

1503517

by Kristian Payne

FILE	15188_KRISTIAN_PAYNE_1503517_174990_1672533452.PDF (1.18M)		
TIME SUBMITTED	14-DEC-2019 10:38AM (UTC+0000)	WORD COUNT	4288
SUBMISSION ID	116391024	CHARACTER COUNT	24603

Course: BSC (Hons) Electrical & Electronic Engineering

Module: SGEE6003: Major Project

Assignment: 1.Project Definition, Research and Quality Planning

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Date submitted: 13/12/2019

Word count: 3642 Words

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1. Executive Summary

This project involves the modification and upgrade of a machine system that is based within a local company. It aims to improve the machines electrical vacuum system's safety and performance by using upgraded components, newer technologies and added functionality that the new modified connected system will introduce. This project is very important to the company due to having previous safety issues with the machine, a high rate of downtime caused by the vacuum system and a high maintenance cost due to weekly inspections needing to be performed.

Following the creation of a project proposal a specification was created that stated the system must: be able to accurately measure vacuum pressure at a location closer to the chuck, raise an alarm in the case of a loss of vacuum pressure (below -19 inHg / -650 mBar), place the machine in a safe state following vacuum failure, be able to automatically run the vacuum switch test procedure when required while still maintaining the ability to be manually tested and to be able to give visual feedback to the machines operator.

Three solutions were then selected that all meet the specification while focusing on providing different options of integrating the vacuum system into the machines control circuitry and PLC control. The first solution provides this integration by using a Pilz safety controller to control the main functionality of the vacuum system while keeping the machines PLC and CNC controller and visually outputting data to a display.

The second solution provides this integration by using a Siemens S7-1200 PLC to control the main functionality of the vacuum system while keeping the machines PLC and CNC controller while outputting data to a display and connecting the system to the network via PROFINET. The system also provides the functionality of connecting a Bluetooth device to directly view data from the vac system sensors.

The third solution provides this integration by using a Siemens S7-1500 PLC to control the main functionality of the vacuum system while also replacing the machines PLC controller and keeping the machines CNC controller to provide CNC program control. This solution would also output data to a display and connect the system to the network via PROFINET.

The first solution was selected due to its lower cost, time required to complete and its concentration on safety.

2. Introduction

The project is to be carried out in industry within a local company that produces products for the aerospace industry. The company uses several secondary manufacturing processes to meet customer's specifications. The project is intended to be installed and commissioned in the Sheet finishing area of the site.

The objective of this project is to modify and upgrade the electrical vacuum system on Narrow Fan Blade Grinder 4 (NFBG4). NFBG4 is a CNC controlled belt finishing/grinding machine that removes material from a sheet to bring it within customers specified tolerances. The current system uses an outdated unreliable diaphragm pressure switch and other unsuitable components that could cause a serious safety related dangerous occurrence.

The new modified system would improve the systems performance by using new state of the art components with obtainable reliability data, it would improve the safety of the machine by making use of safety rated components and reduce the high maintenance cost of the machine from eliminating the need for maintenance to perform a vacuum switch inspection weekly.

3. Project Background, Problem Definition and Constraints

3.2 Project Background

The project is to be carried out in industry within a local company that produces Titanium products for the aerospace industry. The company uses several secondary manufacturing processes to meet customer's specifications. The project is intended to be installed and commissioned in the Sheet finishing area of the site.

The intention is for the project to be installed and commissioned on Narrow Fan Blade Grinder Number 4(NFBG4). NFBG4 (Shown in figure 1) is a CNC belt finishing/grinding machine that removes material from a Titanium sheet to allow the product to meet specified tolerance. The machine is controlled by a NUM 1020 GS PLC & CNC controller, and is operated from a single workstation with one employee transferring material using an independent vacuum lift from a local storage area onto the machine, and then back to the storage area once processing has been completed.



Figure 1: Narrow Fanblade Grinder 4 (NFBG 4)

The material is secured for machine processing using a chuck, mounted on a servo motor-controlled bed. This moving bed allows the material mounted on the chuck to pass under and contact the machines

grinding/finishing belt. The material is held in place on the chuck by vacuum pressure, which is supplied by a designated vacuum pump and reservoir setup. Several components and circuits are connected to make up the machine's electrical vacuum system. This system monitors and controls the vacuum supplied and is integrated in the operation of the machine.



Figure 2: IFM sensor & Bailey & Mackey switch

The current Electrical vacuum system contains: An IFM PN7094 electronic pressure sensor, A Bailey and Mackey 2381 diaphragm pressure switch, a 110V 2-way solenoid valve, several control relays and connected control circuitry (Figure 2). The IFM PN7094 is used to measure vacuum pressure at the reservoir and then send output signals to control circuitry which allows controlled operation of the vacuum pump. The Bailey and Mackey 2381 pressure switch is used to monitor and send output signals to control circuitry that operate the machine's vacuum interlock. The solenoid valve is used to control the supply of vacuum to the chuck and to release vacuum pressure when a product is removed from the machine. The control circuitry also allows the operator to: release the vacuum pressure from the chuck and manually switch off the vacuum pump following vacuum release.

3.3 Problem Definition

The most significant safety hazard of NFBG4 is the ejection of material from the machine caused by material contacting the rotating belt without being properly secured to the chuck. The greatest potential cause of this hazard is a catastrophic or gradual loss of vacuum at the chuck. The vacuum interlock is designed to eliminate this risk. Recently, the dangerous scenario of a material ejection occurred during normal operation of the machine. Following an investigation, the root cause for this dangerous occurrence was discovered to be a failure of the vacuum interlock system (Figure 3).

ROOT CAUSE ANALYSIS (RCA) FORM (DELAYS MORE THAN 12Hrs or FOUR REPEAT OCCURRENCES IN 30 DAYS)			
TO BE COMPLETED BY SHIFT	RCA Type (E/M/HSE)	E/M	Team Members
	Area/Machine :	FBC/NFBG#4	Engineer
	Date/Shift :	11/08/2019	Mech Technician
	Time :	15:00	Elec Technician
	Reported by:	Operator	
	Downtime duration :	18	
	DESCRIPTION OF FAULT AND PROBLEM DEFINITION		
	It was reported by the operator that material had ejected from NFBG 4. The material had broken vacuum during grinding and ejected towards the rear of the grinder. It struck the guarding that has been put in place but stayed within the confines of the grinder. No operators were hurt during this incident and the machine was not damaged.		
	New chuck recently fitted, ground and piped up by mechanical craft. Operator pre-use checks had been completed on the machine, green vacuum OK light was illuminated prior to operator intimating grinding cycle.		
	HOW LONG AGO COULD THIS PROBLEM HAVE BEEN DETECTED ? NA		
5 WHY'S	REASON		
WHY 1	Vacuum OK interlock did not prevent machine cycle start.		
WHY 2	Failure of vacuum interlock system to detect insufficient vacuum at chuck.		
WHY 3	Restriction in vacuum pipe from chuck to vacuum interlock pressure switch		
WHY 4	Grinding sponge inside pipework and vacuum release solenoid valve.		
WHY 5	Switch location will not detect vacuum loss due to restriction in chuck vacuum hose.		

Figure 3: Company Root Cause Analysis form

The vacuum interlock pressure switch's location was a main cause of the vacuum interlock failure. This is due to the switch not being able to detect the loss of vacuum pressure in the system due to a restriction in the chuck vacuum hose. A test was carried out on NFBG4 using a vacuum measurement prototype (See figure 4) that was built out of parts from the company's electrical stores. This prototype was made to be able to test if there would be a difference between the vacuum measured at the chuck and the vacuum measured by the vacuum gauge on the reservoir. The pressure sensor on the prototype measured 200 mbar more than the vacuum gauge, this means that the vacuum interlock would have been deactivated and would allow the machine to run, but the vacuum pressure at the chuck was lower than the set point and safe value to run the machine. Due to this test result it has been decided that the vacuum interlock controlling pressure sensor will be moved closer to the chuck.



Figure 4: Vacuum measurement prototype

The main incentives for the project's proposal are: Safety, System performance and maintenance costs. A new electrical vacuum system will improve system performance and increase safety of the machine by using upgraded components, relocating the vacuum interlock pressure switch and using dedicated safety rated components. It will also reduce maintenance costs due to using more reliable upgraded components and having self-test features instead of manual tests being performed every week.

4. Functional Design Specification and Test Plan

4.2 Specification

The specification of the project is based on the following requirements to give improvements to the existing electrical vacuum monitoring system used on the grinder which will use upgraded components.

1.

To be able to accurately measure vacuum pressure at a location closer to the chuck

To raise an alarm in the case of a loss of vacuum pressure (below -19 inHg / -0.65 Bar)

To place the machine in a safe state and to be able to automatically run the vacuum switch test procedure when required

To give visual feedback to an operator on the status of the system

To be able to be manually tested by maintenance craftsmen.

2. Inputs: The system will measure vacuum pressure using a pressure sensor. Outputs: The system will interlock the machine and give visual feedback to an operator

3. The parameters that will be measured are: vacuum pressure (reduced maintenance costs, increased safety, pressure sensor switches points)

4. The reliability of the system will be compared to previous machine data (Shift reports & plant data) (Rates of failure, MTTF and downtime relating to the vacuum system).

5. The project is located Indoor in industry in a damp and dirty area with an ambient temperature ranging from 10degrees to 35 degrees. Humidity to be measured throughout project. (Expected to be around 35-50%)

6. Modification to be contained in existing panel as much as possible with separate enclosure for pressure sensor and needle valve at side of machine in Rittal IP66 rated steel wall box

7. The industrial supervisor has confirmed that a budget will be made available to develop the system modification. It is envisaged that the total budget will be £3000.

8. All components and circuits will follow the company's electrical standards (sections: 2,4,5,10,11 and 12) and follow BS7671 and BS EN 60204 which will make the system neat and easy to understand and work on.

9. All practical project work will be completed following company health and safety standards, using the permit to work and risk assessment systems. The final system modification will comply with PUWER 1998 (Health and safety standards).

10. The company has a very strong recycling regime where all possible waste is recycled and where possible, components are reused. All waste from the project will be recycled and all Environmental impact

12. The final project report is to be submitted by 24/04/2019.

4.2 Test plan

<u>Test step</u>	<u>Description</u>	<u>Expected outcomes</u>	<u>Result</u>
1) Power up machine using panel isolator	Check if the machine has powered up correctly without any warning alarms sounding or without showing any error indicators	The machine should power up correctly and should then be ready to have material loaded or begin a CNC program	Pass / Fail
2) Check all switches, sensors and indicators	Check if all external sensors, switches and indicators have powered up correctly without showing any error codes/indicators.	All indicators should show the correct state they are meant to be in following machine power up and to allow the machine to start a CNC program	Pass / Fail
3) Check status of machine	Check the status of the machine and its parts are in the correct status according to the controls and switches on the operator panels	Machine should operate according to the position any selector switches are left in.	Pass / Fail
4) Check connections	Visually check all removable external connections are secure (Vacuum pipes & Sensor cables)	All external connections should be secure and undamaged to	Pass / Fail

		prevent any leaks or bad connections.	
5) Check operator controls	Where possible, check operator controls correctly interface with their output devices and all devices/components perform as they are meant to.	All operator controls should operate as intended and should control what they are labelled as.	Pass / Fail
6) Check machine start-up	Check if machine can start up into its “ready” state (Contact roll start) without vacuum & coolant flow interlocks deactivated.	The contact roll should not start up when pressing the start button	Pass / Fail
7) Check vacuum supply & measurement	With a product loaded on the chuck, check if vacuum is being correctly supplied to the chuck and is without leaks by viewing both pressure sensors.	Both pressure sensors should read >700mbar	Pass / Fail
8) Check vacuum pump operation & control	Check if vacuum pump operates correctly and continues to do so if a leak is present	Vacuum pump should run and shut off to control the vacuum pressure according to the pressure sensor	Pass / Fail
9) Check vacuum system	Check if vacuum builds up to above set point and maintains level with a product on the chuck	Vacuum pressure should build up above 700mbar and should not	Pass / Fail

		drop once the vacuum pump has turned off	
10) Check vacuum interlock operation	(Following standard maintenance inspection guideline) Ensure vacuum interlock operates correctly and stops contact roll if vacuum drops below its set point.	Contact roll should stop, and alarm should sound if vacuum pressure at the chuck drops below 650mbar	Pass / Fail
11) Check vacuum system operator visual feedback.	Check all operator visual feedback are functioning correctly	All indicator lamps on the operator panel should show the correct status of the machine (e.g. Coolant on, contact roll running)	Pass / Fail
12) Functional program test	Check machine operates correctly through a full CNC program with material on chuck	Machine should run through a full CNC program cycle without stopping and finish processing the material.	Pass / Fail

5. Literature Review

5.2 Solution 1

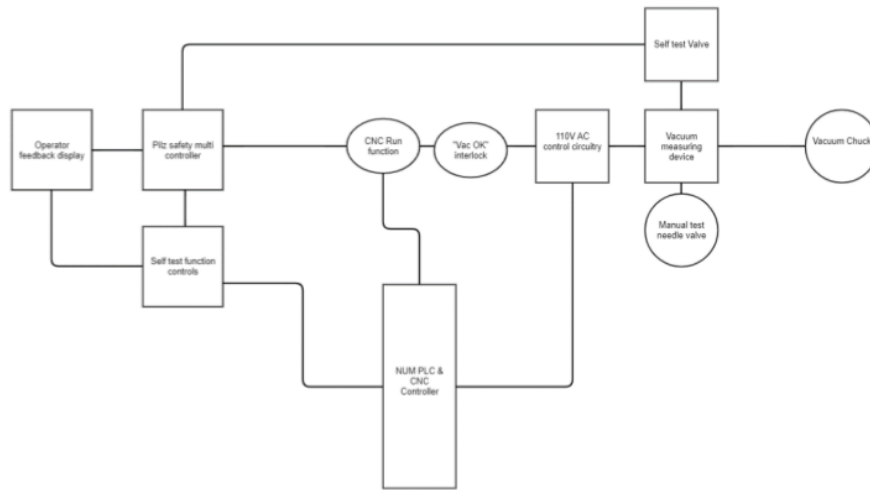


Figure 5: Solution 1

This solution would maintain the use of the machine's current NUM 1020 GS PLC & CNC controller to control the machine's general operation and CNC programs. It would use a Pilz programmable safety controller to operate the self-test function and would allow the pressure sensor to control the machine's vacuum interlock. The vacuum interlock would connect to the NUM controller's "CNC Run" function to inhibit the controller running any PLC functionality and would not allow the machine to run. The operator would receive feedback on the system via a display that would display data from the safety controller.

5.3 Solution 2



Figure 6: Solution 2

Solution 2 would use a Siemens Simatic S7 1500 PLC to replace all PLC control from the NUM 1020 GS. It would become the machine's main PLC and would be its main control device. The machine would still use the CNC controller of the NUM 1020 GS to interact with the new PLC to be able to run its CNC program functionality. The PLC would also operate the self-test function and would allow the pressure sensor to control the machines vacuum interlock. The vacuum interlock would connect to the Simatic PLC's "CNC Run" function to inhibit the NUM controller running any Simatic PLC functionality and would not allow the machine to run. The operator would receive feedback on the system via a Siemens Simatic HMI. Both siemens products would be connected by PROFINET.

5.4 Solution 3

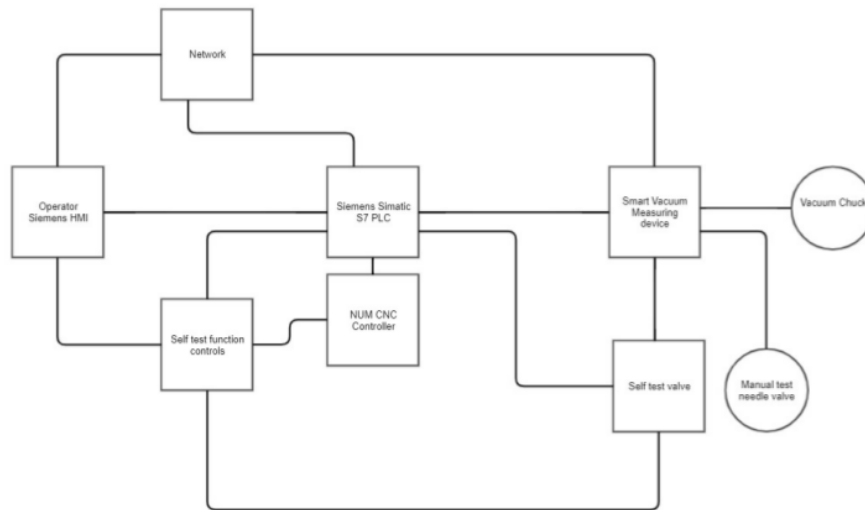


Figure 7: Solution 3

The final solution would use a Siemens Simatic S7 1500 PLC to replace all PLC control from the NUM 1020 GS. It would become the machine's main PLC and would be its main control device. The machine would still use the CNC controller of the NUM 1020 GS to interact with the new PLC to be able to run its CNC program functionality. The PLC would also operate the self-test function and would allow the pressure sensor to control the machines vacuum interlock. The vacuum interlock would connect to the Simatic PLC's "CNC Run" function to inhibit the NUM controller running any Simatic PLC functionality and would not allow the machine to run. The operator would receive feedback on the system via a Siemens Simatic HMI. Both siemens products would be connected by PROFINET.

For all proposed solutions, the author has chosen that a modification of the existing system is the most suitable option instead of creating a new design of electrical vacuum system. This decision was made due to the projects limited timescale and the projects budget.

For each solution, decisions have been made to ensure the companies electrical standard document has been followed. Section 4.6 of the company's electrical standard document details a list of preferred component manufacturers. The preferred component manufacturer for all process sensors is IFM electronic, and where possible the sensor should have IO-Link programmability (Company, 2019).

The chosen pressure sensor & vacuum measuring device that all three solutions would use was chosen to be the IFM PN2099. This is due to: the sensor being suitable for vacuum applications, the sensor having a -1000 to 1000 mbar range, the sensor having a resolution of 5 mbar, the sensor having 2 NC/NO outputs with one being digital or analogue switchable and the sensor having the ability to be programmed over IO-Link (gmbh, IFM Electronic, 2015).

A new vacuum interlock pressure sensor location would be used for all solutions to eliminate the problem of allowing the machine to start without sufficient vacuum pressure at the chuck. All modification solutions would also still maintain a manual method of testing the vacuum interlock for maintenance and fault-finding purposes.

The main control panel of NFBG4 has followed section 4.1.10 of the company's electrical standards document (Company, 2019), and has 25% of the panel left empty to allow for future modifications to the panel to take place, this means that all solutions would mainly make use of the main electrical control panel for its modification with the exception of any components that are unable to be mounted inside the main control panel (e.g. pressure sensors).

<u>Category</u>	<u>Solution</u> <u>1</u>	<u>Solution</u> <u>2</u>	<u>Solution</u> <u>3</u>	<u>Best solution</u>
Cost (Cheapest)	1	3	2	1 , Solution 1 has the lowest costs due to its greatest cost only being the Pilz safety controller instead of a Siemens PLC. Solution 2 is the most expensive due to a combination of the PLC cost and the cost of the installation.
Expandability	3	1	2	2 , Solution 2 has the greatest expandability as the s7-1500 can be expanded very easily to add more inputs & outputs for greater functionality. Solution 1 has the least expandability due to solution 3 also using a siemens s7 PLC
Time required	1	3	1	1&3 , Solutions 1 and 3 would take a lot less time to be installed than a full PLC replacement in solution 2
Safety	1	2	2	1 , Solution 1 has the highest safety rating due to its circuit containing a Pilz safety controller which has an SIL 3 rating. Solutions 2 and three would use normal relays in their circuit.
Ease of integration	1	3	2	1 , Solution 1 would have the easiest integration into the machine due to the company already using the pillz safety

				controller in a lot of other machines and due to its programming being very simple. Solution 2 would still be quite easy to use but is the second-best option due to the amount of programming needed. Solution 3 would be the hardest to integrate as the Siemens PLC would need to replace operate instead of the NUM PLC and interact with the CNC controller and NUM servo drives.
Company compatibility	1	3	3	1, Solution 1 would be the most compatible due to the company already using the same PILZ safety controllers in other areas, already having the software and already having spares and expansion parts available in stores. Even though there are some other Siemens S7 PLC's used within the company they have been part of new machine installs, this means the company has limited licenses for the TIA portal software and maintenance workers are not as experienced with these PLCs which could lead to problems when fault finding.
Complexity	1	3	2	1, Solution 1 is the least complex solution, due to not being connected to a network or replacing any of the machine's main electrical components. Solution 2 does not replace any of the machine's main electrical components but is connected to the network and does require a greater amount of programming. Solution 3 is the most complex due to the replacements of the

				machines main PLC, and it also being connected to the network.
Future proofing	3	1	2	2, Solution 2 is the most future proofed option, due to using a siemens S7 PLC which are very expandable and can be updated to match the software used to program them. The main NUM PLC, CNC controller and servo drives are not replaced and therefore can continue to work with each other. Solution could require an upgraded CNC controller and/or servo drives to be purchased due to compatibility issues with the new Siemens s7 PLC
Reliability	1	2	3	1, Solution 1 is the most reliable solution due to it using a pillz safety controller which has a SIL3 rating. Solutions 2 and 3 could still be considered reliable but as solution 1 uses SIL rated components it makes it the better choice.
Use of new technology	3	2	1	2, Solution 2 makes the greatest use of new technology by using a Bluetooth transmitter to send data to a Bluetooth enabled device to monitor the vacuum pressure levels

5.5 Solution Suitability grading

All three solutions could be selected for the project and could meet the FDS but the most suitable solution for the project is solution 1. The three most important criteria that decided this are: Cost, Time required and safety. Solution 1 could be implemented for the cheapest, would take the least amount of time to complete and would have improved safety functionality due to the Pilz controller. Solution 2

would be very expensive and would require a lot of time to complete. This would be due to the expense of buying the larger S7 1500 PLC for the machine and then the time it would take to install and program it to the machine. Although the price for solution 3 is not as much as solution 2 it would still cost more than solution 1 due to the S7 1200 PLC.

6. Project Planning, Work breakdown and Management Techniques

6.2 WBS

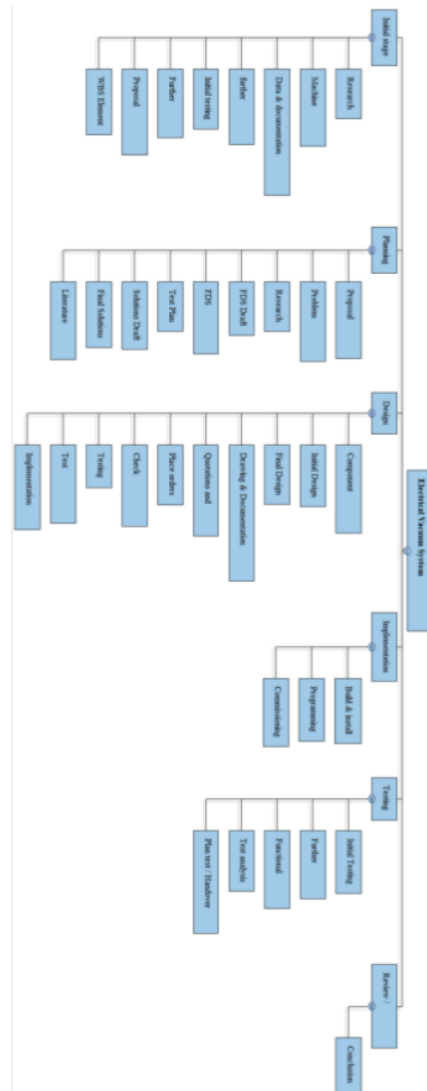


Figure 8: Work Breakdown Structure

A Work Breakdown structure was created to graphically display all stages of the project. The WBS is split up into 6 main sections, to help with progress tracking during the project and to help organise

and distribute workload in order to efficiently complete the project. The WBS was also used to design the project Gantt chart by providing the work tasks.

6.3 Gantt Chart

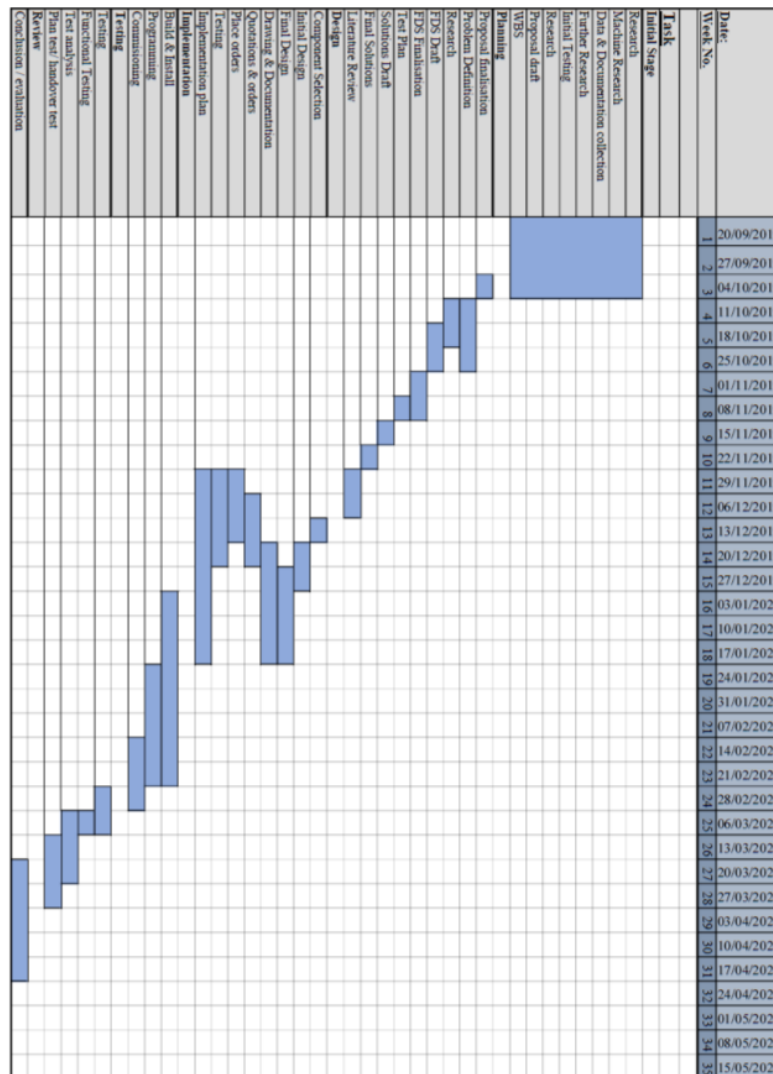


Figure 9: Project Gantt chart

A Gantt chart was created to help track the progress of the project by giving clear timescales of when tasks should be started, when they should be completed as well as what tasks need to be worked on simultaneously. Using the Gantt chart alongside keeping a weekly logbook clearly displays whether the project is correct and on schedule or whether the project and its tasks are behind schedule.

7. Conclusions and Recommendations

The project is currently up to date and following the designed Gantt chart. Following the completion of the first project presentation, the next stages of the project are design and implementation. This is where the selected system modification will be designed, components will be carefully selected and ordered ready for the modification to be built. To improve the efficiency and quality of these next stages, spare time should also be allocated to ensure further research is carried out and any new software and hardware should be made familiar. This will help in the design, implementation, testing and review stages.

Drawings and documentation will be created in the design process to help create a greater understanding for the system design which will also help in the design, implementation, testing and review stages of the project.

The WBS should be looked at before starting every section to ensure that all project work stays on task and to ensure that any tasks that have the potential to be completed simultaneously are completed together.

Exact component and part research should be carried out before any extensive design work has been completed to ensure that there will not be any problems discovered at a late part of the design section which could cause delays in the project,

8. Citation List

Company, 2019. *Electrical standards document*. s.l.:Electrical Engineer.

gmbh, IFM Electronic, 2015. *PN2099 pressure sensor data sheet*. Essen: IFM.

9. Appendix

Appendix 1: Signed Project proposal

SGEE6003 Major Project - Proposal

Kristian Payne

Modification to electrical vacuum system for NFBG 4

Where is the project based?

Project is to be carried out in industry within a local company that produces Titanium products for the aerospace industry. The project is intended to be installed and commissioned in Sheet Finishing area on narrow fan blade grinder number 4.

Why is the project needed?

The project is needed to upgrade the existing electrical vacuum system used on the grinder. Maintenance costs for this machine are high due to the system needing to be inspected and tested every week by maintenance craftsmen. A loss of vacuum pressure is a major safety hazard so it is essential that the inspections are carried out regularly. The existing performance of the vacuum interlock system can be affected by a build-up of coolant in the vacuum reservoir which enters through the vacuum chuck and is meant to be drained off by an operator throughout each working shift. Therefore, an automated system is required.

The purpose of this project

To design and build a panel with modifications to the existing electrical vacuum system to achieve the following by automating the inspection and testing procedure:

- Reduce maintenance costs
- Increase safety
- Increase system performance

Who will be involved with the project?

Author – Kristian Payne (Apprentice electrician / student)

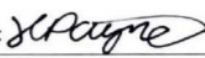
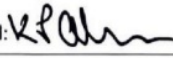
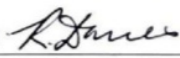
Industrial supervisor – Kevin Alderman (Engineering Technician – Sheet Finishing)

Academic supervisors – Robert Davies and Michael Hall (Coleg Sir Gar, Lecturers)

Through all phases of the project there will be a requirement to liaise with the company's Maintenance Manager, Maintenance Engineers (Electrical / Mechanical) and the Production Department.

What budget is available?

The Industrial supervisor has confirmed that a budget will be made available to develop the system modification. It is envisaged that the total cost will be £3000. The final project report is to be submitted by 24/04/2020.

Kristian Payne Project manager	Kevin Alderman Industrial supervisor	Rob Davies Academic supervisor
Signed: 	Signed: 	Signed: 
Date: 09/10/19	Date: 09/10/19	Date: 11/10/19

FINAL GRADE

GENERAL COMMENTS

Instructor

54/100

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GRADING FORM: NEW CSG-RUBRIC

KRISTIAN
PAYNE

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1. ENGAGEMENT WITH LITERATURE



Some evidence of research though limited to company documents and one source considered for literature review though clearly, further research must have been carried out. Very limited reference to research (2/10) Little evidence of reading, only two sources cited, one being external to the company. Limited sources used (2/5) Total = 4/15

4

2. KNOWLEDGE AND UNDERSTANDING

A good explanation provided for the background and



context of the project. However, commercial, economic and social context not considered. (5/10) Dangerous occurrence on a CNC grinding machine involving ejection of plate metal due to an undetected loss of vacuum (5/10) Little or no consideration given other than references to company standards. Some mention of generic standards in the FDS e.g. BS7671 and EN 60204. (3/10) Some mention in the FDS. Little consideration of these in the report, just a generic statement of the company's general policy for recycling (1/5) No section specifically set aside but some risks have been considered Main risks to the project were from company management pulling the project from him (2/5) Total = 11/30

3. COGNITIVE AND INTELLECTUAL



Good explanation given. Generally well defined as a dangerous occurrence on a CNC grinding machine involving ejection of plate metal due to an undetected loss of vacuum. (4/5) Good level of detail provided. FDS was explained, however this lacked some detail on specifics that would have been expected at this stage. E.g sourcing of some major components. Budget of £3000 was mentioned. (7/10) Detailed plans should enable the system to be fully tested. 12 stage test plan included, this lacked clarity on some tests, e.g. "operator controls should operate as intended". (3/5) More detailed conclusions could have been given about the decisions made. Good recommendation given for moving forward. This section was more descriptive than evaluative. (2/5) Total = 16/25

4. PRACTICAL APPLICATION



A good explanation given for two solutions but the third is identical to the second. A good table of comparison offered. 3 solutions given and comprehensive grading of each was explained, justification for final choice was mentioned. (4/5) Good detailed WBS and Gantt chart (but you could have identified milestones). No evidence of project risk planning and health and safety risk assessment supplied. Gantt chart and WBS used as planning tools, these were detailed and well presented. (7/10)
Total = 11/15

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5. TRANSFERABLE SKILLS



A very good summary of all aspects of the project though it could be written with less words. A good summary of the project and the possible solutions, however testing, commissioning and budget were not mentioned. (4/5) Generally well written with occasional errors. Generally well written and presented (3/5) Not exceeded by more than 10%
3642 words declared (5/5) Total = 12/15

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