



Process Automation for the Production of Nano Cellulose

Bachelor's thesis
Electrical and Automation Engineering
Spring Semester 2025
Dhani Raj Bogati

Electrical and Automation Engineering

Author Dhani Raj Bogati

Subject Process Automation for the Production of Nanocellulose

Supervisors Jan-Peter Nowak, Mika Oinonen

Abstract

Year 2025

Back in 2011, I wrote a research-based bachelor thesis titled " Cellulose based biochemicals and their applications ". The purpose of this thesis is to focus on the process automation for one of the biochemicals I mentioned in my previous bachelor thesis i.e. nanocellulose. The thesis scope included developing a process model, i.e., Siemens's SIMIT SP and a PLC program with Siemens TIA Portal for the nanocellulose production process. Siemen's SIMIT will work as a simulation tool i.e. a basis for the virtual factory. The whole process is a point of virtual manufacturing operation in virtual environment.

Nanocellulose, a renewable and biodegradable material with exceptional mechanical and functional properties, holds immense potential for various industries, including packaging, construction, and biomedical applications. However, current production methods remain inefficient, resource-intensive, and difficult to scale, limiting its broader adoption. This thesis focuses on process automation to produce nanocellulose, aiming to address these challenges through innovative technological solutions. By identifying key bottlenecks in traditional production workflows, this study explores the integration of automation to improve efficiency, reduce energy consumption, and enhance scalability. A comprehensive review of nanocellulose production processes and their limitations forms the basis for developing and testing automated solutions. The research highlights the critical need for sustainable and cost-effective production methods to meet the increasing global demand for nanocellulose. The proposed automation framework is designed to optimize production without compromising the quality of the final product. This study contributes to the growing field of sustainable manufacturing while offering actionable strategies for industries seeking to adopt greener and more efficient practices. The findings provide valuable insights for scaling up nanocellulose production, paving the way for its widespread commercialization and environmental impact. Bio chemicals are more than relevant in the current scenario when we are very concern on saving our environment. This thesis could be a good reference for the industries wanting to automate the production of nanocellulose. The developed SIMIT model could be used as an automation engineering teaching material in the future. For virtual commissioning work, siemens SIMIT SP has been used. Automation work has been realised through Siemens PLC TIA portal. Sequential programming has been used for the automation; loop sequence has been created. For further visualisation, HMI was used.

Keywords Process automation, production automation, nanocellulose, sustainable technology, simulation, PLCSIM advanced, Siemens PLC, Siemens SIMIT SP

Pages 37 pages and appendices 3 pages

Content

1	Introduction	1
2	Theoretical background and system overview.....	3
2.1	Programmable logic control and Siemens TIA portal.....	3
2.1.1	Components of a PLC	3
2.1.2	Functionality of PLCs.....	4
2.1.3	Siemens PLC TIA portal Overview	4
2.2	Siemens SIMIT SP.....	5
2.3	Siemens HMI	6
2.4	Nanocellulose production process	6
3	Process automation implementation	8
3.1	P&ID diagram	8
3.1.1	General overview of the system.....	8
3.2	Functional description	12
3.2.1	System overview	12
3.2.2	System function.....	12
3.2.3	Schematic representation	15
3.2.4	Siemens PLC programming in TIA portal.....	16
3.3	SIMIT modelling.....	29
3.4	Siemens HMI	30
4	Overview of the processes	31
5	Conclusion	33
	References	34

Figures, tables and equations

Figure 1. Small Scale laboratory production of nanocellulose (Pradhan et al,2022).	7
Figure 2. PID diagram representing the processes of Nanocellulose production.....	10
Figure 3. Nanocellulose production process flow diagram.	15
Figure 4. Schematic diagram with connected sensors and motors.....	16

Figure 5. Sequential programme in TIA portal.....	26
Figure 6. SIMIT view of the simulation part.	29
Figure 7. Siemens HMI view of the process.	30
Figure 8. Manual control view of the process in HMI interface	31
Table 1. Process components description from the designed P&ID diagram.	11
Table 2. Level sensors and their signals detail.....	17
Table 3. Wight sensors and their signals detail.	17
Table 4. Temperature sensors and their signals detail.....	18
Table 5. Flow sensor and its signal information.....	18
Table 6. Sulphate sensor and its signal information	18
Table 7. Nanocellulose concentration indicator.	19
Table 8. Valve HS2201 and all its signals detail.....	19
Table 9. Valve HS202 and its signals detail.	19
Table 10. Valve HS205 and its signals detail.	20
Table 11. Valve HS208 and its signals detail.	20
Table 12. Valve HS211 and its signals detail.	20
Table 13. Valve HS212 and its signals detail.	21
Table 14. Valve 214 and its signal detail.....	21
Table 15. Valve HS216 and its sensor detail.....	21

Table 16. Valve HS218 and its sensor detail.....	22
Table 17. Motor M01 and its signals detail.	22
Table 18. Motor M02 and its signals detail.	22
Table 19. Motor M03 and its signals detail.	23
Table 20. Motor M04 and its signals detail.	23
Table 21. Motor M05 and its signals detail.	23
Table 22. Signal mappings of all the sensors.	27

Appendices

- Appendix 1. Data Management Plan
- Appendix 2. Hardware configuration devices list
- Appendix 3. Tag table list for SIMIT interface

List of Abbreviations

SIMIT SP	Simulation and Testing Simulation Platform
PLC	Programmable Logic Controller
TIA	Totally Integrated Automation
HMI	Human Machine Interface
PLCSIM	Programmable Logic Controller Simulation
SIMATIC	Siemens Automation and Control
P&ID or PID	Piping and Instrumentation diagram
RPM	Revolution Per Minute
UPS	Uninterrupted Power Supply
PID	Proportional Integral and Derivative
MCC	Microcrystalline Cellulose
CAD	Computer Aided Design
CPU	Central Processing Unit

1 Introduction

The motivational history to write this thesis goes back to years 2011 and 2014. In 2011, I briefly explored the use and synthesis process of nanocellulose as a part of my Bachelor's thesis, and in 2014, I explored the laboratory synthesis of nanocellulose as part of my Master's thesis. I was required to carry out the synthesis of nanocellulose as it was not available in the market at the time. The focus of this thesis thus is to make it possible to manufacture the nanocellulose on an industrial scale with process and production automation in mind. The main problem this thesis is trying to solve is the production of nanocellulose in industrial scale through automation to achieve a feasible method of production. The pilot manufacturing operation, i.e., the virtual production process uses the Siemens products for the automation process and the main starting ingredients for the production of the nanocellulose used is microcrystalline cellulose. The implementation phase of this thesis describes in detail the creation of functional description of the system processes.

The increasing global demand for sustainable materials has driven significant interest in nanocellulose, a renewable and biodegradable material with versatile applications in industries ranging from packaging to biomedicine. This thesis explores the automation of processes involved in nanocellulose production, a crucial step in making this innovative material commercially viable. My study experience in industrial automation and process optimization has provided a strong foundation for approaching this topic. By leveraging insights from my studies, I have identified inefficiencies and scalability challenges in current production methods that hinder widespread adoption. Nanocellulose's unique properties, such as high strength-to-weight ratio and biocompatibility, underscore the necessity of improving production technologies to meet growing market demands. The research aims to address key questions related to streamlining production workflows, enhancing efficiency, and reducing costs through automation. This project is particularly relevant in light of increasing pressure on industries to adopt eco-friendly practices and technologies. The background research highlights the potential of nanocellulose to revolutionize material science but also emphasizes the barriers posed by labour-intensive and energy-intensive production processes. By justifying the need for innovation in this domain, this study seeks to contribute to both the academic field of process engineering and the practical advancement of sustainable manufacturing. Ultimately, the findings will provide actionable insights for scaling up nanocellulose production while aligning with environmental and economic objectives.

Automated processes to produce all sorts of chemicals including both bio and non-biochemical products are extensively used in the modern day. For example, our day-to-day usable products like toothpaste, liquid soap and industrial products like chemically produced wood pulp, gasolines etc. utilize the automated processes for their production. Straight forward to 2025, we have various competing PLC automation industries providing whole life cycle process automation services for the process industries. Siemens is one of them, and it is one of the pioneers in developing the programmable logical control system for process industries. Siemens in 1990s, developed the concept of TIA, in which every single phase and component of an automated production were unified into a single automation system called SIMATIC. (Siemens, n.d-a)

Production of biochemicals in industries have been implemented for over 100 years of history behind it. Their production however had not been so efficient enough in industries as the use of automation had been limited previously. With the development of automated processes, these industries have been greatly benefiting for the environmentally friendly and more economical approach for their production. Recent technological advancement, such as the concept of fully automated robotic plant, and cyber physical systems have been beneficial for these industries. Biochemicals are very pertinent in the moment as we are very aware of the environmentally friendly efficient production processes. (Zheng et al., 2019)

PID diagram is a detailed and elaborated diagram used in almost all the process industries. The diagram shows process equipment, control devices, and instrumentation, that represents the physical sequence of sensors, valves, and other various components in a process flow. Use of PID diagrams is very essential for the precise overview of the processes in the given specific system as it provides all required information for a smooth and optimal working phenomenon of a process within a system. There are tons of industries where piping and instrumentation diagrams act as the backbone for all production systems. They act as a linkage in the design and control of system components and units and their functions must be always coordinated smoothly and efficiently. Since there are very huge number of industries utilising the diagram and due to their requirements, various design and documentation tools are used for the respective areas. Cogent CAD software is used now a days for the design of the diagram whereas historically, manual production with symbol templates and technical drawing tools was widely used. (CAD Schroer, n.d.)

Simulation is a very useful technology in order to develop planning and preliminary models to enhance decision making. It helps to optimize the operations of complex and smart production systems. It is also helpful to the companies so that they could efficiently evaluate the risks,

costs, implementation barriers and impact on operational performance. The main benefit of the simulation for large process industries are the cost savings with the help of simulation thereby avoiding the need of the real pilot process building. (Ferreira et al., 2020)

2 Theoretical background and system overview

The theoretical background part is essentially subcategorized based on the utilised aspects of the thesis mentioned below.

2.1 Programmable logic control and Siemens TIA portal

Programmable logic controller system for the process industries kicked off intensively already in 1970s when the research to automate processes was in the full swing. Programmable Logic Controllers are industrial digital computers mainly designed for the control of manufacturing processes. These processes are for example assembly lines, machine functions, and other different automated functions. These systems are sturdy, trustworthy, and well designed to operate in tough environments. PLCs are able to handle multiple inputs and outputs. These are programmed to perform simple to complex logical operations. (Siemens, n.d-a)

The concept of PLCs emerged in the late 1960s to replace relay-based control systems. The first PLC our world has ever seen, the Modicon 084, was introduced by General Motors back in 1969. Today's PLCs technology has evolved rapidly and significantly, incorporating advancements in microprocessor technology, software development, and communication protocols. (Alphonsus & Abdullah, 2016)

2.1.1 Components of a PLC

Central Processing Unit (CPU) is the brain of the PLC. It is mainly responsible for the execution of control instructions and processing input/output signals. Input/Output Modules (I/O) are the modules responsible for connecting the PLC to the external environment that allows it to receive signals from sensors and send commands to actuators. Power Supply provides the needed power for the PLC and it's all components. Programming Device represents a computer or handheld device is a programming device that is used to program the PLC. This is done using a specialized software.

2.1.2 Functionality of PLCs

PLCs operate by continuously scanning input devices, executing a user-defined program, and updating output devices. The key basic operation cycle is:

Input Scan: The PLC reads the status of input devices.

Program Execution: The PLC processes the input data according to the programmed logic.

Output Scan: The PLC updates the output devices based on the program execution results.

2.1.3 Siemens PLC TIA portal Overview

Siemens is one of the major manufacturers of PLCs. It offers a wide range of products suitable for various industrial applications. Siemens PLCs are reliable, scalable, and equipped with advanced features. Some of their product series includes:

The Siemens S7-1200 and S7-1500 are popular PLC series that serve to different automation needs. S7-1200 is ideal for small to medium-sized applications. It is compact and cost-effective. It features integrated I/O, communication capabilities, and a modular design for flexibility. S7-1500 is designed for complex automation tasks. It provides high performance, advanced functionalities, and extensive communication options. It is worthy for large-scale applications that requires high-speed processing and data handling.

Key features of Siemens PLCs includes:

Modularity means it can be easily expanded with additional I/O modules, communication processors, and other components. Integrated Safety i.e. It comes with built-in safety features, allowing for the implementation of safety functions in automation systems. It supports several communication protocols, such as PROFINET, PROFIBUS, and Ethernet/IP, enabling seamless integration with other devices and systems. Siemens PLCs provide extensive diagnostic capabilities, helping users identify and troubleshoot issues quickly.

This Portal is Siemens' engineering framework for automation technology. It provides a merged platform for programming, configuring, and managing Siemens automation devices, including PLCs, HMIs and drives. Its key feature includes user friendly Interface i.e. it features an intuitive graphical user interface that simplifies the programming and configuration process, integrating engineering meaning users can configure hardware,

program PLCs, design HMI screens, and set up networks all within a single environment. Moreover, it supports multiuser collaboration with multi-user access, allowing multiple engineers to work on a project simultaneously. Users can create and manage libraries of reusable code blocks, enhancing productivity and consistency across projects. (Siemens, n.d-b)

Programming in TIA Portal can be done using several languages defined by the IEC 61131-3 standard categorized below.

- a) **Ladder Logic (LAD):** It is a graphical programming language resembling electrical relay logic diagrams.
- b) **Function Block Diagram (FBD):** It is a graphical representation of functions and their interconnections, suitable for complex control systems.
- c) **Structured Text (ST):** It is a high-level programming language allowing for more complex algorithms and data handling.
- d) **Instruction List (IL):** It is a low-level language that provides a more straightforward way to program PLCs. It is seldom used today.
- e) **Sequential Function Chart (SFC):** It is a method for designing sequential processes, making it easier to visualize and manage complex operations.

2.2 Siemens SIMIT SP

Siemens SIMIT SP is useful tool to perform virtual commissioning work without having a fully working real time industrial automation ready. It is an extremely practical tool for comprehensive testing of automation applications that provides a very realistic training platform for operators before real system are implemented. It acts as a virtual plant ready to show all the process functions virtually with the help of siemens PLCSIM advanced. Basically, all the output data from SIMIT SP acts as an input feed for Siemens TIA portal and the output feedings from the TIA portal acts as the input feedings for the Siemens SIMIT i.e., PLCSIM advanced acts as a bridge between the SIMIT and TIA portal. In core concept, PLCSIM advanced enables the interactions with local c++ and c# programs i.e., a simulation software over the user interface. Some of the greatest advantages of PLCSIM advanced and SIMIT SP are cost savings and earlier possibilities for the beforehand training of the operators thereby saving time and money and thus increasing efficiency. So, the main purpose of utilization of SIMIT SP is for the creation of virtual plant. (Siemens, 2019)

Process simulation is a vital tool for designing, analysing, and optimizing industrial workflows, particularly in the production of complex materials such as nanocellulose. It involves the use of computational models to replicate real-world processes, enabling researchers and engineers to predict system behaviour under various conditions without the need for costly physical experiments. By simulating processes, it becomes possible to identify inefficiencies, test alternative configurations, and optimize key parameters to enhance performance and reduce resource consumption. Process simulation is particularly beneficial for emerging technologies, where scalability and cost-efficiency are critical challenges. In the context of nanocellulose production, simulation provides insights into intricate steps such as fiber pretreatment, hydrolysis, and drying, helping to streamline these processes. It also enables the assessment of automation strategies, ensuring that proposed solutions are both technically feasible and economically viable. Advanced simulation tools allow for the integration of energy and material balances, offering a holistic understanding of the system's sustainability. Additionally, process simulation supports decision-making by evaluating the impact of variables such as raw material quality, equipment performance, and environmental factors. Through iterative testing and refinement, simulation minimizes risks associated with process changes and accelerates innovation. Ultimately, it serves as a cornerstone for achieving efficient, scalable, and sustainable production systems. (Ferreira et al., 2020)

2.3 Siemens HMI

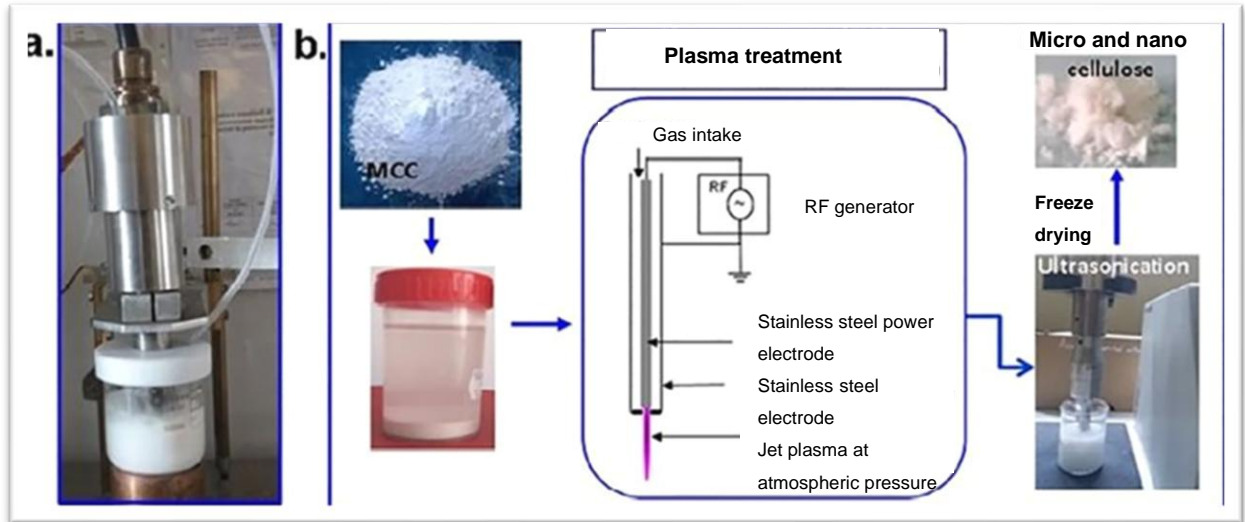
Siemens HMI tool is another useful application to visualize the developed processes in real time. Its HMI systems are engineered to optimize operations, enhance productivity, provide a reliable interface between operators and machines in diverse industrial environment. It has some drawback though, for example inputs cannot be implemented in training format of HMI, the use of memory bits is thus needed to visualize the inputs. (Siemens, n.d-a)

2.4 Nanocellulose production process

Nanocellulose production process involves the series of processes. The most renewable approach is the production where tree woods are used to first extract the fibres and then chemically process it to produce nanocellulose. In this thesis, the later part of the production process is primarily focused on i.e., production through cellulose substrate. Microcrystalline cellulose substrate was considered as a primary raw material. Figure 1 represents the small-scale laboratory synthesis of nanocellulose from microcrystalline cellulose. In short, this

nanocellulose is synthesized with the physiochemical process with the utilization of jet plasma technology. More detail is to be followed from the reference mentioned in the figure.

Figure 1. Small Scale laboratory production of nanocellulose (Pradhan et al., 2022).



3 Process automation implementation

The implementation phase of this thesis work consists of several aspects in the process automation. One of the most important ones is the creation of quality functional description of the processes. All of these are subdivided into several sections as mentioned in the following categories.

3.1 P&ID diagram

Designed P&ID or PID diagram contains all the process valves, sensors, motors with their efficiencies, alarm indications and more. Figure 2 shows the designed PID diagram. The working flow of the associated valves, sensors, motors and chemical filters are briefly introduced in the section of table 1. More detailed information is available in the auto process part of the functional description of the sequential automation part of this thesis mentioned in section 3.2.4.

3.1.1 General overview of the system

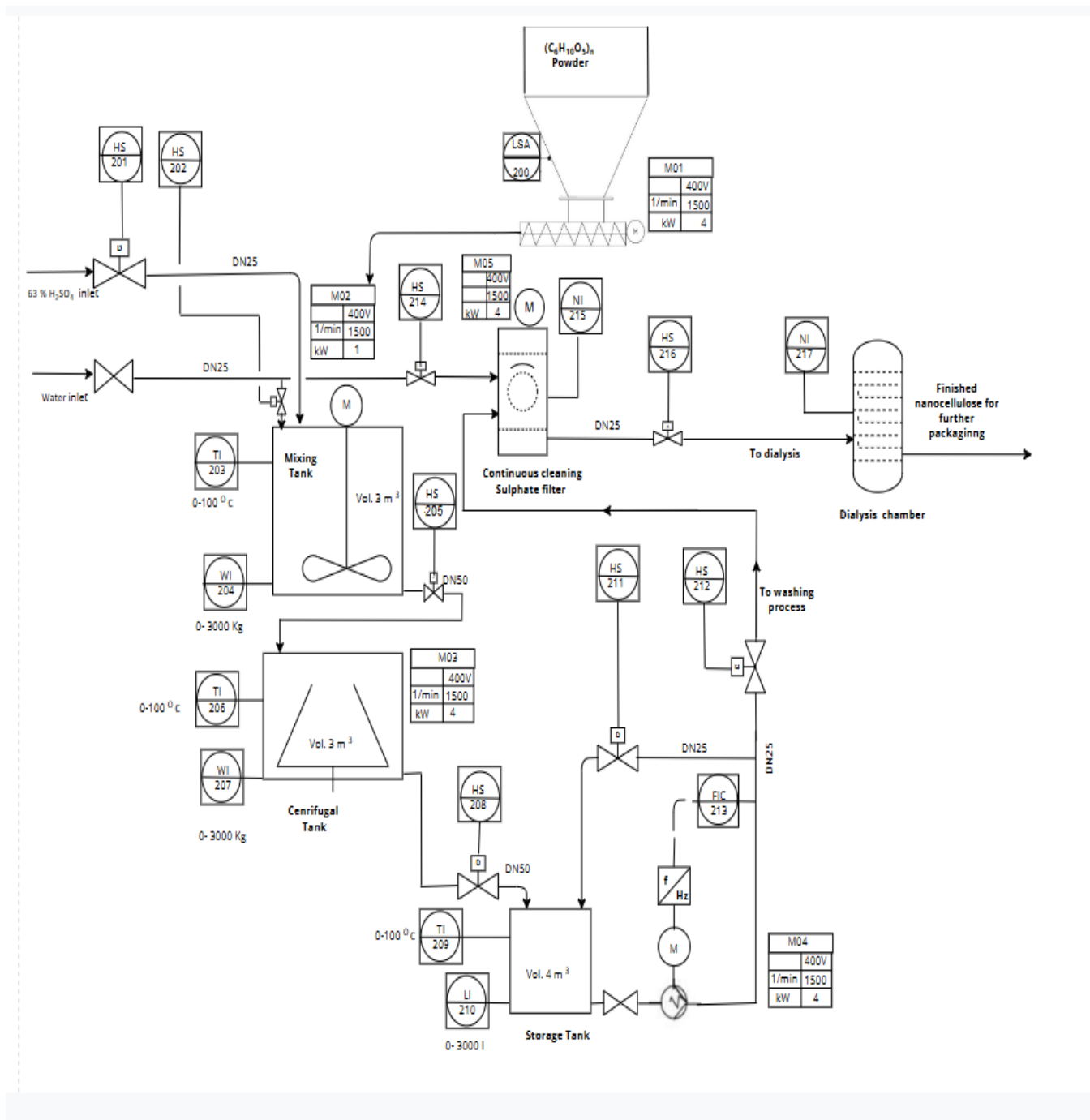
Shown P&ID diagram for the nanocellulose production process visually outlines the sequence of operations from raw material intake to the final nanocellulose product. It includes reactors for chemical treatment, pumps to move the slurry, and filtration or separation units to isolate the nanocellulose. Instrumentation for controlling and monitoring parameters such as pressure, temperature, and flow rate are depicted to ensure consistent quality and efficiency throughout the production stages.

The generic process starts with the flow of sulphuric acid with the valve HS201 opened. This valve closes after set amount of sulphuric acid is fed to the reactor or mixing tank. Thereafter the set amount microcrystalline cellulose powder flows to the reactor with motor M01 open. Chemical reaction called hydrolysis occurs the reactor tank, this is stopped with the water with the valve HS202 opened. After the hydrolysis is stopped, the solution is moved to the centrifugation tank for the centrifugation process with the valve HS205 open. Upon the completion of the centrifugation process, the solution is fed to the storage tank with the valve HS208 open. The produced solution being still not completely pure, it moves to the next stage called filtration with the chemical filtration process monitored with the filter sensor NI215 and with the valve HS212 and HS214 open. The product from the storage tank is further fed to the next step by motor M04 with flow control sensor tracking the precise amount of liquid flowing

in litres/second. Motor M04 is equipped with the variable frequency drive. Further purification is done by the dialysis process with the valve HS216 and HS218 open and purity of nanocellulose tracked by the sensor NI217.

Weight sensors WI204 and WI207 tracks the weight of reactor tank and centrifugation tank respectively. Likewise, the temperature sensors TI203, TI206 and Ti209 tracks the temperature of reactor tank, centrifugal tank and storage tank respectively. Motor M02, M04 and M05 are for the operation of the process in the reactor tank, centrifugal tank and the filtration chamber respectively.

Figure 2. PID diagram representing the processes of nanocellulose production



All process components and their description can be seen in table 1.

Table 1. Process components description from the designed P&ID diagram.

Process tag	Description
<p><u>Valves:</u> HS201 HS202 HS205 HS208 HS211 HS212 HS214 HS216 HS218</p>	<p>Sulfuric acid inlet valve Water inlet valve Valve to let produced product to centrifugal tank Valve to let centrifuged product to storage tank Valve to take the unused products back to storage tank Valve to take product to further point Water inlet valve Valve to control the flow to dialysis chamber Valve to control the flow of deionized water to dialysis chamber</p>
<p><u>Motors:</u> M01 M02 M03 M04 M05</p>	<p>Motor to get microcrystalline cellulose powder to the mixing tank Motor for mixing tank to mix the process components Motor in centrifugal tank Motor for pumping the processed fluid from storage tank to sulphate filter tank Motor that feeds filtered fluid to dialysis chamber</p>
<p><u>Temperature sensors:</u> TI203 TI206 TI209</p>	<p>Temperature sensor mixing tank Temperature sensor for centrifugal tank Temperature indicator for storage tank</p>
<p><u>Weight sensors:</u> WI204 WI207</p>	<p>Weight sensor for mixing tank Weight sensor for centrifugal tank</p>
<p><u>Other sensors:</u> LSA200 LI210</p>	<p>Level switch alarm in powder silo Storage tank's level sensor</p>

FIC213 NI215 NI217	Flow indicator control for the product flow (in l/s) Sulphate filtration indicator Nanocellulose concentration indicator
--------------------------	--

3.2 Functional description

This stage involves the functional specification of the process subcategorized into several substages namely system overview, system function, schematic representation, siemens and PLC programming in TIA portal described in the following section.

3.2.1 System overview

The system utilises the automated process to produce the nanocellulose with several stages in synchronising performance thereby insuring consistency, efficiency and safety.

3.2.2 System function

This step is further subdivided into several sub-stages mainly process steps comprising of all the process components followed by mixing process, which is further followed by centrifugal process, then the storage of the product to be further processed in the steps like filtration and dialysis mentioned in the following sections.

Process steps

The major process components i.e. raw materials for the final product are described below where the main process components being sulphuric acid, microcrystalline cellulose powder and water (both pure distilled water and deionised water).

Prediluted sulphuric acid with the concentration of 63 % (w/w) is pumped to the mixing tank through the valve HS201 based on predetermined weight. The cellulose powder is fed to the mixing tank through the conveyor belt with motor M01 from the silo. The specific ratio of the sulphuric acid and cellulose powder amount is predetermined for the best optimal chemical reaction between the sulphuric acid and cellulose powder. The chemical reaction involved is called hydrolysis. Hydrolysis is stopped with the addition of water to the mixing tank. Water is pumped to the mixing tank through valve HS202 to the required amount for the optimal segregation of unreacted sulphuric acid i.e. to dilute it.

Mixing process

Mixing process is initiated when the desired amount of process components i.e. sulphuric acid and microcrystalline cellulose powder is fed to the mixing tank and is performed by turning on the mixer aided by motor M02. After chemical reaction between the sulphuric acid and microcrystalline cellulose i.e. hydrolysis is complete, the hydrolysis process is stopped by the addition of water to the mixing tank, the amount of water is predetermined too. Mixing process continues for predetermined duration and after that the mixing motor is shut off automatically.

Centrifugation process

The mixture is then transferred to the centrifugal tank with the valve HS205 open. Centrifugation process is done at 400 rpm for predetermined duration, the purpose of which is to remove the acidic supernatant solution. Centrifugation occurs when the motor M03 is turned on. When centrifugation is accomplished, the motor M03 stops and the solution thaws for some predetermined time.

Product storage for further processing

The centrifuged and thawed product is then transferred to the storage, tank the capacity of which is now considered to be 4 m³ with the valve HS208 open. This is not the final product yet as it still contains some acidic supernatant solution which is required to be removed in the next stage called dialysis and performed with the distilled water and later with the deionised water to get the final product i.e. nanocellulose.

Filtration and dialysis

The product coming from storage tank is filtered with the sulphate filter NI215 with the motor M05 on, the product is further pumped to the dialysis chamber where dialysis process happens with the aid of filter NI217, and deionized water is pumped with the valve HS218 on.

Faults and emergency situations

Sensor failure

System notifies if the sensor has failed or not responding remedy of which could be the restart the sensor or replace it completely. This sensor failure triggers other safety measure such as stopping the process and notifying the operator of the alarm present due to the sensor failure. Operator can then shut down the specific modular automation state for the maintenance purpose.

Motor or Pump failure

System keeps track of the motor functionalities by saving its rpm and motor running information. If abnormal behaviour is detected, then the system shuts down the motor and enters to the safe mode until the fault is recognised and corrected by operator.

Valve malfunction

System detects the leaking valve, or the pipes based on the sensor data that keeps track of for example disturbance in flow rate of the liquids.

Power outage

In case the backup power system like UPS is installed in the plant, system detects the black outs and gradually shuts down the whole system and saves the state data. This is important to prevent the damages in pumps, motor and other important expensive system.

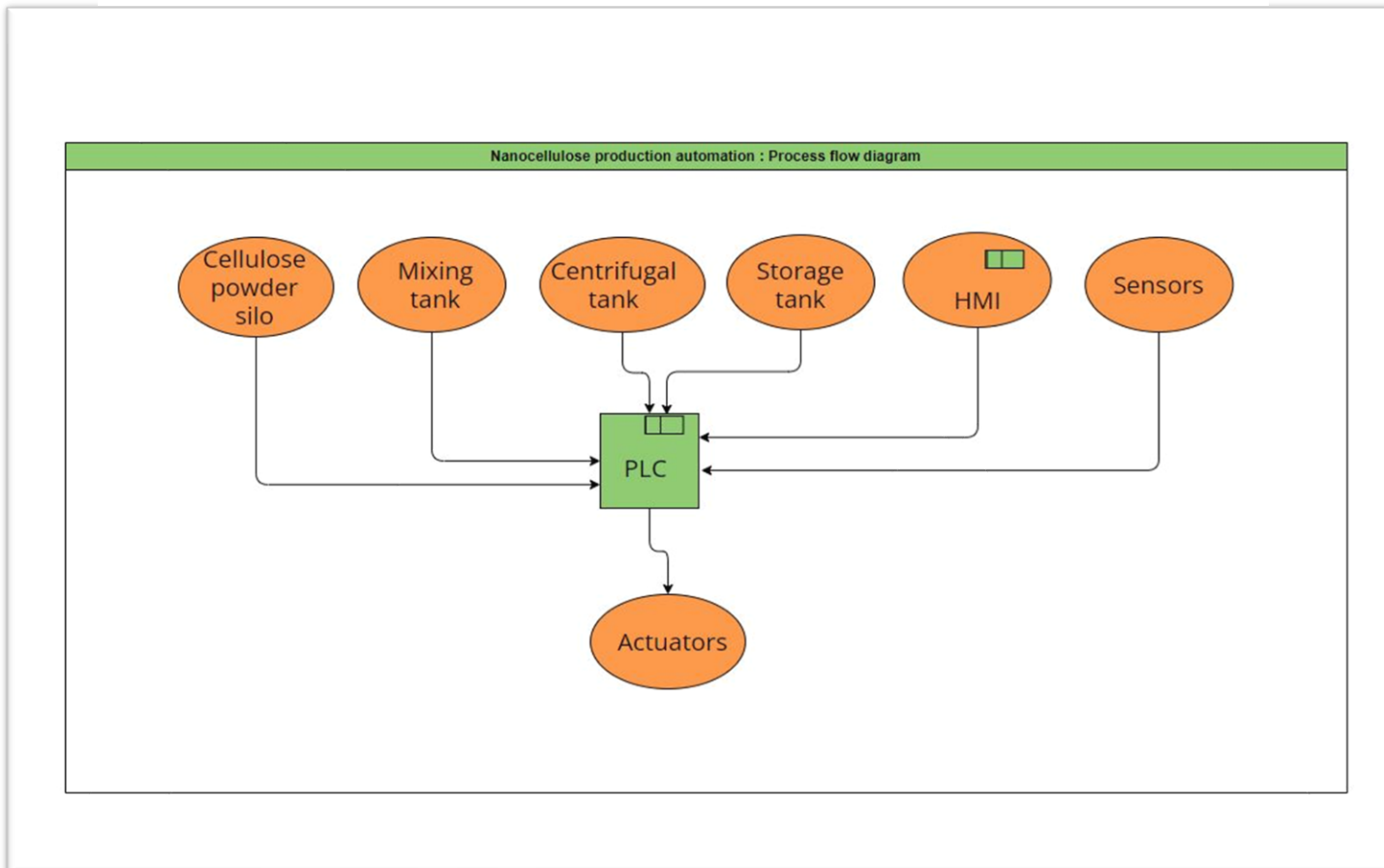
Operator or handler error

System has the provision to implement interlocks to prevent unauthorised or unsafe actions. System do provide clear instructions and warning logs for operators. In case of the error situation, system provides operator to correct the errors.

3.2.3 Schematic representation

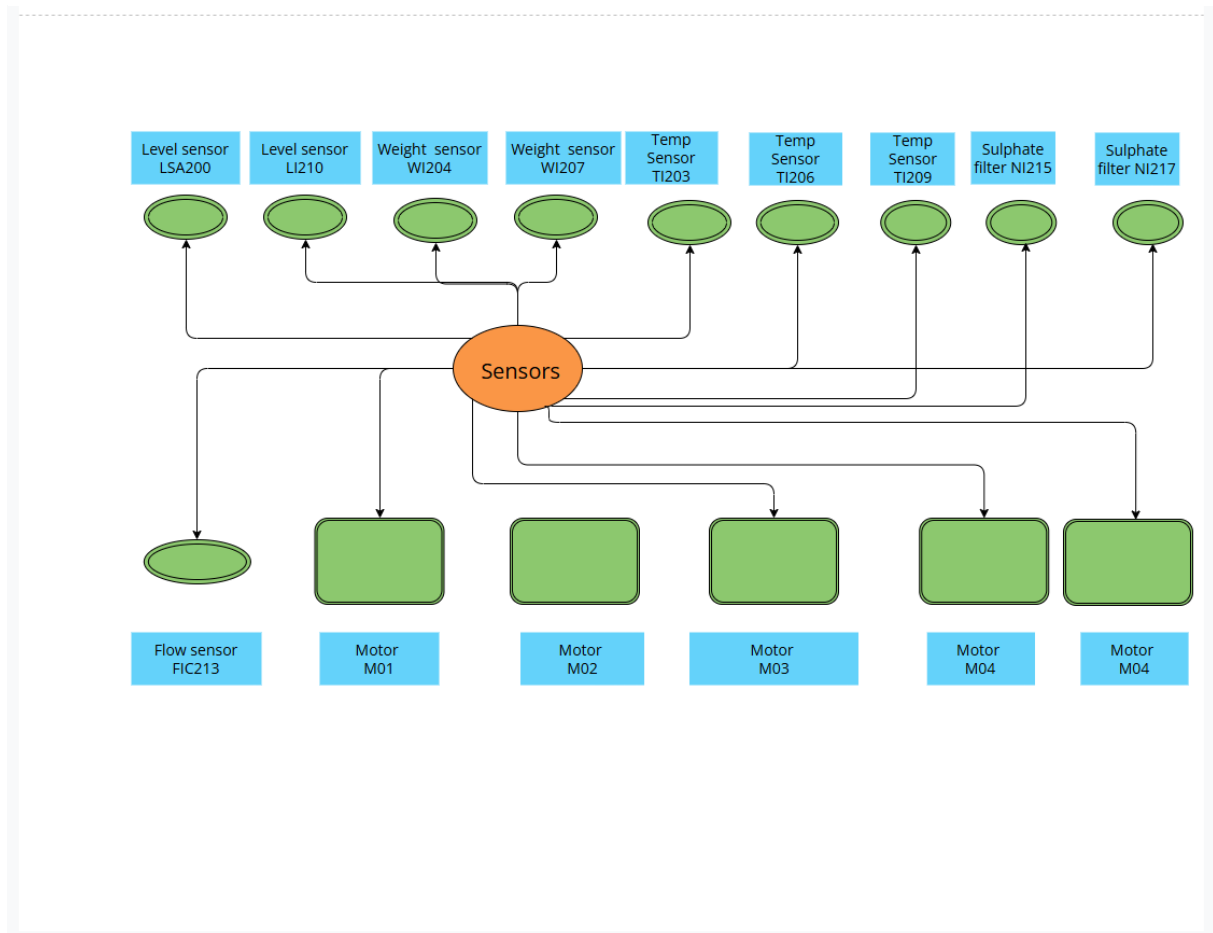
Figure 3 shows the schematic representation of the process based on the usage of different system components mentioning core components and interaction with the automated system.

Figure 3. Nanocellulose production process flow diagram.



The more elaborated system diagram for the process with sensor connections, inputs, and actuators, Outputs, can be seen in figure 4.

Figure 4. Schematic diagram with connected sensors and motors.



3.2.4 Siemens PLC programming in TIA portal

The main programming for the process automation happens from the Siemens TIA portal. In PLC, the central control unit receives the sensor data as inputs and based on predetermined input instructions, the needed command is executed as output i.e. actuators implement the output commands.

Sensor lists:

- Level sensors LSA200, LI210
- Weight sensors WI204, WI207
- Temperature sensors TI203, TI206, TI209
- Flow sensor FIC213
- Chemical sensor NI215, NI217

Actuator lists:

- Valves (HS201, HS202, HS205, HS208, HS211, HS212, HS214, HS216, HS218)
- Motors (M01, M02, M03, M04, M05).

- Sensors and actuators detail

a) Level sensors

The main function of level sensors in this case are to measure the level of produced solution in storage tank and powder level in silo. They are widely used in process industries for process monitoring. Sensor LSA200 is a digital input that monitors the cellulose powder level in the storage tank and set command for motor M01 based on the setpoint of powder level. Sensor LI210 is an analogue input that measures the produced solution level in the storage tank. Table 2 shows the level sensors and their respective general signal types.

Table 2. Level sensors and their signals detail.

Level Sensors	Signals
LSA200	DI
LI210	AI

b) Weight sensors

Weight sensors in this process measure the weight of process components from mixture tank and centrifugal tank. They ensure the sufficient ingredients in the tank. Table 3 shows the weight sensors and their respective general signal types.

Table 3. Weight sensors and their signals detail.

Weight sensors	Signals
WI204	AI
WI207	AI

c) Temperature sensors

Temperature sensors measure the temperature of solution in all the tanks here in this case. Figure 4 shows the temperature sensors and their respective signal types.

Table 4. Temperature sensors and their signals detail.

Temperature sensors	Signals
TI203	AI
TI206	AI
TI209	AI

d) Flow sensor

Flow sensor FIC213 measures the flow rate of the solution in Liter per second in this process. Flow sensor detail can be seen in figure 5.

Table 5. Flow sensor and its signal information.

Flow sensor	Signal
FIC213	AI

e) Chemical Sensors

Two chemical sensors NI215 and NI217 are utilized for the filtration of the sulphate and the for the final concentration of nanocellulose.

- NI215 for the filtration of sulphate from the produced solution as shown in table 6.

Table 6. Sulphate sensor and its signal information

Chemical Sensor	Signal
NI215	AI

- NI217 for the concentration reading of the produced nanocellulose as shown in table 7.

Table 7. Nanocellulose concentration indicator.

Chemical Sensor	Signal
NI217	AI

f) Valves

Total of 9 valves are used to control the flow of liquids and solutions:

- HS201 for the flow control of sulphuric acid as represented in table 8 below.

Table 8. Valve HS201 and all its signals detail.

HS201	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS202 for the flow control of water as represented in figure 9 below.

Table 9. Valve HS202 and its signals detail.

HS202	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS205 for the flow control of solution from mixture tank to centrifugal tank and is showed in table 10 below.

Table 10. Valve HS205 and its signals detail.

HS205	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS208 for the flow control of produced solution from centrifugal tank to storage tank as shown in table 11.

Table 11. Valve HS208 and its signals detail.

HS208	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS211 for the flow control of produced solution from storage tank back to storage tank in case of emergency. Its detail with general signal type is mentioned in table 12.

Table 12. Valve HS211 and its signals detail.

HS211	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS212 for the flow control of produced solution from storage tank to the further processing point as mentioned in table 13.

Table 13. Valve HS212 and its signals detail.

HS212	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS214 for the flow control of water to the filtration process chamber as mentioned in table 14.

Table 14. Valve 214 and its signal detail.

HS214	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS216 for the flow control of filtered product to the dialysis chamber as mentioned in table 15.

Table 15. Valve HS216 and its sensor detail.

HS216	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

- HS218 for the flow control of deionised water to the dialysis chamber as mentioned in table 16.

Table 16. Valve HS218 and its sensor detail

HS218	Solenoid valve	DO
	Open limit	DI
	Closed limit	DI
	Alarm/Fault	DI

g) Motors

- M01 drives the conveyor belt for powder feeding with speed control as detailed in table 17.

Table 17. Motor M01 and its signals detail.

M01	Running	DI
	Fault	DI
	Start	DO

- M02 drives the mixture to assist the reaction between sulphuric acid and microcrystalline cellulose powder as detailed in table 18.

Table 18. Motor M02 and its signals detail.

M02	Running	DI
	Fault	DI
	Start	DO

- M03 drives the centrifugation rotor as detailed in table 19.

Table 19. Motor M03 and its signals detail.

M03	Running	DI
	Fault	DI
	Start	DO

- M04 drives pump, with a frequency converter for variable flow rate control as detailed in table 20.

Table 20. Motor M04 and its signals detail.

M04	Running	DI
	Fault	DI
	Start	DO
	Speed	AO

- M05 drives the chemical sulphate filter to the desirable condition as detailed in table 21.

Table 21. Motor M05 and its signals detail.

M05	Running	DI
	Fault	DI
	Start	DO
	Speed	AO

Functional modes

The sequential program can be controlled both automatically and manually.

Manual mode

In Manual mode, each valve and motor are controlled manually from the HMI interface. Upon activation of manual mode with a click of “manual” mode button, all the input buttons are visible in the HMI interface and manual control system is enabled.

Auto mode

In auto mode, the process is initiated automatically upon the click of “Auto mode” push button after the recipe of all process components have been fed. This was done via sequential programming in TIA portal. After auto mode is activated, valve HS201 opens and mixing tank is filled with 63% concentrated (w/w) sulphuric acid. This valve closes automatically after the predetermined amount of sulphuric acid is fed to the mixing tank. Thereafter valve motor M01 turns on to feed the microcrystalline cellulose powder to the mixing tank through the conveyor belt and this motor closes after set amount of cellulose powder are fed to the mixing tank.

The next step occurs as motor M02 turns on and mixing happens. The chemical reaction between the sulphuric acid and microcrystalline occurs while it is being mixed in the mixing tank. After the set amount of time, the hydrolysis process is stopped by the addition of water to the mixing tank by activating valve HS202 in on position. This valve closes after set amount of water is fed to the mixing tank. The weight of process components in mixing tank is detected by weight sensor WI204. For temperature determination, temperature sensor TI203 is present in mixing tank.

Following the accomplishment of the chemical reaction in the mixing tank, the product is fed to the centrifugal tank for centrifugation process with the valve HS205 open. After all the product is in the centrifugal tank, valve HS205 closes automatically and motor M03 starts for the centrifugation process. After the desired duration, motor M03 stops and products remains in the tank for further predetermined time. This follows with the transfer of the product from

the centrifugal tank to the storage tank with valve HS208 open. When all the product from the centrifugal tank is emptied to the storage tank, valve HS208 closes automatically. In centrifugal tank, the weight of the product is determined by weight sensor WI207. For temperature determination, temperature sensor TI206 is present in centrifugation tank. Weight sensor WI207 determines the product weight in centrifugal tank.

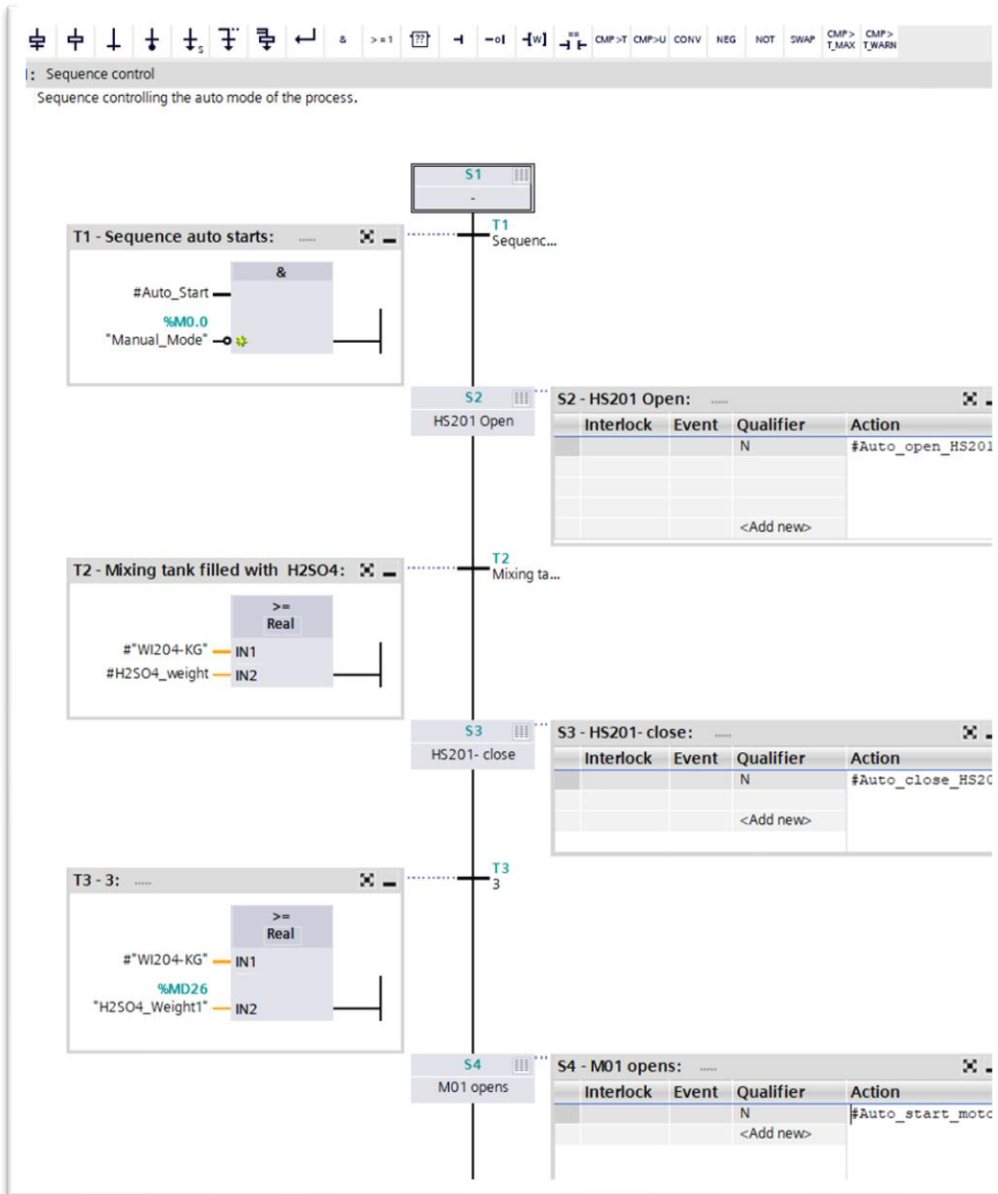
In storage tank, the product from the centrifugal tank keeps on flowing until the set amount of product is reached, determined by level sensor in storage tank i.e. by level sensor LI210. This is followed by the activation of motor M04 which turns on the pump and flow rate is detected by the flow rate sensor FIC213. The pump motor is controlled via variable frequency drive which controls the precise amount of product flow to the further processing point from the storage tank with the valve HS212 open. This valve closes when the level of product falls to the set level point in storage tank. Temperature sensor TI209 detects the temperature of product in the storage tank. With valve HS212 feeding the solution to the sulphate filter chamber valve HS214, HS216 and HS218 are opened simultaneously where valve HS214 feeds the distilled water to the chamber where filtration occurs. HS216 lets the filtered solution to the dialysis chamber. Similarly Valve HS218 feeds the deionised water to the dialysis chamber for the further filtration process.

Filters NI215 and NI217 do the job of filtration of sulphate ions from the product. The values fed from both filters reading is in percent term which signify the percentage of the sulphate filtered, for example with 10 % reading, it means that 10 % of the sulphate have been filtered out.

In case of emergency i.e. if valve HS212 is closed, valve HS211 is opened to feed the product back to the storage tank.

The whole system runs in a sequential batch process and the process can be interrupted by activating manual mode and reset button. The schematic view of sequential programming can be seen in figure 5.

Figure 5. Sequential programme in TIA portal.



Signals mapping part describes the complete elaboration of all the inputs and outputs used in the programming as seen in table 22.

Table 22. Signal mappings of all the sensors.

Inputs	Outputs	Functional relationships
Level sensors (LSA 200)	M01	Conveyor belt is deactivated when the powder level falls below setpoint, Belt is activated after the silo is refilled.
Weight sensor (WI207)	M02	Motor is turned on when the set point for the tank components' weight requirement is met.
Temperature sensors (TI203, TI206, TI209)	M02, M03	Tracks the temperature and motor stops if the temperature is below or about the set points.
Chemical Sensors (NI214, NI216)	M05	Tracks the concentration of sulphate and motor starts if the sulphate concentration is below or about the set points.
Emergency stop	All Actuators	Immediate shutdown of the system in case of emergency.
PLC	HS201	Controls the flow of sulphuric acid based on programmed logic and set points.
PLC	HS202	Controls the flow of water based on programmed logic and set points.
PLC	HS205	Controls the flow of solution from mixing tank to centrifugal tank based on programmed logic and set points.
PLC	HS208	Controls the flow of produced solution from mixing tank to storage tank based on

		programmed logic and set points.
PLC	HS211	Controls the flow of product from storage tank back to storage tank based on programmed logic and set points.
PLC	HS212	Controls the flow of produced solution from storage tank to the next processing stage based on programmed logic and set points.
PLC	HS214	Controls the flow of water to sulphate filter chamber based on programmed logic and set points.
PLC	HS216	Controls the flow of produced solution from storage tank to the sulphate filter chamber based on programmed logic and set points.
PLC	HS218	Controls the flow of produced solution from the sulphate filter chamber to the dialysis chamber based on programmed logic and set points.

3.3 SIMIT modelling

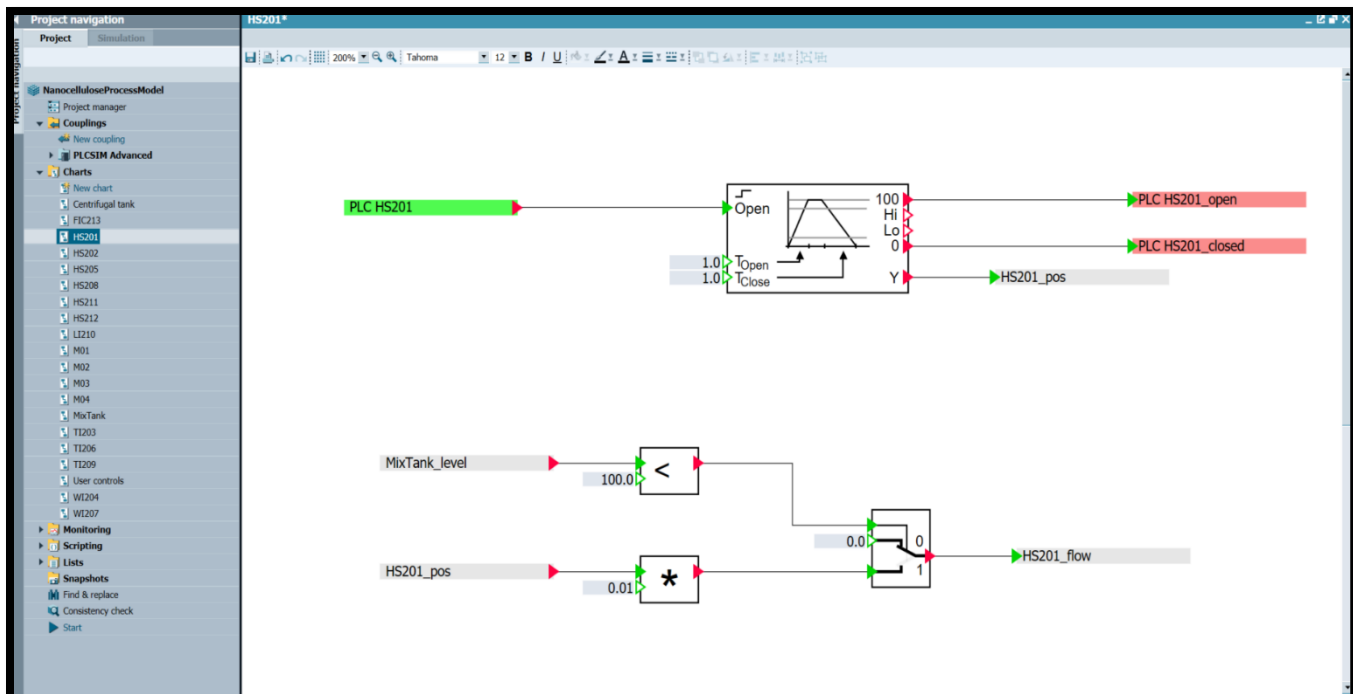
Siemens SIMIT SP was used for the simulation purpose which acted as the source of all the sensors inputs and the motor running information sent to PLC via advanced PLCSIM. Offline SIMIT view from the input sensors and actuator's general view can be seen in figure 6.

As any of the sensors such as weight sensor WI204 detects the valve HS201 opened, it simulates the weight of sulphuric acid until the desired amount of acid is achieved and as valve is closed, this specific weight sensors reacts differently. If none of other valves are opened, the weight stabilises in the set point status. It sends its output commands accordingly i.e. as commanded by PLC.

For the simulation of motors, it gets the information from the PLC that the specific motor has been set to on and accordingly, SIMIT sends the motor running information back to PLC. All these simulated processes can be viewed clearly in SIEMEN's HMI in the following section.

Let us get into motor M04 scenario, here, when the specific amount of produced solution in the storage tank is detected i.e. the set point is reached, motor M04 which is further controlled by

Figure 6. SIMIT view of the simulation part.



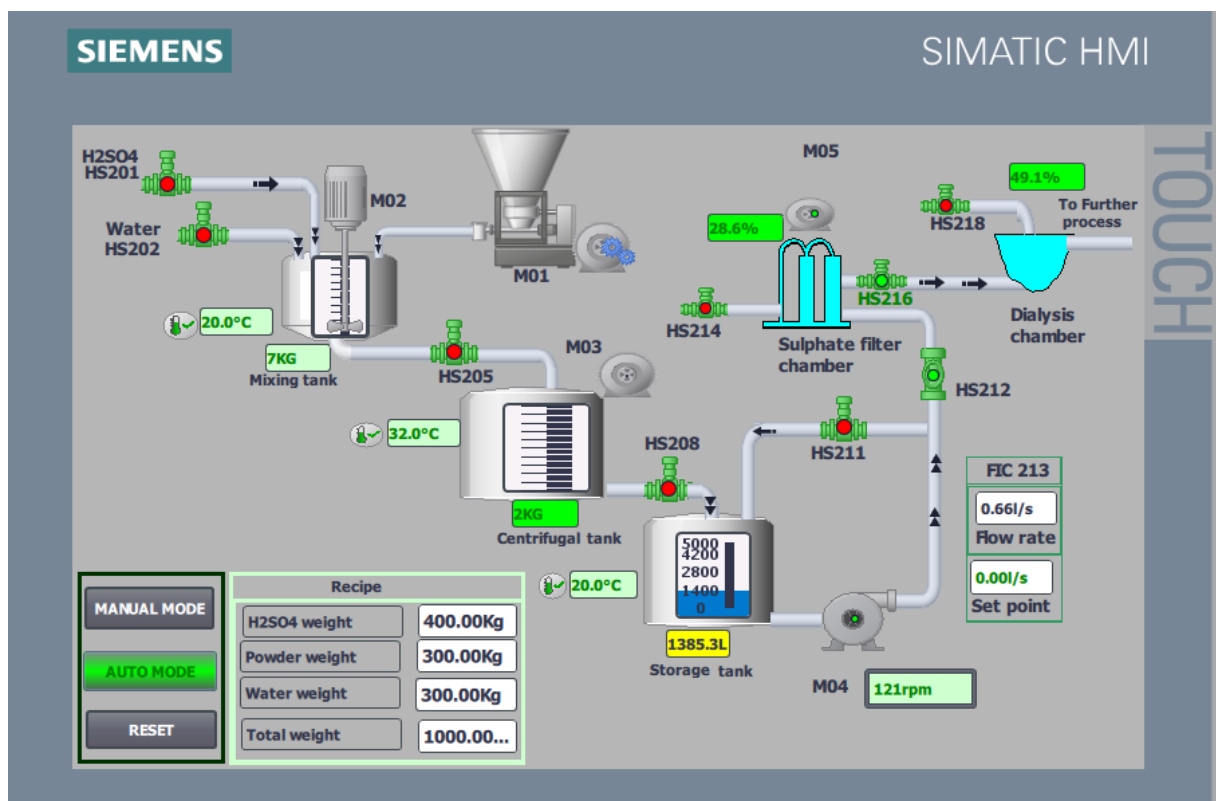
variable frequency drive, starts and it pumps the solution from the storage tank to the further processing point as valve HS212 also opens simultaneously thus letting the produced solution to the next stage. This amount of fluid moving from storage tank is controlled by flow controller

FIC213 which we can control using PID controller. The set point can be seen in litres/second and motor speed as RPM in HMI.

3.4 Siemens HMI

This section showcases the user interface to control processes from both SIMATIC SP and PLC TIA portal programming. I have spent most of my time in designing a good working HMI interface as mentioned in figure 7 below.

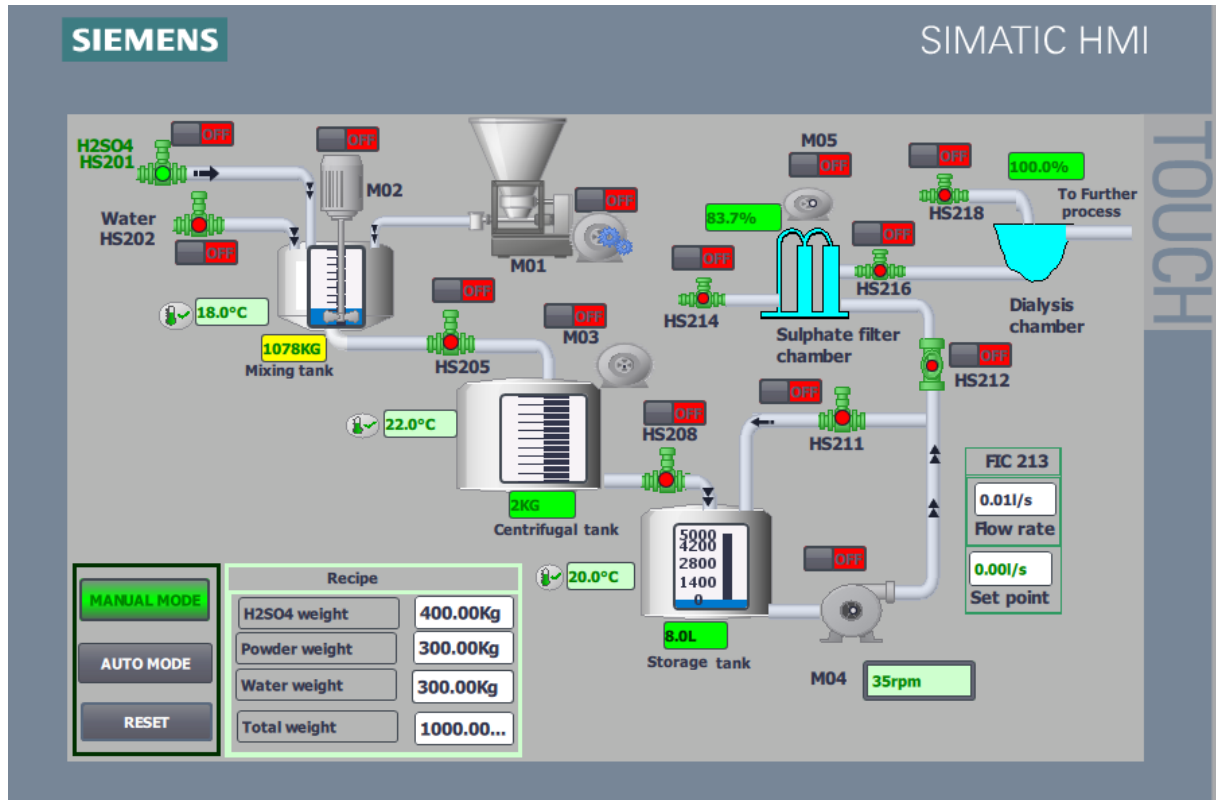
Figure 7. Siemens HMI view of the process with automatic mode running.



In HMI interface, we can see that all the beginning status for the sensor data sections are marked green as background colour. As their values increases while the process is ongoing, the colour changes gradually to yellow and red when the set point is reached. Clock memory of 5 Hz frequency is used for the simulated movement of all the process fluids and microcrystalline cellulose powders as well as for the movement of the centrifugal tank and the mixture rotor. Figure 7 represents the situation where the auto mode has been implemented after the required amount of process components are inserted in the recipe section.

The situation where the manual button is pressed, all the sensors and actuator controls appear for the manual control of the process. Figure 8 shows the manual control view of the HMI interface.

Figure 8. Manual control view of the process in HMI interface



The video of working process of the simulation in HMI can be seen from the following link.

[Process Automation for the production of nanocellulose.](#)

4 Overview of the processes

This process automation to produce nanocellulose involved integrating advanced control systems to manage the various stages of production efficiently and consistently. This included automating the chemical treatments i.e. hydrolysis processes, by using sensors and control valves to monitor and adjust parameters like temperature, pressure, flow rate, weight tracking and concentration in real-time. The automation system also ensured seamless operation of material handling, filtration, and drying, optimizing the flow of materials and energy while maintaining the desired quality of the final nanocellulose product.

The aim was to streamline operations, increase efficiency, and maintain consistent product quality. The process began with the automated handling of raw materials namely hydro sulphuric acid and microcrystalline cellulose powder, which was transported to the processing area. Once the material was prepared, an automated chemical treatment stage followed, where hydrolysis was applied to break down the microcrystalline cellulose into nanoscale structures. Sensors and control systems monitored and adjusted critical parameters such as temperature, concentration, and reaction time during this stage to ensure optimal conditions for nanocellulose production. Chemical treatments namely acid hydrolysis was carefully controlled by automated dosing systems that regulated the concentration of acids and the hydrolysed product. Once the nanocellulose reached the desired result, automated filtration and separation systems was employed to isolate the nanocellulose from the slurry, removing unwanted byproducts. The next step involved the drying or freeze-drying of the nanocellulose, where automation ensured consistent temperature control preserved its properties. The final product was then stored under automated conditions to prevent contamination. Throughout the process, a centralized control system gathered data from sensors across the production line, allowing operators to track performance and identify any deviations in real time. This integrated approach to process automation helped minimize human intervention, reduce errors, and improve overall production efficiency while ensuring the high quality of nanocellulose for various industrial applications.

As earlier described in PLC programming section, we can see that the process can be very feasible to test the system in the virtual environment with the siemens SIMIT SP. This had been a very useful tool for the big manufacturing and process industries to save the money in establishing this kind of simulated environment thus allowing them to skip the need for building a pilot plant in real life. The saving could be easily in the hundreds of thousands of euros per process or per system improvement.

Getting the process accomplished with the siemens TIA portal and siemens SIMIT SP was very possible and feasible. Further improvement of the process and need for the better virtual commissioning of the process is obviously needed.

5 Conclusion

The developed SIMIT modelling worked as expected in the process. All the required sensors and their input parameters set in PLC programming worked as expected. Some issues were discovered in the PID section of the PLC programming. The main issue was when the simulation was turned on in the PLC and SIMIT SP side, and even the PID controller's setpoint was set to zero, a minimal flow sensor value kept on feeding to the PID controller i.e. PID controller tuning would not work as expected often or it would just fail to load a pre-tuning very often.

This thesis explored the automation of nanocellulose production processes with a focus on improving efficiency, scalability, and sustainability although all the aspects were not fully investigated. Through the use of SIMIT SP software for process simulation and Siemens TIA Portal for automation, the research demonstrated how digital tools can optimize complex workflows in nanocellulose manufacturing. The study highlighted key inefficiencies in traditional production methods and proposed innovative automation strategies to address these challenges in a sense that efficient production process is not yet available in the current market. By simulating the production processes, it was possible to identify critical bottlenecks and test automated solutions in a virtual environment, reducing the risks associated with physical trials. The integration of automation somehow showed significant potential in enhancing process control, reducing energy consumption, and ensuring consistent product quality. These findings underscore the value of combining simulation and automation tools to modernize and scale up emerging technologies like nanocellulose production. The research also demonstrated the feasibility of applying industrial automation solutions to meet increasing market demands while adhering to environmental standards. Additionally, the thesis bridged the gap between academic research and practical application, drawing my study experience to develop actionable solutions. Overall, the study contributes to advancing sustainable manufacturing practices and provides a framework for further innovations in nanocellulose production and beyond.

To sum up, I would say that the virtual commissioning of the process automation to produce nanocellulose is realistic to test virtually and implement the result in real life.

References

- Salki, A. (2022). Siemens S7-1200 PLC DC Motor control capabilities. *IFAC-PapersOnLine*, 55(4), 103-108. doi:<https://doi.org/10.1016/j.ifacol.2022.06.017>
- Alphonsus, E., & Abdullah, M. (2016). A review on the applications of programmable logic controllers (PLCs). *Renewable and Sustainable Energy Reviews*, 1185-1205. doi:<https://doi.org/10.1016/j.rser.2016.01.025>
- Bogati, D. R. (2011). Cellulose based biochemicals and their applications. [Bachelor's thesis, Saimaa University of Applied Sciences]. Theseus. <https://urn.fi/URN:NBN:fi:amk-2011113016508>
- Bogati, D. R. (2014). *Cellulose biotemplate for synthesis of layered double hydroxides*. [Master's thesis, Åbo Akademi University]. Turku: Åbo Akademi University.
- Börjesson, F. B. (2023). Comparison of WinMOD and SIMIT for virtual commissioning of an automotive production line. [Bachelor's thesis, Chalmers University of Technology]. Chalmers. <https://odr.chalmers.se/server/api/core/bitstreams/b409799b-94cc-413a-bdf9-362fc674dba3/content>
- CAD Schroer. (n.d.). The piping and instrumentation diagram as the basis for sustainable process design. Retrieved from <https://www.cad-schroer.com/news/articles/the-piping-and-instrumentation-diagram-as-the-basis-for-sustainable-process-design/>
- Morán, H. (2024). Tunable PID Controller from the WinCC Unified Interface via OPC UA. *International Journal of Electrical and Electronic Engineering & Telecommunications*, 397-405. Retrieved from <https://api.semanticscholar.org/CorpusID:272644191>
- Zhang, C., & Sun, Y. (2020). Traffic Light Control System Based on SIMATIC S7-300 and WinCC Configuration Software. *Journal of Physics: Conference Series*. Retrieved from <https://iopscience.iop.org/article/10.1088/1742-6596/1646/1/012137>
- De Paula Ferreira, W., Armellini, F., & Eulalia, L. (2020). Simulation in industry 4.0: A state-of-the-art review. *Computers & Industrial Engineering*, 106868. doi:<https://doi.org/10.1016/j.cie.2020>. Volume 149.
- Florescu, A. (2024). Digital Twin for Flexible Manufacturing Systems and Optimization Through Simulation: A Case Study. *Machines*, 12(11), 785. Retrieved from <https://www.mdpi.com/2075-1702/12/11/785>
- Hui, H., McLaughlin, M., & Sezer, S. (2021). Vulnerability analysis of S7 PLCs: Manipulating the security mechanism. *International Journal of Critical Infrastructure Protection*, 35. doi:<https://doi.org/10.1016/j.ijcip.2021.100470>

- Htay, N. P. (2018). Model Of Metal Sorting Conveyor System Using Siemens S7-1200 PLC. *International Journal of Scientific & Technology Research*, 45-49. Retrieved from <https://api.semanticscholar.org/CorpusID:54845462>
- Chukwuka,I., Deka,I., & Haddijatou,C. (2020). PLC/HMI Control of Boiler for brewing and sterilization. *Global Scientific Journal*, 8(5), 122-131. Retrieved from https://www.globalscientificjournal.com/researchpaper/PLC_HMI_Control_of_Boiler_for_Brewing_and_sterilization.pdf
- Oeing,J., Welscher,W., Krink,N., Jansen,L., Henke, F., & Kockmann,N. (2022). Using artificial intelligence to support the drawing of piping and instrumentation diagrams using DEXPI standard,. *Digital Chemical Engineering*,, 4(100038,). doi:<https://doi.org/10.1016/j.dche.2022.100038>
- Gardiner,J., & Rashid,A.(2020). DEMO: Gone in 20 Seconds - Overview of a Password Vulnerability in Siemens HMIs. *Proceedings of the 2020 Joint Workshop on CPS&IoT Security and Privacy*. Retrieved from <https://api.semanticscholar.org/CorpusID:226239257>
- Langmann, R., & Stiller, M. (2019). The PLC as a Smart Service in Industry 4.0 Production Systems. *Applied Sciences*, 9(18), 3815. Retrieved from <https://www.mdpi.com/2076-3417/9/18/3815>
- Murshalin, M., Ali, M., Halder, A., Shajib, M., Hossain, & M. (2024). Efficient Control and Automation: Exploring Siemens LOGO PLC and PLC-Based Industrial Timer Controllers. *Asian Journal of Applied Science and Technology*, 34-43. doi:<https://ajast.net/data/uploads/78264.pdf>
- Pradhan, D., Jaiswal, A., & Jaiswal, S. (2022). Emerging technologies for the production of nanocellulose from lignocellulosic biomass. *Carbohydrate Polymers*. 285. 119258. DOI:[10.1016/j.carbpol.2022.119258](https://doi.org/10.1016/j.carbpol.2022.119258)
- Pandey,R., & Bhatt, N.(2015). Industrial Burner Automation based on PLC HMI & SCADA. *International Journal for Scientific Research & Development*, 3(9), 87-90.
- Sobhana, S., Bogati, D., Reza, M., Gustafsson, J., & Fardim, P. (2016). Cellulose biotemplates for layered double hydroxides networks. *Microporous and Mesoporous Materials*, 225, 66-73. doi:<https://doi.org/10.1016/j.micromeso.2015.12.009>
- Jeng, S., Chieng, W, & Chen, Y. (2021). Web-Based Human-Machine Interfaces of Industrial Controllers in Single-Page Applications. *Mobile information systems*, Volume 2021, Article ID 6668843, 1-13. doi: <https://doi.org/10.1155/2021/6668843>
- Siemens. (2019). *What is S7-PLCSIM Advanced?* Retrieved from https://docs.plm.automation.siemens.com/content/plant_sim_help/15/plant_sim_all_in_one_html/en_US/tecnomatix_plant_simulation_help/add_ins_reference_help/inter_process_communication_interfaces/plcsim/what_is_s7_plcsim_advanced.html

- Siemens. (n.d-a). *Automation Technology*. Siemens. Retrieved from <https://www.siemens.com/global/en/company/about/history/technology/drive-and-automation-technology/automation-technology.html>
- Siemens. (n.d-b). SIMATIC HMI - Efficient to a new level. Retrieved on 05.21.2024, from <https://www.siemens.com/in/en/products/automation/simatic-hmi.html>
- Wucherer, K. (2001). HMI, The Window to the Manufacturing and Process Industry. *IFAC Proceedings Volumes*, 34(16), 101-108. doi:[https://doi.org/10.1016/S1474-6670\(17\)41508-4](https://doi.org/10.1016/S1474-6670(17)41508-4)
- Yu, E., Cha, J., Lee, T., Kim, J., & Mun, D. (2019). *Features Recognition from Piping and Instrumentation Diagrams in Image Format Using a Deep Learning Network*. *MDPI Open Access Journal*. (12(23):4425.), 1-19. doi:<https://doi.org/10.3390/en12234425>
- Zheng, D., Guo, R., Chang, K., & Yin, J. (2019). Research and Development of High Precision Robot Automatic Docking System Based on mxAutomation. *Journal of Physics: Conference Series*, 8. doi: 10.1088/1742-6596/1267/1/012100

Appendix 1. Data management plan

The research materials and collected data will be kept guarded and sorted for this thesis. All associated data developed plc program, SIMIT SP programs, P&ID diagram and other documents will be stored on my personal computer. Everything will be routinely backed up to prevent the loss of important information.

Sensitive information, such as personal details, addresses will be protected using strong passwords and encryption. Access to the information will only be granted to associated individuals. All research materials will be retained for at least one year after the thesis is approved, simplifying any possible future verification upon request. Likewise, after one-year, proper disposal procedures will be ensured for some materials while some may continue to be used in the future.

Appendix 2. Hardware configuration device list

Order list Project Project

SIEMENS

1. Order list

Basic Panel				
Article number	Name	Quantity	Single parts	
6AV2123-2GB03-0AX0	SIMATIC HMI KTP700 Basic	1 Pieces	1	
S7-1500_1				
Article number	Name	Quantity	Single parts	
6ES7590-1AE80-0AA0	S7-1500, mounting rail 482.6 mm (19")	1 Pieces	1	
6ES7511-1AL03-0AB0	CPU 1511-1PN, 300KB Prog, 1,5MB Data	1 Pieces	1	
6ES7954-8LT04-0AA0	SIMATIC S7 Memory Card, 32 GB	1 Unit	1	
6ES7521-1BH00-0AB0	S7-1500, DI 16x24VDC HF	2 Pieces	2	
6ES7592-1AM00-0XB0	Frontconnector Screw Type (35mm Mod.)	8 Pieces	8	
6ES7522-1BH01-0AB0	S7-1500, DQ 16x24V DC/0.5A HF	1 Pieces	1	
6ES7531-7PF00-0AB0	S7-1500, AI 8 X U/R/RTD/TC HF	2 Pieces	2	
6ES7532-5ND00-0AB0	S7-1500, AQ 4xU/I HF	1 Pieces	1	
SITOP				
Article number	Name	Quantity	Single parts	
6EP1332-1LB00	SITOP PSU100L/1AC/24VDC/2.5A	2 Pieces	2	
6EP1964-2BA00	SITOP PSE202U/Redundancy M./DC24V/10A	1 Pieces	1	
SITOP_2				
Article number	Name	Quantity	Single parts	
6EP1333-1LB00	SITOP PSU100L/1AC/24VDC/5A	2 Pieces	2	
6EP1964-2BA00	SITOP PSE202U/Redundancy M./DC24V/10A	1 Pieces	1	

Appendix 3. Tag table list for SIMT interface.

SIMT interface									
	Name	Data type	Address	Retain	Acces...	Writa...	Visibl...	Supervis...	Comment
1	H5202_open	Bool	%I0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Water Valve open
2	H5202_closed	Bool	%I0.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Water Valve close
3	H5201_open	Bool	%I0.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		H2504 Valve open
4	H5201_closed	Bool	%I0.3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		H2504 Valve close
5	H5205_open	Bool	%I0.4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after mixing tank open
6	H5205_closed	Bool	%I0.5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after mixing tank close
7	H5212_open	Bool	%I0.6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to Process open
8	H5212_closed	Bool	%I0.7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to Process close
9	H5211_open	Bool	%I1.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to return product from process to st...
10	H5211_closed	Bool	%I1.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to return product from process to st...
11	M01_running	Bool	%I1.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Powder delivery motor running
12	M02_running	Bool	%I1.3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Stirrer running in mixing tank
13	LSA200	Bool	%I1.4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Level switch alarm for powder amount
14	H5202	Bool	%Q0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Water Valve
15	H5201	Bool	%Q0.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		H2504 Valve
16	H5205	Bool	%Q0.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after mixing tank
17	H5212	Bool	%Q0.3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to Process
18	H5211	Bool	%Q0.4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to return product from process to st...
19	M01	Bool	%Q0.5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Powder delivery motor
20	M02	Bool	%Q0.6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Stirrer running motor
21	W204	Int	%IW2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Weight indicator mixing tank (Ch 0, byte ...
22	LI210	Int	%IW6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Level indicator for storage tank (Ch 2, byt...
23	FIC213	Int	%IW8	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Flow rate indicator (Ch 3, byte no. 8 and ...
24	TI203	Int	%IW10	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Temperature indicator for mixtures in mixi...
25	TI206	Int	%IW14	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Temperature indicator for mixtures in Cen...
26	M04-speed	Int	%QW2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Speed of the motor pumping product to ...
27	M01-fault	Bool	%I1.5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Powder delivery motor fault
28	M02-fault	Bool	%I1.6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Stirrer running motor fault
29	M03-running	Bool	%I1.7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
30	M03-fault	Bool	%I34.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
31	M03	Bool	%Q0.7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Centrifugal tank motor
32	TI209	Int	%IW18	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Temperature indicator for mixtures in star...
33	W207	Int	%IW4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Weight indicator centrifugal tank (Ch1 , b...
34	M04_running	Bool	%I34.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
35	M04-fault	Bool	%I34.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Stirrer running motor fault
36	M04	Bool	%Q1.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Pump delivering product to process
37	H5208	Bool	%Q1.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after Centrifugal tank
38	H5208_open	Bool	%I34.3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after centrifugal tank open
39	H5208_close	Bool	%I34.4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve after centrifugal tank closed
40	H5214_open	Bool	%I34.5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
41	H5214_close	Bool	%I34.6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
42	H5214	Bool	%Q1.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve for water to sulphate filter chambe
43	H5216_open	Bool	%I34.7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
44	H5216_close	Bool	%I35.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
45	H5216	Bool	%Q1.3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Valve to control flow to dialysis chamber
46	NI215	Int	%IW22	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
47	NI217	Int	%IW24	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
48	M05	Bool	%Q1.4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Pump delivering to dialysis chamber
49	M05-running	Bool	%I35.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
50	M05_fault	Bool	%I35.2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
51	H5218_open	Bool	%I12.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
52	H5218_closed	Bool	%I12.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
53	H5218	Bool	%Q1.6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		