

1708159

by Jonathon Williams

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Name: Jonathon Williams
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Much of the report reads like a journal where it should be more explanatory of how the system works rather than the order it was made.

References should have been made to the drawings in the appendix which should also have been more detailed

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Spelling

1 EXECUTIVE SUMMARY

Solution 1 was fully designed, implemented and tested to meet the needs of the company. This solution involved adding an accumulation line off an existing tote transfer table. ASi relays were used to interface the PLC for the existing controls and the PLC for the accumulation line.

The Functional Design Specification that was previously agreed with the company was given full consideration during the design and implementation, with any variation to this being justified and documented. The design phase looked at the accumulation system, the two modifications to PLC01, (transfer function and telegram updates) and the SCADA updates. Once designed, the software was simulated as far as reasonably practicable to minimise time needed with the plant.

During the implementation stage, all stakeholders were informed of delays and the project timeline and Gantt Chart was updated. When delays did occur, the risk assessment was consulted and the contingency plans were implemented.

Overall, the project was successful, being completed by the deadline of April and coming under the budget of £150,000 set by the company. The total expenditure for the project was £141,831.72. With, the expected saving of £1,327.41 per day, the return on investment is four months, which is lower than the requirement of the company and the functional design specification of 2 years.

To further improve the project, the internet of things could be introduced, looking at tools that could be used for predictive analysis and machine learning in order to predict when a component is near failure so that it can be changed during an agreed maintenance window to minimise downtime.

Summary covers all aspect of what was done

2 INTRODUCTION

Three solutions were proposed to the problem the company was facing with having employees performing non-value-added tasks where they were delivering work to other colleagues due to lack of automation. This was costing the company £1,327.41 per day.

It is not necessary to review the other two solutions in this report. You only need to clarify your aims and objectives in this report.

Solutions 1 and 2 were based on the same operational idea but varied slightly in the technical communication between PLCs. Both solutions 1 and 2 involved building an accumulation line off the existing transfer table on line 7. In solution 1, the communication would be handled via hard-wired I/O between the two PLCs using ASi relays. Solution 2 would use a Profinet Profibus coupler to allow the two PLCs to write to each other directly. Solution 3 included a breaking into the existing tote sorter loop and installing a new exit point and tote lift.

This was determined in assignment 1

Solution 1 was determined to be the best solution after considering the cost of the project, deliverability in the timeframe allocated, complexity, intrusiveness to existing operation and number of support teams required. Solution 1 was developed, having full block diagrams, electrical schematics and other documentation produced. (i.e. risk assessments, technical manuals in English and declaration of conformity as required by The Supply of Machinery (Safety) Regulations 2008). During the design development of this solution, the Functional Design Specification was consulted and the considerations given were documented.

An introduction should be written in the future tense outlining what is going to be done. This reads like a summary.

Project management tools and techniques were used to keep the project on schedule and within budget. Tasks were assigned to all stakeholders and regular review meetings took place with relevant parties to ensure the project was staying on track. A log book was maintained with regular entries to analyse next steps to keep the project progressing forward.

Once the solution was developed it was tested using the testing table that was produced previously. The testing table was reviewed before it was used during the factory acceptances test (FAT) and adapted as required to ensure that the tests were relevant and that nothing is missed out.

3 DESIGN AND IMPLEMENTATION

3.1 DESIGN *This is an interesting section*

Solution 1 consisted of a new PLC, to control a new accumulation conveyor for the totes to be delivered (work in). The accumulation conveyor comprised of driven 24V rollers and slave rollers that would be driven by the powered rollers. The conveyor system will transport totes from an existing transfer conveyor onto the new conveyor system, with the totes needing to be indexed 90° via a lift and drive index conveyor comprising belts that will lift up between the rollers and drive the tote bin off the conveyor at 90° onto the new roller conveyors. Each roller conveyor will be subsequently driven by one of the 24vdc drive roller which will be linked via bands to several slave rollers that all then act as one block of rollers. The rollers will only drive a tote forward if the rollers in front are clear, additionally the rollers will turn off if there are no totes on the conveyor or the one in front for power saving. Each conveyor section will be made up of 3 roller block sections bolted together to form the complete conveyor system. These will be placed onto legs which will also support the exit conveyor above.

Communication is needed between the new PLC and the existing PLC which will feed the line. Consequently, it was decided to use hardwired I/O via ASi bus as this was already in the area where the project was to be deployed. It was also decided to use a Siemens 1500 PLC. Siemens was chosen over Allen-Bradley due to the recent security vulnerability concerns. (Rockwell Automation, 2022) The model of ASi slave was decided on the criteria that it would fit into the extended ASi range, allowing for full utilisation of PLC resources (Pepperl & Fuchs, 2015).

The Functional Design Specification (FDS) was considered in the design process and documented in Table 1 below.

Table 1: FDS Considerations

Reference	Criteria	Considerations
P1.1	Line must accept minimum of 500 totes per hour	Drive rollers must run at a minimum of 11 m/min to achieve this.
P1.2	Work-out (Pack-line) will run at 80 ft/min with a ramp time of 0.5s	Existing control of old line has these settings
P2	System must highlight faults and be presented to the engineering team via pilot	Signals will be included in hardwired signal exchange. (Appendix A)

You should have reviewed the FDS and explained any changes and cited the original version found in assignment 1.

	lights and/or the SCADA System.	
P3.1	Start-up sequence must be as per other lines, work-out-line (top) to wake on start button or on positive edge of sensor	Line in code to be added.
P3.2	Work-in-line (totes) must start automatically when work is detected	Line in code to be added.
P4	System must be controllable from the current operations interface	New tote destination will be added onto the existing telegrams to allow for easy interface.
P5	System must display faults locally on control panel	N/A
P6	Solution must be compatible with the warehouse's OEE system (Metrics dashboard measuring Overall Equipment Effectiveness)	Will add to existing DB in current pack PLC and get status from the hardwire I/O.
P7	Tote conveyor is an accumulating conveyor, allowing the line to fill with totes and not stop when one tote reaches the end of the line.	Programming requirements
E1	Conveyors must have an energy saving mode - after 30 minutes of inactivity, conveyor switches off	Workout line will use the downstream sensor and a timer as there are multiple places for induction where this would not be detected. Work in line – as there is only one induction point, and multiple sensors, energy saving mode will be lowered to 10 seconds monitoring of accumulation is done.
S1	Line must conform to SIL 2 reliability rating, stop category 0 (energy disconnect) according to BS EN IEC 62061	Rollers have a 24V power supply and a separate 24V run input. 24V supply will be taken from a 3ph power supply that is interlocked with an e-stop relay confirming to SIL 2 SC0.
A1	Line must keep aesthetics, must match colours of other conveyance. RAL 7016 & 1023	Requirement in specification given to fabricators.
A3	Tote-conveyor must be 0.75m high	Requirement in specification to conveyor manufactures
A4	Pack-conveyor must be 1.42m high	Requirement in specification to conveyor manufactures
A5	Tote-conveyor must be able to accept totes of the minimum and maximum size and weight as specified in Table 5.	Requirement in specification to conveyor manufactures

A6	Pack-conveyor must be able to fit packages of minimum and maximum size and weights as specified in Table 6.	Requirement in specification to conveyor manufactures
T1	Parts used must be in line with the preferred suppliers list.	Requirement in specification to conveyor manufactures
T2	System must display and send healthy signal when system has no faults	Included in I/O exchange (Appendix A)
T3	BOM, technical and operations manuals are provided	Part of supplier's scope for new elements. Modification elements, will be done by the company.

Electrical Drawings were produced for the interface panel (Appendix B). The electrical schematics for PLC01 were also modified to show the safety interlocked supply to the new accumulation conveyor control panel. International Standards Organisation define control parts of system machinery in ISO 13849-1 and IEC 61508. Within this standard, it defines the reliability rating and stop categories. The three stop categories are explained in Table 2.

Table 2: Emergency Stop Categories

Stop Category	Description
Stop Category 0:	Uncontrolled stop - stopping by immediate removal of power to the machine actuators (i.e. uncontrolled stoppage).
Stop Category 1:	A controlled stop with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved.
Stop Category 2:	A controlled stop with power left available to the machine actuators.

(International Electrotechnical Commission [IEC], 2021)

It was agreed with the customer to use stop category 0 as there is not much inertia on the drives being used, the stop will happen very quickly and category 0 gives instant electrical disconnection. Stop category 2 is prohibited by the customer's safety policy.

Research was conducted using internal company documents to fully understand the technical modifications needed to the existing system. It was established that there were two parts to the software modification. One part would be in the PLC network that controls the movement of the transfer table, the other part is the multiple function blocks, calls and data blocks used to handle the telegrams. The telegrams work by having a data loaded into arrays in a specific DB and then the external software will read or write into the PLC data block. (Sit SteuerungsTechnik GmbH, 2015)

A block diagram for the communication telegrams is shown in Appendix C. From this, it was clear that there were 3 telegrams to be concerned with, 01 - the scan, 51 - the reply and 91 -

the status updates. The company's host interface document was used to determine what the telegram needed to consist of, the lane status for example is a string with each position having an integer between 0 and 5. Each integer displays a status as shown below in Table 3. To add the extra status in the DB, the function call used will also have to be modified.

Table 3 - Telegram 91 status values

Integer value	Description
0	Operational, not (part) full
1	Lane 50% Full
2	Lane full 75 %
3	Lane full 100%
4	Deactivated (switched off)
5	Error

(SIT - SteuerungsTechnik, 2018).

P2 of the functional design specification requires the system to be able to show a fault locally with a pilot light and also on SCADA. To avoid requiring a large amount of lights, the faults were grouped into zones and each zone would have a pilot light. The SCADA screen would have more detail. The accumulation conveyor is made up of 16 "conveyor sections" with each of them having three roller drives. At a top level on SCADA, if there is a blockage on that particular section it will highlight and a textual alarm will be displayed. This can then be opened up and it will show in a finer detail which of the three sensors in that section is blocked.

3.2 IMPLEMENTATION.

A spreadsheet was used to track the expenditure of the project and to ensure the project stayed on budget. The spreadsheet is shown in Appendix D. It is broken down into three sections to allow for ease of tracking by a discipline i.e. control parts, software and hardware.

The work breakdown structure and Gant chart were used to manage the project timelines. Risks facing this project were identified for each category for: external risks, project management, internal risks, technical/equipment and systems and legal. This enabled risk mitigation strategies to be formulated and contingencies to deal with them.

What were the risks and how were they mitigated?

The project was on track for the first tasks up to and including placing the order for materials. Once the order was placed, it was established that due to the on-going global pandemic, material shortages and transport issues, it was reported that the materials were going to be on a greater lead time than the initial 50 days which was planned for in the risk planning stage

under external risks. The biggest delay was on the Interroll drive and slave rollers. Interroll were giving a planned lead time of 98 days. To get around this, the contingency plan of using the alternative supplier Rulmeca, was implemented which reduced the lead time to 70 days.

The second delay was the software development. Code development was scheduled for 40 hours, but that was 40 uninterrupted working hours. During development of the project, different projects resulted in a diversion of resources which subsequently delayed development and overlapped with annual leave.

The Gantt Chart was updated as shown in Appendix E.

You could have explained the differences between this one and the original one.

The first part of the implementation from a software perspective was to add the symbolic of the interface for the new inputs and outputs (I/O). The second part of the software implementation was modifying the transfer function and then the status updates.

Figure 1 shows the mapping of the inputs to static bits. It was done this way as S7 is not as good at handling tags as TIA portal, and if the input had to be changed to something else, the input could be changed in one place without having to go through all the code. Using memory bits or statics in data blocks are a good way of limiting the risk of writing to an output in more than one place.

```
//--- IF<-Signale von SLAM308
A      "I_BO_SA_SLAM_308_RTR"
=      #t_SA_SLAM_308.i_RTR

A      "I_BO_SA_SLAM_308_FgTP"
=      #t_SA_SLAM_308.i_FgStarTP

A      "I_BO_SA_SLAM_308_Zone1OK"
=      #t_SA_SLAM_308.Zone_1_OK
A      "I_BO_SA_SLAM_308_Zone2OK"
=      #t_SA_SLAM_308.Zone_2_OK

A      "I_BO_SA_SLAM_308_Full50"
=      #t_SA_SLAM_308.i_Full_50

A      "I_BO_SA_SLAM_308_Full75"
=      #t_SA_SLAM_308.i_Full_75

A      "I_BO_SA_SLAM_308_Full100"
=      #t_SA_SLAM_308.i_Full_100

I117.4      -- ASI01B-TN10B_01+SLAM_308 Conveyor - Drive running
#t_SA_SLAM_308.i_RTR -- Drive running

I117.5      -- ASI01B-TN10B_01+SLAM_308 Conveyor - Infeed allowed
#t_SA_SLAM_308.i_FgStarTP -- Infeed allowed (Start release TP)

I117.6      -- ASI01B-TN10B_01+SLAM_308 Conveyor - Zone 1 OK
#t_SA_SLAM_308.Zone_1_OK -- conveyors from transfer table to including
I117.7      -- ASI01B-TN10B_01+SLAM_308 Conveyor - Zone 2 OK
#t_SA_SLAM_308.Zone_2_OK -- conveyors in the straight section along t

I117.0      -- ASI01B-TN11B_01+SLAM_308 Conveyor - 50% Full
#t_SA_SLAM_308.i_Full_50 -- 50% Full

I117.1      -- ASI01B-TN11B_01+SLAM_308 Conveyor - 75% Full
#t_SA_SLAM_308.i_Full_75 -- 75% Full

I117.2      -- ASI01B-TN11B_01+SLAM_308 Conveyor - 100% Full
#t_SA_SLAM_308.i_Full_100 -- 100% Full
```

Figure 1 I/O mapping to static bits

The above codes needs more explanation, e.g. for "A", "#", "="

Once the I/O was mapped, the function calls which 'send' the data to the router needed to be updated to account for the extra destination. Some of the additional lines of code were written in German to keep in line with the existing code that is in the PLC.

The actual transfer part to the new destination was achieved by reusing the existing function call used for transport by the company. The call is shown in Figure 2.

```

//--- Transport Transfer zum Ziel "44"=SLAM308
A   #S_BO_Status_Ziel_SH43.Ziel_44
A   #t_SA_SLAM_308.i_FgStartTP
AN  #S_TP_56033_56051.D_BO_Transport
=   #T_BO_Startfreigabe

A   #S_BO_Merken.TE_auf_Transf_56_03_03
=   #T_BO_Anmeldung

CALL #Trapo_56033_SLAM_308
IN_IN_Mode_Befehl      :=1
IN_IN_Taktabstand_VK_VK :=0
IN_IN_Minustol_VK_VK   :=0
IN_IN_Luecke_HK_VK     :=0
IN_IN_Minustol_HK_VK   :=0
IN_IN_min_Lfs_Durchfoerd:=0
IN_IN_Timeout_Transport :=100 // *50ms
IN_BO_Startfreigabe     :=#T_BO_Startfreigabe
IN_BO_Reset_Befehl      :=FALSE
IN_BO_Anmeldung         :=#T_BO_Anmeldung
IN_BO_Abmeldung         :=#S_Trig_LS_SLAM308_B117_3.D_BO_HK_FLK_LS
IN_BO_Durchf_loeschen   :=TRUE
OUT_BO_pos_Flk_Transport:=#S_TP_56033_SLAM_308.D_BO_pos_Flk_Transport
OUT_BO_TpEndeOhneTimeout:=#S_TP_56033_SLAM_308.D_BO_TpEndeOhneTimeout
OUT_BO_Transport        :=#S_TP_56033_SLAM_308.D_BO_Transport
OUT_BO_Durchfoerdern    :=#S_TP_56033_SLAM_308.D_BO_Durchfoerdern
OUT_IN_Zaehler_Abstand  :=#S_TP_56033_SLAM_308.D_IN_Zaehler_Abstand
OUT_IN_Zaehler_Luecke   :=#S_TP_56033_SLAM_308.D_IN_Zaehler_Luecke
IO_BO_Stoe_Transport    :=
IO_UDT_Antrieb_eigener  :="DB_Antriebe"._560_03_01 // Antrieb Transfer

```

Figure 2 Transport function call

In parallel with the software research and development, there was the physical removal and installation of the original packing conveyor. With the material shortage mentioned above aside, the physical installation took the same amount of time as was planned for in the work breakdown structure and Gantt chart.

Regular meetings were held with project stakeholders to ensure that everyone was aware of the latest updates and the chance to raise any potential blockers. During the review meeting the Gantt chart was always reviewed and updated. [How and why?](#)

The project was installed and completed on the 23rd February 2022 being 2 weeks overdue. However, the revised schedule allowed a short period for commissioning works.

Once the installation was completed, the AWCS team were contacted and asked to deploy their change.

A security review was also submitted to the company's Information Security (Infosec) department to add this device onto the existing VLAN for PLCs. The request contained the IP address of the PLC and any ports that would be needed for use, for example port 8088 is required for the S7-1500 PLC to communicate with the company's OPC/UA server which is used for their SCADA.

Once the security review had been approved and the PLC could be networked, the agreed SCADA design was implemented on the development server in preparation for testing.

Rather than configure the PLC to be an OPC server and make its block structure available to external sources, the SCADA would just read one DB to pull the SCADA data. Siemens S7-1200 and 1500 series PLC by default have block optimisation, so that a user can make full use of the PLCs memory. In order to make it compatible with the SCADA requirements, a block was created for SCADA (DB1000) and “optimise block access” had to be unselected from the DB attribute menu in TIA Portal. *good, this is correct for TIA Portal*

To save on tags, process time and memory on the SCADA server, dynamic mathematical fields with limits were added for the sensor labels. As the tag is passed to the maintenance page when it is selected, the sensor number could be determined from the conveyor number by multiplying it by three and then subtracting from it depending on which of the positions it is on the block of three sensors as shown below in Figure 3.

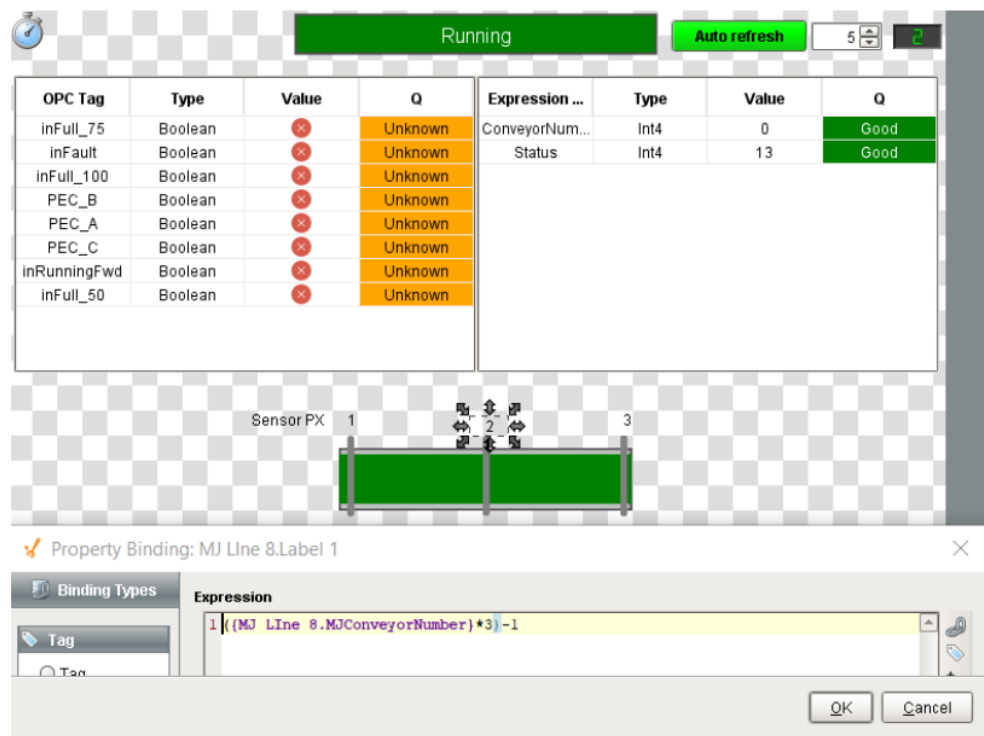


Figure 3 - SCADA Maintenance Screen

4 TESTING AND RESULTS

Once the software had been written, the code was simulated using the built in PLC simulator in TIA Portal. As the telegrams get written to a data block, it enabled different values to be forced into the DB and check that the output was as expected. The first simulation was to check that the original functions of the transfer table had not been disturbed. This was done by simulating the value of destinations SH41 – 43 and by monitoring which auxiliary drive get activated.

Once it was proven that the original function was working as designed, the new functionality was tested by loading 44 into the data block. The simulation performed as expected and activated what would be the drive for that conveyor. Figure 4 below shows the tags “Flk_Transport_308” and “TpEndeOhneTimeout_308” tag at logic 1, showing they had been activated by the block when called.

*Flk_Transport_3...	%M99.0	Bool	☒ TRUE	☐	Transport Flank
*TpEndeOhneTim...	%M99.2	Bool	☐ FALSE	☐	Transport Timeout
Transport_308	%M99.3	Bool	☒ TRUE	☐	Activate Transport
*Durchfoerdern...	%M99.4	Bool	☐ FALSE	☐	Continue Transfer

Figure 4 - Transport bit simulated

The blockage when the de-registration signal (transfer complete) had not been reached within 3 seconds, the tag “TpEndeOhneTimeout_308” would be activated to show that the transfer had timed out as shown in Figure 5. This would then need an operator to come and clear the transfer area and activate a reset button.

*Flk_Transport_3...	%M99.0	Bool	☐ FALSE	☐	Transport Flank
*TpEndeOhneTim...	%M99.2	Bool	☒ TRUE	☐	Transport Timeout
Transport_308	%M99.3	Bool	☐ FALSE	☐	Activate Transport
*Durchfoerdern...	%M99.4	Bool	☐ FALSE	☐	Continue Transfer

Figure 5 - Transport timeout

As the section of conveyance being diverted to is controlled by a separate PLC, PLC01 turns on an output relay to signal to the new accumulation conveyor PLC that it needs to start if it has gone into energy saving mode. Once the simulation was proven to work, a change request was raised and submitted to the company for authorisation to execute change on the day requested.

Once the simulation had been proven, the next thing to test was supporting the AWCS deployment to ensure that the routing side was correct.

This was tested by using a pre-notification tool to force totes to existing different destinations. Totes were sent to all 11 existing destinations plus the new line 8 destination to ensure the new system was not impairing any of the existing functionality. Once AWCS side had been proven, the project testing table was used to ensure all criteria in the functional design specification had been met. The testing table was then extended to allow for comments on the actual outcome of the test to be added. The testing table is shown in Table 4 with evidence of the tests in Table 7 in Appendix G.

Table 4 Testing Table

Test Number	FDS Reference	Test Description	Expected outcome	Actual Outcome	Pass Or Fail
1	A1	Check colour of frame work matches specification	Colours match specification.	Colours match specification.	Pass
2	A2	Check layout of conveyors is as per FDS	Layout of conveyors is as per FDS	Layout as per FDS	Pass
3	A3	Measure height of tote conveyor	Conveyor is 0.75m high	Conveyor is 0.75m High	Pass
4	A4	Measure height pack-conveyor	Conveyor is 1.42m high	Conveyor is 1.42m high	Pass
5	A5	Check tote-conveyor can accept totes of the minimum and maximum size and weight as specified in Table 5.	Conveyor can accept material within set dimensions and weight (Appendix F)	Conveyor accepts materials within the set dimensions and weight	Pass
6	A6	Check pack-conveyor can fit packages of the minimum and maximum size and weights as specified in Table 6.	Conveyor can accept material within set dimensions and weight (Appendix F)	Conveyor accepts materials within the set dimensions and weight	Pass
7	T2	With no faults on the tote line, check PLC01 receives system healthy signal	PLC01 gets healthy signal	Health signal received (Figure 8)	Pass

8	P1.1	Load totes onto line for 1 hour, set up photocell on line to trigger a counter.	After 1 hour, counter must be greater than 500 to accept line can cope with 500 totes per hour.	After 1 hour, counter was greater than 500. Figure 9	Pass
9	P1.2	Measure belt speed using tachometer	Speed is between 80±5 ft/min	Speed is 84ft/min Figure 10	Pass
10	P1.2	Check ramp time of VFD controlling motor	Ramp time is 0.5s	VDF setting show 0.5s ramp time in the VDF configuration. Figure 11	Pass
11	P3.1	Press start button for line	Pack-line starts when start button is pressed	Pack line starts	Pass
12	P3.2	Flag incoming tote sensor	Tote accumulation line starts	Line starts on positive flag.	Pass
13	E1	Leave the pack-line for 20 minutes.	When no photocells on the line have been triggered for 20 minutes, the conveyor will turn off.	Conveyor goes to sleep and wakes on the correct signals. Figure 12	Pass
14	S1	Activate emergency stop	On activation of E-stop, the line will stop and energy will disconnect.	Line stopped and energy disconnected. Figure 13	Pass
15	P2/P5	Place fault on line by blocking sensors,	Fault light displays on panel and sends fault condition signal to PLC01	Fault light show on PLC panel and sends signal to PLC01 Figure 14 and Figure 15	Pass
16	P4	Route tote to line using operations interface and check telegram status	Tote routes correctly and send a successful telegram	Totes route correctly using operations interface and sends a successful telegram Figure 16	Pass
17	P6	Modification is able to be added to OEE platform	Modification added to OEE and performance can be measured	Line has been added to OEE using the interface with PLC01. Figure 17	Pass
18	P7	Load line with totes	Totes accumulate correctly	Totes accumulate correctly	Pass
19	T1	Check components used/BOM matches preferred suppliers	Parts used are preferred manufactures	Parts used are the preferred suppliers.	Pass

20	T3	Check documentation list for required documents	All required documentation is present	All documentation provided. Declaration of conformity Bill of Materials Manuals Recommended spare parts	Pass
21	F1	Project is within budget	Project is within budget	Project come in within budget	Pass
22	F2	Calculate ROI	Project will have a Return on investment is less than 2 years	Return on investment is under 2 years	Pass
23		Fill accumulation line to 50%	50% full relay is activated, PLC01 registers line is 50% full and updates telegram	50% full relay activated and PLC01 sent updated telegram	Pass
24		Fill accumulation line to 100% full	100% full relay is activated, PLC01 registers line is 100% full and updates telegram	100% full relay activated and PLC01 sent updated telegram	Pass
25		Introduce a fault on zone 1	With a fault on zone 1, plc01 should get the signal via the interface and set lane status to unavailable	PLC01 got the signal zone 1 was in fault and updated the telegram.	Pass

Once the SCADA was proven to be working, the project on the development server was then propagated onto the other six front end SCADA servers.

One of the problems that was encountered early on was the accumulation line kept stopping after a tote transfer was completed. This was because the vendor who programmed the accumulation line was using the signal “Start to run” like a global run signal where it was intended to be used as a wake signal when a tote is about to be transferred to that line. To overcome this, as there was spare I/O in both PLCs, a “global run” signal was added that could be used.

A second problem that was faced was that when the accumulation line panel was turned off on the isolator, the transfer table would go into error. When a tote is on the transfer table, in a DB it registers that there is a tote doing a transfer. The tote gets de-registered after it passes one of

the exit sensors. Due to the design on the transfer table, there was no easy way to mount a sensor for deregistration of a tote onto the new accumulation line. To solve this, a solid-state relay was installed in the accumulation line panel and was triggered when the sensor on the accumulation line sensor was flagged.

The company uses normally closed contacts for all of its sensors. This proved a problem when the panel was turned off, as the “sensor” input to PLC01 goes low and after 3 seconds, the transfer table registers there is a blockage on the table, which then stops the workflow. To overcome this, a new sensor was installed on the transfer table for PLC01 to use for the tote deregistration signal.

5 EVALUATION AND THE WIDER ISSUES

All elements of the functional design specification were achieved. All aesthetic parts were matched by having the line material powder coated in the same colours of the existing lines. From the safety and compliance perspective, the majority of the outcomes were met. The electrical supply for the drives were interlocked with the existing safety relay in the area so that it would isolate in the event of an emergency stop, achieving stop category 0.

The only element that varied slightly was the compliance. The functional design specification stated that the system must be marked with a UKCA mark as the project was being launched after January 2022. Towards the start of the 2022, the Department for Business, Energy & Industrial Strategy announced that the CE mark could be continued to be used until January 2023 to allow more time for businesses to adapt to the new requirements. As a result, the new accumulation line was given a CE mark, which means it conformed to the Machinery Directive 2006/42/EG rather than The Supply of Machinery (Safety) Regulations 2008. The UK designated standards in The Supply of Machinery Regulations are identical to the EU harmonized standards, meaning that the machines are designed safely, have technical documentation produced, have operating instructions produced in English and the local language and a declaration of conformity is issued.

The topic of debate could be raised around whether the instructions need to be in Welsh as well as English since that is the local language of where the machine is being placed. However, as it is EU legislation and Wales is not a member in its own right of the EU whereas, the UK was, the local language of the UK is English. Consequently, only English documentation needed to be produced. Furthermore, as the machine and documentation are not being produced by a public body but by a private company, the Welsh Language Act does not apply in this scenario.

Due to the type of VFD (variable frequency drive) being used to control the pack line, a tolerance of ± 5 ft/min was added to the speed specification for the packing line. This is possible due to the process that the line is being used for. As the line only delivers packages to a machine to have a shipping label applied, the speed of this line is not too important as the Shipping Label Apply Machine (SLAM) will regulate the incoming packages. The speed set on the packing line was 84 ft/min which is within the tolerance allowed.

In accordance with regulation 3 of the Management of Health and Safety at Work Regulations 2003, a detailed risk assessment was carried out on the modification to the existing system and for the new installation. This was given to the company on handover.

The project was given a budget of £150,00. During the planning phase, the project's solution was estimated to cost £137,000. The actual cost of the project came to a total of ~£140,000. Therefore, the project still came in under budget, although slightly over the planned spend.

The reasons for the extra expenditure were:

- Upgrading to express delivery of parts to keep the project on time increased delivery costs
- The customer's operations decided to change the positions of the workstations on the line as a result of starting to roll back covid-19 protection measures such as Perspex screens and distances between the stations.
- Each of the tote stands had custom slots machined out to accommodate the sensors and reflectors. As, the positions of the stands then had to change to what was originally agreed, they needed to be modified.

The customer for this project is very safety orientated and asks for over what is required. The existing system was CE marked as was the new accumulation system, but by their respective OEMs (Original Equipment Manufacturer). The customer has asked for one CE to cover both systems. For this to happen, the accumulation systems declaration of conformity, was submitted to the OEM for the customers site with a declaration of incorporation for the modification and then a new declaration of conformity was issued to cover both systems.

The financial part of the FDS stated that this project must have a return on investment in under 2 years. Due, to the significant saving of removing the extra headcount that this project provides (£21,800 per month), the return on investment is 4 months.

By identifying, analysing, managing, and communicating risks through appropriate risk assessments and writing out the job specifications, the 6 principles specified in the Engineering Council's risk guidelines were followed. These were:

- i Contributing to building a sustainable society, present and future- by considering the full range of implications across the life span of the installation
- ii Applying professional and responsible judgement and taking a leadership role
- iii Doing more than just comply with legislation and codes
- iv Using resources efficiently and effectively
- v Seek multiple views to solve sustainability challenges- by sharing good practice and being part of multi-disciplinary teams including non-engineers
- vi Manage risk to minimise adverse impact to people or the environment

The company, suppliers, and all contractors involved signed a contract of work. To restrict liability and commercial risk, this included work schedules, project deliverables, timetables, and non-disclosures. After being examined by the legal representatives, all contracts were signed on behalf of the company by the appropriate authorised person.

To support sustainability on this project, where possible materials were reused. Instead of fabricating a new section for the work out pack conveyor, an extension to the original pack-convey was fabricated to minimise waste of materials. Waste packaging was minimised, and local installation companies were used as far as reasonably practicable to reduce the project's carbon footprint. Any waste materials that were produced were recycled and disposed of responsibly by using a suitably licensed waste management company.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

A business case was initially made for the need to automate tote delivery to line 8 in order to make efficiency savings and promote a more sustainable and efficient way of working. A Functional Design Specification was agreed with the company and broken down into specific deliverables which could be seen in this report. Solution 1 was fully designed, developed and then implemented against the Functional Design Specification agreed with the company. It can be concluded that these deliverables were met, albeit later than planned. However, it was still within the company's deadline.

As the per the original proposal submitted, if successfully executed, this project would save the company £1,327.41 per day as a result of removing non-value-added tasks. With this saving and the expenditure of the project, the return on investment was calculated and it was determined the project would have a return on investment after four months. The functional design specification stated that the return on investment had to be less than two years, therefore, this point was achieved.

A full testing plan was used to test the project and tests were successfully referenced against a line in the functional design specification. There were some extra tests that would not have been in the initial testing plan as this was only possible once the solution had been fully designed to know exactly what tests were required and the way they could be carried out determined. *This shows that the FDS should have been prepared more carefully to take this tests into account*

During the planning phase, an evaluation of project management techniques determined that a combination of the work breakdown structure (WBS) structure, together with the Gantt chart and cost analysis spread sheet would have been the most effective to ensure the project was delivered on time within budget and within scope. This determination was correct as the spreadsheet was used to keep live track of the budget and current expenditure of the project. The Gantt chart was useful as a visual chart to show the timelines of the project, but also to show the slippage against the initial baseline and milestones and the WBS allowed the project to be divided into the more manageable tasks of design, documentation, manufacturing, software integration and management to ensure an easy progression between them. *How did the original compare with the final version?*

It can also be determined that the risk assessment carried out for project risks, assessing risks from external sources, internal sources, legal and technology was fit for purpose. Therefore,

when the risks for external sources occurred, the risk was easy to overcome as control measures had already been documented, such as an alternative suppliers list.

The importance of clear written communication was highlighted during this project. As one of the stakeholder teams for this project was based in Canada, face to face meetings were not possible and virtual meetings were difficult due to the 5-hour time difference. Therefore, e-mails were the best form of communication with this team. As a result of having the time differences, delays in communicating with this team were frequent. Therefore, it was very important that anything communicated was done in a clear and concise way and that the expectations were set.

To conclude the project, as per the plans for project management set out previously, all stakeholders were notified once the project had been finalised and all testing passed. All the relevant documents (Factory acceptance tests, deceleration of conformity) were signed by the authorised individuals. All project related documentation was stored on relevant document storage systems.

6.2 RECOMMENDATIONS

The future development for this project would be to add more controls functionality to help maintenance engineers. *This should have been thought of in your FDS.* Currently there are no manual functions. A recommendation would be to add a small HMI to the accumulation line control panel and give it the ability to turn the line into manual to drive the rollers. An alarm list could also be configured to be displayed on the HMI screen. This would be useful as currently faults are displayed on the company's SCADA system, which would be no use if the person at the conveyor did not have a laptop with them to access the SCADA system.

Another recommendation for development for this project would be to introduce some industry 4.0 concept and build in predictive maintenance. Vibration sensors could be installed across the key drive rollers, which would establish a baseline over a short period of running. Continuous monitoring could then take place during operations and machine learning/predictive analysis used to predict when a bearing in a roller would be likely to fail. Maintenance and operations teams could then arrange for a window to replace the roller with the suspect bearing in it, minimising downtime and impact to the customer.

7 CITATION LIST

[Company's] Worldwide Design Engineering - Controls Engineering, 2020. *WWDE-CNTRL-STND-GLOBAL-SPEC-R214-121620*. s.l.:s.n.

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[Accessed 4th April 2022].

Rockwell Automation, 2022. *Logix Controllers May Allow for Unauthorized Code Injection*.
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Available at:
https://rockwellautomation.custhelp.com/app/answers/answer_view/a_id/1134276
[Accessed 4th April 2022].

SIT - SteuerungsTechnik, 2018. *Interface Description PLC - Host*, Einsteinstr: SIT.

Sit SteuerungsTechnik GmbH, 2015. *Sit Standard 2013*. 3 ed. s.l.:s.n.

This list is rather small for a final report.

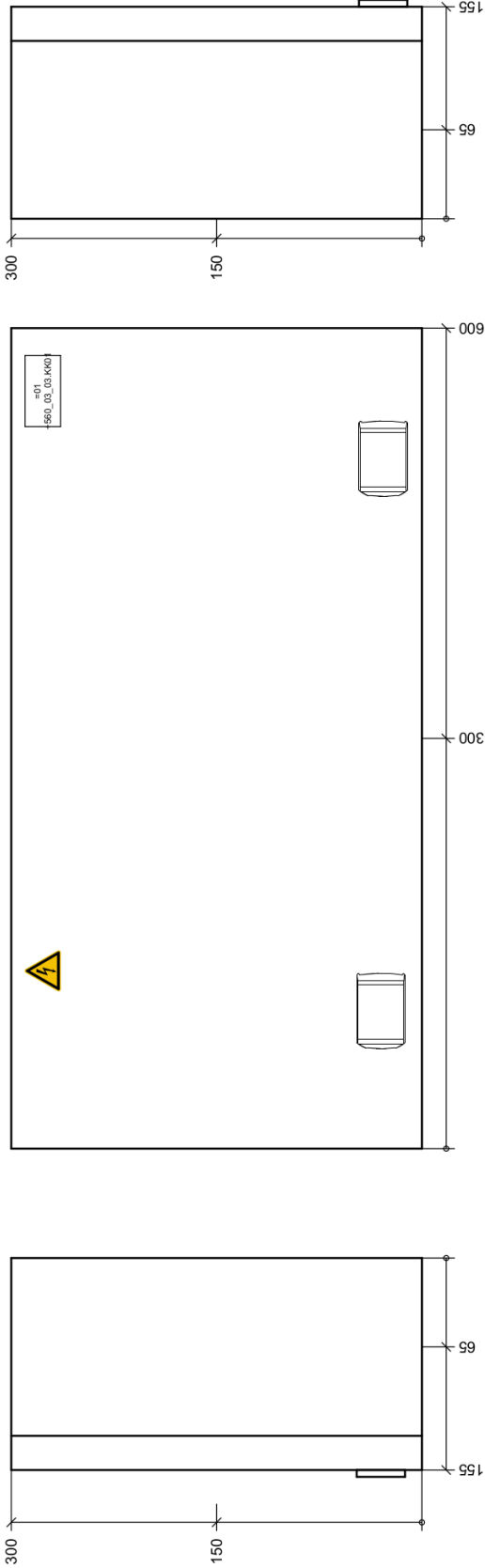
8 APPENDICES

8.1 APPENDIX A - SIGNAL EXCHANGE

<u>ASI01B-TN11B</u>	<u>SLAVE 2 Inputs</u>
E117.0	1. 50% Full. (close the contact to indicate the fill rate of the straight section across the pack line)
E117.1	2. 75% Full. (fill rate of the straight section across the pack line)
E117.2	3. 100% Full. (fill rate of the straight section across the pack line)
E117.3	4. Trigger LS
<u>ASI01B-TN10B</u>	<u>SLAVE 1 Inputs</u>
E177.4	1. Running. (M&J will close the contact to indicate the transfer conveyors are running).
E117.5	2. Infeed allowed. (M&J will close the contact to indicate the system is able to accept a tote, if the system becomes full and cannot accept totes this signal will go down. Any totes ongoing transfer will complete the transfer unless the "Running" signal also goes down).
E117.6	3. Zone 1 OK. (Contact close to indicate conveyors from transfer table to including the bend are OK to run).
E117.7	4. Zone 2 OK. (Contact close to indicate conveyors in the straight section along the pack line are OK to run).
<u>ASI01B-TN10B</u>	<u>SLAVE 1 Outputs</u>
A117.4	1. Start to run (Amazon controls will energize requesting the M&J system to wake up from power saving and start accepting totes).
A117.5	2. Stop plate up (Amazon will energize requesting the plate to be in the up position, de-energize to request the down position).
A117.6	3. <i>Global Enable Signal</i>

8.2 APPENDIX B—INTERFACE ELECTRICAL SCHEMATICS

All figures in the appendix could have been numbered and referenced and explained in the text of the report.

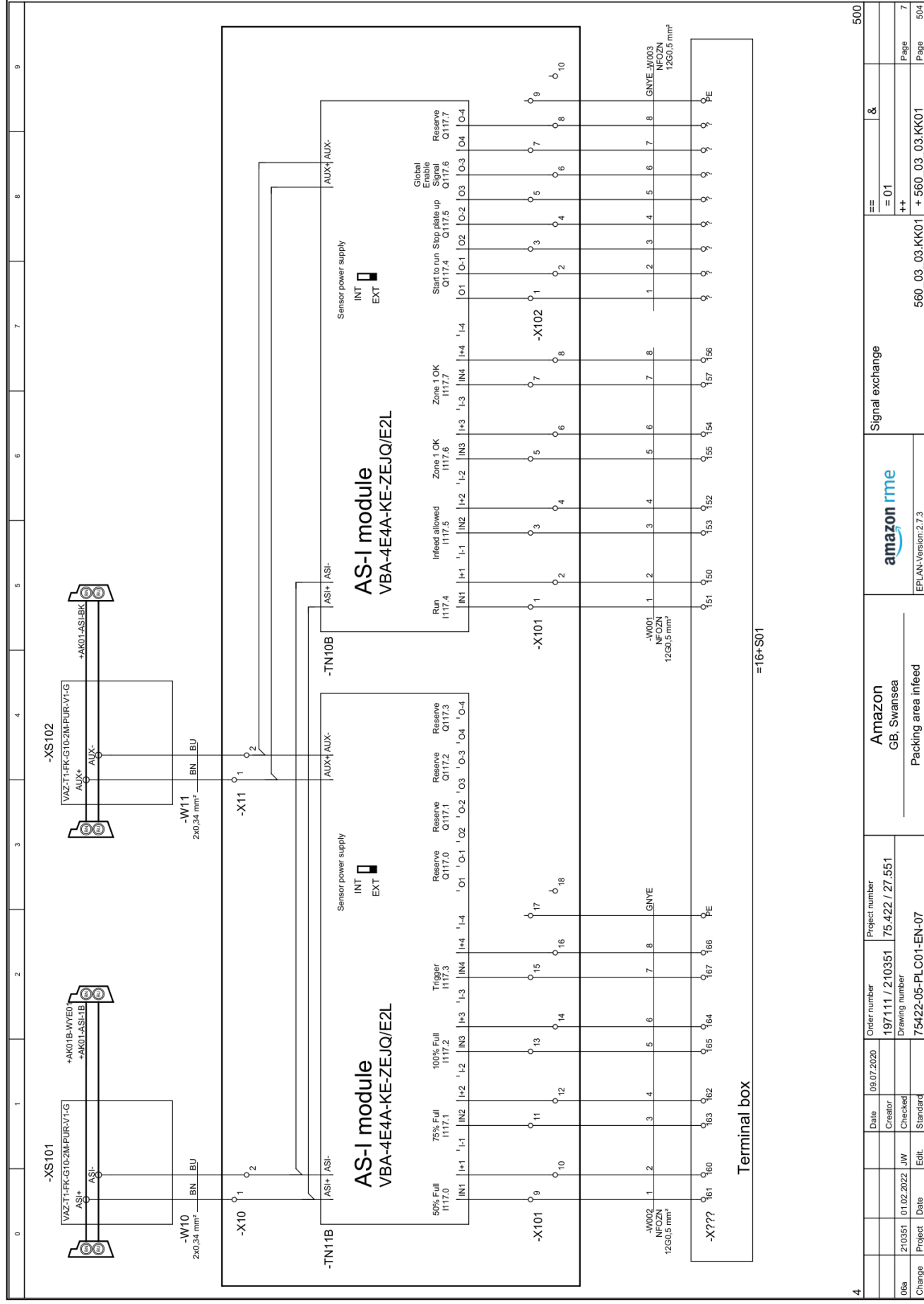


This is meaningless without an explanation and is lacking in detail.

+560_03_01/1		09.07.2020		Order number		Project number		Mounting enclosure		== &		3	
197.111 / 210351		Creator		197.111 / 210351		75.422 / 27.551		amazon rme		= 01			
210351		01.02.2022		Drawing number		75422-05-PLC01-EN-07		EPLAN-Version: 2.7.3		++		Page	
Change		Project		Date		Edit.		Packing area infieed		560_03_03.KK01		Page	
												504	

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[illegible]



8.3 APPENDIX C - TELEGRAMS

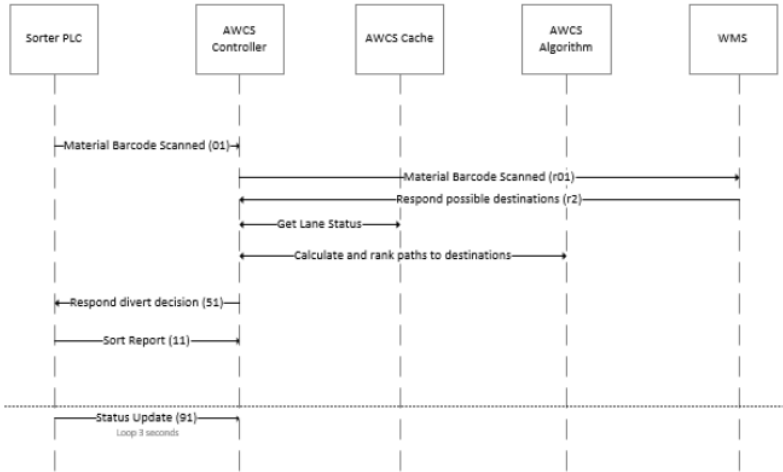
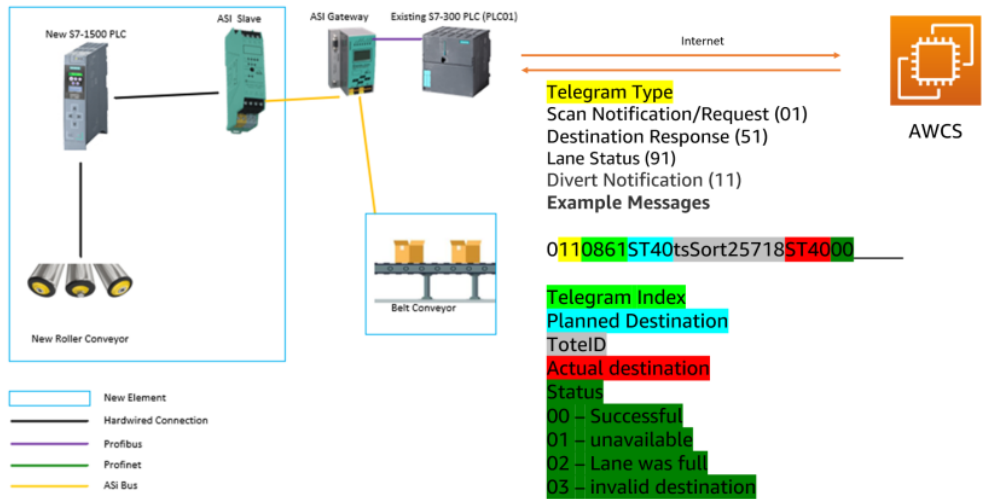


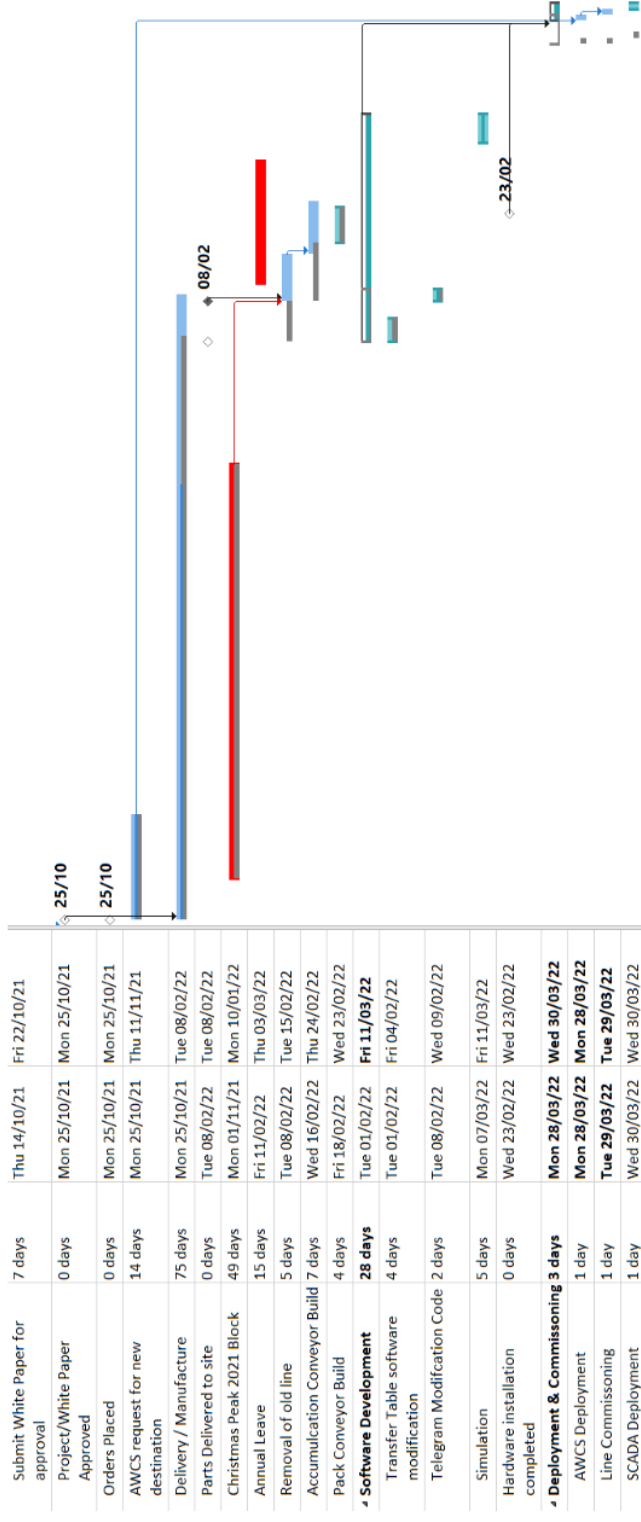
Figure 6 Telegram overview



8.4 APPENDIX D – COSTING SPREADSHEET

Controls		
Power Supplies	£	519.40
PLC CPU	£	560.00
I/O Cards	£	1,472.00
Terminals, contactors, relays, consumables	£	350.00
Panel	£	500.00
Labour	£	1,600.00
Drive Cards	£	2,880.00
Labour Layout Change	£	1,600.00
	£	9,481.40
Software		
Internal PL01	£	1,500.00
Internal A/WCS	£	250.00
Accumulation PLC	£	1,200.00
	£	2,950.00
Hardware		
Drive Rollers 445mm	£	7,200.00
Drive Rollers 720mm	£	900.00
Slave Rollers 445mm	£	4,416.00
Slave Rollers 720mm	£	108.00
Drivebands	£	1,040.00
Transfer section	£	2,000.00
Fabrication	£	10,000.00
Pre-build	£	30,000.00
transport	£	700.00
Tote stand re-fabrication	£	1,000.00
	£	57,364.00
instalation/Commissioning		30000
Services		
Single Phase Power Drop	£	2,188.00
Date to Newtork PLC	£	591.60
	£	2,779.60
Spare Parts		8118.1
Site Declernation of Conformity		£ 7,500.00
Total Spend (+VAT)		£ 141,831.72

8.5 APPENDIX E - GANTT CHART.



8.6 APPENDIX F – TOTE & SHIPMENT WEIGHTS AND DIMENSIONS

Table 5 Tote Dimension and weights

	Minimal	Maximal
Length	600 mm	600 mm
Width	400 mm	400 mm
Height	350 mm	350 mm
Weight	1.5 kg	30 kg

([Company's] Worldwide Design Engineering - Controls Engineering, 2020)

Table 6 Packages dimensions and weights

	Minimal	Maximal
Length	170 mm	600 mm
Width	120 mm	400 mm
Height	6 mm	375 mm
Weight	0.08 kg	31.5 kg

([Company's] Worldwide Design Engineering - Controls Engineering, 2020)

8.7 APPENDIX G - TESTING EVIDENCE

Table 7 Testing evidence

Test	Evidence																																																								
7	 Figure 7- No Faults on system <table><tr><td>I 117.0</td><td>"I_BO_SA_SLAM_308_FulI50"</td><td>BOOL</td><td>false</td></tr><tr><td>I 117.1</td><td>"I_BO_SA_SLAM_308_FulI75"</td><td>BOOL</td><td>false</td></tr><tr><td>I 117.2</td><td>"I_BO_SA_SLAM_308_FulI100"</td><td>BOOL</td><td>false</td></tr><tr><td>I 117.3</td><td>"I_BO_SA_SLAM_308_Trig_LS"</td><td>BOOL</td><td>true</td></tr><tr><td>I 117.4</td><td>"I_BO_SA_SLAM_308_RTR"</td><td>BOOL</td><td>true</td></tr></table> Figure 8 - Healthy input signal into PLC01	I 117.0	"I_BO_SA_SLAM_308_FulI50"	BOOL	false	I 117.1	"I_BO_SA_SLAM_308_FulI75"	BOOL	false	I 117.2	"I_BO_SA_SLAM_308_FulI100"	BOOL	false	I 117.3	"I_BO_SA_SLAM_308_Trig_LS"	BOOL	true	I 117.4	"I_BO_SA_SLAM_308_RTR"	BOOL	true																																				
I 117.0	"I_BO_SA_SLAM_308_FulI50"	BOOL	false																																																						
I 117.1	"I_BO_SA_SLAM_308_FulI75"	BOOL	false																																																						
I 117.2	"I_BO_SA_SLAM_308_FulI100"	BOOL	false																																																						
I 117.3	"I_BO_SA_SLAM_308_Trig_LS"	BOOL	true																																																						
I 117.4	"I_BO_SA_SLAM_308_RTR"	BOOL	true																																																						
8	<table><tr><td>MW 99</td><td>DEC</td><td>500</td></tr></table> Figure 9- 500 totes per hour achieved	MW 99	DEC	500																																																					
MW 99	DEC	500																																																							
9	 Figure 10 - Belt runs at 84 ft/min																																																								
10	<table><tr><th>Index</th><th>ID</th><th>Value</th><th>VariableText</th><th>Min</th><th>Max</th><th>Unit</th><th>Default</th></tr><tr><td colspan="8">6. Drive Control (12)</td></tr><tr><td>P 6.2</td><td>117</td><td>0</td><td>Primary remote speed reference</td><td>N/A</td><td>N/A</td><td></td><td>3</td></tr><tr><td>P 6.3</td><td>101</td><td>0.50</td><td>Minimum frequency</td><td>N/A</td><td>N/A</td><td>Hz</td><td>0.00</td></tr><tr><td>P 6.4</td><td>102</td><td>50.00</td><td>Maximum frequency</td><td>N/A</td><td>N/A</td><td>Hz</td><td>50.00</td></tr><tr><td>P 6.5</td><td>103</td><td>0.5</td><td>Primary acceleration time (acc1)</td><td>N/A</td><td>N/A</td><td>s</td><td>5.0</td></tr><tr><td>P 6.6</td><td>104</td><td>0.5</td><td>Primary deceleration time (dec1)</td><td>N/A</td><td>N/A</td><td>s</td><td>2.0</td></tr></table> Figure 11 - VFD ramp time configurations	Index	ID	Value	VariableText	Min	Max	Unit	Default	6. Drive Control (12)								P 6.2	117	0	Primary remote speed reference	N/A	N/A		3	P 6.3	101	0.50	Minimum frequency	N/A	N/A	Hz	0.00	P 6.4	102	50.00	Maximum frequency	N/A	N/A	Hz	50.00	P 6.5	103	0.5	Primary acceleration time (acc1)	N/A	N/A	s	5.0	P 6.6	104	0.5	Primary deceleration time (dec1)	N/A	N/A	s	2.0
Index	ID	Value	VariableText	Min	Max	Unit	Default																																																		
6. Drive Control (12)																																																									
P 6.2	117	0	Primary remote speed reference	N/A	N/A		3																																																		
P 6.3	101	0.50	Minimum frequency	N/A	N/A	Hz	0.00																																																		
P 6.4	102	50.00	Maximum frequency	N/A	N/A	Hz	50.00																																																		
P 6.5	103	0.5	Primary acceleration time (acc1)	N/A	N/A	s	5.0																																																		
P 6.6	104	0.5	Primary deceleration time (dec1)	N/A	N/A	s	2.0																																																		

13	<pre>//Drive CALL #FB_Antrieb_60181 IN_BO_Enable :=#T_BO_Enable_Antrieb IN_BO_Reset_Flanke :=#T_BO_Reset IN_BO_Kaskadenfreigabe :="M_BO_Kaskade_AK01_3" IN_BO_Motorschutz_i_O :="I_BO_ready_60181" IN_BO_Wartungssch_ein :="I_BO_Auto_60181" IN_BO_Tippbetrieb_ein :=FALSE IN_BO_Tippbetrieb_laufen:=FALSE IN_IN_Delay_Einf_erlaubt:=10 IN_IN_Energiesparzeit :=1200 OUT_BO_Antrieb :="Q_BO_M1_runs_60181" IO_BO_Meld_Motorschutz :="DB_Stoerungen".STG.RAMO_RASP._601_08_01 IO_BO_Meld_Wartungssch :="DB_Stoerungen".BM.Kein_Automatik._601_08_01 IO_BO_Meld_Tippbetrieb := IO_UDT_Antrieb_eigener :="DB_Antriebe"._601_08_01 IO_UDT_Antrieb_voraus :="DB_Antriebe"._SLAM8</pre>
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Figure 12 - Energy saving timer (1200 seconds = 20 minutes)

14	
----	---

Figure 13- E-stop activated and all power supplies have disconnected

15	
----	---

Figure 14 - PLC panel pilot light showing fault

I 117.6	"I_BO_SA_SLAM_308_Zone10K"	BOOL	false
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Figure 15 - PLC01 receiving fault



Figure 16 - Successful telegram message

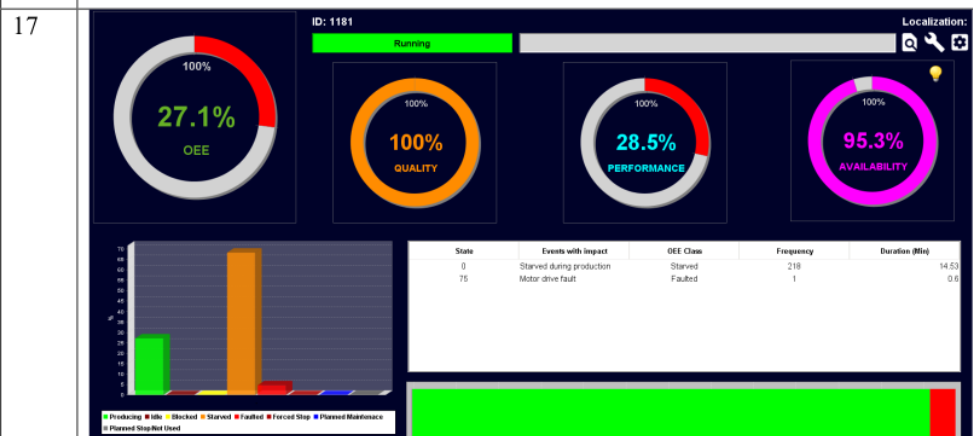


Figure 17 - Line interfaced with OEE System

FINAL GRADE

GENERAL COMMENTS

Instructor

70

/100

PAGE 1

Text Comment. Much of the report reads like a journal where it should be more explanatory of how the system works rather than the order it was made.

Text Comment. References should have been made to the drawings in the appendix which should also have been more detailed

PAGE 2

PAGE 3

QM

Spelling

Spelling error

PAGE 4

Text Comment. Summary covers all aspect of what was done

PAGE 5

Text Comment. It is not necessary to review the other two solutions in this report. You only need to clarify your aims and objectives in this report.

Text Comment. This was determined in assignment 1

Text Comment. An introduction should be written in the future tense outlining what is going to be done. This reads like a summary.

Text Comment. This is an interesting section

Text Comment. You should have reviewed the FDS and explained any changes and cited the original version found in assignment 1.

Text Comment. data is a plural word



Word usage

A more appropriate word could have been used here



Spelling

Spelling error

Text Comment. What were the risks and how were they mitigated?

Text Comment. You could have explained the differences between this one and the original one.

Text Comment. The above codes needs more explanation, e.g. for "A", "#", "="

Text Comment. How and why?



Punctuation Error

Punctuation error

Text Comment. good, this is correct for TIA Portal

QM

Spelling

Spelling error

QM

Spelling

Spelling error

QM

Word/s missing

Text Comment. the

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

Text Comment. This shows that the FDS should have been prepared more carefully to take this tests into account

Text Comment. How did the original compare with the final version?

PAGE 22

Text Comment. This could have been included in the appendix if the company allowed it.

Text Comment. This should have been thought of in your FDS

PAGE 23

Text Comment. This list is rather small for a final report.

PAGE 24

PAGE 25

Text Comment. All figures in the appendix could have been numbered and referenced and explained in the text of the report.

PAGE 26

Text Comment. This is meaningless without an explanation and is lacking in detail.

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

GRADING FORM: NEW CSG-RUBRIC

JONATHON WILLIAMS

70

1. ENGAGEMENT WITH LITERATURE



Section 3: Judicial use and critical evaluation of technical literature in the design of the project: There is clear evidence of use of technical literature including standards and legislation

5

relating to automation systems. Section 4: Extent of reading, range of credible sources and use of Harvard method: Correct method of citing sources has been used all of which are appropriate but only a small range of sources has been listed. 5/10

2. KNOWLEDGE AND UNDERSTANDING

 design of the project: There is evidence of good knowledge and understanding shown in the report particularly in the software side. However, some of the electrical drawings lack detail and have not been explained nor referred to in the text. 6/10

6

3. COGNITIVE AND INTELLECTUAL

 Section 5: Testing and analysis of result: The solutions appear to have been thoroughly tested with some evidence provided and results analysed. Section 5: Critical evaluation of the project outcomes: The project outcomes have been fully evaluated and all aspects of the FDS appear to have been met. Section 6: Conclusions and recommendations: The report contains a good section on conclusions and relevant recommendations for improving the project. 21/30

21

4. PRACTICAL APPLICATION

 Section 3: The project solution is certainly innovative and meets the requirements in a cost effective and sustainable way within the constraints imposed by the customer. Section 4:

27

Software developed has used appropriate methods in line with company standards and it is good to see the use of STL language within TIA Portal. Hopefully the company will adopt this method as its standard in the future. Hardware was mainly carried out by a third party but checked and tested by the student. Section 4: The final product is of a high standard and view by the tutor upon visiting the factory in March. Section 5: There is some use of test equipment for measuring line speed and simulation method for testing software within TIA Portal. Sections 3 and 5. The design process has managed well but better evidence could have been provided as to how the Gantt chart and costing spreadsheet needed to change through the life cycle of the project.27/35

5. TRANSFERABLE SKILLS



Sections 1 and 2: Executive summary, acknowledgements and introduction: Report contains a good summary covering all aspects of the project. Acknowledgements are clear but the introduction should not have evaluated the three solutions as this was done in assignment 1. All Sections: Quality of the report: Good structure and presentation. However, there are punctuation and spelling errors and all figure in the appendix should have been numbered. Word count: Not exceeded 11/15