UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

A THESIS REPORT ENTITLED

IMPROVING THE EFFICIENCY OF TIPPLING AND SHIP LOADING PLANTS AT GHANA BAUXITE COMPANY LIMITED, TAKORADI PORT FACILITY USING SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM

BY

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

THESIS SUPERVISOR

…………………………………………….

MR ERWIN NORMANYO

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AUGUST 2020

DECLARATION

I declare that this thesis is my own work. It is being submitted for the degree of Master of Science in Electrical and Electronic Engineering in the University of Mines and Technology (UMaT), Tarkwa. It has not been submitted for any degree or examination in any other University.

…………………………
(Signature of Candidate)

….. day of August, 2020

ABSTRACT

Plant automation is a necessity today in most industrial settings if a company should remain competitive and achieve optimal time to market delivery of product. In this research, focus is given to the tippling and ship loading plants which hitherto are operated using traditional mimic and operating panels making use of a total of eighteen personnel. To make gains on reduced number of operators, higher plant availability and reduced operational cost, the two plants have been automated using RS Logix 5000 Allen Bradley PLC for effective sequencing of operations and InTouch Wonderware SCADA software for human machine interface development. Results of the SCADA automation gave 50% reduction in manpower requirement, availability increased from 40.34% to 92.83% for the tippling plant all resulting in plant efficiency of 74.27% from 32.27%. Similar results for the ship loading plant stood at 66.7% reduction in operators, 61.08% from 1.30% availability giving the efficiency of 48.87% from 1.04%. The tippling plant, however, could not stand viable for a 5-year operation period when interest on loan stands at 32% or more. The ship loading plant is feasible for the amortisation period of 5 years at same interest rate of 32%. SCADA is hereby recommended for the automation of the two plants to gain a competitive advantage.

DEDICATION

This thesis is dedicated to my lovely parents; Mr Moses Quadzie and Ms Elizabeth Panford and my scintillating wife, Mrs Joana Quadzie.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
A	Availability
AC	Alternating Current
AGA	American Gas Association
APC	Advance Process Control
AMD	Advanced Micro Devices
ANSYS	Analysis Systems
BIDI	Bidirectional
BLC	Barge Loader Conveyor
CATIA	Computer – Aided Three – dimensional Interactive Application
CATV	Category Five
CPS	Cyber Physical System
CPU	Central Processing Unit
CSU	Continuous Ship Unloader
CTBF	Cumulative Time Between Failure
CTTR	Cumulative Time To Repair
DC	Direct Current
DCS	Distributed Control System
DNP3	Distributed Network Protocol 3
EMI	Electromagnetic Interference
FC	Ferule Connector
FTTx	Fiber to the x
GBC	Ghana Bauxite Company
GUI	Graphic User Interface
HMI	Human Machine Interface
ICS	Industrial Control System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
IoT	Internet of Things

kVA	Kilovolt Ampere
LC	Lucent Connector
LCD	Liquid Crystal Display
LSZH	Low Smoke Zero Halogen
MAS	Multi – Agent Systems
MCC	Motor Control Centre
MPO	Multi – fibre Push On
MTBF	Mean Time Between Failure
MTRJ	Mechanical Transfer Registered Jack
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
MTU	Master Terminal Unit
NIST	National Institutes of Standards and Technology
OEE	Overall Equipment Efficiency
OFNP	Optical Fibre Nonconductive Plenum
OPC	Open Process Control
OSGi	Open Source Gateway initiative
PLC	Programmable Logic Controller
POE	Power Over Ethernet
PON	Passive Optical network
PVC	Polyvinyl Chloride
QoS	Quality of Service
RAM	Random Access Memory
RFI	Radio Frequency Interference
RTD	Resistance Temperature Device
RTU	Remote Terminal Unit
SC	Subscriber Connector
SCADA	Supervisory Control and Data Acquisition System
SONET	Synchronous Optical Network
ST	Straight Tip
TBF	Time Between Failure
TPF	Takoradi Port Facility
TTR	Time To Repair
UPC	Ultra – Physical Contact

UPS	Uninterrupted Power Supply
UTP	Unshielded Twisted Pair
VA	Volt Ampere
VRLA	Valve – Regulated Lead Acid
WDM	Wavelength – Division Multiplexing
XMPP	Extensible Messaging and Presence Protocol

LIST OF SYMBOLS

Apron feeder availability after SCADA system implementation	A_{SAF}
Apron feeder availability before SCADA system implementation	A_{AF}
Acceleration due to gravity	g
Availability of one plant technician after SCADA implementation	A_{SH}
Availability of one plant technician before SCADA implementation	A_{H}
Barge loader conveyor availability after SCADA system implementation	A_{SBLC}
Barge loader conveyor availability before SCADA system implementation	A_{BLC}
Belt Tension Area	A
Belt Tension at steady state	T_S
Belt Tension while starting up	T_{SS}
Boom circuit availability after SCADA system implementation	A_{SBMC}
Boom circuit availability before SCADA system implementation	A_{BMC}
Boom conveyor availability after SCADA system implementation	A_{SBM}
Boom conveyor availability before SCADA system implementation	A_{BM}
Bypass circuit availability after SCADA system implementation	A_{SBCT}
Bypass circuit availability before SCADA system implementation	A_{BCT}
Bypass conveyor availability after SCADA system implementation	A_{SBC}
Bypass conveyor availability before SCADA system implementation	A_{BC}
Coefficient of Friction	f/µ
Cost of additional labour for ship loading for three months	C_{SLQ}
Cost of additional labour for ship loading for three shipping vessels	C_{SL}
Cost of additional labour for tippling operations for three months	C_{TPQ}
Cost of SCADA System Implementation	C_{SIP}
Diameter of Pulley	D
Diameter of rollers	d
Efficiency	η

Estimated total cost of materials for SCADA System	C_{SC}
Force	N
Inclination angle of the conveyor	θ
Installation cost of SCADA System	C_{IC}
Load due to belt	M_b
Load due to conveyed material	M_m
Load due to idlers	M_i
Material density	ρ
Minimum motor Power	P_{mim}
Number of revolutions per minute	n
Multiplication	$\prod$
Performance of ship loading plant	P_s
Performance of tippling plant	P_t
Power at drive pulley	P_p
Quality of ship loading plant	Q_s
Quality of tippling plant	Q_t
Ship loading plant OEE after SCADA implementation	OEE_{ss}
Ship loading plant OEE before SCADA implementation	OEE_{sm}
Ship loading conveyor 1 availability after SCADA system implementation	A_{SCV1}
Ship loading conveyor 1 availability before SCADA system implementation	A_{CV1}
Ship loading conveyor 2 availability after SCADA system implementation	A_{SCV2}
Ship loading conveyor 2 availability before SCADA system implementation	A_{CV2}
Ship loading conveyor 3 availability after SCADA system implementation	A_{SCV3}
Ship loading conveyor 3 availability before SCADA system implementation	A_{CV3}
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Start – up factor	Ks
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Tippling conveyor 1 availability before SCADA system implementation	A_{TCV1}
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Tippling conveyor 3 availability before SCADA system implementation	A_{TCV3}
Tippling conveyor 4 availability after SCADA system implementation	A_{STCV4}
Tippling conveyor 4 availability before SCADA system implementation	A_{TCV4}
Tippling conveyor 5 availability after SCADA system implementation	A_{STCV5}
Tippling conveyor 5 availability before SCADA system implementation	A_{TCV5}
Tippling plant availability after SCADA system implementation	A_{STP}
Tippling plant availability before SCADA system implementation	A_{TP}
Tippling plant OEE after SCADA implementation	OEE_{ts}
Tippling plant OEE before SCADA implementation	OEE_{tm}
Torsional moment	M_t
Total cost of additional labour for tippling and ship loading for one year	C_{TTY}
Total cost of additional labour for tippling and ship loading for three months	C_{TT}
Total tangential force at the periphery of the pulley	F_U
Velocity/belt speed	v
Vertical height of the conveyor	H
Weight of material and belt	W

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Quantity	**Unit**	**Symbol**
Area	Square meter	m^2
Density	Kilogram per cubic meter	kg/m^3
Electric current	ampere	A
Force	Newton	N
Length	Meters	m
Power	watt	W

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background to the Research

In this age of industrialisation, technological revolution/automation is fast shrinking the need for humans to assist in operating machinery. Looking at the current industrial scenario, birth of new products and private brands are sharply raising the competition among industries. In order to hold out the promise of timely delivery of product, high tech automated production is essential (Sharnagat and Thakare, 2015). With today's ever-increasing competition in the industrial world, flexibility, cost effectiveness and high efficiency are a must for the survival of a company, and it is of this importance that industrial automation has been of great demand as more productivity, better quality standard, higher accuracy and optimum utilisation of available resources and manpower have to be achieved.

Ghana Bauxite Company (GBC) Limited, Takoradi Port Facility (TPF) operates two separate plants at the facility, for off-loading bauxitic ore from the trucks onto the stockpile and loading of bauxitic ore from the stockpile into barges to be carried to the ship side for them to be offloaded into the ship for shipment. These two plants are operated and monitored with the use of traditional mimic and operating panels and with this, full exploitation of the facility is not achieved. This research therefore seeks to propose a better approach to fully exploit the facility by designing a Supervisory Control and Data Acquisition (SCADA) system to monitor and control the two plants in the facility.

1.2 Problem Definition

Plants, depending on the product or commodity produced, have different challenges and different needs. However, one commonality they share is the need for technology that lowers cost of design, construction, and overhead, and optimises the efficiency of workflow processes (Anon., 2016a). Factory owners want their equipment to deliver the highest output with as little production cost as possible. In process automation, the computer program uses measurements to show not only how the plant is working but to simulate different operating modes and find the optimal strategy for the plant. A unique characteristic of this software is its ability to “learn” and predict trends, helping speed up the response to changing conditions (Anon., 2016b).

GBC Limited, TPF operates two plants at the facility, for off-loading bauxitic ore from the trucks onto the stockpile and loading of bauxitic ore from the stockpile into barges to be carried to the ship for shipment. These two plants are operated and monitored with the use of traditional mimic and operating panels and with this, full exploitation of the facility is not achieved. The existing tippling plant consists of seven belt conveyors and an apron feeder. The belt conveyors and apron feeder are assigned technicians to monitor them during operation and to stop the conveyor/apron feeder, notify the immediate supervisor or take an immediate corrective action if the need be. The existing ship loading plant consists of eight belt conveyors. Just as in the case of the tippling plant, technicians are also assigned to the various conveyors for monitoring and control.

The existing system of operation of the plants at GBC Limited, TPF results in low efficiency due to:

i. Ineffective monitoring of plants by technicians resulting in frequent breakdowns and low plant availability;
ii. More technicians are required to run operations which come with high costs;
iii. Difficulties in troubleshooting as equipment history cannot be properly traced; and
iv. High level of hazard exposure of technicians to machinery.

1.3 Purpose of the Research

This research is purposed to improve upon the operations of both tippling and ship loading plants at GBC Limited, TPF.

1.4 Objectives of the Research

The main objective of this research is to improve the efficiency of tippling and ship loading plants of GBC Limited, TPF making use of SCADA automation. The specific objectives include:

i. Reduction in the manpower requirement;
ii. Increase in plant availability by reducing downtime; and
iii. Reduction of the operational cost.

1.5 Research Questions and Hypothesis

The objectives of the research give rise to the following research questions:

i. Can the efficiency of the two plants in the TPF be improved?
ii. Would SCADA automation be a suitable approach for improving efficiency of the plants in the TPF?

The research hypothesis is stated thus:

A SCADA automation can improve the efficiency of tippling and ship loading plants at GBC Limited, TPF.

1.6 Expected Outcomes

It is expected that the research would produce the following outcomes:

i. A designed SCADA system for the tippling and ship loading plants of GBC Limited, TPF;
ii. An improved efficiency of the two plants at the facility;
iii. A reduction in the manpower requirement of the facility; and
iv. A reduction in the operating cost of the facility.

1.7 Scope of the Research

This research is focused on only the TPF of GBC Limited, the hardware and relevant software that will facilitate optimal operation.

1.8 Research Methods Used

In order to achieve the above objectives and outcomes, and provide answers to the research questions, the following methodologies are adopted:

i. Review of related literature;
ii. Field studies, data acquisition and analyses;
iii. Design of SCADA system; and
iv. Design of Programmable Logic Controller (PLC) program for the two plants.

1.9 Facilities Used for the Research

The following facilities are used for the research:

i. Library, Laboratory, Computer and Internet facilities at the University of Mines and Technology;
ii. Computer, archives and Internet facilities at the GBC Limited, TPF;
iii. Personal computer with RSLogix 5000 Emulate software and Wonderware InTouch software; and
iv. Tippling and ship loading plants of GBC Limited, TPF.

1.10 Significance of the Research

Traditional mimic panel control of plants at GBC Limited, TPF is unable to help obtain a higher plant efficiency. Low level of monitoring and analyses of plant equipment, high cost of labour and low safety level of plant technicians are some of the effects of this type of control. This research will therefore help control the plants in a better way. Furthermore, it will help GBC limited meet the ever-increasing demand of her customers.

1.11 Limitations of the Research

The outcome and conclusions of this research will be based on results of application of computer software and not on field implementation.

1.12 Definition of Terms and Key Concepts

Programmable logic controller: It is a digital computer used for automation of typical industrial electromechanical processes, such as control of machinery on factory assembly lines.

Supervisory control and data acquisition: It refers to an industrial computer system that monitors and controls processes.

Conveyor belt: A continuous, moving belt that transports materials or packages from one place to another.

Ship loading plant: This is a set of conveyor belts that transports bauxitic ore from the stockpile into barges to be transported to the shipside for offloading.

Tippling plant: A set of conveyor belts and an apron feeder that transports bauxitic ore unto a stockpile after the ore is tipped off from trucks.

1.13 Organisation of the Thesis

The thesis is organised into six main chapters. Each of the chapters has sub-chapters that explain the main chapters.

Chapter 1 is the general introduction to the research. It includes the background to the research, problem definition, objectives of the research, research questions and hypothesis, expected outcomes of the research, scope of the research, research methods used, facilities used for the research, significance of the research, limitations of the research, definition of terms and key concepts and the organisation of the thesis.

In Chapter 2, automation, conveyor and SCADA systems are covered. SCADA automation as an efficiency improvement technique is presented. Related works on industry applications of SCADA as well as related works on automation of tippling and ship loading plants have been discussed.

Chapter 3 is devoted to the tippling and ship loading plants of GBC limited, TPF. The hardware composition, manpower requirements and operational modes of the two plants are discussed.

Chapter 4 presents the system redesign. Here, the design concept, design criteria and the mode of operation of the redesigned system are presented together with the data acquisition, presentation and analyses. Development of the SCADA system is presented and items required for the new system are selected.

Chapter 5 is dedicated to the results and discussion of SCADA automation of the two plants. A cost analysis comparing the traditional way of operating the plants, to the SCADA automated system is also presented. The summary of findings is given in this chapter.

Finally, Chapter 6 offers conclusions and recommendations to the research. It also gives direction for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

SCADA automation of plant is adjudged suitable in improving the efficiency of tippling and ship loading plants at GBC Limited, TPF. In this chapter is presented the concept of automation, conveyors, SCADA systems and review of some related works in the domain of the research topic.

2.2 Automation

Automation is defined by Hudedmani *et al.* (2017) as the process of having machines follow a predetermined sequence of operations with or without human intervention in a manufacturing process. The main objectives of automation are integration of manufacturing processes, increased safety levels of operator, increased productivity, improved quality, efficiency, and reduction of labour costs and human errors.

Chui *et al.* (2015) researched on automation and its impact on job security. It is proven that as the automation of physical and knowledge work advances, many jobs will be redefined rather than eliminated. The research presents four findings elaborating on the core insight that the road ahead is less about automating individual jobs wholesale, than it is about automating the activities within occupations and redefining roles and processes.

Anon. (2019a) explained how automation technologies can reduce cost and raise productivity. An overview of how automation technologies are being used, potential implications for employment, skills, education and inequality in the coming decades were all discussed.

Anon. (2019b) discussed the impact of automation on the future work and society. Negative and positive impacts are outlined with the brief optioning for companies to adopt an approach to automation that will empower their current workforce to adapt to automation as well as build future talent pipeline (that is educated, trained and capable of meeting the needs of the future) were also presented.

Mehdiyeva and Guliyeva (2017) outlined the state of HMI/SCADA system usage in the country of Azerbaijan. Modern building principles of HMI/SCADA system such as scalability, flexibility, unification, reliability and openness are lacked in the existing system. This led to the information about production processes being either unreliable or insufficiently complete, non-existent or inaccessible to decision makers or available in a form that does not allow the use of modern methods of integrated system.

Florian (2015) discussed the effect of automation on human behaviour with a focus on some important aspects regarding the interaction between human workforce and fully automated production lines. An examination of the effects produced by the introduction of robots in factories all over the world is also presented. Positive and negative facts about automation demonstrate promising results for improving upcoming technologies.

Kalaivan and Jagadeeswari (2015) automated a boiler in a thermal plant using PLC and SCADA. This approach was identified as a reliable monitoring system to avoid catastrophic failure in the thermal plant.

Coombs *et al.* (2018) reported on a rapid evidence review of the impact of artificial intelligence, robotics and automation technologies on work. A summary of findings of the impact of these emerging technologies on knowledge and service work, relevant professions and society was presented focusing on academic literature that had been published since 2011.

Leonardi *et al*. (2014) researched on the Industrial Control System (ICS) of the electrical sector and especially on the smart grid. The research focused on substation automation in the power transmission and distribution domains. The state-of-the-art analysis on architectures, technologies, communication protocols applications and information standards were presented.

Negrete (2018) gave an overview of automation of agriculture in Mexico where agriculture is one of the most important economic activities. Application of mechatronic technologies to agriculture to help improve productivity was vigorously discussed.

2.3 Conveyor Systems

According to Daniyan *et al.* (2014), a conveyor system is a mechanical system used in moving materials from one place to another and finds application in most processing and manufacturing industries. It is easier, safer, faster, more efficient and cheaper to transport materials from one processing stage to another with the aid of material handling equipment devoid of manual handling. Handling of materials, which is an important factor in manufacturing is an integral part of facilities design and the efficiency of material handling equipment adds to the performance level of a firm (Jagtap *et al*., 2015*)*. According to Anon. (2019j), conveyor systems are in widespread use across a range of industries due to the numerous benefits they provide such as:

i. Conveyors are able to safely transport materials from one level to another, which when done by human labour would be strenuous and expensive;
ii. They can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials;
iii. They can move loads of all shapes, sizes and weights; also, many have advanced safety features that help prevent accidents; and
iv. There are a variety of options available for running conveying systems, including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs.

Many types of conveyor systems exist according to Anon. (2019j). However, the pneumatic, aero mechanical, vibrating, screw and belt conveyor systems are hereby elucidated.

2.3.1 Pneumatic Conveyor Systems

Every pneumatic system uses pipes or ducts called transportation lines that carry a mixture of materials and a stream of air. These materials are free flowing powdery materials like cement and fly ash. Products are moved through tubes by air pressure. Pneumatic conveyors are either carrier systems or dilute-phase systems. Carrier systems simply push items from one entry point to one exit point, such as the money-exchanging pneumatic tubes used at a bank drive-through window. Dilute-phase systems use push-pull pressure to guide materials through various entry and exit points (Anon., 2019j).

2.3.2 Aero Mechanical Conveyors

Aero mechanical conveyors have a tubular design where a cable assembly, with evenly spaced polyurethane discs, move at high speed. The cable assembly runs in specially designed sprockets at each corner and at each end of the conveyor. The action of the cable assembly traveling at high speed creates an air stream running at the same velocity. As the material is fed into the airstream, it is fluidized and conveyed to the outlet where it is centrifugally ejected. All conveying takes place in a totally sealed tubular system which ensures dust-free transfer of even the finest powders. Because of the total transfer capability of aero mechanical conveyors, cleaning is not necessary for most applications. To avoid cross contamination of product, it is often sufficient to simply purge the conveyor with a sacrificial quantity of material. Common uses for aero mechanical conveyors are the transfer of food ingredients and abrasive or corrosive chemical industry products (Anon., 2019j).

2.3.3 Vibrating Conveyor Systems

A vibrating conveyor is a machine with a solid conveying surface which is turned up on the side to form a trough. They are used extensively in food grade applications to convey dry bulk solids where sanitation, wash-down, and low maintenance are essential. Vibrating conveyors are also suitable for harsh, very hot, dirty, or corrosive environments. Due to the fixed nature of the conveying pans, vibrating conveyors can also perform tasks such as sorting, screening, classifying and orienting parts (Anon., 2019j).

2.3.4 Screw Conveyor

A screw conveyor is a mechanism that uses a rotating screw blade called ‘flighting’ to transport material. The screw is a helix usually wrapped around a central shaft or pipe. As the screw turns, the product is pushed along by the face of the helix. With each revolution of the screw, the product moves forward the distance of one pitch of the screw. Screw conveyors are one of the most economical options for moving dried bio solids because they can be sealed to completely contain odours and dust. In industrial control applications, the device is often used as a variable rate feeder by varying the rotation rate of the shaft to deliver a measured rate or quantity of material into a process (Derikvand, 2015).

2.3.5 Belt Conveyor System

The belt conveyor is a transporting machine made up of an endless wide belt which carries a load on its upper surface. It operates between a head pulley and a return or tail pulley and is supported by idlers, which in turn are supported by a frame or by steel cables. Belt conveyors are one of the most widely used and efficient means of transporting bulk materials. They are usually the least expensive powered conveyor and are capable of handling a wide array of materials. As independent units, they are well suited for rapid transportation of loose material. They have less mobility and flexibility than trucks and scrapers, and are therefore used chiefly where large volumes of material are to be moved along one route. They are particularly applicable where the load must be lifted steeply, or carried across rough country where road construction would be difficult. They are desirable as feeders for processing plants because they provide an even and continuous flow (Derikvand, 2015).

Conveyor belt equations

The design of an effective and efficient belt conveyor system has in consideration some design parameters such as dimension, capacity and speed, belt power and tension, roller diameter, pulley diameter, motor and many more (Jagtap *et al.*, 2015). Some of these considerations are expressed in the following equations.

$$v = d \times \pi \tag{2.1}$$

where, v = belt speed (m/s)

d = diameter of rollers (m)

π = pi

$$BC = 3.6 \times A \times \rho \times v \tag{2.2}$$

where, BC = belt capacity (kg/s)

A = belt sectional area (m^2)

ρ = material density (kg/m^3)

$$P_P = \frac{F_U \times v}{1000} \tag{2.3}$$

where, P_P = power at drive pulley drum (kW)

F_U = total tangential force at the periphery of the pulley (N)

$$T_S = 1.37 \times f \times L \times g\,[\,2 \times M_i + (\,2 \times M_b + M_m\,)\,\text{Cos}\,\theta\,] \qquad (2.4)$$

where, T_S = belt tension at steady state (N)

f = coefficient of friction

L = conveyor length (m)

g = acceleration due to gravity (m/s^2)

M_i = load due to the idlers (kg)

M_b = load due to belt (kg)

M_m = load due to conveyed materials (kg)

θ = inclination angle of the conveyor (^{0})

H = vertical height of the conveyor (m)

$$T_{SS} = T_S \times K_S \qquad (2.5)$$

where, T_{SS} = belt tension while starting up (N)

K_S = start-up factor

$$P_{min} = \frac{P_P}{\eta} \qquad (2.6)$$

where, P_{min} = minimum motor power (kW)

P_P = power at drive pulley (kW)

η = efficiency of the reduction gear (%)

$$M_t = \frac{1}{2} \times D \times (F + \mu W g) \qquad (2.7)$$

where, M_t = torsional moment (N/mm)

D = diameter of pulley (m)

F = force (N)

μ = coefficient of friction

W = weight of material and belt (kg/m)

g = acceleration due to gravity (m/s^2)

$$n = \frac{9500 \times 1000 \times P}{M_t} \tag{2.8}$$

where, n = number of revolutions per minute

P = power of electric motor (kW)

2.4 SCADA Systems

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level of control. As such, it is a purely user-friendly software that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules such as Remote Terminal Units (RTUs) (Anon., 2019l). SCADA encompasses collecting of the information, transferring it back to the central site, carrying out any necessary analysis and control and then displaying that information on a number of operator screens or display. The required control actions are then conveyed back to the process (Ansari and Iram, 2017).

SCADA systems are essential components of modern industrial automation. This category of software is widely used to monitor and operate industrial plants from a central station, regardless of size of plant or the distance of the equipment and sensors. Besides industrial applications, SCADA systems are employed in other areas, such as the power generation and distribution, building automation/surveillance and automatic data acquisition in scientific research. Local and remote data acquisition are key features of these systems, usually made by communicating with RTUs or PLCs. Data can be automatically stored and monitored, with alarms that can be set to notify abnormal behaviour to operators allowing them to take action in such cases. Also, the history of the plant operation and status provides relevant data to the manager and administrative levels to support planning and decision making. Another important feature is the human machine interface (HMI) which is used by operators to interact with the system, not only by monitoring data, but also to exert high-level control actions onto the plant (Rocha and Scholl, 2015).

In every industry, managers need to control multiple factors and the interactions between those factors. SCADA systems provide the sensing capabilities and the computational power to track everything that is relevant to operations (Anon., 2016c).

A SCADA system gives the power to fine-tune knowledge of systems. Sensor controls are placed at every critical point in a managed process enabling a more and detailed view of operations by virtue of monitoring in real time to be achieved. So, even for very complex manufacturing processes, large electrical plants, etc., an eagle-eye view of every event is exerted enabling correction of errors and improving of efficiency. With SCADA, more is done at less cost, providing a direct increase in profitability (Anon., 2016i). SCADA is not a specific technology, but a type of application.

A SCADA system application has two elements:

i. The process/system/machinery to be monitored and controlled - this can be a power plant, a water system, a network, a system of traffic lights or anything else; and
ii. A network of intelligent devices that interfaces with the first system through sensors and control outputs. This network, which is the SCADA system, gives the ability to measure and control specific elements of the first system.

Fig. 2.1 (Anon., 2016f) illustrates a SCADA system overview.

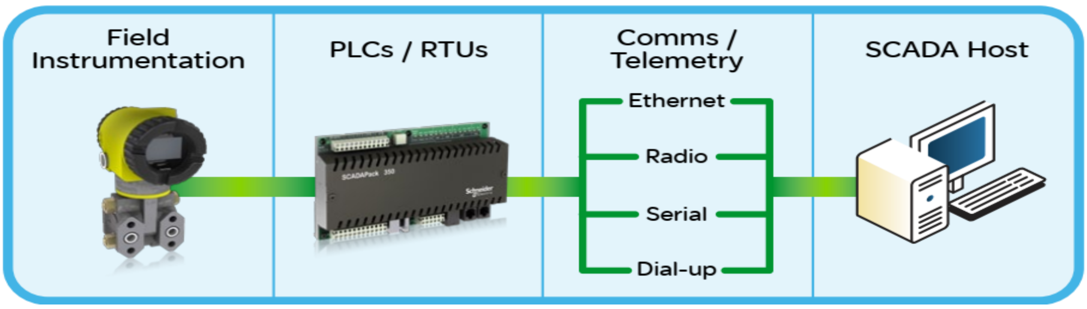


Fig. 2.1 Overview of SCADA System

2.4.1 Brief History of SCADA

SCADA began in the early 1960s as an electronic system operating as input and output transmissions between a master station and a remote station. Each master station was connected to its own remote station. The master station would receive data through a telemetry network and display this on a panel which was a big wall that housed lights to present alarm and other conditions. Analogue values were presented by analogue electromechanical meters. Controls were initiated by pressing switches on the panel. The whole plant that was supervised by the system was graphically presented on the panel (Anon. 2016k).

In the early 1970s, Distributed Control Systems (DCS) were developed to control separate remote subsystems and in the 1980s, with the development of the microcomputer, process control could be distributed among sites. Further development enabled DCS to use PLCs, which have the ability to control sites without taking direction from a master control unit (Anon., 2016j).

In the late 1990s, SCADA systems were built with DCS capabilities and systems were customised based on certain proprietary control features built in by the designer. Recently, with the Internet being utilised more as a communication tool, SCADA and telemetry systems are using automated software with certain portals to download information or control a process. This however, also introduced the security risks in the form of cyber-attacks and software viruses. Engineered SCADA systems today not only control processes but are also used for measuring, forecasting, billing, analysing and planning (Anon., 2016j). A modern SCADA system must meet a whole new level of control automation while interfacing with obsolete equipment yet flexible enough to adapt to future developments (Anon., 2016k).

2.4.2 Components of a SCADA System

Typically, components of a SCADA system are HMI, supervision subsystem, RTUs, PLCs and communications infrastructure. The SCADA components and their characteristics are summarised into Table 2.1.

Table 2.1 SCADA Components and their Characteristics

SN	SCADA Component	Characteristics
1.	HMI	Serves as operator control and monitoring interface.
2.	Supervision Subsystem	Information/data gathering and control of process are done here.
3.	RTUs	Make changes to operational parameters remotely. Log key data pieces at high interval for troubleshooting and optimisation. Uses accepted engineering calculations for updating operating set points automatically.

Table 2.1 Cont'd

4.	PLCs	Make changes to operational parameters remotely. Log key data pieces at high interval for troubleshooting and optimisation. Uses accepted engineering calculations for updating operating set points automatically.
5.	Communications Infrastructure	This serves as a communication link between supervisory subsystem, PLCs and RTUs.

(Sources: Anon., 2016e; Anon., 2016g; Shahzad *et al.*, 2014)

A typical SCADA application has tags, drivers, HMI, alarms, loggers and scripts. Table 2.2 summarises the application segments.

Table 2.2 A Summary on the Application Segments of SCADA

SN	SCADA Application	Comment
1.	Tags	This is simply a link to memory location or soft components that store data in memory. Use of tags defines links to memory location and is used repeatedly throughout the application.
2.	Drivers	These are loadable modules that manage a particular communication protocol/equipment. Usually, tags are linked to the driver that handles the communications with the remote equipment that provides the data they store.
3.	HMI	This comprise screens that contain various widgets linked to tags to display alert and to respond to user or plant events.
4.	Alarms	These are usually related to tags in order to automate its monitoring.
5.	Loggers	This handles plant operation history and can be stored in single files or Database Management System. (DBMS).
6.	Scripts	The written commands in a specific language to be executed by SCADA.

(Source: Anon., 2016h; Rocha and Scholl, 2015)

2.4.3 Functions of a SCADA System

A SCADA system performs four functions namely, data acquisition, networked data communication, data presentation and control. Table 2.3 gives the functionalities of a typical SCADA system.

Table 2.3 Functionalities of a SCADA System

SN	SCADA Functionality	Components Responsible	Capabilities
1.	Data Acquisition	Sensors (analogue/digital) RTUs	Hundreds to thousands of sensors are interfaced with the managed system and are used to gather information from the field. RTUs also serve as local collection points for gathering reports from sensors and delivering commands to control relays.
2.	Networked Data Communication	Ethernet, IP over SONET, LANs/WANs, Protocols	They connect SCADA master units to field devices enabling transport of data to and from sensors to master stations.
3.	Data Presentation	HMI, HCI	Provide human interface to the system and automatically regulate the managed system in response to sensor inputs. More comprehensive view of entire managed system is presented and also data processing, report logging and historical trends are maintained.
4.	Control	SCADA, Master units PLCs	They regulate processes with no or less human intervention.

(Source: Anon., 2016f and Anon., 2016g)

2.4.4 Communications in a SCADA System

Without a properly designed communications networks, a SCADA system cannot exist. All supervisory control and data acquisition aspects of the SCADA system rely entirely on the communications system to provide a conduit for flow of data between the supervisory controls, data acquisition units, and any controllers that may be linked to the system. The purpose of a communications network within a SCADA system is to connect the RTUs, PLCs, and Intelligent Electronic Devices (IEDs) with the SCADA Master. Fig. 2.2 (Anon., 2016d) illustrates the communications network functionality of SCADA equipment.

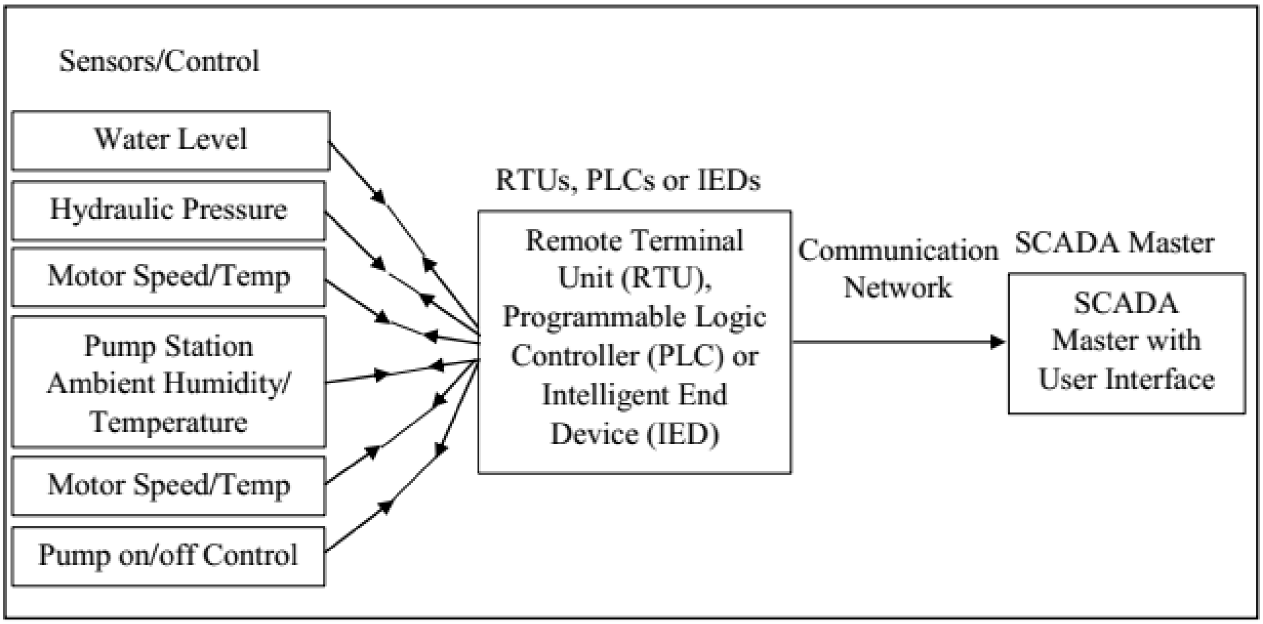


Fig. 2.2 Communications Network of a Typical SCADA-Based Equipment (Anon., 2016d)

Security is an important consideration when designing a SCADA network. Many existing SCADA systems have been found wanting in this regard, leaving essential systems vulnerable to outside influence (Anon., 2016d). Perimeter, interior and transport securities constitute the three levels of security normally considered. Perimeter security limits access to systems and networks equipment from unauthorised sources. Interior security requires at the very least a login to access a network segment in an attempt to gain control. Transport security ensures that it is difficult to illicitly access a network segment in an attempt to gain control. Additionally, a cohesive security plan requires authentication ("who are you"), authorisation ("what are you allowed to do") and accounting ("who did what").

Communications network options

The way the SCADA system network (topology) is set up can vary with each system but there must be uninterrupted, bidirectional communication between the Master Terminal Unit (MTU) and the Remote Terminal Unit (RTU) for a SCADA or data acquisition system to function properly. This can be accomplished in various ways, i.e. private wire lines, buried cable, telephone, radios, modems, microwave dishes, satellites, or other atmospheric means, and many times, systems employ more than one means of communicating to the remote site. This may include dial-up or dedicated voice grade telephone lines, Digital Subscriber Line (DSL), Integrated Service Digital Network (ISDN), cable, fibre optics, Wireless Fidelity

(Wi-Fi), or other broadband services (Anon., 2016i). Currently, fibre optics is the mostly used network.

2.5 SCADA Automation as an Efficiency Improvement Technique

A SCADA system enables control of complex processes and computations to be achievable. Real-time status control is achievable as SCADA system serves as a medium between field instruments connected to the PLC which reads the control program, makes mathematical calculations and as a result controls various hardware (outputs) all in a time frame of milliseconds. The aid of SCADA in accomplishing such tasks has brought great enhancements in productivity. Advanced process control and real-time optimisation are techniques that can improve a plant's profitability and efficiency by maintaining a process at desired operating conditions while taking process constraints into account (Amin, 2016). Process control is designed to minimise variations in processes and keep them within specified boundaries. The main purpose of process control is to maintain a process at desired operating conditions while taking process constraints into account. This is achievable with the use of SCADA system as real-time data are monitored and controlled (Amin, 2016).

The benefits of Advanced Process Control (APC) and advanced analytics have become increasingly well established in the process industry. Through continually evolving technologies, the benefits of APC are now accessible to a much broader range of industries and users by providing mainstream tools and leveraging diverse industry experience. Recently, industry requirements of plant historian and HMI/SCADA products have grown, driven by pressure to reduce production costs, meet regulatory requirements and survive as competition increases. The challenge now is to meet the industry's expectations to use these products to improve process optimisation. Many manufacturing and processing facilities have invested in historian technology, allowing them to capture large volumes of process information. These valuable repositories provide trends, reports and analyses from which companies make decisions about process performance (Leppiaho and Moolman, 2009).

According to Fogoros (2015), today's business climate is putting plants under intense financial pressure, and operations and maintenance budgets are among the first to be cut. Fewer personnel are expected to operate and maintain more equipment, manage larger and often remote systems, process greater volumes of data and supervise increased levels of automation all at a lower cost. In addition, these plants must also maintain staffing proficiency, while also delivering higher throughput, higher availability and higher profits with ageing assets. Unfortunately, these trends show no sign of changing, so plants must therefore increase the productivity of their existing maintenance and operations teams while continuing to look for ways to reduce costs even more. One of the areas where significant opportunities for improvement exist is the SCADA software usage to control and operate these systems (Fogoros, 2015).

2.6 Review of Related Works on SCADA Applications in Industry

Al-Mofleh *et al*. (2015) discussed the need for a SCADA system in the Malaysian energy management for smooth operation. The need for efficient utilisation and diversification of energy sources while minimising its waste was a necessity hence, the need for a SCADA system. The paper discussed the available technologies for energy efficient equipment and energy conservation methods and tools with special emphasis on the development of SCADA system.

Jain and Haridas (2014) automated a bottling plant using PLC and SCADA. The research offers a hardware assembly for a complete production line bottling facility incorporating the use of PLC and SCADA which in turn resulted into improved efficiency, energy savings and cost effectiveness. The idea of achieving high efficiency and energy savings along with speed control could be realised. Key components used in the setting up of the complete plant were elaborated.

Jagadeeswari and Keerthika (2015) described the use of PLC and SCADA in coal conveyor belt fault detection and control in thermal power systems. Sensors had to be mounted at certain positions in order to detect such faults as belt tear, overloading fault and moisture content.

Kumar *et al*. (2012) implemented the service orientated framework for industrial automation systems with the help of SCADA and Extensible Messaging and Presence Protocol (XMPP). The proposed system was built using service bundles that were made to be flexible and modular. Proposed system provided data acquisition and control which were done in real time and offered near real time alarm event handling. Graphical User Interface (GUI) that facilitated the ease of use was demonstrated. As Open Services Gateway initiative (OSGi) applications run on Java, the application prototype is platform and hardware independent. Services were deployed on two popular platforms namely Windows Operating System (OS) and Ubuntu OS. Prototype is scalable as it can be integrated with interactive graphical SCADA system, which is industry standard SCADA software used world-wide. This will save cost of obtaining legacy industrial controllers for an industrial automation system.

Cherdantseva *et al*. (2015) demonstrated the need for effective management of cyber security risks in SCADA systems. An in-depth examination of selected twenty-four risk assessment methods developed for or applied in the context of a SCADA system was discussed. A description of the essence of the methods and analysis of them in terms of aim, application domain, the stages of risk assessment addressed, key risk management concepts covered, impact measurement, sources of probabilistic data, evaluation and tool support were all considered.

Shahzad *et al*. (2014) reviewed SCADA system main components, architecture and some protocols. Master Terminal Unit (MTU), Remote Terminal Unit (RTU), Human Machine Interface (HMI), historian and SCADA communication media or link were discussed as SCADA main components. SCADA communication architecture which transitioned from monolithic (first generation) through distributed (second generation) to networked (third generation) was elaborated. Some SCADA protocols such as Modbus, DNP3 and Profibus were also reviewed.

Zhang and Zhao (2012) in their SCADA power distribution monitoring system design used PLC to collect data from various intelligent instruments on site and electrical parameters of devices and uploaded them to the monitoring system by a switch through a server. The design used Fame View (FV) monitoring configuration software to achieve data real-time display and status display for field equipment and integrated them with reports, database, curves and other functions to enable query of historical data. The debugging and running experiments show that the system is characterised by easy operation, stability and safety i.e. design objectives were achieved. The design system architecture was categorised into three layers as system monitoring layer which consisted of background monitoring system and management, acousto-optic alarm and printing system; the communication management layer which includes switch, serial server and PLC; and field device layer which also includes low-voltage and medium-voltage switchgears, various intelligent instruments, computer protection and many other devices.

Kim (2013) explained SCADA and emphasised the need for encryption schemes to secure communication in SCADA systems. SCADA was explained to be the combination of telemetry and data acquisition and it is composed of collection and transfer of the information to the central site, carrying out any necessary analysis and control and then displaying that information on an operator screen. The need for encryption in SCADA communication was seen to be of necessity as most SCADA are now on the Internet or are web-based. Two encryption schemes known as symmetric key encryption and asymmetric encryption were also discussed. It was concluded that the schemes could be integrated into SCADA communication for managing security levels.

Wang (2011) called for system protection of vulnerable SCADA – based control system. In response, American Gas Association (AGA), International Electrotechnical Commission (IEC) TC57, Institute of Electrical and Electronics Engineers (IEEE), National Institutes of Standards and Technology (NIST) and National SCADA Test Bed Program (NSTBP) have been actively designing cryptographic standards to protect SCADA systems. A suite of security protocols optimised for SCADA systems included point-to-point secure channels, authenticated broadcast channels, authenticated emergency channels and revised authenticated emergency channels which are designed to address the specific challenges faced by SCADA systems.

Sajid *et al.* (2016) recommended Cyber Physical System (CPS) integration with the Internet of Things (IoT) utilising cloud computing services to reduce operational expenses and capably provide stability, fault tolerance and flexibility. SCADA system is seen to be mostly utilised by CPS to monitor critical infrastructure of which web SCADA is an application used for smart medical technologies, making improved patient monitoring and more timely decisions possible. The focus of the study highlighted on the security challenges that the industrial SCADA systems face in an IoT–cloud environment and also provided the existing best practices and recommendations for improving and maintaining security. Finally, authors briefly described future research directions to secure these critical CPSs and helped the research community in identifying the research gaps in this regard.

Rocha and Scholl (2015) looked at the initial stages of the development process of an open source SCADA software. The adoption of low cost, low processing power platforms for simple applications and scientific experimentation serve as a motivation for this piece as large adoption of SCADA software comes with its increased complexity and resource demands.

Barbosa and Pras (2010) directed effort on the problem of intrusion detection in SCADA networks. Further research was conducted to improve accuracy and provide more information on anomalous traffic.

Abbas *et al*. (2015) proposed an approach for simply developing flexible and interoperable SCADA systems based on the integration of Multi-Agent Systems (MAS) and Open Process Control (OPC) protocol. According to them, conventional solutions such as custom SCADA packages and communication protocols and centralised architectures are no longer appropriate for engineering high demand, real-time access to industrial processes due to continuously changing working environments. This proposed SCADA system is said to have advantages of being simple, flexible and interoperable.

Kadivar (2014) clarified the attributes of the "concept of cyber-attack" by examining definitions on cyber-attacks from the literature and information on ten high-profile attacks. Cyber-attacks are known to be one of the major threats to the safe, productive and creative use of the internet. He made clear the fact that the concept of cyber-attacks remains underdeveloped in the academic literature.

Nivethan and Papa (2016) investigated the major open source firewalls for use in SCADA networks and identify Linux 'Iptables' potential as an effective SCADA firewall. The use of firewalls in communication networks transcends to SCADA systems since SCADA also uses some protocols just as in IT networks. They recommended Iptable as a powerful open-source firewall solution that allows for dynamic inspection of packet data.

Galloway and Hancke (2013) explained that industrial networking concerns itself with the implementation of communications protocols between field equipment, digital controllers, software suites and external systems. They clarified that the most essential difference between industrial networks and commercial networks is that industrial networks are connected to physical equipment in some form and are used to control and monitor real-world actions and conditions. This had resulted in the emphasis on a different set of Quality of Service (QoS) considerations of industrial networks to those of commercial networks.

2.7 Review of Related Works on Tippling and Ship Loading Plants

In this section, a review of related literature on both tippling and ship loading plants are presented.

2.7.1 Review of Related Works on the Automation of Tippling Plant

Ojha *et al.* (2016) discussed a methodology for operational improvement in coal handling plant. An approach for monitoring the coal handling equipment of which wagon tippler is one was given and this approach seeks to minimise the failure rate of the equipment. An emphasis on the different types of technology and sensors were used for measuring the coal handling equipment which increases the production rate and also helpful for management of smooth operation.

Kushwaha *et al.* (2018) proposed modernisation of electrical relay logic-based wagon tippler using PLC. Ladder logic was used to replace hardwired electrical relay logic. It was outlined that PLC facilitates accurate breakdown analyses, offers very easy modification and monitoring of system. Thus, PLC is more preferable than the hardwired relay logic.

Gupta *et al.* (2009) discussed the development of a Markov model for performance evaluation of coal handling unit of a thermal plant using probabilistic approach. The coal handling unit which consists of wagon tippler, underground hopper, vibrating feeder and belt conveyors were categorised into two subsystems with two possible states i.e. working and failed. Failure and repair rates of both subsystems were taken to be constant. After drawing transition diagrams, differential equations were generated. Steady state probabilities were determined. Besides, some decision matrices were also developed, which provided various performance levels for different combinations of failure and repair rates of all subsystems. Based upon various performance values obtained in decision matrices and plots of failure rates/repair rates of various subsystems, performance of each subsystem was analysed and then maintenance decisions were taken for all subsystems. The developed model helped in comparative evaluation of alternative maintenance strategies.

2.7.2 Review of Related Works on the Automation of Ship Loading Plant

Anon. (2018a) wrote on ship loader remote controller which mirrors the fixed control panel and mean seamless transition for system operators. A benefit of many flexible options including an LCD display for alarm and load statistics on the remote control was offered. Controller ergonomics and the full customisable face plate to mirror the fixed control also meant seamless transition for system operators.

Liu and Xue (2012) researched on the auto control system for ship loader based on AC800M. An auto detection technology of cabin position and material distribution was introduced. Also, advancement in a new control measure for automated loading was made by adopting the field-bus technology of Profibus, AC800M series PLC, inverter and encoder to build automatic control system.

Anon. (2019k) discussed ship loader automation as a major optimisation target for export terminals globally. The first and largest step to achieve ship loader automation is collision avoidance, which requires accurate knowledge of the ship loader position in relation to the vessel. The second step is profiling the material and combining this information with the knowledge of the vessel shape and position.

Shen (2016) proposed an anti-collision method for slip barrel in the process of automatic ship loading in bulk terminals. The method accurately positions the cargo of cabin which is blocked by slip barrel and shovel, and provides a reliable guarantee for an automatic loading operation. An analyses and illustration of the reliability and validity of the proposed method were demonstrated by a case study of the application in automatic ship loading system in Tianjin coal terminal.

Mi *et al.* (2013) proposed a solution for the target detection and identification of automatic ship loader. A Laser Measurement System (LMS) is used to detect the target automatically which is a prerequisite to achieve automatic running of the ship loader during loading and unloading operations. The gradient algorithm was used to detect the cargo hold edge since the LMS could not recognise distances beyond its maximum detectable distance.

2.8 Summary

This chapter got treated to the concept of automation and reviewed some related literature, discussed about conveyor system with more emphasis on belt conveyors and presented some belt conveyor equations. SCADA system, its related advantages and the use of it in the various industrial sectors such as the process/manufacturing industries were also presented. The idea of SCADA automation as an efficiency improvement technique in GBC Limited, TPF was touched on and finally ended with review of some related literature on tippling and ship loading plants from the perspective of SCADA automation. Use of SCADA automation as an efficiency improvement technique for tippling and ship loading plants to the best of one’s knowledge, has not been researched on and this serves as the focus of this thesis.

CHAPTER 3

THE TIPPLING AND SHIP LOADING PLANTS OF GHANA BAUXITE COMPANY LIMITED, TAKORADI PORT FACILITY

3.1 Introduction

GBC Limited, TPF is a branch of GBC Limited, Ghana which is a subsidiary of Bosai Mineral Group, China. The TPF is situated at the Takoradi harbour due to its nature of operations. At the TPF, trucks of bauxitic ore which are mined, crushed, washed in Awaso and transported either by rail or road are offloaded and stockpiled. Trucks of bauxitic ore hauled by rail are offloaded using the wagon tippler whilst the ones hauled by road are offloaded by the trucks themselves with the help of the directives of a Marksman. The ore is then loaded unto shipping vessels for export. For quite some time now, the rail haulage has been suspended due to the non-functioning nature of some section of the rail network hence, the adaptation to the road haulage. The TPF due to its nature of operations is categorised into two main plants with the administration and stores aiding the whole operations of the facility. The two main plants are the tippling and ship loading plants. Much emphasis would be focused on the tippling and ship loading plants as they are the ones whose efficiency need to be improved using SCADA automation.

3.2 The Tippling Plant

The tippling plant is the plant used to offload the bauxitic ore hauled from Awaso to the TPF either by rail or road. It consists of a wagon tippling subsystem and belt conveyor subsystem that are used to offload the ore from both the locomotive trucks and long vehicle trucks unto the stockpile. Now, because the rail haulage has been suspended for quite some time, the wagon tippling subsystem is not in full operation but rather, a section of its operation is being utilised during unloading of the ore hauled by vehicles. Fig. 3.1 shows a block diagram of the tippling plant.

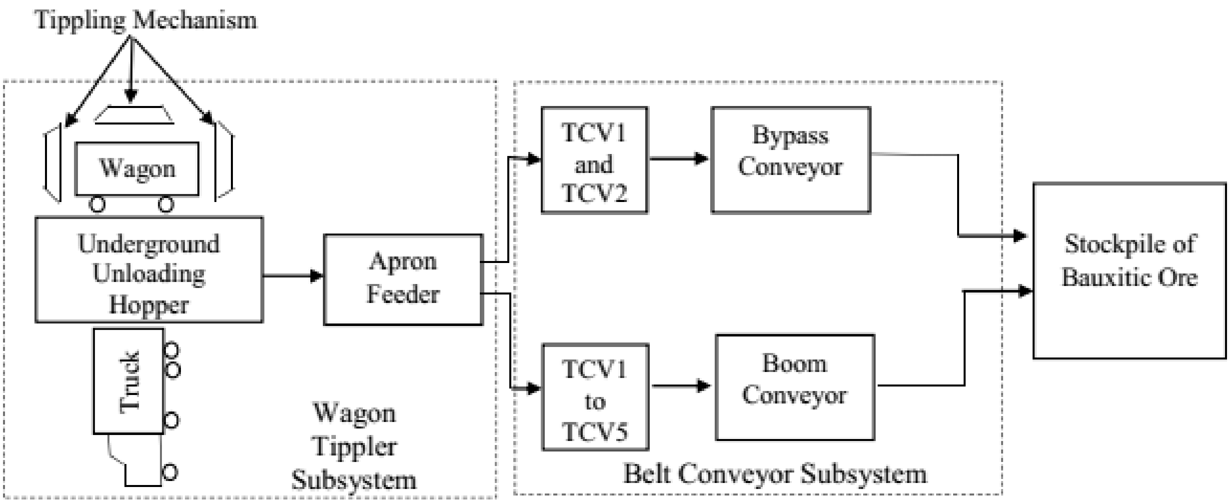


Fig. 3.1 Block Diagram of the Tippling Plant

3.2.1 The Wagon Tippler System

The wagon tippler subsystem consists of wagon tippler, the wagon positioning equipment, underground unloading hopper and an apron feeder below the hopper for evacuating the material unloaded into the hopper.

Wagon tippler

Wagon tippler is a mechanism used for unloading cars such as a wagon, hopper cars, and many more (Ojha *et al.*, 2016). The wagon tippler in the TPF has been used to offload only wagons and vehicular trucks. For the wagon, the tippler holds a section of the wagon and rotates it together to dump out the contents onto the underground hopper. For the vehicular trucks, the trucks offload the contents themselves per the directives of the marksman. The tippler structure consists of two main drum-like cages resting on the eight support roller assemblies in which the wagons are rolled over and tipped to offload the ore. The ore falls onto a conveyor system through the underground unloading hopper and apron feeder for transportation unto the stockpile. Unlike the wagon tippling, vehicular truck tippling is done differently. The loaded trucks stand in-between two concreted walls and under the guidance of a Marksman, trucks are operated by their respective drivers to offload the ore unto the underground unloading hopper and with the aid of the apron feeder, the ore is transported unto the belt conveyor subsystem which then transports the ore unto the stockpile. Fig. 3.2 and Fig. 3.3 show a picture of the wagon tippler and ore tipping by a vehicle, respectively at the tippling plant of TPF.

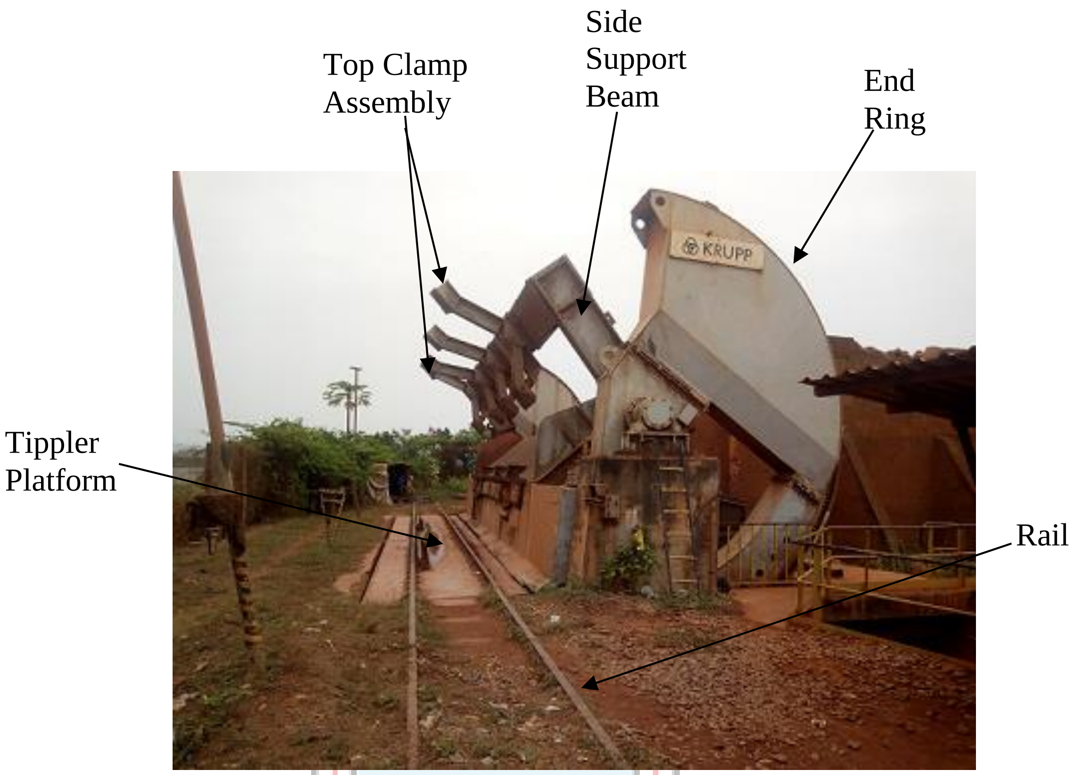


Fig. 3.2 Picture of the Wagon Tippler at Tippling Plant

Fig. 3.3 Picture of a Truck Tipping Bauxitic Ore at the Tippling Plant

Wagon positioning equipment

The wagon positioning equipment is used to position the various wagon trucks on the tippler platform during unloading of ore. At GBC Limited, TPF, the locomotive engine is the one used to carry out this duty. The locomotive engine pushes the whole length of wagons onto the tippler platform one after the other starting from the last wagon. When the last wagon is well positioned on the tippler platform, it is decoupled from the rest of the wagons. And with the help of the tippler's top clamp assembly, the wagon is lifted up in a semi-circular form and then unloads the ore unto the underground hopper. The empty wagon after tipping is pushed backwards from the tippler platform whilst positioning the next loaded wagon for tipping. Further, empty wagons are coupled together as the process continues till the last wagon which is the immediate wagon behind the locomotive engine is unloaded. After unloading, the locomotive engine is coupled to the empty wagons and then moved for another loading of ore from Awaso.

Underground unloading hopper

The underground unloading hopper is provided below the wagon tippler and is used to house the ore during unloading. Unloading of trucks of ore unto the hopper enables easy transport of ore unto the stockpile. The hopper is a Reinforced Cement Concrete (RCC) structure plated with steel liners at the inside. Thus, Fig. 3.4 gives a picture of unloading hopper at the tippling plant of TPF.

Fig. 3.4 Picture of Unloading Hopper Located Underground at the Tippling Plant

Apron feeder below hopper

The apron feeder located below the underground unloading hopper is more suitable for this application due to the impact of the falling materials. The apron feeder is driven by a gearbox coupled to a three-phase 30 kW squirrel cage induction motor for smoother operation. Fig. 3.5 presents a picture of the apron feeder at the tippling plant of TPF.

Fig. 3.5 Picture of the Apron Feeder below the Hopper at Tippling Plant

3.2.2 Belt Conveyor Subsystem

The 7-belt conveyor subsystem at the tippling plant involves seven belt conveyors aligned in a certain direction to help convey the ore bit by bit from the apron feeder point to the stockpile. The seven belt conveyors are named as follows: Boom Conveyor, Conveyor 5, Conveyor 4, Conveyor 3, Bypass Conveyor, Conveyor 2 and Conveyor 1. The belt conveyor subsystem is run first and sequentially, followed by the apron feeder during tippling operations. Two methods of running the belt conveyor subsystem exist: One is starting from the Boom Conveyor and the other is starting from the Bypass Conveyor. Starting from the Boom Conveyor involves running all the conveyors excluding the Bypass Conveyor. Starting from the Bypass Conveyor involves running only three conveyors consisting of the Bypass Conveyor, Conveyor 2 and Conveyor 1. The different approaches of running the belt conveyor subsystem are adopted so as to evenly distribute the ore on the stockpile and also to be able to do unloading in case of any breakdown which involves the Boom Conveyor, Conveyor 5, Conveyor 4 or Conveyor 3. Fig. 3.6 and Fig. 3.7 show the picture of conveyors of belt conveyor subsystem of the tippling plant.

Fig. 3. 6 Picture of Belt Conveyor Subsystem at Tippling Plant: Conveyor 2, 3, 4, 5 and Boom Conveyor

Fig. 3. 7 Picture of Belt Conveyor Subsystem at Tippling Plant: Conveyor 1, 2 and Bypass Conveyor

A conveying unit of the belt conveyor subsystem at GBC limited, TPF consists of certain components coming together to form the unit. These components are: Conveyor Belt, Conveyor Pulley, Conveyor Roller and Belt Drive Unit. A brief discussion of each of these components is presented below.

Conveyor belt

A conveyor belt is a continuously-moving strip of rubber and it functions by serving as a medium for moving objects from one destination to another destination (Anon., 2018e).

Conveyor pulley

Conveyor pulleys are designed for use on belt conveyor systems as a means to drive, redirect, provide tension to, or help track the conveyor belt (Anon., 2018d). Different applications of conveyor pulleys used at GBC limited, TPF are as follows:

Drive/Head pulley: It is a conveyor pulley used for the purpose of driving a conveyor belt. It is typically mounted in external bearings and driven by an external drive source.

Return/Tail pulley: It is a conveyor pulley used for the purpose of redirecting a conveyor belt back to the drive pulley. Tail pulleys can utilise internal bearings or can be mounted in external bearings and are typically located at the end of the conveyor bed. Tail pulleys commonly serve the purpose of a take-up pulley on conveyors of shorter length.

Snub pulley: This is a conveyor pulley used to increase belt wrap around a drive pulley, typically for the purpose of improving traction.

Take-up pulley: This is a conveyor pulley used to remove slack and provide tension to a conveyor belt. Take-up pulleys are more common to conveyors of longer lengths.

Bend pulley: It is a conveyor pulley used to redirect the belt and provide belt tension where bends occur in the conveyor system.

Conveyor roller

A product used either in the bed of conveyor as support for the conveyed product or in the return section under the conveyor bed as support for the conveyor belt. Fig. 3.8 shows a typical conveyor pulley and Fig. 3.9 gives a picture of the belt conveyor subsystem at the tippling plant.

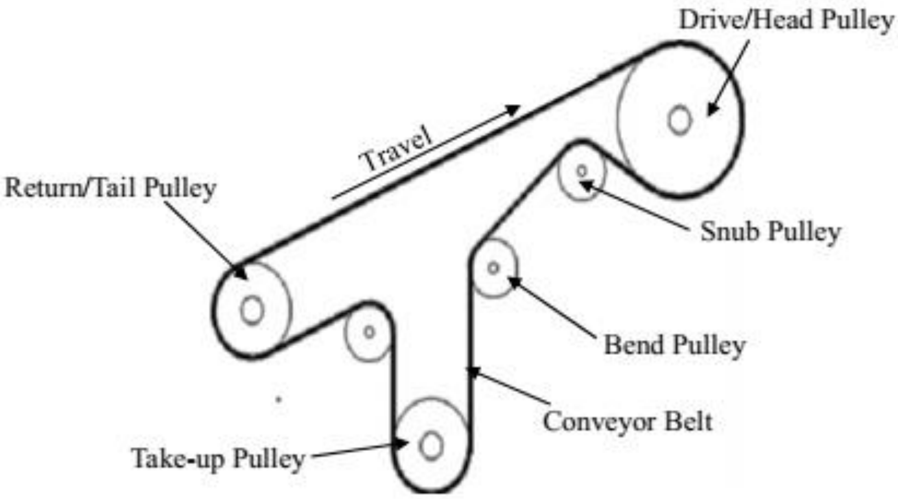


Fig. 3.8 A Typical Conveyor Pulley

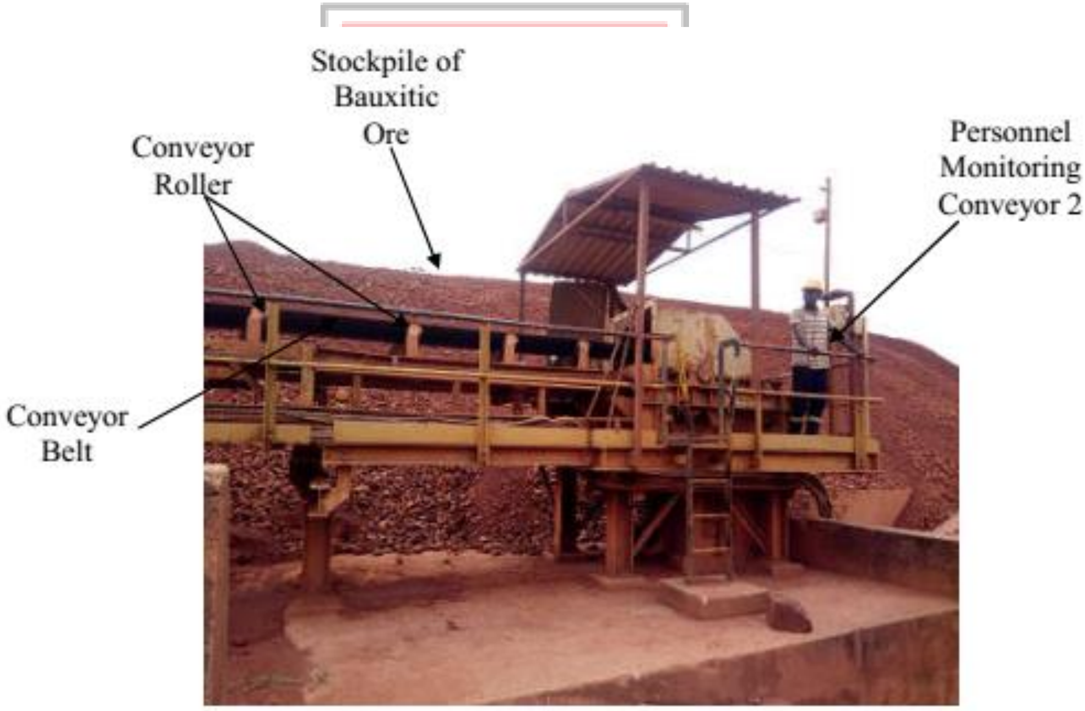


Fig. 3.9 Picture of a Conveying Unit of the Belt Conveyor Subsystem at the Tippling Plant

Belt drive unit

The belt drive unit at GBC limited, TPF usually consists of a gearbox, fluid drive and a three-phase squirrel cage induction motor. The gearbox is coupled to the drive pulley whilst the electric motor is also coupled to the gearbox with the fluid drive serving as an intermediary between the gearbox and the electric motor. A belt drive unit at TPF is depicted in Fig. 3.10.

Fig. 3.10 Picture of Belt Drive Unit

3.2.3 Description of the Tippling Plant Process

Tippling process involves six technicians to operate the tippling plant when ran from the boom conveyor and three technicians when ran from the bypass conveyor. These technicians do inspect, monitor, report and sometimes correct faults on the conveyor lines during operations. If the conveyor lines are to be ran starting from the Boom Conveyor, a selector switch, situated at the Motor Control Centre (MCC) is switched to Position 1 and at Position 2 if it is to be ran from the Bypass Conveyor. The technician who monitors both Conveyor 5 and Boom Conveyor starts the Boom Conveyor manually by pressing the start button switch if running the entire conveyor system. This gets the siren of the Boom Conveyor to sound at a pre-set time and as the pre-set time is up, Boom Conveyor gets started. Conveyor 5 alarm begins to sound immediately the Boom conveyor starts running and as the pre-set time set for the alarm is attained, Conveyor 5 starts automatically. The successive conveyors excluding Bypass Conveyor follow the same routine to have them all started till the apron feeder also starts running. Unloading of ore from vehicles commences as the entire belt conveyor subsystem and the apron feeder start running. Similar procedure is adopted when starting from the Bypass Conveyor. Fig. 3.11 gives a sketch of the tippling plant.

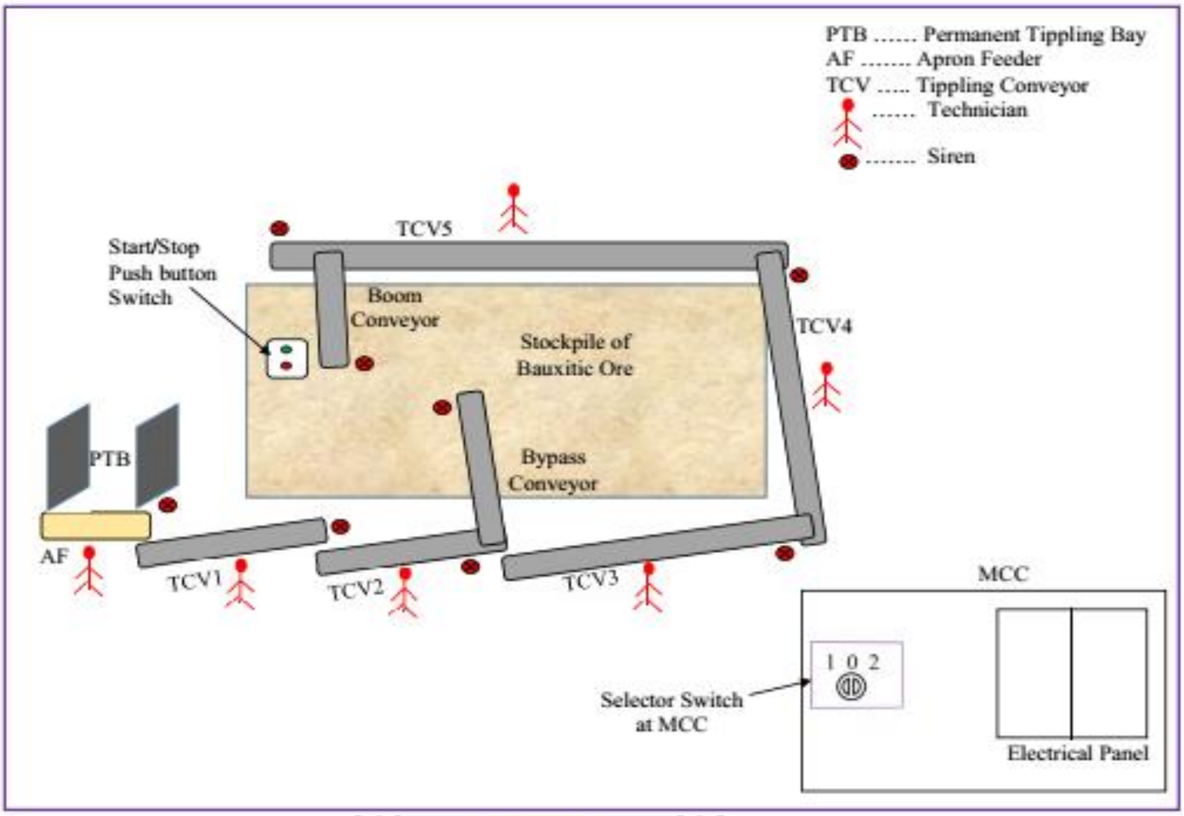


Fig. 3.11 Sketch of the Existing Design of Tippling Plant at GBC Limited, TPF

3.3 The Ship Loading Plant

A ship loader is a large machine used for loading bulk solid materials like iron ore, coal, fertilizers, grains and/or material in bags into ships. Ship loaders are commonly used in ports and jetties from where bulk materials are exported. It mainly consists of an extendable arm or boom, belt conveyor, a tripper to elevate and transfer product from a source conveyor or feeder and a mobile structure to support the boom. It is usually mounted on rails and sometimes on tyres and can move in order to be able to reach the whole length of the ship. The boom also can move front and back, up and down by separate drives so that it can fill the whole breadth of the hold and adapt to the ship's increasing draught while it is loaded. At the discharge, a special telescoping chute, with rotating, pivoting spoon, facilitates even and complete filling of the holds (Anon. 2018f).

Most of the ship loaders are fixed installations, which cannot be removed from the quay, but there are also mobile versions. The challenge of mobile ship loaders is to bring the material from the quay in a short stretch to the height of the ship's deck to the hatch (Anon., 2018b). The ship loading plant consists of eight belt conveyors in series namely Conveyor 1, Conveyor 2, Conveyor 3, Conveyor 4, Conveyor 5, Conveyor 6, Conveyor 7 and Barge

Loader Conveyor (BLC) which are run sequentially during operations starting from the barge loader conveyor. The ship loading plant is categorised into five sections namely: Loading station; Surge hopper; Main Control Room; Towers and Jetty. Fig. 3.12 shows the block diagram of the ship loading plant. The jetty, comprises of head of conveyor 7, BLC and the Jetty Control Room (JCR).

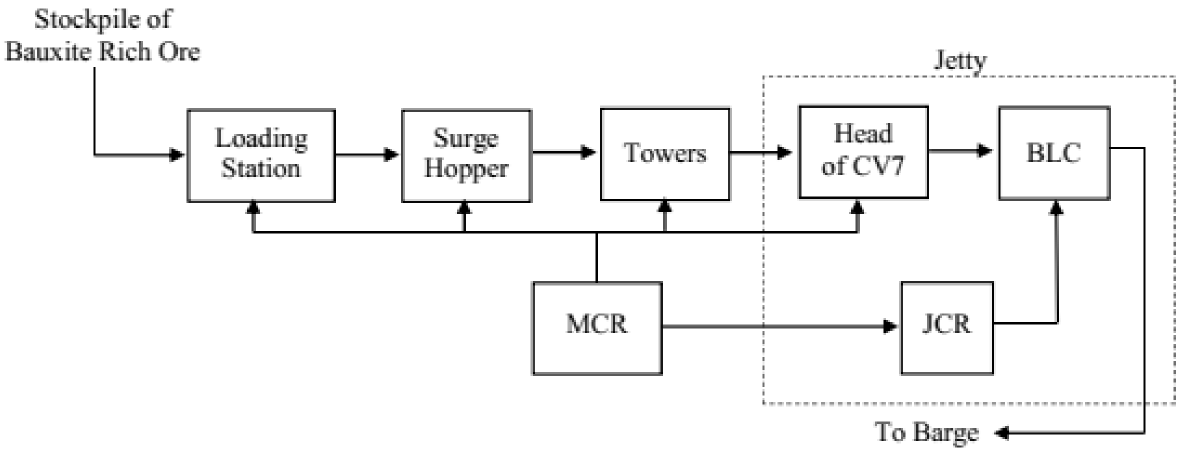


Fig. 3.12 Block Diagram of Ship Loading Plant

3.3.1 Loading Station

Here is where loading commences during operation. The loading station involves part of Conveyor 1 (that is from the tail end to the middle) and sixteen vibrating chutes with vibrating motor fixed at the back of each chute. The vibrating chutes are linked to the stockpile so that during operation, some particular chutes are opened and with the vibrating motor running, Conveyor 1 is loaded with ore directed into the Surge Hopper. The loading station is shown in Fig. 3.13.

Fig. 3.13 Picture of Loading Station of Ship Loading Plant

3.3.2 Surge Hopper

The surge hopper consists of an eighty tonnes capacity hopper which is used to store a certain amount of ore during operation and a vibrating feeder. The ore in the hopper is then regulated at a certain feed rate to load Conveyor 2 with the use of the vibrating feeder. Conveyor 1 ends here with its head on top of the hopper and Conveyor 2 begins from here with its tail end below the vibrating feeder which is below the hopper. Fig. 3.14 shows the surge hopper of the ship loading plant.

Fig. 3.14 Picture of the Surge Hopper of Ship Loading Plant

3.3.3 Towers

The towers are places where technicians stay permanently during ship loading operations to inspect and monitor the conveyors, correct and report any fault or anything which is capable of impeding the ship loading operations. The towers in each has a communication unit placed for communication purposes. Also, there are two mini panels placed in each tower and are linked to the main control room panel to enable easy wiring on the field. Just like other sections of the plant, technicians stay here for the twelve-hour shift during ship loading operations. The towers are five in number, namely; Tower 1, Tower 2, Tower 3, Tower 4 and Tower 5. Tower 1 is situated at the head of Conveyor 2 and tail of Conveyor 3. Tower 2 is situated at the head of Conveyor 3 and tail of Conveyor 4. Towers 3, 4 and 5 follow the same trend with Conveyor 7 ending at Jetty with the head. Tower 1 of ship loading plant is depicted in Fig. 3.14.

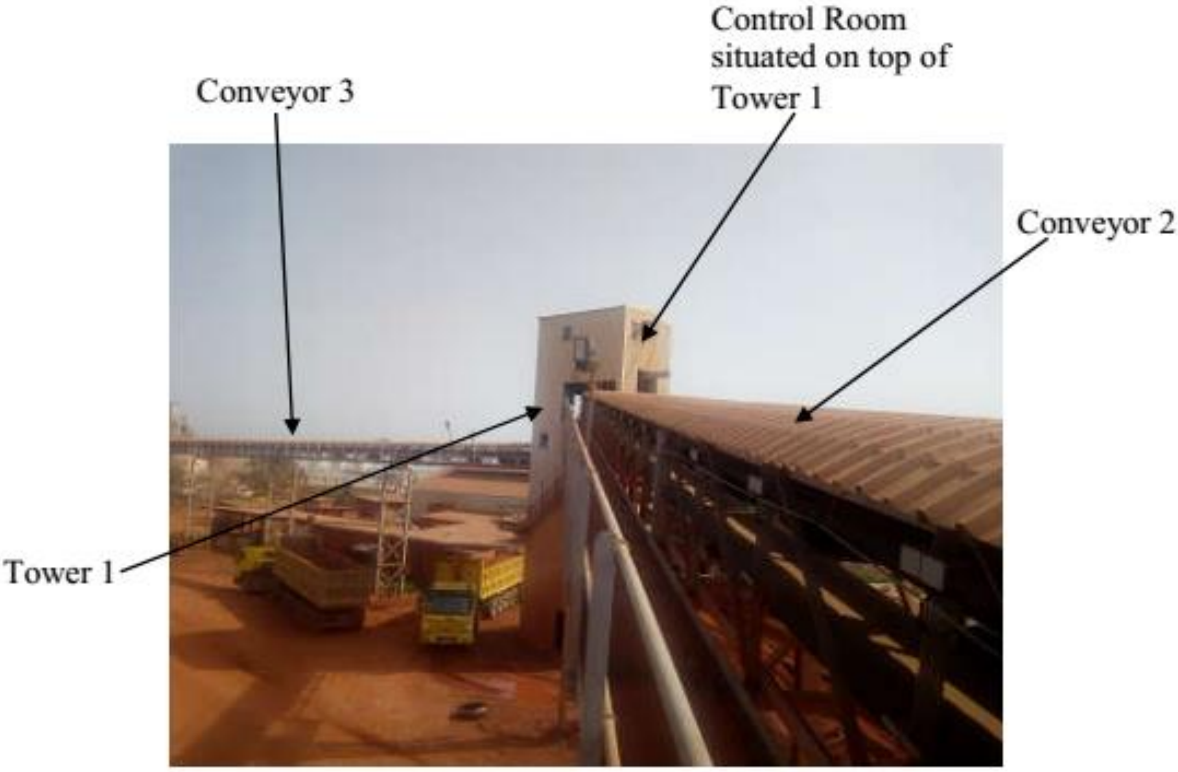


Fig. 3.15 Picture of Tower 1 of Ship Loading Plant

3.3.4 Jetty

A jetty is a structure that projects from land into water. Often, jetty refers to a walkway accessing the centre of an enclosed water body (Anon., 2018c). The ship loading plant ends at jetty with BLC being the last conveyor. At jetty, there is a mini control room from where the ship loading plant is started sequentially. Monitoring of the plant is also done at JCR. Two technicians stay at the Jetty for a shift, one being electrical and the other mechanical. The electrical technician monitors the panel whilst the mechanical technician inspects, monitors, rectifies and reports any fault related to the BLC and conveyor 7. Fig. 3.16 shows the BLC at jetty.

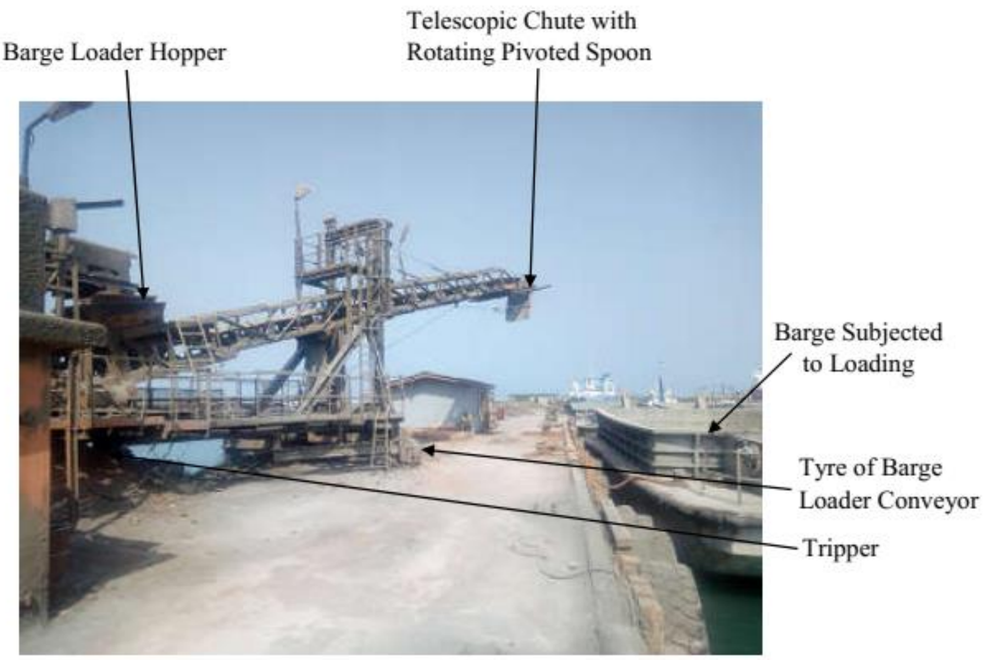


Fig. 3.16 Picture of Barge Loader Conveyor at Jetty of Ship Loading Plant

3.3.5 Main Control Room

Main Control Room (MCR) is the heart of the ship loading plant. The control room consists of an electrical panel from which all sections of the ship loading plant take their electrical power source from. This panel also has various indicating lights which are used to monitor the plant during operations. An electrical technician stays in here permanently during ship loading operations to monitor the plant and also to resolve any electrical problem should there be any. The opened version of the control panel is shown in Fig. 3.17.

Fig. 3.17 Picture of Opened Control Panel for the Ship Loading Plant at Main Control Room

3.3.6 Description of the Ship Loading Plant Process

Twelve technicians are required to run the ship loading plant when loading a vessel. Two electrical technicians monitor the MCR and JCR independently, whilst ten mechanical technicians monitor the plant starting from the loading station through surge hopper to the BLC. The mechanical technicians inspect the belt conveyors from time to time, monitor the belts, rectify or report any fault on the belts if there should be any. The electricians also monitor the whole plant from their respective panels. In the event of an electrical fault, series of communications are done between these two electrical technicians to provide a solution to ensure successful operation of the plant. With technicians well positioned at the stations, successful loading is achieved. Fig. 3.18 shows a sketch of the ship loading plant.

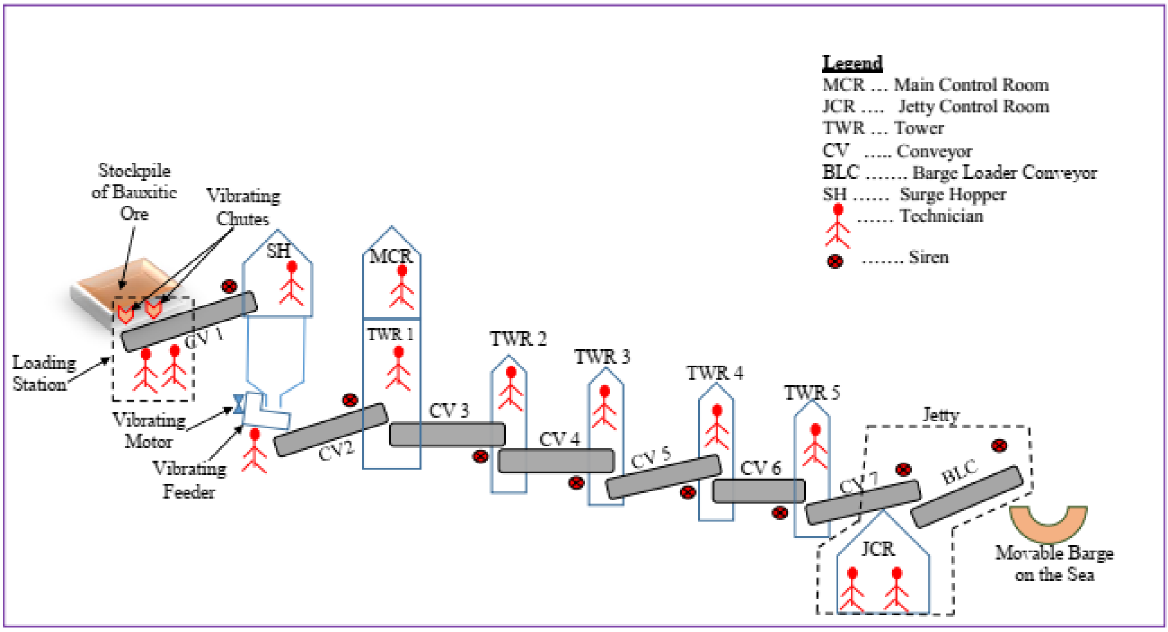


Fig. 3.18 Sketch of the Existing Design of Ship Loading Plant at GBC Limited, TPF

3.4 Summary

This chapter presented the tippling and ship loading plants at GBC limited, TPF. The tippling plant which consisted of wagon tippling subsystem and belt conveyor subsystem were explained and elaborated on in terms of the activities undertaken by them. Operation of the tippling plant process was also presented. The ship loading plant was also categorised into sections as: loading station, surge hopper, towers, jetty and main control room. Various activities undertaken at the aforementioned sections were all explained and finally, a description of the ship loading plant process was given.

CHAPTER 4

SYSTEM REDESIGN

4.1 Introduction

This chapter presents an outline of the design criteria considered in the new design and presents the new system design of both the tippling and ship loading plants at GBC Limited, TPF. A step-by-step approach used in the SCADA design are also presented in a flowchart. A description of selected items considered in the SCADA design is explained.

4.2 Design Concept and Criteria

This section presents both the design concept and design criteria for the new design.

4.2.1 Design Concept

Here, the redesigned system of tippling plant, redesigned system of ship loading plant and SCADA system representation of the tippling and ship loading plants are presented in Fig. 4.1, Fig. 4.2, Fig. 4.3 and Fig. 4.4, respectively.

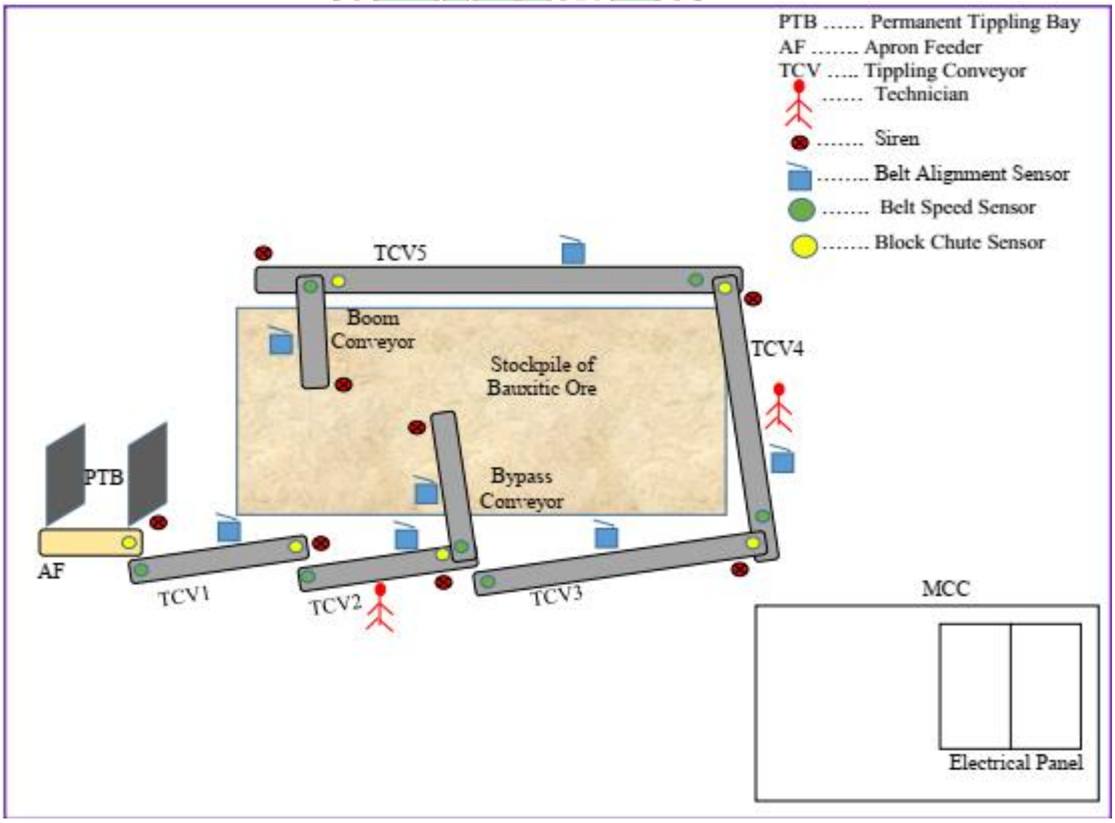


Fig. 4.1 Sketch of the Redesigned System of the Tippling Plant

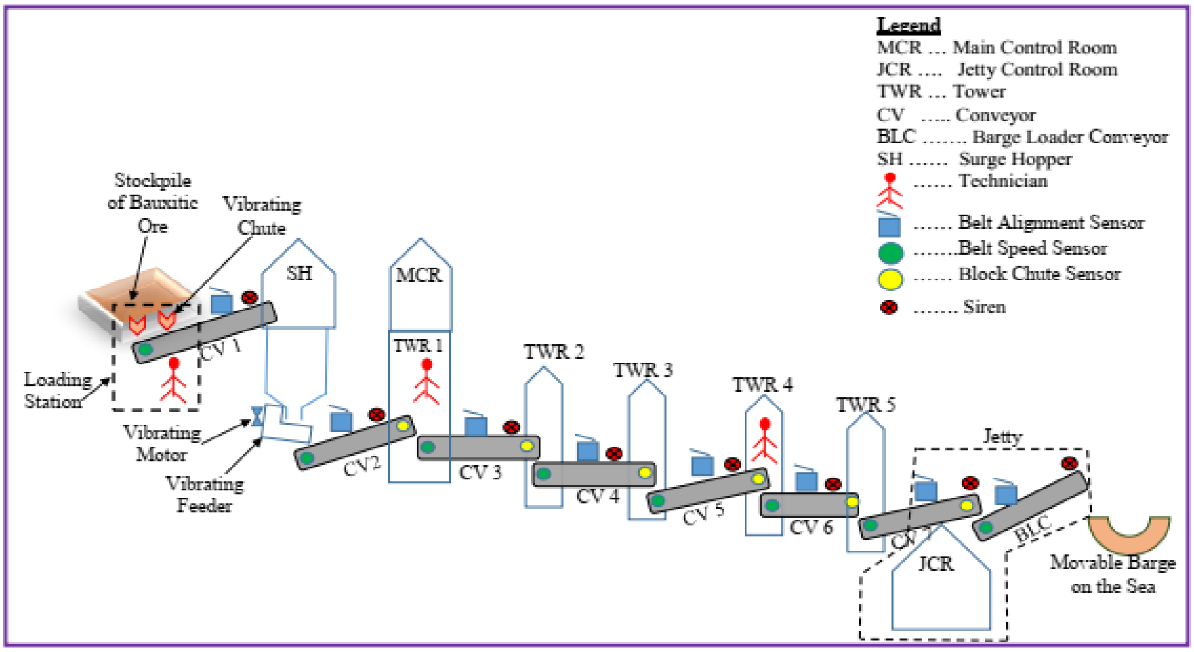


Fig. 4.2 Sketch of the Redesigned System of the Ship Loading Plant

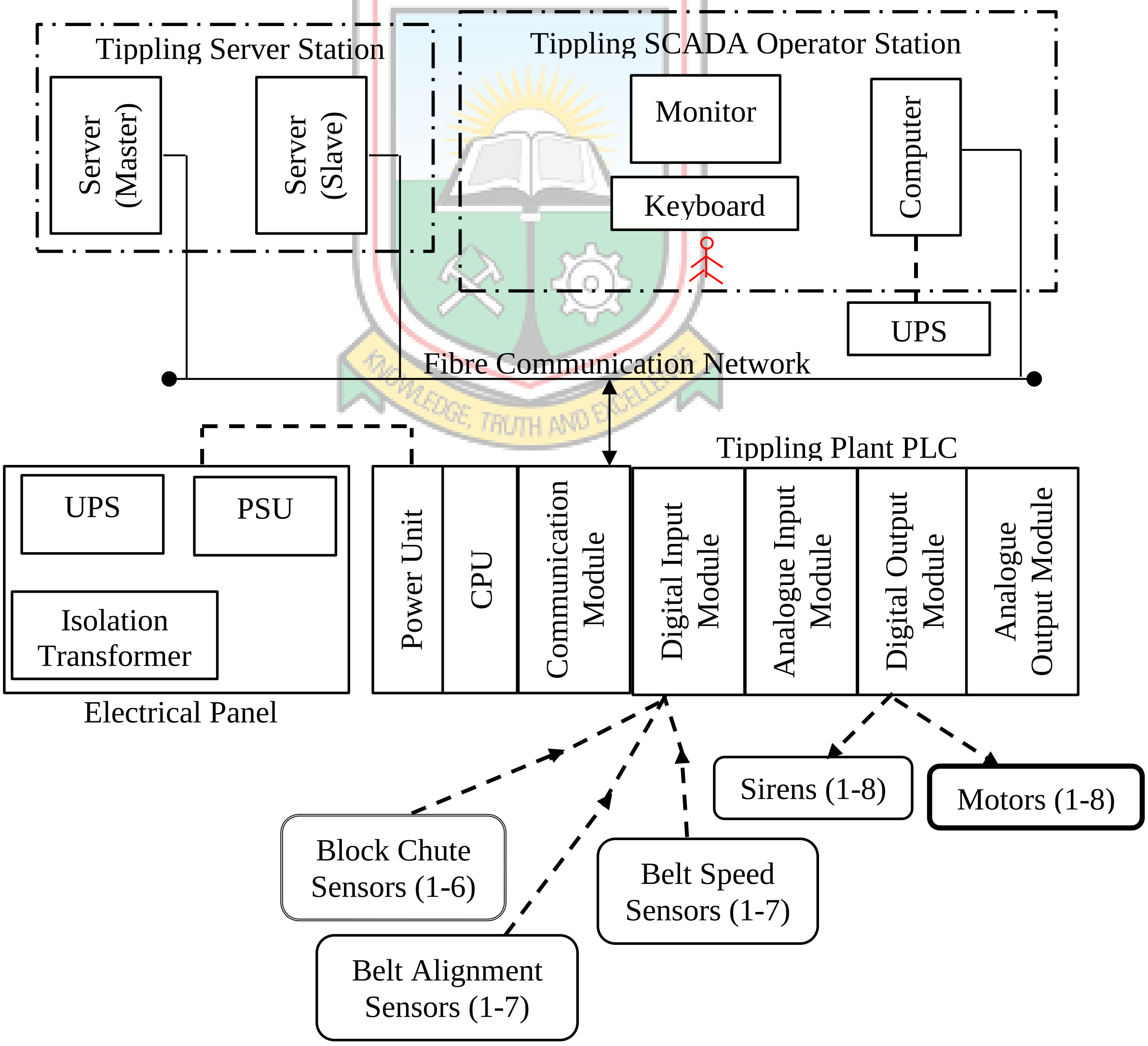
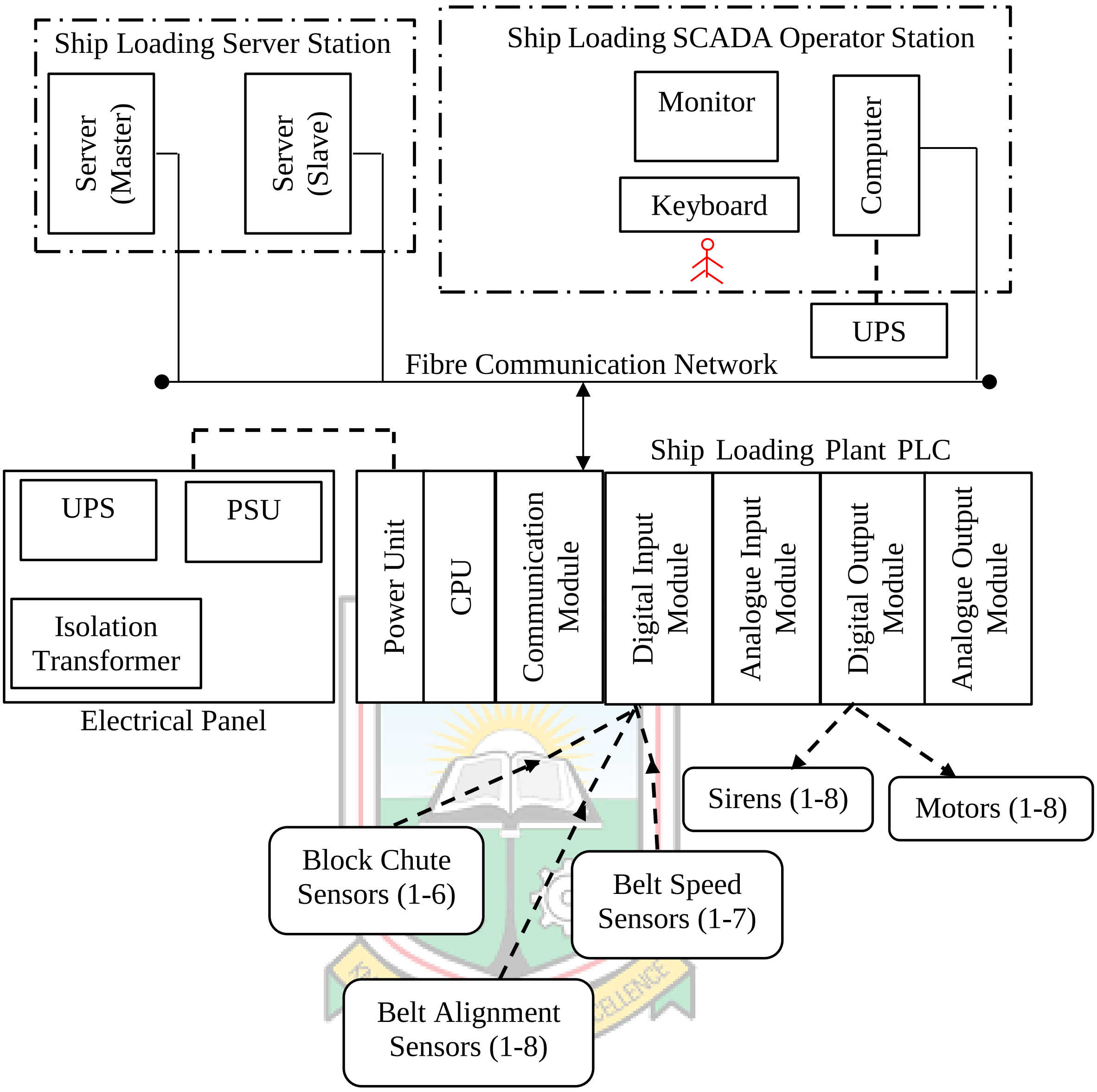


Fig. 4.3 SCADA System Representation of Tippling Plant for TPF



Legend

Communication Link

Electrical/Control Cable

UPS --- Uninterrupted Power Supply

PSU …. Power Supply Unit

CPU …. Central Processing Unit

Fig. 4.4 SCADA System Representation of Ship Loading Plant for TPF

4.2.2 Design Criteria

The design concepts are guided by the following criteria:

i. The new design should be built on the conveyer and drive systems of the existing design;
ii. Human direct involvement in plant operations should be drastically reduced;
iii. The number of permanent staff running both tippling and ship loading plants must be reduced to not more than half of the number;
iv. Field devices should be remotely monitored and controlled; and
v. Performance history of equipment should be traceable and be utilised for analyses.

4.2.3 Mode of Operation of the Redesigned Systems

Here, the mode of operation of the redesigned system of tippling and ship loading plants are explained, supporting them with flowcharts.

Operation of the redesigned tippling system

During start-up of the tippling plant, the SCADA operator checks the state of all equipment/instruments to ensure they are in healthy state and if not, SCADA operator calls the field technician to attend to the faults and fix them. The field technician after fixing the problem calls the SCADA operator to check and confirm if the faults are fixed. If not, field technician continues to work on the faults until the faults are fixed. If faults are fixed and confirmed by SCADA operator, the plant is then started from the HMI screen beginning from either the boom conveyor or bypass conveyor depending on the circuit being run by the SCADA operator. SCADA operator then confirms with field technician to know if the tippling plant is running or not as seen from the HMI interface. If the plant is running then plant start-up is completed but if not, SCADA operator calls the field technician to attend to the faults, fix them and confirms it for start-up. In the event of a fault on the field, the plant is stopped and a field technician is called to attend to the fault and fix it and then the plant is started again. The tippling plant start-up process is demonstrated in a flowchart in Fig. 4.5.

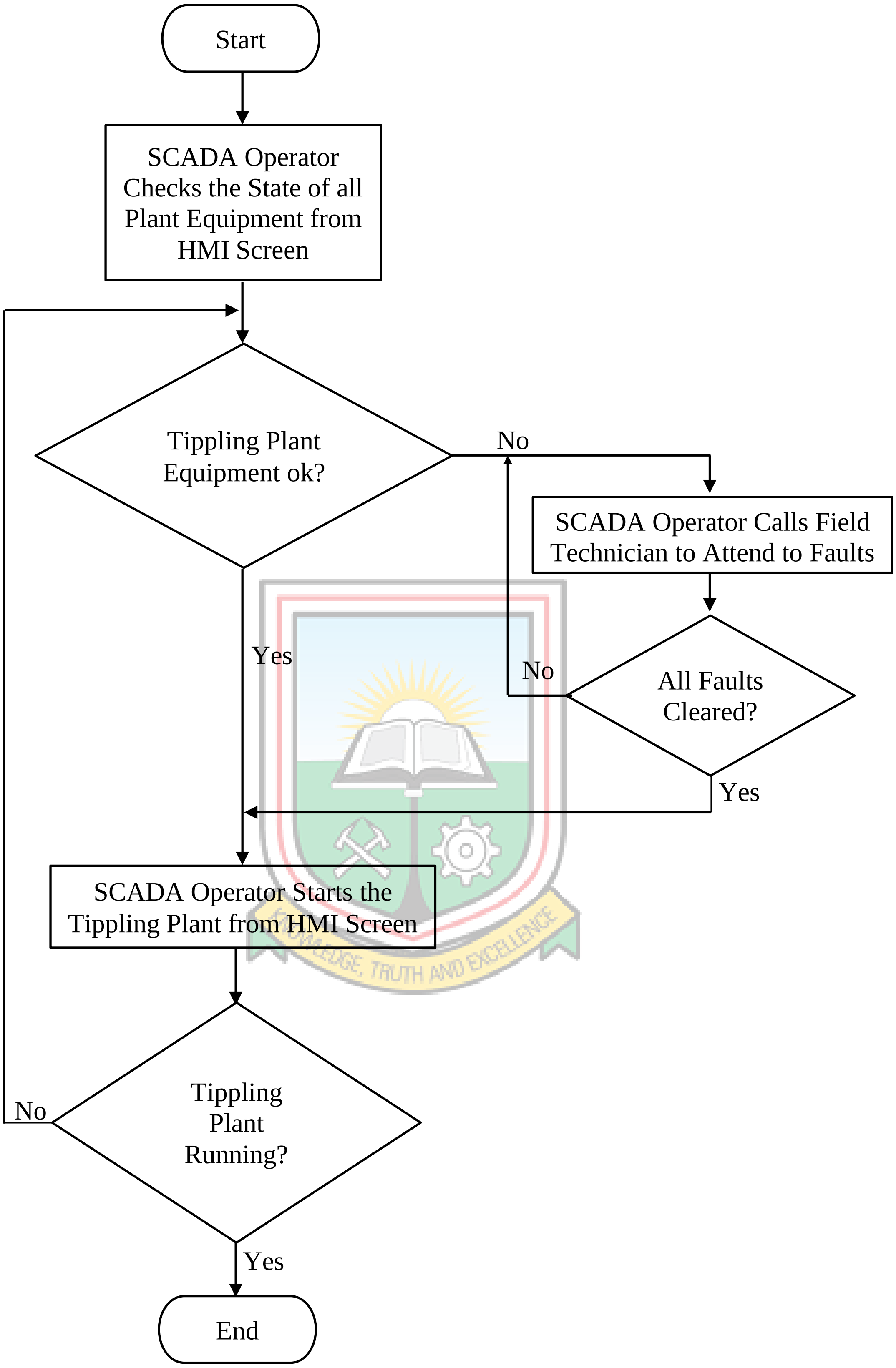


Fig. 4.5 A Flowchart of Tippling Plant Start-up Process

Steps of the flowchart:

Step 1: SCADA Operator checks all equipment states from HMI screen to determine whether all equipment states are ready for start-up.

Step 2: If equipment states are ok, SCADA Operator starts tippling plant from HMI screen. If any equipment state is not ok, SCADA Operator calls field technician to fix fault.

Step 3: Field technician confirms faults clearance with SCADA Operator after fixing them. If faults cleared, SCADA Operator starts tippling plant from HMI screen. If fault not cleared, field technician continues to fix problem until faults are cleared.

Step 4: SCADA Operator starts tippling plant from HMI screen after faults are cleared.

Step 5: SCADA Operator confirms with field technician to know tippling plant is running on the field after starting it from the HMI screen.

Step 6: If tippling plant is running, the process ends but if tippling plant is not running, SCADA operator goes back to check all equipment state from HMI screen to determine whether all equipment states are ok and the process repeats again.

Operation of the redesigned ship loading system

During start-up of the ship loading plant, the SCADA operator checks the state of all equipment/instruments to ensure they are in healthy state and if not, SCADA operator calls the field technician to attend to the faults and fix them. The field technician after fixing the problems calls the SCADA operator to check and confirm if the faults are fixed. If not, field technician continues to work on the faults until the faults are fixed. If faults are fixed and confirmed by SCADA operator, the plant is then started from the HMI screen beginning from the BLC by the SCADA operator. SCADA operator then confirms with field technician to know if the ship loading plant is running as seen from the HMI interface. If the plant is running then plant start-up is completed but if not, SCADA operator calls the field technician to attend to the faults, fix them and confirm for plant start-up. In the event of a fault on the field, the plant is stopped and a field technician is called to attend to the fault and fix it and then the plant is started again. The ship loading plant start-up process is demonstrated by the flowchart presented in Fig. 4.6.

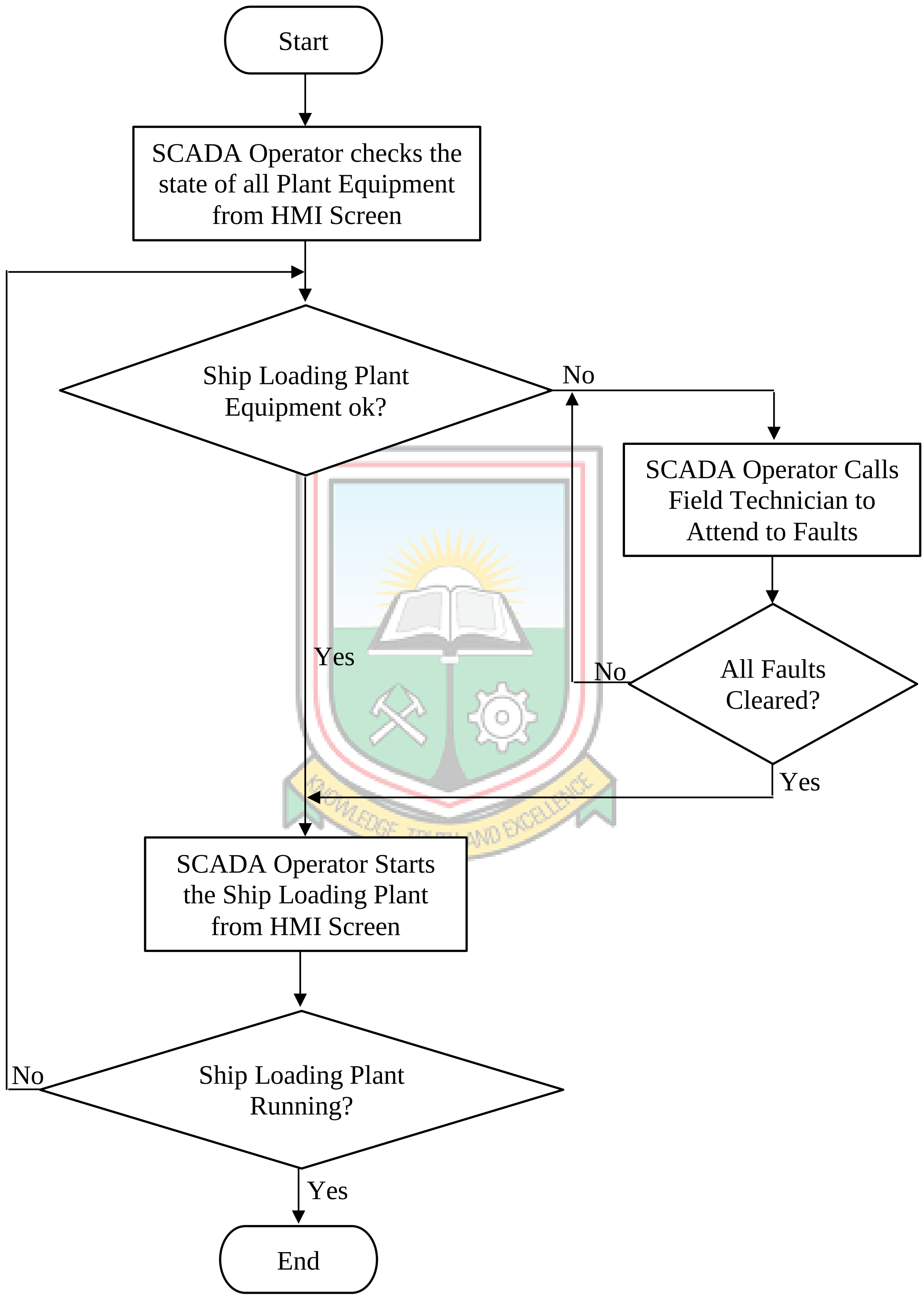


Fig. 4.6 A Flowchart of Ship Loading Plant Start-up Process

Steps of the flowchart:

Step 1: SCADA Operator checks all equipment states from HMI screen to determine whether all equipment states are ready for plant start-up.

Step 2: If equipment states are ok, SCADA Operator starts ship loading plant from HMI Screen. If equipment states are not ok, SCADA Operator calls field technician to fix the faults.

Step 3: Field technician confirms faults clearance with SCADA Operator after fixing them. If faults are cleared, SCADA Operator starts ship loading plant from HMI screen. If faults are not cleared, field technician continues to fix problem until faults are cleared.

Step 4: SCADA Operator starts ship loading plant from HMI screen after faults are cleared.

Step 5: SCADA Operator confirms with field technician to know ship loading plant is running on the field after starting it from the HMI screen.

Step 6: If ship loading plant is running, the process ends but if ship loading plant is not running, SCADA operator goes back to check all equipment states to determine whether all equipment states are ok and the process repeats again.

4.3 Data Acquisition, Presentation and Analyses

This section is devoted to data acquisition, presentation and analyses.

4.3.1 Data Acquisition

Data was collected and the compilation of the annual plant performance in metric tons (mt) of GBC Limited, TPF from 2013 to 2017 was done. Data for the year 2018 could not be added and used for analysis. This is due to the fact that GBC Limited encountered a major challenge with the Ghana government and also with a contractor who hauls the bauxitic ore from the jetty to the ship loading side. These challenges affected the 2018 year's performance so much that it cannot be used for the analysis. The raw data gathered are provided in Table A.1 to Table A.5 of Appendix A. A summary of the five-year performance of GBC limited, TPF is presented in Table 4.1. Also, data on the tippling plant apron feeder and conveyor motors and ship loading plant conveyor motors are provided in Table 4.2 and Table 4.3, respectively.

Table 4.1 A Summary of Annual Performance of TPF from 2013 to 2017

SN	Year	Annual Tonnage Performance (Tonne)	
		Tippling Plant (t)	Ship Loading Plant (t)
1.	2013	786360.53	783586.00
2.	2014	754530.00	906461.00
3.	2015	888853.00	1068841.00
4.	2016	1137021.20	1090922.00
5.	2017	1483111.64	1539892.00

Table 4.2 Tippling Plant Apron Feeder and Conveyor Motor Information

Motor Data								
Item	Length of Item (m)	Power Rating (kW)	Line Voltage (V)	Speed (rpm)	Current (A)	IP	Phases	Frequency (Hz)
AF	10.00	30.0	400	1470	57	55	3	50
TCV1	125.00	30.0	400	1475	57	55	3	50
TCV2	125.00	30.0	400	1470	57	55	3	50
BC	15.00	18.5	400	1470	34	55	3	50
TCV3	100.00	30.0	400	1470	57	55	3	50
TCV4	100.00	30.0	400	1470	57	55	3	50
TCV5	270.00	30.0	400	1470	57	55	3	50
BmC	10.00	18.5	400	1470	34	55	3	50

Table 4.3 Ship Loading Plant Conveyor Motor Information

Motor Data								
Item	Length of Item (m)	Power Rating (kW)	Line Voltage (V)	Speed (rpm)	Current (A)	IP	Phases	Frequency (Hz)
CV1	127.00	45.0	400	1480	83	55	3	50
CV2	81.00	37.0	400	1465	68	55	3	50
CV3	156.70	37.0	400	1465	68	55	3	50
CV4	170.05	18.5	400	1460	34	55	3	50
CV5	376.25	45.0	400	1480	83	55	3	50
CV6	15.00	18.5	400	1460	34	55	3	50
CV7	183.32	37.0	400	1465	65	55	3	50
BLC	15.00	18.5	400	1460	34	55	3	50

4.3.2 Data Presentation

This section organises the data of annual performance of GBC Limited, TPF from the years 2013 to 2017 into graphical representations and are presented in Fig. 4.7, Fig. 4.8, Fig. 4.9, and Fig. 4.10.

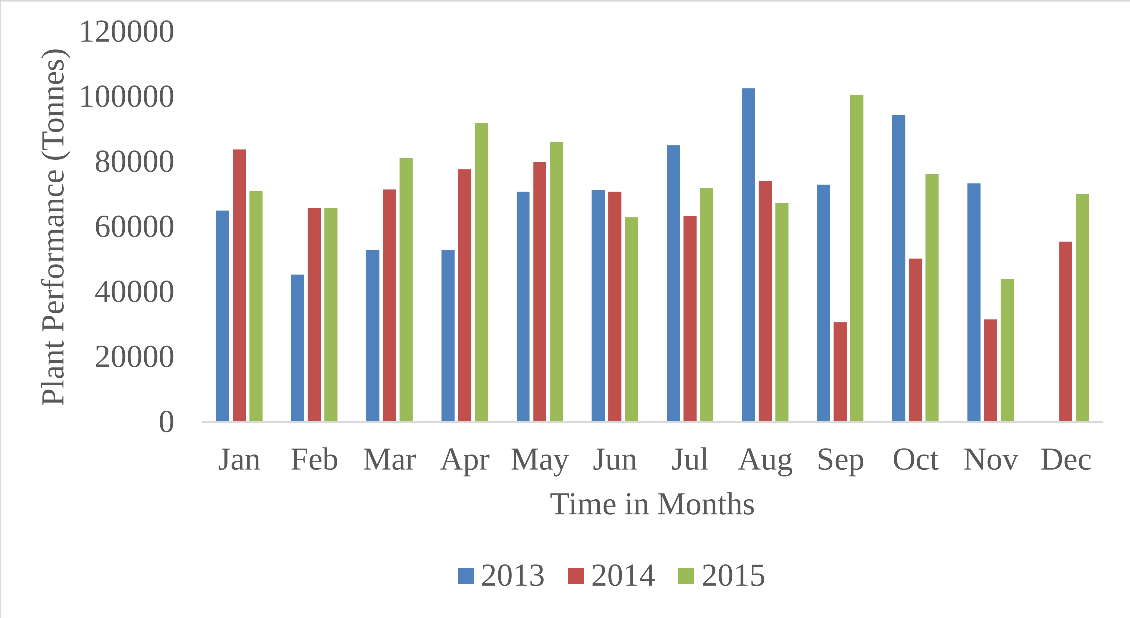


Fig. 4.7 Performance of Tippling Plant from Year 2013 to Year 2015

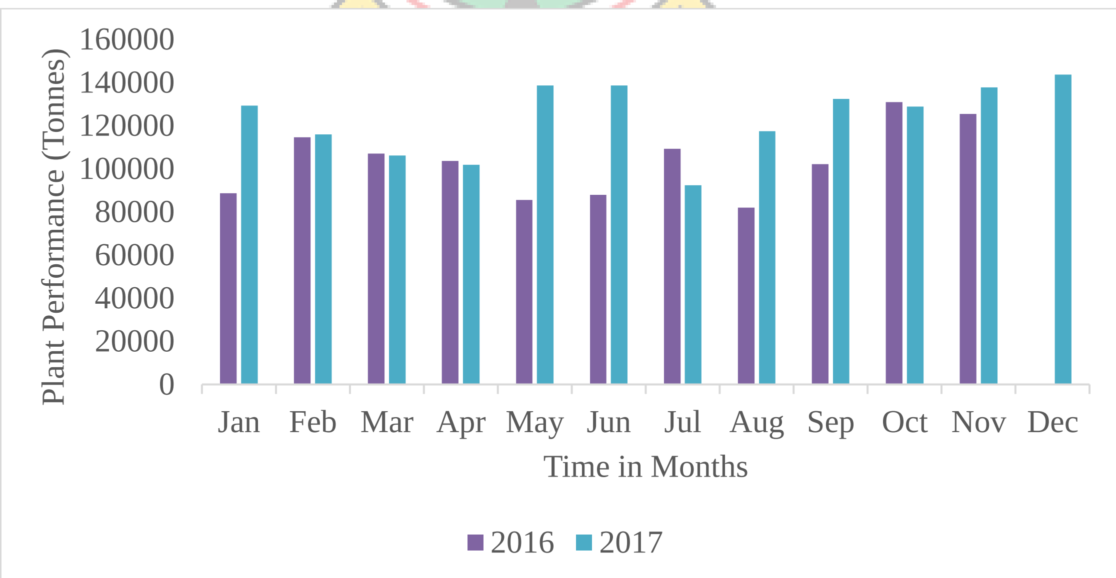


Fig. 4.8 Performance of Tippling Plant from 2016 to 2017

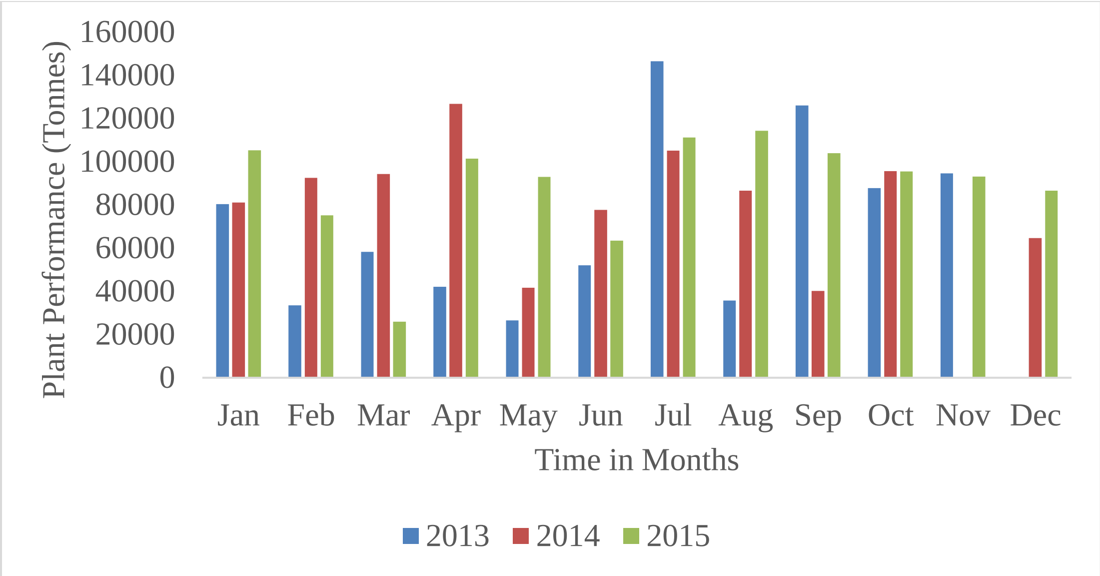


Fig. 4.9 Performance of Ship Loading Plant from 2013 to 2015

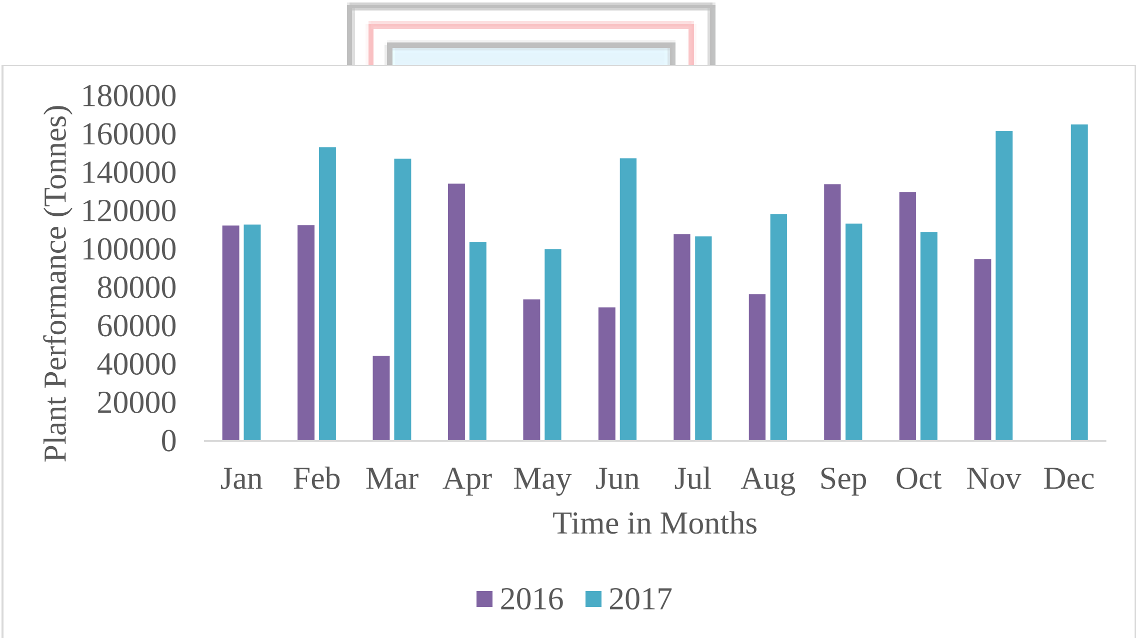


Fig. 4.10 Performance of Ship Loading Plant from 2016 to 2017

4.3.3 Data Analyses

From Section 4.3.2, it can be seen that a little increase in the annual performance of TPF of GBC is witnessed in the years of 2013 to 2016. It is evidenced from Table 4.1 that the year 2017 experienced a "frog-leap" performance compared to the previous years. According to the plant personnel, this leap could be attributed to the fact that certain mechanisms such as proper maintenance schedule, proper records keeping and follow-up and modifications in the plant were put in place. Thus, with much effort put in, an improved performance can be achieved.

4.4 Development of the Supervisory Control and Data Acquisition System

A step-by-step approach adopted in the development of the SCADA system is presented in the flowchart of Fig. 4.11 with the various steps outlined.

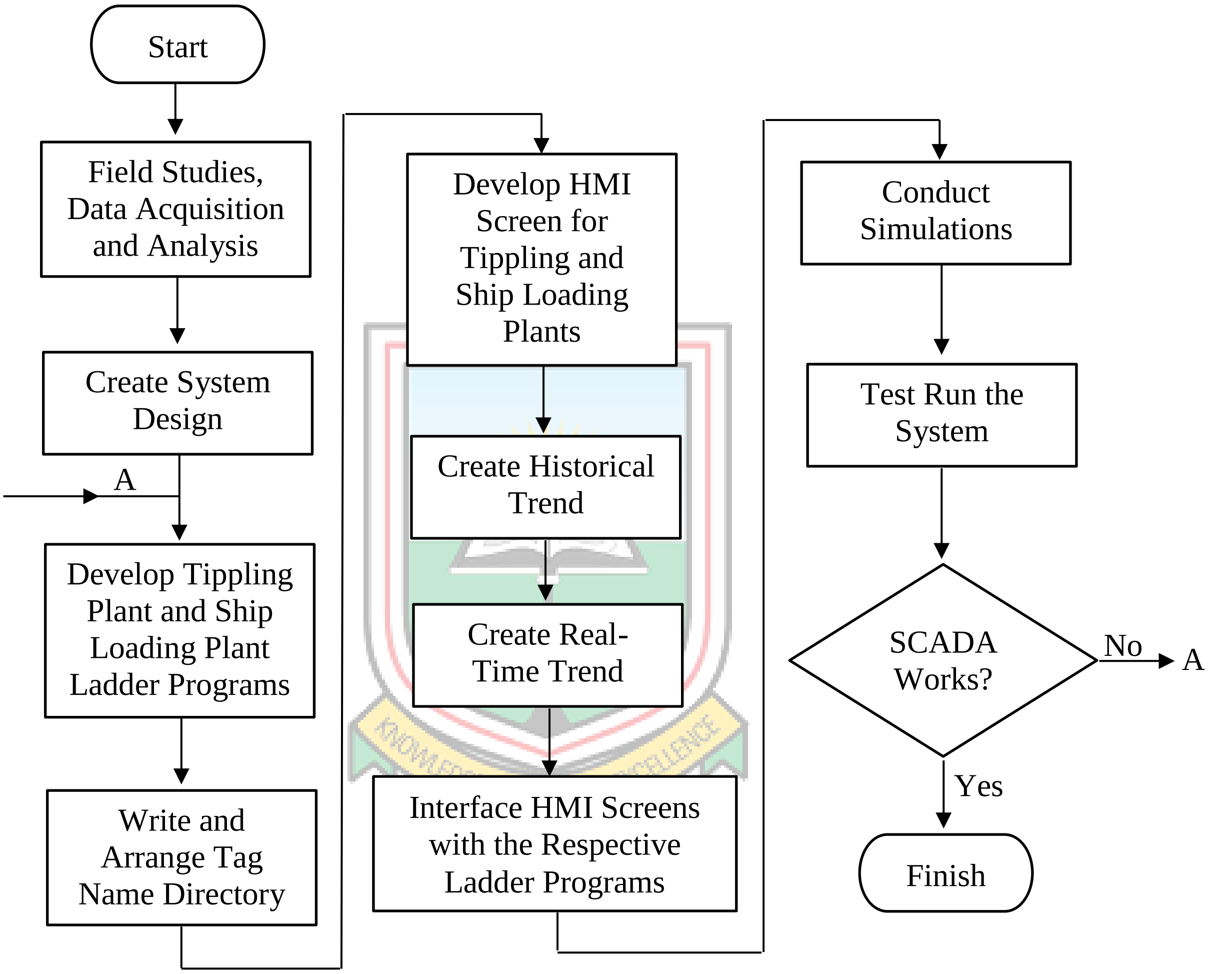


Fig. 4.11 A Flowchart of the SCADA System Development Process

Steps of the flowchart are as follows:

Step 1: Conduct field visits to study both tippling and ship loading plants to get data for analyses.

Step 2: Create system design

Step 3: Develop PLC program for tippling and ship loading plants

Step 4: Write tag names for the digital and analogue input/output devices and assign tag names to the respective field devices.

Step 5: Develop HMI screens for both tippling and ship loading plants.

Step 6: Create historical trend. This helps in tracing the history of an instrument or field device.

Step 7: Create real-time trend.

Step 8: Interface HMI screens with their respective ladder programs.

Step 9: Simulate the HMI screen with the ladder program by going online and run the program.

Step 10: Test run the system and check the behaviour and response of field devices from the HMI screen to see if they perform as required, if not return to the ladder program development to correct error.

Step 11: End the program if SCADA runs up to the required set point.

4.5 Selection of Items for the SCADA System Design

This section lists the items selected for the SCADA system design and explains the selection criteria used.

4.5.1 Belt Alignment Sensor

The belt alignment sensor is a sensor designed to interlock with the conveyor shut down systems in the event of belt misalignment. It is mounted on both sides of the conveyor belt with roller actuator arms positioned tens of millimetres from the belt. In the event of a very long conveyor system, several of these sensors are mounted at marginal intervals. In the event of any belt misalignment on either the right side or left side of the conveyor belt, the sensor activates and stops the conveyor belt. Many different belt alignment sensors are available however, knowledge about the type of application and basic operating condition requirements can create a more informed and accurate choice (Festo, 2018). The LHL-N11 belt alignment sensor (Anon., 2019n) is selected based on the considered factors that are summarised into Table 4.4.

Table 4.4 A Summary of Considerations in Selecting the Belt Alignment Sensor

SN	Factors Considered	Value
1.	Type of Sensing	Limit sensing
2.	Composition of Target	Non-metallic
3.	Distance to Target	Sensor activates at about 60^{o} angle of tilt
4.	Control Interface	2 wire AC
5.	Electrical Connection	Integrated quick-disconnect
6.	Operating Voltage (VAC)	220 – 250
7.	Degree of Protection	Must be dust proof and water proof (IP 67)
8.	Ambient Temperature (^{o}C)	10 – 80
9.	Discrete or Analogue	Discrete

(Source: Anon., 2019n)

4.5.2 Belt Speed Sensor

According to Menke (2010), selecting an industrial sensor can be a daunting task especially with so many different sensing technologies and the endless variety of products in today's market. Nevertheless, Menke (2010) outlines some of the considerations when making a choice of a sensor for an application, considered are type of sensing, composition of target, distance to target, form factor, control interface, special requirements and electrical connection. However, selecting a belt speed sensor entails further requirements. Table 4.5 gives a summary of belt speed sensor selection factors. The NJ15S+U1+N belt speed sensor (Anon., 2019o) is hereby selected based on the considered factors.

Table 4.5 A Summary of Considerations in Selecting the Belt Speed Sensor

SN	Factors Considered	Value
1.	Type of Sensing	Proximity
2.	Composition of Target	Metallic
3.	Distance to Target (mm)	About 15
4.	Control Interface	2 wire AC
5.	Electrical Connection	Integrated quick-disconnect
6.	Operating Voltage (VAC)	220 – 250
7.	Degree of Protection	Must be dust proof and water proof (IP 67)
8.	Ambient Temperature (^{o}C)	10 – 80
9.	Discrete or Analogue	Discrete

(Source: Anon., 2019o)

4.5.3 Block Chute Sensor

Different sensors for the block chute detection application exist but the Wadeco microwave block chute detector is preferred due to the unique factors considered in selecting it as summarised into Table 4.6. The MWS-ST/SR-2 block chute sensor (Anon., 2019p) is selected.

Table 4.6 A Summary of Considerations in Selecting the Block Chute Sensor

SN	Factors Considered	Value
1.	Type of Sensing	Microwave
2.	Composition of Target	Solid, granular
3.	Distance to Target	Falls within the range of 1meter
4.	Control Interface	3 wire AC/DC
5.	Electrical Connection	Integrated quick-disconnect
6.	Operating Voltage (VAC)	220 – 250
7.	Degree of Protection	Must be dust proof and water proof (IP 67)
8.	Ambient Temperature ^{o}C	10 – 80
9.	Discrete or Analogue	Discrete

(Source: Anon., 2019p)

4.5.4 Programmable Logic Controller

In selecting a PLC for an application, several factors are considered to enable a successful installation. But the most important ones among the factors outlined by Anon. (2019m) are proposed system (new or existing), environmental conditions, discrete devices required, analogue devices required, specialty features, CPU required (memory capacity, data memory, program volume and scan time), I/O locations, communications and programming requirements. Table 4.7 summarises on the considerations for the selection of PLC for tippling plant and for the ship loading plant.

Table 4.7 A Summary of Considerations in Selecting the PLC

SN	Factors Considered	Value
1.	Proposed System	New
2.	Environmental Condition	Open to ambient conditions
3.	Discrete Devices Required	Belt Alignment Sensor Belt Speed Sensor Block Chute Sensor
4.	Analogue Devices Required	No Analogue device required for now but a provision would be made for future purposes
5.	Special Features	No speciality module required
6.	CPU Required (MB)	16
7.	Input/Output (I/O) Location	Local I/Os only
8.	Communications	PLC communicates with field devices (sensors, motors and sirens) and interfaced with HMI

Table 4.7 Cont'd

SN	Factor Considered	Value
9.	Programming Language	Ladder logic

(Source: Anon., 2019q)

The 1756-L71 Allen Bradley Control Logix PLC (Anon., 2019q) is selected for both the tippling and ship loading plants.

4.5.5 Uninterruptible Power Supply

An Uninterruptible Power Supply (UPS), also known as a battery backup, provides backup power when the regular power source fails or voltage drops to an unacceptable level. A UPS allows for the safe, orderly shutdown of a computer and connected equipment. Kiehn (2019) enumerates some requirements such as system performance, runtime, reliability, maintenance and total cost of ownership when choosing an UPS for an application. They are power capacity, input and output outlet, efficiency, battery type, protection, frequency and standard outlet. Thus, these factors led to the selection of PSU-804 UPS (Anon., 2019r). Table 4.8 gives the summary of the considerations.

Table 4.8 A Summary of Considerations in Selecting the UPS

SN	Factors Considered	Value
1.	System Performance	Must have good power protection, able to handle overloads and step loads and be double conversion with respect to its topology.
2.	Runtime	5 minutes
3.	Reliability	High degree of reliability
4.	Maintenance	Easy to maintain
5.	Total Cost of Ownership	Very affordable
6.	Efficiency	AC mode: >97% DC mode: >80%
7.	Battery Type	Lead acid battery
8.	Frequency (Hz)	50
9.	Standard Outlet	2 Sockets

(Source: Anon., 2019r)

4.5.6 Power Supply Unit

Power Supply Unit (PSU) plays a very important role in the design and installation of PLCs and SCADA systems and its importance cannot be overlooked since without it some field instruments cannot work. This device supplies power to the field instruments to facilitate their functionality. According to Anon. (2019g), in selecting a PSU for a design, one has to keep the following requirements in mind to ensure proper selection of the device:

i. Power source, input voltage and frequency (AC/DC);
ii. Number of DC devices to be powered;
iii. Voltage requirements of DC devices;
iv. Wattage/Amperage of each DC device required;
v. Maximum/peak draw of each DC device;
vi. Physical space available and mounting requirements; and
vii. Applicable safety approval for the location and safety.

Table 4.9 A Summary of Considerations in Selecting the PSU

SN	Factors Considered	Value
1.	Power source, input voltage and frequency (AC/DC)	220 VAC, 50 Hz
2.	Number of DC devices to be powered	No DC device to be powered yet but provision would be made for them
3.	Voltage requirements of DC devices	24 VDC
4.	Wattage/Amperage of each DC device required	Not known yet
5.	Maximum/peak draw of each DC device	Not known yet
6.	Physical space available and mounting requirements	Not too big, but it should be able to be put into a panel
7.	Applicable safety approval for the location and safety	ISO certified

(Source: Anon., 2019g)

The T-30B (Anon., 2019t) is selected for the application.

4.5.7 Isolation Transformer

According to Anon. (2019h), an isolating transformer is a transformer used to transfer electric power from a source of Alternating Current (AC) power to an equipment or device while isolating the powered device from the source, usually for safety reasons. Isolation transformers are mostly primary type of transformers used in industries, supplying power to sensitive devices/equipment. They provide galvanic isolation and are used to protect against electric shock, to suppress electrical noise in sensitive devices, or to transfer power between two circuits which must be connected. This transformer is often built with special insulation between primary and secondary windings and is specified to withstand a high voltage between the windings. Isolation transformers block transmission of the DC component in signals from one circuit to the other, but allow AC components in signals to pass. Isolation transformers with electrostatic shields are used for power supplies for sensitive equipment such as computers, medical devices, or laboratory instruments. Anon. (2019i) discusses some basic steps to follow in the selection of an isolation transformer.

Determination of the kVA, amperage or wattage required by the load

Transformer size is determined by the kVA of the load. For the required single-phase isolation transformer, the kVA rating is computed using equation (4.1) and equation (4.2) for the respective plants.

$$S_{TP} = \frac{V_{ph} \times I_{TP}}{1000} \tag{4.1}$$

$$S_{SLP} = \frac{V_{ph} \times I_{SLP}}{1000} \tag{4.2}$$

where, S_{TP} = apparent power of tippling plant

S_{SLP} = apparent power of ship loading plant

V_{ph} = phase voltage (V)

I_{TP} = total current required at tippling plant (A)

I_{SLP} = total current required at ship loading plant (A)

The currents are computed as demonstrated in Table 4.10 and Table 4.11 that tabulate the sensors used with their respective current rating and quantity to be installed for tippling and ship loading plants, respectively.

Table 4.10 Calculating the Total Current Required by the Isolation Transformer for Tippling Plant

Device	Current Rating (A)	Quantity to be Installed	Total Current (A)
Belt Alignment Sensor	4.000	18	72.000
Belt Speed Sensor	0.003	7	0.021
Block Chute Sensor	0.180	6	0.108
Total Current Required (I_{TP})			**72.129**

Table 4.11 Calculating the Total Current Required by the Isolation Transformer for Ship Loading Plant

Device	Current Rating (A)	Quantity to be Installed	Total Current (A)
Belt Alignment Sensor	4.000	30	120.000
Belt Speed Sensor	0.003	8	0.024
Block Chute Sensor	0.180	7	0.126
Total Current Required (I_{SLP})			**120.150**

At a phase voltage V_{ph} = 230 VAC,

$$S_{TP} \geq \frac{230 \times 72.129}{1000} = 16.59 \text{ kVA}$$

$$S_{SLP} \geq \frac{230 \times 120.15}{1000} = 27.63 \text{ kVA}$$

Based on the computations, a 25 kVA isolation transformer is selected for the tippling plant whilst a 37.5 kVA rated transformer is selected for the ship loading plant (Square, 2020).

4.5.8 Fibre Communication Network

A fibre communication network consists of fibre optic cable, fibre patch cord and fibre optic cable converter. According to Zhang (2016), Fibre optic cable is a very thin glass strand through which a pulse of light is transmitted with very high immunity to electromagnetic interference and radio frequency interference. Fibre optic cables are used in the transfer of optical signals for significant distances, being local area, wide area, or metropolitan area. Fibre optic cable can be divided into single-mode fibre cable and multimode fibre cable. In selecting a fibre optic cable for an application, a careful consideration should be given to upcoming applications and capacity needs, future bandwidth demands, transmission distances, applications and network architecture. The GYTY53 (Anon., 2019s) fibre cable is considered for the application with the factors in Table 4.12 being considered.

Table 4.12 A Summary of Considerations in Selecting Fibre Optic Cable

SN	Factors Considered	Specification/Value
1.	Application	Networking
2.	Capacity Needs (Mbps)	100
3.	Future Bandwidth Demands (GB)	1
4.	Transmission Distance (m)	10,000
5.	Network Architecture	LAN

(Source: Zhang, 2016)

A fibre patch cable, also known as fibre patch cord, which is widely applied to connect telecommunication equipment and backbone cabling, is a length of fibre optic cable capped at either end with connectors that allow it to be rapidly and conveniently connected to Category Five (CATV), an optical switch or other telecommunication equipment (Gui, 2015). According to Anon. (2019c), selection of the right patch cord for an installation involves several steps as: connector type; cable type; fibre patch cord type, the right cable length, connector polish type and cable jacket type. Thus, the ST-ST (Anon., 2019t) patch cord is chosen for the application with the factors in Table 4.13 being considered.

Table 4.13 A Summary of Considerations in Selecting Fibre Optic Patch Cord

SN	Factors Considered	Specification/Value
1.	Connector Type	Straight Tip (ST)
2.	Cable Type	Multimode
3.	Fibre Patch Cord Type	Multimode
5.	Connector Polish Type	Ultra-physical Contact (UPC)
7.	Cable Length (m)	2
8.	Jacket Type	PVC

(Source: Anon., 2019c)

A fibre media converter is a simple networking device that connects and translates signals between fibre optic cabling and another type of cabling media such as Unshielded Twisted Pair (UTP) copper ethernet cables. It translates electronic signals to light signals and vice versa (Anon., 2019d). Some factors enumerated by Anon., (2019e) to consider when going in for fibre media converter for an application are data rates, transmission media, port types, transmission distance, power availability and power supply. The NF-C550-SFP (Anon., 2019u) is selected considering the factors in Table 4.14.

Table 4.14 A Summary of Considerations in Selecting Fibre Optic Media Converter

SN	Factors Considered	Specification/Value
1.	Data Rate (Mbps)	100
2.	Transmission Media	Fibre to copper
3.	Port Type	One for RJ45 and one for fibre port
4.	Transmission Distance (m)	10,000
5.	Power Supply (VAC)	220
6.	Power Availability	Should be installed where power is readily available
7.	Operating Temperature (°C)	0 to 50

(Source: Anon., 2019e)

4.5.9 Control Cable

In selecting a control cable for a particular application, a number of factors have to be taken into consideration such as: instrument type; length of cable run; electrical interference and environmental conditions identification (Anon., 2019f) which are summarised in Table 4.15. Thus, these factors led to the selection of KVV22 control cable (Anon., 2019v).

Table 4.15 A Summary of Considerations in Selecting the Control Cable

SN	Factors Considered	Value
1.	Instrument Type	General purpose cable
2.	Length of Cable Run (m)	2000
3.	Electrical Interference	Cable provided with metallic foil to reduce electrical interference
4.	Environmental Conditions Identification	Open to normal environmental condition
5.	Insulation Material	Polyvinyl Chloride (PVC)

(Source: Anon., 2019f)

4.5.10 Server

According to Mitchell (2018), a server is a computer designed to process requests and deliver data to another computer over the internet or a local network. Although any computer running the necessary software can function as a server, the most typical use of the word references the enormous, high-powered machines that function as the pumps pushing and pulling data from the internet. Strictly speaking, the server is the software that handles a specific task. However, the powerful hardware that supports this software is also usually called a server because server software coordinating a network of hundreds or thousands of clients requires hardware much more robust than what one would buy for ordinary consumer use. Burkels (2016) summarises eight things to help decide on the right hosting provider and hardware configuration of a dedicated server in Table 4.16. Thus, X35 server was selected with these factors considered.

Table 4.16 A Summary of Considerations in Selecting a Dedicated Server

SN	Parameter	Specification/Value
1.	Business Impact of Downtime	Very costly hence the provision of a backup (slave server)
2.	Scalability of Application	No scalability
3.	Performance Requirements of Server	Maximum of six users hence the need of only one main and one slave servers.
4.	Load Balancing across Multiple Dedicated Servers	No need for load balancing
5.	Predictability of Bandwidth Usage (MB)	100
6.	Network Quality	Server station situated very close to SCADA operator station
7.	Self-service and Remote Management	Technical personnel would be provided
8.	Knowledge Partner	Technical personnel would be provided

(Source: Burkels, 2016)

4.5.11 Computer

Dowling (2019) enumerates some key things to consider when buying a computer and these are budget, desktop or laptop, processor, computer memory, hard drive, graphics, computer software, anti-virus software and computer lifeline. Thus, these factors that led to the selection of DJ-C003 computer (Anon., 2019w) for the application are considered in Table 4.17.

Table 4.17 A Summary of Considerations in Selecting the Computer

SN	Factors Considered	Specification/Value
1.	Budget	USD 400
2.	Desktop or Laptop	Desktop
3.	Processor (GHz)	2.5
4.	RAM (Computer Memory) (GB)	2
5.	Hard Drive (GB)	250
6.	Graphics	AMD
7.	Computer Software	Windows 10
8.	Anti-Virus Software	Kaspersky
9.	Computer Lifeline, Internet	Vodafone fixed broadband

(Source: Dowling, 2019)

4.5.12 Siren

Sirens are installed on belt conveyors or machinery to give specific information. To some, it is used as an alarm; either low level alarm, high level alarm or a fault alarm. In GBC limited TPF, they are used to alert technicians that a belt conveyor is to be started. Some sort of considerations are undertaken in the selection of a siren for an application. The considerations are summarised into Table 4.18.

Table 4.18 A Summary of Considerations in Selecting a Siren

SN	Factors Considered	Specification/Value
1.	Current Type	AC
2.	Decibels at 1 meter (dB)	120
3.	Supply Voltage (AC)	220 – 250
4.	Decibel Range (dB)	120
5.	Temperature Range (^oC)	15 - 40
6.	IP Rating	IP66
7.	Siren Material	Plastic

(Source: Anon., 2019x)

Based on the considerations, the siren PNS-0011 (Anon., 2019x) is selected for the plants.

4.5.13 Selection of Software for the SCADA Automation

In this research, RSLogix 5000 software is used to write the PLC program for both the tippling and ship loading plants. RSLogix 5000 software uses one software package consisting of four styles of programming languages: ladder logic, structured text, function block and sequential function chart. Also, whether one has discrete, process, batch, motion, safety and drive-based applications, RSLogix 5000 offers an easy-to- use IEC61131-3 compliant interface, symbolic programming with structures and arrays and a comprehensive instruction set that serves many types of applications. For the SCADA programming, Wonderware InTouch software is selected for the SCADA HMI screen designer development for both the tippling and ship loading plants. Wonderware InTouch software provides a unified integrated view of all controls and information resources. With functionalities such as: ready to use symbol library; situational awareness for operator effectiveness; powerful and sophisticated virtualisation technologies; runtime pan and zoom; visualisation access from anywhere and unequal investment protection, one can create meaningful content to drive enterprise-wide productivity. An Excel Loan

Amortisation Schedule (LAS) version 1.0 software is used to determine the interest and the payback period of the capital invested.

Table 4.19 put together the selected SCADA system hardware elements. The specifications of these elements could be found in Appendix B.

Table 4.19 A List of Summary of Selected Items for the SCADA System Design

SN	Item	Model
1.	Belt Alignment Sensor	LHL-N11
2.	Belt Speed Sensor	NJ15S+U1+N
3.	Block Chute Sensor	MWS-ST/SR-2
4.	PLC	1756-L71
5.	UPS	PSU-804
6.	PSU	T-30B
7.	Isolation Transformer	JBK
8.	Fibre Optic Cable	GYTY53
9.	Fibre Optic Patch Cord	ST – ST
10.	Fibre Optic Cable Converter	NF-C550-SFP
11.	Control Cable	KVV22
12.	Dedicated Server	X35
13.	Desktop Computer	DJ-C003
14.	Siren	PNS – 0011

4.6 Programmable Logic Controller Programming of the Plants

Here, various stages through which the PLC programs are developed are demonstrated.

4.6.1 PLC Programming of Tippling Plant

Some screenshots of PLC programming stages are shown in Fig. 4.12, Fig. 4.13, Fig. 4.14 and Fig. 4.15.

Stages of development of RSLogix 5000 PLC Ladder program for tippling plant are as follows:

Stage 1: From the desktop double click on the RSLogix 5000 enterprise series icon to open the Quick Start window (ie. Fig. 4.12).

Stage 2: Select 'New Project' from the 'quick start' window. New Controller dialog box opens (ie. Fig. 4.13).

Stage 3: In the New Controller dialog box, select 'RSLogix Emulate 5000 Controller' at the 'type' option; 'Tippling plant ladder program' at the 'description' option; '16' at the 'revision' option; type in 'Tippling Plant' at the 'Name' section; select '1756 – A10 10-slot ControlLogix Chassis' at the 'Chassis' option; select '1' at the 'Slot' option; select the folder where the project is to be created and click OK. Tippling plant programming window opens (ie. Fig. 4.14).

Stage 4: From the new window, click on the + sign beside the folder named 'Mainprogram' (ie. Fig. 4.14).

Stage 5: Double click on the MainRoutine or right click on the MainRoutine file and select 'open' to activate the ladder program (ie. Fig. 4.15). To create another routine, right click on the MainProgram folder and select 'NewRoutine' from the options to create a new routine.

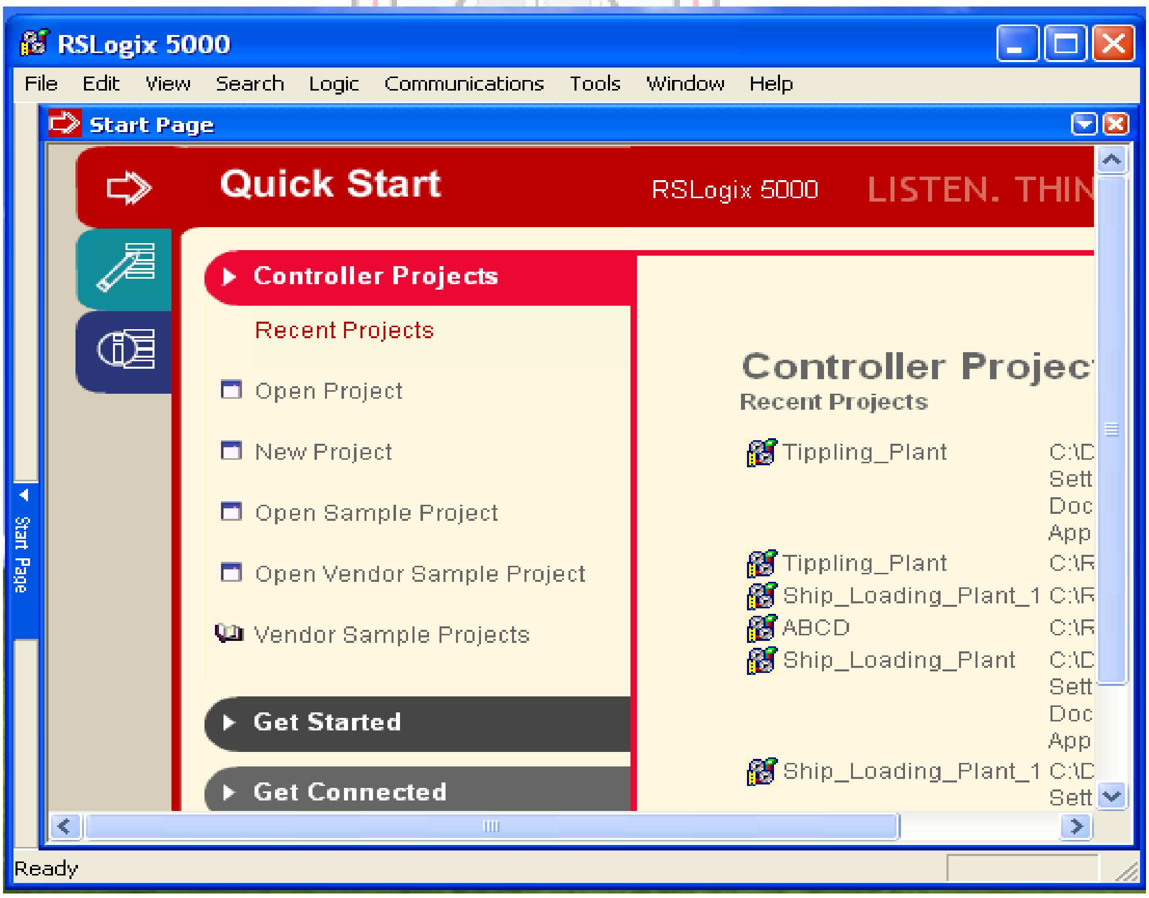


Fig. 4.12 The Quick Start Window of Tippling Plant

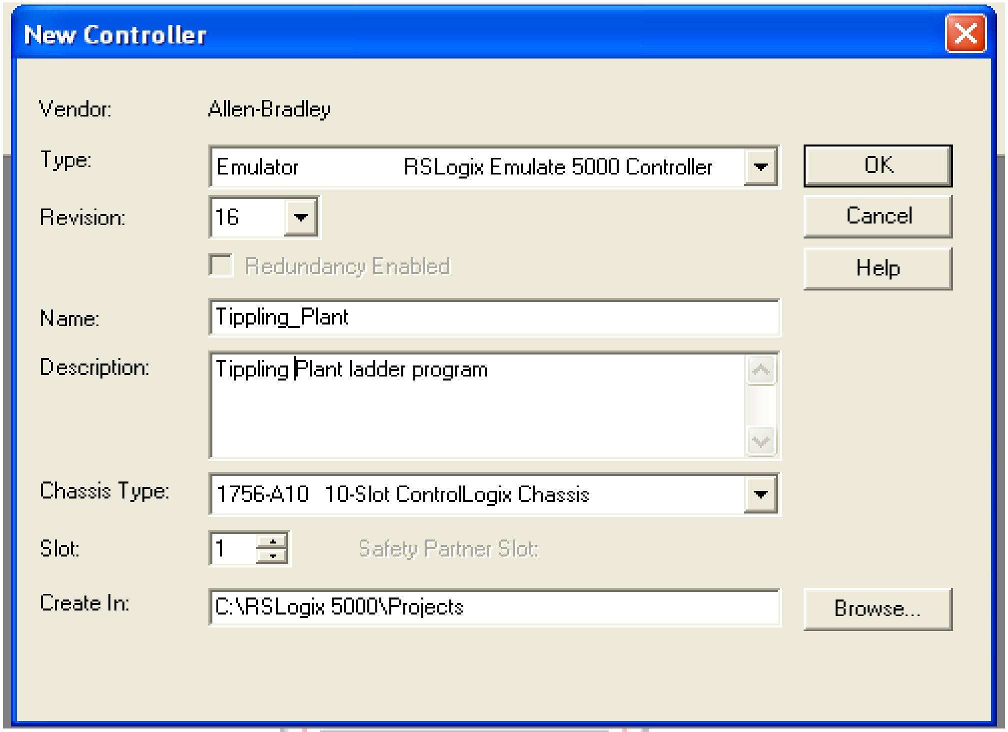


Fig 4.13 New Controller Dialog Box of Tippling Plant

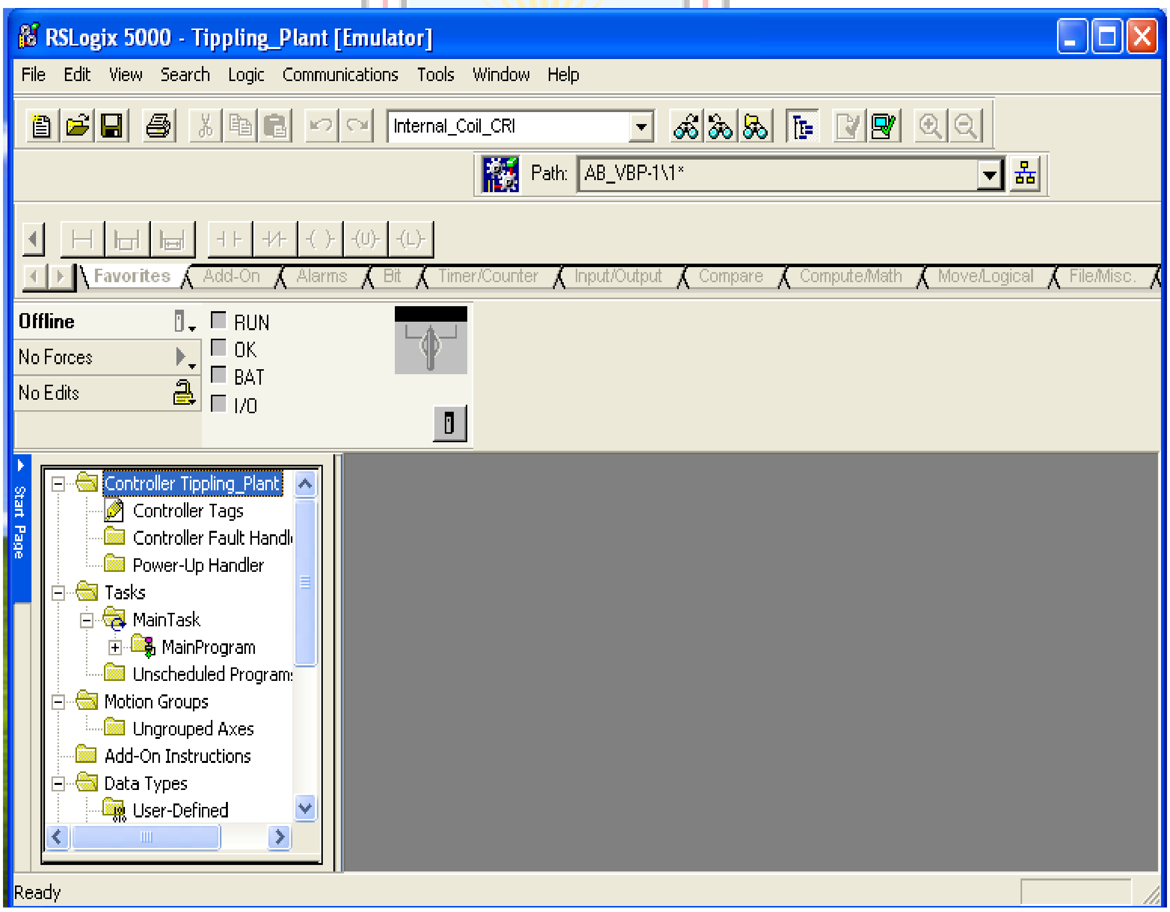


Fig. 4.14 Tippling Plant Programming Window

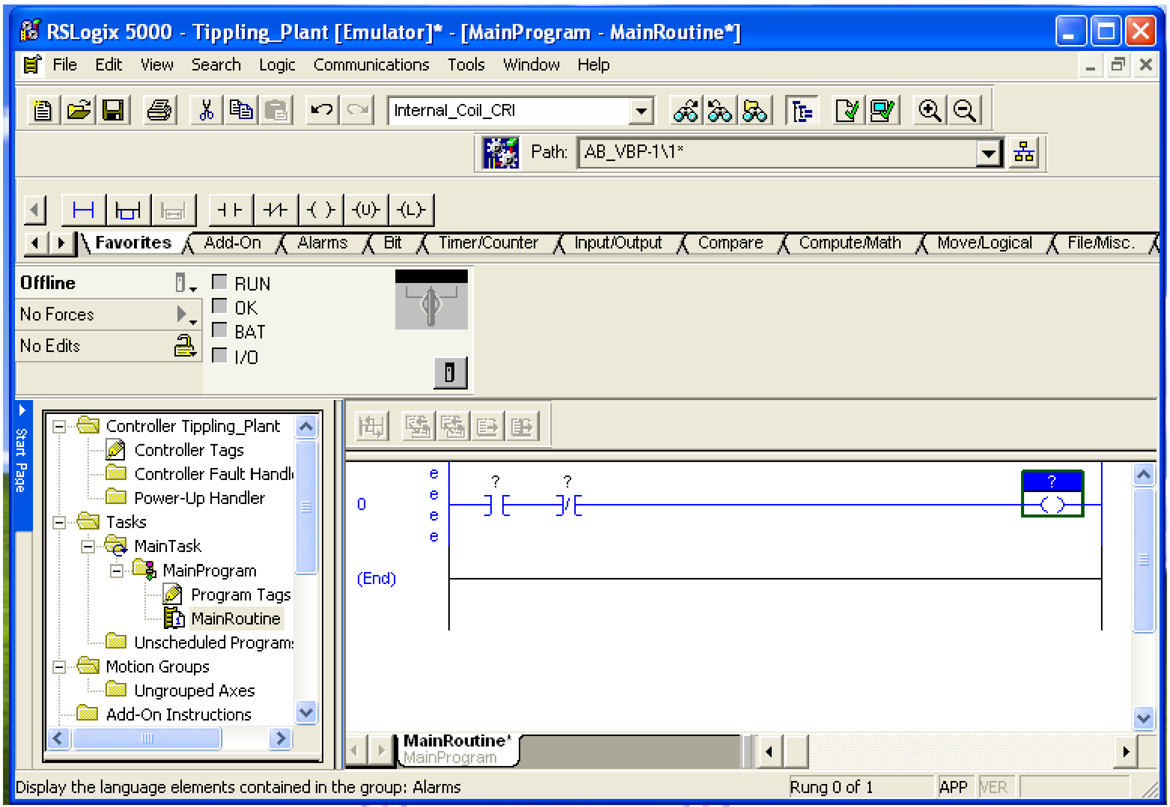


Fig. 4.15 Tippling Plant Ladder Programming Activated

4.6.2 PLC Programming of Ship Loading Plant

Some screenshots of the PLC programming stages are demonstrated in Fig. 4.16, Fig. 4.17, Fig. 4.18 and Fig. 4.19.

Stages of development of RSLogix 5000 PLC Ladder program for ship loading plant are as follows:

Stage 1: Double click on the RSLogix 5000 enterprise series icon from the desktop to open the Quick Start window (ie. Fig. 4.16).

Stage 2: Select from the 'Quick Start' menu 'New Project'. New Controller dialog box opens (ie. Fig. 4.17).

Stage 3: In the New Controller dialog box, select 'RSLogix Emulate 5000 Controller' at the 'type' option, '16' at the 'revision' option, type in 'Ship Loading Plant' at the 'Name' section, select '1756 – A10 10-slot ControlLogix Chassis' at the 'Chassis' option, select '1' at the 'Slot' option, select the folder where the project is to be created and click OK. A new window opens.

Stage 4: From the new window, click on the + sign beside the folder named ‘Mainprogram’ (ie. Fig. 4.18).

Stage 5: Double click on the MainRoutine or right click on the MainRoutine file and select ‘open’ to activate the ladder program (ie. Fig. 4.19). To create another routine, right click on the MainProgram folder and select ‘NewRoutine’ from the options to create a new routine.

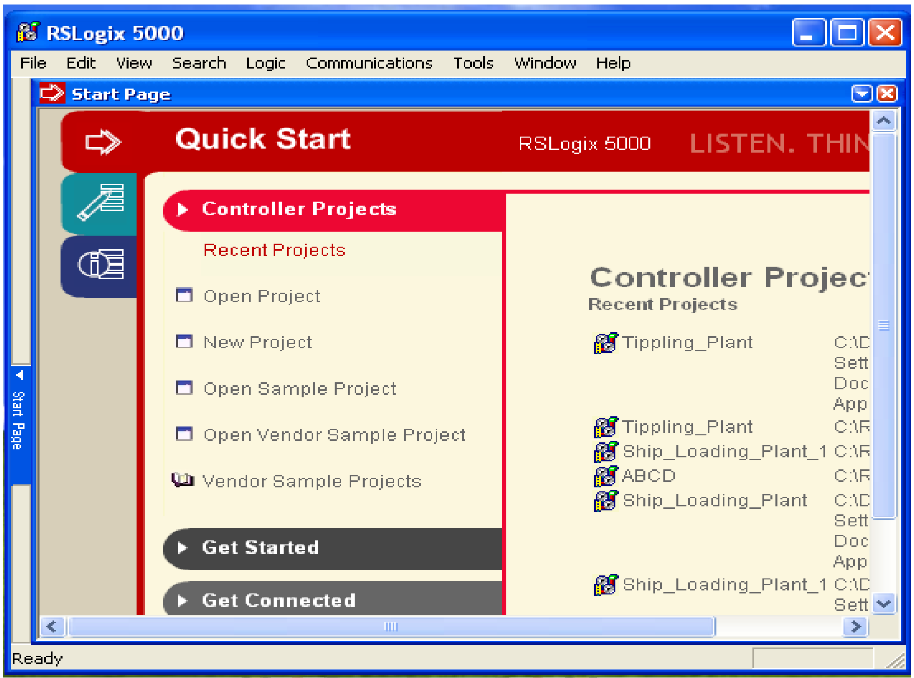


Fig. 4.16 The Quick Start Window of Ship Loading Plant

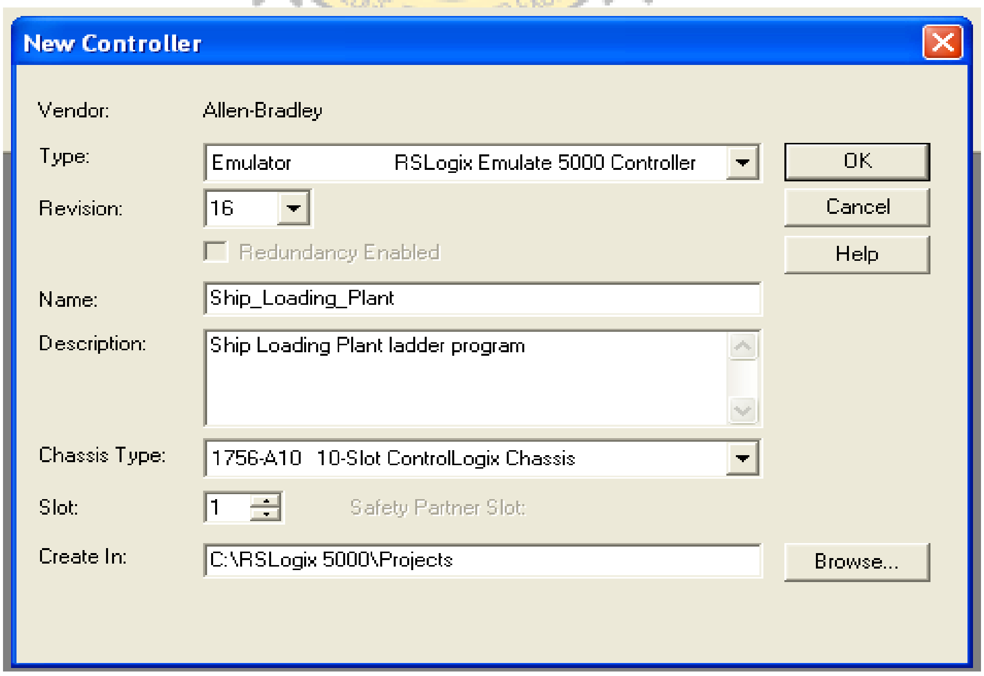


Fig. 4.17 New Controller Dialog Box of Ship Loading Plant

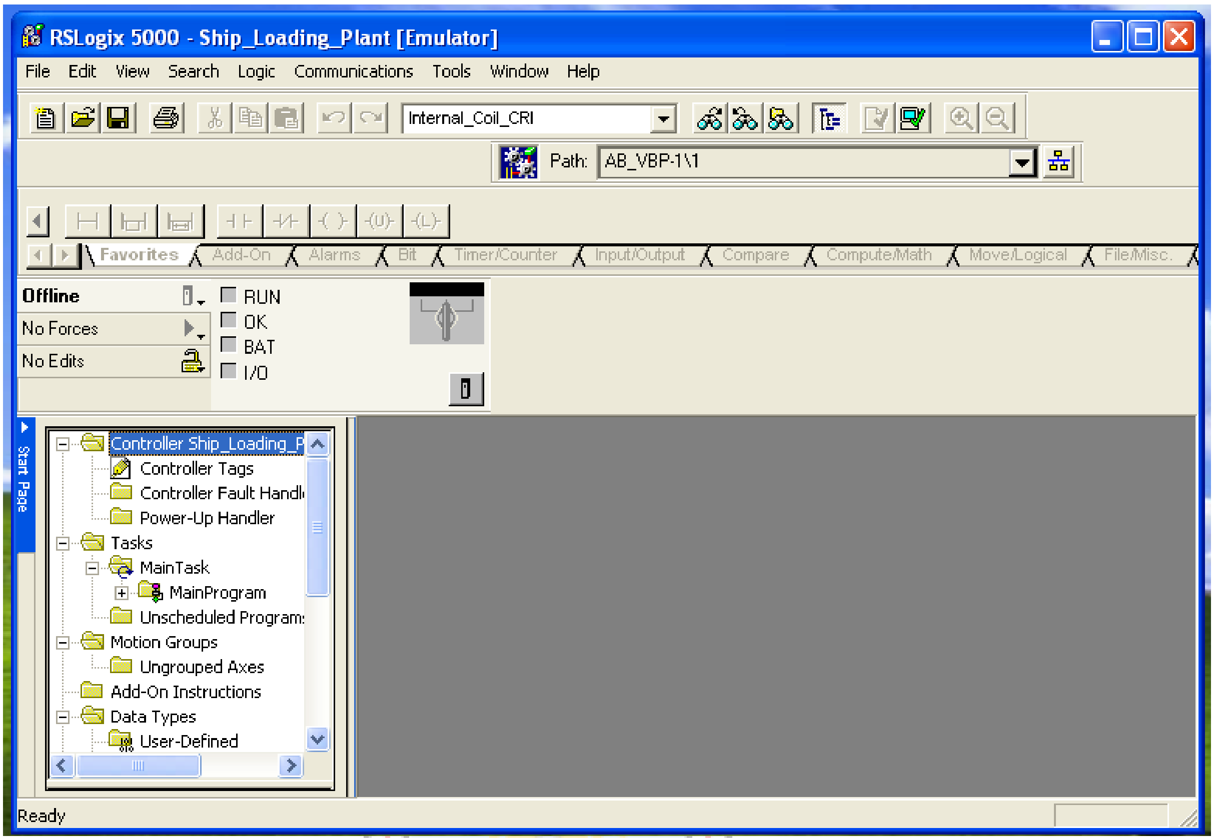


Fig. 4.18 Ship Loading Plant Programming Window

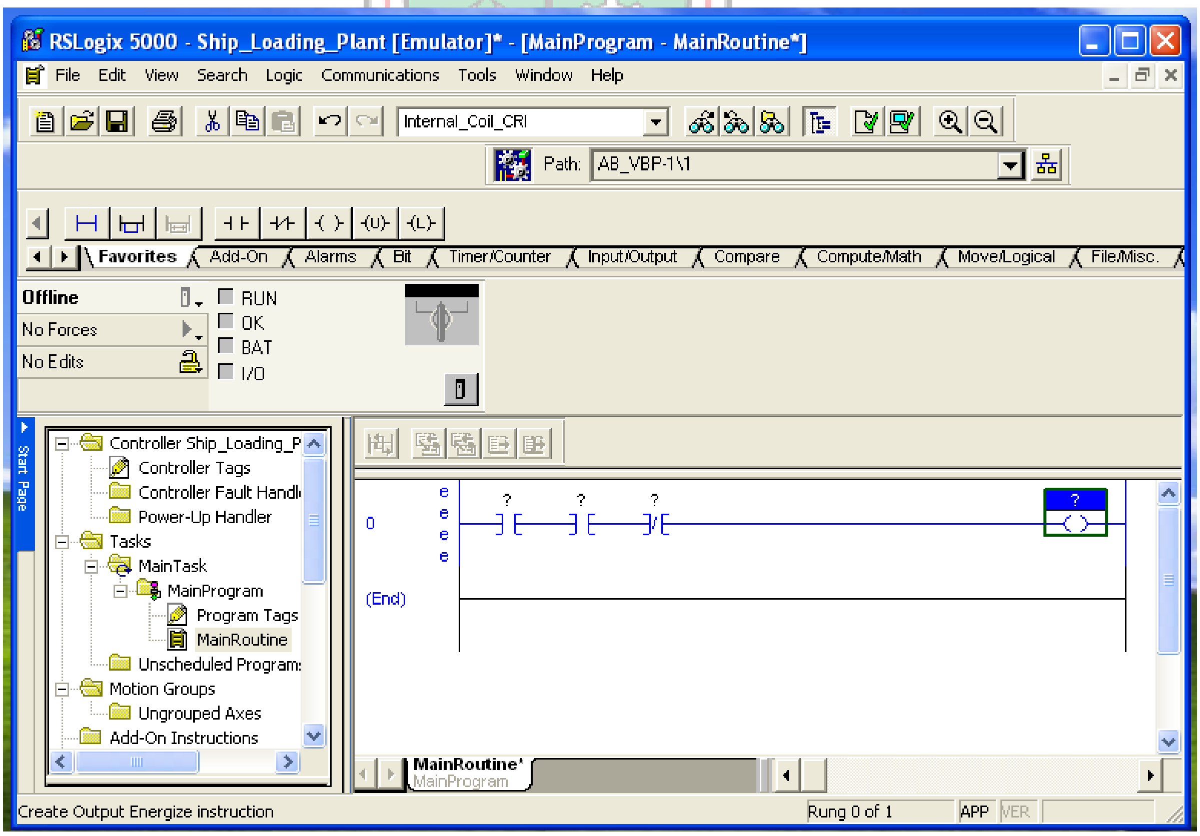


Fig. 4.19 Ship Loading Plant Ladder Programming Activated

4.7 SCADA HMI Screen Development for the Plants

In this section, the stages through which the SCADA program for HMI screen developments are achieved are demonstrated.

4.7.1 SCADA HMI Screen for Tippling Plant

This section demonstrates some stages during the tippling plant HMI development.

Stages of the HMI screen development for the tippling plant are presented as follows:

Stage 1: From the start menu select 'InTouch' to open an InTouch Application manager window (ie. Fig. 4.20).

Stage 2: From the InTouch application manager window click on 'file' and select 'New'. A new window named 'Create New Application' appears (ie. Fig. 4.21).

Stage 3: In create new application window, enter the base path to store all InTouch applications and click 'next' (ie. Fig. 4.21).

Stage 4: Enter 'Takoradi HMI Screens' as the directory to create the application and click 'next' (ie. Fig. 4.22).

Stage 5: Enter 'Takoradi HMI Screens' as the name of the InTouch application and click 'Finish' (ie. Fig. 4.23). A new window then appears called Window Properties (ie. Fig. 4.24).

Stage 6: Type 'Tippling Plant' at the column titled 'Name' and click 'Ok' to create the tippling plant HMI screen window (ie. Fig. 4.25).

Stage 7: From the application menu bar of the tippling plant HMI window, select 'wizard' to choose symbols for the HMI design.

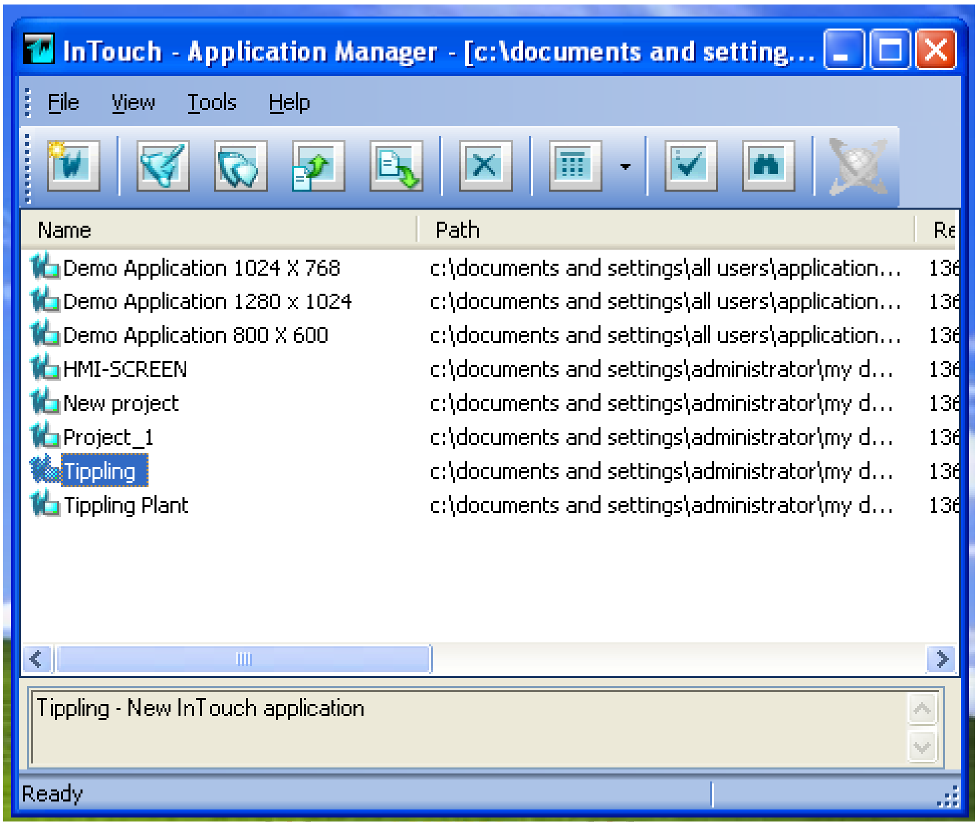


Fig. 4.20 InTouch Application Manager Window for Tippling Plant

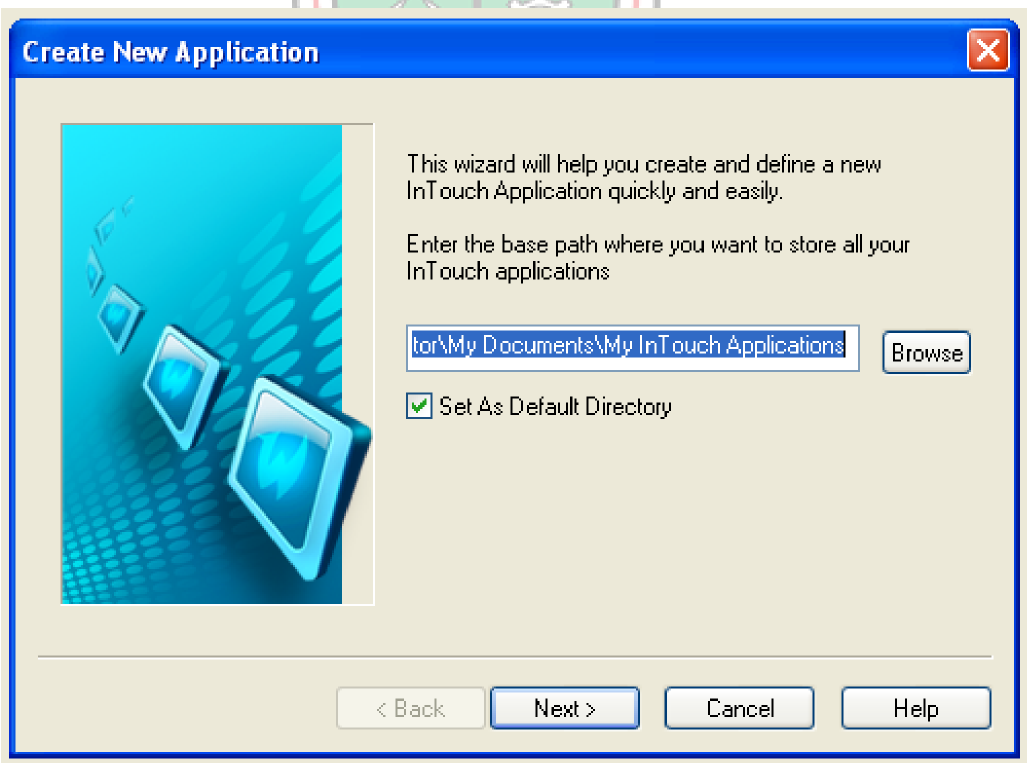


Fig. 4.21 Creation of New Application Window for Tippling Plant

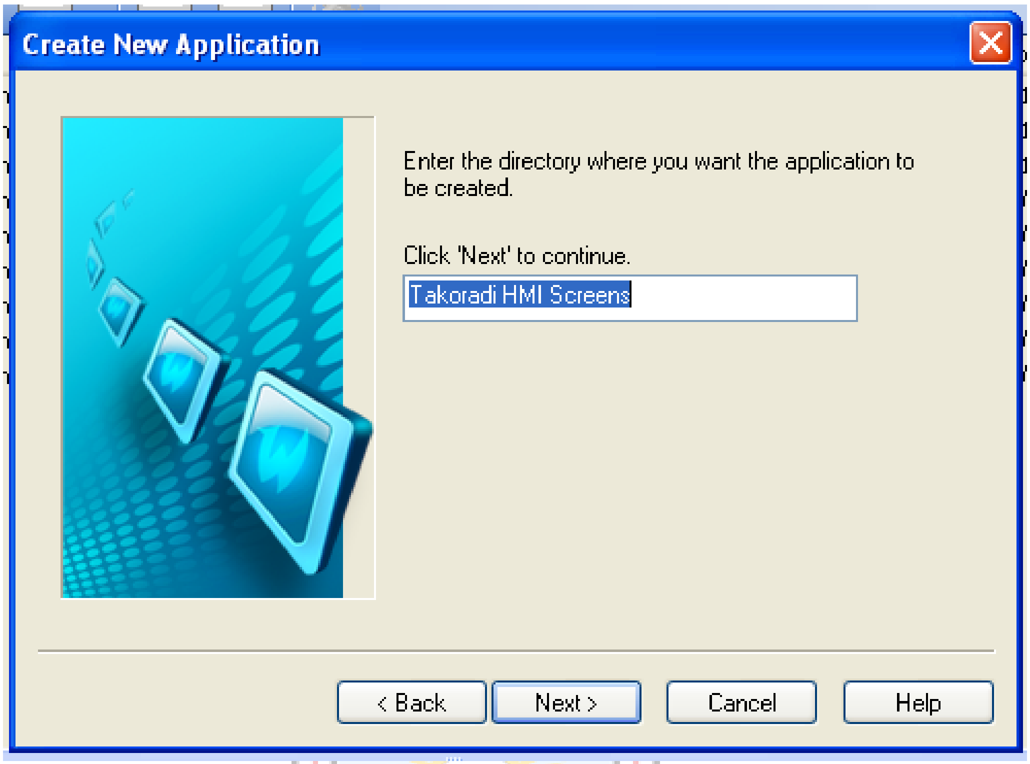


Fig. 4.22 Creation of Application Directory for Tippling Plant

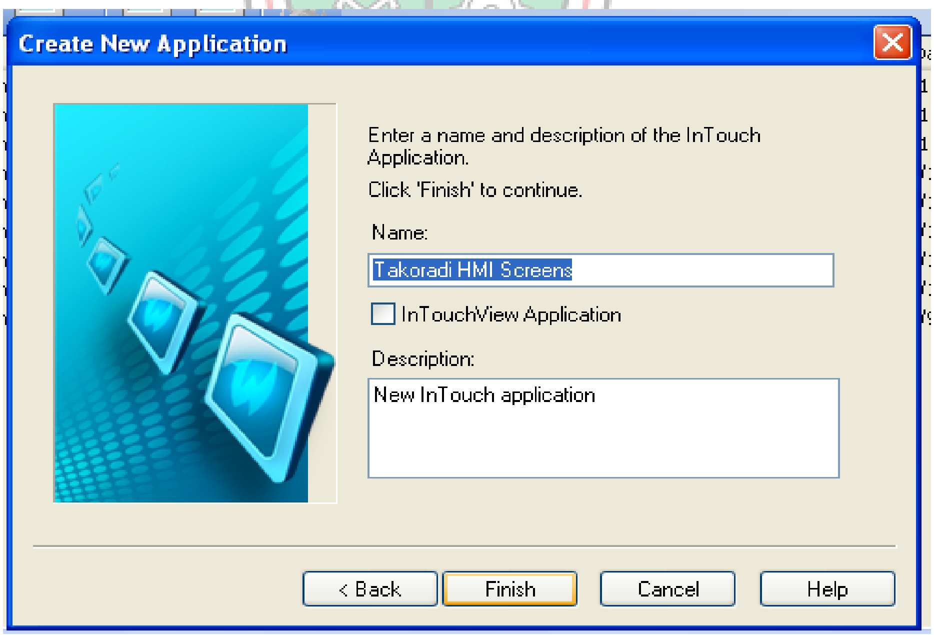


Fig. 4.23 Naming of the InTouch Application for Tippling Plant

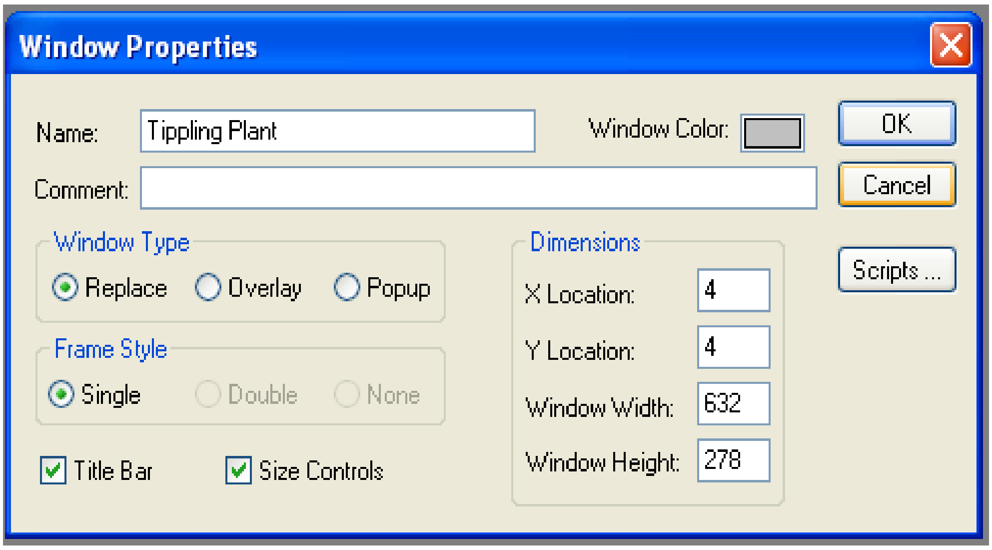


Fig. 4.24 Window for the Window Properties for Tippling Plant

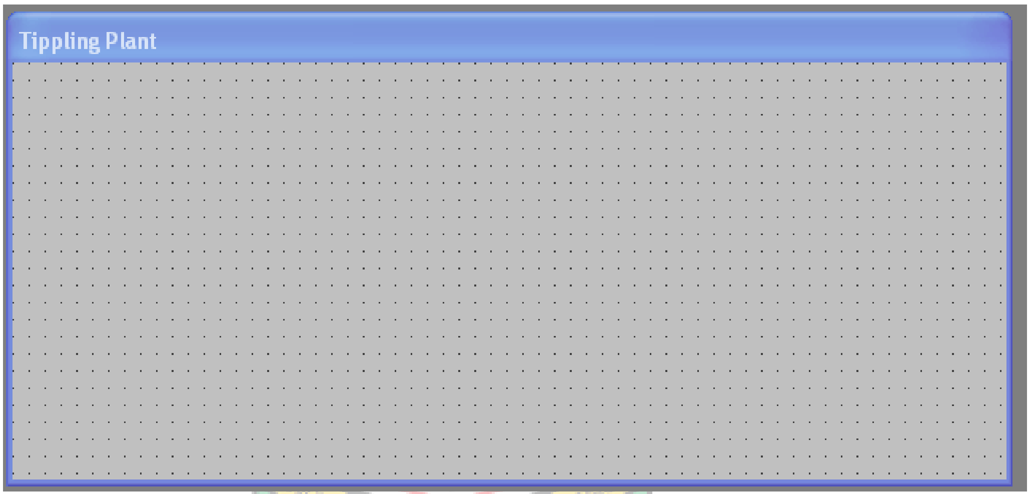


Fig. 4.25 Tippling Plant HMI Design Window Activated

Design of tippling plant HMI screen after Fig. 4.25 entails:

i. Selection of symbols from "wizard selection" interface and pasting them on the tippling plant HMI activated window;
ii. Naming of the symbols and linking them to their respective tag names in the PLC ladder program in the RSLogix 5000 software; and
iii. Alignment of the symbols to suit the required tippling plant HMI design.

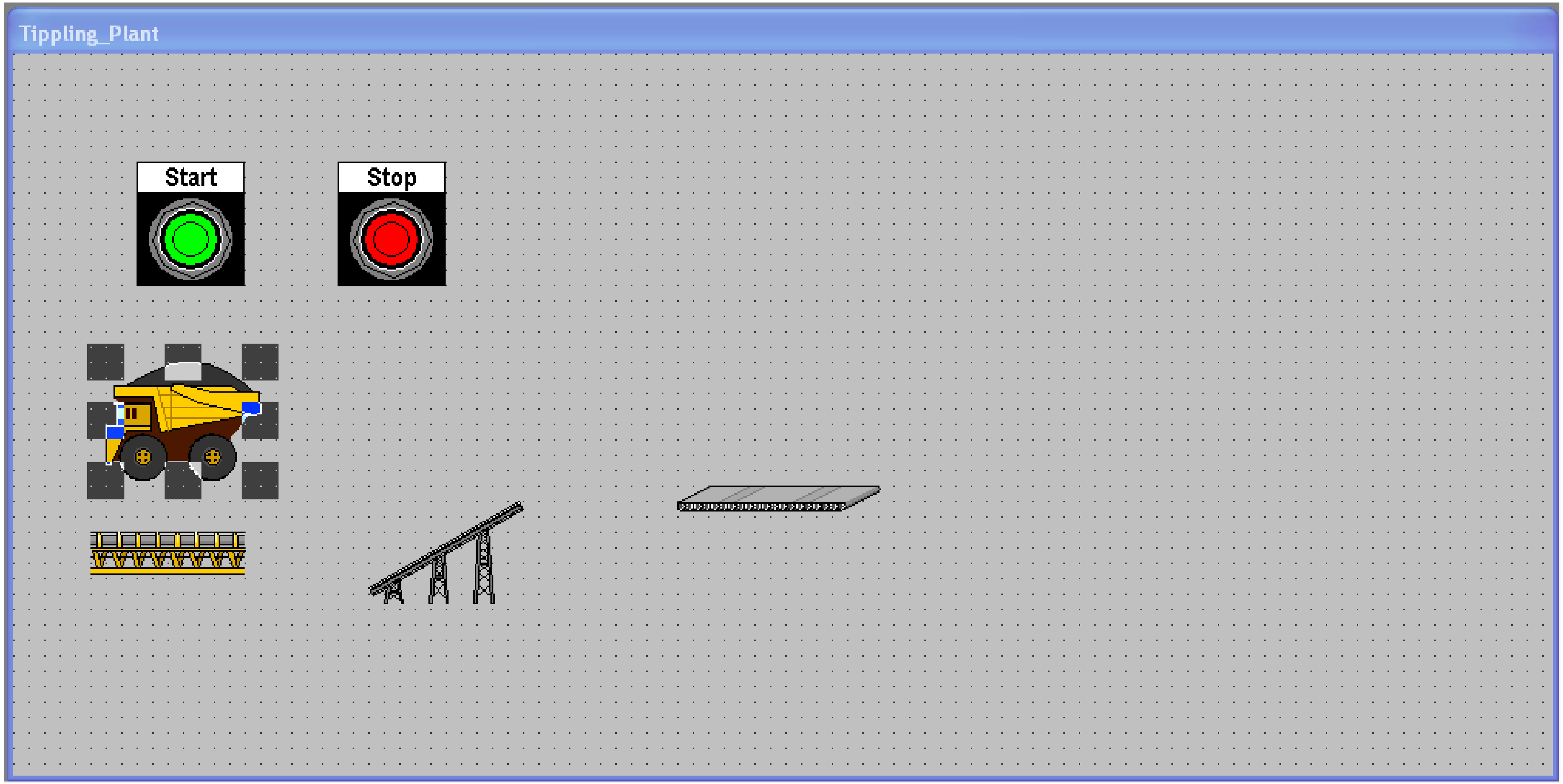


Fig. 4.26 Ongoing Tippling Plant HMI Screen Design

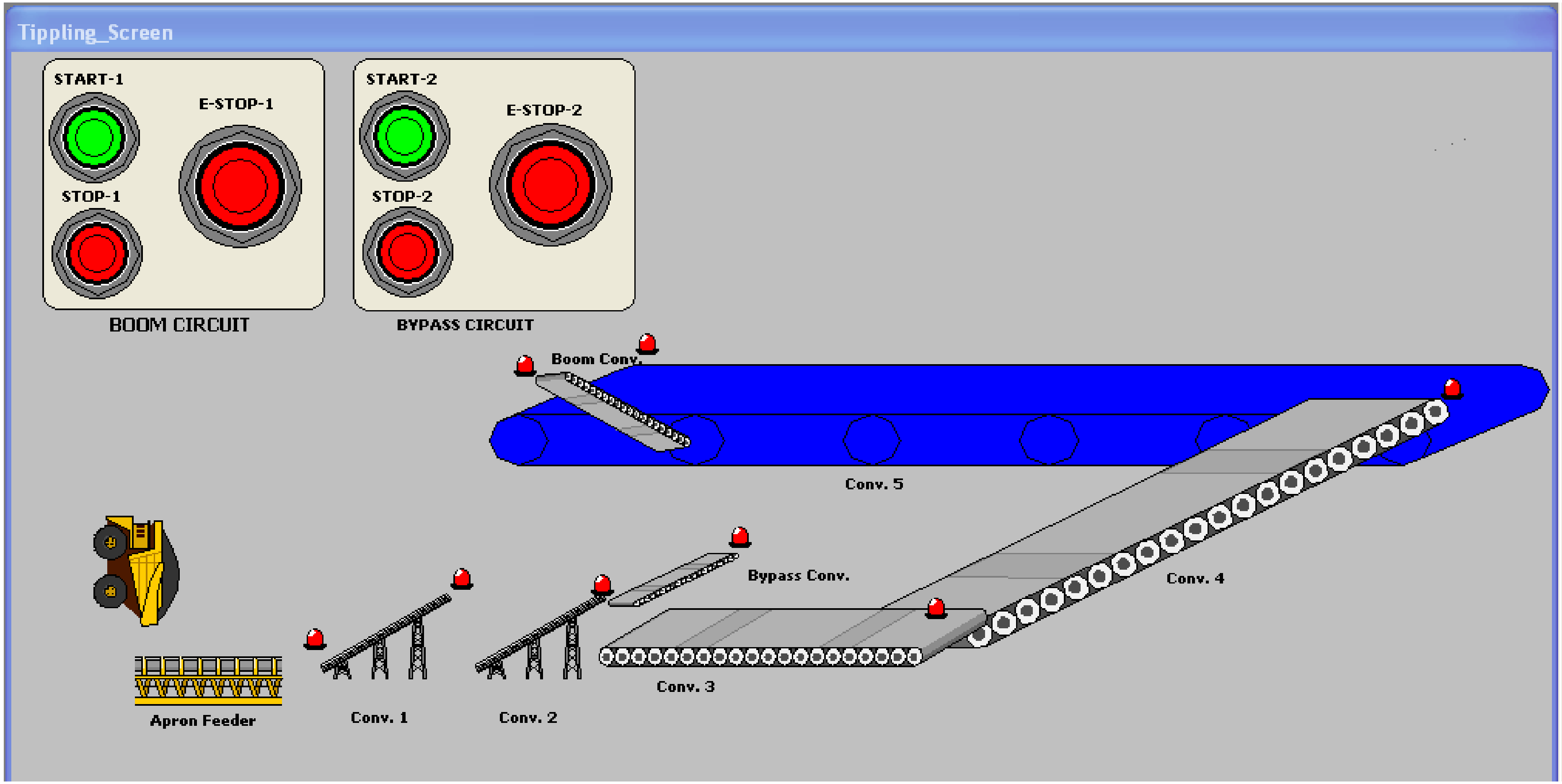


Fig. 4.27 CompleteTippling Plant HMI Screen Design

4.7.2 SCADA HMI Screen for Ship Loading Plant

This section demonstrates some stages during the ship loading plant HMI development.

Stages of the HMI screen development for the ship loading plant are as follows:

Stage 1: From the start menu select ‘InTouch’ to open an InTouch Application manager window (ie. Fig. 4.28).

Stage 2: From the InTouch application manager window click on ‘file’ and select ‘New’. A new window named ‘Create New Application’ appears (ie. Fig. 4.29).

Stage 3: In create new application window, enter the base path to store all InTouch applications and click ‘next’ (ie. Fig. 4.30).

Stage 4: Enter Takoradi HMI Screens as the directory to create the application and click ‘next’ (ie. Fig. 4.30).

Stage 5: Enter Takoradi HMI Screens as the name of the InTouch application and click ‘Finish’ (ie. Fig. 4.31). A new window then appears called Window Properties (ie. Fig. 4.32).

Stage 6: Type ‘Ship Loading Plant’ at the column titled ‘Name’ and click ‘Ok’ to create the Ship Loading Plant HMI screen window (ie. Fig. 4.33).

Stage 7: From the application menu bar of the ship loading plant HMI window, select ‘wizard’ to choose symbols for the HMI design.

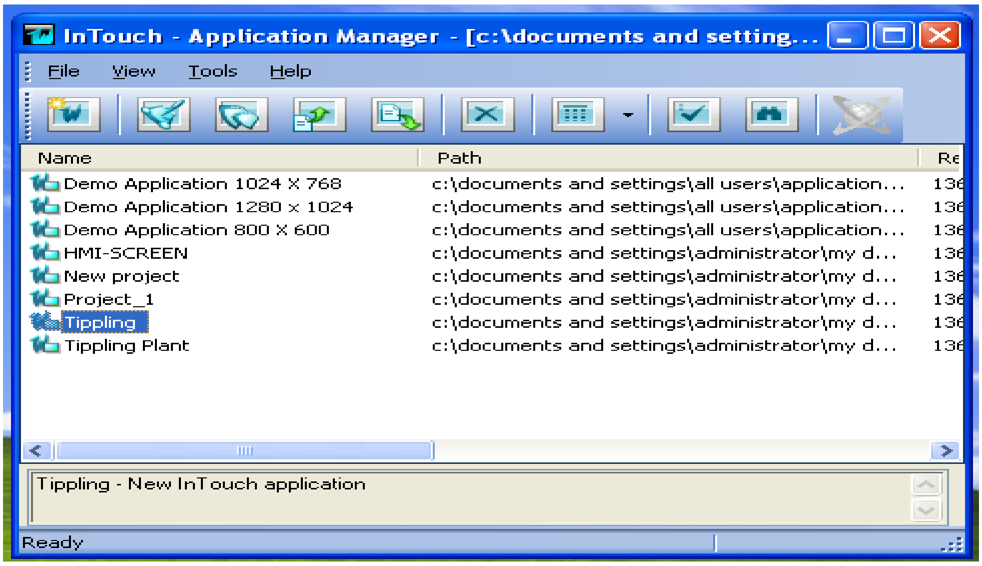


Fig. 4.28 InTouch Application Manager Window for Ship Loading Plant

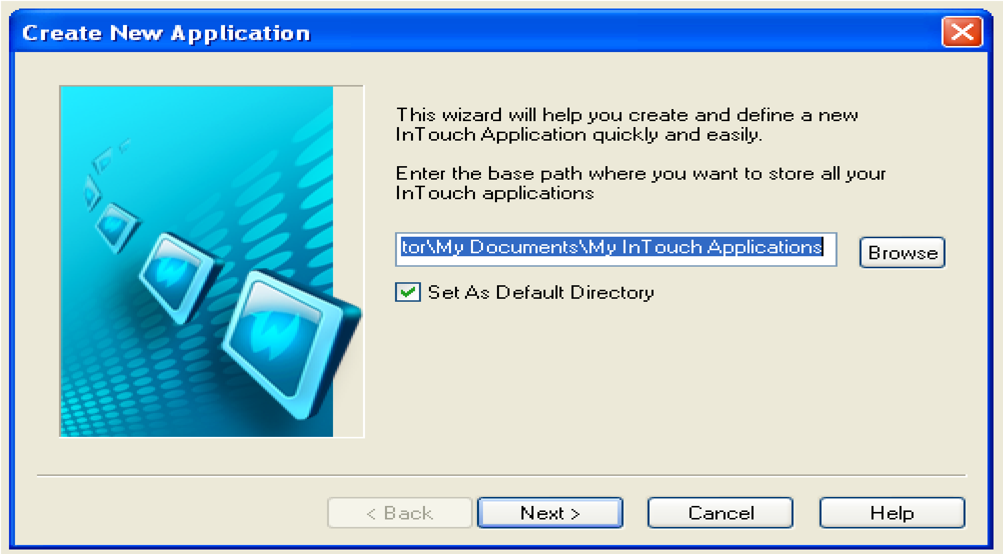


Fig. 4.29 Creation of New Application Window for Ship Loading Plant

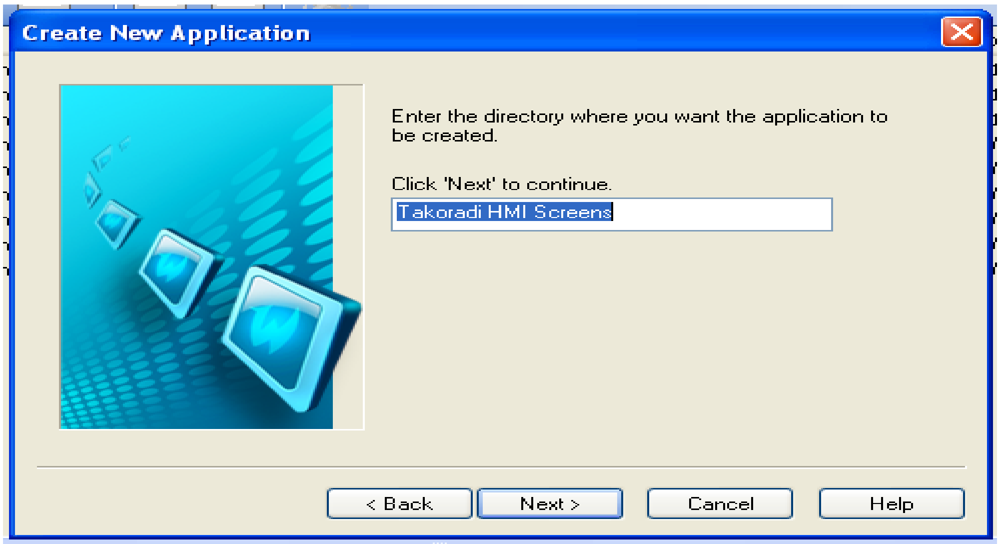


Fig. 4.30 Creation of Application Directory for Ship Loading Plant

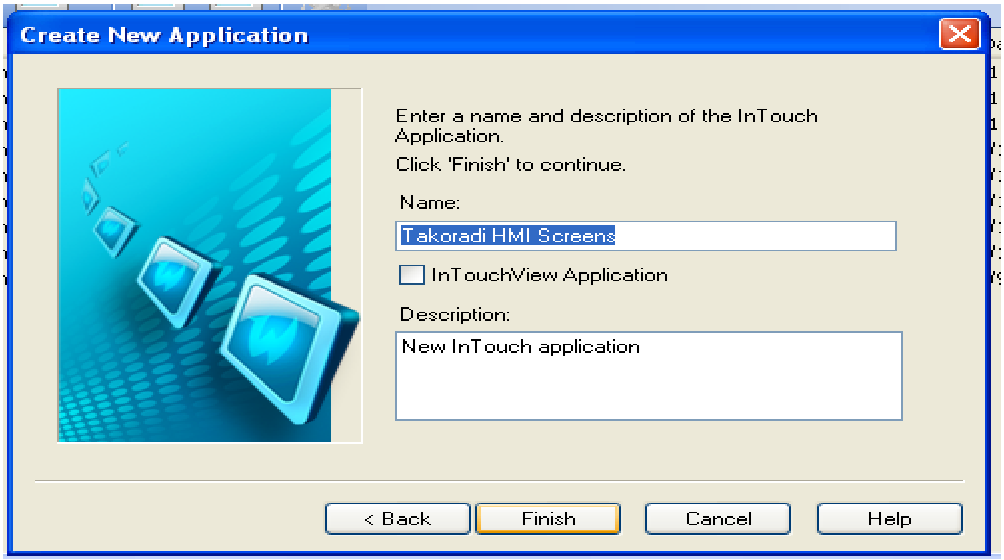


Fig. 4.31 Naming of the InTouch Application for Ship Loading Plant

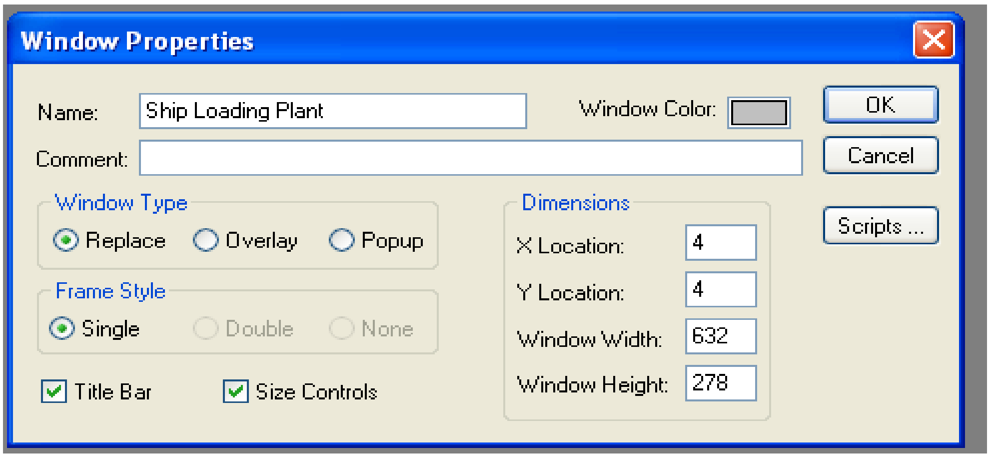


Fig. 4.32 Window for the Window Properties for Ship Loading Plant

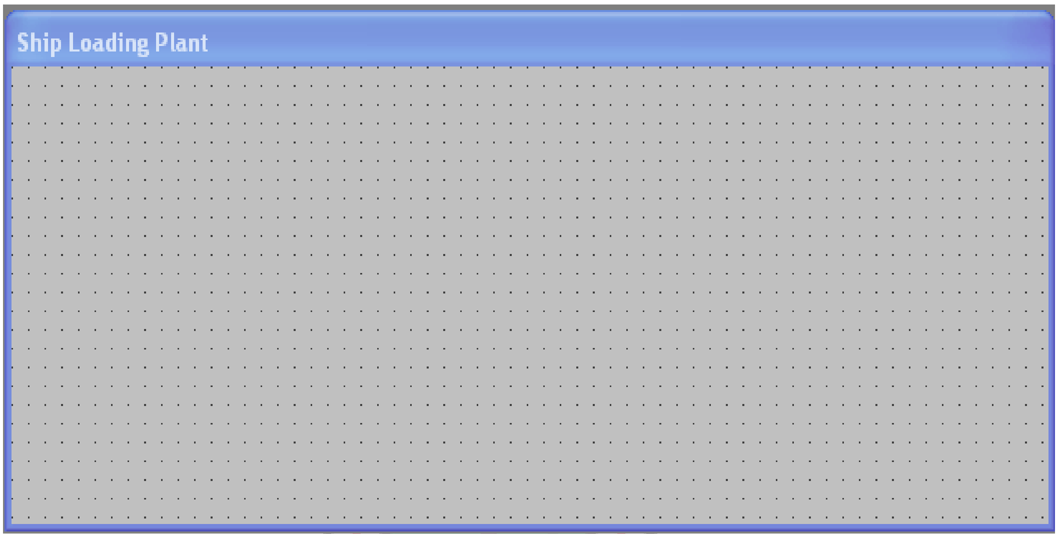


Fig. 4.33 Ship Loading Plant HMI Design Window Activated

Design of the ship loading plant HMI screen after Fig. 4.33 entails:

i. Selection of symbols from “wizard selection” interface and pasting them on the ship loading plant HMI activated window;

ii. Naming of the symbols and linking them to their respective tag names in the PLC ladder program in the RSLogix 5000 software; and

iii. Alignment of the symbols to suit the required ship loading plant HMI design.

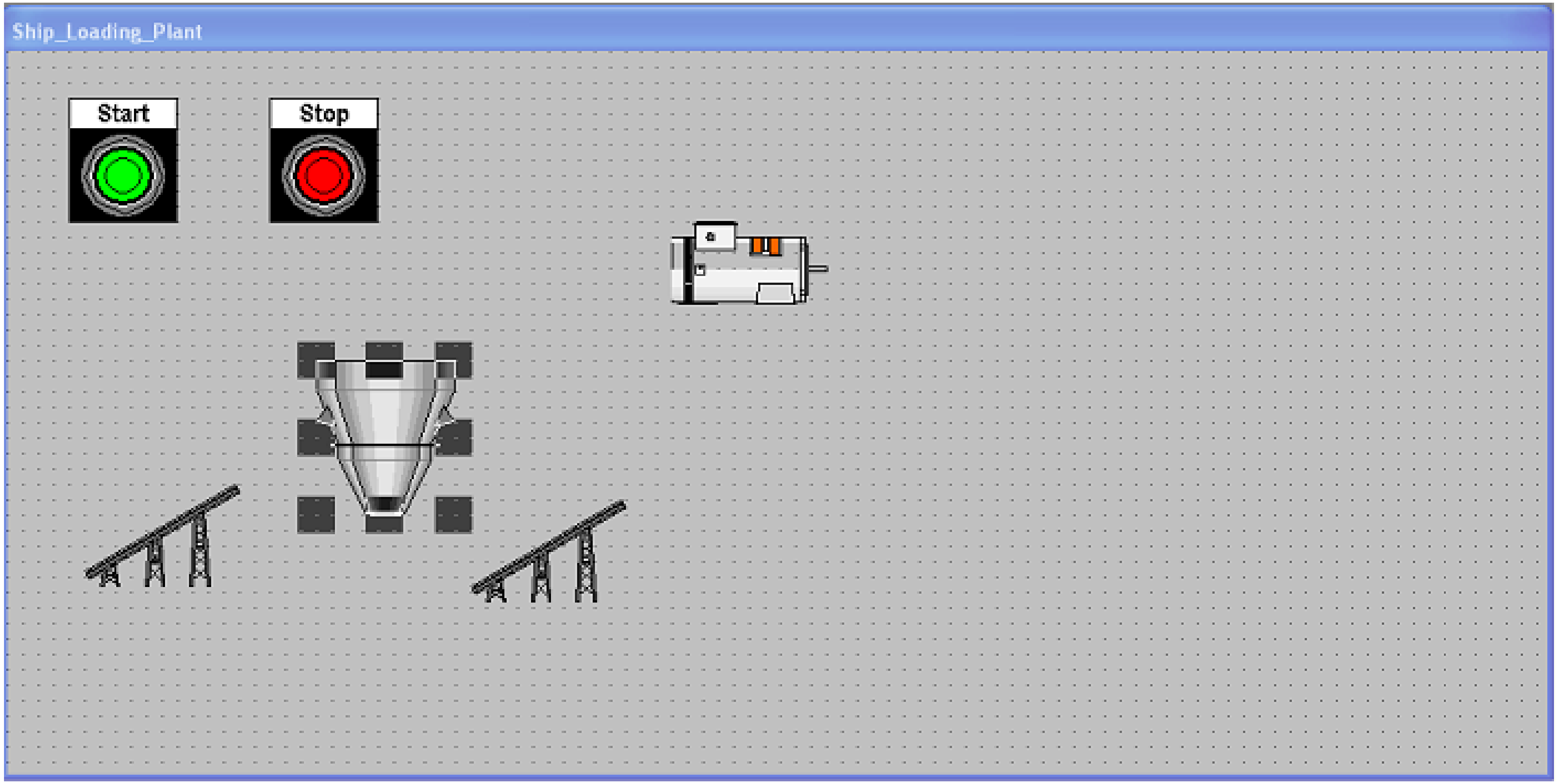


Fig. 4.34 Ongoing Ship Loading Plant HMI Screen Design

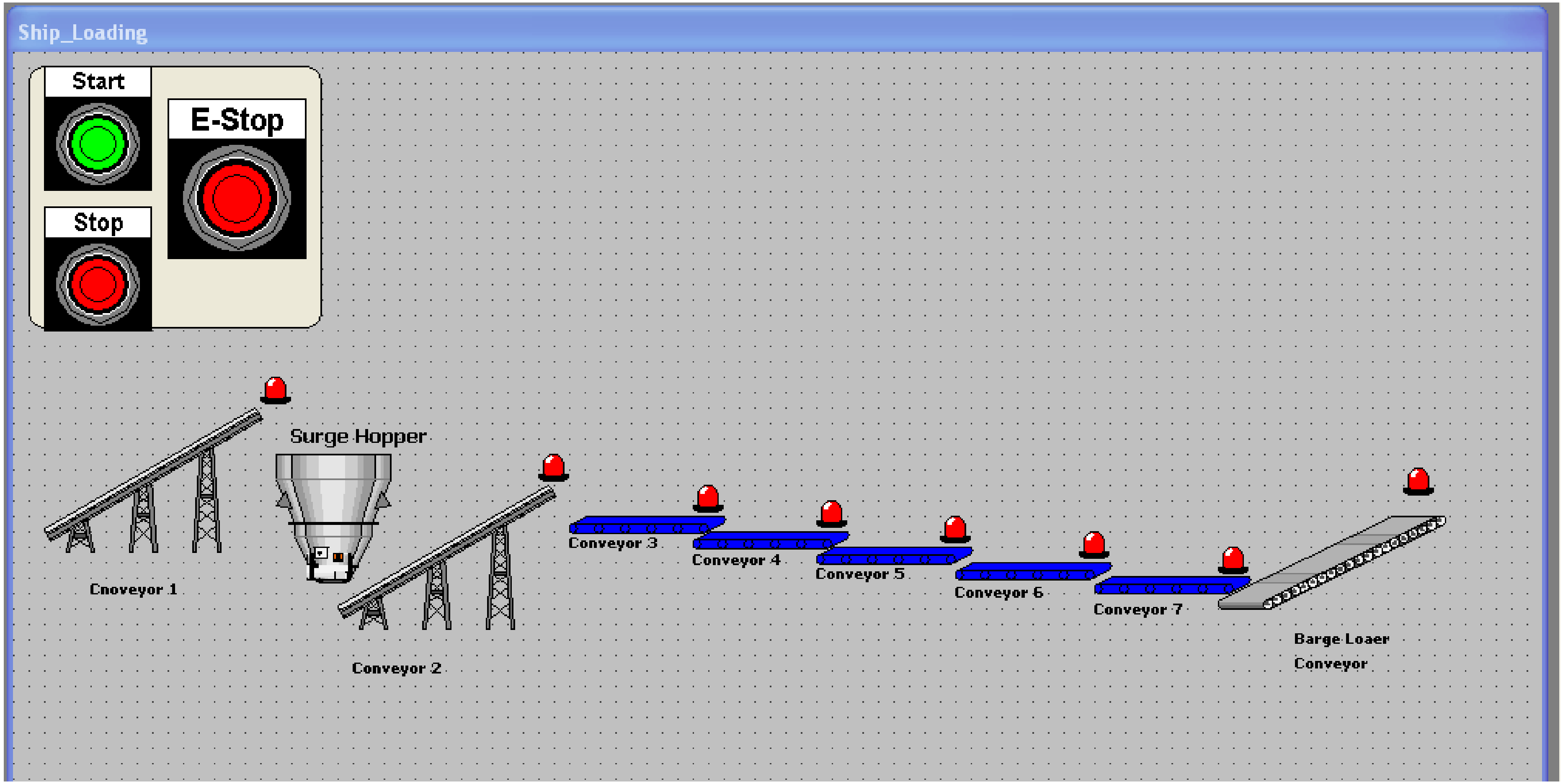


Fig. 4.35 Ship Loading Plant HMI Screen Design Completed

4.8 Summary

This chapter presents the new system design. Here, design concept and design criteria of the new system were presented and also explained the mode of operation of the redesigned system. Data acquisition, presentation and analysis was done and also carried out SCADA system development. Component selection for the new system design was done and finally ended with PLC programming and SCADA HMI screen development for both tippling and ship loading plants.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

In this chapter the results of the study are presented and discussed with reference to the specific objectives of the research, which are reduction in manpower requirement, increase in plant availability and reduction of operational cost. The cost analyses of SCADA operation in comparison with the current traditional way of operating the two plants in the facility are also presented and discussed.

5.2 Results of Tippling Plant Automation

This section is categorised into three sub-sections as PLC programming results, results of SCADA HMI screen design and trending results.

5.2.1 Results of PLC Programming

The PLC program written for the running of the tippling plant is presented in Fig. 5.1 and Fig. 5.2. The PLC program is in two folds, one named the boom circuit PLC program which is to run the boom circuit and the other is the bypass circuit PLC program which also runs the bypass circuit.

5.2.2 Results of SCADA HMI Screen Design

Screenshots of the HMI screen for the designed SCADA system for the tippling plant are presented in Fig. 5.3, Fig. 5.4 and Fig. 5.5, showing HMI screen during start-up of boom circuit, HMI screen when ran from the boom circuit and HMI screen when ran from the bypass circuit, respectively.

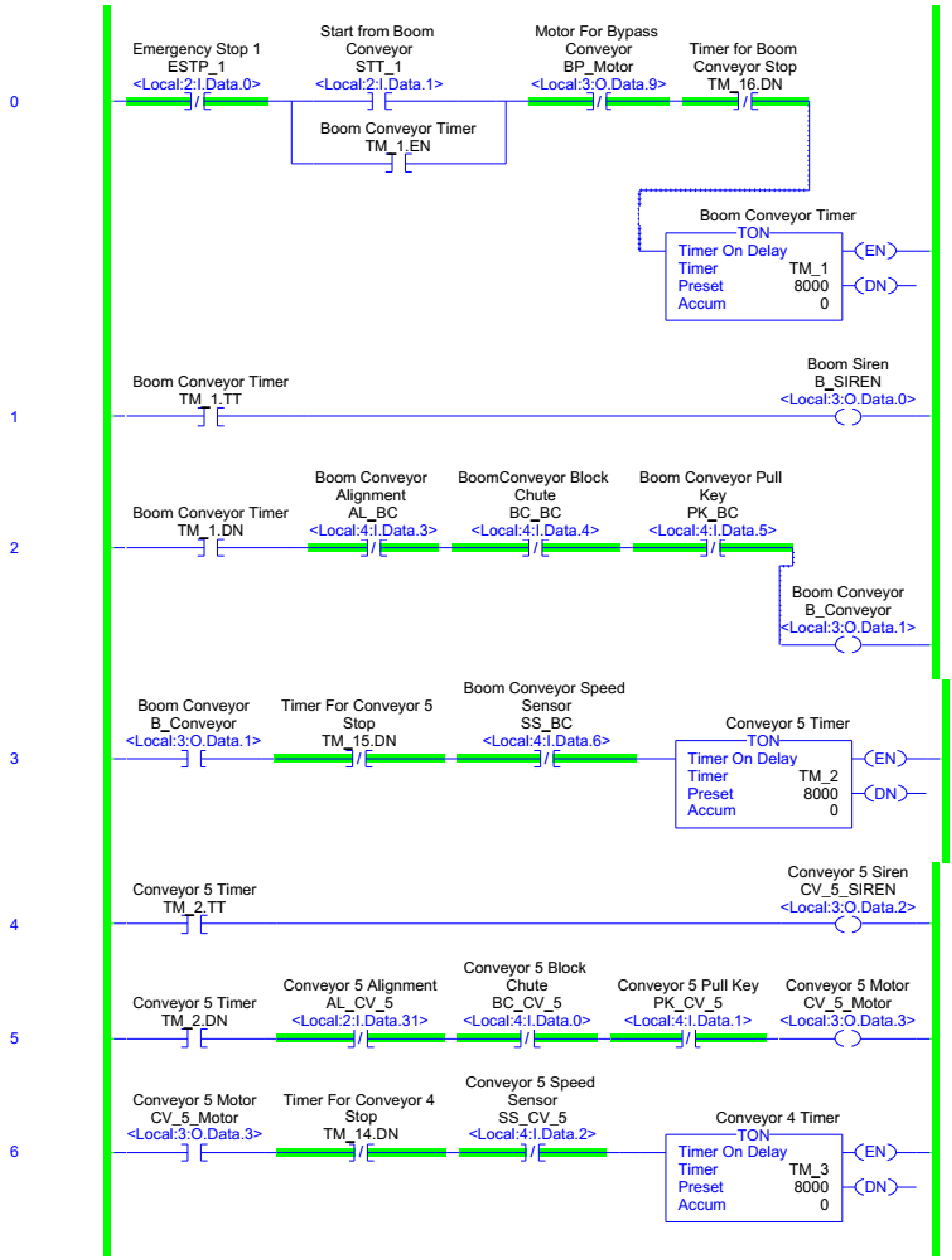


Fig. 5.1 Boom Circuit PLC Program

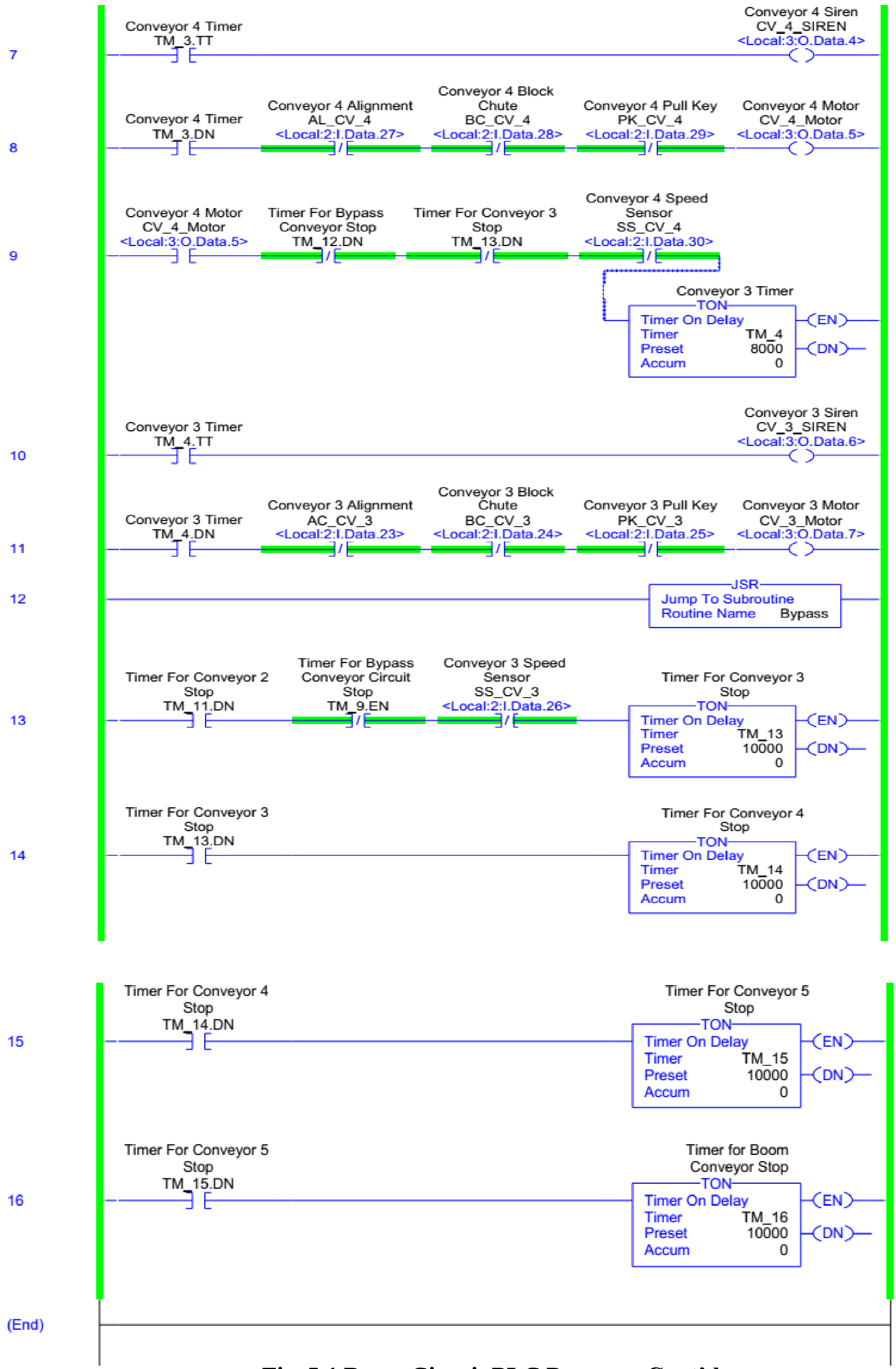


Fig. 5.1 Boom Circuit PLC Program Cont'd

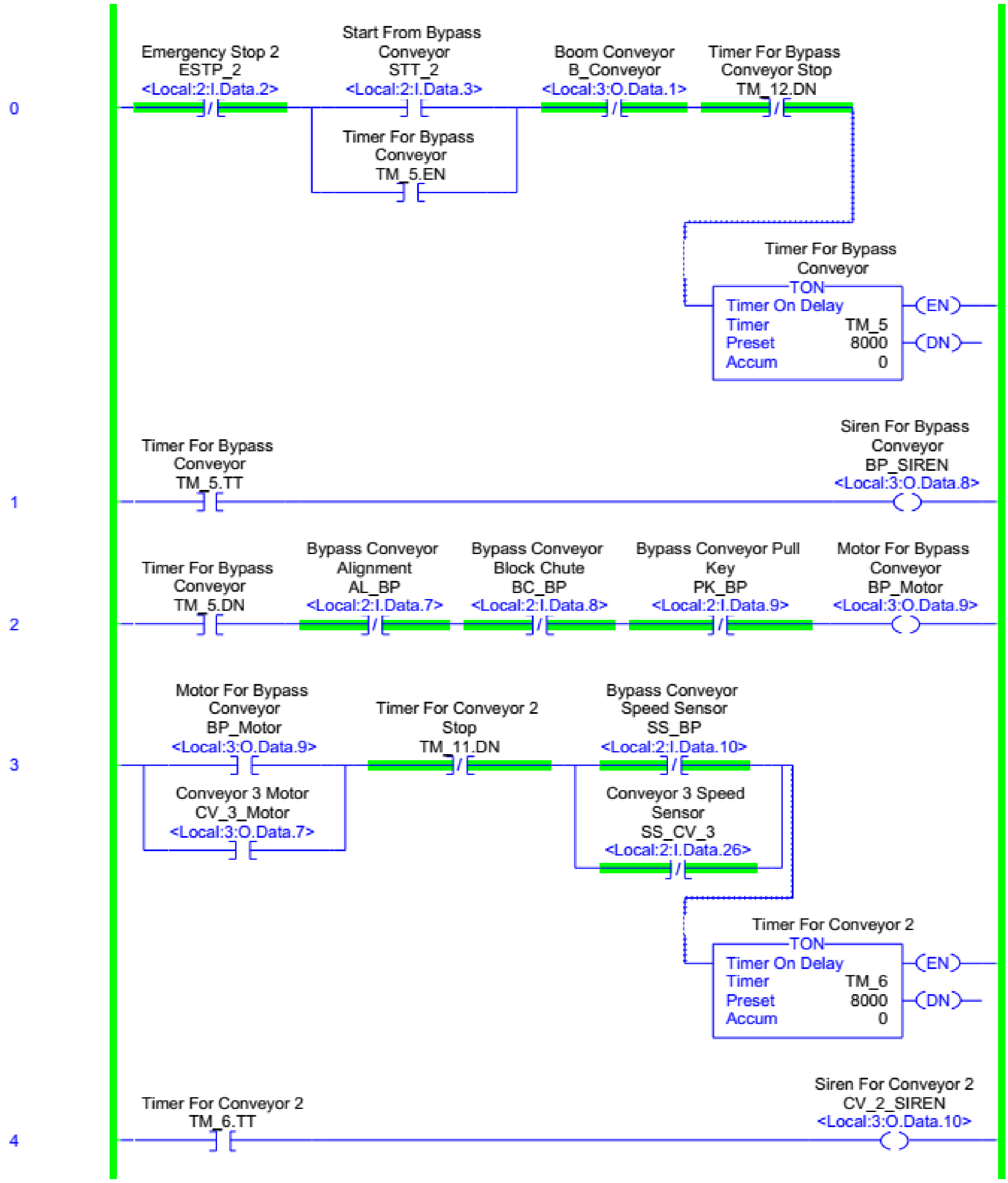


Fig. 5.2 Bypass Circuit PLC Program

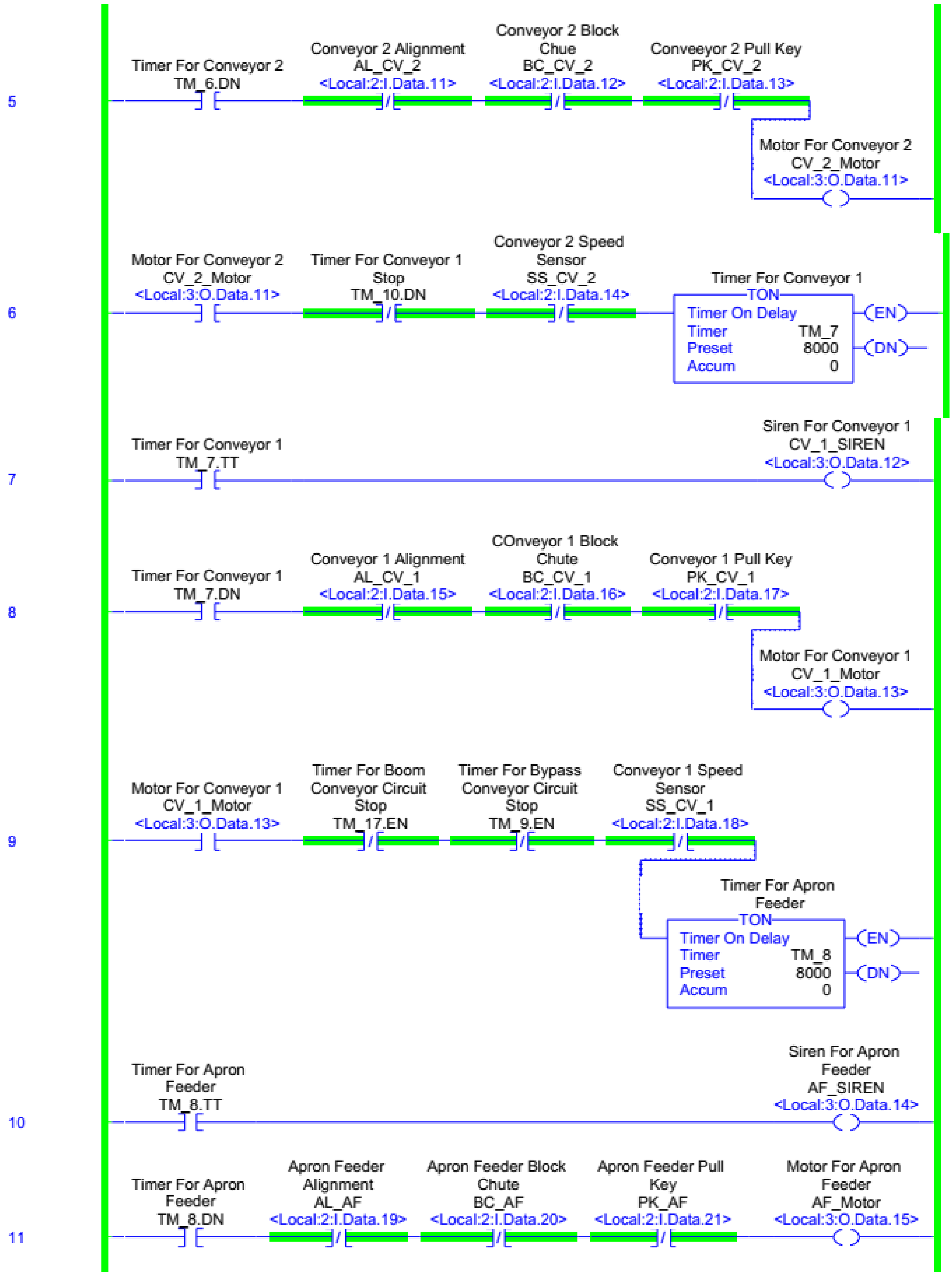


Fig. 5.2 Bypass Circuit PLC Program Cont'd

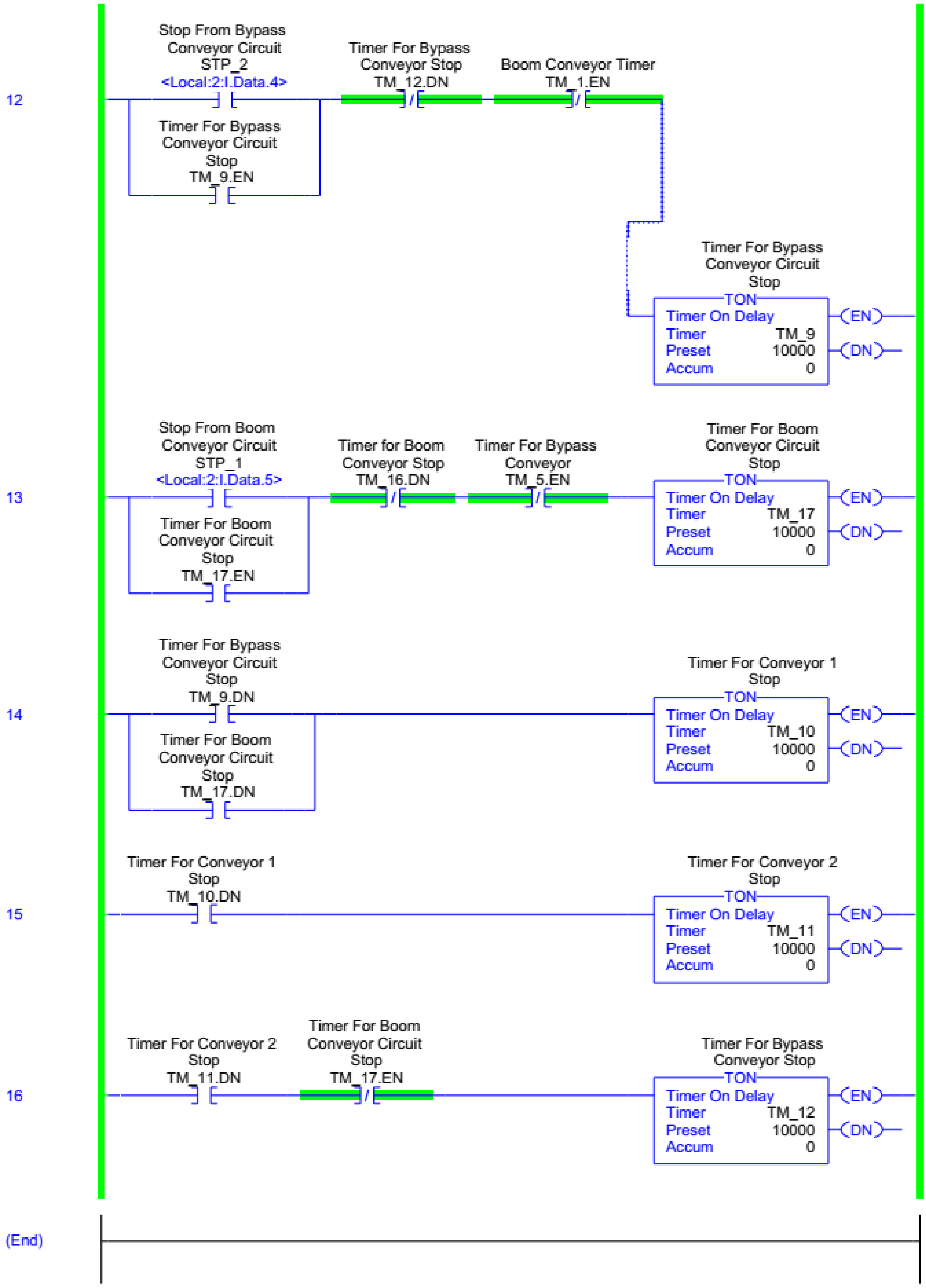


Fig. 5.2 Bypass Circuit PLC Program Cont'd

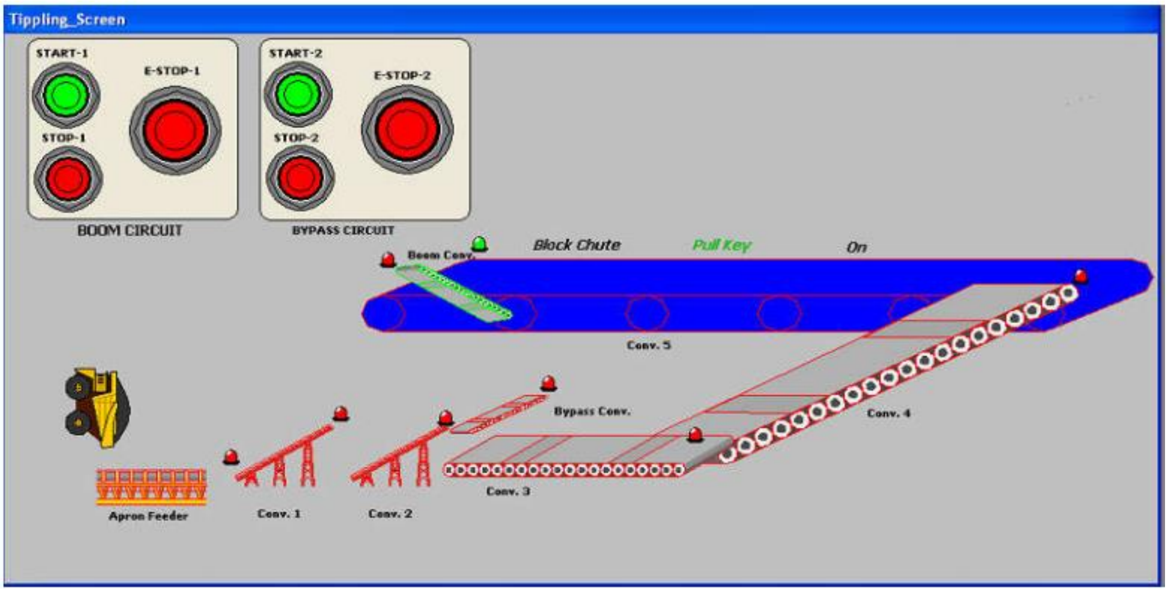


Fig. 5.3 Screenshot of Tippling Plant HMI Screen during Start-up of Boom Circuit

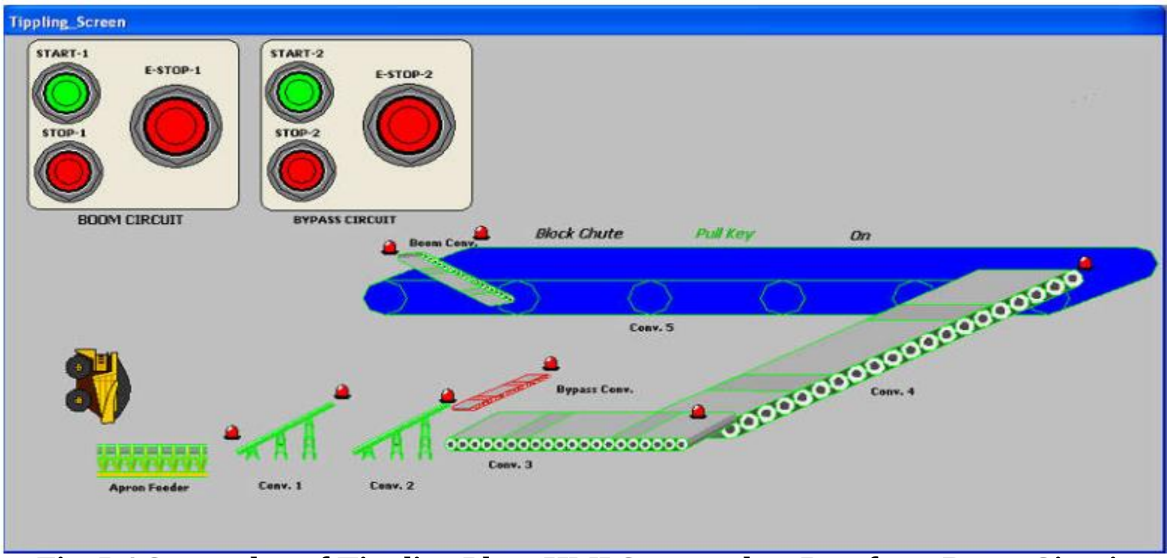


Fig. 5.4 Screenshot of Tippling Plant HMI Screen when Run from Boom Circuit

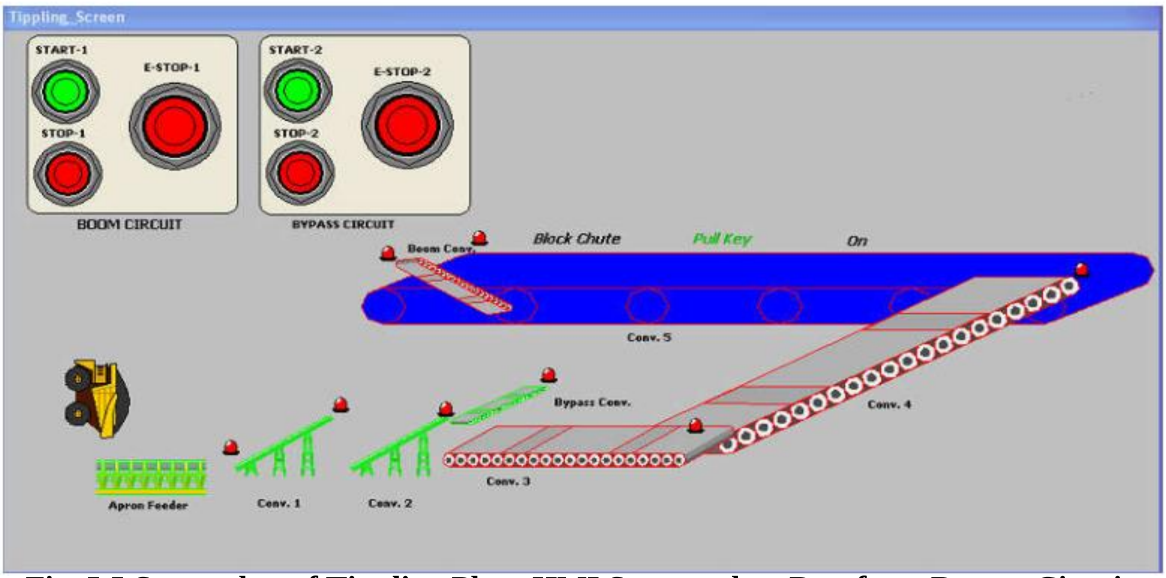


Fig. 5.5 Screenshot of Tippling Plant HMI Screen when Run from Bypass Circuit

5.2.3 Results of Trending

Fig. 5.6, Fig. 5.7, Fig. 5.8 and Fig 5.9 show the trends of Conveyor 3 instruments, boom circuit motors, Conveyor 2 instruments and bypass circuit motors all of the tippling plant. Fig. 5.6 and Fig. 5.7 show the trends of Conveyor 3 instruments and Boom circuit motors, respectively when the tippling plant was ran for ten minutes with Table C.1 and Table C.2 at Appendix C being the corresponding generated tables. Conveyor 3 instruments are represented in the graph as AC_CV_3 (Conveyor 3 Alignment Sensor), BC_CV_3 (Conveyor 3 Block Chute Sensor) and SS_CV_3 (Conveyor 3 Speed Sensor). Boom circuit motors are tagged AF_Motor (Apron Feeder Motor), CV_1_Motor (Conveyor 1 Motor), CV_2_Motor (Conveyor 2 Motor), CV_3_Motor (Conveyor 3 Motor), CV_4_Motor (Conveyor 4 Motor), CV_5_Motor (Conveyor 5 Motor) and B_Conveyor (Boom Conveyor Motor).

Conveyor 3 instruments were assumed Boolean 1 for ‘off’ state and Boolean 0 for ‘on’ state. The motors were assumed Boolean 0 for ‘off’ state and Boolean 1 for ‘on’ state. Fig. 5.8 and Fig. 5.9 show the trends of Conveyor 2 instruments and the Bypass circuit motors, respectively. Conveyor 2 instruments are tagged as AC_CV_2 (Conveyor 2 Alignment Sensor), BC_CV_2 (Conveyor 2 Block Chute Sensor) and SS_CV_2 (Conveyor 2 Speed Sensor). The tag names for Conveyor 2, Conveyor 1 and Apron feeder have already been stated as these motors also form part of the boom circuit. The Bypass Conveyor is tagged BP_Motor. Corresponding generated tables for Fig. 5.8 and Fig. 5.9 are shown in Table C.3 and Table C.4 in Appendix C.

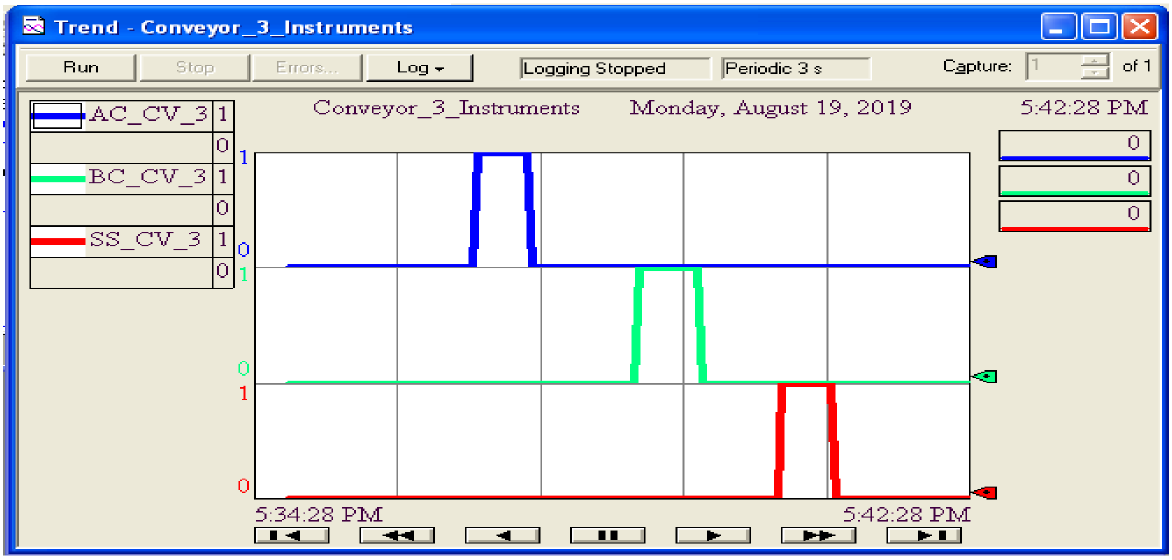


Fig. 5.6 Trend of Conveyor 3 Instruments at Tippling Plant

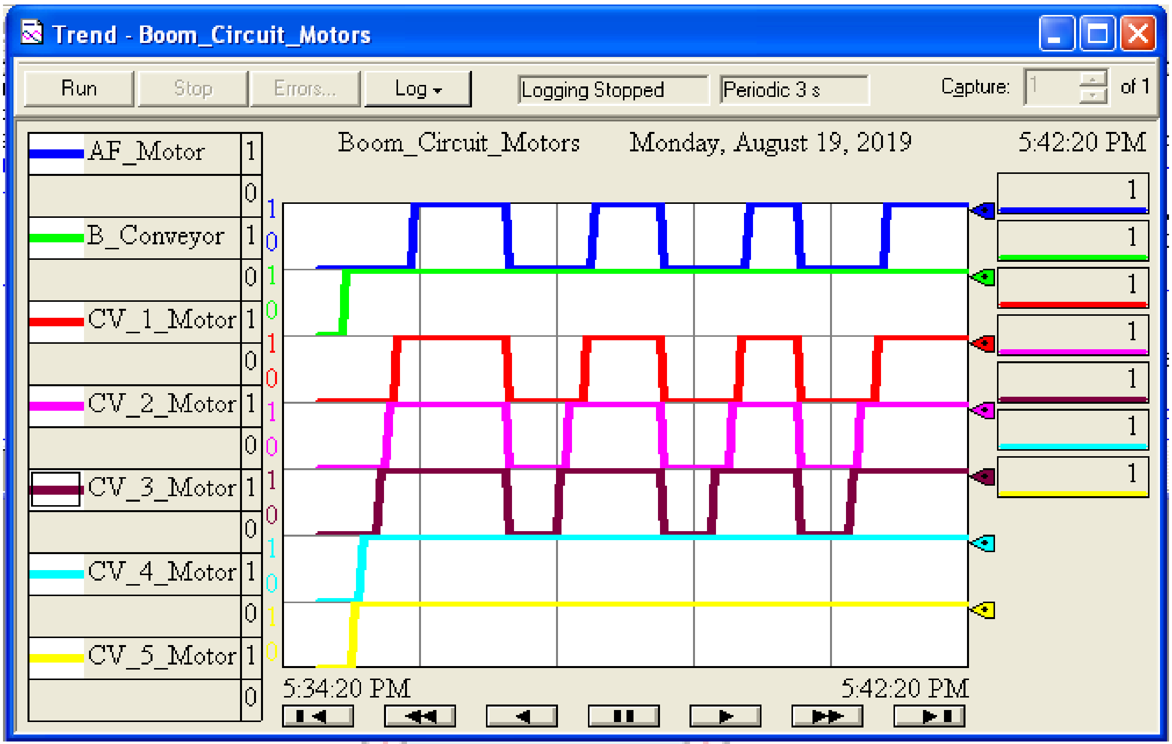


Fig. 5.7 Trend of Boom Circuit Motors at Tippling Plant when Testing Conveyor 3 Instruments

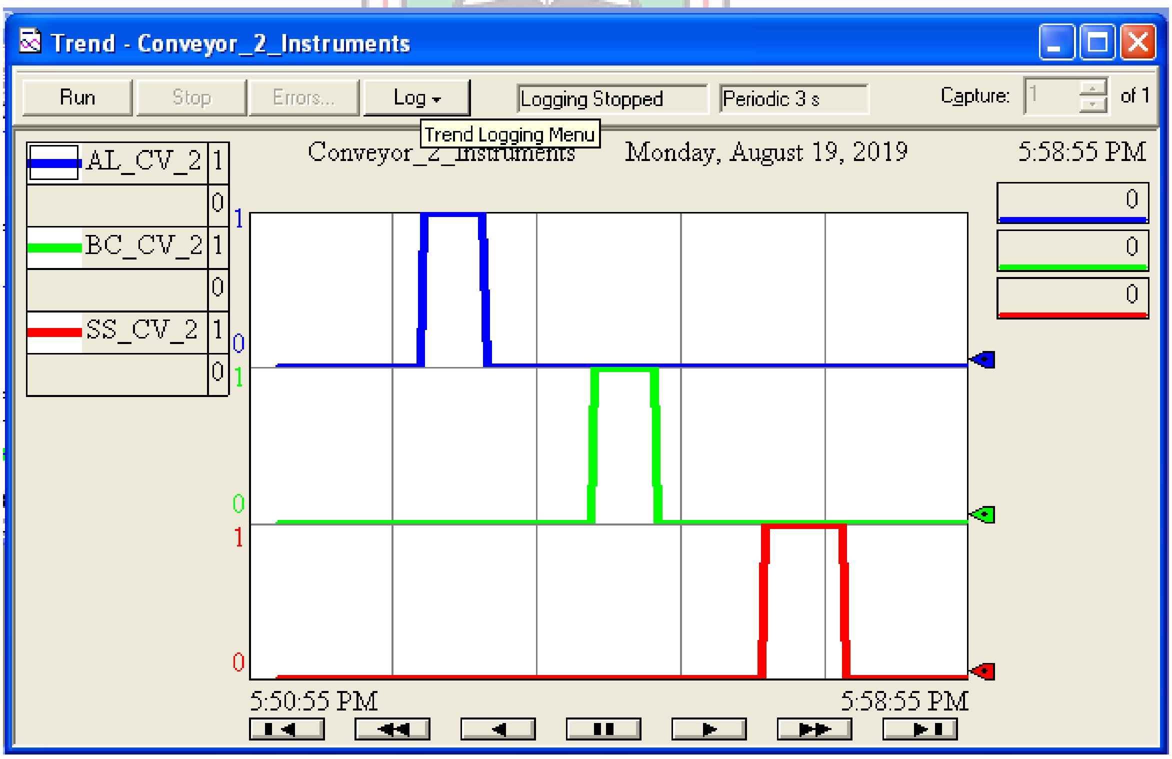


Fig. 5.8 Trend of Conveyor 2 Instruments at Tippling Plant

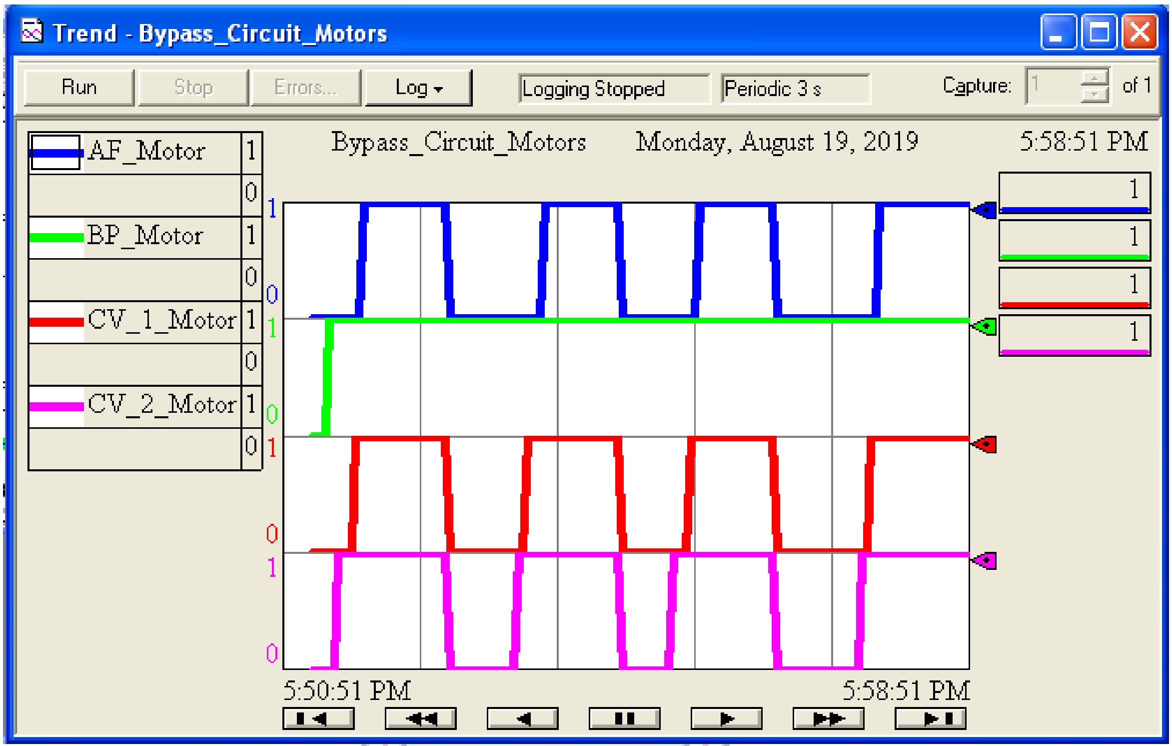


Fig. 5.9 Trend of Bypass Circuit Motors at Tippling Plant when Testing Conveyor 2 Instruments

5.3 Results of Ship Loading Plant Automation

The results of ship loading plant automation are also categorised into three sub-sections as results of PLC programming, results of SCADA HMI screen design and trending results.

5.3.1 Results of PLC Programming

The ship loading plant PLC program is presented in Fig. 5.10 and 5.11. The PLC program is also in two folds, one for running the conveyors named Conveyor Circuit PLC program and the other for running the feeder named Feeder Control Circuit PLC program.

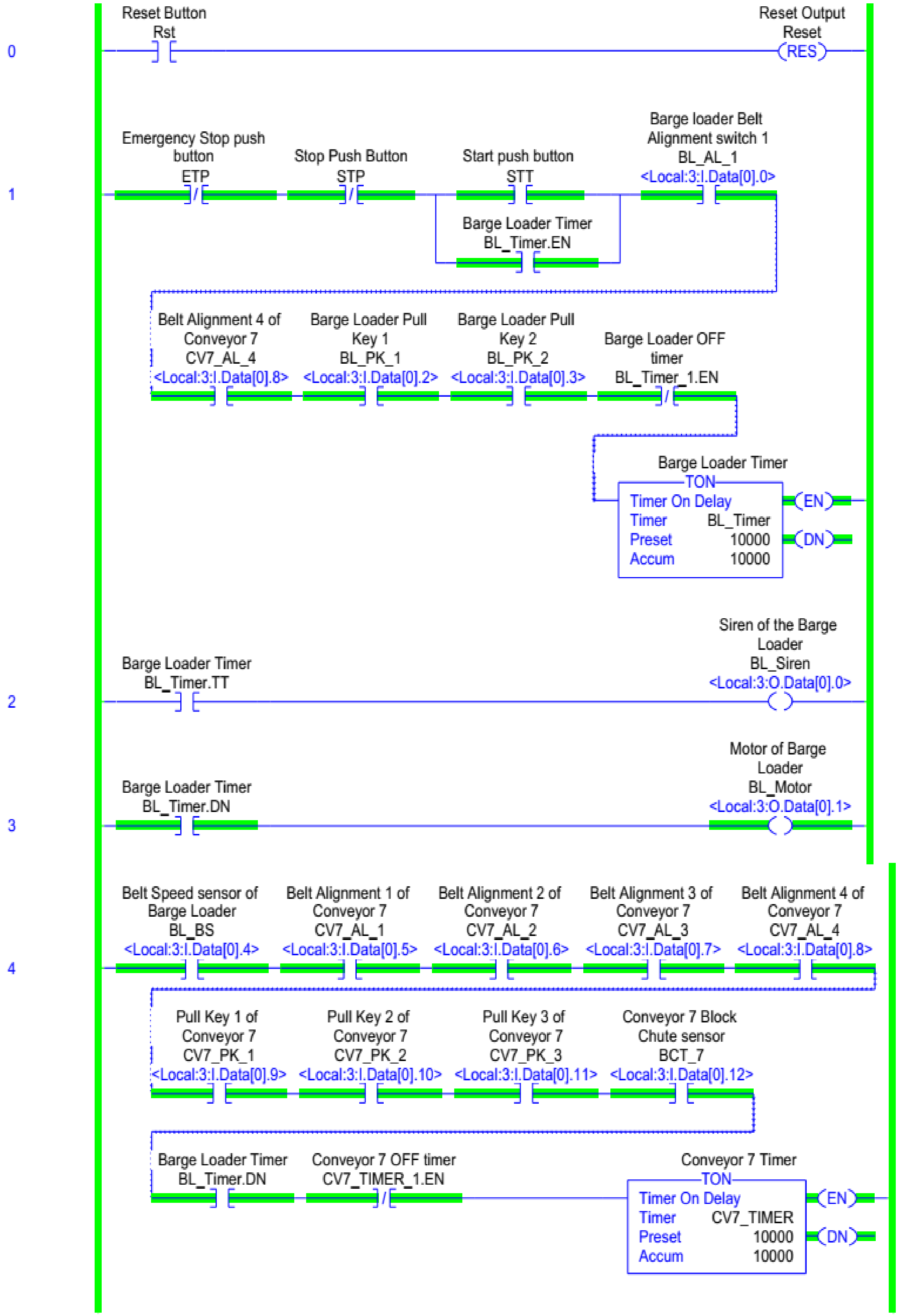


Fig. 5.10 Conveyor Circuit PLC Program

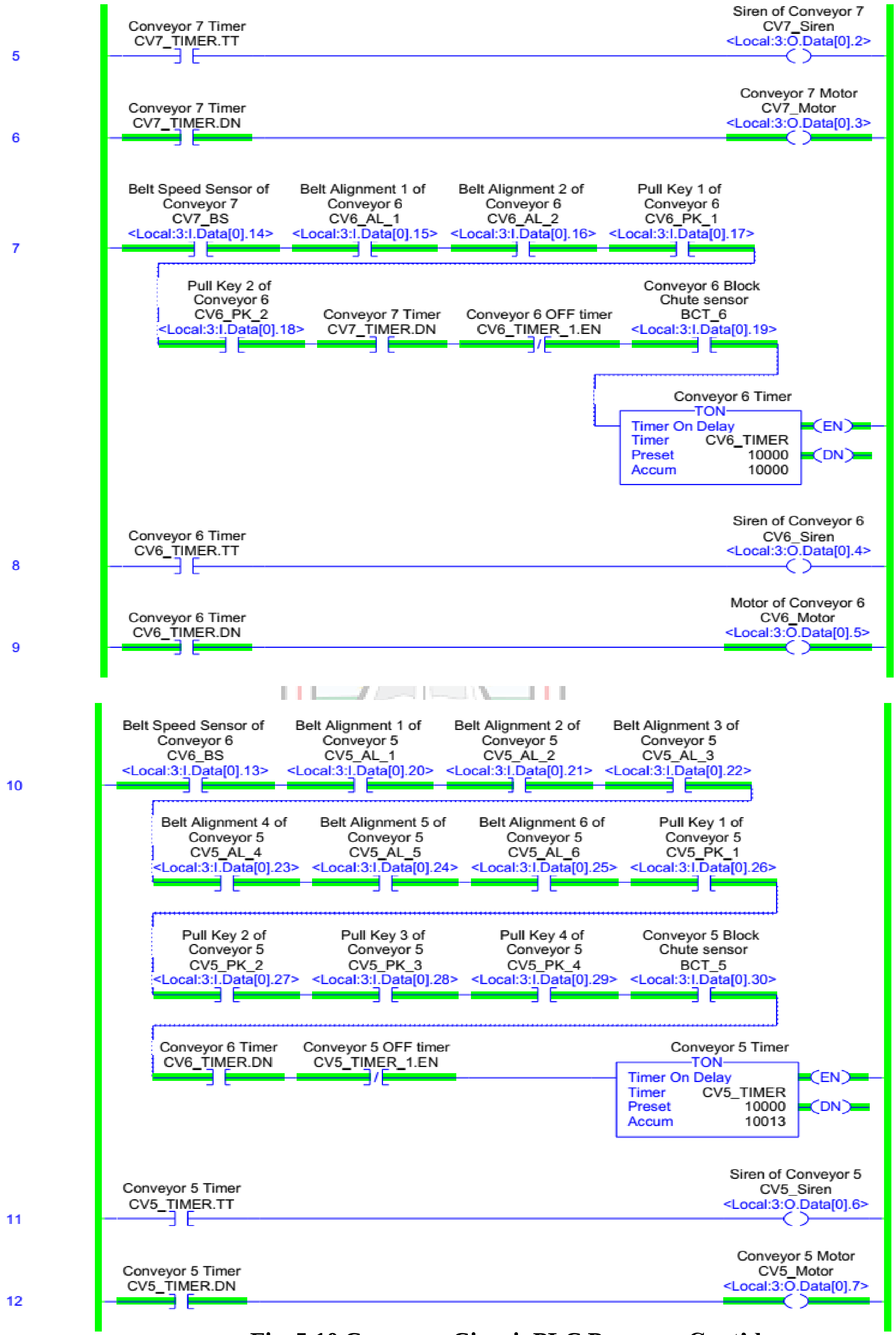


Fig. 5.10 Conveyor Circuit PLC Program Cont'd

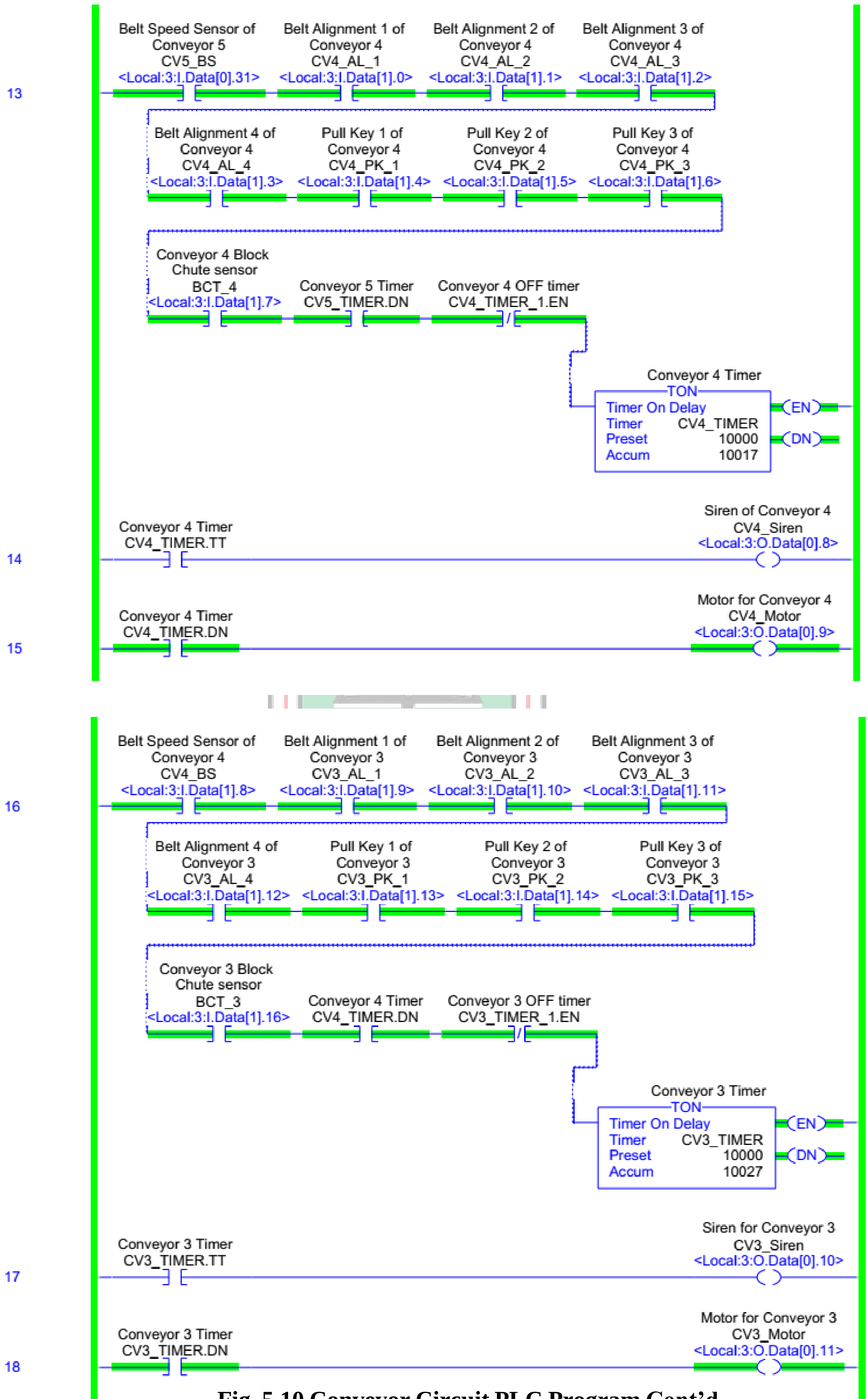


Fig. 5.10 Conveyor Circuit PLC Program Cont'd

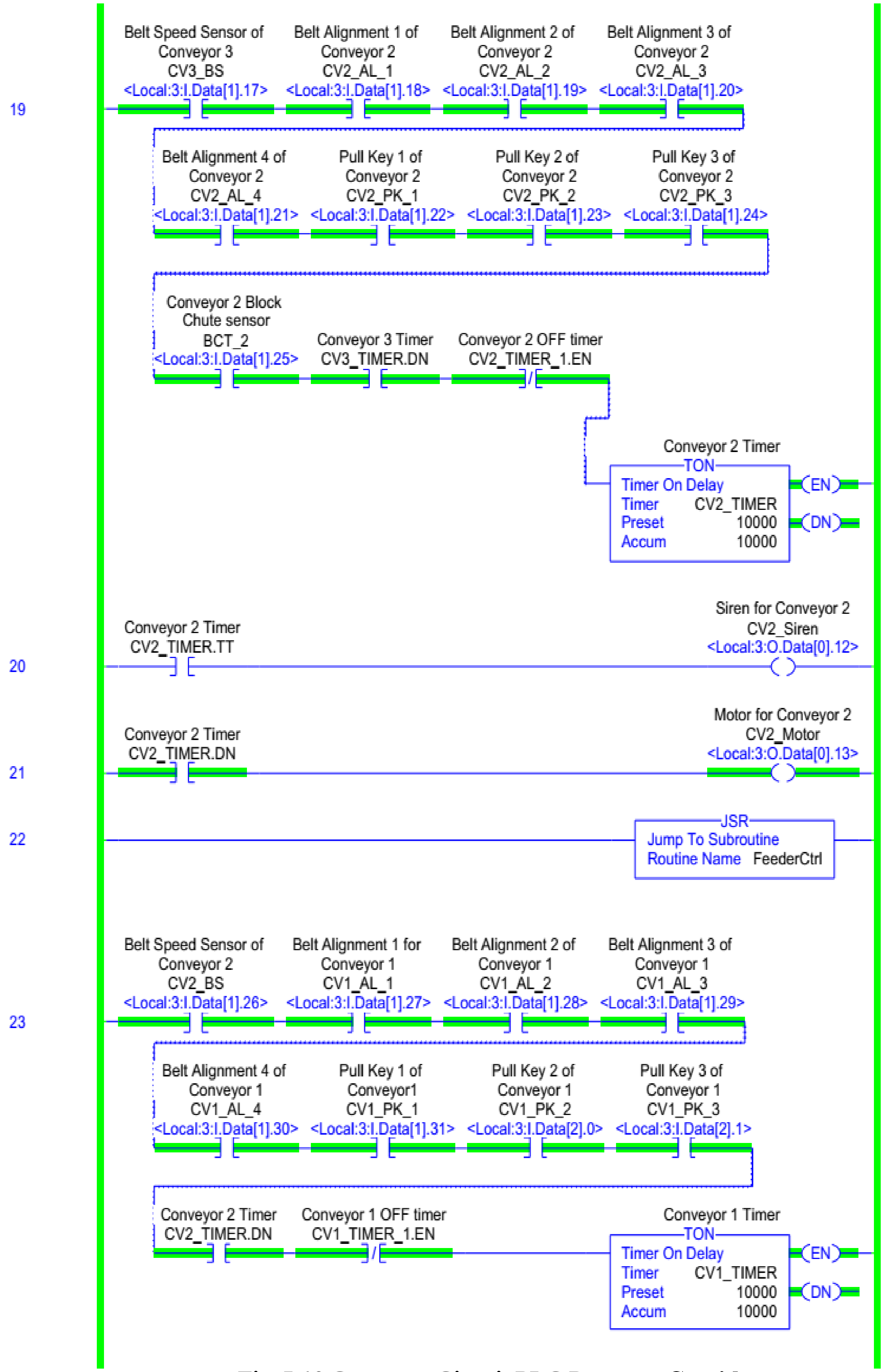


Fig. 5.10 Conveyor Circuit PLC Program Cont'd

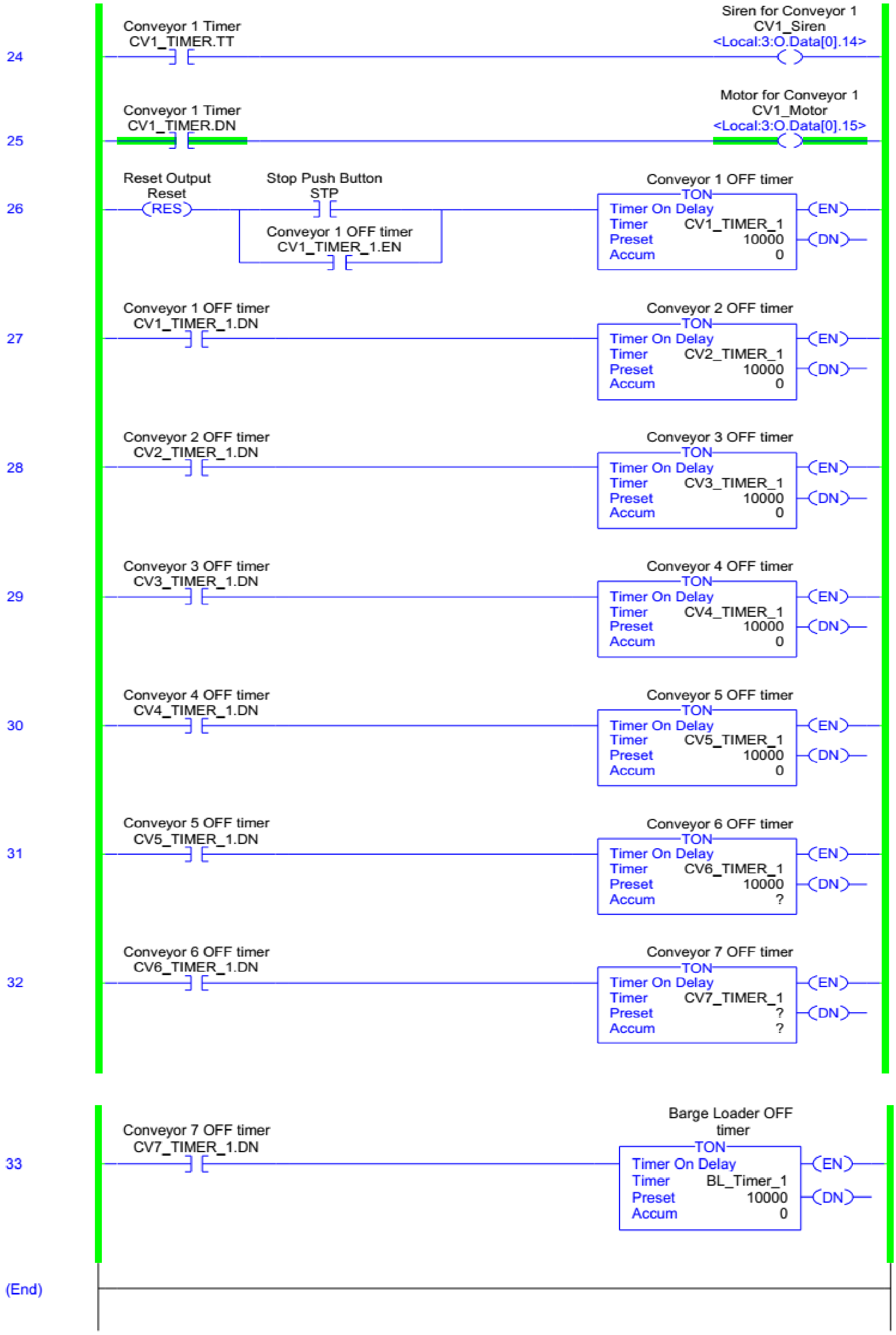


Fig. 5.10 Conveyor Circuit PLC Program Cont'd

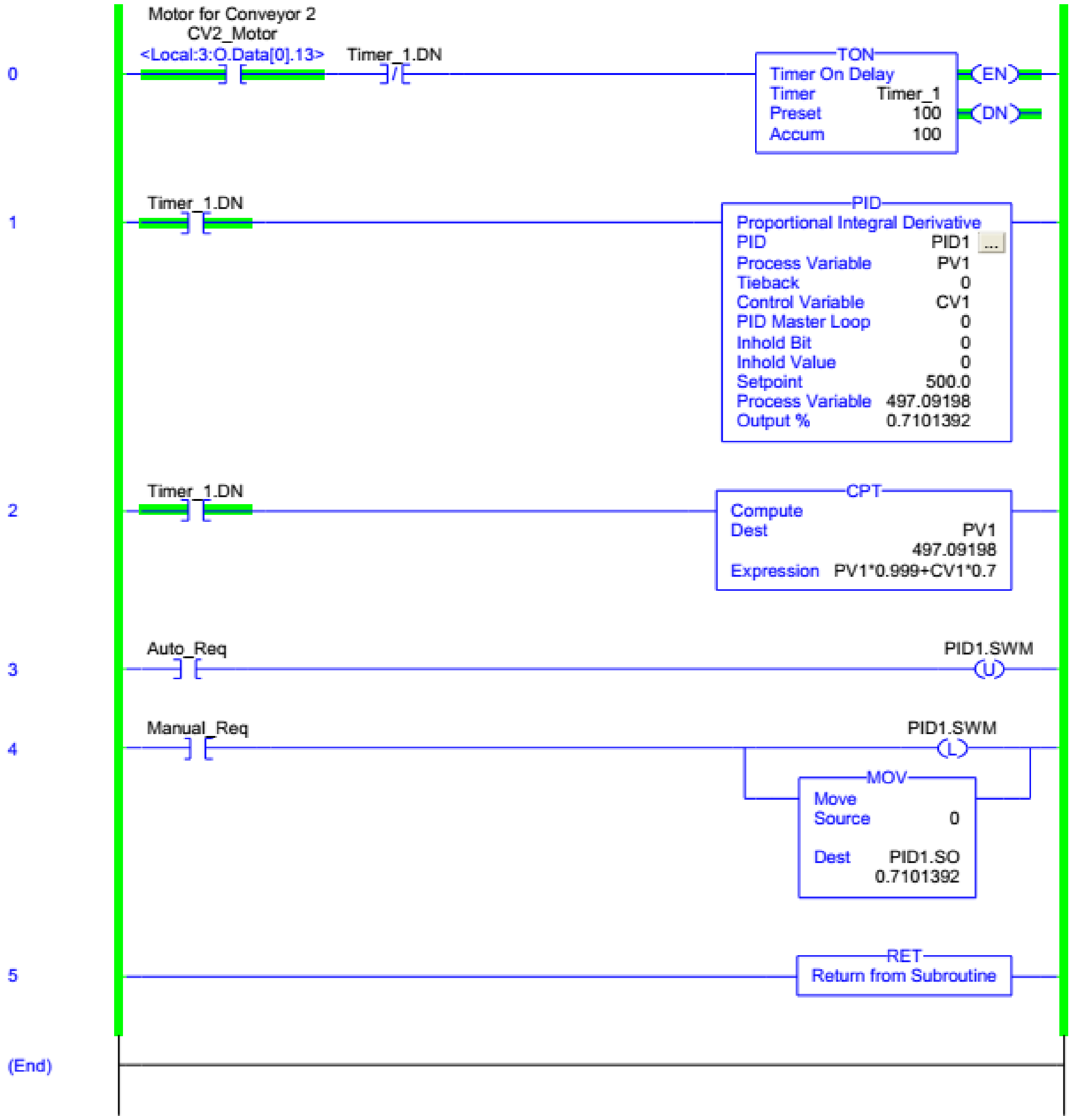


Fig. 5.11 Feeder Control Circuit PLC Program

5.3.2 Results of SCADA HMI Screen Design

In Fig. 5.12, Fig. 5.13 and Fig. 5.14 are also presented screen shots of the HMI screen of the ship loading plant at different states, that is before plant start-up, during plant start-up and when the whole ship loading plant is running, respectively.

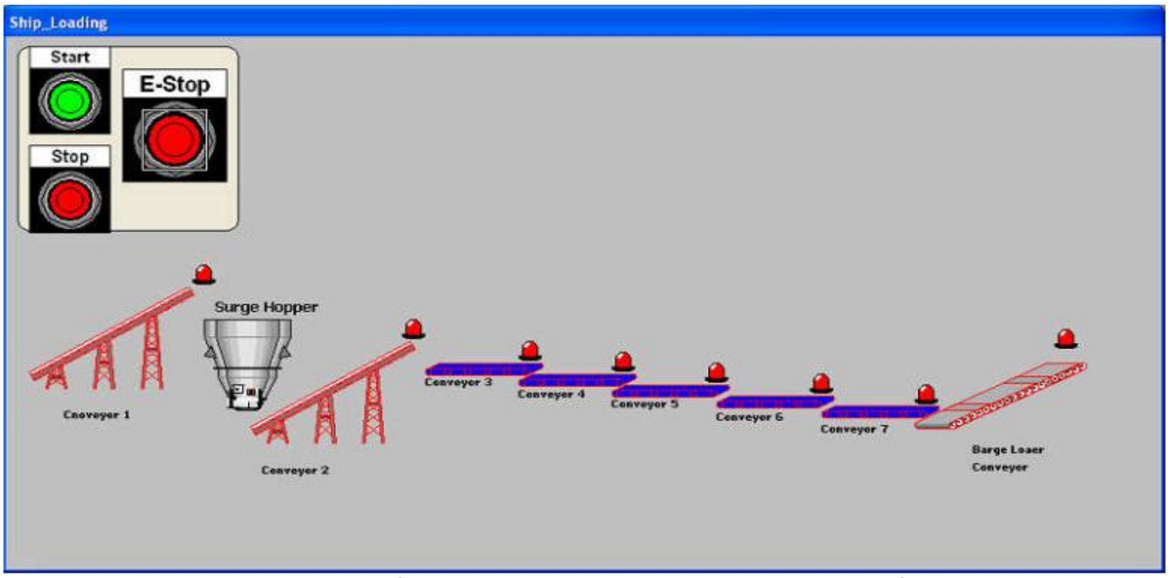


Fig. 5.12 Screenshot of Ship Loading Plant HMI Screen Before Start-up

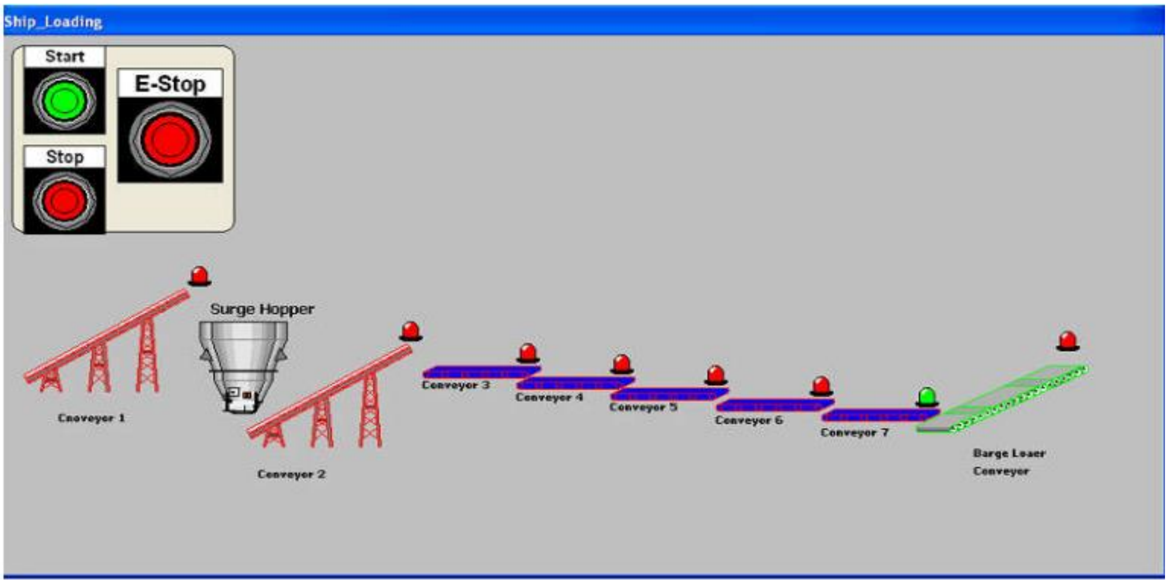


Fig. 5.13 Screenshot of Ship Loading Plant HMI Screen during Start-up

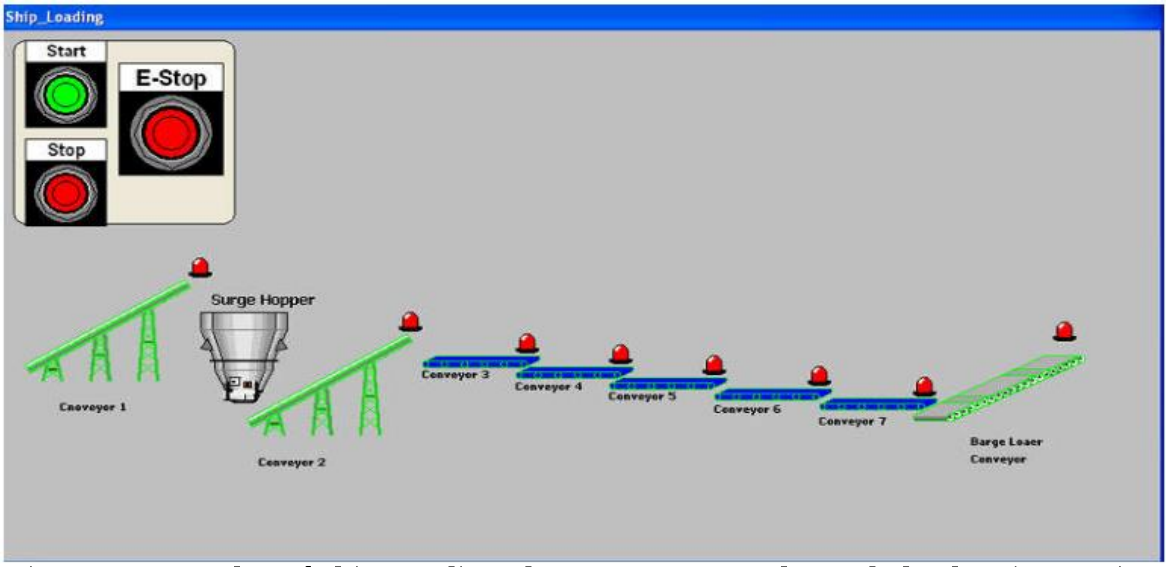


Fig. 5.14 Screenshot of Ship Loading Plant HMI Screen when Whole Plant is Running

5.3.3 Results of Trending

Fig. 5.15, Fig. 5.16, Fig. 5.17 and Fig 5.18 respectively show the trend of Conveyor 7 instruments, the trend of ship loading plant motors when Conveyor 7 instruments were tested, the trend of Conveyor 3 instruments and the trend of ship loading plant motors when Conveyor 3 instruments were tested. Conveyor 7 instruments are tagged BCT_7 (Block Chute sensor), CV7_BS (Belt Speed sensor) and CV7_AL_1 (Alignment sensor). Conveyor 3 instruments are also tagged BCT_3 (Block Chute sensor), CV3_BS (Belt Speed sensor) and CV3_AL_1 (Alignment sensor). The ship loading plant motors are labelled as CV1_Motor (Conveyor 1 Motor), CV2_Motor (Conveyor 2 Motor), CV3_Motor (Conveyor 3 Motor), CV4_Motor (Conveyor 4 Motor), CV5_Motor (Conveyor 5 Motor), CV6_Motor (Conveyor 6 Motor), CV7_Motor (Conveyor 7 Motor) and BL_Motor (Barge Loader Conveyor Motor).

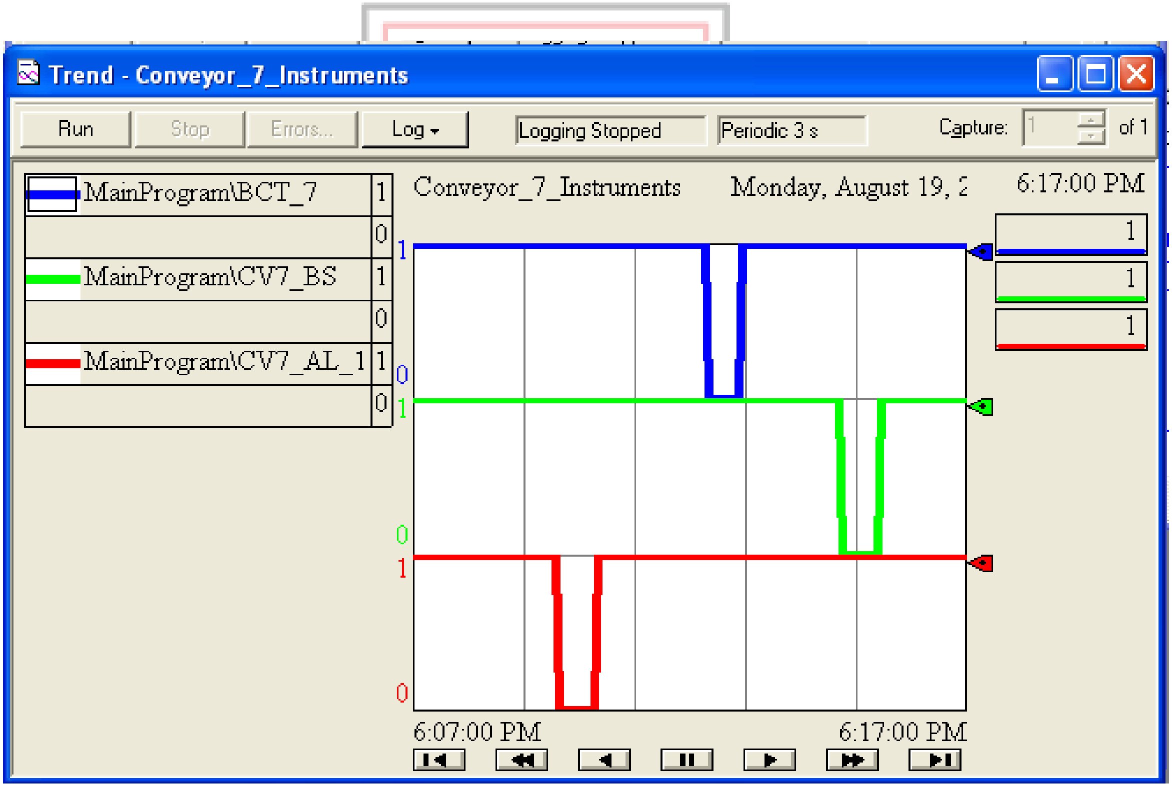


Fig. 5.15 Trend of Conveyor 7 Instruments at Ship Loading Plant

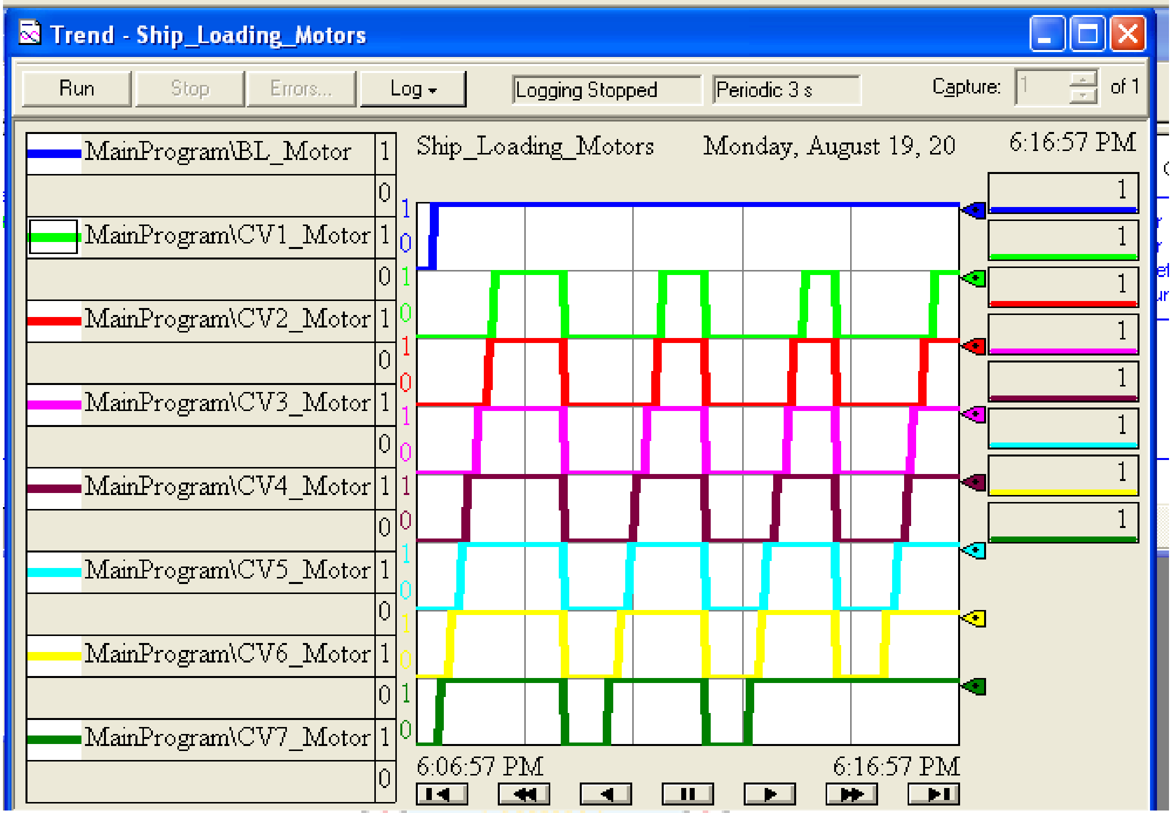


Fig. 5.16 Trend of Ship Loading Plant Motors when Testing Conveyor 7 Instruments

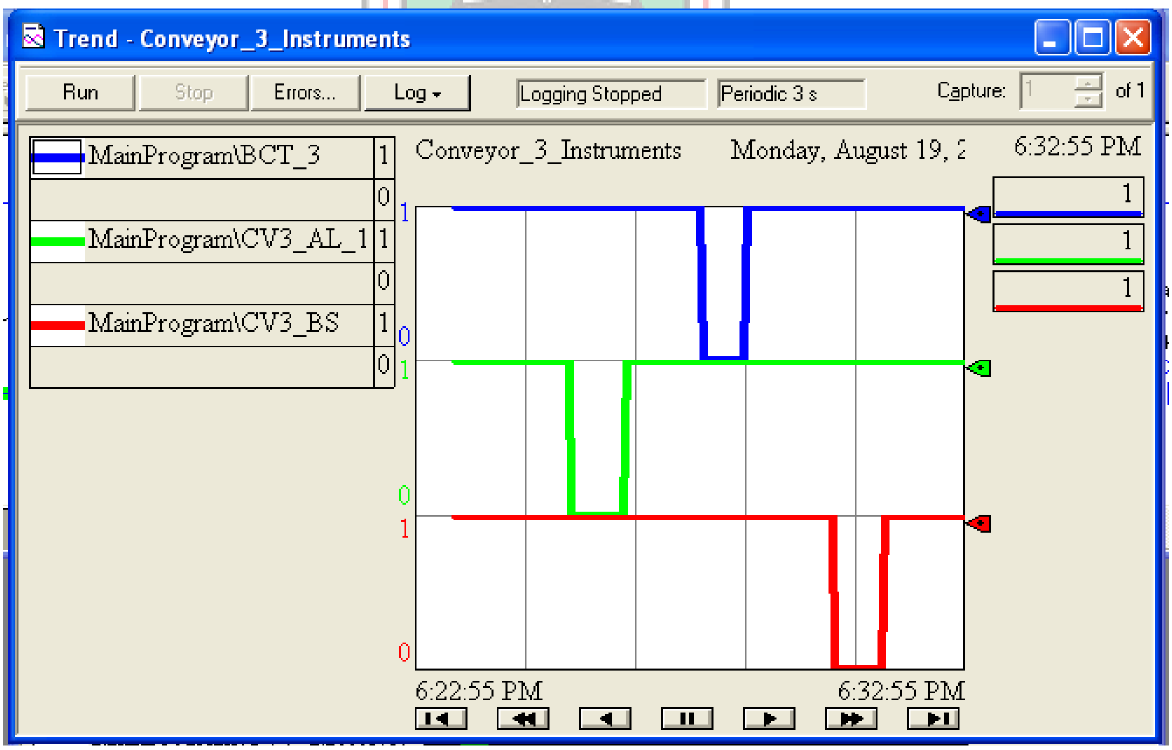


Fig. 5.17 Trend of Conveyor 3 Instruments at Ship Loading Plant

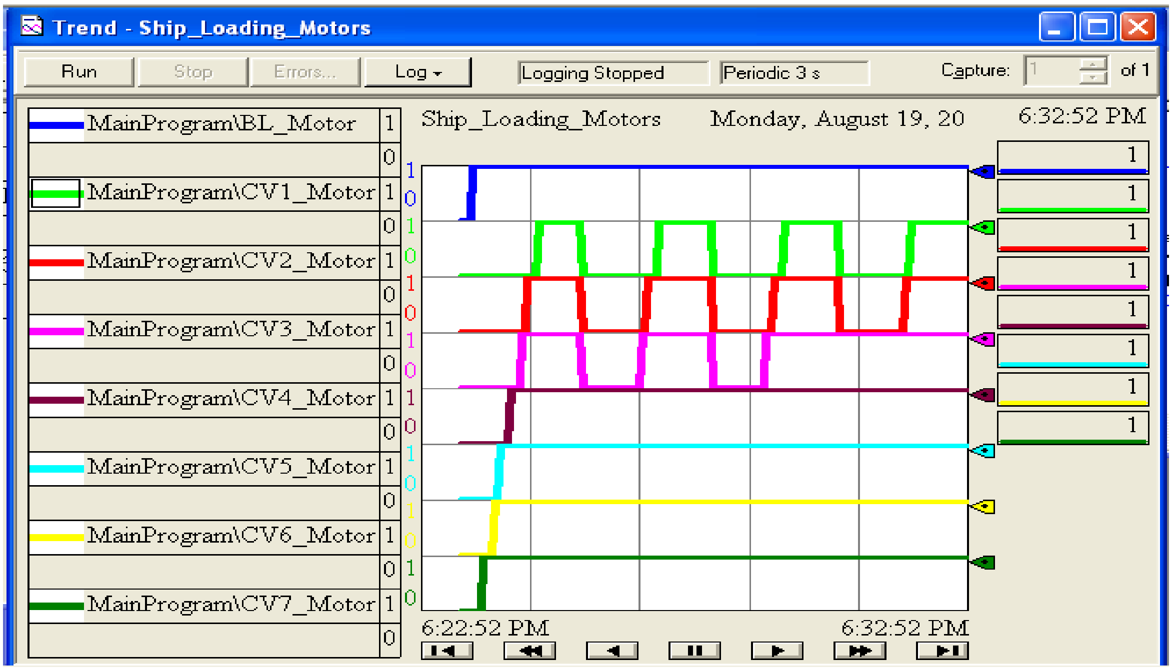


Fig. 5.18 Trend of Ship Loading Plant Motors when Testing Conveyor 3 Instruments

5.4 Discussions

Here, the results of both tippling plant automation and ship loading plant automation are discussed.

5.4.1 Discussion of Results of Tippling Plant Automation

With the SCADA system in place, the number of technicians required to run the tippling plant is reduced from six to three; that is two of them monitoring the plant from the field and one monitoring it from the HMI screen.

From Fig. 5.6, it is realised that at time (t = 17:36:58;530) AC_CV_3 went off (changed state from 'on' to 'off') and reset at time (t = 17:37:34;530). This resulted in the stoppage of Conveyor 3, Conveyor 2, Conveyor 1 and the Apron feeder since their states also changed from 'on' to 'off' simultaneously as depicted in Fig. 5.7. At time (t = 17:38:46;530) from Fig. 5.6, Conveyor 3 also experienced a chute blockage which triggered the block chute sensor BC_CV_3. This also caused stoppage of Conveyor 3, Conveyor 2, Conveyor 1 and the Apron feeder as depicted in Fig. 5.7. At time (t = 17:40:22;530) on Fig. 5.6, SS_CV_3 triggered due to low belt speed and it produced a corresponding effect of Conveyor 3, Conveyor 2 Conveyor 1 and the Apron feeder all stopping as shown in Fig. 5.7. From Fig. 5.8, it is seen that there was a change of state from Boolean 0 to Boolean 1 at time (t = 17:52:52;295) by the belt alignment sensor of Conveyor 2. This produced stoppage of

Conveyor 2, Conveyor 1 and Apron feeder as depicted in Fig. 5.9. At time (t = 17:54:46;295) on Fig. 5.8, BC_CV_2 went off and resulted in the stoppage of Conveyor 2, Conveyor 1 and Apron feeder as shown in Fig. 5.9. Also, at time (t = 17:56:40;295) from Fig. 5.8, SS_CV_2 triggered due to low belt speed and effectively stopped Conveyor 1 and Apron feeder.

5.4.2 Discussion of Results of Ship Loading Plant Automation

With the SCADA system in place, the technicians required to run the ship loading plant has also been reduced from twelve to four. Three of them are required to monitor the plant from the field whilst one monitors the entire plant from the HMI screen.

From Fig. 5.15, it can be seen that at time (t =18:12:21;452), BCT_7 was triggered off and was reset at time (t = 18:12:57;452). This caused the stoppage of Conveyor 1, Conveyor 2, Conveyor 3, Conveyor 4, Conveyor 5, Conveyor 6 and Conveyor 7 as depicted in Fig. 5.16. At time (t = 18:09:39;452) from Fig. 5.15, CV7_AL_1 also went off resulting in the stoppage of Conveyor 1, Conveyor 2, Conveyor 3, Conveyor 4, Conveyor 5, Conveyor 6 and Conveyor 7 as shown in Fig. 5.16. At time (t = 18:14:45;452) from Fig. 5.15, CV7_BS went off and rendered Conveyor 1, Conveyor 2, Conveyor 3, Conveyor 4, Conveyor 5 and Conveyor 6 stopped. This is also shown in Fig. 5.16. From Fig. 5.17, Conveyor 3 instruments were tested and produced a corresponding effect in Fig. 5.18. At time (t = 18:28:10;703) on Fig. 5.17, BCT_3 went off and resulted in the stoppage of Conveyor 3, Conveyor 2 and Conveyor 1 as presented in Fig. 5.18. At time (t = 18:30:34;703) on Fig. 5.17, CV3_BS also went off and effected the stoppage of Conveyor 2 and Conveyor 1 which is shown in Fig. 5.18. At time (t = 18:25:46;703) from Fig. 5.17, CV3_AL_1 went off and caused the stoppage of the linked conveyors as represented in Fig. 5.18.

According to Sooley and Little (2013), historical data provides information for reporting, situational traceability for upset analysis and historical comparison for process improvement. Clark (2015) also stated that historian provides a great way to store and access machine data which can be transformed for use by machine operators, plant engineers and management in factories and plants, thus allowing knowledge workers to influence the future based on past collected data.

Tables such as Table C.1 and Table C.2 can be used to calculate the downtime of the whole plants and thus determine plant availability. These tables also serve as knowledge-based information usable during maintenance. That is, instrument/machine that experiences more faults can be worked on to improve its efficiency and that of the whole plant. In effect, every instrument/equipment/machine can be monitored and its information stored for present and future analysis and decision making.

5.5 Cost Analyses

Let, C_{TSC} = Estimated cost of materials for tippling plant SCADA system

C_{SSC} = Estimated cost of materials for ship loading plant SCADA system

C_{TM} = Miscellaneous cost for tippling plant SCADA system

C_{SM} = Miscellaneous cost for ship loading plant SCADA system

C_{ICT} = Installation cost of tippling plant SCADA system

C_{ICS} = Installation cost of ship loading plant SCADA system

C_{TSIP} = Cost of SCADA system implementation for tippling plant

C_{SSIP} = Cost of SCADA system implementation for ship loading plant

C_{TPQ} = Cost of additional labour for tippling operations for three months

C_{SL} = Cost of additional labour for ship loading operations for three vessels

C_{SLQ} = Cost of additional labour for ship loading operations for three months

C_{TTY} = Additional labour cost for tippling operations for one year

C_{TSY} = Additional labour cost for ship loading operations for one year

5.5.1 Cost Analysis for Tippling Plant Automation

From Table D.1 in Appendix D,

C_{TSC} = USD 43,057.86, C_{ICT} = USD 5,000.00, C_{TM} = USD 4,305.79

$$\text{But, } C_{TSIP} = C_{TSC} + C_{ICT} + C_{TM} \tag{5.1}$$

Which implies that: C_{TSIP} = 43,057.86 + 5,000.00 + 4,305.79 = USD 52,363.65

From Fig. D.1, Fig D.2 and Fig D.3, in Appendix D, and at an exchange rate of USD 1:00 = GH¢ 5.47 as at 24th November, 2019,

$$C_{TPQ} = \text{GH¢ } 25{,}826.40 = \text{USD } 4{,}721.46$$

Also, $$C_{TTY} = C_{TPQ} \times 4 \text{ (since there are 4 quarters in a year)} \quad (5.2)$$

Which implies that: $C_{TTY} = 4{,}721.46 \times 4 = \text{USD } 18{,}885.84$

Therefore, for a five-year period, additional labour cost for tippling operations is:

$$18{,}885.84 \times 5 = \text{USD } 94{,}429.20$$

Table E.1 in Appendix E presents a loan amortisation schedule for the tippling plant, assuming the money for the tippling plant SCADA installation is a loan at an interest rate of 31% (Anon., 2019z) and should be paid within a period of five years.

By comparing the total capital cost of investment of the tippling plant SCADA system to total additional labour cost for tippling operations, it can be deduced that the total capital cost of investment for SCADA installation would not be paid off in five years.

5.5.2 Cost Analysis for Ship Loading Plant Automation

From Table D.2 in Appendix D,

$$C_{SSIP} = \text{USD } 50{,}813.50,\; C_{ICS} = 5000,\; C_{SM} = 5{,}081.35$$

But, $$C_{SSIP} = C_{SSC} + C_{ICS} + C_{SM} \quad (5.3)$$

Which implies that: $C_{SSIP} = 50{,}813.50 + 5{,}000 + 5{,}081.35 = \text{USD } 60{,}894.85$

From Fig. D.4, Fig D.5 and Fig D.6 in Appendix D,

$$C_{SL} = \text{GH¢ } 17{,}698.10 = \text{USD } 3{,}235.48$$

$$\text{But, } C_{SLQ} = 3 \times C_{SL} \quad (5.4)$$

Which implies that: $C_{SLQ} = 3 \times 3{,}235.48 = \text{USD } 9{,}706.44$

$$\text{Also, } C_{TSY} = C_{SLQ} \times 4 \quad (5.5)$$

Which implies that: $9{,}706.44 \times 4 = \text{USD } 38{,}825.76$

Hence, for a five-year period, additional labour cost for ship loading operations is:

$$38{,}825.76 \times 5 = \text{USD } 194{,}128.80$$

Table E.2 in Appendix E presents a loan amortisation schedule for the ship loading plant, assuming the money for the ship loading plant SCADA installation is a loan at an interest rate of 31% (Anon., 2019) and should be paid within a period of five years.

By comparing the total capital cost of investment of the ship loading plant SCADA system to total additional labour cost for ship loading operations, it can be deduced that the total capital cost of investment for SCADA installation would totally be paid off in five years.

5.6 Plant Availability and Efficiency

This section discusses the availability and efficiency of both tippling and ship loading plants of GBC Limited, TPF after the SCADA implementation.

5.6.1 Plant Availability

According to Smith and Hinchcliffe (2006), availability is defined as a measure of the percentage (or fraction) of time that a plant is capable of producing its end product at some specified acceptable level. Thus, availability must account for plant outages; both planned (scheduled) and unplanned (forced). Availability is controlled by two main parameters, which are Mean Time Between Failure (MTBF) and Mean Time To Restore (MTTR). MTBF is defined as a measure of how long, on average, a plant (or an individual item of equipment) will perform as specified before an unplanned failure will occur. MTTR is also explained as the measure of how long, on average, it will take to bring the plant or equipment item back to normal serviceability when it does fail.

Mathematically, Availability, $$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \qquad (5.6)$$

For a serial system, Availability, $$A = \prod A\,(\text{Component}_i) \qquad (5.7)$$

For a parallel system, Availability, A = 1 – Unavailability (parallel)

$$= 1 - \prod \left[1 - A\,(\text{Component}_i)\right] \qquad (5.8)$$

In order to determine the plant's availabilities of both tippling and ship loading plants, a collection of failure and repair data of the various conveyor subsystems belonging to tippling and ship loading plants from the daily maintenance report books over a period of six months are collected and analysed in the following section.

Computation of values of time of tippling plant conveyor subsystem

This section presents the computations of values of time such as Time Between Failure (TBF), Cumulative Time Between Failure (CTBF), Time To Repair (TTR) and Cumulative Time To Repair (CTTR) of the tippling plant. Thus, time computations of the Apron Feeder, Tippling Conveyor 1, Tippling Conveyor 2, Bypass Conveyor, Tippling Conveyor 3, Tippling Conveyor 4, Tippling Conveyor 5 and Boom Conveyor are presented in Table 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7 and 5.8 respectively. Table 5.9 also presents the availability of each conveyor subsystem of the Tippling Plant.

Table 5.1 Time Computations for Apron Feeder

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	13/06/2017 09:15	-	-	13/06/2017 14:25	5:10	5:10
2.	14/06/2017 13:15	28:00	28:00	14/06/2017 17:45	4:30	9:40
3.	25/06/2017 09:50	260:35	288:35	25/06/2017 13:05	3:15	12:55
4.	07/07/2017 10:35	288:45	577:20	09/07/2017 17:30	6:55	19:50
5.	14/07/2017 13:20	170:45	748:05	14/07/2017 17:50	4:30	24:20
6.	02/09/2017 08:30	1195:10	1943:15	02/09/2017 16:40	8:10	32:30
7.	17/10/2017 10:20	1081:50	3025:05	17/10/2017 15:23	5:03	37:33
8.	04/11/2017 09:17	430:57	3456:02	`04/11/2017 16:00	6:43	44:16

Table 5.2 Time Computations for Tippling Conveyor 1

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	01/06/2017 12:20	-	-	02/06/2017 16:55	28:35	28:35
2.	15/06/2017 08:50	332:30	332:30	15/06/2017 15:35	6:45	35:20
3.	19/06/2017 10:40	97:50	430:20	19/06/2017 16:22	5:42	41:02
4.	11/08/2017 10:25	1271:45	1702:05	11/08/2017 15:15	4:50	45:52

Table 5.2 Cont'd

5.	29/09/2017 07:30	1173:05	2875:10	29/09/2017 11:35	4:05	49:57
6.	13/10/2017 08:50	337:20	3212:30	13/10/2017 14:55	6:05	56:02
7.	22/11/2017 13:20	964:30	4177:00	22/11/2017 17:48	4:28	60:30

Table 5.3 Time Computations for Tippling Conveyor 2

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	05/08/2017 11:15	-	-	05/08/2017 13:35	2:20	2:20
2.	16/08/2017 10:17	263:02	263:02	16/08/2017 16:50	6:33	8:53
3.	23/10/2017 09:40	1631:23	1894:25	23/10/2017 17:35	7:55	16:48

Table 5.4 Time Computations for Bypass Conveyor

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	05/08/2017 14:05	-	-	05/08/2017 15:35	1:30	1:30
2.	24/08/2017 11:20	453:15	453:25	24/08/2017 15:40	4:20	5:50
3.	04/09/2017 09:30	262:10	715:35	04/09/2017 14:52	5:22	11:12
4.	12/12/2017 08:27	2374:57	3063:22	12/12/2017 14:05	5:38	16:50

Table 5.5 Time Computations for Tippling Conveyor 3

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	10/06/2017 7:20	-	-	10/06/2017 13:33	6:13	6:13
2.	19/08/2017 08:50	1681:30	1681:30	19/08/2017 17:20	8:30	14:43
3.	29/11/2017 13:05	2452:15	4133:45	29/11/2017 16:55	3:50	18:33
4.	18/12/2017 16:08	459:03	4592:48	18/12/2017 20:15	4:07	22:40
5.	27/12/2017 08:40	208:32	4801:20	28/12/2017 11:20	2:40	25:30

Table 5.6 Time Computations for Tippling Conveyor 4

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	08/09/2017 07:50	-	-	08/09/2017 10:20	2:30	2:30
2.	25/09/2017 13:09	413:19	413:19	25/09/2017 17:25	4:16	6:46
3.	30/10/2017 09:48	836:39	1249:58	30/10/2017 13:20	3:32	10:18
4.	10/11/2017 07:40	261:52	1511:50	10/11/2017 10:58	3:18	13:36
5.	24/12/2017 12:20	1060:40	2572:30	24/12/2017 15:37	3:17	16:53

Table 5.7 Time Computations for Tippling Conveyor 5

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	09/06/2017 08:25	-	-	09/06/2017 14:17	5:52	5:52
2.	02/07/2017 12:10	555:45	555:45	02/07/2017 14:13	2:03	7:55
3.	15/10/2017 09:40	2517:30	3073:15	15/10/2017 16:32	6:52	14:47
4.	28/10/2017 14:50	317:10	3390:25	28/10/2017 17:35	2:45	17:32
5.	12/11/2017 12:20	357:30	3747:55	12/11/2017 16:12	3:53	21:25
6.	29/11/2017 16:40	412:20	4160:15	29/11/2017 21:10	4:30	25:55
7.	17/12/2017 13:15	428:35	4588:50	17/12/2017 15:45	2:30	28:25

Table 5.8 Time Computations for Boom Conveyor

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	12/08/2017 10:28	-	-	12/08/2017 17:05	6:37	6:37
2.	25/08/2017 09:15	310:47	310:47	25/08/2017 14:25	5:10	11:47
3.	08/10/2017 11:42	1058:27	1369:14	08/10/2017 13:55	2:13	14:00
4.	15/12/2017 12:12	1632:30	3001:44	15/12/2017 15:40	3:28	17:28

Table 5.9 Availability of Each Conveyor Subsystem of Tippling Plant

Subsystem	Failure Frequency (No. of times/6 months)	MTBF (Hours)	MTTR (Hours)	Availability (/6 months)
Apron Feeder	8	432.0042	5.5333	0.98735
Tippling Conveyor 1	7	596.7143	8.6429	0.98572
Tippling Conveyor 2	3	631.4722	5.6000	0.99121
Bypass Conveyor	4	765.8418	4.2083	0.99454
Tippling Conveyor 3	5	960.2667	5.1000	0.99472
Tippling Conveyor 4	5	514.5000	3.3767	0.99348
Tippling Conveyor 5	7	655.5476	4.0595	0.99385
Boom Conveyor	4	750.4333	4.3667	0.99421

Computation of values of time of Ship Loading Plant Conveyor Subsystem

This section presents the computations of values of time such as Time Between Failure (TBF), Cumulative Time Between Failure (CTBF), Time To Repair (TTR) and Cumulative Time To Repair (CTTR) of the ship loading plant. Thus, time computations of Conveyor 1, Conveyor 2, Conveyor 3, Conveyor 4, Conveyor 5, Conveyor 6, Conveyor 7 and Barge Loader Conveyor all of Ship Loading Plant are presented in Table 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16 and 5.17 respectively. Table 5.18 also presents the availability of each conveyor subsystem of the Ship Loading Plant.

Table 5.10 Time Computations for Ship Loading Conveyor 1

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	03/07/2017 11:15	-	-	03/07/2017 17:45	6:30	6:30
2.	27/07/2017 11:20	576:05	576:05	27/07/2017 17:55	6:35	13:05
3.	02/12/2017 08:20	3069:00	3645:05	02/12/2017 13:30	5:10	18:15

Table 5.11 Time Computations for Ship Loading Conveyor 2

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	25/06/2017 09:20	-	-	25/06/2017 13:25	4:05	4:05
2.	18/07/2017 09:15	551:55	551:55	18/07/2017 13:32	4:17	8:22
3.	03/12/2017 09:20	3312:05	3864:00	03/12/2017 12:30	3:10	11:32
4.	09/12/2017 07:20	142:00	4006:00	09/12/2017 16:05	8:45	20:17
5.	14/12/2017 11:30	124:10	4130:10	14/12/2017 16:45	5:15	25:32

Table 5.12 Time Computations for Ship Loading Conveyor 3

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	18/07/2017 15:15	-	-	18/07/2017 17:15	2:00	2:00
2.	22/07/2017 08:45	89:30	89:30	22/07/2017 16:15	7:30	9:30
3.	14/09/2019 09:30	1296:45	1386:15	14/09/2019 15:42	6:12	15:42
4.	27/11/2017 09:30	1776:00	3162:15	27/11/2017 14:25	4:55	20:37
5.	02/12/2017 16:30	127:00	3289:15	02/12/2017 18:50	2:20	22:57
6.	03/12/2017 13:15	20:45	3310:00	03/12/2017 16:20	3:05	26:02

Table 5.13 Time Computations for Ship Loading Conveyor 4

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	06/06/2017 10:20	-	-	06/06/2017 14:35	4:15	4:15
2.	29/10/2017 14:15	3483:55	3483:55	29/10/2017 16:35	2:20	6:35
3.	02/12/2017 14:15	816:00	4299:55	02/12/2017 16:15	2:00	8:35

Table 5.14 Time Computations for Ship Loading Conveyor 5

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	29/06/2017 09:17	-	-	29/06/2017 17:40	8:23	8:23
2.	19/07/2017 08:41	479:24	479:24	19/07/2017 11:17	2:36	10:59
3.	31/07/2017 8:30	287:49	767:13	31/07/2017 16:25	7:55	18:54
4.	27/08/2017 09:15	648:45	1415:58	27/08/2017 10:05	0:50	19:44
5.	22/10/2017 13:15	1348:00	2763:58	22/10/2017 15:42	2:27	22:11
6.	30/10/2017 07:50	186:35	2950:33	30/10/2017 13:45	5:55	28:06
7.	04/11/2017 10:25	122:35	3073:08	04/11/2017 13:50	3:25	31:31
8.	27/11/2017 15:15	556:50	3629:58	27/11/2017 16:25	1:10	32:41

Table 5.15 Time Computations for Ship Loading Conveyor 6

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	29/10/2017 10:12	-	-	29/10/2017 12:25	2:13	2:13
2.	04/11/2017 14:05	147:53	147:53	04/11/2017 17:30	3:25	5:38
3.	27/11/2017 16:30	554:25	702:18	27/11/2017 17:25	0:55	6:33

Table 5.16 Time Computations for Ship Loading Conveyor 7

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	15/07/2017 08:50	-	-	15/07/2017 15:35	6:45	6:45
2.	19/07/2017 12:30	99:40	99:40	19/07/2017 15:05	2:35	9:20
3.	23/10/2017 09:15	2300:45	2400:25	23/10/2017 13:34	4:19	13:39
4.	05/11/2017 12:28	315:13	2715:38	05/11/2017 15:42	3:14	16:53
5.	12/11/2017 09:45	165:17	2880:55	12/11/2017 13:12	3:27	20:20
6.	13/11/2017 08:50	23:05	2904:00	13/11/2017 15:15	6:25	26:45
7.	27/11/2017 18:00	345:10	3249:10	27/11/2017 19:25	1:25	28:10

Table 5.17 Time Computations for Barge Loader Conveyor

SN	Failure Date	TBF (Hours)	CTBF (Hours)	Repair Date	TTR (Hours)	CTTR (Hours)
1.	01/06/2017 07:30	-	-	01/06/2017 15:10	7:40	7:40
2.	07/06/2017 09:15	145:45	145:45	07/06/2017 16:52	7:37	15:17
3.	12/06/2017 09:35	120:20	266:05	12/06/2017 16:20	6:45	22:02
4.	26/06/2017 10:28	336:53	602:58	26/06/2017 15:32	5:04	27:06
5.	30/06/2017 10:23	95:55	698:53	01/07/2017 14:20	3:57	31:03
6.	23/08/2017 11:15	1296:52	1995:45	23/08/2017 14:10	2:55	33:58

Table 5.18 Availability of Each Conveyor Subsystem of Ship Loading Plant

Subsystem	Failure Frequency (No. of times/6 months)	MTBF (Hours)	MTTR (Hours)	Availability (/6 months)
Ship Loading Conveyor 1	3	1215.2778	6.0833	0.99502
Ship Loading Conveyor 2	5	826.0333	5.1067	0.99386
Ship Loading Conveyor 3	6	551.6667	4.3389	0.99220
Ship Loading Conveyor 4	3	1433.3056	2.8611	0.99801
Ship Loading Conveyor 5	8	453.7458	4.0854	0.99109
Ship Loading Conveyor 6	3	234.1000	2.1833	0.99076
Ship Loading Conveyor 7	7	464.1667	4.0238	0.99141
Barge Loader Conveyor	6	332.6250	5.6611	0.98372

Computation of tippling plant availability before SCADA system implementation

Let A_{AF} = apron feeder availability before SCADA system implementation

A_{TCV1} = tippler conveyor 1 availability before SCADA system implementation

A_{TCV2} = tippler conveyor 2 availability before SCADA system implementation

A_{BC} = bypass conveyor availability before SCADA system implementation

A_{TCV3} = tippler conveyor 3 availability before SCADA system implementation

A_{TCV4} = tippler conveyor 4 availability before SCADA system implementation

A_{TCV5} = tippler conveyor 5 availability before SCADA system implementation

A_{BM} = boom conveyor availability before SCADA system implementation

A_{BCT} = bypass circuit availability before SCADA system implementation

A_{BMC} = boom circuit availability before SCADA system implementation

A_{TP} = tippling plant availability before SCADA system implementation

A_{H} = availability of one plant technician before SCADA implementation (which is assumed to be 0.70 according to Anon., 2019y)

Therefore, $A_{BCT} = A_{AF} \times A_{TCV1} \times A_{TCV2} \times A_{BC} \times A_{H} \times A_{H} \times A_{H}$

$$= 0.98735 \times 0.98572 \times 0.99121 \times 0.99454 \times 0.7 \times 0.7 \times 0.7 = 0.32908$$

$$A_{BMC} = A_{AF} \times A_{TCV1} \times A_{TCV2} \times A_{TCV3} \times A_{TCV4} \times A_{TCV5} \times A_{BM} \times A_{H} \times A_{H} \times A_{H} \times A_{H} \times A_{H} \times A_{H}$$

$= 0.98735 \times 0.98572 \times 0.99121 \times 0.99472 \times 0.99348 \times 0.99385 \times 0.99421 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \quad = 0.11082$

But bypass circuit is parallel to the boom circuit, which implies that:

$$A_{TP} = 1 - \{(1 - A_{BMC})(1 - A_{BCT})\}$$

$$= 1 - \{(1 - 0.32908)(1 - 0.11082)\} = 1 - 0.59657 = 0.40343$$

Computation of ship loading plant availability before SCADA system implementation

Let A_{CV1} = ship loading conveyor 1 availability before SCADA system implementation

A_{CV2} = ship loading conveyor 2 availability before SCADA system implementation

A_{CV3} = ship loading conveyor 3 availability before SCADA system implementation

A_{CV4} = ship loading conveyor 4 availability before SCADA system implementation

A_{CV5} = ship loading conveyor 5 availability before SCADA system implementation

A_{CV6} = ship loading conveyor 6 availability before SCADA system implementation

A_{CV7} = ship loading conveyor 7 availability before SCADA system implementation

A_{BLC} = barge loader conveyor availability before SCADA system implementation

A_{SLP} = ship loading plant availability before SCADA system implementation

$$A_{SLP} = A_{CV1} \times A_{CV2} \times A_{CV3} \times A_{CV4} \times A_{CV5} \times A_{CV6} \times A_{CV7} \times A_{BLC} \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H \times A_H$$

$$= 0.99502 \times 0.99386 \times 0.99220 \times 0.99801 \times 0.99109 \times 0.99076 \times 0.99141 \times 0.98372 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 \times 0.7 = 0.01298$$

Fig. 5.19 and 5.20 present the block diagrams of Tippling Plant SCADA System and Ship Loading Plant SCADA System respectively.

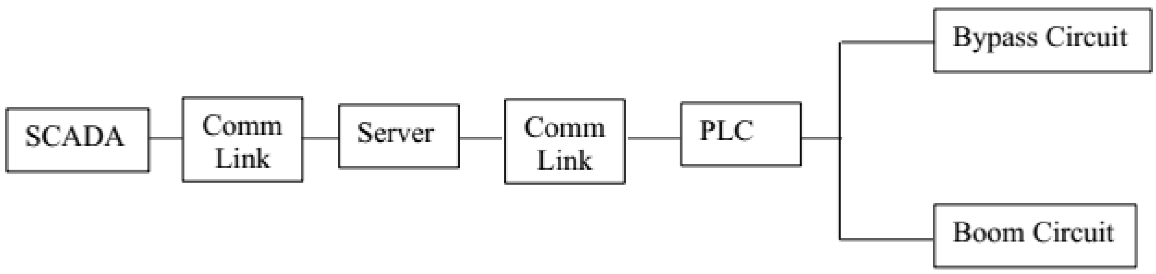


Fig. 5.19 Block Diagram of Tippling Plant SCADA System

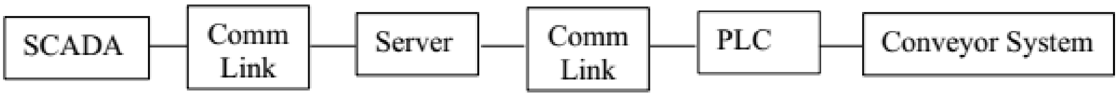


Fig. 5.20 Block Diagram of Ship Loading Plant SCADA System

Computation of the availabilities of belt speed sensor, belt alignment sensor and block chute sensor

Let A_{BS} = availability of belt speed sensor

A_{BA} = availability of belt alignment sensor

A_{BC} = availability of block chute sensor

For belt speed sensor: according to Anon. (2019o), MTBF = 8,116.2, MTTR = 6.2, (Anon., 2019y)

$$\text{Therefore, } A_{BS} = \frac{8{,}116.2}{8{,}122.4} = 0.999237$$

For belt alignment sensor: MTBF = 222,222.22 according to Anon. (2019ab), MTTR = 3.2 (Anon., 2019y)

$$\text{Therefore, } A_{BA} = \frac{222{,}222.22}{222{,}225.42} = 0.9999856$$

For block chute sensor: MTBF = 75,757.5758 according to N.S.W.C. (2010), MTTR = 4.6 (Anon., 2019y),

$$\text{Therefore, } A_{BC} = \frac{75{,}757.5758}{75{,}762.1758} = 0.999939$$

Table 5.19, 5.20, 5.21, 5.22 and 5.23 documents the availabilities of PLC Components, Tippler Conveyor Subsystem Sensors availabilities, Tippler Conveyor Subsystem availabilities, Ship Loading Conveyor Subsystem Sensors availabilities and Ship Loading Conveyor Subsystem availabilities respectively.

Table 5.19 PLC Components and their Availabilities

SN	Component	Availability
1.	Personal Computer (PC)	0.999500
2.	PLC	0.999850
3.	Communication Link	0.990000
4.	PC Software	0.999970
5.	PLC Software	0.999990
6.	Trained Human Personal	0.900000
7.	Belt Speed Sensor	0.999237

Table 5.19 Cont'd

8.	Belt Alignment Sensor	0.999986
9.	Block Chute Sensor	0.999939

(Source: Anon., 2019o; Anon. 2019ab; N.S.W.C. (2010), and Cetinkaya (2001)

Table 5.20 Tippler Conveyor Subsystem Sensors Availabilities

Name of Subsystem	Number of Belt speed sensors used	Number of Belt alignment sensors used	Number of block chute sensors used	Sensor Availability
Apron Feeder	1	4 in series	1	0.999118
Tippling Conveyor 1	1	6 in series	1	0.999090
Tippling Conveyor 2	1	6 in series	1	0.999090
Bypass Conveyor	1	4 in series	1	0.999118
Tippling Conveyor 3	1	6 in series	1	0.999090
Tippling Conveyor 4	1	6 in series	1	0.999090
Tippling Conveyor 5	1	6 in series	1	0.999090
Boom Conveyor	1	4 in series	1	0.999118

Table 5.21 Tippler Conveyor Subsystem and their Availabilities

Name of Subsystem	Availability before SCADA	Sensor Availability	Availability after SCADA
Apron Feeder	0.98735	0.999118	0.986479
Tippling Conveyor 1	0.98572	0.999090	0.984822
Tippling Conveyor 2	0.99121	0.999090	0.990308
Bypass Conveyor	0.99454	0.999118	0.993663
Tippling Conveyor 3	0.99472	0.999090	0.993815
Tippling Conveyor 4	0.99348	0.999090	0.992576
Tippling Conveyor 5	0.99385	0.999090	0.992946
Boom Conveyor	0.99421	0.999118	0.993333

Table 5.22 Ship Loading Conveyor Subsystem Sensors Availabilities

Name of Subsystem	Number of Belt Speed Sensors Used	Number of Belt Alignment Sensors Used	Number of Block Chute Sensors Used	Sensor Availability
CV1	1	6 in series	1	0.999090
CV2	1	6 in series	1	0.999090
CV3	1	6 in series	1	0.999090
CV4	1	6 in series	1	0.999090
CV5	1	8 in series	1	0.999064
CV6	1	4 in series	1	0.999118
CV7	1	6 in series	1	0.999090
BLC	1	4 in series	1	0.999118

Table 5.23 Ship Loading Conveyor Subsystem and their Availabilities

Name of Subsystem	Availability before SCADA	Sensor Availability	Availability after SCADA
Ship Loading Conveyor 1	0.99502	0.999090	0.994115
Ship Loading Conveyor 2	0.99386	0.999090	0.992956
Ship Loading Conveyor 3	0.99220	0.999090	0.991297
Ship Loading Conveyor 4	0.99801	0.999090	0.997102
Ship Loading Conveyor 5	0.99108	0.999064	0.990152
Ship Loading Conveyor 6	0.99076	0.999118	0.989886
Ship Loading Conveyor 7	0.99141	0.999090	0.990508
Barge Loader Conveyor	0.98372	0.999118	0.982852

Computation of tippling plant availability after SCADA system implementation

Let A_{SAF} = apron feeder availability after SCADA system implementation

A_{STCV1} = tippler conveyor 1 availability after SCADA system implementation

A_{STCV2} = tippler conveyor 2 availability after SCADA system implementation

A_{SBC} = bypass conveyor availability after SCADA system implementation

A_{STCV3} = tippler conveyor 3 availability after SCADA system implementation

A_{STCV4} = tippler conveyor 4 availability after SCADA system implementation

A_{STCV5} = tippler conveyor 5 availability after SCADA system implementation

A_{SBM} = boom conveyor availability after SCADA system implementation

A_{SBCT} = bypass circuit availability after SCADA system implementation

A_{SBMC} = boom circuit availability after SCADA system implementation

A_{STP} = tippling plant availability before SCADA system implementation

A_{SH} = availability of one plant technician after SCADA implementation (which is assumed to be 0.90 according to Anon., 2019y)

$$A_{SBCT} = A_{SAF} \times A_{STCV1} \times A_{STCV2} \times A_{SBC} \times A_{SH} \times A_{SH}$$

$$= 0.986479 \times 0.984822 \times 0.990308 \times 0.993663 \times 0.9 \times 0.9 = 0.774355$$

$$A_{SBMC} = A_{SAF} \times A_{STCV1} \times A_{STCV2} \times A_{STCV3} \times A_{STCV4} \times A_{STCV5} \times A_{SBM} \times A_{SH} \times A_{SH} \times A_{SH}$$

$$= 0.986479 \times 0.984822 \times 0.990308 \times 0.993815 \times 0.992576 \times 0.992946 \times 0.993333 \times 0.9 \times 0.9 \times 0.9 = 0.682391$$

From equation (5.8), $A_{STP} = 1 - \{(1 - A_{SBCT}) \times (1 - A_{SBMC})\}$

$$= 1 - \{(1 - 0.774355) \times (1 - 0.682391)\} = 1 - 0.071667 = 0.928333$$

Computation of ship loading plant availability after SCADA system implementation

Let A_{SCV1} = ship loading conveyor 1 availability after SCADA system implementation

A_{SCV2} = ship loading conveyor 2 availability after SCADA system implementation

A_{SCV3} = ship loading conveyor 3 availability after SCADA system implementation

A_{SCV4} = ship loading conveyor 4 availability after SCADA system implementation

A_{SCV5} = ship loading conveyor 5 availability after SCADA system implementation

A_{SCV6} = ship loading conveyor 6 availability after SCADA system implementation

A_{SCV7} = ship loading conveyor 7 availability after SCADA system implementation

A_{SBLC} = barge loader conveyor availability after SCADA system implementation

A_{SSLP} = ship loading plant availability after SCADA system implementation

From equation (5.7), $A_{SSLP} = A_{SCV1} \times A_{SCV2} \times A_{SCV3} \times A_{SCV4} \times A_{SCV5} \times A_{SCV6} \times A_{SCV7} \times A_{SBLC} \times A_{SH} \times A_{SH} \times A_{SH} \times A_{SH}$

$$= 0.994115 \times 0.992956 \times 0.991297 \times 0.997102 \times 0.990152 \times 0.989886 \times 0.990508 \times 0.982852 \times 0.9 \times 0.9 \times 0.9 \times 0.9$$

$$= 0.610820$$

5.6.2 Plant Efficiency

According to Anon. (2019z), one crucial area that every plant can improve on is efficiency, and one of the best measures of efficiency is Overall Equipment Efficiency or Effectiveness (OEE). OEE is a measure of the efficiency and effectiveness of a manufacturing process (i.e. machines, cells, assembly lines, processes, etc.). OEE is a simple and powerful metric for tracking and improving a plant's efficiency. The context of fierce competition among industrial companies forces them to continuously improve their performances. The development of 'Lean Manufacturing' programs to fulfil this purpose brings out the popularity of the Overall Equipment Effectiveness (OEE); a measurement tool assessing the productivity of an equipment depending on its availability, performance and quality (Fernandez, 2016). Effective management of OEE together with proper maintenance and inspection regimes are proven to greatly improve the availability of plant and vastly reduce unplanned outages (Anon., 2019z).

Mathematically, OEE = Availability $\times$ Performance $\times$ Quality (5.9)

where Availability = measure of productivity losses resulting from downtime

Performance = measure of loss in productivity due to slow cycle

Quality = measure of manufacturing subpar products

Computation of tippling plant and ship loading plant efficiencies

Let P_t = performance of tippling plant (assuming P_t = 0.8)

Q_t = quality of tippling plant (assuming Q_t = 1

P_s = performance of ship loading plant (assuming P_s = 0.8

Q_s = quality of ship loading plant (assuming Q_s = 1)

OEE_{tm} = tippling plant OEE before SCADA implementation

OEE_{ts} = tippling plant OEE after SCADA implementation

OEE_{sm} = ship loading plant OEE before SCADA implementation

OEE_{ss} = ship loading plant OEE after SCADA implementation

From equation (5.9), $OEE_{tm} = A_{TP} \times P_t \times Q_t$ (5.10)

$$= 0.40343 \times 0.8 \times 1 = 0.322744 = 32.27\%$$

Also, $OEE_{ts} = A_{STP} \times P_t \times Q_t$ (5.11)

$$= 0.928333 \times 0.8 \times 1 = 0.7426664 = 74.27\%$$

From equation (5.9), $OEE_{sm} = A_{SLP} \times P_s \times Q_s$ (5.12)

$$= 0.01297 \times 0.8 \times 1 = 0.010376 = 1.04\%$$

Also, $OEE_{SSLP} = A_{ss} \times P_s \times Q_s$

(5.13)

$$= 0.610820 \times 0.8 \times 1 = 0.488656 = 48.87\%$$

5.7 Summary of Findings

The summary of findings of this research are presented as follows:

5.7.1 Findings on the Tippling Plant Automation

The summary of findings on the tippling plant automation are stated as follows:

i. The SCADA system automation is able to achieve an increase in the efficiency of the tippling plant from 32.27% to 74.27%.
ii. A little higher interest rate than the current rate (say 32% and above) would make SCADA automation of the tippling plant not economically viable since the loan repayment period would take more than five years.
iii. The SCADA system automation is able to achieve an increase in the availability of the tippling plant from 40.34% to 92.83%.
iv. The SCADA system is able to reduce the manpower requirement of the tippling plant from six to three operators, which is a 50% reduction in running of the tippling plant.
v. A reduced operational cost of the tippling plant is achieved which is as a result of the 50% reduction in manpower requirement in running the tippling plant.

5.7.2 Findings on the Ship Loading Plant Automation

The summary of findings on the ship loading plant automation are stated follows:

i. The SCADA system automation is able to achieve an increase in the efficiency of the ship loading plant from 1.04% to 48.87%.
ii. The SCADA system automation of the ship loading plant is indeed a profiting venture because, with even a higher interest rate of say 50% on the loan, the project would still be economically viable.
iii. The SCADA system automation is able to achieve an increase in the availability of the ship loading plant from 1.30% to 61.08%.
iv. The SCADA system automation is able to reduce the manpower requirement from twelve to four operators, which is a 66.7% reduction in running the ship loading plant.
v. A reduced operational cost of the ship loading plant is achieved which is as a result of the 66.7% reduction of technicians in manpower requirement in running the ship loading plant.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Improving plant efficiency has been the quest of management of GBC Limited, TPF Ghana, as the company seeks to expand her marketing demands, and among available technologies is SCADA automation to help achieve this goal. The redesign which consists of RSLogix 5000 emulator software interfaced with Wonderware InTouch software was successfully accomplished. The existing systems are augmented with SCADA HMI screen, PLC and three sets of sensors namely, belt alignment sensor, belt speed sensor and block chute sensor.

From this research, the following conclusions emanate from the findings:

i. SCADA automation is able to improve plant availability of both tippling and ship loading plants, thereby improving the overall efficiency of the two plants of GBC Limited, TPF;
ii. SCADA automation is economically viable for its implementation at GBC Limited, TPF;
iii. SCADA automation is capable of reducing the manpower requirement needed to operate the two plants of GBC Limited, TPF; and
iv. SCADA automation is able to bring a reduction in the operating cost required to run the two plants of GBC Limited, TPF.

6.2 Recommendations

i. SCADA automation is hereby recommended for implementation at the GBC Limited, TPF to enable the company meet her current market demands and remain competitive.
ii. Safety Instrumented System (SIS) of the Takoradi Port Facility can be researched into.

6.3 Future Research

Future research works could look at optimising tippling and ship loading plants using Artificial Intelligence (AI) techniques.

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APPENDICES

APPENDIX A

ANNUAL MINE PERFORMANCE OF GBC LIMITED

Table A.1 Mine Performance for Year 2013

Month	Mined C4 Rom (t)	Tons Produces (t)	Road Haulage- (t)	Road Haulage-Contractors (t)	Ship Loading Plant (t)	Tippling Plant (t)
Jan	140682.00	98219.00	28081.00	36872.00	80306.00	64953.00
Feb	146220.57	102093.66	21282.43	24011.28	33460.00	45293.71
Mar	73594.00	49802.00	24949.00	27981.00	58300.00	52930.00
Apr	77287.00	51411.00	28274.00	24503.00	42047.00	52777.00
May	112104.53	78318.27	34172.87	36585.95	26585.00	70758.82
Jun	91422.00	64148.00	32709.00	38605.00	52080.00	71314.00
Jul	108463.00	75980.00	36625.00	48460.00	146555.00	85085.00
Aug	119308.00	82924.00	37550.00	65004.00	35780.00	102554.00
Sep	133158.00	91711.00	24899.00	48051.00	125990.00	72950.00
Oct	72393.00	49822.00	25837.00	68580.00	87830.00	94417.00
Nov	91352.00	63326.00	20734.00	52594.00	94653.00	73328.00
Dec	--	--	--	--	--	--

Table A.2 Mine Performance for Year 2014

Month	Mined C4 Rom (t)	Tones Produces (t)	Road Haulage-GBC (t)	Road Haulage-Contractors (t)	Ship Loading Plant (t)	Tippling Plant (t)
Jan	121801.00	85076.00	25887.00	57940.00	81075.00	83827.00
Feb	83670.00	58546.00	22977.00	42799.00	92601.00	65776.00
Mar	97830.00	73258.00	23612.00	47844.00	94291.00	71456.00
Apr	127217.00	88696.00	27576.00	50095.00	126757.00	77671.00
May	107326.00	74769.00	25878.00	54046.00	41715.00	79924.00
Jun	107563.00	75329.00	20426.00	50394.00	77710.00	70820.00
Jul	101082.00	78448.00	13798.00	49482.00	105173.00	63280.00
Aug	138649.00	103913.00	23388.00	50618.00	86580.00	74006.00
Sep	103377.00	73120.00	15531.00	15108.00	40200.00	30639.00
Oct	84509.00	59242.00	21612.00	28599.00	95701.00	50211.00
Nov	39661.00	27716.00	16703.00	14797.00	--	31500.00
Dec	84423.00	58903.00	20818.00	34602.00	64658.00	55420.00

Table A.3 Mine Performance for Year 2015

Month	Mined C4 Rom (t)	Tonnes Produces (t)	Road Haulage-GBC (t)	Road Haulage-Contractors (t)	Ship Loading Plant (t)	Tippling Plant (t)
Jan	91860.00	66109.00	26696.00	44355.00	105215.00	71051.00
Feb	50746.00	36703.00	20922.00	44843.00	75113.00	65765.00
Mar	117432.00	94150.00	21088.00	60011.00	26001.00	81099.00
Apr	133669.00	93202.00	25474.00	66517.00	101427.00	91991.00
May	145744.00	99977.00	27256.00	58832.00	93021.00	86088.00
Jun	141605.00	97019.00	16244.00	46635.00	63515.00	62879.00
Jul	147312.00	101407.00	21201.00	50662.00	111202.00	71863.00
Aug	140434.00	96900.00	25198.00	42088.00	114310.00	67286.00
Sep	111708.00	77861.00	46484.00	54139.00	103888.00	100623.00
Oct	48401.00	33908.00	42052.00	34159.00	95456.00	76211.00
Nov	71236.00	49718.00	43909.00	--	93150.00	43909.00
Dec	113751.00	79926.00	45524.00	24564.00	86543.00	70088.00

Table A.4 Mine Performance for Year 2016

Month	Mined C4 Rom (t)	Tones Produces (t)	Road Haulage-GBC (t)	Road Haulage-Contractors (t)	Ship Loading Plant (t)	Tippling Plant (t)
Jan	112811.00	86345.00	37741.00	50898.00	112446.00	88639.00
Feb	118379.00	118377.50	40580.00	73979.00	112611.00	114559.00
Mar	107013.00	93556.00	35167.00	71846.00	44569.00	107013.00
Apr	112339.00	88151.00	44457.31	59194.58	134345.00	103651.90
May	119207.00	98621.00	49187.00	36369.00	73930.00	85556.00
Jun	131647.00	103847.00	51428.00	36459.00	69687.00	87878.00
Jul	165423.00	120321.00	60473.00	48737.00	107882.00	109210.00
Aug	146442.00	135839.00	56450.00	25472.00	76600.00	81922.00
Sep	138143.00	111052.00	60144.00	42064.00	133954.00	102208.00
Oct	140293.00	108281.00	61183.06	69706.45	129948.00	130889.50
Nov	157951.00	119082.00	59521.29	65973.54	94950.00	125494.80
Dec	--	--	--	--	--	--

Table A.5 Mine Performance for Year 2017

Month	Mined C4 Rom (t)	Tones Produces (t)	Road Haulage-GBC (t)	Road Haulage-Contractors (t)	Ship Loading Plant (t)	Tippling Plant (t)
Jan	88815.38	88815.38	62829.37	66488.78	113012.00	129318.15
Feb	108378.00	101574.00	59635.21	56370.38	153300.00	116005.59
Mar	166799.00	162332.00	43647.00	62450.00	147386.00	106097.00
Apr	89835.00	83377.58	40934.71	60980.38	103865.00	101915.09
May	155614.00	137206.80	43854.37	94766.08	100020.00	138620.45
Jun	149824.00	111462.00	42666.40	95932.16	147533.00	138598.56
Jul	96152.00	67307.00	32889.00	59474.00	106701.00	92363.00
Aug	151194.00	108860.20	51563.61	65869.31	118508.00	117432.92
Sep	175387.00	142733.00	51398.00	80978.00	113452.00	132376.00
Oct	156405.00	130950.00	51526.00	77362.00	109120.00	128888.00
Nov	182695.00	149310.00	52771.00	84974.00	161850.00	137745.00
Dec	151335.50	64359.10	48221.05	95530.83	165145.00	143751.88

APPENDIX B

SPECIFICATIONS OF SELECTED SCADA SYSTEM ELEMENTS

Table B.1 Specifications of the LHL-N11 Belt Alignment Sensor

SN	Parameter	Specification/Value
1.	Operating Voltage (Vac)	250
2.	Current (A)	4
3.	Design of Control Element	Normally Close (NC), Normally Open (NO)
4.	Vibration Frequency (Hz)	10 – 55
5.	Ambient Temperature (^oC)	-30 – 90
6.	Degree of Protection	IP65
7.	Actuation Direction	Each time 60^o right-hand side and left-hand side rotation

(Source: Anon., 2019n)

Table B.2 Specifications of the NJ15S+U1+N Belt Speed Sensor

SN	Parameter	Specification/Value
1.	Type of Sensing	Proximity
2.	Composition of Target	Metallic
3.	Distance of Object from Sensor (mm)	15
4.	Operating Voltage (Vac)	125/250
5.	Switching Function (f)	Normally Closed
6.	Reduction Factor (r_{AL})	0.4
7.	Reduction Factor (r_{Cu})	0.3
8	Output Type	2-wire
9.	Switching Frequency (Hz)	0 – 150
10.	Ambient Temperature (^oC)	-40 – 100
11.	Degree of protection	IP68

(Source: Anon., 2019o)

Table B.3 Specifications of the MWS-ST/RS-2 Block Chute Sensor

SN	Parameter	Specification/Value	
		Transmitter	Receiver
1.	Type	MWS-ST-2	MWS-SR-2
2.	Operating Voltage	200~240 VAC ±10%, 50/60Hz	
3.	Power Consumption (VA)	2	2
4.	Operating Distance (m)	Less than 80	
5.	Frequency and Transmission Power	24 GHz approximate, less than 10 mW	

(Source: Anon., 2019p)

Table B.4 Specifications of the PSU-804 UPS

SN	Parameter	Specification/Value
1.	Product Name	Pure Sine Wave Line-interactive UPS
2.	Model Number	PSU-804
3.	Power Capacity (VA)	2000
4.	Input Voltage (Vac)	140 – 275
5.	Output Voltage (V)	220V -13%+10%
6.	Efficiency	AC mode: > 97% DC mode: > 80%
7.	Battery Type	Lead acid battery, 3-stage charging scheme
8.	Protection	Overload, Over heat, Short circuit, Battery over charge/discharge, battery reverse connection
9.	Frequency	The same as input frequency
10.	Standard Outlet	2 Sockets

(Source: Anon., 2019r)

Table B.5 Specifications of the T-30B PSU

SN	Parameter	Specification/Value		
1.	Model Number	T-30B		
2.	DC Output	+5 V 3 A	+12 V 1 A	-12 V 0.5 A
3.	Wave and Noise	80 mVp-p	120 mVp-p	120 mVp-p
4.	Load Regulation (%)	±1.5	±3.0	±1.0
5.	Efficiency (%)	77		
6.	AC Input Voltage Range	85 – 264 Vac 47-63 Hz 120-370 VDC		
7.	Overload Protection	110% - 150% hiccup mode, auto-recovery		
8.	Over-Voltage Protection	115% - 140% rated output voltage		
9.	Working Temperature (°C)	-10 °C - +50 °C		

(Source: Anon., 2019g)

Table B.6 Specifications of the GYTY53 Fibre Optic Cable

SN	Parameter	Specifications
1.	Attenuation at 1310 nm	≤0.34 dB/km ≤0.36 dB/km
2.	Attenuation at 1550 nm	≤0.20 dB/km ≤0.22 dB/km
3.	Zero Dispersion Wavelength	1300~1324 nm
4.	Zero Dispersion Slope	≤0.092 ps/nm^2 ·km
5.	PMD (Polarization Mode Dispersion)	≤0.2 ps/√km
6.	Cable Cut-off Wavelength (λcc)	≤1260 nm
7.	Macro bending Loss (100 turns; Φ50 mm) at 1550 nm (100 turns; Φ50 mm) at 1625 nm	 ≤ 0.05 dB ≤ 0.10 dB
8.	Mode Field Diameter at 1310 nm	9.2±0.4 μm
9.	Cladding Diameter	125 ±1 μm
10.	Core/clad Concentricity Error	≤0.6 μm
11.	Cladding Non-Circularity	≤1.0%
12.	Proof Stress	≥0.69 Gpa

Table B.6 Cont'd

13.	Fibre Count	12
14	Operation Temperature Range (ºC)	-60 to + 70

(Source: Anon., 2019s)

Table B.7 Specifications of the ST-ST Fibre Optic Patch Cord

SN	Parameter	Specification/Value
1.	Restriction of Hazardous Substances (RoHS)	Y
2.	Model Number	M302-006
3.	Network Speed (Gbps)	1
4.	Fibre Type	62.5/125 - OM1
5.	Model Type	ST/ST
6.	Cable Types	Multimode 62.5/125 Fibre Optic
7.	Cable Length (m)	2
8.	Jacket type	PVC

(Source: Anon., 2019t)

Table B.8 Specifications of the NF-C550-SFP Fibre Optic Media Converter

SN	Parameters	Specifications
1.	Wavelength	Multi-mode: 850 nm or 1310 nm
2.	Model Number	NF-C550S80
3.	Transmission Distance	Multi-mode: 2 km (Fibre size: 62.5/125 or 50/125 µm)
4.	Port	One RJ45 port One Fibre port (ST/SC/FC Optional, LC:SFP Module)
5.	Power Supply	Outside:5 VDC 1 A Built-in: 100 V to 265V AC 50 Hz to 60 Hz
6.	Operating Temperature	0 °C to +70 °C
7.	Storage Temperature	-20 °C to +80 °C
8.	Relative Humidity	5% to 90% (non-condensing)

(Source: Anon., 2019u)

Table B.9 Specifications of the KVV22 Control Cable

SN	Parameter	Specification/Value
1.	Voltage (V)	450/750
2.	Temperature Rating (ºC)	0 to 90
3.	Conductor Material	Cupper
4.	Conductor Type	Flexible
5.	Insulation Material	Polyvinyl Chloride (PVC)

(Source: Anon., 2019v)

Table B.10 Specifications of the X35 Dedicated Server

SN	Parameter	Specification/Value
1.	Graphics Card Type	Integrated Card
2.	Model Number	X35
3.	Processor Model	i7 5500U
4.	Processor Brand	Intel
5.	Hard Drive Capacity (GB)	500
6.	Memory Capacity (GB)	16
7.	Processor Main Frequency (GHz)	2.20
8.	Processor Graphics	Intel HD Graphics 5500
9.	Operation System	Windows 10/8/7, Linux
10.	Hard Disk Capacity	480GB mSATA SSD
11.	Interface	1 HDMI, 1 VGA, 6 USB, 2 WIFI, 1 LAN, 1 SPK

(Source Anon., 2019w)

Table B.11 Specifications of the DJ-C003 Desktop Computer

SN	Parameter	Specification/Value
1.	Model Number	DJ-C003
2.	Processors	Intel dual core 2.93G
3.	Hard Disk Driver	320G 7200RPM SATA
4.	Memory	2G DDR3 1333 MHz
5.	Monitor	17 inch VGA port
6.	Drive Type	DVD-RW
7.	Display Type	LCD
8.	Operating System	Windows
9.	Graphics	Internal Graphics
10.	Network	Realtek 10/100
11.	Socket	775

(Source: Anon., 2019w)

Table B.12 Specifications of the Siren with Model Number PNS-0011

SN	Parameter	Specification/Value
1.	Current Type	AC
2.	Decibels at 1 meter (dB)	120
3.	Supply Voltage (VAC)	120/230
4.	Decibel Range (dB)	120
5.	Temperature Range (°C)	-25 to +55
6.	IP Rating	IP66
7.	Series	Nexus 120
8.	Body Material	ABS
9.	Additional Functions	64 Selectable Tones
10.	Cover Material	Polycarbonate
11.	Mounting Style	Surface Mount

(Source: Anon., 2019x)

APPENDIX C

TRENDING ANALYSIS

Table C.1 Trend of Conveyor 3 Instruments of Boom Circuit at Tippling Plant

Controller Name	**Tippling_Plant**			
Trend Name	**Conveyor_3_Instruments**			
Trend Tags	**3**			
Sample Period	**6000 ms**	**Tag Name**		
Date	**8/19/2019**			
Start Time	**17:34:52;530**			
Stop Time	**17:42:28;530**			
Header	**Time**	**AC_CV_3**	**BC_CV_3**	**SS_CV_3**
Data	17:34:52;530	0	0	0
Data	17:34:58;530	0	0	0
Data	17:35:04;530	0	0	0
Data	17:35:10;530	0	0	0
Data	17:35:16;530	0	0	0
Data	17:35:22;530	0	0	0
Data	17:35:28;530	0	0	0
Data	17:35:34;530	0	0	0
Data	17:35:40;530	0	0	0
Data	17:35:46;530	0	0	0
Data	17:35:52;530	0	0	0
Data	17:35:58;530	0	0	0
Data	17:36:04;530	0	0	0
Data	17:36:10;530	0	0	0
Data	17:36:16;530	0	0	0
Data	17:36:22;530	0	0	0
Data	17:36:28;530	0	0	0
Data	17:36:34;530	0	0	0
Data	17:36:40;530	0	0	0
Data	17:36:46;530	0	0	0
Data	17:36:52;530	0	0	0
Data	17:36:58;530	1	0	0
Data	17:37:04;530	1	0	0
Data	17:37:10;530	1	0	0
Data	17:37:16;530	1	0	0
Data	17:37:22;530	1	0	0
Data	17:37:28;530	1	0	0
Data	17:37:34;530	0	0	0
Data	17:37:40;530	0	0	0
Data	17:37:46;530	0	0	0
Data	17:37:52;530	0	0	0

Data	17:37:58;530	0	0	0
Data	17:38:04;530	0	0	0
Data	17:38:10;530	0	0	0
Data	17:38:16;530	0	0	0
Data	17:38:22;530	0	0	0
Data	17:38:28;530	0	0	0
Data	17:38:34;530	0	0	0
Data	17:38:40;530	0	0	0
Data	17:38:46;530	0	1	0
Data	17:38:52;530	0	1	0
Data	17:38:58;530	0	1	0
Data	17:39:04;530	0	1	0
Data	17:39:10;530	0	1	0
Data	17:39:16;530	0	1	0
Data	17:39:22;530	0	1	0
Data	17:39:28;530	0	0	0
Data	17:39:34;530	0	0	0
Data	17:39:40;530	0	0	0
Data	17:39:46;530	0	0	0
Data	17:39:52;530	0	0	0
Data	17:39:58;530	0	0	0
Data	17:40:04;530	0	0	0
Data	17:40:10;530	0	0	0
Data	17:40:16;530	0	0	0
Data	17:40:22;530	0	0	1
Data	17:40:28;530	0	0	1
Data	17:40:34;530	0	0	1
Data	17:40:40;530	0	0	1
Data	17:40:46;530	0	0	1
Data	17:40:52;530	0	0	1
Data	17:40:58;530	0	0	0
Data	17:41:04;530	0	0	0
Data	17:41:10;530	0	0	0
Data	17:41:16;530	0	0	0
Data	17:41:22;530	0	0	0
Data	17:41:28;530	0	0	0
Data	17:41:34;530	0	0	0
Data	17:41:40;530	0	0	0
Data	17:41:46;530	0	0	0
Data	17:41:52;530	0	0	0
Data	17:41:58;530	0	0	0
Data	17:42:04;530	0	0	0
Data	17:42:10;530	0	0	0
Data	17:42:16;530	0	0	0

Table C.2 Trend of Boom Circuit Motors at Tippling Plant

Controller Name	Tippling_Plant	Tag Name						
Trend Name	Boom_Circuit_Motors							
Trend Tags	7							
Sample Period	6000 ms							
Start Time	17:34:47;484							
Stop Time	17:42:20;484							
Date	8/19/2019							
Header	Time	AF_Motor	B_Conveyor	CV_1_Motor	CV_2_Motor	CV_3_Motor	CV_4_Motor	CV_5_Motor
Data	17:34:47;484	0	0	0	0	0	0	0
Data	17:34:53;484	0	0	0	0	0	0	0
Data	17:34:59;484	0	0	0	0	0	0	0
Data	17:35:05;484	0	1	0	0	0	0	0
Data	17:35:11;484	0	1	0	0	0	0	1
Data	17:35:17;484	0	1	0	0	0	1	1
Data	17:35:23;484	0	1	0	0	0	1	1
Data	17:35:29;484	0	1	0	0	1	1	1
Data	17:35:35;484	0	1	0	1	1	1	1
Data	17:35:41;484	0	1	1	1	1	1	1
Data	17:35:47;484	0	1	1	1	1	1	1
Data	17:35:53;484	1	1	1	1	1	1	1
Data	17:35:59;484	1	1	1	1	1	1	1
Data	17:36:05;484	1	1	1	1	1	1	1
Data	17:36:11;484	1	1	1	1	1	1	1
Data	17:36:17;484	1	1	1	1	1	1	1
Data	17:36:23;484	1	1	1	1	1	1	1
Data	17:36:29;484	1	1	1	1	1	1	1
Data	17:36:35;484	1	1	1	1	1	1	1
Data	17:36:41;484	1	1	1	1	1	1	1
Data	17:36:47;484	1	1	1	1	1	1	1
Data	17:36:53;484	1	1	1	1	1	1	1
Data	17:36:59;484	0	1	0	0	0	1	1
Data	17:37:05;484	0	1	0	0	0	1	1
Data	17:37:11;484	0	1	0	0	0	1	1
Data	17:37:17;484	0	1	0	0	0	1	1
Data	17:37:23;484	0	1	0	0	0	1	1
Data	17:37:29;484	0	1	0	0	0	1	1

Data	17:37:35;484	0	1	0	0	1	1	1
Data	17:37:41;484	0	1	0	1	1	1	1
Data	17:37:47;484	0	1	0	1	1	1	1
Data	17:37:53;484	0	1	1	1	1	1	1
Data	17:37:59;484	1	1	1	1	1	1	1
Data	17:38:05;484	1	1	1	1	1	1	1
Data	17:38:11;484	1	1	1	1	1	1	1
Data	17:38:17;484	1	1	1	1	1	1	1
Data	17:38:23;484	1	1	1	1	1	1	1
Data	17:38:29;484	1	1	1	1	1	1	1
Data	17:38:35;484	1	1	1	1	1	1	1
Data	17:38:41;484	1	1	1	1	1	1	1
Data	17:38:47;484	0	1	0	0	0	1	1
Data	17:38:53;484	0	1	0	0	0	1	1
Data	17:38:59;484	0	1	0	0	0	1	1
Data	17:39:05;484	0	1	0	0	0	1	1
Data	17:39:11;484	0	1	0	0	0	1	1
Data	17:39:17;484	0	1	0	0	0	1	1
Data	17:39:23;484	0	1	0	0	1	1	1
Data	17:39:29;484	0	1	0	0	1	1	1
Data	17:39:35;484	0	1	0	1	1	1	1
Data	17:39:41;484	0	1	1	1	1	1	1
Data	17:39:47;484	1	1	1	1	1	1	1
Data	17:39:53;484	1	1	1	1	1	1	1
Data	17:39:59;484	1	1	1	1	1	1	1
Data	17:40:05;484	1	1	1	1	1	1	1
Data	17:40:11;484	1	1	1	1	1	1	1
Data	17:40:17;484	1	1	1	1	1	1	1
Data	17:40:23;484	0	1	0	0	0	1	1
Data	17:40:29;484	0	1	0	0	0	1	1
Data	17:40:35;484	0	1	0	0	0	1	1
Data	17:40:41;484	0	1	0	0	0	1	1
Data	17:40:47;484	0	1	0	0	0	1	1
Data	17:40:53;484	0	1	0	0	0	1	1
Data	17:40:59;484	0	1	0	0	1	1	1
Data	17:41:05;484	0	1	0	1	1	1	1
Data	17:41:11;484	0	1	0	1	1	1	1
Data	17:41:17;484	0	1	1	1	1	1	1
Data	17:41:23;484	1	1	1	1	1	1	1
Data	17:41:29;484	1	1	1	1	1	1	1
Data	17:41:35;484	1	1	1	1	1	1	1
Data	17:41:41;484	1	1	1	1	1	1	1
Data	17:41:47;484	1	1	1	1	1	1	1

Table C.3 Trend of Conveyor 2 Instruments of Bypass Circuit at Tippling Plant

Controller Name	Tippling_Plant	Tag Name		
Trend Name	Conveyor_2_Instruments			
Trend Tags:	3			
Sample Period	6000 ms			
Date	8/19/2019			
Start Time	17:51:16;295			
Stop Time	17:58:55;295			
Header	**Time**	**AL_CV_2**	**BC_CV_2**	**SS_CV_2**
Data	17:51:16;295	0	0	0
Data	17:51:22;295	0	0	0
Data	17:51:28;295	0	0	0
Data	17:51:34;295	0	0	0
Data	17:51:40;295	0	0	0
Data	17:51:46;295	0	0	0
Data	17:51:52;295	0	0	0
Data	17:51:58;295	0	0	0
Data	17:52:04;295	0	0	0
Data	17:52:10;295	0	0	0
Data	17:52:16;295	0	0	0
Data	17:52:22;295	0	0	0
Data	17:52:28;295	0	0	0
Data	17:52:34;295	0	0	0
Data	17:52:40;295	0	0	0
Data	17:52:46;295	0	0	0
Data	17:52:52;295	1	0	0
Data	17:52:58;295	1	0	0
Data	17:53:04;295	1	0	0
Data	17:53:10;295	1	0	0
Data	17:53:16;295	1	0	0
Data	17:53:22;295	1	0	0
Data	17:53:28;295	1	0	0
Data	17:53:34;295	0	0	0
Data	17:53:40;295	0	0	0
Data	17:53:46;295	0	0	0
Data	17:53:52;295	0	0	0
Data	17:53:58;295	0	0	0
Data	17:54:04;295	0	0	0
Data	17:54:10;295	0	0	0
Data	17:54:16;295	0	0	0
Data	17:54:22;295	0	0	0
Data	17:54:28;295	0	0	0
Data	17:54:34;295	0	0	0
Data	17:54:40;295	0	0	0

Data	17:54:46;295	0	1	0
Data	17:54:52;295	0	1	0
Data	17:54:58;295	0	1	0
Data	17:55:04;295	0	1	0
Data	17:55:10;295	0	1	0
Data	17:55:16;295	0	1	0
Data	17:55:22;295	0	1	0
Data	17:55:28;295	0	0	0
Data	17:55:34;295	0	0	0
Data	17:55:40;295	0	0	0
Data	17:55:46;295	0	0	0
Data	17:55:52;295	0	0	0
Data	17:55:58;295	0	0	0
Data	17:56:04;295	0	0	0
Data	17:56:10;295	0	0	0
Data	17:56:16;295	0	0	0
Data	17:56:22;295	0	0	0
Data	17:56:28;295	0	0	0
Data	17:56:34;295	0	0	0
Data	17:56:40;295	0	0	1
Data	17:56:46;295	0	0	1
Data	17:56:52;295	0	0	1
Data	17:56:58;295	0	0	1
Data	17:57:04;295	0	0	1
Data	17:57:10;295	0	0	1
Data	17:57:16;295	0	0	1
Data	17:57:22;295	0	0	1
Data	17:57:28;295	0	0	1
Data	17:57:34;295	0	0	0
Data	17:57:40;295	0	0	0
Data	17:57:46;295	0	0	0
Data	17:57:52;295	0	0	0
Data	17:57:58;295	0	0	0
Data	17:58:04;295	0	0	0
Data	17:58:10;295	0	0	0
Data	17:58:16;295	0	0	0
Data	17:58:22;295	0	0	0
Data	17:58:28;295	0	0	0
Data	17:58:34;295	0	0	0
Data	17:58:40;295	0	0	0
Data	17:58:46;295	0	0	0
Data	17:58:52;295	0	0	0
Data	17:58:55;295	0	0	0

Table C.4 Trend of Bypass Circuit Motors at Tippling Plant

Controller Name	Tippling_Plant				
Trend Name	**Bypass_Circuit_ Motors**				
Trend Tags	**4**				
Sample Period	**6000 ms**				
Date	**8/19/2019**				
Start Time	**17:51:12;499**				
Stop Time	**17:58:51;499**				
Header	**Time**	**AF_ Motor**	**BP_ Motor**	**CV_1_ Motor**	**CV_2_ Motor**
Data	17:51:12;499	0	0	0	0
Data	17:51:18;499	0	0	0	0
Data	17:51:24;499	0	1	0	0
Data	17:51:30;499	0	1	0	1
Data	17:51:36;499	0	1	0	1
Data	17:51:42;499	0	1	1	1
Data	17:51:48;499	1	1	1	1
Data	17:51:54;499	1	1	1	1
Data	17:52:00;499	1	1	1	1
Data	17:52:06;499	1	1	1	1
Data	17:52:12;499	1	1	1	1
Data	17:52:18;499	1	1	1	1
Data	17:52:24;499	1	1	1	1
Data	17:52:30;499	1	1	1	1
Data	17:52:36;499	1	1	1	1
Data	17:52:42;499	1	1	1	1
Data	17:52:48;499	0	1	0	0
Data	17:52:54;499	0	1	0	0
Data	17:53:00;499	0	1	0	0
Data	17:53:06;499	0	1	0	0
Data	17:53:12;499	0	1	0	0
Data	17:53:18;499	0	1	0	0
Data	17:53:24;499	0	1	0	0
Data	17:53:30;499	0	1	0	0
Data	17:53:36;499	0	1	0	1
Data	17:53:42;499	0	1	1	1
Data	17:53:48;499	0	1	1	1
Data	17:53:54;499	1	1	1	1
Data	17:54:00;499	1	1	1	1
Data	17:54:06;499	1	1	1	1
Data	17:54:12;499	1	1	1	1
Data	17:54:18;499	1	1	1	1
Data	17:54:24;499	1	1	1	1

Data	17:54:30;499	1	1	1	1
Data	17:54:36;499	1	1	1	1
Data	17:54:42;499	1	1	1	1
Data	17:54:48;499	0	1	0	0
Data	17:54:54;499	0	1	0	0
Data	17:55:00;499	0	1	0	0
Data	17:55:06;499	0	1	0	0
Data	17:55:12;499	0	1	0	0
Data	17:55:18;499	0	1	0	0
Data	17:55:24;499	0	1	0	1
Data	17:55:30;499	0	1	0	1
Data	17:55:36;499	0	1	1	1
Data	17:55:42;499	1	1	1	1
Data	17:55:48;499	1	1	1	1
Data	17:55:54;499	1	1	1	1
Data	17:56:00;499	1	1	1	1
Data	17:56:06;499	1	1	1	1
Data	17:56:12;499	1	1	1	1
Data	17:56:18;499	1	1	1	1
Data	17:56:24;499	1	1	1	1
Data	17:56:30;499	1	1	1	1
Data	17:56:36;499	0	1	0	0
Data	17:56:42;499	0	1	0	0
Data	17:56:48;499	0	1	0	0
Data	17:56:54;499	0	1	0	0
Data	17:57:00;499	0	1	0	0
Data	17:57:06;499	0	1	0	0
Data	17:57:12;499	0	1	0	0
Data	17:57:18;499	0	1	0	0
Data	17:57:24;499	0	1	0	0
Data	17:57:30;499	0	1	0	0
Data	17:57:36;499	0	1	0	1
Data	17:57:42;499	0	1	1	1
Data	17:57:48;499	1	1	1	1
Data	17:57:54;499	1	1	1	1
Data	17:58:00;499	1	1	1	1
Data	17:58:06;499	1	1	1	1
Data	17:58:12;499	1	1	1	1
Data	17:58:18;499	1	1	1	1
Data	17:58:24;499	1	1	1	1
Data	17:58:30;499	1	1	1	1
Data	17:58:36;499	1	1	1	1
Data	17:58:42;499	1	1	1	1

Table C.5 Trend of Conveyor 7 Instruments of Conveyor Circuit at Ship Loading Plant

Controller Name:	Ship_Loading_Plant	Tag Name		
Trend Name:	Conveyor_7_Instruments			
Trend Tags:	3			
Sample Period:	6000 ms			
Date	8/19/2019			
Start Time:	18:07:03;452			
Stop Time:	18:17:00;452			
Header:	Time	BCT_7	CV7_BS	CV7_AL_1
Data	18:07:03;452	1	1	1
Data	18:07:09;452	1	1	1
Data	18:07:15;452	1	1	1
Data	18:07:21;452	1	1	1
Data	18:07:27;452	1	1	1
Data	18:07:33;452	1	1	1
Data	18:07:39;452	1	1	1
Data	18:07:45;452	1	1	1
Data	18:07:51;452	1	1	1
Data	18:07:57;452	1	1	1
Data	18:08:03;452	1	1	1
Data	18:08:09;452	1	1	1
Data	18:08:15;452	1	1	1
Data	18:08:21;452	1	1	1
Data	18:08:27;452	1	1	1
Data	18:08:33;452	1	1	1
Data	18:08:39;452	1	1	1
Data	18:08:45;452	1	1	1
Data	18:08:51;452	1	1	1
Data	18:08:57;452	1	1	1
Data	18:09:03;452	1	1	1
Data	18:09:09;452	1	1	1
Data	18:09:15;452	1	1	1
Data	18:09:21;452	1	1	1
Data	18:09:27;452	1	1	1
Data	18:09:33;452	1	1	1
Data	18:09:39;452	1	1	0
Data	18:09:45;452	1	1	0
Data	18:09:51;452	1	1	0
Data	18:09:57;452	1	1	0
Data	18:10:03;452	1	1	0
Data	18:10:09;452	1	1	0
Data	18:10:15;452	1	1	0
Data	18:10:21;452	1	1	1

Data	18:10:27;452	1	1	1
Data	18:10:33;452	1	1	1
Data	18:10:39;452	1	1	1
Data	18:10:45;452	1	1	1
Data	18:10:51;452	1	1	1
Data	18:10:57;452	1	1	1
Data	18:11:03;452	1	1	1
Data	18:11:09;452	1	1	1
Data	18:11:15;452	1	1	1
Data	18:11:21;452	1	1	1
Data	18:11:27;452	1	1	1
Data	18:11:33;452	1	1	1
Data	18:11:39;452	1	1	1
Data	18:11:45;452	1	1	1
Data	18:11:51;452	1	1	1
Data	18:11:57;452	1	1	1
Data	18:12:03;452	1	1	1
Data	18:12:09;452	1	1	1
Data	18:12:15;452	1	1	1
Data	18:12:21;452	0	1	1
Data	18:12:27;452	0	1	1
Data	18:12:33;452	0	1	1
Data	18:12:39;452	0	1	1
Data	18:12:45;452	0	1	1
Data	18:12:51;452	0	1	1
Data	18:12:57;452	1	1	1
Data	18:13:03;452	1	1	1
Data	18:13:09;452	1	1	1
Data	18:13:15;452	1	1	1
Data	18:13:21;452	1	1	1
Data	18:13:27;452	1	1	1
Data	18:13:33;452	1	1	1
Data	18:13:39;452	1	1	1
Data	18:13:45;452	1	1	1
Data	18:13:51;452	1	1	1
Data	18:13:57;452	1	1	1
Data	18:14:03;452	1	1	1
Data	18:14:09;452	1	1	1
Data	18:14:15;452	1	1	1
Data	18:14:21;452	1	1	1
Data	18:14:27;452	1	1	1
Data	18:14:33;452	1	1	1
Data	18:14:39;452	1	1	1
Data	18:14:45;452	1	0	1

Data	18:14:51;452	1	0	1
Data	18:14:57;452	1	0	1
Data	18:15:03;452	1	0	1
Data	18:15:09;452	1	0	1
Data	18:15:15;452	1	0	1
Data	18:15:21;452	1	0	1
Data	18:15:27;452	1	1	1
Data	18:15:33;452	1	1	1
Data	18:15:39;452	1	1	1
Data	18:15:45;452	1	1	1
Data	18:15:51;452	1	1	1
Data	18:15:57;452	1	1	1
Data	18:16:03;452	1	1	1
Data	18:16:09;452	1	1	1
Data	18:16:15;452	1	1	1
Data	18:16:21;452	1	1	1
Data	18:16:27;452	1	1	1
Data	18:16:33;452	1	1	1
Data	18:16:39;452	1	1	1
Data	18:16:45;452	1	1	1
Data	18:16:51;452	1	1	1
Data	18:16:57;452	1	1	1
Data	18:17:00;452	1	1	1

Table C.6 Trend of Ship Loading Plant Motor when Testing Conveyor 7 Instruments

Controller Name	**Ship_Loading_Plant**	**Tag Name**							
Trend Name	**Ship_Loading_Motors**								
Trend Tags	**8**								
Sample Period	**6000 ms**								
Date	**8/19/2019**								
Start Time	**18:07:00;217**								
Stop Time	**18:16:57;217**								
Header	**Time**	**BL_Motor**	**CV1_ Motor**	**CV2_ Motor**	**CV3_ Motor**	**CV4_ Motor**	**CV5_ Motor**	**CV6_ Motor**	**CV7_ Motor**
Data	18:07:00;217	0	0	0	0	0	0	0	0
Data	18:07:06;217	0	0	0	0	0	0	0	0
Data	18:07:12;217	0	0	0	0	0	0	0	0
Data	18:07:18;217	1	0	0	0	0	0	0	0
Data	18:07:24;217	1	0	0	0	0	0	0	1
Data	18:07:30;217	1	0	0	0	0	0	0	1
Data	18:07:36;217	1	0	0	0	0	0	1	1
Data	18:07:42;217	1	0	0	0	0	0	1	1
Data	18:07:48;217	1	0	0	0	0	1	1	1
Data	18:07:54;217	1	0	0	0	1	1	1	1
Data	18:08:00;217	1	0	0	0	1	1	1	1
Data	18:08:06;217	1	0	0	1	1	1	1	1
Data	18:08:12;217	1	0	0	1	1	1	1	1
Data	18:08:18;217	1	0	1	1	1	1	1	1
Data	18:08:24;217	1	1	1	1	1	1	1	1
Data	18:08:30;217	1	1	1	1	1	1	1	1
Data	18:08:36;217	1	1	1	1	1	1	1	1

Data	18:08:42;217	1	1	1	1	1	1	1	1
Data	18:08:48;217	1	1	1	1	1	1	1	1
Data	18:08:54;217	1	1	1	1	1	1	1	1
Data	18:09:00;217	1	1	1	1	1	1	1	1
Data	18:09:06;217	1	1	1	1	1	1	1	1
Data	18:09:12;217	1	1	1	1	1	1	1	1
Data	18:09:18;217	1	1	1	1	1	1	1	1
Data	18:09:24;217	1	1	1	1	1	1	1	1
Data	18:09:30;217	1	1	1	1	1	1	1	1
Data	18:09:36;217	1	1	1	1	1	1	1	1
Data	18:09:42;217	1	0	0	0	0	0	0	0
Data	18:09:48;217	1	0	0	0	0	0	0	0
Data	18:09:54;217	1	0	0	0	0	0	0	0
Data	18:10:00;217	1	0	0	0	0	0	0	0
Data	18:10:06;217	1	0	0	0	0	0	0	0
Data	18:10:12;217	1	0	0	0	0	0	0	0
Data	18:10:18;217	1	0	0	0	0	0	0	0
Data	18:10:24;217	1	0	0	0	0	0	0	0
Data	18:10:30;217	1	0	0	0	0	0	0	1
Data	18:10:36;217	1	0	0	0	0	0	0	1
Data	18:10:42;217	1	0	0	0	0	0	1	1
Data	18:10:48;217	1	0	0	0	0	0	1	1
Data	18:10:54;217	1	0	0	0	0	1	1	1
Data	18:11:00;217	1	0	0	0	1	1	1	1
Data	18:11:06;217	1	0	0	0	1	1	1	1
Data	18:11:12;217	1	0	0	1	1	1	1	1
Data	18:11:18;217	1	0	0	1	1	1	1	1
Data	18:11:24;217	1	0	1	1	1	1	1	1

Data	18:11:30;217	1	1	1	1	1	1	1	1
Data	18:11:36;217	1	1	1	1	1	1	1	1
Data	18:11:42;217	1	1	1	1	1	1	1	1
Data	18:11:48;217	1	1	1	1	1	1	1	1
Data	18:11:54;217	1	1	1	1	1	1	1	1
Data	18:12:00;217	1	1	1	1	1	1	1	1
Data	18:12:06;217	1	1	1	1	1	1	1	1
Data	18:12:12;217	1	1	1	1	1	1	1	1
Data	18:12:18;217	1	0	0	0	0	0	0	0
Data	18:12:24;217	1	0	0	0	0	0	0	0
Data	18:12:30;217	1	0	0	0	0	0	0	0
Data	18:12:36;217	1	0	0	0	0	0	0	0
Data	18:12:42;217	1	0	0	0	0	0	0	0
Data	18:12:48;217	1	0	0	0	0	0	0	0
Data	18:12:54;217	1	0	0	0	0	0	0	0
Data	18:13:00;217	1	0	0	0	0	0	0	0
Data	18:13:06;217	1	0	0	0	0	0	0	1
Data	18:13:12;217	1	0	0	0	0	0	0	1
Data	18:13:18;217	1	0	0	0	0	0	1	1
Data	18:13:24;217	1	0	0	0	0	1	1	1
Data	18:13:30;217	1	0	0	0	0	1	1	1
Data	18:13:36;217	1	0	0	0	1	1	1	1
Data	18:13:42;217	1	0	0	0	1	1	1	1
Data	18:13:48;217	1	0	0	1	1	1	1	1
Data	18:13:54;217	1	0	1	1	1	1	1	1
Data	18:14:00;217	1	0	1	1	1	1	1	1
Data	18:14:06;217	1	1	1	1	1	1	1	1
Data	18:14:12;217	1	1	1	1	1	1	1	1

Data	18:14:18;217	1	1	1	1	1	1	1	1
Data	18:14:24;217	1	1	1	1	1	1	1	1
Data	18:14:30;217	1	1	1	1	1	1	1	1
Data	18:14:36;217	1	1	1	1	1	1	1	1
Data	18:14:42;217	1	0	0	0	0	0	0	1
Data	18:14:48;217	1	0	0	0	0	0	0	1
Data	18:14:54;217	1	0	0	0	0	0	0	1
Data	18:15:00;217	1	0	0	0	0	0	0	1
Data	18:15:06;217	1	0	0	0	0	0	0	1
Data	18:15:12;217	1	0	0	0	0	0	0	1
Data	18:15:18;217	1	0	0	0	0	0	0	1
Data	18:15:24;217	1	0	0	0	0	0	0	1
Data	18:15:30;217	1	0	0	0	0	0	0	1
Data	18:15:36;217	1	0	0	0	0	0	1	1
Data	18:15:42;217	1	0	0	0	0	0	1	1
Data	18:15:48;217	1	0	0	0	0	1	1	1
Data	18:15:54;217	1	0	0	0	0	1	1	1
Data	18:16:00;217	1	0	0	0	1	1	1	1
Data	18:16:06;217	1	0	0	1	1	1	1	1
Data	18:16:12;217	1	0	0	1	1	1	1	1
Data	18:16:18;217	1	0	1	1	1	1	1	1
Data	18:16:24;217	1	0	1	1	1	1	1	1
Data	18:16:30;217	1	1	1	1	1	1	1	1
Data	18:16:36;217	1	1	1	1	1	1	1	1
Data	18:16:39;217	1	1	1	1	1	1	1	1

Table C.7 Trend of Conveyor 3 Instruments of Conveyor Circuit at Ship Loading Plant

Controller Name:	Ship_Loading_Plant	Tag Name		
Trend Name:	Conveyor_3_Instruments			
Trend Tags:	3			
Sample Period:	6000 ms			
Date	8/19/2019			
Start Time:	18:23:40;703			
Stop Time:	18:32:55;703			
Header:	Time	BCT_3	CV3_AL_1	CV3_BS
Data	18:23:40;703	1	1	1
Data	18:23:46;703	1	1	1
Data	18:23:52;703	1	1	1
Data	18:23:58;703	1	1	1
Data	18:24:04;703	1	1	1
Data	18:24:10;703	1	1	1
Data	18:24:16;703	1	1	1
Data	18:24:22;703	1	1	1
Data	18:24:28;703	1	1	1
Data	18:24:34;703	1	1	1
Data	18:24:40;703	1	1	1
Data	18:24:46;703	1	1	1
Data	18:24:52;703	1	1	1
Data	18:24:58;703	1	1	1
Data	18:25:04;703	1	1	1
Data	18:25:10;703	1	1	1
Data	18:25:16;703	1	1	1
Data	18:25:22;703	1	1	1
Data	18:25:28;703	1	1	1
Data	18:25:34;703	1	1	1
Data	18:25:40;703	1	1	1
Data	18:25:46;703	1	0	1
Data	18:25:52;703	1	0	1
Data	18:25:58;703	1	0	1
Data	18:26:04;703	1	0	1
Data	18:26:10;703	1	0	1
Data	18:26:16;703	1	0	1
Data	18:26:22;703	1	0	1
Data	18:26:28;703	1	0	1
Data	18:26:34;703	1	0	1
Data	18:26:40;703	1	0	1
Data	18:26:46;703	1	1	1
Data	18:26:52;703	1	1	1
Data	18:26:58;703	1	1	1
Data	18:27:04;703	1	1	1

Data	18:27:10;703	1	1	1
Data	18:27:16;703	1	1	1
Data	18:27:22;703	1	1	1
Data	18:27:28;703	1	1	1
Data	18:27:34;703	1	1	1
Data	18:27:40;703	1	1	1
Data	18:27:46;703	1	1	1
Data	18:27:52;703	1	1	1
Data	18:27:58;703	1	1	1
Data	18:28:04;703	1	1	1
Data	18:28:10;703	0	1	1
Data	18:28:16;703	0	1	1
Data	18:28:22;703	0	1	1
Data	18:28:28;703	0	1	1
Data	18:28:34;703	0	1	1
Data	18:28:40;703	0	1	1
Data	18:28:46;703	0	1	1
Data	18:28:52;703	0	1	1
Data	18:28:58;703	1	1	1
Data	18:29:04;703	1	1	1
Data	18:29:10;703	1	1	1
Data	18:29:16;703	1	1	1
Data	18:29:22;703	1	1	1
Data	18:29:28;703	1	1	1
Data	18:29:34;703	1	1	1
Data	18:29:40;703	1	1	1
Data	18:29:46;703	1	1	1
Data	18:29:52;703	1	1	1
Data	18:29:58;703	1	1	1
Data	18:30:04;703	1	1	1
Data	18:30:10;703	1	1	1
Data	18:30:16;703	1	1	1
Data	18:30:22;703	1	1	1
Data	18:30:28;703	1	1	1
Data	18:30:34;703	1	1	0
Data	18:30:40;703	1	1	0
Data	18:30:46;703	1	1	0
Data	18:30:52;703	1	1	0
Data	18:30:58;703	1	1	0
Data	18:31:04;703	1	1	0
Data	18:31:10;703	1	1	0
Data	18:31:16;703	1	1	0
Data	18:31:22;703	1	1	0
Data	18:31:28;703	1	1	1

Data	18:31:34;703	1	1	1
Data	18:31:40;703	1	1	1
Data	18:31:46;703	1	1	1
Data	18:31:52;703	1	1	1
Data	18:31:58;703	1	1	1
Data	18:32:04;703	1	1	1
Data	18:32:10;703	1	1	1
Data	18:32:16;703	1	1	1
Data	18:32:22;703	1	1	1
Data	18:32:28;703	1	1	1
Data	18:32:34;703	1	1	1
Data	18:32:40;703	1	1	1
Data	18:32:46;703	1	1	1

Table C.8 Trend of Ship Loading Plant Motors when Testing Conveyor 3 Instrument

Controller Name	**Ship_Loading_Plant**								
Trend Name	**Ship_Loading_Motors**								
Trend Tags	**8**								
Sample Period	**6000 ms**								
Date	**8/19/2019**								
Start Time	**18:23:37;374**								
Stop Time	**18:32:52;374**								
Header	**Time**	**BL_ Motor**	**CV1_ Motor**	**CV2_ Motor**	**CV3_ Motor**	**CV4_ Motor**	**CV5_ Motor**	**CV6_ Motor**	**CV7_ Motor**
Data	18:23:40;374	0	0	0	0	0	0	0	0
Data	18:23:46;374	0	0	0	0	0	0	0	0
Data	18:23:52;374	1	0	0	0	0	0	0	0
Data	18:23:58;374	1	0	0	0	0	0	0	0
Data	18:24:04;374	1	0	0	0	0	0	0	1
Data	18:24:10;374	1	0	0	0	0	0	0	1
Data	18:24:16;374	1	0	0	0	0	0	1	1
Data	18:24:22;374	1	0	0	0	0	1	1	1
Data	18:24:28;374	1	0	0	0	0	1	1	1
Data	18:24:34;374	1	0	0	0	1	1	1	1
Data	18:24:40;374	1	0	0	0	1	1	1	1
Data	18:24:46;374	1	0	0	1	1	1	1	1
Data	18:24:52;374	1	0	1	1	1	1	1	1
Data	18:24:58;374	1	0	1	1	1	1	1	1
Data	18:25:04;374	1	1	1	1	1	1	1	1
Data	18:25:10;374	1	1	1	1	1	1	1	1
Data	18:25:16;374	1	1	1	1	1	1	1	1

Data	18:25:22;374	1	1	1	1	1	1	1	1
Data	18:25:28;374	1	1	1	1	1	1	1	1
Data	18:25:34;374	1	1	1	1	1	1	1	1
Data	18:25:40;374	1	1	1	1	1	1	1	1
Data	18:25:46;374	1	1	1	1	1	1	1	1
Data	18:25:52;374	1	0	0	0	1	1	1	1
Data	18:25:58;374	1	0	0	0	1	1	1	1
Data	18:26:04;374	1	0	0	0	1	1	1	1
Data	18:26:10;374	1	0	0	0	1	1	1	1
Data	18:26:16;374	1	0	0	0	1	1	1	1
Data	18:26:22;374	1	0	0	0	1	1	1	1
Data	18:26:28;374	1	0	0	0	1	1	1	1
Data	18:26:34;374	1	0	0	0	1	1	1	1
Data	18:26:40;374	1	0	0	0	1	1	1	1
Data	18:26:46;374	1	0	0	0	1	1	1	1
Data	18:26:52;374	1	0	0	0	1	1	1	1
Data	18:26:58;374	1	0	0	1	1	1	1	1
Data	18:27:04;374	1	0	1	1	1	1	1	1
Data	18:27:10;374	1	0	1	1	1	1	1	1
Data	18:27:16;374	1	1	1	1	1	1	1	1
Data	18:27:22;374	1	1	1	1	1	1	1	1
Data	18:27:28;374	1	1	1	1	1	1	1	1
Data	18:27:34;374	1	1	1	1	1	1	1	1
Data	18:27:40;374	1	1	1	1	1	1	1	1
Data	18:27:46;374	1	1	1	1	1	1	1	1
Data	18:27:52;374	1	1	1	1	1	1	1	1
Data	18:27:58;374	1	1	1	1	1	1	1	1
Data	18:28:04;374	1	1	1	1	1	1	1	1

Data	18:28:10;374	1	1	1	1	1	1	1	1
Data	18:28:16;374	1	0	0	0	1	1	1	1
Data	18:28:22;374	1	0	0	0	1	1	1	1
Data	18:28:28;374	1	0	0	0	1	1	1	1
Data	18:28:34;374	1	0	0	0	1	1	1	1
Data	18:28:40;374	1	0	0	0	1	1	1	1
Data	18:28:46;374	1	0	0	0	1	1	1	1
Data	18:28:52;374	1	0	0	0	1	1	1	1
Data	18:28:58;374	1	0	0	0	1	1	1	1
Data	18:29:04;374	1	0	0	0	1	1	1	1
Data	18:29:10;374	1	0	0	1	1	1	1	1
Data	18:29:16;374	1	0	0	1	1	1	1	1
Data	18:29:22;374	1	0	1	1	1	1	1	1
Data	18:29:28;374	1	0	1	1	1	1	1	1
Data	18:29:34;374	1	1	1	1	1	1	1	1
Data	18:29:40;374	1	1	1	1	1	1	1	1
Data	18:29:46;374	1	1	1	1	1	1	1	1
Data	18:29:52;374	1	1	1	1	1	1	1	1
Data	18:29:58;374	1	1	1	1	1	1	1	1
Data	18:30:04;374	1	1	1	1	1	1	1	1
Data	18:30:10;374	1	1	1	1	1	1	1	1
Data	18:30:16;374	1	1	1	1	1	1	1	1
Data	18:30:22;374	1	1	1	1	1	1	1	1
Data	18:30:28;374	1	1	1	1	1	1	1	1
Data	18:30:34;374	1	0	0	1	1	1	1	1
Data	18:30:40;374	1	0	0	1	1	1	1	1
Data	18:30:46;374	1	0	0	1	1	1	1	1
Data	18:30:52;374	1	0	0	1	1	1	1	1

Data	18:30:58;374	1	0	0	1	1	1	1	1
Data	18:31:04;374	1	0	0	1	1	1	1	1
Data	18:31:10;374	1	0	0	1	1	1	1	1
Data	18:31:16;374	1	0	0	1	1	1	1	1
Data	18:31:22;374	1	0	0	1	1	1	1	1
Data	18:31:28;374	1	0	0	1	1	1	1	1
Data	18:31:34;374	1	0	0	1	1	1	1	1
Data	18:31:40;374	1	0	0	1	1	1	1	1
Data	18:31:46;374	1	0	1	1	1	1	1	1
Data	18:31:52;374	1	1	1	1	1	1	1	1
Data	18:31:58;374	1	1	1	1	1	1	1	1
Data	18:32:04;374	1	1	1	1	1	1	1	1
Data	18:32:10;374	1	1	1	1	1	1	1	1
Data	18:32:16;374	1	1	1	1	1	1	1	1
Data	18:32:22;374	1	1	1	1	1	1	1	1
Data	18:32:28;374	1	1	1	1	1	1	1	1
Data	18:32:34;374	1	1	1	1	1	1	1	1
Data	18:32:40;374	1	1	1	1	1	1	1	1
Data	18:32:46;374	1	1	1	1	1	1	1	1
Data	18:32:52;374	1	1	1	1	1	1	1	1

APPENDIX D

COST OF MATERIALS

Table D.1 Estimated Cost of Materials for SCADA System Design of Tippling Plant

SN	Material Description	Range/Rating	Brand Name	Quantity	Unit Price (USD)	Total Price (USD)
1.	1756 ControlLogix plc	Total I/O, max 3072, SER: ABCDE, Series PLC-5	Allen Bradley	1	12000 - 38000	20000.00
2.	Fibre Optic Cable	GYTA -12core	Wanbao	4	100/Km	400.00
3.	Fibre Optic Patch Cord	GPON, CATV, FTTH, LAN	ODM	5	0.2 - 1.5/ unit	7.50
4.	Fibre Optic Cable Converter	Data rate: 10/100 Mbps, wavelength: 850 nm/1310 nm, 1550 nm	NuFibre	3	6.8 - 12.8/ piece	38.40
5.	Proximity Sensor	Switching function: Normally Closed, rated operating distance : 15 mm, Output type 2-wire	Pepperl-fuchs	10	80/piece	800.00
6.	Block Chute Sensor	220 Vac, 50 m operating range	Wadeco	7	2249	15743.00
7.	Belt Alignment Switch	Maximum voltage: 250 V, Contact type: Double circuit line, Maximum current: 5 A	Lema	18	6.15-6.92/ piece	124.56
8.	Control Cable	Voltage: 0.6/1 kV, Number of cores: 2-61 Cores, conductor material: Copper, Sectional area: 0.75 sqmm - 6 sqmm	Guowang	700 m	1/meter	700.00
9.	Server	HDD: 500 GB, Input: 110-220 Vac, Processor Main frequency: 3.0 GHz, Memory Capacity: ≥ 4 GB	Kingkie	1	320-400/ piece	400.00

Table D.1 Cont'd

10.	Desktop Computer	Model Number: DJ-C003, Processor Main Frequency: 2.8 GHz, Memory Capacity: 2 GB	OEM	1	660/set	260.00
11.	UPS	Phase: Single, Input Voltage: 140-275 Vac, Output Voltage: 220 Vac	Staba/OEM	1	30 - 200/ piece	200.00
12.	Power Supply Unit	Input Voltage: 90-132 Vac/180-264 Vac, Output Voltage: 5 V / 12 V / -12 V, Output Current: 3 A/1 A/0.5 A	Winston	1	**7.7**	7.70
13.	Isolating Transformer	Phase: Single, Frequency: 50/60 Hz, Rating: 2 kVA	Ecko	1	50/piece	50.00
14.	Siren	Supply voltage: 120 Vac / 230 Vac, Current type: AC, Decibels at 1 meter: 120 Db, Temperature range: -25 ^{o}C – 55 ^{o}C	Nexus	10	392.67	3926.70
	Cost of materials					43057.86
	Miscellaneous (10% of material cost)					4305.79
	Installation Cost					5000.00
	Total Estimated Cost					**52363.65**

Table D.2 Estimated Cost of Materials for SCADA System Design of Ship Loading Plant

SN	Material Description	Range/Rating	Brand Name	Quantity	Unit Price (USD)	Total Price (USD)
1.	1756 ControlLogix plc	Total I/O, max 3072, SER: ABCDE, Series PLC-5	Allen Bradley	1	12000 - 38000	20000.00
2.	Fibre Optic Cable	GYTA -12core	Wanbao	6	100/Km	600.00
3.	Fibre Optic Patch Cord	GPON, CATV, FTTH, LAN	ODM	5	0.2 - 1.5/ unit	7.50
4.	Fibre Optic Cable Converter	Data rate: 10/100 Mbps, wavelength: 850 nm/1310 nm, 1550 nm	NuFibre	5	6.8 - 12.8/ piece	64.00

Table D.2 Cont'd

5.	Proximity Sensor	Switching function: Normally Closed, rated operating distance : 15 mm, Output type 2-wire	Pepperl-fuchs	15	80/piece	1200.00
6.	Block Chute Sensor	220 Vac, 50 m operating range	Wadeco	10	2249	22490.00
7.	Belt Alignment Switch	Maximum voltage: 250 V, Contact type: Double circuit line, Maximum current: 5 A	Lema	30	6.15-6.92/ piece	207.60
8.	Control Cable	Voltage: 0.6/1 kV, Number of cores: 2-61 Cores, conductor material: Copper, Sectional area: 0.75 sqmm - 6 sqmm	Guowang	1000	1/meter	1000.00
9.	Server	HDD: 500 GB, Input: 110-220 Vac, Processor Main frequency: 3.0 GHz, Memory Capacity: $\geq$ 4 GB	Kingkie	1	320-400/ piece	400.00
10.	Desktop Computer	Model Number: DJ-C003, Processor Main Frequency: 2.8 GHz, Memory Capacity: 2 GB	OEM	1	660/set	660.00
11.	UPS	Phase: Single, Input Voltage: 140-275 Vac, Output Voltage: 220 Vac	Staba/OEM	1	30 - 200/ piece	200.00
12.	Power Supply Unit	Input Voltage: 90-132 Vac /180-264 Vac, Output Voltage: 5 V /12 V /-12V, Output Current: 3 A / 1 A / 0.5 A	Winston	1	**7.7**	7.70
13.	Isolating Transformer	Phase: Single, Frequency: 50/60 Hz, Rating: 2kVA	Ecko	1	50/piece	50.00
14.	Siren	Supply voltage: 120 Vac /230 Vac, Current type: AC, Decibels at 1 meter: 120 Db, Temperature range: -25 ^{o}C – 55 ^{o}C	Nexus	10	392.67	3926.70
	Cost of materials					50813.50
	Miscellaneous (10% of material cost)					5081.35
	Installation Cost					5000.00
	Total Estimated Cost					**60894.85**

Invoices of Additional Labour Cost for TPF

MEGALUX VENTURES

CONTRACT SUPPLIERS OF GENERAL GOODS AND SERVICES

TEL.031-20-22824/024-6311218/0208328556/0266541639

P.O.BOX 01370 TAKORADI

OUR REF.................................. YOUR REF..............................

GHANA BAUXITE CO LTD RECEIVED 20 SEP 2017 TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI.

14/9/17

Dear Sir,

INVOICE—DUTIES BY SPILLAGE CLEANERS AT TIPPLER SUPPORTING TIPPING GANG FOR AUGUST 2017

We present invoice NO. MG/9/GBC/073 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC.]
J. NKRUMAH	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
E. MENSAH	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
J. ANNOBIL	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
T. ENTSIN	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
S. ASIEDU	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
K. ACHAAB	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
F. ALI	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
D. KRAKU	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
J. QUARSHIE	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
R. YAMOAH	6.00 AM-----6.00 PM[12]	01/8/17-----31/8/17 [31]	815.30
E. WILSON	6.00 AM-----6.00 PM[12]	01/8/17-----28/8/17 [28]	736.40
		TOTAL	8,889.40

N.B. APPLICABLE RATE FROM 01/6/17 IS 17.53 PER 8 HRS. AND 26.30 GHC. PER 12 HRS. DUE DATE IS IN 15[FIFTEEN] DAYS TIME

Please be advised. I.E. /28/9/17

Yours faithfully,

Checked by
Bernadette Amoo

JOE MENSAH
[DIRECTOR]

GHANA BAUXITE CO LTD. P. O. BOX 21 TAKORADI

Fig. D.1 Invoice of Additional Labour for Tippling Operations for August 2017

MEGALUX VENTURES

Clearing And Forwarding, Transport, Labour And Specialized Labour Providers

BANKERS: ADB, UT Bank

P.O. Box 01370
Takoradi.
Mobile: 0246311218
0208328556

Your Ref:

Our Ref:

Date:

GHANA BAUXITE CO LTD
RECEIVED
17 OCT 2017
TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI.

07/10/17

Dear Sir,

INVOICE-- SPILLAGE CLEANERS AT TIPPLER SUPPORTING TIPPING GANG FOR SEPTEMBER, 2017

We present invoice NO. MG/9/GBC/082 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC.]
E. MENSAH	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
J. ANNOBIL	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
J. NKRUMAH	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
T. ENTSIN	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
K. ACHAAB	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
F. ALI	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
M. KRAKU	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
J. QUARSHIE	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
S. O.ASIEDU	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
M. NTAAMAH	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
E. AMOAH	6:00 AM-----6:00 PM [12]	01/9/17-----30/9/17 [30]	789.00
		TOTAL	8,679.00

N.B. APPLICABLE RATE FROM 01/6/17 IS 17.53 PER 8 HRS. AND 26.30 GHC. PER 12 HRS.

Please be advised.

Checked by
Bernadette Amoo

Yours faithfully,

JOE MENSAH
[DIRECTOR]

GHANA BAUXITE CO. LTD.
P. O. BOX 21
TAKORADI

Fig. D.2 Invoice of Additional Labour for Tippling Operations for September 2017

MEGALUX VENTURES

CONTRACT SUPPLIERS OF GENERAL GOODS AND SERVICES

TEL.031-20-22824/024-6311218/0208328556/0266541639

P.O.BOX 01370 TAKORADI

OUR REF................................ YOUR REF............................

GHANA BAUXITE CO LTD
RECEIVED
11 DEC 2017
TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI.

06/12/17

Dear Sir,

INVOICE—DUTIES BY SPILLAGE CLEANERS AT TIPPLER SUPPORTING TIPPING GANG FOR NOVEMBER 2017

We present invoice NO. MG/9/GBC/101 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC.]	
J. NKRUMAH	6.00 AM-----6.00 PM[12] 6.00 AM-----6.00 PM[12]	1/11—4/11&6/11—16/11/17 [15] 18/11—23/11&25/11—30/11/17[12]	394.50 315.60	710.10
E. MENSAH	6.00 AM-----6.00 PM[12] 6.00 AM-----6.00 PM[12]	1/11--7/11&9/11—15/11/17[14] 17/11---28/11&30/11/17 [13]	368.20 341.90	710.10
D. KRAKU	6.00 AM-----6.00 PM[12] 6.00 AM-----6.00 PM[12]	1/11—18/11&20/11—25/11/17 [24] 27/11/17-----30/11/17 [4]	631.20 105.20	736.40
M. NTAAMAH	6.00 AM-----6.00 PM[12]	01/11/17-----30/11/17 [30]		789.00
S. ASIEDU	6.00 AM-----6.00 PM[12]	1/11—11/11&13/11—30/11/17 [29]		762.70
K. ACHAAB	6.00 AM-----6.00 PM[12]	01/11/17-----30/11/17 [30]		789.00
F. ALI	6.00 AM-----6.00 PM[12]	01/11/17-----30/11/17 [30]		789.00
J. ANNOBIL	6.00 AM-----6.00 PM [12] 6.00 AM-----6.00 PM [12]	1/11&3/11—4/11&6/11—11/11/17[9] 13/11—21/11&23/11—30/11/17 [17]	236.70 447.10	683.80
J. QUARSHIE	6.00 AM-----6.00 PM[12]	01/11/17-----30/11/17 [30]		789.00
T. ENTSIN	6.00 AM-----6.00 PM[12]	1/11—8/11&10/11—30/11/17 [29]		762.70
B. AMOAH	6.00 AM-----6.00 PM[12] 6.00 AM-----6.00 PM [12]	1/11—4/11&6/11—9/11/17 [8] 11/11/17-----30/11/17 [20]	210.40 526.00	736.40
		TOTAL		**8258.00**

N.B. APPLICABLE RATE FROM 01/6/17 IS 17.53 PER 8 HRS. AND 26.30 GHC. PER 12 HRS. DUE DATE IS IN 10[TEN]DAYS TIME

Please be advised. I.E. 26/12//17

Yours faithfully,

Checked By
Bernadette Amoo

JOE MENSAH
[DIRECTOR]

GHANA BAUXITE CO. LTD.
P. O. BOX 21
TAKORADI

Fig. D.3 Invoice of Additional Labour for Tippling Operations for November 2017

MEGALUX VENTURES

CONTRACT SUPPLIERS OF GENERAL GOODS AND SERVICES

TEL.031-20-22824/024-6311218/0208328556/0266541639

P.O.BOX 01370 TAKORADI

OUR REF.................................. YOUR REF..............................

GHANA BAUXITE CO LTD
RECEIVED
02 NOV 2017
TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI. 27/10/17

Dear Sir,

INVOICE—M.V.IMME OLDENDORFF SHIPLOADING LABOUR FROM 09/10/17 TO 21/10/17

We present invoice NO. MG/9/GBC/086 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC.]
P. ACKON	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
G. ASARE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
S. OKYERE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
S. KWAKYE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
S. MUAH	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
S. EYIAM	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
K. DARKO	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
G. ACQUAYE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
T.BERGRAMME	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
P. KWOFIE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
K. CUDJOE	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
A. APPIAH	6.00AM-----6.00PM [12]	09/10/17-----21/10/17 [13]	341.90
S. BROWN	6.00AM-----6.00PM [12]	10/10/17-----21/10/17 [12]	315.60
P. OKWAISIE	6.00AM-----6.00PM [12]	10/10/17-----21/10/17 [12]	315.60
M. ODOOM	6.00AM-----6.00PM [12]	10/10/17-----21/10/17 [12]	315.60
R. AGBEME	6.00AM-----6.00PM [12]	10/10/17-----21/10/17 [12]	315.60
G. OPOKU	6.00AM-----6.00PM [12]	12/10—15/10&17/10—21/10/17 [9]	236.70
E. ESSIEN	6.00AM-----6.00PM [12]	11/10/17-----21/10/17 [11]	289.30
J. AKROMAH	6.00AM-----6.00PM [12]	09/10—18/10&20/10—21/10/17 [12]	315.60
		TOTAL	6,206.80

N.B. APPLICABLE RATE FROM 01/6/17 IS 17.53 PER 8 HRS. AND 26.30 GHC. PER 12 HRS. PAYABLE WITHIN 10 DAYS

Please be advised. I.E. 06/11/17

Yours faithfully,

checked by
Bernadette Amo

JOE MENSAH
[DIRECTOR]

GHANA BAUXITE CO. LTD.
P.O. BOX 21
TAKORADI

Fig. D.4 Invoice of Additional Labour for Ship Loading Operations for MV. Imme Oldendorff Vessel

MEGALUX VENTURES

CONTRACT SUPPLIERS OF GENERAL GOODS AND SERVICES

TEL.031-20-22824/024-6311218/0208328556/0266541639

P.O.BOX 01370 TAKORADI

OUR REF.................................. YOUR REF..............................

GHANA BAUXITE CO LTD
RECEIVED
14 JUN 2017
TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI.

08/6/17

Dear Sir,

INVOICE—MV. NAUTICAL HILLARY SHIPLOADING LABOUR FROM 15/5/17 TO 27/5/17

We present invoice NO. MG/9/GBC/050 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC.]
P. ACKON	6.00 AM-----6.00 PM [12]	15/5/17-----27/5/17 [13]	308.10
F. ASARE	6.00 AM-----6.00 PM [12]	15/5/17-----27/5/17 [13]	308.10
J. AKROMAH	6.00 AM-----6.00 PM [12]	15/5/17-----27/5/17 [13]	308.10
B. APPIAH	6.00 AM-----6.00 PM [12]	15/5/17-----27/5/17 [13]	308.10
F. AKANWIEWAH	6.00 AM-----6.00 PM [12]	15/5/17-----27/5/17 [13]	308.10
S. BROWN	6.00 AM-----6.00 PM [12]	15/5—18/5&24/5—27/5/17[8]	189.60
S. EMYIAM	6.00 AM-----6.00 PM [12]	16/5—20/5&22/5—27/5/17[11]	260.70
K. AGYEMANG	6.00 AM-----6.00 PM [12]	15/5&17/5/17----20/5/17 [5]	118.50
K. DARKO	6.00 PM-----6.00 AM [12]	16/5/17-----26/5/17 [11]	260.70
P. OKWAISI	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
G. ACQUAYE	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
M. ODOOM	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
P. KWOFIE	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
G. KWOFIE	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
R. AGBEME	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
J.BERGRAMME	6.00 AM-----6.00 PM [12]	16/5/17-----26/5/17 [11]	260.70
E. ESSIEN	6.00 AM-----6.00 PM [12]	17/5—24/5&26/5/17 [9]	213.30
C. CUDJOE	6.00 AM-----6.00 PM [12]	16/5—22/5&24/5—26/5/17[10]	237.00
F. HOLDBROOKE	6.00 PM-----6.00 AM [12]	18/5/17-----24/5/17 [7]	165.90
		TOTAL	4,811.10

N.B. APPLICABLE RATE FROM 01/6/16 IS 15.80 PER 8 HRS. AND 23.70 GHC. PER 12 HRS. PAYMENT IN 15 DAYS – 23/6/17

Please be advised.

Checked by
Bernadette Amoo

Yours faithfully,

JOE MENSAH
[DIRECTOR]

GHANA BAUXITE CO. LTD
P. O. BOX 21
TAKORADI

Fig. D.5 Invoice of Additional Labour for Ship Loading Operations for MV. Nautical Hillary Vessel

MEGALUX VENTURES

CONTRACT SUPPLIERS OF GENERAL GOODS AND SERVICES
TEL.031-20-22824/024-6311218/0208328556/0266541639
P. O.BOX 01370 TAKORADI

OUR REF.................................. YOUR REF...............................

GHANA BAUXITE CO. LTD.
RECEIVED
04 SEP 2017
TAKORADI

THE PORT MANAGER
GHANA BAUXITE CO.
TAKORADI.

31/8/17

Dear Sir

INVOICE – MV FAIR FIELD EAGLE SHIPLOADING LABOUR FROM 14/8/17 TO 28/8/17

We present invoice NO. MG/9/GBC/070 for the above named as detailed below.

NAMES	HOURS WORKED	DAYS WORKED	RATE [GHC]
P. ACKON	6.00 AM-----6.00PM [12]	14/8/17-----28/8/17 [15]	394.50
S. MUAH	6.00 AM-----6.00PM [12]	14/8/17-----28/8/17 [15]	394.50
S. OKYERE	6.00 AM-----6.00PM [12]	14/8/17-----28/8/17 [15]	394.50
J. WALANYO	6.00 AM-----6.00PM [12]	14/8/17-----28/8/17 [15]	394.50
G. ASARE	6.00 AM-----6.00PM [12]	14/8----25/8&27/8—28/8/17[14]	368.20
S. BROWN	6.00 AM-----6.00PM [12]	15/8/17-----28/8/17 [14]	368.20
S. EMYIAM	6.00 AM-----6.00PM [12]	14/8/17-----27/8/17 [14]	368.20
S. KWAKYE	6.00 AM-----6.00PM [12]	15/8/17-----28/8/17 [14]	368.20
K. DARKO	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
P. OKWEISIE	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
G. ACQUAYE	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
K. CUDJOE	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
E.ESSIEN	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
J. AKROMA	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
M. ODOOM	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
T. BERGRAMME	6.00 AM-----6.00PM [12]	15/8/17-----27/8/17 [13]	341.90
P. KWOFIE	6.00 AM-----6.00PM [12]	15/8/--17/8 & 19/8--26/8/17 [11]	289.30
R. AGBEME	6.00 AM-----6.00PM [12]	15/8/--24/8 & 26/8--27/8/17 [12]	315.60
A. APPIAH	6.00 AM-----6.00PM [12]	15/8 & 17/8--24/8 & 26/8--27/8 [11]	289.30
		TOTAL	**6,680.20**

NB: APPLICABLE RATE FROM 01/6/17 IS 17.54 PER 8HRS. AND 26.30GHC PER 12HRS

Please be advised.

Yours faithfully,

JOE MENSAH
[DIRECTOR]

Checked by

Fig. D.6 Invoice of Additional Labour for Ship Loading Operations for MV. Fair Field Eagle Vessel

APPENDIX E

LOAN AMORTISATION SCHEDULE FOR TIPPLING AND SHIP LOADING PLANTS

Table E.1 Loan Amortisation Schedule for Tippling Plant

Loan Amortisation Schedule								
	Enter Values			**Loan Summary**				
	Loan Amount		52363.65	Scheduled Payment		$1,726.45		
	Annual Interest Rate		31.00%	Scheduled Number of Payments		60		
	Loan Period in Years		5	Actual Number of Payments		60		
	Number of Payments per Year		12	Total Early Payments		$0.00		
	Start Date of Loan		27/06/2019	Total Interest		$51,223.12		
	Optional Extra Payments		$0.00	**Lender Name**	Barclays Bank			
Pmt No.	**Payment Date**	**Beginning Balance ($)**	**Scheduled Payment ($)**	**Total Payment ($)**	**Principal ($)**	**Interest ($)**	**Ending Balance ($)**	**Cumulative Interest ($)**
1.	27/06/2019	52,363.65	1,726.45	1,726.45	373.72	1,352.73	51,989.93	1,352.73
2.	27/07/2019	51,989.93	1,726.45	1,726.45	383.37	1,343.07	51,606.56	2,695.80
3.	27/08/2019	51,606.56	1,726.45	1,726.45	393.28	1,333.17	51,213.28	4,028.97
4.	27/09/2019	51,213.28	1,726.45	1,726.45	403.44	1,323.01	50,809.85	5,351.98
5.	27/10/2019	50,809.85	1,726.45	1,726.45	413.86	1,312.59	50,395.99	6,664.57
6.	27/11/2019	50,395.99	1,726.45	1,726.45	424.55	1,301.90	49,971.44	7,966.46
7.	27/12/2019	49,971.44	1,726.45	1,726.45	435.52	1,290.93	49,535.92	9,257.39
8.	27/01/2020	49,535.92	1,726.45	1,726.45	446.77	1,279.68	49,089.15	10,537.07
9.	27/02/2020	49,089.15	1,726.45	1,726.45	458.31	1,268.14	48,630.84	11,805.21
10.	27/03/2020	48,630.84	1,726.45	1,726.45	470.15	1,256.30	48,160.69	13,061.50

11.	27/04/2020	48,160.69	1,726.45	1,726.45	482.29	1,244.15	47,678.40	14,305.66
12.	27/05/2020	47,678.40	1,726.45	1,726.45	494.75	1,231.69	47,183.64	15,537.35
13.	27/06/2020	47,183.64	1,726.45	1,726.45	507.54	1,218.91	46,676.11	16,756.26
14.	27/07/2020	46,676.11	1,726.45	1,726.45	520.65	1,205.80	46,155.46	17,962.06
15.	27/08/2020	46,155.46	1,726.45	1,726.45	534.10	1,192.35	45,621.36	19,154.41
16.	27/09/2020	45,621.36	1,726.45	1,726.45	547.89	1,178.55	45,073.47	20,332.96
17.	27/10/2020	45,073.47	1,726.45	1,726.45	562.05	1,164.40	44,511.42	21,497.36
18.	27/11/2020	44,511.42	1,726.45	1,726.45	576.57	1,149.88	43,934.85	22,647.24
19.	27/12/2020	43,934.85	1,726.45	1,726.45	591.46	1,134.98	43,343.39	23,782.22
20.	27/01/2021	43,343.39	1,726.45	1,726.45	606.74	1,119.70	42,736.65	24,901.92
21.	27/02/2021	42,736.65	1,726.45	1,726.45	622.42	1,104.03	42,114.23	26,005.95
22.	27/03/2021	42,114.23	1,726.45	1,726.45	638.50	1,087.95	41,475.74	27,093.90
23.	27/04/2021	41,475.74	1,726.45	1,726.45	654.99	1,071.46	40,820.75	28,165.36
24.	27/05/2021	40,820.75	1,726.45	1,726.45	671.91	1,054.54	40,148.84	29,219.90
25.	27/06/2021	40,148.84	1,726.45	1,726.45	689.27	1,037.18	39,459.57	30,257.08
26.	27/07/2021	39,459.57	1,726.45	1,726.45	707.07	1,019.37	38,752.50	31,276.45
27.	27/08/2021	38,752.50	1,726.45	1,726.45	725.34	1,001.11	38,027.16	32,277.55
28.	27/09/2021	38,027.16	1,726.45	1,726.45	744.08	982.37	37,283.08	33,259.92
29.	27/10/2021	37,283.08	1,726.45	1,726.45	763.30	963.15	36,519.78	34,223.07
30.	27/11/2021	36,519.78	1,726.45	1,726.45	783.02	943.43	35,736.76	35,166.50
31.	27/12/2021	35,736.76	1,726.45	1,726.45	803.25	923.20	34,933.51	36,089.70
32.	27/01/2022	34,933.51	1,726.45	1,726.45	824.00	902.45	34,109.52	36,992.14
33.	27/02/2022	34,109.52	1,726.45	1,726.45	845.28	881.16	33,264.23	37,873.31
34.	27/03/2022	33,264.23	1,726.45	1,726.45	867.12	859.33	32,397.11	38,732.63
35.	27/04/2022	32,397.11	1,726.45	1,726.45	889.52	836.93	31,507.59	39,569.56
36.	27/05/2022	31,507.59	1,726.45	1,726.45	912.50	813.95	30,595.09	40,383.50
37.	27/06/2022	30,595.09	1,726.45	1,726.45	936.07	790.37	29,659.02	41,173.88
38.	27/07/2022	29,659.02	1,726.45	1,726.45	960.25	766.19	28,698.77	41,940.07
39.	27/08/2022	28,698.77	1,726.45	1,726.45	985.06	741.38	27,713.70	42,681.45

40.	27/09/2022	27,713.70	1,726.45	1,726.45	1,010.51	715.94	26,703.20	43,397.39
41.	27/10/2022	26,703.20	1,726.45	1,726.45	1,036.61	689.83	25,666.58	44,087.22
42.	27/11/2022	25,666.58	1,726.45	1,726.45	1,063.39	663.05	24,603.19	44,750.28
43.	27/12/2022	24,603.19	1,726.45	1,726.45	1,090.86	635.58	23,512.33	45,385.86
44.	27/01/2023	23,512.33	1,726.45	1,726.45	1,119.04	607.40	22,393.28	45,993.26
45.	27/02/2023	22,393.28	1,726.45	1,726.45	1,147.95	578.49	21,245.33	46,571.75
46.	27/03/2023	21,245.33	1,726.45	1,726.45	1,177.61	548.84	20,067.72	47,120.59
47.	27/04/2023	20,067.72	1,726.45	1,726.45	1,208.03	518.42	18,859.69	47,639.01
48.	27/05/2023	18,859.69	1,726.45	1,726.45	1,239.24	487.21	17,620.45	48,126.22
49.	27/06/2023	17,620.45	1,726.45	1,726.45	1,271.25	455.20	16,349.20	48,581.41
50.	27/07/2023	16,349.20	1,726.45	1,726.45	1,304.09	422.35	15,045.11	49,003.77
51.	27/08/2023	15,045.11	1,726.45	1,726.45	1,337.78	388.67	13,707.33	49,392.43
52.	27/09/2023	13,707.33	1,726.45	1,726.45	1,372.34	354.11	12,334.99	49,746.54
53.	27/10/2023	12,334.99	1,726.45	1,726.45	1,407.79	318.65	10,927.20	50,065.19
54.	27/11/2023	10,927.20	1,726.45	1,726.45	1,444.16	282.29	9,483.04	50,347.48
55.	27/12/2023	9,483.04	1,726.45	1,726.45	1,481.47	244.98	8,001.57	50,592.46
56.	27/01/2024	8,001.57	1,726.45	1,726.45	1,519.74	206.71	6,481.83	50,799.16
57.	27/02/2024	6,481.83	1,726.45	1,726.45	1,559.00	167.45	4,922.83	50,966.61
58.	27/03/2024	4,922.83	1,726.45	1,726.45	1,599.27	127.17	3,323.56	51,093.78
59.	27/04/2024	3,323.56	1,726.45	1,726.45	1,640.59	85.86	1,682.97	51,179.64
60.	27/05/2024	1,682.97	1,726.45	1,682.97	1,639.49	43.48	0.00	51,223.12

Table E.2 Loan Amortisation Schedule for Ship Loading Plant

Loan Amortisation Schedule								
	Enter Values			**Loan Summary**				
	Loan Amount		60894.85	Scheduled Payment		$2,007.72		
	Annual Interest Rate		31.00%	Scheduled Number of Payments		60		
	Loan Period in Years		5	Actual Number of Payments		60		
	Number of Payments per Year		12	Total Early Payments		$0.00		
	Start Date of Loan		27/06/2019	Total Interest		$59,568.50		
	Optional Extra Payments		$0.00	**Lender Name**	Barclays Bank			
Pmt No.	**Payment Date**	**Beginning Balance ($)**	**Scheduled Payment ($)**	**Total Payment ($)**	**Principal ($)**	**Interest ($)**	**Ending Balance ($)**	**Cumulative Interest ($)**
1.	27/06/2019	60,894.85	2,007.72	2,007.72	434.61	1,573.12	60,460.24	1,573.12
2.	27/07/2019	60,460.24	2,007.72	2,007.72	445.83	1,561.89	60,014.41	3,135.01
3.	27/08/2019	60,014.41	2,007.72	2,007.72	457.35	1,550.37	59,557.06	4,685.38
4.	27/09/2019	59,557.06	2,007.72	2,007.72	469.17	1,538.56	59,087.90	6,223.94
5.	27/10/2019	59,087.90	2,007.72	2,007.72	481.29	1,526.44	58,606.61	7,750.37
6.	27/11/2019	58,606.61	2,007.72	2,007.72	493.72	1,514.00	58,112.89	9,264.38
7.	27/12/2019	58,112.89	2,007.72	2,007.72	506.47	1,501.25	57,606.42	10,765.63
8.	27/01/2020	57,606.42	2,007.72	2,007.72	519.56	1,488.17	57,086.86	12,253.79
9.	27/02/2020	57,086.86	2,007.72	2,007.72	532.98	1,474.74	56,553.88	13,728.54
10.	27/03/2020	56,553.88	2,007.72	2,007.72	546.75	1,460.98	56,007.14	15,189.51
11.	27/04/2020	56,007.14	2,007.72	2,007.72	560.87	1,446.85	55,446.27	16,636.36
12.	27/05/2020	55,446.27	2,007.72	2,007.72	575.36	1,432.36	54,870.91	18,068.73
13.	27/06/2020	54,870.91	2,007.72	2,007.72	590.22	1,417.50	54,280.68	19,486.22
14.	27/07/2020	54,280.68	2,007.72	2,007.72	605.47	1,402.25	53,675.21	20,888.47
15.	27/08/2020	53,675.21	2,007.72	2,007.72	621.11	1,386.61	53,054.10	22,275.08

16.	27/09/2020	53,054.10	2,007.72	2,007.72	637.16	1,370.56	52,416.94	23,645.65
17.	27/10/2020	52,416.94	2,007.72	2,007.72	653.62	1,354.10	51,763.32	24,999.75
18.	27/11/2020	51,763.32	2,007.72	2,007.72	670.50	1,337.22	51,092.82	26,336.97
19.	27/12/2020	51,092.82	2,007.72	2,007.72	687.82	1,319.90	50,404.99	27,656.87
20.	27/01/2021	50,404.99	2,007.72	2,007.72	705.59	1,302.13	49,699.40	28,959.00
21.	27/02/2021	49,699.40	2,007.72	2,007.72	723.82	1,283.90	48,975.58	30,242.90
22.	27/03/2021	48,975.58	2,007.72	2,007.72	742.52	1,265.20	48,233.06	31,508.10
23.	27/04/2021	48,233.06	2,007.72	2,007.72	761.70	1,246.02	47,471.35	32,754.12
24.	27/05/2021	47,471.35	2,007.72	2,007.72	781.38	1,226.34	46,689.98	33,980.47
25.	27/06/2021	46,689.98	2,007.72	2,007.72	801.56	1,206.16	45,888.41	35,186.62
26.	27/07/2021	45,888.41	2,007.72	2,007.72	822.27	1,185.45	45,066.14	36,372.07
27.	27/08/2021	45,066.14	2,007.72	2,007.72	843.51	1,164.21	44,222.63	37,536.28
28.	27/09/2021	44,222.63	2,007.72	2,007.72	865.30	1,142.42	43,357.32	38,678.70
29.	27/10/2021	43,357.32	2,007.72	2,007.72	887.66	1,120.06	42,469.66	39,798.77
30.	27/11/2021	42,469.66	2,007.72	2,007.72	910.59	1,097.13	41,559.07	40,895.90
31.	27/12/2021	41,559.07	2,007.72	2,007.72	934.11	1,073.61	40,624.96	41,969.51
32.	27/01/2022	40,624.96	2,007.72	2,007.72	958.24	1,049.48	39,666.71	43,018.99
33.	27/02/2022	39,666.71	2,007.72	2,007.72	983.00	1,024.72	38,683.72	44,043.71
34.	27/03/2022	38,683.72	2,007.72	2,007.72	1,008.39	999.33	37,675.32	45,043.04
35.	27/04/2022	37,675.32	2,007.72	2,007.72	1,034.44	973.28	36,640.88	46,016.32
36.	27/05/2022	36,640.88	2,007.72	2,007.72	1,061.17	946.56	35,579.71	46,962.87
37.	27/06/2022	35,579.71	2,007.72	2,007.72	1,088.58	919.14	34,491.13	47,882.02
38.	27/07/2022	34,491.13	2,007.72	2,007.72	1,116.70	891.02	33,374.43	48,773.04
39.	27/08/2022	33,374.43	2,007.72	2,007.72	1,145.55	862.17	32,228.88	49,635.21
40.	27/09/2022	32,228.88	2,007.72	2,007.72	1,175.14	832.58	31,053.74	50,467.79
41.	27/10/2022	31,053.74	2,007.72	2,007.72	1,205.50	802.22	29,848.24	51,270.01
42.	27/11/2022	29,848.24	2,007.72	2,007.72	1,236.64	771.08	28,611.59	52,041.09
43.	27/12/2022	28,611.59	2,007.72	2,007.72	1,268.59	739.13	27,343.00	52,780.22
44.	27/01/2023	27,343.00	2,007.72	2,007.72	1,301.36	706.36	26,041.64	53,486.58

45.	27/02/2023	26,041.64	2,007.72	2,007.72	1,334.98	672.74	24,706.66	54,159.33
46.	27/03/2023	24,706.66	2,007.72	2,007.72	1,369.47	638.26	23,337.20	54,797.58
47.	27/04/2023	23,337.20	2,007.72	2,007.72	1,404.84	602.88	21,932.35	55,400.46
48.	27/05/2023	21,932.35	2,007.72	2,007.72	1,441.14	566.59	20,491.21	55,967.05
49.	27/06/2023	20,491.21	2,007.72	2,007.72	1,478.37	529.36	19,012.85	56,496.40
50.	27/07/2023	19,012.85	2,007.72	2,007.72	1,516.56	491.17	17,496.29	56,987.57
51.	27/08/2023	17,496.29	2,007.72	2,007.72	1,555.73	451.99	15,940.56	57,439.55
52.	27/09/2023	15,940.56	2,007.72	2,007.72	1,595.92	411.80	14,344.63	57,851.35
53.	27/10/2023	14,344.63	2,007.72	2,007.72	1,637.15	370.57	12,707.48	58,221.92
54.	27/11/2023	12,707.48	2,007.72	2,007.72	1,679.45	328.28	11,028.03	58,550.20
55.	27/12/2023	11,028.03	2,007.72	2,007.72	1,722.83	284.89	9,305.20	58,835.09
56.	27/01/2024	9,305.20	2,007.72	2,007.72	1,767.34	240.38	7,537.86	59,075.47
57.	27/02/2024	7,537.86	2,007.72	2,007.72	1,812.99	194.73	5,724.87	59,270.20
58.	27/03/2024	5,724.87	2,007.72	2,007.72	1,859.83	147.89	3,865.04	59,418.09
59.	27/04/2024	3,865.04	2,007.72	2,007.72	1,907.88	99.85	1,957.16	59,517.94
60.	27/05/2024	1,957.16	2,007.72	1,957.16	1,906.60	50.56	0.00	59,568.50

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