

2017197

by Aeron Smitham

Submission date: 15-Dec-2024 12:54AM (UTC+0000)

Submission ID: 246155034

File name: 16679_Aeron_Smitham_2017197_183601_427296267.pdf (1,001.97K)

Word count: 10992

Character count: 63450

Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEL6000 Independent Project
Assignment: 1. Project Definition, Research and Quality Planning
Name: Aeron Smitham
University number: 2017197
Date submitted: 14/12/2024
Word count: 3924

An excellent report in every way Thoroughly researched, very detailed Clearly thought out solutions, correctly chosen final solution All aspects of wider issues considered with constraints and standards. Excellent evidence of management techniques used.

Table of Contents

Table of Figures.....	4
Table of Tables.....	5
Table of Equations	5
1. Executive Summary.....	6
2. Introduction	7
3. Project Background and Problem Definition and Constraints.....	8
3.1. Problem Background	8
3.2. Problem Definition	8
3.3. Constraints.....	9
3.3.1. Ethical Engineering	9
3.3.2. Sustainability.....	10
3.3.3. Legal/Commercial Requirements	11
4. Functional Design Specification and Test Plan.....	12
4.1. Functional Design Specification	12
4.2. Test Plan	15
5. Literature Review and Choice of Final Solution.....	19
5.1. Solution 1.....	19
5.2. Solution 2.....	21
5.3. Solution 3.....	22
5.4. Comparison.....	23
6. Project Planning, Work Breakdown and Management Techniques	25
6.1. Work Breakdown Structure	25
6.2. Gantt Chart	25
6.3. Costing Spreadsheet	26
6.4. Risk Assessment.....	26
7. Conclusions and Recommendations	27
8. References	29
9. Appendix	33
9.1. Project Proposal.....	33
9.2. Constraints.....	34
9.2.1. Ethical Engineering	34
9.2.2. Sustainability.....	35
9.2.3. Legal/Commercial	37
9.3. Risk Assessment for Implementation Phase	38
9.3.1. Risk Assessment Key	38

9.3.2.	Miller 3 Risk Assessment.....	39
9.4.	Comparison Table of Solutions.....	41
9.5.	Scoring Matrix for Solutions	42
9.6.	WBS Chart.....	44
9.7.	Gantt Chart	45
9.8.	Costing Spreadsheet	46
9.9.	Log Entries	48

Table of Figures

Figure 1 – Solution 1 Block Diagram 20

Figure 2 – Solution 2 Block Diagram 21

Figure 3 – Solution 3 Block Diagram 22

Figure 4 – Radar Diagram Comparison 23

Figure 5 – Graph detailing at risk jobs from automation (Office for National Statistics, 2019) 34

Figure 6 – The 17 Goals (Department of Economic and Social Affairs, 2024) 36

Figure 7 – Risk Assessment Key 38

Figure 8 – Wiring of 690+ Parker VFD (Parker, 2012) 43

Figure 9 - WBS.....44

Figure 10 – Gantt Chart.....45

Table of Tables

Table 1 – FDS Key 12

Table 2 – FDS Document 14

Table 3 – Test Plan 18

Table 4 – Block diagram key.....19

Table 5 – Preferred Manufacturers List 35

Table 6 – PLr Rating.....37

Table 7 – Implementation Risk Assessment 40

Table 8 – Solution Comparison Table 41

Table 9 – Scoring Matrix 42

Table 10 – Solutions Cost Comparison.....42

Table 11 – Costing Spreadsheet.....47

Table of Equations

Equation 1 – Expected Time Equation 25

1. Executive Summary

The Miller 3 ICS Upgrade project addresses operational, safety, and sustainability challenges at a titanium products manufacturing site. The project aims to modernise the mothballed Miller 3 duplex milling machine by replacing its faulty hydraulic-driven table feed with an electric motor-driven system and upgrading its legacy relay-based control system to a modern PLC and HMI configuration. This upgrade aligns with the company's goal of standardising control systems and enhancing productivity while maintaining compliance with current industry standards.

A comprehensive FDS has been developed, detailing system performance, diagnostics, safety, and environmental requirements. Three potential solutions were evaluated: DC drive, AC drive, and AC servo drive systems. A structured comparison based on criteria such as reliability, precision, cost, and sustainability identified the AC servo drive system as the optimal choice due to its superior performance, precision control, and minimal maintenance requirements despite higher initial costs.

The project design follows ethical engineering principles, including addressing job security concerns and ensuring operator involvement in the design process. Sustainability has been enhanced by reusing replaced components as spares and standardising new parts, minimising waste, and simplifying maintenance. Additionally, legal and safety compliance has been ensured by adhering to the latest Machinery Directive and BS EN standards.

Project management methodologies have been planned which include a detailed WBS, a Gantt chart with three-point estimation for task timelines, and a comprehensive risk assessment. With a project budget of £50,000, all components and labour costs have been accounted for, leaving contingency funds for unforeseen expenses.

The project ensures a sustainable, compliant, and efficient milling operation through modernised control systems, improved diagnostics, and enhanced operator usability, contributing to the company's long-term operational success.

This is the correct way to write a summary that contains all aspects of the project.

2. Introduction

This report will outline the completion of key engineering tasks undertaken as part of the industrial project, focusing on the control system upgrade of an industrial milling machine. The project's primary aim is to apply engineering principles, project management techniques, and technical problem-solving skills to modernise the machine's control system and address persistent mechanical issues.

There will be key tasks including defining the project's technical problem, conducting in-depth research, and evaluating potential solutions based on industry standards. A comprehensive FDS will be developed to detail system requirements, followed by creating a test plan to verify the machine's performance and reliability.

The report will involve a detailed literature review comparing motor control technologies, ultimately selecting a servo-driven system for precise and reliable operation. Project planning tools such as a WBS, Gantt chart, and budget management techniques will be used to ensure timely and cost-effective completion.

Throughout the process, ethical engineering principles, sustainability, and compliance with regulatory standards will be considered. The report will conclude with recommendations for future improvements, and reflections on the outcomes that have been decided during the machine's upgrade.

A good introduction outlining the contents of the report

3. Project Background and Problem Definition and Constraints

3.1. Problem Background

Miller 3 is a duplex milling machine in the site Machine Centre where there are eight milling machines, five are duplex type and three gantry type. Three of the five duplex machines perform the same task and process the same products, Miller 3 being one of these.

Due to the order book for these products being reduced over the last few years, only two machines were required to complete these orders, and as the machine had recurring faults it was mothballed. When the machine was in use, too much time was spent on fault finding, but due to an upturn in orders, the machine is now required in production and hence the need to reduce the maintenance time.

3.2. Problem Definition

The machine has 7 hydraulic directional-control-valves (DCVs) and a hydraulic motor. The DCVs control the clutches, clamps and position of the two milling heads, while the hydraulic motor controls the table which feeds the product into the fixed milling heads. The main cause of the faults has been identified as a leak within the hydraulic system. Scavenger pumps have been employed to return the leaking oil back to the tank, but this has not been successful. Due to this, the oil tank must be repeatedly filled up causing an increased cost to the business. The oil is also leaking onto the walkway, causing a slip hazard.

The source of the leak has been attributed to the hydraulic motor that controls the table feed, and as such, this must be replaced with an electrically driven motor. As the position and speed of the table feed is critical to the process, a servo drive could be an option for the task, and also as the company has servo drives controlling similar functions in the Machine Centre.

There is also an engineering policy to begin upgrading legacy machine control systems and standardising the PLCs and HMIs across the site. As the machine is controlled via relay logic and push buttons, this will make it easier for the operators, better troubleshooting aides for maintenance staff, data acquisition to the site data logger and historian, and reduce the number of spares held in the stores.

This problem, along with the hydraulic fault, makes a good case for a control system upgrade which could, as one of a number of potential solutions, feature a PLC, HMI and motor drive unit. This will increase the complexity of the machine.

3.3. Constraints

3.3.1. Ethical Engineering

Ethical engineering introduces constraints to a project by prioritising considerations other than just the functionality of the machine. Some of these constraints include the safety of the machinery, environmental responsibility, and fairness.

The machine oil leak poses a significant environmental and health hazard. Ethically, this violates principles of employee safety, public safety, and company integrity (Drinking Water Inspectorate, 2020). The continuous leakage could contribute to water contamination, as there are drains to the site effluent plant which treats the water from the main plant before releasing it to the public sewage works. But it is not equipped for oil contamination – resulting in oil contaminated water being discharged by the company and could result in fines or imprisonment (Water Resources Act, 1991). The oil could also potentially soak into the ground around the machine and could leach through plastic water pipes and contaminate drinking water (Wessex Water, 2020). The oil leak must be rectified within this project to overcome the ethical constraints.

As the project includes replacing the control system, there may be concerns from the operators that this is a new automation and their job may be at risk. According to the Office for National Statistics (2019), 63.73% of metal working machine operatives jobs are at risk of automation. This concern can be addressed by involving the operators in the design process and to inform them that their role will remain much the same, and the upgraded control system will be utilised to make the operators' job easier, rather than replace it. Figure 5 in section 9.2.1 of the appendix shows the graph detailing the jobs most at risk of being replaced by automation, with machine operatives shown as the second most likely sector as a whole, with metal working machine operatives highlighted as one of the most at risk specific jobs.

As the machine is being modified, an ethical decision must be made to adhere to the relevant regulations regarding machinery safety. The project could be completed and the machine function as previous, with no regard given to the safety of the machinery but this would be ethically wrong, as well as legally, as it could lead to an injury to the operator or maintenance personnel. According to the Machinery Directive (2019), when upgrading a machine, a risk assessment must be conducted to ensure the changes meet the directives essential health and safety requirements, and if there are substantial changes considerations must be made to bring the machine up to standard, which could include adding guarding to the machine, which could cause hassle to the operator and slow down production but would be the morally correct option.

3.3.2. Sustainability

As part of the project, a significant amount of equipment will be replaced, with these used parts added back into the site stores as common spares for other machinery. The replacement parts will all be common spares from across the site to reduce the amount of different inventory kept in the site stores, with the goal to only use one manufacturer for each component. In the site electrical standard document, the preferred manufacturer list is detailed for each component, which can be seen in table 5 in section 9.2.2 of the appendix.

Several of the preferred manufacturers are also ranked as some of the most sustainable companies in the world. For instance, Schneider Electric were voted the most sustainable company in the world in 2024 (TIME, 2024). Schneider follow the United Nations Sustainable Development Agenda, which includes a pledge to aim towards 17 goals before 2030 that will transform the world, for people and the planet (United Nations, 2024). The 17 goals can be seen in figure 6 of section 9.2.2 in the appendix.

In the same list created by TIME, Siemens – another preferred manufacturer – were ranked as the 11th most sustainable company in the world (TIME, 2024). Siemens are ranked consistently as one of the leaders in global Environmental and Governance (ESG) lists, being ranked in the top 1% of all companies assessed (Siemens, 2024).

For the majority of the components required for this project, the preferred manufacturer is either Schneider or Siemens, ensuring the project meets its sustainability goals.

As mentioned in the ethics section, the frequent oil spills are also a sustainability concern. The 100L hydraulic tank needed to be replenished weekly when the machine was in operation, costing around £250.00. An investigation will need to be undertaken to confirm the hydraulic motor is the sole source of the leak. If there are other sources of leaks, then the project scope will change – otherwise the sustainability constraints will continue.

3.3.3. Legal/Commercial Requirements

The machine has operated as it was first installed, but as the control system is being upgraded, a review of the safety system should be undertaken. As the machine was installed many years ago, it is likely that the system would not meet the latest standards and regulations. The Health and Safety Executive states that, "The extent of the changes made to the original machinery, together with its pro Correctly cited result in new legal obligations on the owner, user or person undertaking such work" (2024). If methods of controlling a machine are replaced, then it may be considered a 'new' machine, and as such, a conformity assessment must be undertaken and all relevant regulations met (Supply of Machinery Safety Regulations, 2008).

As part of the machinery safety assessment, the required performance level (PLr) of the safety related functions must be determined (BS EN ISO 13849-1, 2015). Table 6 in section 9.2.3 of the appendix details the PLr for three hazards that have been identified. Hazard 1 requires guarding to stop access to the rotating cutting heads of the machine with a PLr of c. Hazard 2 requires guarding to prevent personnel coming into contact with the moving parts of the bed, while hazard 3 is the same but with the moving parts of the head, with both given a PLr of d. A risk assessment can be seen in section 9.3.2 of the appendix which has evaluated the risks associated with the machinery, with risk reduction measures given (BS EN ISO 12100, 2010).

A commercial constraint for this type of project is usually the long lead time Punctuation Error is such as PLCs, HMIs, VFDs, servo drives, and other electronic components (Financial Times, 2023). Spelling to the glob Spelling conductor shortage between 2020 and 2023 (Forbes, 2024), the companies' policy was too stock as many components with long lead times as possible. As such, many of the components needed for this type of upgrade are available in the site stores. Any of the parts that are not stocked in the site stores will be ordered at the first opportunity to ensure the project can be delivered on time.

4. Functional Design Specification and Test Plan

4.1. Functional Design Specification

A Functional Design Specification (FDS) table has been created to document all the requirements of the project to be deemed a success. The FDS comprises 8 types of deliverables which can be seen in table 1.

FDS Table Key	
Code	Description
A	Appearance
B	Diagnostics
C	Documentation
D	Environmental
E	Ergonomics
F	Measurables
G	Performance
H	Safety

Table 1 – FDS Key

Table 2 shows the FDS reference, the design requirement and its reference document.

Functional Design Specification		
FDS Reference	Design Requirement	Reference
A.1	Operator Station to be sheet steel finished to colour RAL 7035	Company Electrical Specification
A.2	Operator Station to be Rittal AX Command panel with handle strips	Company Electrical Specification
A.3	Symbols and colours of panel actuators and LEDs to follow BS EN 60204-1:2018	BS EN 60204-1:2018
A.4	Engraved labels to be used for all devices mounted on panel doors or operator stations	Company Electrical Specification
A.5	Panel wiring colours in accordance with BS EN 60204	BS EN 60204-1:2018

A.6	All wiring to have the same identification at each end of the wiring	Company Electrical Specification
A.7	All wiring to have colour coded chevron type cable markers at each end of the wiring	Company Electrical Specification
A.8	All field cabling to have cable number identification	Company Electrical Specification
B.1	Live alarms to be displayed to operator and logged	Customer Requirement
B.2	Historical alarms to be displayed to operator and logged	Customer Requirement
B.3	Alarm siren and beacon to notify operator of live alarm	Customer Requirement
B.4	Displayed alarms to come with information on how to rectify fault	Customer Requirement
C.1	Electrical schematics to be provided in pdf and .dwg format	Company Electrical Specification
C.2	Declaration of Conformity to be provided	Company Electrical Specification
C.3	O&M manual, Risk Assessment, Safety Function Performance Level (PL) Calculations, Cable Schedule, and FDS to be provided	Company Electrical Specification
D.1	Electrical parts must be in the Company Electrical Specification to reduce number of spares held in stores	Company Electrical Specification
D.2	Sources of energy must be automatically turned off after a period of inactivity	Customer Requirement
E.1	Operator station must be above 1.5m	BS EN 60204-1:2018
F.1	Table speed when milling must be 10m/s	Customer Requirement
F.2	Table speed in rapid must be 100m/s	Customer Requirement
F.3	Milling cutters must rotate at 30rpm	Customer Requirement

F.4	Coolant flow must be above 20L/min	Customer Requirement
F.5	Vacuum must be less than -700psi	Customer Requirement
F.6	Spindle clutch hydraulic pressure must be above 1 bar	Customer Requirement
G.1	All motors must be able to be started automatically and manually	Customer Requirement
G.2	Table must have a rapid speed and running speed	Customer Requirement
G.3	Vacuum, coolant flow, and hydraulic pressure must be present before milling cutter motors can start	Customer Requirement
G.4	A sounder must alarm if vacuum is lost or coolant flow is insufficient	Customer Requirement
H.1	Emergency stop shall stop all operations and inhibit any start commands	BS EN 13850:2008
H.2	Emergency stops shall be located at the operator station and control panel, as well as other applicable locations in the cell where the operator will work	BS EN 13850:2008
H.3	Operation cannot be restarted after an emergency stop until the reason has been cleared and system reset	BS EN 13850:2008

Table 2 – FDS Document (BS EN 60204-1, 2018) (BS EN ISO 13850, 2008)

4.2. Test Plan

Table 3 below shows the test plan that will be used as part of the implementation of the project to prove the deliverables have been met. These are a mix of conformity checks and functional tests. The conformity tests are checking, for example, that the correct colours have been used, while the functional tests are checking if the motors are going the correct speed.

Test Plan					
Test No.	FDS Reference	Description of Test	Expected Outcome	Actual Outcome	Pass/Fail
1	A.1	Operator station must be made of sheet steel finished to colour RAL 7035	Operator station is made of sheet steel finished to colour RAL 7035		
2	A.2	Operator station must be Rittal AX Command panel with handle strips	Operator station is Rittal AX Command panel with handle strips		
3	A.3	Symbols and colours of panel actuators and LEDs must follow BS EN 60204-1:2018	• All 'Start' push buttons are coloured white • All 'Stop' push buttons are coloured black • The 'Reset' push button is coloured blue.		
4	A.4	All switches and indicators must have engraved labels matching the ID in electrical schematics	Engraved labels used for all devices mounted on panel doors and operator stations		
5	A.5	Panel wiring colours in accordance with BS EN 60204	• Check 24VDC wiring is coloured blue • Check 110VAC wiring is coloured red		

				Check AC power cabling is coloured black				
6	A.6	Each individual wire must have the same identification at each end, i.e. if a wire has L1 at one end, check it also has L1 at the other.		All wiring has the same identification at each end of the wiring				
7	A.7	All wiring must have colour coded chevron type cable markers to identify it.		All wiring to have colour coded chevron type cable markers at each end of the wiring				
8	A.8	All field cabling must have cable number identification which matches the cable schedule.		All field cabling to have cable number identification				
10	B.1	All live motor circuit breaker tripped alarms to be displayed to operator. I.e. "Motor Circuit Breaker -1Q1 has tripped"		Live alarms displayed to operator				
11	B.2	All motor circuit breaker tripped historical alarms to be displayed to operator. I.e. "Motor Circuit Breaker - 1Q1 has tripped"		Historical alarms displayed to operator				
12	B.3	Alarm siren and beacon activates when there is a live motor circuit breaker tripped alarm.		Alarm siren and beacon to notify operator of live alarm when a motor circuit breaker has tripped				
13	B.4	Motor circuit breaker tripped alarms to come with prompts on how to rectify fault. I.e. "Reset -1Q1 Motor Circuit Breaker"		Prompt appears with each alarm on how to rectify fault				

You could have explained better how to carry out some of these tests so that another person could do them

14	C.1	Schematics must be provided in pdf .dwg format	Electrical schematics to be provided in pdf and .dwg format			
15	C.2	Declaration of Conformity must be completed and provided	Declaration of Conformity to be provided			
16	C.3	Technical File must be provided to site Electrical Engineer	O&M manual, Risk Assessment, Safety Function Performance Level (PL) Calculations, Cable Schedule, and FDS provided to site Electrical Engineer			
17	D.1	Parts used in project must conform with the Company Electrical Specification	Electrical parts must be in the Company Electrical Specification to reduce number of spares held in stores			
18	D.2	Test that all motors turn off after 15 minutes of inactivity	All motors must be automatically turned off after a period of 15 minutes of inactivity			
19	E.1	Operator station must be above 1.5m from the ground	Operator station must be above 1.5m			
20	F.1	Test that table speed is 10m/s when milling with a handheld Tacho	Table speed when milling must be 10m/s			
21	F.2	Test that table speed is 100m/s when in rapid with a handheld Tacho	Table speed in rapid must be 100m/s			
22	F.3	Test that milling cutters are rotating at 30rpm with a handheld Tacho	Milling cutters must rotate at 30rpm			
23	F.4	Test that coolant flow is above 20L/min on the IFM SM8000 sensor	Coolant flow must be above 20L/min			
24	F.5	Test that vacuum is less than - 700psi on the IFM PN 2092 sensor	Vacuum must be less than -700psi			

How are you going to measure linear speed with a tacho?

25	F.6	Test that spindle clutch hydraulic pressure is above 1bar on the IFM PN2099 sensor	Spindle clutch hydraulic pressure must be above 1bar			
26	G.1	Test that all motors can be jogged via push buttons and set to constantly run	All motors can be jogged and set to constantly run			
27	G.2	Test the rapid and operation speed of the table	Table must have a rapid speed and operation speed			
28	G.3	Test that the milling cutters cannot be started without vacuum, coolant flow and hydraulic pressure at or above their setpoints	Vacuum, coolant flow, and hydraulic pressure must be present before milling cutter motors can start			
29	G.4	Test the sounder alarms when vacuum is above -700psi or coolant flow is less than 20L/min	A sounder must alarm if vacuum is lost or coolant flow is insufficient			
30	H.1	Test that an emergency stop, stops all operations and inhibits any start commands	Emergency stop shall stop all operations and inhibit any start commands			
31	H.2	Check that an E-Stop has been mounted on operator station, control panel and junction box	Emergency stops shall be located at the operator station, control panel, and at junction box			
32	H.3	Test that the machine operation cannot be restarted until alarms are cleared and the system has been reset	Operation cannot be restarted after an emergency stop until the reason has been cleared and system reset			

Table 3 – Test Plan

5. Literature Review and Choice of Final Solution

Three solutions have been researched in order to meet the requirements of the FDS with their accompanying block diagrams which give the overview layout of each solution. Table 4 provides a key to the colours used in each block diagram.

Key	
Red	Digital IO
Orange	Encoder Signal
Black	Power
Green	Profinet
Blue	Ethernet

Table 4 – Block diagram key

5.1. Solution 1

Solution 1 consists of a DC motor and drive to control the 'Table Feed' of the milling machine. DC motors are well-suited for applications requiring high torque at low speeds, which is critical for precise control of the milling machine's table feed (Krishnan, 2001). The speed of the motor will be controlled by a Parker 590+ drive and will have a rapid speed and an operation speed. An incremental rotary encoder will provide feedback for position control, which will require an optional encoder module added on to the drive (Parker, 2014).

The control of the motor will be via Parkers drive software, DSE Lite. The position control loop will utilise the data from the encoder and set a zero value at the start position of the 'Table Feed', by the switching of a home reference limit switch, and an end value once the table has travelled the required distance and the encoder value has been reached (Parker, 2024). The speed control loop will be set up to drive at the two speeds, rapid and operation, by two digital inputs on the drive. There are 3 digital inputs on the drive, terminals C6-C8, which can be configured in the DSE Lite software to suit the application. In this instance, terminal C7 will be the input for operation speed, while terminal C8 will be configured for the input for rapid speed (Parker, 2024).

The DC drive is integrated with a Siemens S7-1215F PLC, which will output rapid and operational speed signals to the drive, from the onboard I/O of the PLC which has 14 DI, 10 DQ, 2 AI, and 2 AQ (Parmley Graham, 2024). Operators interact with the system via a Siemens Comfort TP1200 HMI, which will have soft switches for rapid and operational speed, with the rapid speed only working when the rapid soft switch is depressed (Siemens, 2024).

A Siemens ET200SP remote I/O unit will be used in the operator station to also allow for hardwired push button inputs for control of the table feed speeds, as the HMI can become

faulty if the same area is repeatedly pressed, and as some operators prefer the feel of a physical push button (Bacidore, 2018). The remote I/O unit, Siemens power monitor, HMI, and PLC will communicate via ProfiNet, as it is the most advanced industrial ethernet solution (Profinet, 2024). A spare ProfiNet port on the PLC will be used for connection to the site network for remote connection and communication with the site data acquisition software for historical logging of data, as the two ProfiNet ports can have different IP addresses (Siemens, 2024).

While this solution is relatively simple and cost-effective, it has limitations in reliability due to the maintenance requirements of the DC motor's brushes and commutator (Drury & Hughes, 2019).

The block diagram can be seen for solution 1 in figure 1.

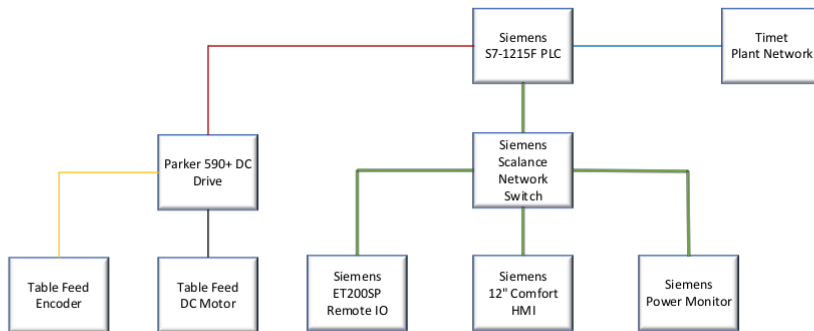


Figure 1 – Solution 1 Block Diagram

5.2. Solution 2

In this configuration, an AC induction motor is paired with a Parker 690+ variable frequency drive (VFD). The VFD controls motor speed and direction by adjusting the frequency and voltage supplied to the motor, making it suitable for applications requiring variable speeds. A rotary encoder provides feedback to the drive, ensuring accurate table feed positioning and speed (Drury, 2001).

The control of the AC motor will be via Parkers drive software, DSE Lite. As with the previous solution, the position control loop will utilise the data from the encoder and set a zero value at the start position of the 'Table Feed', by the switching of a home reference limit switch, and an end value once the table has travelled the required distance and the encoder value has been reached (Parker, 2024). The speed control loop will be set up to drive at the two speeds, rapid and operation, by two digital inputs on the drive. In this solution, the jog and start parameters will be used as rapid and operation speeds, respectively. Terminal 12 will be used for operation, and terminal 16 will be used for rapid (Parker, 2012). An example of the wiring for this can be seen in figure 8 of appendix section 9.5.

The hardwired signals between the PLC and VFD will be similar to solution 1, as well as the whole ProfiNet system, including the HMI, remote I/O, power monitor, and connection to the plant network.

This solution is reliable and energy-efficient, aligning with sustainability requirements. Its lower complexity makes it easier to program and maintain. However, the solution lacks the precision of the other systems, which makes it unsuitable for extremely fine control required in some milling applications (CNC Lathing, 2021).

The block diagram for solution 2 can be seen in figure 2.

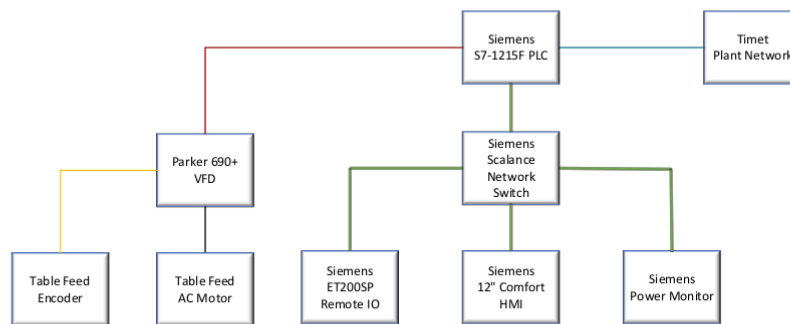


Figure 2 – Solution 2 Block Diagram

5.3. Solution 3

The most advanced of the three, this solution employs an AC servo motor controlled by a Stober SDS500 servo drive. Servo systems are designed for applications requiring high precision and rapid responsiveness, making this configuration ideal for controlling the milling machines table feed. The servo drive uses a high-resolution encoder for continuous feedback, enabling precise table positioning and speed adjustments (Stober, 2016).

The Siemens S7-1215F PLC communicates with the servo drive via digital signals as in the other solutions. The PLC will output rapid and operation signals to the digital inputs of the drive, and will also send a signal to the drive to tell it that the table feed is in the home position, once a reference home limit switch has been actuated, zeroing the servo motor and encoders position. The servo drive will be set up to travel a 2m distance, and once the equivalent encoder count has been reached, the drive will send a digital output to the PLC and the table will reverse back to the home position. These servo drive parameters can be set up using Stobers POSITool software (Stober, 2013)

This solution excels in reliability and performance, with minimal maintenance requirements and optimized energy efficiency. Despite its higher complexity and cost, the servo systems superior precision and adaptability make it a good choice for meeting the functional and operational needs of the milling machine.

The block diagram for solution 3 can be seen in figure 3.

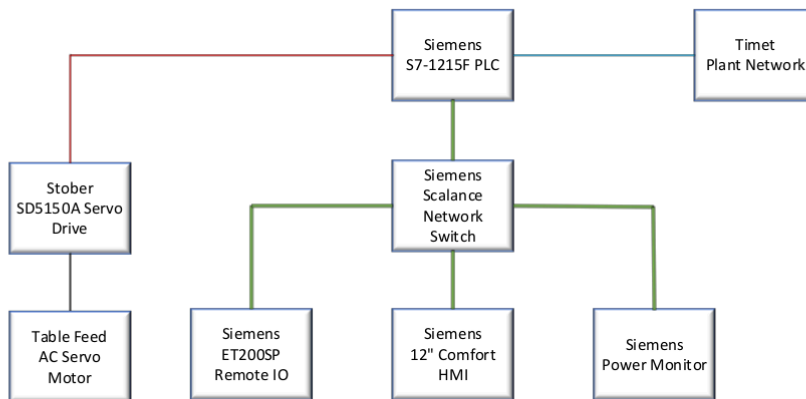


Figure 3 – Solution 3 Block Diagram

5.4. Comparison

Each solution meets the requirements of the FDS, proving to be a suitable option for the table feed drive modification. All three solutions have a form of motor speed control that would perform adequately. The VFD in solution 2 would be the lowest cost option and the easiest to implement, while the DC drive of solution 1 would also be an easily implemented and cost-effective solution as the author has experience using them, and they are readily available from the site stores. The AC servo drive of solution 3 is the industry standard regarding position control and are used in other similar processes throughout the site. Table 8 in section 9.4 of the appendix compares each solution against criteria which will be used to identify the most suitable option.

To aid with choosing the most appropriate solution, a scoring matrix was tabulated to give a value to each criterion in table 8, on a scale of 1 – 3, with 3 being the most appropriate, and 1 the least. The scoring matrix can be seen in table 9 in section 9.5 of the appendix.

From the scoring matrix, a radar diagram has been produced to visualise the scores of the three solutions. The radar diagram can be seen in figure 4.

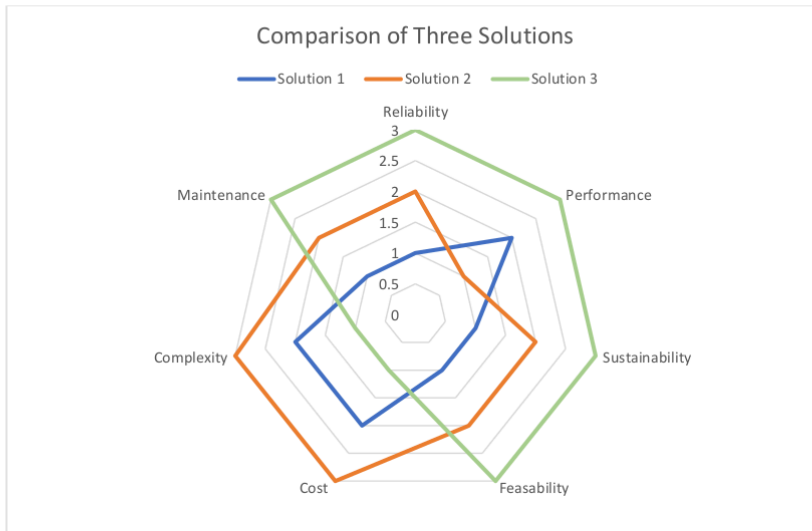


Figure 4 – Radar Diagram Comparison

From figure 4, it is clear that Solution 3 is the best option, as it scored best in 5/7 of the criteria. As can be seen in the scoring matrix, Solution 3 scored 17/21, far higher than the other options. Solution 3 scored poorly in complexity, due to the advanced control systems and precision

feedback which is required of servo drives when compared with the other solutions. It also had the lowest score in the cost criteria.

Solution 1 scored poorly throughout, never being the best option in any of the criteria and having the lowest total score of 10/21. The reliability, sustainability, feasibility, and maintenance of a DC drive and motor were the main contributing factor to the solutions poor score. DC drives used to be the most popular form of motor control in industry, but due to the advancements performance of AC induction motors and VFDs, they have largely been replaced as there are reliability issues with DC motors due to the maintenance requirements of the carbon brushes and commutator. The DC motor is also less sustainable than the other options due to the higher energy consumption and wearable parts of the machine. The feasibility of this solution for a low speed, high torque application would be good, but due to the rapid changes in speed and direction required this makes it the least feasible option of the three.

Solution 2 scored well in the majority of the criteria, with a total of 15/21, but was beaten by Solution 3 in 5/7 of the criteria. The AC motor and drive only scored poorly in the performance criteria, as even though it is suitable for speed control, it is not ideal for high precision position control. It was the best option for complexity and cost, as the author has experience programming VFDs and AC motors are cheap and readily available when compared with the other solutions.

Cost and complexity are important factors to consider when choosing the equipment for an application, but as Solution 3 scored highest in all other criteria, it is obvious that this option is the correct solution for the application.

A comparison of cost between the three solutions can be seen in table 10 in section 9.5 of the appendix.

This is a good choice

6. Project Planning, Work Breakdown and Management Techniques

6.1. Work Breakdown Structure

A WBS has been developed for the project, with three levels of deliverables. The first level is the overall project, with the second level splitting the deliverables into three sections: design, build, and implementation. These sections are broken down further into the third level, which highlights each significant task.

The WBS can be seen in figure 9 of section 9.6 of the appendix. The first level has been highlighted blue, second level highlighted red, and the third level tasks highlighted orange. Each deliverable in the third level has been given a reference number which is used to cross reference with the Gantt chart in the next section.

6.2. Gantt Chart

The deliverables set out in the WBS are then used to create a Gantt chart. Each task has its corresponding WBS reference, person assigned to the task, start and expected end dates, number of weekdays spent working on each task, its status, and percentage done indicator. The project Gantt chart can be seen in figure 10 of section 9.7 of the appendix.

Depending on the status and % done data, the colour of the bar chart will change. The planned duration of each task is in light green, with a milestone indicator at the end of task. If the milestone is met on time, the milestone block will turn orange, and the other weeks will turn dark green. If the task overruns the expected end date, all the blocks for that task will turn red.

The Gantt chart shows an expected end date of 21/04/2025. A contingency has been allowed for each task with the “Three Point Estimation” management technique utilised. This technique uses an optimistic (O), most likely (M), and pessimistic (P) time estimate to work out the expected time of the task, which can be seen in equation 1. The expected and pessimistic time difference can then be used as a contingency estimate (Project Management Info, 2024).

$$Expected\ Time = \frac{O + 4M + P}{6}$$

Equation 1 – Expected Time Equation

6.3. Costing Spreadsheet

The costing spreadsheet for the project can be seen in table 11 of section 9.8 of the appendix. The total cost of parts and labour are shown, with part numbers, suppliers, and quantity required. The total cost equates to £25,126.55, well within the £50,000.00 budget. This leaves sufficient contingency in case of parts that have been missed and allows for extra labour to be provided if required.

6.4. Risk Assessment

A risk assessment was carried out for the implementation phase of the project with 6 hazards identified that will be rectified as part of this project. The control measures to be implemented will ensure the risk levels of each hazard will be reduced to negligible. The risk assessment key can be seen in figure 7 in section 9.3.1 of the appendix. While the risk assessment can be seen in table 7 in section 9.3.2 of the appendix.

7. Conclusions and Recommendations

The Miller 3 ICS Upgrade project represents a comprehensive approach to resolving critical operational challenges while aligning with the company's strategic goals of standardising machinery. This project's successful execution will enable the organisation to reintegrate a previously mothballed milling machine into production, addressing issues with the hydraulics and ensuring compliance with modern standards. Through an assessment of technical and operational requirements, the proposed solutions have been designed to meet the FDS criteria while considering ethical, legal, and sustainability constraints.

The evaluation of three potential solutions - DC drive, AC drive, and AC servo drive systems - highlighted the strengths and limitations of each approach. While all options demonstrated the capability to meet the project's requirements, the AC servo drive system was clearly the most robust choice. It offers superior precision, reliability, and efficiency, aligning closely with the FDS objectives for performance, diagnostics, and environmental sustainability. Although the AC servo solution has higher upfront costs and complexity, its advanced capabilities justify the investment, particularly as the application requires high precision and rapid response.

The project's design phase will incorporate ethical engineering principles, addressing potential concerns about automation's impact on job security and ensuring operator inclusion in the design process. This proactive approach will foster transparency and collaboration, reinforcing the organisation's commitment to ethical practices. Furthermore, the project will adhere to the latest safety regulations, such as the Machinery Directive and BS EN and ISO standards, ensuring compliance and safeguarding personnel during operation. Hazards have been identified which will be rectified in the implementation stage, with three hazards given a PLR of c, d, and d.

From a planning perspective, the WBS and Gantt chart provide clear deliverables, ensuring a structured and efficient workflow. This approach will reduce the risk of delays and ensure alignment with the company's goal of completing the project by April 2025.

The sustainability focus of the project is particularly noteworthy. By recycling replaced components as spares and standardising new parts across the site, the project will minimise waste and align with the company's environmental policies. The parts used will all conform to the company's electrical specification, ensuring maintenance personnel will be experienced and competent on the equipment. The use of companies, like Schneider and Siemens, who have a proven commitment to sustainable business practices ensure the project has a positive impact on environmental, societal, and economic issues.

Moving forward, some recommendations would be to ensure the Gantt chart is followed and updated weekly to ensure the deliverables remain on track. The logbook should be utilised to ensure that any issues and noteworthy information is logged for future reference throughout the implementation phase.

A further recommendation would be to utilise time during the PLC programming activity to allow for simulation in the PLC program. This will ensure the code can be validated by virtual commissioning, before starting the actual commissioning, significantly reducing system start up time (Shomroni, 2015).

Excellent conclusions and recommendations

8. References

Anderson, G., 2013. *Variable Frequency Drives: Installation & Troubleshooting*. 1st ed. s.l.:Amazon.

Bacidore, M., 2018. *Get Physical with Buttons*. [Online]

Available at: <https://www.controldesign.com/displays/hmi/article/11311768/machine-input-get-physical-with-buttons>

[Accessed 03 11 2024].

BS EN 60204-1, 2018. *Safety of Machinery - Electrical equipment of machines*, s.l.: BSI.

BS EN ISO 12100, 2010. *Safety of Machinery - General principles for design - Risk assessment and risk reduction*, s.l.: BSI.

BS EN ISO 13849-1, 2015. *Safety of Machinery - Safety related parts of control systems*, s.l.: BSI.

BS EN ISO 13850, 2008. *Safety of machinery - Emergency stop - Principles for design*, s.l.: BSI.

CNC Lathing, 2021. *What Are Factors Affecting Milling Machining Accuracy & How To Fix*. [Online]

Available at: <https://www.cnclathing.com/guide/what-are-factors-affecting-milling-machining-accuracy-how-to-fix-cnclathing>

[Accessed 04 11 2024].

Cox, J., 2003. *Electric Motors*. 11th ed. Dorset: Special Interest Model Books.

Department of Economic and Social Affairs, 2024. *The 17 Goals*. [Online]

Available at: <https://sdgs.un.org/goals>

[Accessed 01 11 2024].

Drinking Water Inspectorate, 2020. *Oil, Fuel and other Hydrocarbons*. [Online]

Available at: <https://dwi.gov.uk/oil-fuel-and-other-hydrocarbons/#:~:text=If%20you%20notice%20a%20fuel%20or%20petrol%20type,use%20oil%20for%20heating%20and%20have%20storage%20tanks>

[Accessed 06 11 2024].

Drury, B., 2001. *The Control Techniques Drives & Controls Handbook*. 1st ed. Cambridge: The Institution of Electrical Engineers.

Drury, B. & Hughes, A., 2019. *Electric Motors & Drives*. 5th ed. Oxford: Newnes.

European Parliament, 2019. *Machinery Directive*. [Online]

Available at: <https://eur-lex.europa.eu/eli/dir/2006/42/2019-07-26>

[Accessed 15 10 2024].

Financial Times, 2023. *Chip industry slowdown will last longer than expected, manufacturers warn*.

[Online]

Available at: <https://www.ft.com/content/6973aa75-0e25-49b8-b59d-5e8d38faa6b2>

[Accessed 01 12 2024].

Forbes, 2024. *The Semiconductor Crisis: Addressing Chip Shortages And Security*. [Online]

Available at: <https://www.forbes.com/sites/heatherwishartsmith/2024/07/19/the-semiconductor-crisis-addressing-chip-shortages-and-security/>

[Accessed 01 12 2024].

HSE, 2024. *Refurbished & Modified Machinery*. [Online]

Available at: <https://www.hse.gov.uk/work-equipment-machinery/refurbished-modified-machinery.htm>

[Accessed 15 10 2024].

Krishnan, R., 2001. *Electric Motor Drives: Modeling, Analysis, and Control*. Upper Saddle River: Prentice-Hall.

OCEANA, 2024. *Oil Pollution in UK seas*. [Online]

Available at: <https://uk.oceana.org/press-releases/oil-pollution-in-uk-seas-being-grossly-underestimated-due-to-opaque-and-misleading-reporting/>

[Accessed 08 11 2024].

Office for National Statistics, 2019. *Which Occupations are at Risk of Being Automated*. [Online]

Available at:

<https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/whichoccupationsareathighestriskofbeingautomated/2019-03-25>

[Accessed 15 10 2024].

Parker, 2012. *690+ Quick Start*. [Online]

Available at:

<https://www.parker.com/Literature/SSD%20Drives/AC%20Drives/AC690/HA470631U100.pdf>

[Accessed 04 11 2024].

Parker, 2014. *Encoder Option Module*. [Online]

Available at: <https://www.parker.com/content/dam/Parker-com/Literature/Electromechanical-Europe/User-Guides/HA502217U001.pdf>

[Accessed 03 11 2024].

Parker, 2024. *590+ DC Digital Drive*. [Online]

Available at:

<https://www.parker.com/literature/SSD%20Drives%20Division%20North%20America/Manuals/Legacy%20DC/HA470388.pdf>

[Accessed 01 11 2024].

Parker, 2024. *590+ Quick Start*. [Online]

Available at:

<https://www.parker.com/Literature/Electromechanical%20Europe/User%20Guides/HA500651U000.pdf>

[Accessed 03 11 2024].

Parker, 2024. *690+ AC Drive*. [Online]

Available at: <https://www.parker.com/content/dam/Parker-com/Literature/Electromechanical-North-America/SERVICE-USER-GUIDES/HA465492.pdf>

[Accessed 01 11 2024].

Parmley Graham, 2024. *Siemens S7-1215F*. [Online]

Available at: <https://www.parmley-graham.co.uk/automation/siemens/plc-s/s7-1200-basic-controllers/6ES7215-1AF40-0XB0>

[Accessed 02 11 2024].

Profinet, 2024. *Profinet Explained*. [Online]

Available at: <https://www.profinet.com/profinet-explained/technology-description>

[Accessed 04 11 2024].

Project Management Info, 2024. *Three Point Estimation*. [Online]

Available at: <https://project-management.info/three-point-estimating-pert/>

[Accessed 1 12 2024].

Shomroni, S., 2015. *Virtual Commissioning – A practical guide*. [Online]

Available at: <https://blogs.sw.siemens.com/tecnomatix/virtual-commissioning-a-practical-guide/>

[Accessed 08 12 2024].

Siemens, 2024. *S7-1200 System Manual*. [Online]

Available at:

https://cache.industry.siemens.com/dl/files/302/109977302/att_1307432/v1/s71200_system_manual_en-US.pdf

[Accessed 04 11 2024].

Siemens, 2024. *SIMATIC HMI TP1200 Comfort*. [Online]
 Available at: <https://www.industry-mobile-support.siemens-info.com/en/article/detail/109972019>
 [Accessed 02 11 2024].

Siemens, 2024. *Sustainability Rankings, Ratings & Figures*. [Online]
 Available at: <https://www.siemens.com/global/en/company/sustainability/sustainability-figures.html>
 [Accessed 01 11 2024].

Stober, 2013. *POSITool Operation Manual*. 5th ed. s.l.:Stober.

Stober, 2016. *POSIDYN® SDS 5000 Operation Manual*. 6th ed. s.l.:Stober.

Supply of Machinery Safety Regulations, 2008. *Conformity Assessment Procedures*. [Online]
 Available at: <https://www.legislation.gov.uk/ukxi/2008/1597/contents>
 [Accessed 12 11 2024].

TIME, 2024. *Worlds Most Sustainable Companies 2024*. [Online]
 Available at: <https://time.com/collection/worlds-most-sustainable-companies-2024/>
 [Accessed 05 12 2024].

United Nations, 2024. *The Sustainable Development Agenda*. [Online]
 Available at: <https://unodsd.un.org/content/sustainable-development-goals-sdgs>
 [Accessed 01 12 2024].

Water Resources Act, 1991. *Chapter 2: Pollution Offences*. [Online]
 Available at: <https://www.legislation.gov.uk/ukpga/1991/57/part/III/chapter/II/1991-12-01>
 [Accessed 08 11 2024].

Weidauer, J. & Meser, R., 2014. *Electrical Drives*. 1st ed. Berlin: Publicis Publishing.

Wessex Water, 2020. *Fuel Contamination and Your Water Supply*. [Online]
 Available at: <https://www.wessexwater.co.uk/media/m5mnci4m/oil-contamination-guidance.pdf>
 [Accessed 06 11 2024].

9. Appendix

9.1. Project Proposal

SGEL6000 INDEPENDENT PROJECT

PROJECT PROPOSAL DOCUMENT

Student Name: Aeron Smitham
Project Title: Miller 3 ICS Upgrade
Date: 04/10/2024
Budget: £50,000

Description of Project

The project will be based at a titanium products manufacturer in Swansea, in the Machine Centre department, which is the area for milling flat titanium plates.

The project is required on a machine which has been mothballed due to recurring faults involving the hydraulic system. Since the product is now getting numerous orders, the machine is required to be put back in production. The company policy is also to have all machines connected to our plant network for historical logging of data to be used for analysis. The machine is currently controlled by relay logic and therefore is unable to be connected to the plant network. A machinery safety assessment is also required to see if the machine meets the relevant safety standards.

The people involved in the project will be:

Aeron Smitham - Project Lead/Electrical Engineering Technician
Leo Farquhar - Mechanical Engineering Technician
Gavin Barlow - Electrical Engineer
Andrew Curtis - Senior Mechanical Engineer

A £50,000 budget has been approved out of the Plant Maintenance Budget.

The project will be broken down into separate parts. The first part of the project will be a hydraulic upgrade to get the machine back in production and will be completed by the end of 2024. The second part of the project will be a control system upgrade that will enable connection to our plant network, and this must be completed by the end of Quarter 1 2025.

Agreement for project proposal

Student Signature:	A.Smitham	Date: 27/09/2024
Industrial Supervisor Signature:	A.Curtis	Date: 27/09/2024
Academic Tutor Signature:	R.Davies	Date: 02/10/2024

9.2. Constraints

9.2.1. Ethical Engineering

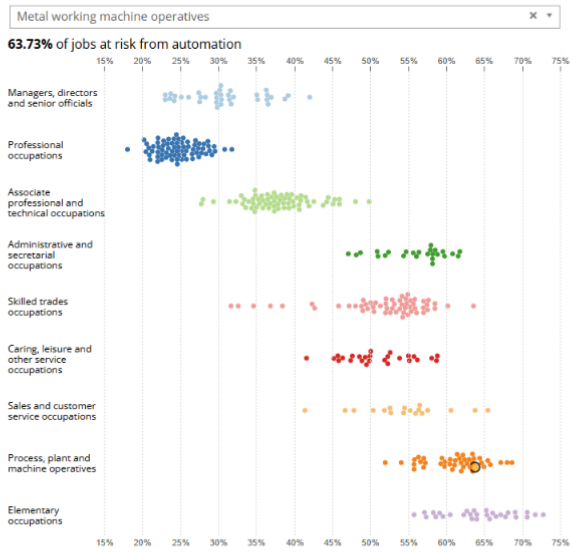


Figure 5 – Graph detailing at risk jobs from automation (Office for National Statistics, 2019)

9.2.2. Sustainability

Site Electrical Standard		
Part	Manufacturer	Alternative
Contactors	Schneider	N/A
Overloads	Schneider	N/A
Circuit Breakers	Schneider	N/A
Push Buttons & Switches	Schneider	N/A
LEDs	Schneider	N/A
Fused Switch Disconnects	Eaton Glasgow	N/A
Relays	Omron	Finder
Terminals	Weidmuller	N/A
PLCs	Siemens S7-1200 & S7-1500	Mitsubishi Q-Series
Remote I/O	Siemens ET200SP	N/A
HMI	Siemens Comfort 12"	Mitsubishi GOT
Unmanaged Network Switch	Hirschmann Spider	N/A
VFDs	Parker 690+	Siemens
DC Drives	Parker 590+	Siemens
Servo Drives	Stober SDS500	N/A

Table 5 – Preferred Manufacturers List



Figure 6 – The 17 Goals (Department of Economic and Social Affairs, 2024)

9.2.3. Legal/Commercial

Ref	Hazard	Severity of Injury (S)	Frequency and/or exposure times to hazard (F)	Possibility of avoiding hazard or limiting harm (P)	Safety Function Required Performance Level (PLr)
1	Access to rotating cutting heads	S2	F1	P1	c
2	Unguarded bed movement along rails	S2	F2	P1	d
3	Unguarded head movement along rails	S2	F2	P1	d

Table 6 – PLr Rating

9.3. Risk Assessment for Implementation Phase

9.3.1. Risk Assessment Key

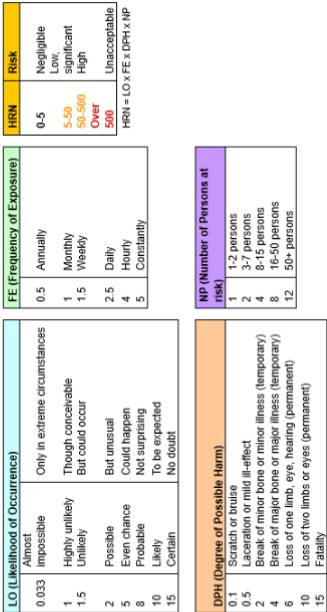


Figure 7 – Risk Assessment Key

9.3.2. Miller 3 Risk Assessment

Risk Number	Identified Risks	Potential Consequences	Initial assessment						Control Measures required
			LO	FE	DPH	NP	HRN	Risk level	Date
RA 1	Operator Access to rotating cutter	Possible severe injuries, entanglement, drawn in ETC	2	4	10	1	80	High	06/12/2024
RA 2	Access to rotating cutter by maintenance personnel	Possible severe injuries, entanglement, drawn in ETC	2	1	10	1	20	Low, significant	07/12/2024
RA 3	Crush hazard to operating personnel from table lateral movement at rear of machine	Possible crush injuries and entrapment.	2	2.5	10	1	50	Low, significant	06/08/2018
RA 4	Coolant splashing on operator station	Electric shock	1	5	15	1	75	High	16/10/2018

RA 5	Unauthorised access to cell through guards	Possible crush injuries, entanglement, entrapment, drawn in, severe injuries ETC	2	2.5	10	1	50	High	16/10/2018	1. Gate is interlocked and will not open in operation 2. When gate is open machine will not run.
RA 6	Operator trapped inside the machine guarding	Possible crush injuries, entanglement, entrapment, drawn in, severe injuries	2	4	10	1	80	High	16/10/2018	1. Guard interlocks must be energised to lock by the operator, so the guards do not automatically lock behind operator. 2. Any E stop activated release gates 1 & 2 when cutter is stationary.

Table 7 – Implementation Risk Assessment

9.4. Comparison Table of Solutions

Motor Drive Comparison Against Criteria			
Criteria	DC Drive	VFD	AC Servo Drive
Reliability	Reliable but requires regular maintenance.	Highly reliable with fewer mechanical parts, leading to less maintenance.	Very reliable and designed for continuous operation with high precision and minimal wear.
Performance	Good performance for moderate precision applications.	Suitable for speed control but not for precision position control.	Superior performance with high precision & rapid response.
Sustainability	Less sustainable due to high energy consumption and frequent maintenance.	Energy efficient motors which are classified up to IE4 class.	Highly energy efficient with optimised motor performance which reduces energy consumption.
Feasibility	Feasible for simple applications with moderate precision requirements.	Feasible for applications requiring varying speed control.	The most feasible option for high precision position control applications.
Cost	Low initial cost, but higher maintenance costs.	Low initial cost.	High initial cost.
Complexity	Complex due to the different control loops for armature and field control.	Least complex option as just frequency is adjusted.	High complexity due to the advanced control required.
Maintenance	Regular maintenance required for wearable parts such as the carbon brushes and commutator.	Less maintenance requirements but motor fins and fan must be kept clean.	Low maintenance requirements.

Table 8 – Solution Comparison Table

9.5. Scoring Matrix for Solutions

Scoring Matrix			
Criteria	Solution 1	Solution 2	Solution 3
Reliability	1	2	3
Performance	2	1	3
Sustainability	1	2	3
Feasability	1	2	3
Cost	2	3	1
Complexity	2	3	1
Maintenance	1	2	3
	10	15	17

Table 9 – Scoring Matrix

Cost Comparison					
Solution 1		Solution 2		Solution 3	
Parts/Labour	Cost	Parts/Labour	Cost	Parts/Labour	Cost
Siemens S7-1215F PLC	£700	Siemens S7-1215F PLC	£700	Siemens S7-1215F PLC	£700
Siemens PLC Modules	£1000	Siemens PLC Modules	£1000	Siemens PLC Modules	£1000
Siemens 12" HMI	£2000	Siemens 12" HMI	£2000	Siemens 12" HMI	£2000
Rittal Operator Station	£1500	Rittal Operator Station	£1500	Rittal Operator Station	£1500
DC Motor	£2500	AC Motor	£1700	Servo Drive	£3000
Parker DC Drive	£2000	Parker AC Drive	£1500	Stober Servo Drive	£2165
Motor Cabling	£200	Motor Cabling	£200	Motor Cabling	£450
Labour	£6000	Labour	£4800	Labour	£8437
Total	£15900	Total	£13400	Total	£19242

Table 10 – Solutions Cost Comparison

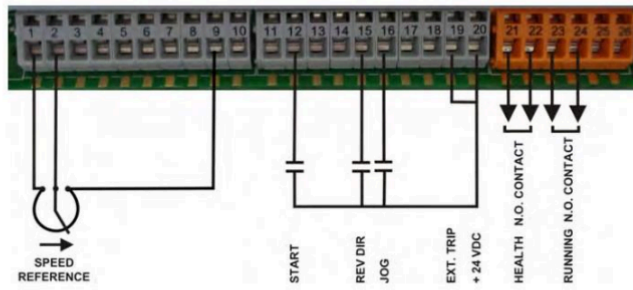


Figure 8 – Wiring of 690+ Parker VFD (Parker, 2012)

9.6. WBS Chart

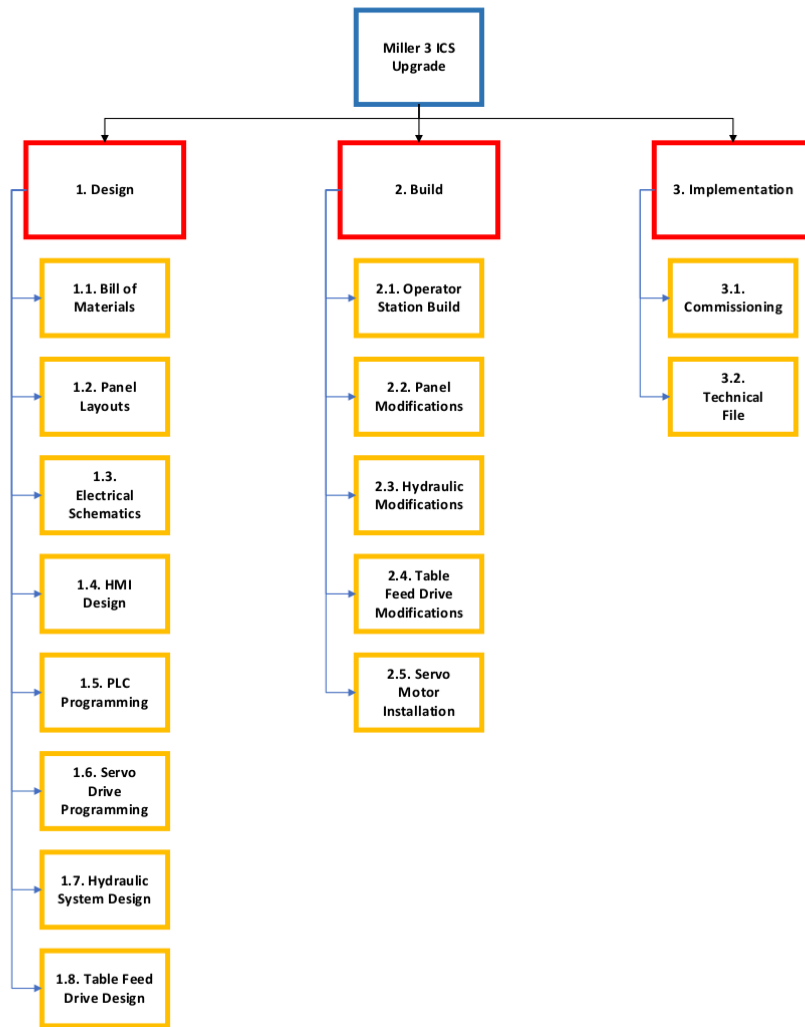


Figure 9 - WBS

9.7. Gantt Chart

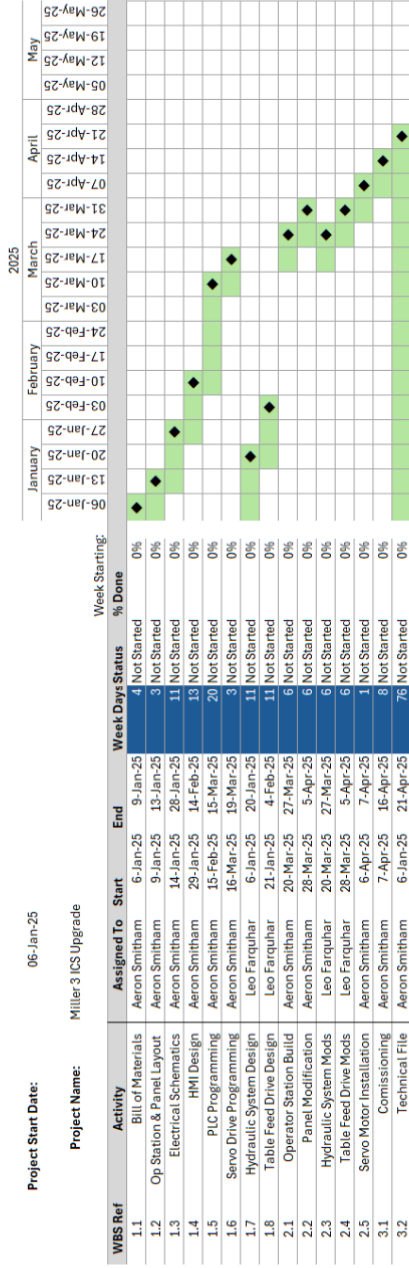


Figure 10 – Gantt Chart

9.8. Costing Spreadsheet

Bill of Materials					
Parts	Part Number	Stores/Requisition	Stores Number/Vendor	Number of Parts	Total Cost
Siemens S7-1200 PLC (14DI 10DQ 2AI 2AQ)	6ES7215-1AF40-0XB0	Stores	10071794	1	£773.26
SM1226 16F-DI Module	6ES7226-6DA32-0XB0	Stores	10071792	1	£306.68
SM1226 4F-DQ Module	6ES7226-6BA32-0XB0	Stores	10071795	2	£346.10
SM1221 16DI Module	6ES7221-1BH32-0XB0	Stores	10071750	2	£296.34
SM1222 8DQ Module	6ES7222-1BH32-0XB0	Stores	10071791	2	£186.04
SM1231 4AI Module	6ES7231-4HD32-0XB0	Stores	10071793	1	£191.80
ET200SP IM155-6 PN	6ES7155-6AU01-0BN0	Stores	10075935	1	£224.43
ET200SP RJ45 Profinet Adapter	6ES7193-AR00-0AA0	Stores	10077707	1	£57.46
ET200SP Module Base	6ES7193-6BP00-0BA0	Stores	10066653	4	£64.80
ET200SP 8F-DI Module	6ES7136-6BA00-0CA0	Stores	10066657	1	£167.16
ET200SP 16DI Module	6ES7131-6BF01-0BA0	Stores	10075936	2	£180.40
ET200SP 8DQ Module	6ES7132-6BF01-0AA0	Stores	10075941	2	£112.54
12" HMI TP1200	6AV2124-0MC01-0AX0	Stores	10066651	1	£2,284.20
IFM PN2099 Pressure Sensor	PN2099	Stores	10064855	2	£588.44
IFM PN2092 Pressure Sensor	PN2092	Stores	10077374	3	£1,219.38
Multi-core & Ethernet Cable (to Op Station)	N/A	Purchase Requisition	Fastec	1	£1,000.00
Rittal Panel Operator Station	6315650	Purchase Requisition	RS Components	1	£375.16
Rittal 90° Angle Piece Adapter	6212600	Purchase Requisition	RS Components	2	£291.74
Rittal 500mm Support Section	6212150	Purchase Requisition	RS Components	1	£72.43
Rittal 1000mm Support Section	6212110	Purchase Requisition	RS Components	1	£127.20
Rittal Coupling for Support Arm	6212300	Purchase Requisition	RS Components	1	£166.71
Rittal Adapter for Support Arm	6212500	Purchase Requisition	RS Components	1	£54.88
Rittal Adjustable Wall Hinge	6212740	Purchase Requisition	RS Components	1	£371.74

Schneider Illuminated PB	XB4BW33B5	Purchase Requisition	RS Components	20	£624.20
Schneider NO Contact	ZBE101	Purchase Requisition	RS Components	10	£48.70
Schneider NC Contact	ZBE102	Purchase Requisition	RS Components	10	£48.70
Schneider E-Stop	ZB4BS844	Purchase Requisition	RS Components	2	£47.52
Siemens Selectivity Module PSE200U	6EP1961-2BA21	Purchase Requisition	RS Components	1	£133.00
Siemens Sitop PSU 20A	6EP1436-2BA10	Purchase Requisition	RS Components	1	£254.00
Siemens Scalance Ethernet Switch	6GK5008-0BA10-1AB2	Purchase Requisition	RS Components	1	£130.00
100A Current Transducer	2308108	Purchase Requisition	RS Components	5	£1,102.80
Stober Servo Drive		Stores		1	£2165.00
AC Servo Motor		Stores		1	£3000.00
AC Servo Motor Cabling		Stores		1	£450.00
Labour					£8437.00

Table 11 – Costing Spreadsheet

SGEL6000
Independent Project
Log Book

Aeron Smitham
Miller 3 ICS Upgrade
2024-2025

Summary of Entries

Log Entry	Date	Brief Description of Activity	Duration (hrs)	Accumulated time (hrs)
1	20/9/24	Discussed project ideas with management	4	4
2	27/9/24	Agreed budget, scope and deadlines with management	4	8
3	04/10/24	Defined initial project problem	6	14
4	11/10/24	Compare options for an electrically driven motor	8	22
5	18/10/24	Worked on Task 4	6	28
6	25/10/24	Task 4 continued	6	34
7	1/11/24	FDS	8	42
8	8/11/24	Test Plan	6	48
9	15/11/24	Test Plan finished and Literature Review	8	56
10	22/11/24	Literature Review Continued	8	64
11	29/11/24	Literature Review Completed	8	72
12	6/12/24	WBS, Gantt Chart, Conclusions and Recommendations	8	80
13	13/12/24	Finishing the Report	16	96

Log Entry Sheet

Log Number	1
Date	20/9/24
Duration (hrs)	4
Accumulated time (hrs)	4

Record of activities and achievements

Discussed project ideas with management. Decided on an upgrade to our Miller 3 flat plate milling machine as it is currently mothballed due to recurring hydraulic faults, and a decision had been made to no longer run the machine as too much time was spent on fault finding, but now due to increased orders of a certain product, the machine is now required.

The machine is also relay logic controlled with no connection to our plant network and data acquisition server. Our engineering department plan is to upgrade all machines to be PLC & HMI controlled for increased ease of use for operators, improved troubleshooting aides for maintenance on the HMI - with alarming, fault-finding pages, and IO pages - and machine data to be logged for data analysis.

Plans for next week

Create a Bill of Materials to ensure the project is doable within the budget given.

Begin looking at the design process - what is required to stop the hydraulic fault, what is required to convert the relay logic control to PLC & HMI.

Signed: A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	2
Date	27/09/24
Duration (hrs)	4
Accumulated time (hrs)	8

Record of activities and achievements

Budget agreed with management, see emails below. £50,000 set aside from the annual maintenance budget for the upgrade. Meetings with key stakeholders to discuss the requirements of the project, including when the machine is required back in production, and when the project must be completed.

From: Curtis, Andrew <Andrew.Curtis@Timet.com>
Sent: Thursday, October 3, 2024 12:06 PM
To: Smitham, Aeron <Aeron.Smitham@Timet.com>
Subject: RE: Degree Project & Budget

Hi Aeron,

Spend approved.

Regards,

Andrew Curtis | Engineering Manager Designate | TIMET UK, A PCC Company
Waunarlwydd | Swansea | SA5 4SF
O: 01792 870383 | M: 07391865947 | E: andrew.curtis@timet.com

From: Smitham, Aeron <Aeron.Smitham@Timet.com>
Sent: 03 October 2024 12:05
To: Curtis, Andrew <Andrew.Curtis@Timet.com>
Subject: Degree Project & Budget

Hi Andrew,

Further to our discussions about the Miller 3 Control System upgrade, can you please approve the release of £50,000 from the annual Maintenance budget for the parts required.

Kind regards

Aeron Smitham | Electrical Engineering Technician | TIMET, A PCC Company
Waunarlwydd Works, Ystrad Road | Swansea , SA5 4SF
O: +44(0) 1792 870377 | M: +44(0) 7553 298371 | E: aeron.smitham@timet.com

Plans for next week

Research the hydraulic issues with the machine to further understand the problem.
Decide on the best course of action to resolve the issue.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	3
Date	04/10/2024
Duration (hrs)	6
Accumulated time (hrs)	14

Record of activities and achievements

The problem with the hydraulic system was researched and defined. The main problem is a hydraulic leak within the machine that cannot be located and rectified. The machine is operated by various hydraulic actuators, with the table feed driven by a hydraulic motor, and the two milling heads are controlled via various hydraulic solenoids which control the positions, clutches which engage the milling cutters and clamps to hold the position. The mechanical engineer believes that the hydraulic motor is the source of the fault, and this is affecting the table feed speed as well as the rest of the hydraulic system. Due to this we've suggested replacing the hydraulic motor with an electrically driven motor.

Plans for next week

Look at the options for the electrically driven motor.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	4
Date	11/10/24
Duration (hrs)	8
Accumulated time (hrs)	22

Record of activities and achievements

Options for an electrically driven motor were researched to replace the hydraulic table feed motor. The current hydraulic motor controls the feed via limit switches which determine where the feed starts, stops and speeds up. The speed the table feed when the product is being milled is vitally important, as well as the position of the table, as the product could be damaged if the table stops in the wrong position. The limits are the plunger actuator type, and the repeatability and reliability of these are a recurring issue.

A DC motor and drive could be used, as they have good speed control properties, but this would add unnecessary complexity to the system, as well as additional maintenance on the DC motor.

An induction motor and VFD would be the simplest and cost-effective option, but unless some form of position feedback was added, the motor would still have to use the plunger limits.

A servo motor and drive has a built in encoder for position feedback and are the superior option for position control. There are also servo motors used on site for similar operations making it the ideal option. The number of spares kept on site will not be increased as this same type is already used.

Plans for next week

Benchmark speeds and positions of the hydraulic driven table feed.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	5
Date	18/10/2024
Duration (hrs)	6
Accumulated time (hrs)	28

Record of activities and achievements

Work was carried out to complete Task 4 of the assignment. A background of the machine was given, as well as defining the problem with the machine and how the project will eliminate the issue. Research was undertaken on the legal and commercial aspect of the constraints involved in this project, and how a machine modification will require a conformity assessment to see if there is such a change that this will make the machine a "new" machine, and as such, further regulations must be met.

The HSE website was used for this research, with the page on 'Refurbished and modified machinery' used extensively.

Plans for next week

Work on the remaining parts of Task 4.

Signed A.Smitham

Signed *R. Davies*

Log Entry Sheet

Log Number	6
Date	25/10/2024
Duration (hrs)	6
Accumulated time (hrs)	34

Record of activities and achievements

Further research was undertaken to complete the constraints section of Task 4, with the Ethical Engineering and Sustainability sections looked at.

Ethical engineering introduces constraints to a project by prioritising considerations other than just the functionality of the machine. Some of these constraints include the safety of the machinery, cyber-security, environmental responsibility, and fairness.

As part of the project, a significant amount of equipment will be replaced, with these used parts added back into the site stores as common spares for other machinery. The replacement parts will all be common spares from across the site to reduce the amount of different inventory kept in the site stores, with the goal to only use one manufacturer for each component.

Plans for next week

Begin looking at Task 5, the Functional Design Specification

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	7
Date	1/11/24
Duration (hrs)	8
Accumulated time (hrs)	42

Record of activities and achievements

The Functional Design Specification was started, beginning to look at the project outcomes which must be delivered. The following standards were referenced for the task:

- BS EN 60204-1:2018
- BS EN 13850:2006
- Company Electrical Specification

The functions of the different parts of the project were looked at, which included the servo drive upgrade, the PLC & HMI

Plans for next week

The FDS will be finished and the Test Plan will be started.

Signed A.Smitham

Signed *R. Davies*

Log Entry Sheet

Log Number	8
Date	8/11/24
Duration (hrs)	6
Accumulated time (hrs)	48

Record of activities and achievements

The FDS was finished, with additional bits added to the safety and appearance deliverables. The test plan was started, with tests and expected outcomes added for most tests.

Plans for next week

Test plan to be finished and literature review started.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	9
Date	15/11/24
Duration (hrs)	8
Accumulated time (hrs)	56

Record of activities and achievements

Test plan finished with expected outcomes added for the motor speeds, coolant flows, hydraulic pressures.

Literature review started, with different solutions looked at to resolve the problems identified and meet the FDS.

Plans for next week

Literature review continued next week.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	10
Date	22/11/2024
Duration (hrs)	8
Accumulated time (hrs)	64

Record of activities and achievements

The literature review was continued this week, with the 3 different solutions set out. These all consisted of a Siemens PLC & HMI, but the motor control method of the table feed had different options.

The solutions were:

DC Motor & Drive

AC Motor & Drive

AC Servo Motor & Drive

All these solutions could meet the requirements of the FDS, enabling control of the table feed and the data acquisition requirements that were met with the PLC/HMI.

Plans for next week

Compare and choose the best solution for the project.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	11
Date	29/11/2024
Duration (hrs)	8
Accumulated time (hrs)	72

Record of activities and achievements

The three solutions were compared, with a scoring matrix and radar graph used to select the best option.

The different criteria used were: reliability, performance, sustainability, feasibility, cost, complexity & maintenance.

The AC Servo Drive solution was chosen as it scored highest on the matrix, even though it wasn't the cheapest option. The performance was the main reason for its selection, as the Servo Drive is far superior to the other two solutions.

Plans for next week

Finish project plan and start conclusion.

Signed A.Smitham

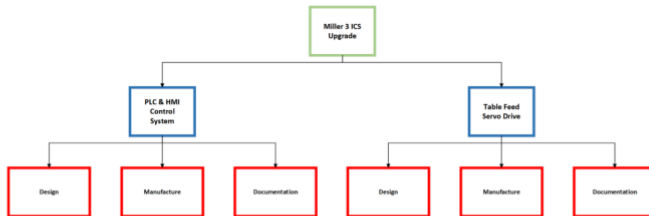
Signed *R.Davies*

Log Entry Sheet

Log Number	12
Date	06/12/2024
Duration (hrs)	8
Accumulated time (hrs)	80

Record of activities and achievements

This week the Gantt chart was finished, detailing the deliverables of the project. Along with the WBS, which can be seen below.



The conclusions and recommendations were then completed for this stage of the project.

Plans for next week

Report due next week, so all of next week will be spent finishing the report.

Signed A.Smitham

Signed *R.Davies*

Log Entry Sheet

Log Number	13
Date	13/12/2024
Duration (hrs)	16
Accumulated time (hrs)	96

Record of activities and achievements

Spent the week finishing the report ready to hand in.

Plans for next week

Christmas break. Next step will be creating the project presentation.

Signed A.Smitham

Signed *R.Davies*

82/100

PAGE 1

Text Comment. An excellent report in every way Thoroughly researched, very detailed Clearly thought out solutions, correctly chosen final solution All aspects of wider issues considered with constraints and standards. Excellent evidence of management techniques used.

PAGE 2

Text Comment. A well structured report

PAGE 3

PAGE 4

PAGE 5

PAGE 6

Text Comment. This is the correct way to write a summary that contains all aspects of the project.

PAGE 7

QM

Punctuation Error

Punctuation error

QM

Punctuation Error

Punctuation error

QM

Punctuation Error

Punctuation error

Text Comment. A good introduction outlining the contents of the report

PAGE 8

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Punctuation Error

Punctuation error

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Punctuation Error

Punctuation error

QM

Spelling

Spelling error

QM

Spelling

Spelling error

Text Comment. You could have explained better how to carry out some of these tests so that another person could do them

Text Comment. How are you going to measure linear speed with a tachometer?

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Punctuation Error

Punctuation error

Text Comment. This is a good choice

Text Comment. Excellent conclusions and recommendations



Wide Range of Sources

You have shown good evidence of reading from a wide range of sources.



Correct method of listing.

You have listed your sources correctly according to the Harvard method.

GRADING FORM: NEW CSG-RUBRIC

AERON SMITHAM

82

1. ENGAGEMENT WITH LITERATURE



Sections 3 and 5: Engagement in research, judicial use and critical evaluation sources for project constraints and literature review of solutions
Exceptional engagement with an extensive range of relevant and credible literature, informed by the latest research. (9/10)
Sections 3, 5 and 8: Extent of reading, use of credible sources, use of Harvard method for listing and citing
High-level referencing skills consistently and professionally applied. (8/10)

17

17/20

2. KNOWLEDGE AND UNDERSTANDING



Section 3: Project background and problem definition

16

Excellent and clearly explained (4/5)
Section 3: Project constraints: Ethical.
Excellent and clearly explained (4/5)
Section 3: Project constraints: Sustainability
Excellent and clearly explained (4/5)
Section 3: Project constraints: Legal/Commercial
Excellent and clearly explained (4/5)

16/20

3. COGNITIVE AND INTELLECTUAL



Section 4: Functional Design Specification
Thoroughly specified with reference to standards (4/5)
Section 4: Test planning
A good testing plan. However, tests and expected results often read the same. Each test should be more specific so that someone else could easily carry them out. It is not clear how to measure linear speed using a tachometer? (4/5)
Section 5: Evaluation of solutions and justification of final solution
Excellent evaluation and clear choice of solution (4/5)
Section 7: Conclusions and Recommendations
Excellent end to the report (4/5)

16

16/20

4. PRACTICAL APPLICATION



Section 6: Project Plan
Excellent evidence of planning (4/5)
Section 6: Working breakdown structure, costing exercise and management techniques
Excellent WBS and management methods (4/5)
Appendix: Risk assessment for implementation phase
A well thought out risk assessment for this stage (4/5)

15

Appendix: Planning phase log-book entries.
Some entries are detailed, others a brief (3/5)

15/20

5. TRANSFERABLE SKILLS



Section 1: Executive summary

Excellent summary of the project (4.5/5)

All Sections: Presentation quality of the report,
diagrams, charts, tables, figure numbering, page,
and section numbering etc

Excellent report in all aspects (4.5/5)

All Sections: Quality of the writing style, use of
punctuation and grammar

Generally very good, with some spelling and
punctuation errors (4/5)

Word count limit not exceeded

Not exceeded (5/5)

18

18/20