units are much lower profile than BN3500 racks, and can be skid mounted or mounted on a DIN rail within a cabinet. The 1701 system consists of a terminal base where monitor cards and peripherals are mounted. The base accommodates a single power supply, 4 dual-channel vibration monitors (each having an associated transducer I/O module), one Keyphasor input module, one 1701/22 Management Interface Module, and I/O terminations for up to 9 externally-wired transducers [17].

2.3.3 System 1 condition monitoring system in gas plant

While standalone BN3500 and BN1701 systems provide continuous automatic shutdown protection of monitored assets, they do not provide any visibility of data for diagnostic or trending evaluation. According to [32], for this reason, the BN systems also serve as a gateway to the GE's System 1 software platform. System 1 is GE Energy's original software stage for the real-time optimisation of machinery, condition monitoring, and event diagnostics. It enables a predictive maintenance strategy by linking portable data collection instruments and permanent monitoring by BN3500 and BN1701 systems in an integrated condition monitoring environment [7]. The 3500/22M and 1701/22 data interface modules provide Ethernet ports for connecting the BN3500 and BN1701 systems to a server computer running System 1 software over a LAN.

The GE System 1 also interfaces with many of today's most typical computerised protection administration software, computerised maintenance management system (CMMS) packages such as SAP, Meridium, and IBM MAXIMO [27]. In the gas plant the System 1 software will interface with the CMMS.

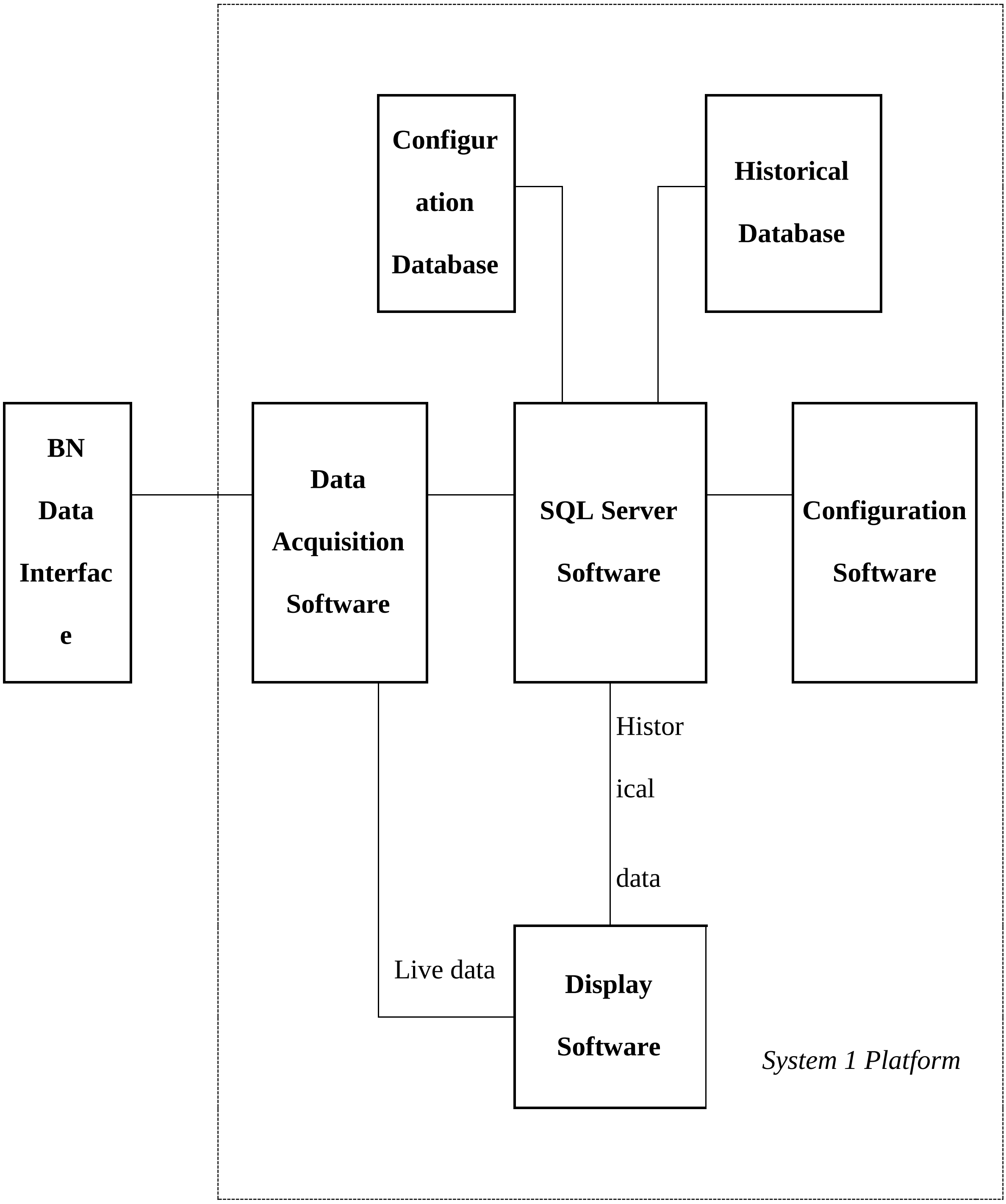


Figure 3 Principal System 1 software components and data flow paths.

(Source: Created by the author)

[31] pointed that the System 1 platform also installs a set of utility applications. One such application is the Transient Data Manager Initialisation utility, which is used to configure the 3500/22M and 1701/22 communications modules.

Using this utility, IP addresses, Keyphasor transducer parameters, and other operating conditions are established. There are two major System 1 distributions on offer from GE [23]. System 1 Classic, which is the platform that GE has implemented for their refrigerant compressors, is the legacy version, and will ultimately be discontinued by GE in favour of System 1 Evolution. For the purpose of this scoping project, System 1 Classic will be used.

[38] discussed that in the long term, it is the intention to use System 1 Evolution as the central platform for vibration data storage, analysis, and monitoring at a gas plant. This platform will be integrated with Meridium and CMMS with the verification and uploading of data performed by qualified personnel. System 1 Evolution is offered in two packages; fundamental and premium. The Fundamental Package is the base level package designed to operate with supported portable vibration analysers. The Premium Package integrates with both Portable Vibration Analysers. GE, using a points system where points are calculated from the number of equipment probes, issues system 1 Software licenses and associated costs.

[37] stated that the System 1 condition monitoring software represents Bently Nevada leader online condition checking arrangement with integration to the business driving line of online apparatus assurance and condition monitoring devices. Bently Nevada gives adaptable arrangements ranging from delivery of product from conveyance of item with flexible solutions with deployment services to finish arrangement scope through supporting administration understanding. The System 1 software represents an approach to providing the clients with particular ecosystem for plant-wide equipment administration. Using the System 1 condition monitoring software provides the following advantages:

- Capability: [34] stated that the premium package of System 1 condition monitoring software is most beneficial in its aid for prioritization of work, database management and diagnostics. It provides high-resolution trend, alarm, and start up data. It reports the diagnostic data.
- Accessibility: Flourishing condition monitoring programs require association between departments and prescribed access to the tools. It has access to remote transferable data transfer and user safety profiles.
- Embedded expertise: The vibration monitoring is differentiated by giving focused equipment explanations as well as best observe configuration [2].

[38] Investigated that all power-generating units consist of machinery that causes vibration at the time of rotating the machines. It creates huge vibration in the gas plant, which needs to be monitored. The machinery is monitored with an installed condition monitoring system in order to conquer the vibration problems within the machines. The most of the gas plants are monitoring their machinery on a cyclic basis using the moveable data collector and a database program [27]. The monitoring system consists of medium and large steam turbine generator, which is defined as Turbine Supervisory Instrumentation (TSI) system [31]. It consists of radial displacement vibration as well as axial position dimensions, which are connected with the high speed of rotating machinery. Periodic monitoring provides an extremely cost-efficient solution for the gas plants. It is due to a large number of positions to monitor every month, usually 700 or 800. Still, some of the gas plants have moved their measurement points on periodic monitoring to continuous monitoring [44]. This has achieved a superior standard of maintenance, better machine operating condition and personnel safety.

Hardware configuration

There are two practical approaches to facilitate a connection between the Bently Nevada units and System 1 software, both having their own advantages and disadvantages. These are:

- Utilizing a VLAN configured over existing (already patched) optical fibres.
- Configuring a dedicated BN condition monitoring LAN using spare optical fibres.

The following sub-sections discuss the key hardware requirements for implementing a dedicated BN condition monitoring network. In addition, LAN and VLAN network architectures are proposed, including their hardware configuration requirements and discussion of their relative pros and cons.

2.3.5 Network hardware requirements

Network switches

Network switch is a device that uses packet switching to send and receive data between devices connected on a computer network at the data link layer (layer 2 of the OSI model). Devices are uniquely identified by a MAC address. The make and model of the network switch required to implement a condition monitoring network depends on the network architecture (VLAN or LAN), location of the switch, and the type of media that it must accept. Future expansion must also be considered when designing a condition monitoring network. Indeed, projects to install Wi-Fi access points in substations and connecting programmable logic controllers (PLCs) to the CCA via are at varying stages of planning. For this reason, larger switches with spare ports are preferred over smaller devices in locations.

The network switches in telecom racks within substation buildings are Cisco Catalyst 3750-X rack-based managed switches. These devices can be configured with a range of optical fibre and UTP port types and densities. The model found in CCA and substation cabinets is the 3750-X-24PS switch, which offers 24V DC Power over Ethernet (PoE) enabled ports, as well as a network module with four 10 Gigabit Ethernet fibre optic ports . The 3750-X switches also support a number of Cisco's proprietary VLAN configuration protocols. All ports on existing 3750-X switches at gas plant have been configured for VLANs by IS, and so cannot be configured for an otherwise unmanaged LAN. Therefore, new and existing 3750-X switches can be used in a condition monitoring VLAN.

A different approach is needed to implement a condition monitoring LAN. As the BN units are located in non-standard equipment enclosures rather than 19 inch racks, it makes practical sense to use DIN-mounted switches to permit shorter cabling. Hirschmann RS20 series DIN-mount managed switches are used in Upstream Operations (USO) to add connectivity to equipment packages, and have also been used to facilitate fibre to copper conversion in the GE BN network on gas plant. Due to their proven track record and for consistency with other areas of the business, RS20s are a better option. Like the 3750-X switches, RS20's are available in a range of copper and fibre port densities. To sensibly construct a condition monitoring LAN, certain locations also require network switches with > 2 optical fibre ports.

Rack and enclosure space

The network hardware in gas plant substation buildings is housed in APC NetShelter SX equipment racks, which are industry standard 19-inch in width and 42 Rack Units (RU) in height. BN racks are either panel mounted or bulkhead mounted in non-standard equipment enclosures containing other control and monitoring hardware. If the DIN mounted switches and power supplies must be installed to provide connectivity to a BN rack, they should be mounted as close as possible to the unit (Marwala, 2012).

Power Supply

[31] reflected that a power supply unit (PSU) must accompany the installation of any new network switch to supply and regulate the voltage required by the device. For rack mounted equipment, Power Distribution Unit (PDU) rails are fitted in the rear of all 42RU racks. They are rated to supply up to 10A at 230V, and accept a C14 input plug type, while outputs are C13 type receptacles [14]. DIN mounted network switches demand a DIN mounted power supply. A range of these power supplies are used across the gas plant, from suppliers such as Phoenix Contact and Traco Power [33]. As shown in Table 1, Phoenix Contact QUINT-PS/1AC/24DC/10 have been used for the existing GE BN network to power Hirschmann network switches, so it is suggested that these also be used to supply DIN mounted switches in equipment racks.

Table 1 DIN mounted equipment in rack 33CPW-CAR-07 in the CAR.

Phoenix Contact QUINT-PS/1AC/24DC/10 Power Supply Unit	
Input voltage range	100V AC – 240V AC
AC Frequency range	45Hz – 60Hz
Output voltage	24V DC ± 1%
Output current (rated)	10A
Output power	240W
Connection method	Pluggable screw connection

(Source: [33], pp-7139)

[5] discussed that the Phoenix Contact PSU accepts screw terminal connections from 2.5mm2 wire. Depending on their location, equipment enclosures may have access to a variety of power incomers, ranging from essential, non-essential, and UPS supplies. In all cases, the DIN PSU will be powering a single Hirschmann network switch, ranging from 4-port to 16-port models. Even though all ports utilized power on the 16-port switch, maximum power consumption is just 11.8W, so the switches will draw near-negligible current from the enclosure feeder [29]. Thus, while power feeders to the PSUs should be chosen to minimize the impact on other critical loads, the load being added is very small.

VLAN Approach

A VLAN is a set of devices on the LAN that are configured to converse as if they were fixed with the same wire, when they are located on various number of the LAN segments. One possible implementation of a GAS PLANT BN condition monitoring network is to configure a partitioned VLAN over the existing Ethernet and optical fibre network. The condition monitoring VLAN will utilize dedicated ports on existing and new network switches to connect BN units via a VLAN trunk to a switch in the CCA telecom room. This VLAN configuration can be done remotely at a software level by Information Services (IS), meaning the only spare optical fibres required are those needed to connect to BN racks without network switches within physical proximity (i.e. TIAC Buildings and Regeneration Gas Compressor Packages).

For BN units in the Main Substations and Loading Substation, the physical network connections needed to connect to System 1 servers via a VLAN. In general, a new CAT5e Ethernet cable is needed to connect each BN rack to the nearest network switch. In case of the GTGs, the BN1701 units in the main substations require a DB-9 to CAT5e Ethernet cable.

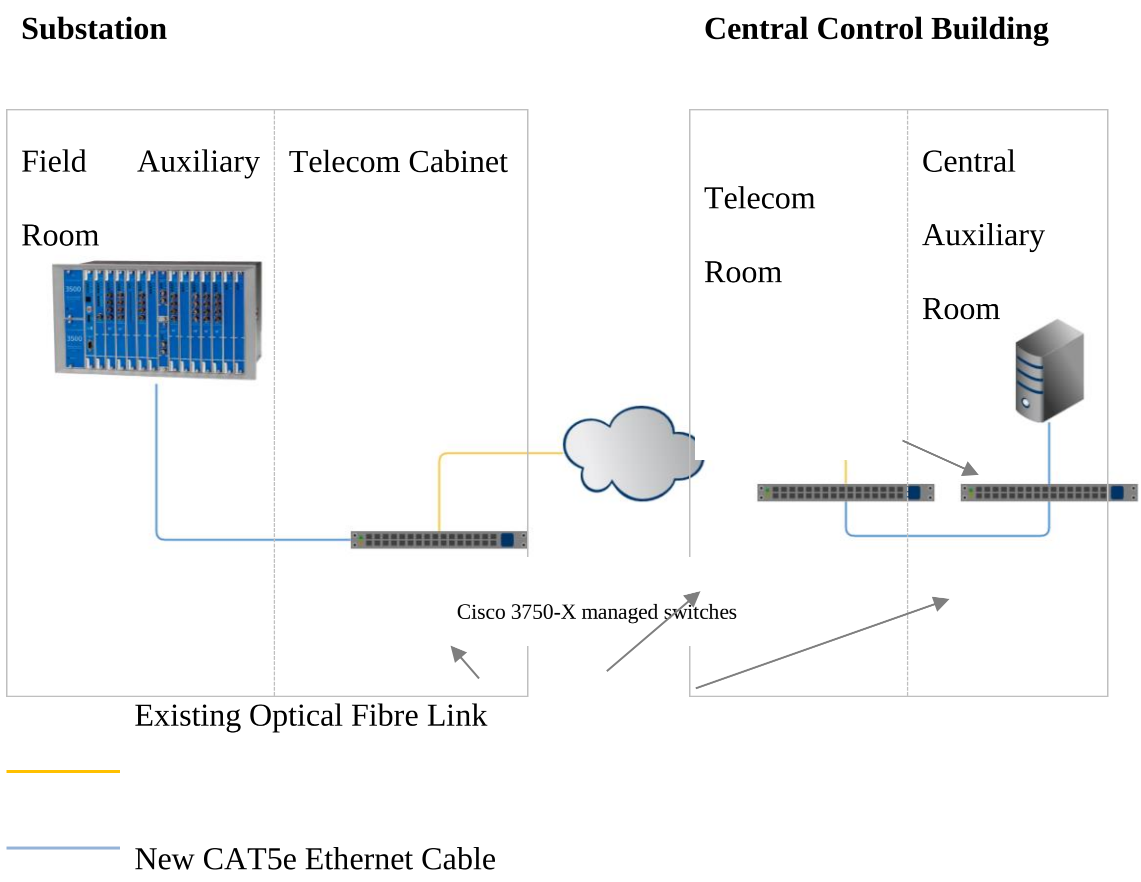


Figure 4 VLAN approach to connect a single BN unit to the System 1 server.

(Source: Created by the author)

VLAN switches in substation buildings and CCA are Cisco Catalyst 3750-X Series devices. Siemens RUGGEDCOM RSG2300 switches are used in the TIAC buildings for the IEC 61850 Power Management System (PMS) network, and MOXA EDS managed switches are located on the regeneration gas compressor packages. However, IS has no visibility or control over these devices, so they cannot be configured for a dedicated vibration monitoring VLAN. As the Cisco 3750-X switches are rack-based, they cannot be installed at the regeneration gas compressor package or in TIAC Buildings. [31] suggested that a DIN-mounted network switch be used to attach the BN rack to the nearby fibre patch panel. From the patch panel, spare optical fibre will be used to connect to a Cisco 3750-X network switch in the nearest substation. In case of the regeneration gas compressor packages, this is the Propane Substation, while BN3500 racks in the TIAC buildings should be connected to network switches in the Compressor Substation.

As part of the Ebara transfer and loading pumps package, the two 3500/22M Transient Data Interface modules in loading substation cabinet 33/34CPV-MMS-01 are already connected to a Sixnet SLS-5ES-3SC unmanaged network switch. [25] stated that the model of network switch to be installed at each location depends on the number of devices that connect to it. A Local Area Network is simply a group of interconnected devices within physical proximity of each other. As distinct from a VLAN, communication between devices on a LAN occurs on a dedicated channel, without sharing resources with other networks. In case of a GAS PLANT, this interconnection is facilitated by patching spare optical fibre from the location of a BN unit to the CCA building (in some cases via an intermediary network switch). Its concluded that it requires converting the UTP connection from the BN unit to fibre using a fibre enabled network switch, and back to a UTP connection at the switch in the CCA building, as shown in Figure 5. In essence, there is a ‘single path of light’ between each BN rack and the CAR.

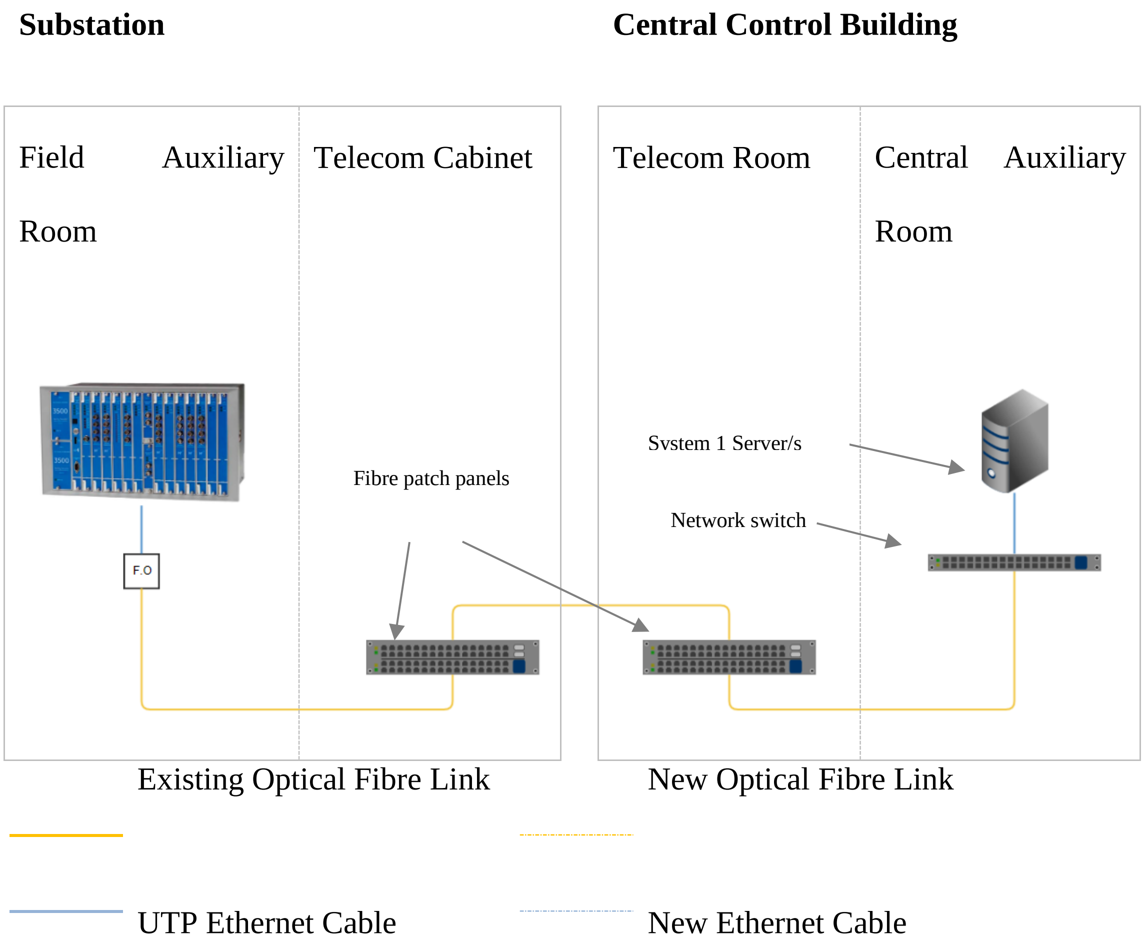


Figure 5 LAN approach to connect a single BN unit to the System 1 server.

(Source: Created by the author)

BN racks located in the TIAC buildings and regeneration gas compressor package will connect directly to the CCA via a dedicated fibre optic cable. BN racks in the Main Substations and Loading Substation will connect to a network switch in their respective buildings, which will in turn direct their data to the CCA. The distinction between connection types is made, which shows the proposed fibre optic cable architecture connecting the BN racks to the telecommunications room in the CCA.

2.3.7 Software Configuration

In addition to the investment in hardware, all BN units and System 1 servers must be appropriately configured at the software level to facilitate interconnection between the field and CAR. In general, the steps that must be taken to configure the BN racks and System 1 software are well documented by GE. Useful documentation includes:

- 3500 Monitoring System Installation Manual (Revision E)
- System 1 Classic Installation Quick Start Guide (Revision NC)

BN3500 software configuration

Table 4 outlines the software contained on the 3500 Monitoring System Rack Configuration Software DC.

Table 2 DIN mounted equipment in a 19 inch rack in the Central Auxiliary Room.

Rack Configuration	**Tool for setting the operating parameters of modules in each 3500 monitoring rack**
RIM Host Port Test	Tests the output of the Configuration Port on the Rack Interface Module (3500/22M) and the Host Connector on the Rack Interface I/O Module.
Communications Gateway Port Test	Tests the host and rack ports on the Communication Gateway I/O module.

(Source: [22], pp-854)

As all the BN racks on the gas plant are operational, their rack configurations, alarm set points, and alarm drive logic for relay channels will already have been configured. However, to enable a network interface to the BN racks via the 3500/22M Transient Data Interface (TDI) module, the racks require additional configuration. This will involve connecting a laptop computer directly to the TDI module's configuration port via an RS232 cable. After a rack is configured to communicate over a LAN, subsequent re-configurations can be made remotely over the network connection.

The process of configuring the 3500/22M TDI module is described in Section 3.3 of the 3500 Monitoring System Installation Manual. It permits the user to set up the rack IP address and subnet mask; a rack network device name and a connection password. Once a 3500 rack has a network connection to a DAQ Server and software, it will be visible to configure via System 1 software [29].

2.3.8 BN1701 Software Configuration

System 1 Configuration

This section provides an outline of the System 1 setup process Within the System 1 Configuration Software, each BN3500 and BN1701 Monitor Rack, monitor, and channel must be configured in an Instrument Hierarchy. [37] stated that each channel is linked to a sampler card in the 3500/22M or 1701/22 module. Once the online monitors are configured in the Instrument Hierarchy, each channel is then mapped to a measurement location in the Enterprise Hierarchy [28]. Measurement locations must then be mapped to a corresponding hardware device, so that the System 1 software knows where to find the data for that point. Online monitoring of machinery data requires the System 1 Data Acquisition software to be active 24/7.

Due to the complexity and scale of the System 1 platform, specialist GE technicians should be engaged to install and configure the System 1 software and servers.

2.3.9 Gas plant condition monitoring philosophy

Like any industrial plant, the gas plant facility contains a diverse range of assets that combine to provide a service; in this case the refinement and liquefaction of natural gas [42]. At the gas plant, condition monitoring and maintenance philosophies have been developed based on the criticality of the individual assets and their role in the overall process; namely, criticality level-A, level-B and level-C. It has also been widely suggested that one of the most efficient condition monitoring techniques is the vibration monitoring that can be used to determine the existence, cause, and severity of excessive equipment vibration. Monitoring is carried out by acquiring vibration data from transducers mounted on the rotating equipment and analysing this data to detect and identify the causes of any abnormal vibration [10]. These papers support condition monitoring as an effective tool for carrying out planned corrective maintenance prior to any functional failure is realised.

The degree of analysis of the acquired data at the gas plant depends on the criticality and type of the monitored equipment. Such equipment includes refrigerant compressor packages, gas turbine generator packages, LNG loading pumps, LNG transfer pumps, Boil-Off Gas (BOG) compressors, regeneration gas compressors, and Turbine Inlet Air Chilling (TIAC) package compressors. Besides, as stated that online vibration monitoring systems use permanently installed transducers, data processing, and data storage systems. The advantage of online monitoring is that the data can be constantly measured and compared with alarm threshold values, and trended for emerging faults [31]. It is envisaged that criticality level-A and level-B machines on the gas plant will be continuously monitored for vibration data using an ‘online’ condition monitoring system.

All offline monitoring system requires manual collection of data on a periodic basis. An offline system consists of a portable vibration data collector/analyzer and a central data processing and storage system. Offline data collection is used for all equipment other than criticality level-A. In the gas plant GE refrigerant compressor packages (including turbines, gearboxes, and compressors) are criticality level-A. All criticality level-B equipment will also be monitored online. All lower criticality equipment will be on run-to-failure or proactive maintenance strategies to optimise maintenance costs.

2.3.10 Existing Systems

Condition monitoring procedure

The current procedure for the collection of vibration data involves manual data logging with BN SCOUT portable vibration analysers. The work orders (WOs) for the scheduled data collections are generated by Oracle eAM (GAS PLANT’s CMMS), and clearly define the measurement points and vibration parameters to be collected. The vibration measurements will be taken by an externally-contracted vibration technician. After the collection process, the measurements will be uploaded to the System 1 Evolution software (which has native support for BN SCOUT portables) for analysis and exception reporting.

Labour time and cost

The largest cost of continuing with an offline vibration data collection program is labour. Contractor charge-out rates depend on the experience of technical and engineering personnel performing data collection. Hourly rates are shown in Table 3.

Table 3 Contract engineering support labour charge-out rates.

Labour Rates	Hourly Rate (Excl. GST)		
	Normal	Overtime	Weekend & Public Holidays
Technician Personnel			
Technician	$126.70	$151.40	$196.70
Senior Technician	$139.10	$166.80	$216.30
Engineering Personnel			
Engineer	$139.10	$166.80	$216.30
Senior Engineer	$183.90	$221.10	$283.90
Principal Engineer	$232.80	$279.10	$356.40
Specialist Principal Engineer	$315.20	$378.00	$481.00

(Source: Created by the author)

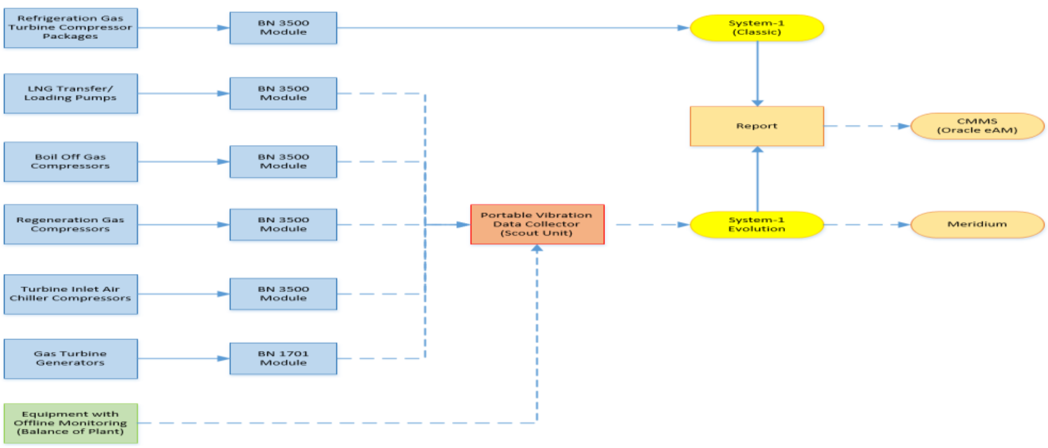
While senior engineers will be involved in the early stages of establishing and refining data collection routes and procedures, data collection in the long term will be performed by vibration technicians. Staff will perform data collection across two-week shifts, including weekends. Taking the charge-out rate of a senior technician to be indicative of the labour costs over LNG's operational life, adding 10% for meal and accommodation allowances, and 10% for GST, the average labour hourly rate is calculated to be:

Average hourly rate = (5/7 × $139.10 + 2/7 × $216.30) × 1.1 × 1.1 = $195.00

Table 4 Time allocation for vibration data collection by equipment type.

Equipment	Equipment Units	Collections per year	Collection duration	Collection hours per year
GTGs	6	6	2	72
BOG compressors	3	6	2	36
Regen. gas compressors	2	6	2	24
TIACs	8	6	1	48
LNG Loading pumps	8	6	0.5	24
LNG Transfer pumps	4	6	1	24
			Total Hrs	228

(Source: Created by the author)



Note:

/online connection

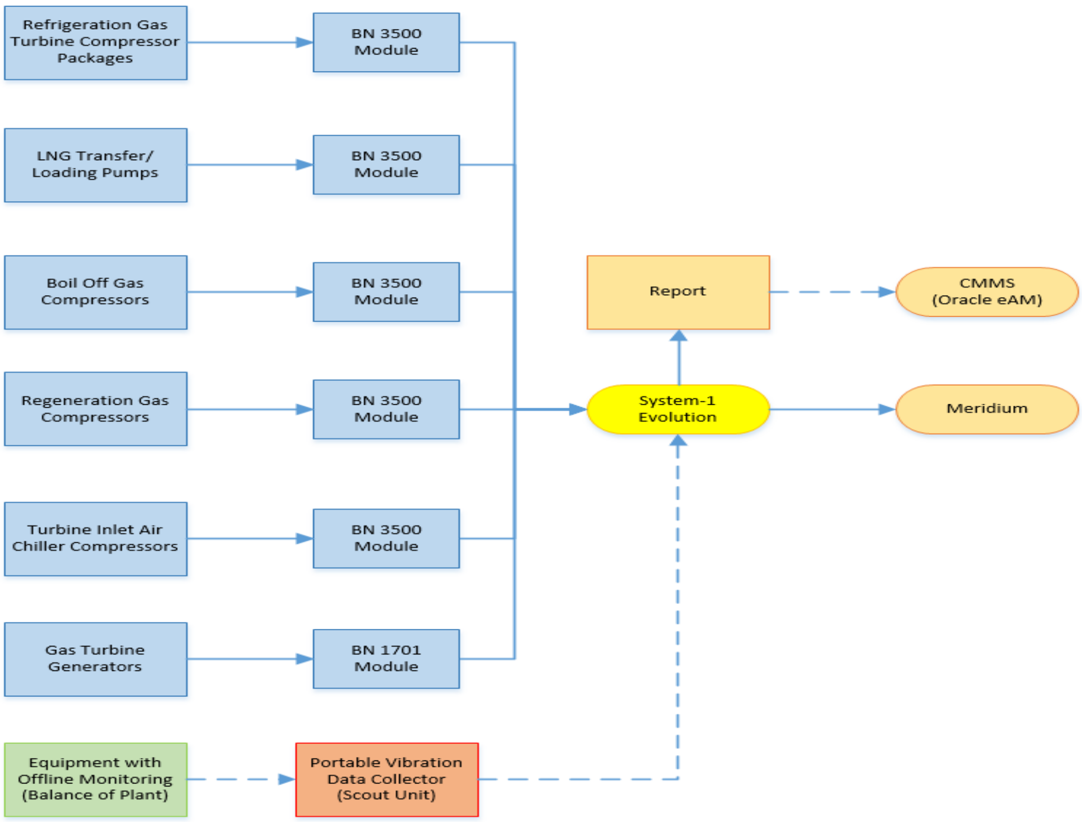
Manual/offline connection

Figure 6 Current 'semi-online' vibration data monitoring strategy used in the gas plant.

(Source: Created by the author)

2.3.11 Desired System

All high-criticality equipment on gas plant will migrate to a completely online condition monitoring strategy in the near future. This will eliminate the need for manual data collection from BN units using portable devices. Instead, vibration data will be transmitted from BN units across the gas plant data network, so it can be stored on System 1 servers and trended to enable predictive maintenance.



Note:

/online connection

Manual/offline connection

Figure 7 Desired 'fully-online' vibration data monitoring strategy.

(Source: Created by the author)

2.4 Features of the System 1 condition monitoring software

System 1 condition monitoring is implemented within the gas plant for low-speed machines as they are large and it consists of high rotating inertia. In most of the low-speed machines, bearings are the critical component, which are required to be monitored. [30] researched on identifying the rolling element bearing which faults by means of the vibration analysis. When the machine is at a slow speed, the impact energy between the rotating parts and defects is low. It is identified through the use of vibration transducer.

Sophisticated alarm management: System 1 allows management by exemption with alarm handling abilities for the gas plant. It ensures that at the time of any issue and problems the alarm will ring.

- Analytic and diagnostic capabilities: The data is manipulated using library tools and functions. The data is analysed in the spreadsheets. Advanced plot management tool like plot grouping are used to generate, duplicate, keep, and access plots of ordinary interest.
- Resolution of storage: The data is stored and captured in a configurable for each point. It is stated that when machinery is monitored, there is a high risk data theft and access to data by any third party users [19]. Therefore, it will securely give resolution to storage of monitored data.
- Customizable display: [16] stated that the users of System 1 can configure the display capabilities and ensure that the assets and portions are relevant as presented.
- Support for Virtual private network technologies: The corporate network accesses most of the VPN technologies without affecting the security of the data. The System 1 condition monitoring should support technology and provide remote access capabilities.

2.5 Improvement in safety issues by using System 1 condition monitoring system

Condition monitoring (CM) is referred to monitoring key parameters as well as indicators of equipment condition in the gas plant. It is used to analyse health of the machinery to make improvement in the safety issues. Jung and Bae (2015) investigated that due to the implementation of this system in a gas plant, the machinery stops safely and prevents the machinery from stopping abruptly. Therefore, fatal accidents and injuries are reduced that are caused by the machinery. CM system is used manually by different diagnostic checks such as levels and kinds of dissolved gases, checking of gas pressure and timing and operating checks of the machinery. [36] Suggested that use of online monitoring system is achieved with the use of sensors and devices. This online system is more advanced and, therefore, it is continuously grown as new ones in the developed market.

[30] reflected on some of the experiences, which are gained due to the use of online, monitoring devices are gas in the monitoring of oil, monitoring of temperature and moisture of the gas plant. According to [32], the online monitoring is continuous, and it picks up vital issues before traditional diagnostics, and it is used to attain business benefits within gas plant. The condition monitoring system is implemented using integrated approach by working with commercial equipment suppliers [11]. An integrated approach is used to provide reliable as well as comprehensive solutions required by the industry. [20] investigated that there are four condition monitoring techniques such as vibration, offline analysis of oil sample, acoustic emission, and offline real time lubricant condition monitoring.

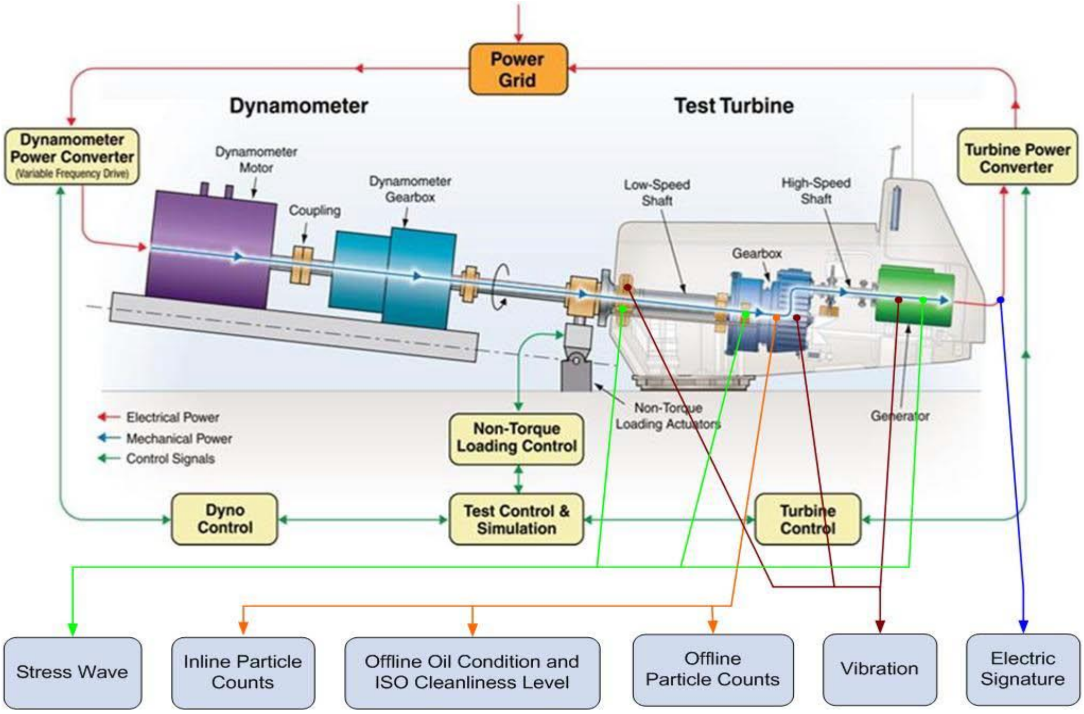


Figure 8 Implementation of condition monitoring system.

(Source: [46], pp-263)

The following table describes the improvements achieved in safety issues by using system 1 condition monitoring system

Table 5 Improvement in safety issues by use of system 1 condition monitoring system.

Improvement		Methods by which condition monitoring improves safety issues	
		Lead time	**Better knowledge of machine**
Safety	Reduction in number of injuries as well as fatal accidents caused by machinery	It enables the gas plant to be stopped safely while instant stop of the machinery is not possible.	If instant shut down of the machinery is permitted, then the condition of the machine is indicated by the alarm.
Output of using system 1 condition monitoring system	It increases the running time of machinery.	It enables the machine to shut down for required production. It losses unexpected shutdown of the machines.	It allows time between planned machine overhauls to maximize.
	It reduces maintenance time of machinery.	It enables the machine to shut down without destruction. The maintenance team is ready with spare parts of machinery so that they can work on maintenance when the machine is shut down.	It reduces the time of inspection after the shutdown. It speeds up the start of the machine.
	Improvement in quality of	It allows planning to reduce the breakdown of	It gives high quality product and services.

	products	machinery. It also reduces the time to work on customer's complaints, and it enhances the reputation of the company.	

(Source: Created by the author)

2.6 Improvements in production loss and maintenance issues by using System 1 condition monitoring system

The online condition monitoring systems are particularly helpful in the heavy industry where 24 hr production is maintained.

Result of frequent mechanical failures across the paper mill, Alma Paper Mill, Quebec, Canada conducted bearing seize and bearing fault case study. An effective solution to a mill's maintenance problems is to operate a programme where the condition of the machines is measured, and maintenance is carried out based on these measurements [47]. Vibration monitoring of rotating machinery is considered as the best method of determining a machine's condition. This allows repair to be carried out only when the measurements indicate that the condition of the machine is deteriorating, and maintenance to be scheduled well ahead of time [47]. In this way unexpected breakdowns are avoided and machine running time is maximized. Based on the case study recommendation, the paper mill management decided to install an online condition monitoring system in the mill.

2.7 Summary

The proposed system is used manually by different diagnostic checks such as stages, sorts of dissolved gases, examination of gas pressure, and time and in-service checks of the equipment. The vibration analysis leads to modern condition monitoring systems, which can progress the production of a gas plant.

Online condition monitoring also enables truly planned maintenance, meaning maintenance resources can be allocated more efficiently. For instance, servicing and part replacement can be scheduled in advance to minimise disruption to production and other parts of the operation. As a consequence, there are obvious and immediate efficiency improvements that come with migrating vibration monitoring to an online system plus huge cost savings.

High site occupancy rate will be reduced by the proposed online data collection. The amount of time taken to collect data from BN racks for the various equipment types is estimated as too high.

The online vibration monitoring system at the Alma Paper Mill, Quebec, Canada has shown itself to be a resounding success story. There have been no expected breakdowns on the monitored equipment since installation of the system. All problems have been detected by the system early enough to enable repair to be scheduled for a planned maintenance [47]. This record means that initial investment for the system and training has paid back.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

The research methodology chapter articulates the reasons for choosing a particular data collection procedure and technique for the survey. The chosen methods are appropriate to fulfil the aims of the research study. Use of the research philosophy helps in comprehending the strategy adopted in investigating the connection of the Bently Nevada vibration racks to the GE System 1 condition monitoring software. [12] pointed out that following a research methodology also limits some errors. In addition, the specialist has tried to be relevant at every step of the process of examination that can assist in an improved study of the benefits of connecting the Bently Nevada vibration racks to the GE System 1 condition monitoring software.

3.2 Research philosophy

The research philosophy is adopting important assumptions based on the selected research topic. [35] pointed that assumptions are required to conduct a research study for achieving a successful outcome. In part, the philosophy which is adopted, will be influenced by practical considerations. The critical thinking process is required to evaluate the selected research topic [5]. There are three categories of research philosophy: Positivism, Interpretivism, and Realism, as shown in the Figure 9.

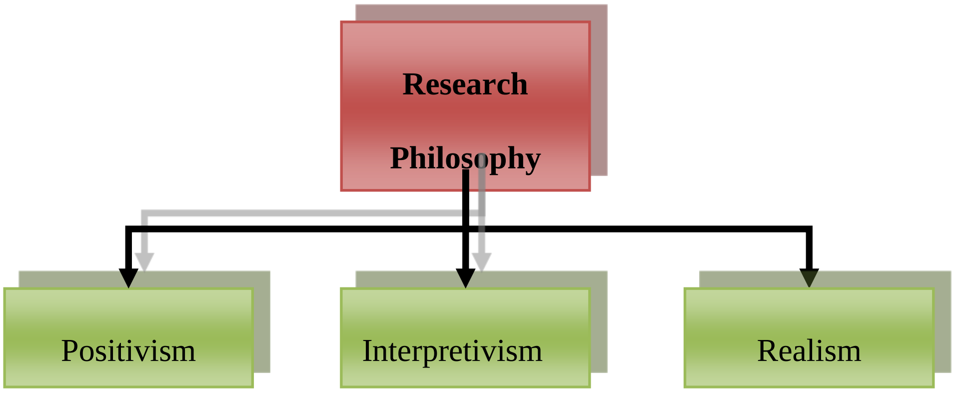


Figure 9 Three types of research philosophy.

(Source: [6], pp-178)

The three categories of research philosophy are described below:

- Positivism: It is a research philosophy that helps to build a logical statement of the research topic, which also helps to analyze the hidden facts and information. While using the Positivist approach, the research study is undertaken in a value-free way [26]. This philosophy uses a highly structured methodology to facilitate replication.
- Interpretivism: It is epistemological that supports the concept of complex structure of research studies.
- Realism: It is epistemological that relates to the scientific investigation. The Realism theory is related to the independence of the mind. It assumes a scientific approach to knowledge development [8]. The assumptions that are made underpins the data collection as well as an understanding of data.

3.3 Data Collection procedures and techniques

The procedure of data collection is an important aspect of this type of research study. A process is used to gather as well as measure the information based on the selected research topic [3]. In order to perform a feasibility study on the effectiveness of the System 1 software, the researcher should ensure that accurate as well as proper data collection methods are selected [9]. Selection of proper data collection method reduces the occurrence of errors. Also, accurate data ensures that the collected data is highly acceptable for the research.

3.3.1 Data sources

In this research study, two categories of data sources are used: primary and secondary. Primary data sources provide original information on which the research study is based. The source of primary data is a population sample [28]. The first step in the research process is to determine the target population. The sources of primary data collection procedures are survey, interview, and focus group. Secondary data sources provide the analysis of primary sources. It is used to support this particular thesis to persuade the audiences to accept a certain point of view.

3.4 Sample and population

In the present study, the employees and managers form the population group. The sample of employees is simply a random probability sampling, where no other criterion to select is used. With the use of an online survey questionnaire, the employees are asked to participate in the survey. The questionnaire is based on the satisfaction and dissatisfaction level of employees. To conduct the study, a sample size of 100 employees is considered.

3.5 Gantt chart for the research study

Table 6 Gantt chart.

Main activities/ stages	Oct 2016	Nov 2016	Jan 2017	Feb 2017	March 2017	March 2017	April 2017
Investigation and proposal	•	•					
Findings and Discussion			•	•			
Rough draft writing					•		
Supervisor review						•	
Final editing							•

(Source Created by the author)

3.6 The Adopted research strategy

Notably, the strategy adopted in data collection includes the following:

Two scenarios were built, namely: the offline and online modes with the former incorporating the GE system 1to the monitoring system architecture while the latter was implemented by just allowing the manual monitoring where transmission of vibration results were manually done unlike the other scenario where results transmission was electronically relayed to the receiving station. Typically, vibration measurements were done for a full shift per day for a period of 4 months and vibrational trends were monitored as well.

Parameters such as cost of unplanned breakdowns were monitored in a systematic fashion where the operators directly involved in the section under question would make an occurrence note and one of the data collection assistants would prepare a bimonthly report detailing the relevant parameters such as: root cause, duration, monetary effects, safety and production bottlenecks experienced in the cause of plant performance. To narrow the scope of study, a section of the gas plant facility, namely the compressor section was identified as the research location.

The expert, operators and technicians opinion were also taken into account. It was important to get the worker opinion on the likely changes in the monitoring system should it prove a success. Notably, questionnaires were designed to help capture first hand perception, acceptability and attitude of the workers. It should be noted that the rationale of seeking the expert opinion on the said subject was chiefly to gain the experiential and informational resources critical to the analysis and presentation of a more fact-backed research findings. This was done by organizing coordinated interviews spread across the entire 4-month period.

Secondary sources such as journals and books by different authors were perused with the intention to uncover the emerging concepts such as online vibration monitoring modes. Additionally, the secondary sources revealed a near perfect systems monitoring architectural platforms that have been implemented in related industries in different companies.

CHAPTER 4. FINDINGS AND DISCUSSION

4.1 Introduction

In the Findings and Discussion chapter, the researcher analyzes the collected data, which is gathered from the employees and managers working in the gas plant. With the help of the quantitative analysis, the data is analyzed to investigate the selected topic and increase the quality of information. This data analysis helps the research analyst to implement theoretical knowledge within the practical application. However, the data analysis might also involve some limitations and data manipulation. The role of the employees and managers is evaluated in this particular chapter by using the feedback given by the participants of the gas plant. Based on the analyzed data, the research analyst gained information for analyzing the findings.

4.2 Data analysis and findings

In this research study, the employees are asked to answer an online questionnaire survey to help the research analyst in identifying the effectiveness of the Bently Nevada to System 1 condition monitoring system. The total sample size for this research study is 100. The primary data source and quantitative data technique is used for collecting data.

Quantitative analysis- feasibility study on the effectiveness of proposed system

How long have you been working in the gas plant?

Table 7 No of years working in gas plant.

No of years working in gas plant	**No of respondents**
Less than 1 year	39
1-3 years	36
3-5 years	18
More than 5 years	7
Total	100

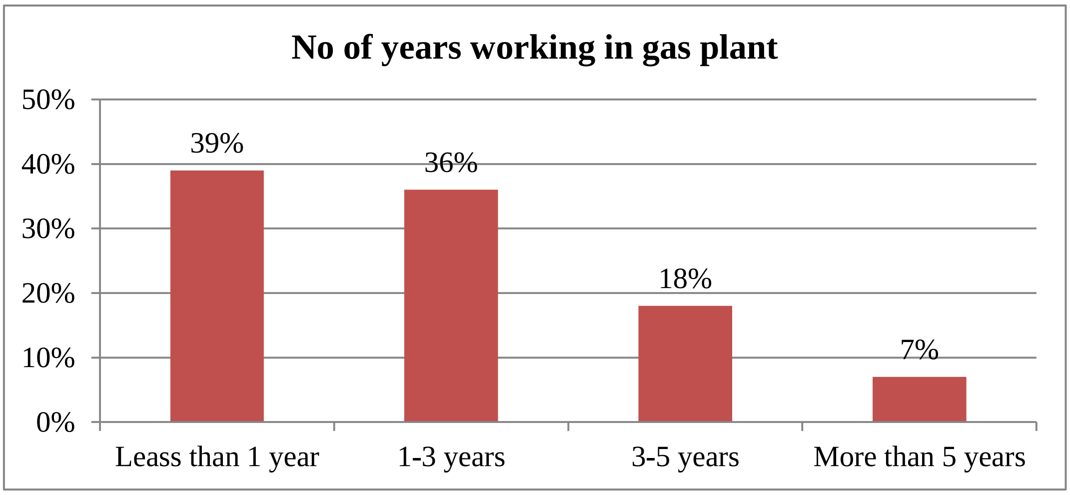


Figure 10 No of years working in gas plant.

(Source: Created by the author)

Findings

From the above data, it is analyzed that most of the employees working in the gas plant were less than 1 year such as 39%. Therefore, the organization as well as the proposed system is new for them to use. They are quite interested to use the system and want to know the benefits and features of system 1 condition monitoring system. As new employees are facing safety issues, they are quite satisfied with the installation of this new condition monitoring system. However, 36% of employees who were working from past 1-3 years are quite experienced with the current system use.

1. Are you satisfied with the existing condition monitoring software of the gas plant?

Table 8 Satisfied with the existing condition monitoring software of gas plant.

Existing condition monitoring software of gas plant	No of respondents
Strongly satisfied	16
Satisfied	48
Neutral	24
Dissatisfied	6
Strongly dissatisfied	6
Total	100

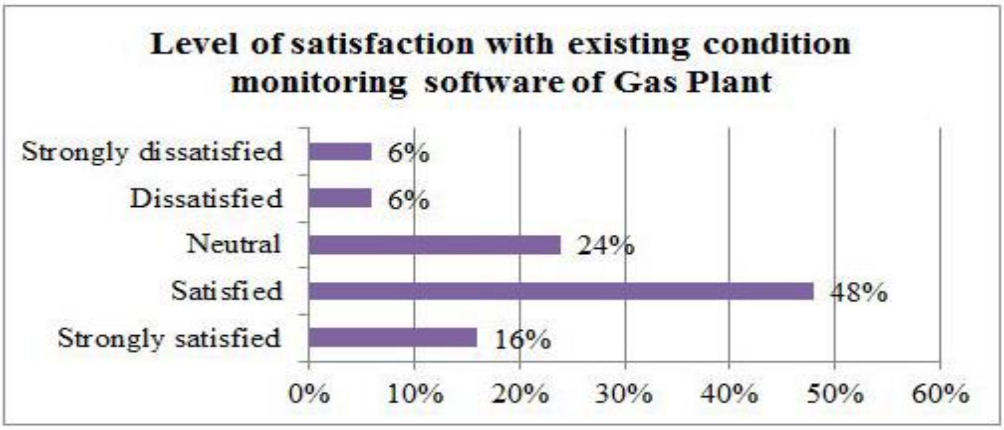


Figure 11 Level of satisfaction with the existing condition monitoring software of gas g.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 48% of the respondents are satisfied and 24% of the respondents are neutral with the use of existing condition monitoring software in gas plant. 16% are strongly satisfied with the use of this system. On the other hand, 6% are strongly dissatisfied with the existing system. The use of existing condition monitoring system by the gas plant are satisfied the employees as using this system, the work orders for scheduled data collections are generated by Oracle. It defines the measurement points and vibration parameters to be collected. The vibration technician takes the measurements of the vibration. The employees are also satisfied as the System 1 software is extremely versatile, and it is configured amongst a central or distrusted group of servers with a network connection.

2. **Do you agree with the decision to install System 1 condition monitoring software?**

Table 9 Agree with the decision to install System 1 condition monitoring software.

Agree with the decision to install System 1 condition monitoring software	No of respondents
Strongly agree	14
Agree	52
Neutral	24
Disagree	5
Strongly disagree	5
Total	100

(Source: Created by the author)

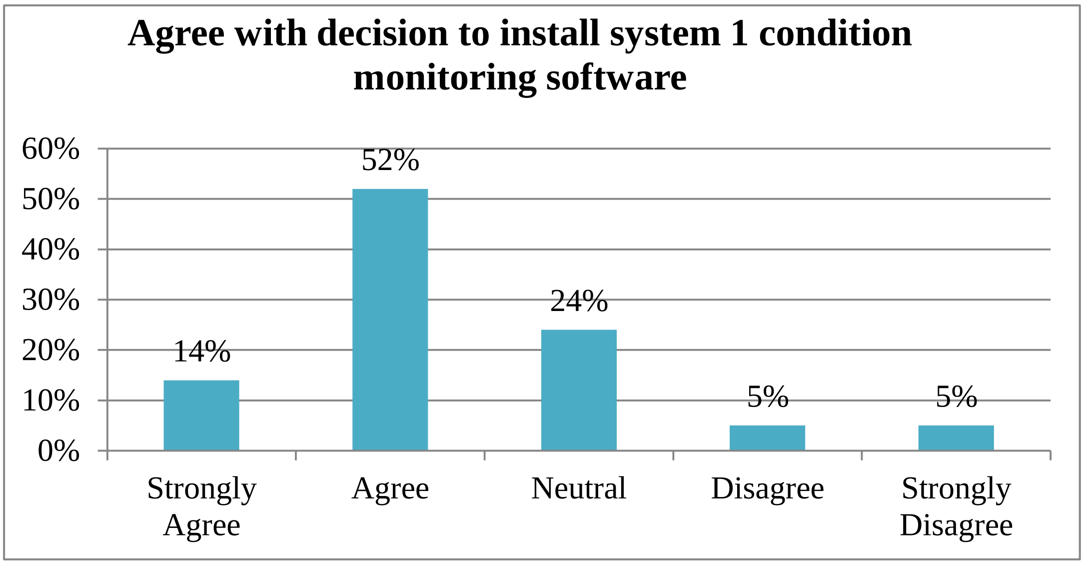


Figure 12 Agree with the decision to install System 1 condition monitoring software.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 52% and 14% of the respondents agreed and strongly agreed, respectively. 24% of the respondents are neutral with the decision to install the System 1 condition monitoring software in a gas plant. 5% of respondents strongly disagree and disagree with the decision. The decision to install the system is better as effective condition monitoring techniques used in the gas plantis vibration monitoring that acquires the data related to vibration from transducers mounted on the rotating equipment. They analyzed the data with use of this proposed system to detect the vibration in the machinery. The system gives value to the employees as sensor and data acquisition system is installed within the system so that the data are collected remotely. It also detects damages and reduces the human interference.

3. **Do you agree that the proposed system will meet the business requirements of your company?**

Table 10 Agree that the proposed system will meet the business requirements.

Agree that the proposed system will meet the business requirements	**No of respondents**
Strongly agree	13
Agree	53
Neutral	22
Disagree	8
Strongly disagree	4
Total	100

(Source: Created by the author)

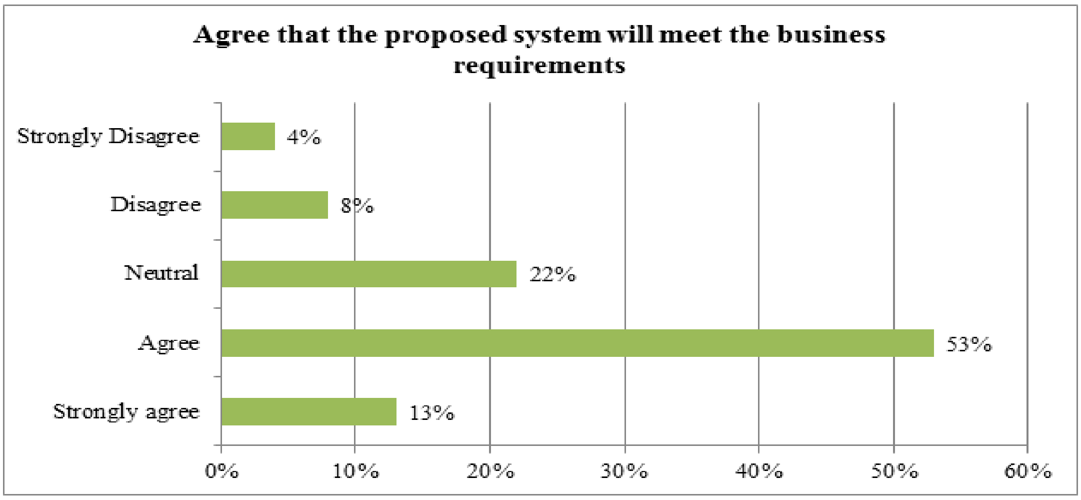


Figure 13 Agree that the proposed system will meet the business requirements.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 53% and 22% of the respondents agreed as well as neutral and 13% of the respondents strongly agree that the proposed system should meet with business requirements in gas plant. 4% and 8% strongly disagree and disagree with the proposed system, respectively. The proposed system has sophisticated alarm management, resolution for storage, customizable display and support for virtual private network technologies. This System 1 condition monitoring system is required to reduce the vibration of machinery. This system will have diagnostic checks such as levels and kinds of dissolved gases, checking of gas pressure and timing and operating checks of the machinery.

4. **Do you agree with the maintenance of standardization of the software is crucial for the company?**

Table 11 Agree with maintenance of standardization of the software is crucial.

Agree with maintenance of standardization of the software is crucial	**No of respondents**
Strongly agree	14
Agree	53
Neutral	21
Disagree	6
Strongly disagree	6
Total	100

(Source: Created by the author)

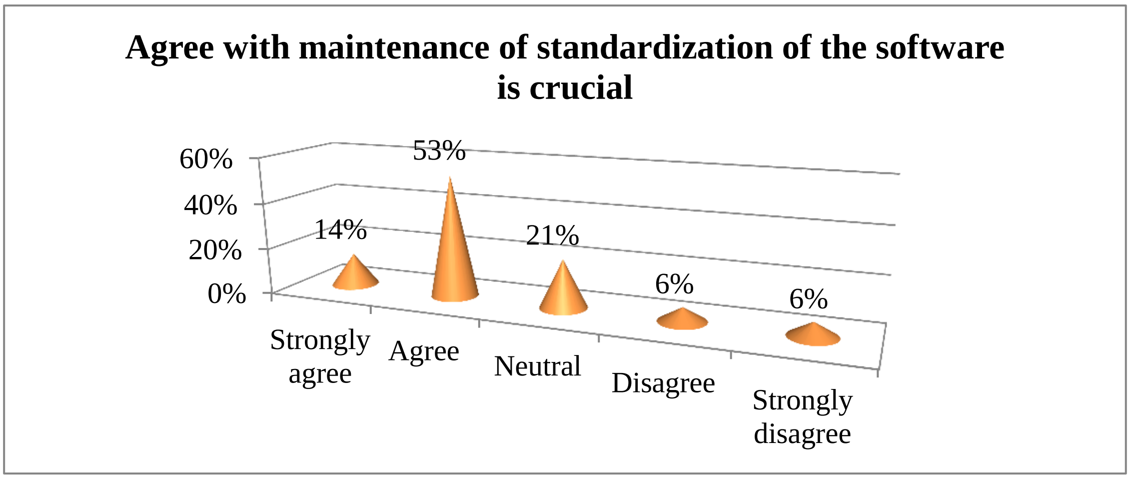


Figure 14 Agree with maintenance of standardization of the software is crucial.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 53% and 21% of the respondents are agreed as well as neutral and 14% of the respondents are strongly agree that the maintenance of standardization of the software is crucial in gas plant. 6% are strongly disagreeing and disagree with standardization of the software. As the proposed monitoring system is completed by procuring vibration information from transducers mounted on the turning gear and investigating this information to recognize and distinguish the reasons for any strange vibration. It also enables corrective maintenance to be executed in an arranged manner before any failure is detected. The gas plant is using information system to encourage intercommunication between sub-frameworks, for example, field estimation gadgets, control frameworks, and central monitoring equipment.

5. **Do you agree that the proposed system will help to increase the reliability in the gas plant?**

Table 12 Agree that the proposed system helps to increase the reliability in the gas plant.

Agree that the proposed system helps to increase the reliability in the gas plant	**No of respondents**
Strongly agree	20
Agree	37
Neutral	27
Disagree	11
Strongly disagree	5
Total	100

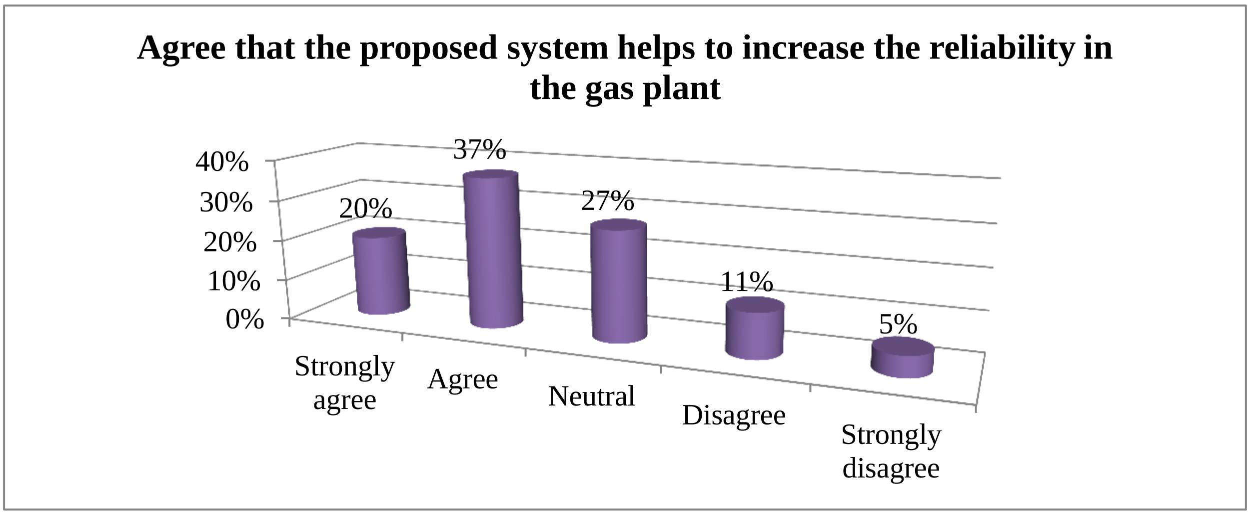


Figure 15 Agree that the proposed system helps to increase the reliability in the gas plant.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 37% and 27% of the respondents agreed as well as neutral and 20% of the respondents strongly agree that the proposed system helps to increase the reliability in the gas plant. 11% and 5% strongly disagree and disagree with its reliability, respectively. Within the gas plant, this type of machinery enables to shop the machines safely when instant shut down is not possible. In this way, it will increase the running time of machinery. The machine is shut down without any sort of destruction. The team of maintenance is ready with spare parts of machinery such that they can work on maintenance when the machine is shut down. It reduces maintenance time of machinery.

6. **Do you agree that the System 1 condition monitoring system should give real time information to the users?**

Table 13 Agree that the System 1 condition monitoring system should give real time information to the users.

Agree that the System 1 condition monitoring system should give real time information to the users	No of respondents
Strongly agree	18
Agree	40
Neutral	25
Disagree	9
Strongly disagree	8
Total	100

(Source: Created by the author)

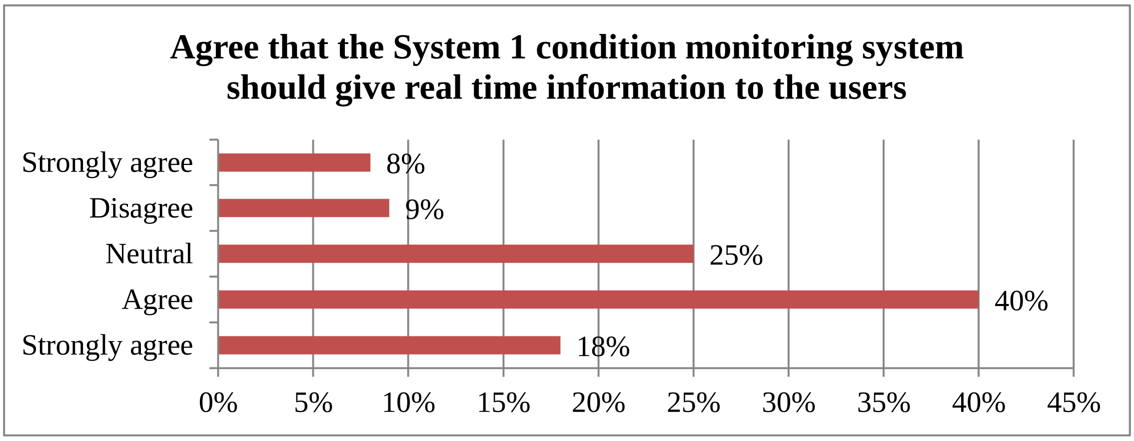


Figure 16 Agree that the System 1 condition monitoring system should give real time information to the users.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 40% and 25% of the respondents agreed as well as neutral and 18% of the respondents strongly agree that the proposed system gives real time information to the users. 8% and 9% strongly disagree and disagree with the proposed system. The real-time information of the data, which are acquired from the analysis, is based on the type of monitored equipment. The offline monitoring system consists of portable vibration data and also a central data processing as well as storage system. The real-time information is given to the users as the gas plant monitors their machinery using movable data collector and also database program.

7. **Do you agree that the implementation of system 1 condition monitoring software in gas plant will reduce the safety issues?**

Table 14 Agree with implementation of system 1 condition monitoring software in gas plant will reduce the safety issues.

Agree with implementation of system 1 condition monitoring software in gas plant will reduce the safety issues	**No of respondents**
Strongly agree	21
Agree	43
Neutral	21
Disagree	8
Strongly disagree	7
Total	100

(Source: Created by the author)

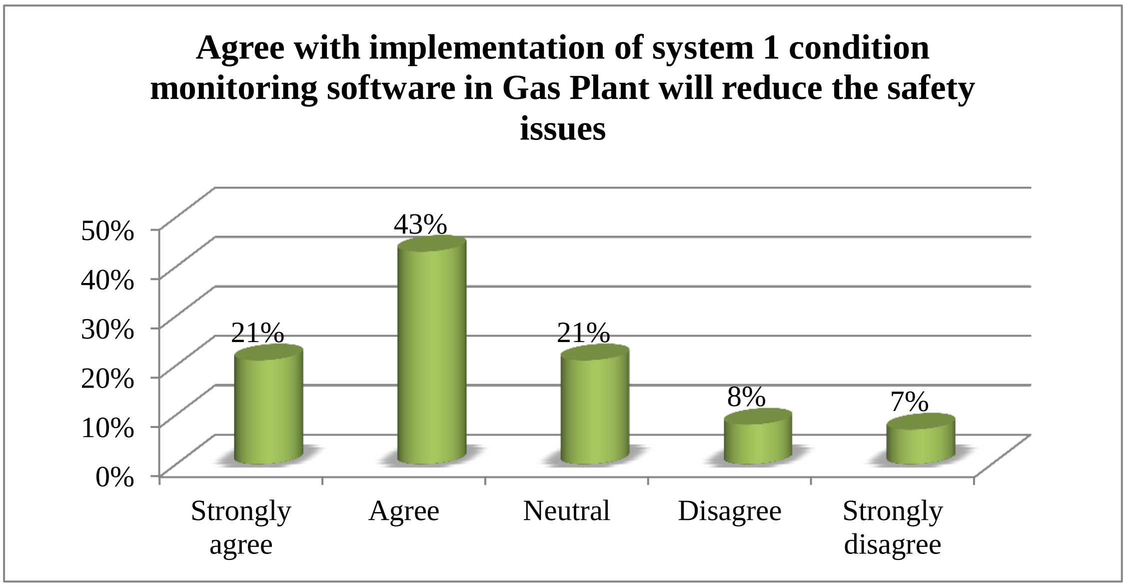


Figure 17 Agree with implementation of system 1 condition monitoring software in gas plant will reduce the safety issues.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 43% of the respondents agreed and 21% were neutral, and 21% of the respondents strongly agreed that the proposed system will reduce the safety issues. 8% and 7% strongly disagreed and disagreed, respectively, with the proposed system. The proposed system should reduce the breakdown of the machinery and reduces the time to work on customer's complaints. The instant shut down of the machinery is also reduced so it improves over safety issues.

8. **Do you think the proposed system has encountered a sudden rise in the production of gas plant?**

Table 15 Proposed system has encountered a sudden rise in the production.

Proposed system has encountered a sudden rise in the production of gas plant	**No of respondents**
Strongly agree	17
Agree	34
Neutral	33
Disagree	10
Strongly disagree	6
Total	100

(Source: Created by the author)

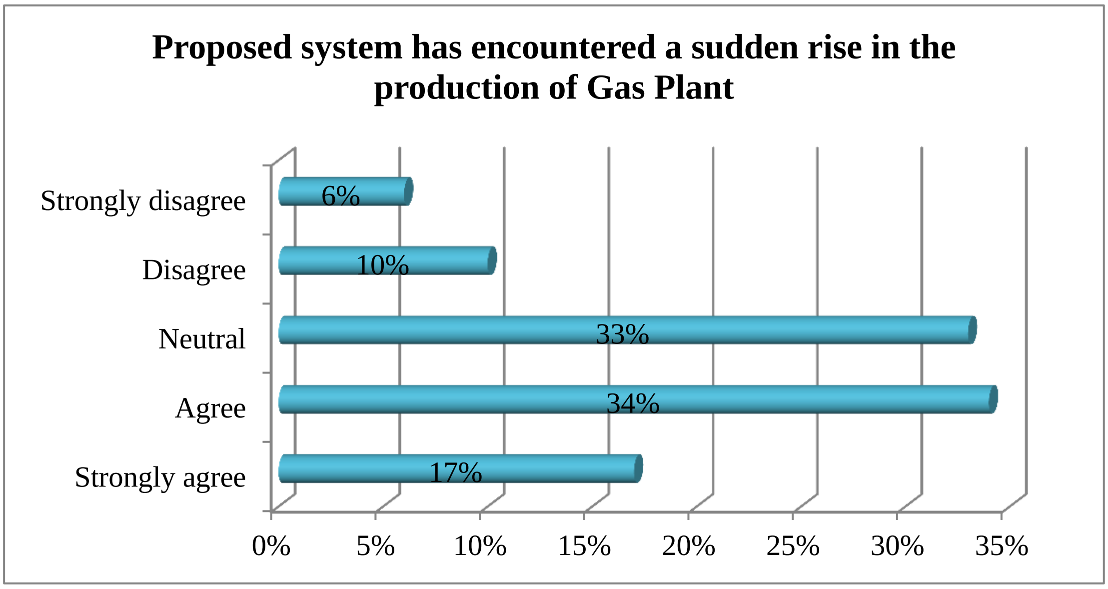


Figure 18 Proposed system has encountered a sudden rise in the production.

(Source: Created by the author)

Findings

From the above table, it is analyzed that 34% of the respondents are agreed, and 33% were neutral, and 17% of the respondents strongly agreed that the proposed system will encounter a sudden rise in production within the gas plant. 6% and 10% strongly disagreed and disagreed, respectively, with the proposed system. The gas plant provides the real time information, reduces the safety issues and takes proper vibration measurements steps to reduce machinery vibration and noise.

4.3 Discussion and Conclusion

Based on the data analysis and findings, it is concluded that the research project is highlighting the relationship between the effectiveness of the GE System 1 condition monitoring software and the improvement in safety issues of a gas plant. It is observed from the primary research that the use of proposed system will reduce errors in the machinery and vibration reduction. The entire research study describes the response of the employees as well as managers working in the gas plant. It is done so that their feedback can be analyzed to identify if the proposed system will be beneficial for the company. From the entire research, it is analyzed that most of the respondents are employees and most of them are satisfied with the use of the proposed condition monitoring system.

The majority of people who have agreed to the integration are end users of the final data from System 1 and prefer a more accurate and usable information for their daily work. Almost everyone was appealed by the fact that there will be improved safety and operational reliability.

The majority of people who have disagreed to the integration are analysts and data gatherers who see the integration as yet another are to be become trained and familiar with. Their ways of working may change or worse still their role may become redundant.

Providing good training and continued support could influence this group to change their mind. It will be at least 3 to 4 years before the complete benefit of this integration can be realised. Hence redundancy is not an immediate threat.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The entire research study is focused on performing a feasibility study of the effectiveness GE System 1 online condition monitoring system in the gas plant. As cited from the entire research, the use of this advanced condition monitoring system helps to reduce the unpredictable shutdown that occurs in the machinery by continuous monitoring and advanced analysis. Sometimes, the vibration causes high sound levels and harms the health of the employees working in the organization. Therefore, this system will reduce the noise and gives a peaceful environment to the employees working in the gas plant. The new desired system is relying on the concept to reduce noise and vibration and providing a secured and comfortable working environment. This particular chapter, Conclusion and Recommendations presents a conclusion on the research issues and problems based on selected topic. It also presents recommendations on using the System 1 continuous condition monitoring system for gas plant such that they can predict the fault and vibration in the machinery before they arise. Finally, area of future study is also analyzed such that the reader can investigate the use of the proposed system in the future.

5.2 Conclusions about the research problem

In order to reduce and control excessive vibration of the machinery and equipment, Bently Nevada condition monitoring systems are used. The other research problem is that of implementation cost to install the condition monitoring system is high, therefore, before implementing the process, the research analyst conducts a cost-benefit analysis to estimate the capital and operational expenditure required for implementing an online condition-monitoring network. It would save gas plant money over the plant's operational life. Project schedule is also done so that the employees, managers and research analyst can identify the total time required to conduct the study. Estimation of labour for installation of network hardware is also required to overcome the limitations of resource management. Therefore, time for permitting operator consultation, and walking to the site are also estimated properly before starting the plan. Selection of proper vendors and the software should be licensed properly so that the proposed software can be properly installed into the gas plant.

5.3 Implications for theory

One of the vital implications on this convergent study is that this model serves as a productive framework from which the research analyst's conceptions on solving of problem are detailed. In this study, attention is paid if the observations can be generalized across the comparable samples. The observational reliability with the findings in previous stages yields a generalized means over the samples within same population.

5.4 Recommendations

The following recommendations are suggested:

- Advanced BN condition monitoring network: A network dedicated to monitoring the performance of rotating equipment. If the network fails, the online critical data collection analysis and health monitoring will operate as normal and alert issues automatically.
- Online condition monitoring: Online condition monitoring provides constant, real-time data collection. By comparison, offline vibration data collection only ever gives a snapshot of machinery performance – it does not provide a continuous data visibility, nor necessarily capture the unique vibration

signatures of equipment during start-up, loading or shutdown. While data is collected at two-monthly intervals, within the potential-to-failure (P-F) interval for common failure modes of rotating equipment, offline collection introduces an inherent lag between when data is collected and when it can be viewed and trended for fault diagnosis. Thus earlier defect identification is enabled with online monitoring. The use of continuous monitoring will also result in increased reliability of heavy machinery, extended machine life, reduction in downtime which means increased production, and less operating costs.

- Back up in case the online mode fails: Over reliance on the online mode can be disastrous. Certainly along the operational journey of the GE system 1 will face some technical hitches. To avoid such an unfortunate scenario, there should be an offline back up assistant and this must be brought on board few seconds after the online mode fails to avoid unnecessarily costly maintenance due to unmanned monitoring.
- Training of operators in the use of the system
- Operators are the major custodians of the said system hence they must be involved at every stage of implementation. They need to be prepared on the technicalities involved in the implementation of the said system hence they should thoroughly be trained on the operation and maintenance of the online monitoring mode.

5.5 Areas of further study

It is identified that there is a chance of further study on the selected research topic as the high-criticality equipment on gas plant would migrate to a completely online condition monitoring strategy in the near future. This will eliminate the need for manual data collection from BN units using portable devices. Instead, vibration data will be transmitted from BN units across the gas plant data network, so it can be stored on System 1 servers and trended to enable predictive maintenance. Additionally, there is need to pursue further the inter-switching fashion of the online and offline modes as failure is inevitable hence the plant must be cushioned against unnecessary disruptions.

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APPENDICES

1. Survey Questionnaire

1. Please indicate the age group

- Under 25
- 26-39
- 40-49
- Above 50

2. Please select your gender

- Male
- Female

3. Please select your designation *

- Project Manager
- Employee
- IT Manager
- System Analyst

Feasibility study on effectiveness of proposed system

1. How long have you been working at the gas plant?

- Less than 1 year
- 1 – 3 years
- 3 – 5 years

- More than 5 years

2. Are you satisfied with the existing condition monitoring software of gas plant?

- Strongly satisfied
- Satisfied
- Neutral
- Dissatisfied
- Strongly dissatisfied

3. Do you agree with the decision to install the System 1 condition monitoring software?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

4. Do you agree that the proposed system will meet the business requirements of your company?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

5. Do you agree with maintenance of standardization of the software is crucial for the company?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

6. Do you agree that the proposed system helps to increase the reliability in the gas plant?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

7. Do you agree that the System 1 condition monitoring system should give real time information to the users?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

8. Do you agree implementation of system 1 condition monitoring software in gas plantwill reduce the safety issues?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

9. Do you think the proposed system has encountered a sudden rise in the production of gas plant?

    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree