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Final Project (ENX313)

BEng (Hons)

ELECTRICAL AND ELECTRONIC ENGINEERING

Student Name : KAHAWATHTHAGE JAYANTHA CHITHRA BANDARA

Student Number : 189219095

Supervisor : DR. INDRAJANAKA MAHAKALANDA

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Contents

1 Chapter 1 introduction

1.1 Background

Tea is the most consumed drink after the water in world. 273 billion liters' global consumption recorded in 2018 and it will be reach to 297 billion liters in 2021. In 1824 the first tea plant was brought from china to our country by British people and planted in Peradeniya royal botanical garden for exhibition purpose. In 1867, James Tayler started the first Sri Lankan tea estate by starting plantation in *Loolkandura* estate in up country Kandy. The *Loolkandura* tea plantation is 19 acres and the fully equipped factory began work in 1873.

After that, there were many number of plantation companies and factories developed under the traditional tea making method. The first stage of the tea making is the withering process, where one tea leaf contains 20% of chemicals and 79-80% of water. Rolling is the second stage of tea making process and 43% of water content should be removed from the above mentioned 80% of water before been sent to the rolling stage. The purpose of the rolling stage is to break down cell walls in the leaf, and facilitate the next step oxidizing. In the oxidizing stage temperature and humidity must control in carefully. Fifth stage is fixing stage and it stop oxidizing process by heating leaves. Last stage is Drying and remove any residual moisture. Up to date, most of the factories are still using the 147 years old mechanism and traditional method for withering process.

According to Sri Lanka tea exporters association, in 2019 total tea export was 268,921 metric tons. Main source of the Sri Lankan government revenue and foreign exchange is from the tea industry which is helps to develop our country. It provides many job opportunities and is a key player of our economy for more than a century. These are the main reasons for the need to develop the tea industry for a better future.

1.2 Rationale of the topic

Modern tea factories and plantations use various technologies to make their tea making process easy and the industrial technology has rapidly developed in the last decades as well as consumer electronics. Automatic withering system is convenient and saves time if they can operate efficiently. This system uses the existing traditional method under new value added modification by using modern electrical, electronic and mechanical technologies to increase quality as well as productivity of the harvest. In this project I hope to develop the existing withering system by using low cost microcontroller based accurate and energy efficient system.

1.3 Problem identification

Presently, tea factories use 147 years old withering mechanism system which consumes lot of energy as electricity and heat. Most of the factories monitor the condition of the withering leaves by using their skilled experienced supervisors and sometimes conditions of the leaves may be different when comparing with other withering stages, because of the different experience levels and skill levels of the supervisors.

Lot of man power is required to handle tea leaves where it takes over 8 to 12 hours to the withering cycle and nowadays man power available is very poor than past decades. According to A. Jayathilake (2014), Most of the tea workers are moving from states due to poor motivation, poor housing, low wages and other problems. This is the main issue presently and some factories were permanently closed due to less workforce.

1.4 Aim and Objectives

1.4.1 Aim

The automatic withering system will definitely give good solution for above matters and it saves lots of human effort and time.

There are many advantages from using an automatic withering system. Some of these advantages are as follows;

- ✓ Develop existing withering system by using low cost microcontroller based system for automatic operation.
- ✓ Reduce the labour intensive, energy losses, high attention/ consideration and man hours for the process.
- ✓ Increase the overall efficiency of the process, proper energy management and quality.

1.4.2 Objectives

The main aim of the project is to implement a low cost microcontroller based automatic withering system.

- Study about different type of withering systems and methods from referring research papers.
- Study and develop moisture-sensing system to detect the water content of the green tea leaves.
- Develop a mechanism part to existing withering system for mix tea leaves during process. (to change top bottom side of the leaves)
- Develop the existing manual withering system as an automatic system.
- Understand the different types of climate changes how effected to the withering process.

1.5 Project Scope

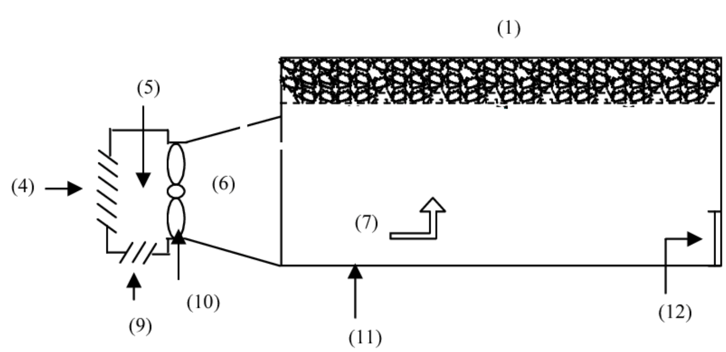
- Sense the air temperature and humidity level by using temperature sensor and humidity sensor.
- Calculate the wet bulb and dry bulb values according to above sensor outputs.
- Check the difference between dry bulb and wet bulb values.
- Set the withering cycle time.
- Control the fresh air intake main fan and hot air intake damper to maintain above value as set value.
- Run the withering cycle automatically according to pre-set time with maintaining set value.

2 <u>Literature review</u>

In this section I would like to review the type of tea withering systems, operation of tea withering system, calculate the temperature and humidity sense from sensors, in this chapter discus the designs and methods to achieve the objective of above mentioned in this project.

2.1 Current Withering system

According to Anderson, W. (1909) there are two types of withering methods. One is called as physical withering and other one is chemical withering. Physical withering can be done by using net, tunnel, drum, and trough withering systems. Trough withering system is the most popular and commonly used method for tea withering process and it is important first steps to improve the quality of the final tea. Selected tea leaves usually spread in a closed / open series trench mounted holes in holes under forced air circulation. Freshly harvested leaves are physically and chemically conditioned for next operation of tea rolling. Before the rolling stage the moisture level of shoots from 70-80% to 60-70%. (ONISHI, I 1975)



(1)	Leaf bed	(7)	Airflow path
		(9)	Warm air
(4)	Cold air	(10)	Axial fan
(5)	Mixing chamber	(11)	Plenum chamber
(6)	Transformation duct	(12)	Gable door

Figure 1 The trough withering system

Source: httpsd3i71xaburhd42.cloudfront.net60b12944df471b3afdc1a654a6ca98e612b1dc7d8

According to Sarac, B. (2015). Withering process is the largest energy consumer in the processing of tea as electricity and heat. Even cost of infrastructure is major for withering. According to John, I (2018) the ambient air and heat are the key players of the archive desired moisture level to remove moisture from any wet condition. By heating air, it increases the volume and pressure. Also atmosphere contains humidity and it depends on various condition such as places and altitude. As mentioned in Starchefs.com. (2020). There are 4 types of withering.

- Physical withering
- Chemical withering
- Normal withering
- Two- stage withering

Figure 2 Physical withering tea trough

Source: Withering trough at New Vithanakande tea factory, Delwala, Rathnapura, Sri Lanka.

2.2 Humidity and temprature measurement

As discussed above the temperature and humidity control is most important thing. According to Huang, Y., Zhang, K., Yang, S. and Jin, Y. (2013) the humidity and temperature is an important factor under control in any drying or moisture removing process. There is different equipment to measure humidity and temperature such as electronic hydrometer and psychometric hydrometer.

As mentioned by the Bahadori, A., Zahedi, G., Zendehboudi, S. and Hooman, K. (2013) the psychometric hydrometer is consisting with two identical temperature meter, one is dry-bulb thermometer and other one is wet-bulb thermometer. Dry-bulb thermometer is indicating ambient temprature and wet-bulb thermometer with some wet piece of cloth or cotton gauze wrap around the bottom side of the thermometer. The continuous air flow around the thermometers are important to read correct temprature readings when evaporate water from wet cloth. Reading are given in Celsius and Fahrenheit. Relative humidity (RH) value can be obtain by using psychometric chart or RH% chart. Psychometric hydrometer is easy to maintain and get readings. Psychometric hydrometer is very simple compared with electronic sensors. Therefore, psychometric hydrometer will not give problems and always present accurate answer. Therefore, these type hydrometers are suitable to take measurements in the harsh environment.

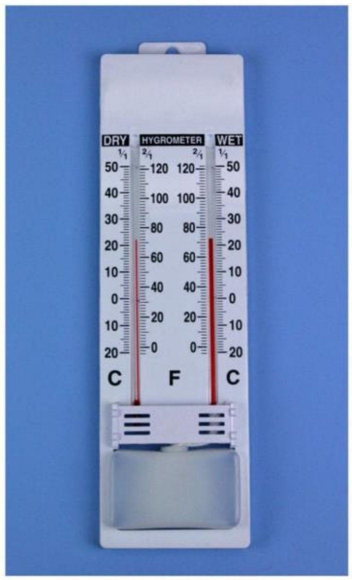


Figure 3 Dry and wet bulb hydrometer

Source: httpsn3.sdlcdn.comimgsi0kDry-Wet-Hygrometer-Analog-Psychrometer-SDL271843675-3-c5abc.jpeg

Relative Humidity %

Dry Bulb Temperature (Celsius)	Difference Between Wet-bulb and Dry-bulb Temperatures (ºC)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-20	100	28														
-18	100	40														
-16	100	48														
-14	100	55	11													
-12	100	61	23													
-10	100	66	33													
-8	100	71	41	13												
-6	100	73	48	20												
-4	100	77	54	32	11											
-2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

Figure 3 Relative humidity chart

Source: httpswww.ontrack-media.netscience8s8m0l6image8.jpg

2.3 Air flow control by controlling motor

According to Kumar, D (2018) the 3 phase induction motors are widely used large industrial type areas such as automobile, chemical, cement, fertilizer, water handling, construction etc. because it can perform in highly harsh environment due to it rugged and simple design. According to Melfi, M. and Umans, S. (2012) a 3-stage induction motor is theoretically self-starting motor. The stator of an induction motor consists of three winding stages. Stator will create Rotating magnetic field when connected to a three-phase AC supply. The rotating magnetic field will connect the rotor and cut it conductors that cause rotor current create a magnetic field in the rotor. The magnetic field created by the rotor will interact with the rotating magnetic field in the stator and produce rotation. There are many methods for start and control motors and some common methods as follows.

- Direct online start
- Star- Delta start
- Auto transformer start
- Rotor resistance control start
- Electronic drive start

2.3.1 Direct online motor start

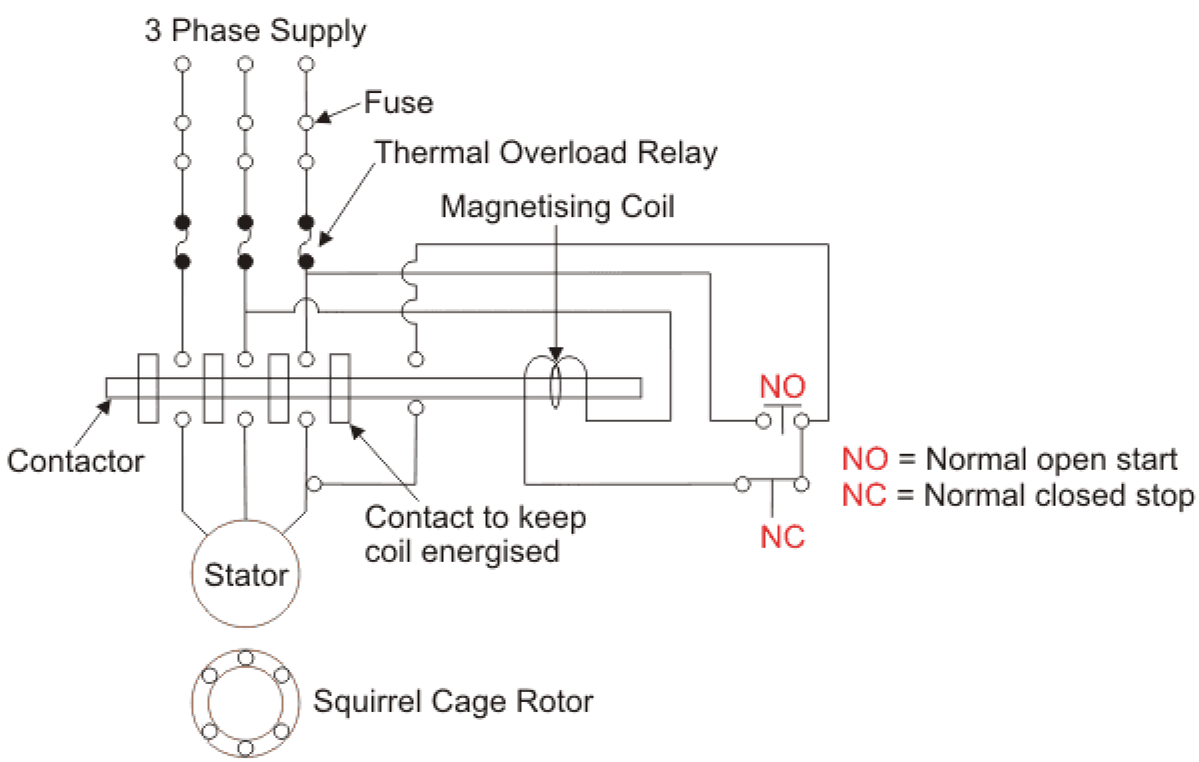


Figure 4 Direct online starter

Source: httpswww.electrical4u.comwp-contentuploadsDOL-Starter-Control-Diagram.png

According to Melfi, M. and Umans, S. (2012) when directly connect a motor to the supply, starting current will be very large, 6-8 times rated current. High starting current cause to voltage drops in supply line. Due to high starting current direct online starter used to which motor power is less than 7.5 kW. Direct online starter is the cheapest starter solution for 3 phase induction motors due to simple design and less components.

2.3.2 Star delta starter

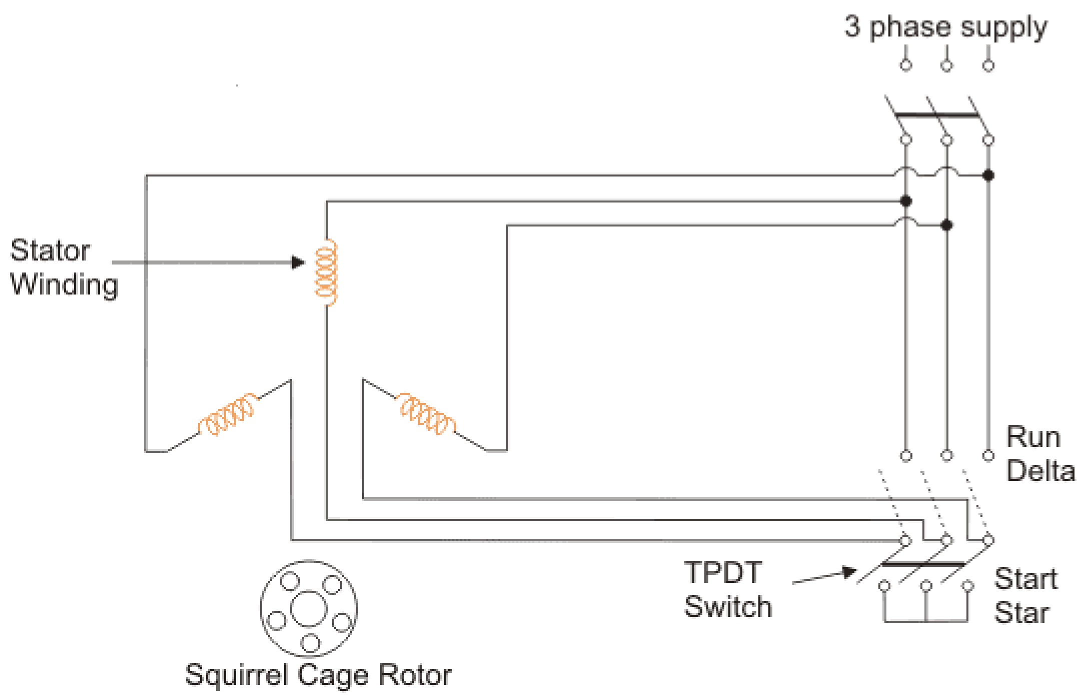


Figure 5 Star delta starter

Source: httpswww.electrical4u.comwp-contentuploadsWhat-is-star-delta-starter.png

Star delta starter is very commonly used in industry which is motor power over 5.5kW motors. Compared with other types of starters this method is reduce supply voltage in starting. When connect the motor to the supply the windings in STAR connection archive low starting current. Then after the motor speed reached 80% of rated speed, changeover the switch from STAR connection to DELTA connection. In this method starting current is reduced to one to third as compared with starting delta windings connection.

2.3.3 Electronic drive start

According to Wu, B. and Narimani, M. (2017) electronics starters are divided in to two categories, variable speed drives, AC drives or variable frequency drives (VSD, VFD) and Soft starter. Soft starters are used to reduce the motor starting current by varying the motor acceleration time. Then motor comes to rated speed the soft starter is bypass using switch on a bypass contactor. Figure 6 shows a soft starter.

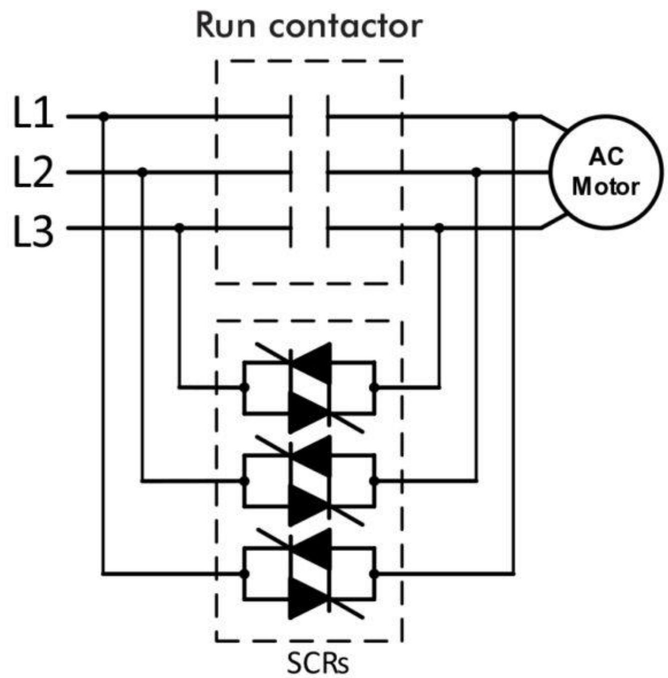


Figure 6 Soft starter with bypass contactor

Source: httpswww.ee.co.zawp-contentuploads201606Drives-Zest-Weg-fig-1-600x605.jpg

According to Allen, C. and Pillay, P. (1992) Variable frequency drive is used to vary the speed by controlling output frequency and voltage. Variable speed drives, adjustable speed drives, AC drive, inverter and micro drive are other names. Frequency is directly involving to the motor speed and other hand when increase the frequency, motor speed will increase. If an operation does not need to run motor in full speed, the VFD can reduce the frequency and voltage to meet required level of the speed. As the application's motor speed need to change the VFD is the most suitable device to control speed up down. Other vice some VFD has more analogue and digital inputs for easy installation and modification without PLC devices.

Figure 7 ABB Variable frequency drive

Source: https://encrypted-tbn0.gstatic.com/images

2.4 Furnace and heat exchangers for hot air make

According to Sinha, A. et al. (2015) the tea drying furnace correspond to an open system, which is shown in below fig 8 by using control volume. There are two volumes considered as furnace and mixing section. Fuel and combustion air intake to the furnace and burn. Fire wood, coal, saw dust and furnace oil can be use as fuel. Cause of the fuel, the furnace body get heat and this generated heat will be absorbing the fresh air coming through the mixing section. Then the heated air blows out by using blower fan and send to the central hot air duct lines for withering and dryer section. Combustion gases go to the slack by using ID fan.

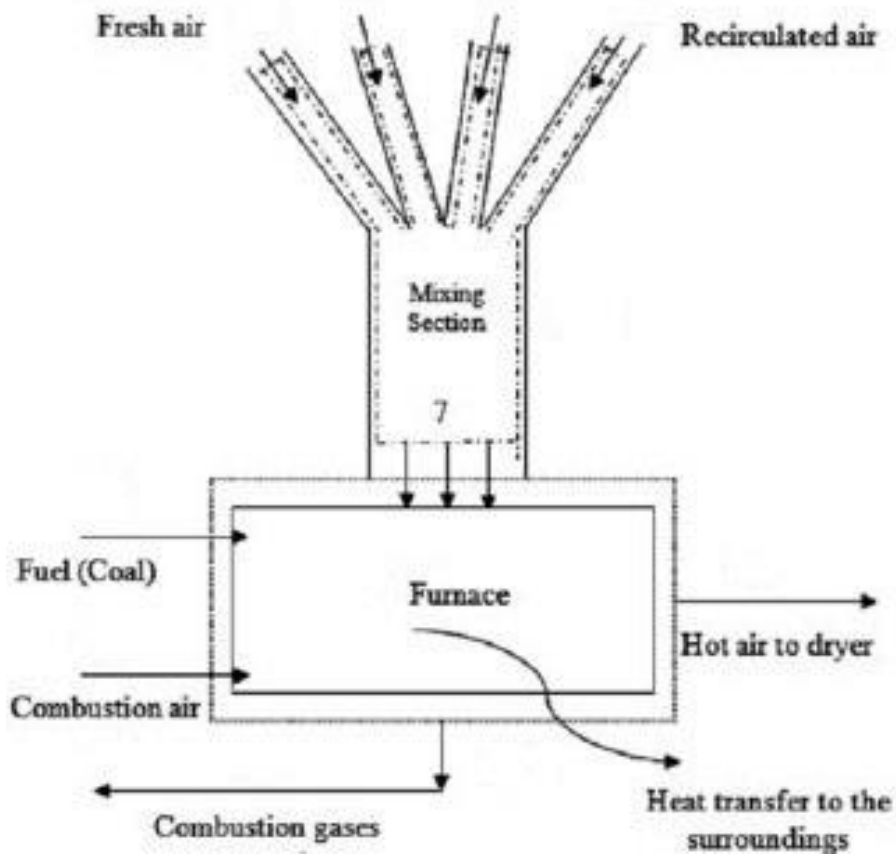


Figure 8 Furnace at a tea factory

Source: httpswww.researchgate.netprofileDr_Abhijit_Sinha_drying-furnace-analysis_Q320.jpg

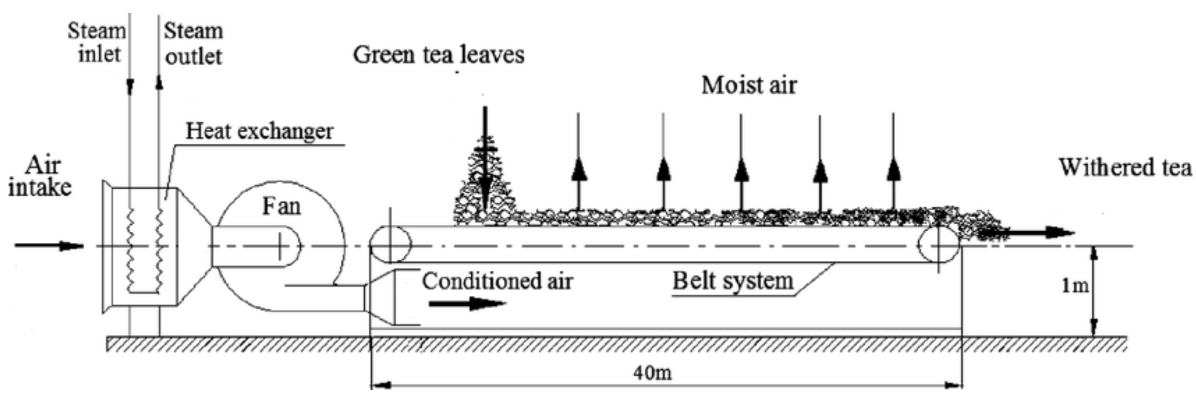


Figure 9 Schematic layout of green tea withering process using dry air and continuous belt system

Source: httpswww.researchgate.netprofil dry-air-and-continuous-belt-system.png

2.5 Calculate wet-bulb temperature from relative humidity and air temperature

According to Stull, R. (2011). Some applications require value of wet bulb temprature for electronic sensor measurements or numerical forecast. Presently wet bulb temprature is used by tea industry, industrial hygienists, athletes and military etc.

Below mentioned an empirical inverse solution found by using Temprature (**T**) and relative humidity (**RH%**)

$$\mathbf{T_W = T\ [0{:}151977(RH\% + 8{:}313\ 659)^{1/2}\ ] + (T + RH\%) - (RH\% - 1{:}676331) + (0{:}003\ 918\ 38(RH\%)^{3/2}\ )\ x\ (0{:}023101\ x\ RH\%) - 4{:}686035.}$$

Example: T= 20 C^0, RH%= 50%

$$T_W = \mathbf{20}\ [0{:}151977(\mathbf{50} + 8{:}313\ 659)^{1/2}\ ] + (\mathbf{20} + \mathbf{50}) - (\mathbf{50} - 1{:}676331) + (0{:}003\ 918\ 38(\mathbf{50})^{3/2}\ )\ x\ (0{:}023101\ x\ \mathbf{50}) - 4{:}686035\mathbf{.\ = 13.7\ C^0}$$

This equation can be used for electronic sensor reading process in microcontrollers.

3 Methodology

This chapter describe about three models which can be used to achieve the objectives the project. Among these three models, the optimum design is selected and justified the reason for the selection of that design.

3.1 Conceptual design 1

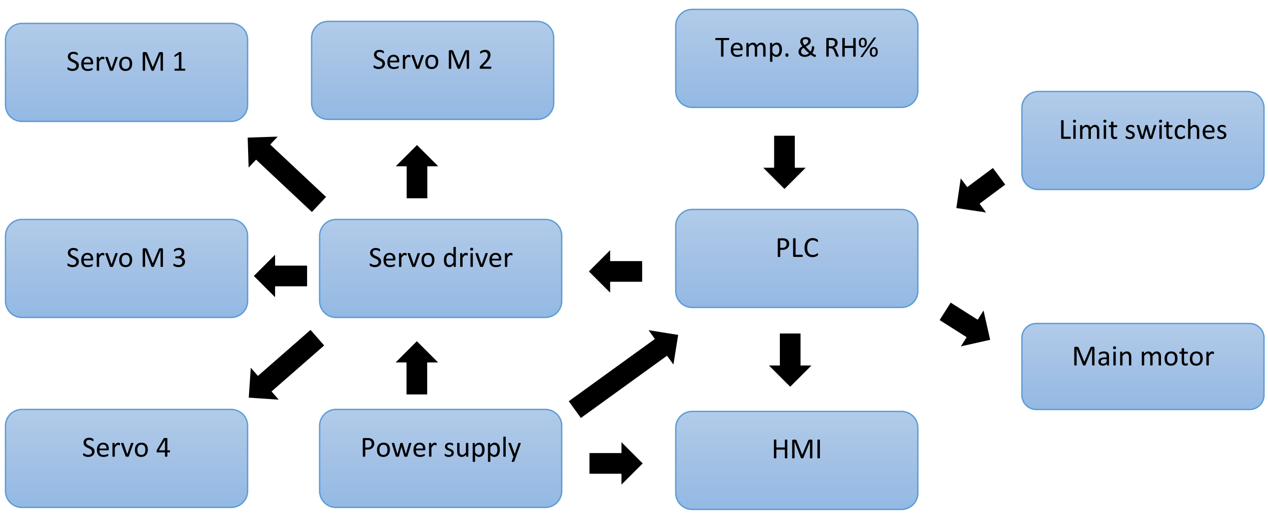


Figure 10 Conceptual design 1 control diagram

In this configuration the temprature and humidity sensor input the sensor signals to the PLC, then by using HMI device we can see the wet bulb and dry bulb reading. In normal withering process, we need to maintain difference value near to 10 between dry bulb and wet bulb. Normally withering cycle takes 12 hours to complete. By increasing hot air content, we can reduce the cycle time to 9 hours. When reducing hot air and increasing fresh air, the withering cycle time can be extending. Tea leaves mixing process starts after 3 hours when withering process started, and again do this mixing process after 6-7 hours. We can set the withering cycle time by using HMI device.

Then PLC read the difference between wet bulb and dry bulb values. The PLC command to the servo driver to operate servo motor 1 and 2 to open hot air/ fresh air intake to maintain the above mentioned difference. After the maintain the value according to the time, Servo motor 3,4 used to mix the tea leaves in the trough. Limit switches are used to limit the movement of the mixing mechanism carrier. In this method main fan motor is run at full speed an air flows control by using dampers.

3.2 Conceptual design 2

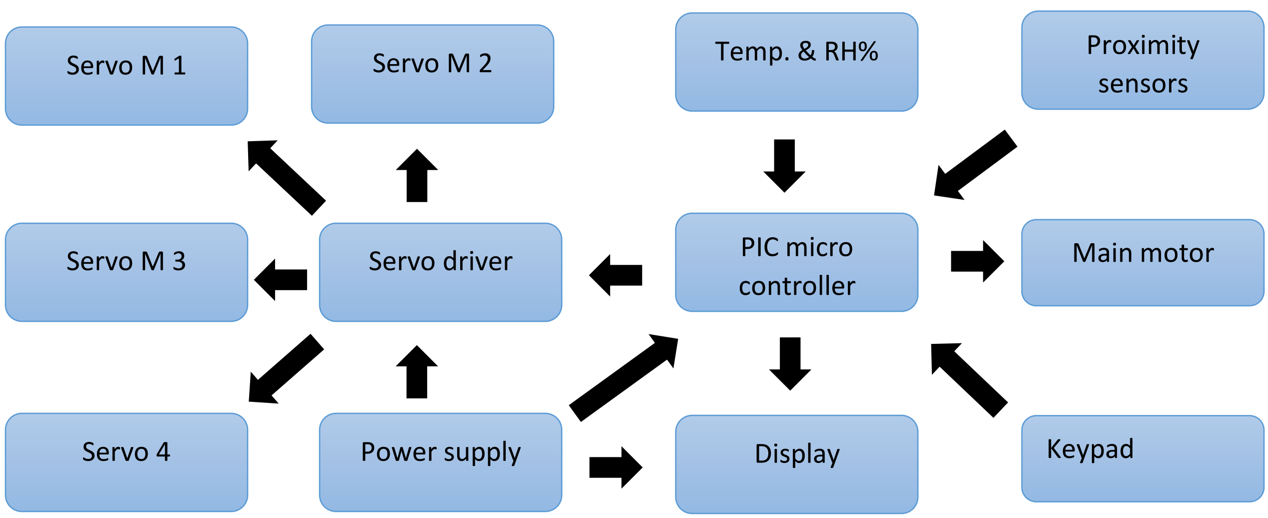


Figure 11 Conceptual design 2 control diagram

In this configuration the temprature and humidity sensor input the sensor signals to the PIC microcontroller, then by using display device we can see the wet bulb and dry bulb reading. We can set the withering cycle time by using Keypad device. Then PIC microcontroller read the difference between wet bulb and dry bulb values. The PIC command to the servo driver to operate servo motor 1 and 2 to open hot air/ fresh air intake to maintain the above mentioned difference. After the maintain the value according to the time, Servo motor 3,4 used to mix the tea leaves in the trough. Proximity sensors are used to limit the movement of the mixing mechanism carrier. In this method main fan motor is run at full speed an air flows control by using dampers.

3.3 Conceptual design 3

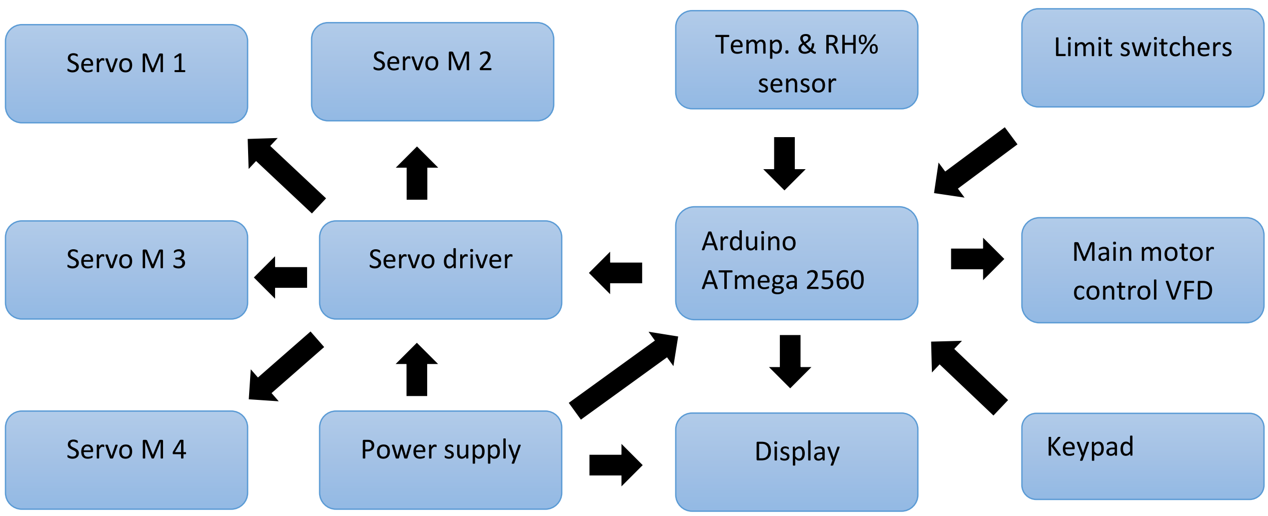


Figure 12 Conceptual design 3 control diagram

In this configuration the temprature and humidity sensor input the sensor signals to the AT mega 2560 micro controller, then by using display device we can see the wet bulb and dry bulb reading. We can set the withering cycle time by using keypad device. Then mega 2560 micro controller read the difference between wet bulb and dry bulb values. The mega 2560 micro controller command to the servo driver to operate servo motor 1 and 2 to open hot air/ fresh air intake to maintain the above mentioned difference. After the maintain the value according to the time, Servo motor 3,4 used to mix the tea leaves and carry the mechanism on the trough. Limit switches are used to limit the movement of the mixing mechanism carrier. In this method main fan motor is runs through VFD and fresh air intake can be control by varying the speed of the motor. Hot air intake control by using dampers.

3.4 Selecting the optimum design and justification

The optimum design will be selected based on the objectives which is mentioned in the chapter 1. The optimum design is selecting on which design can achieve the mentioned objectives more efficient way with keeping its reliability.
The selected design from the above three designs is design 3. The justifications which are made to select design 3 as the optimum design, are described below.

Mainly use Arduino AT mega 2560 micro controller as the central unit. It is low cost and easy to interface with other devices. It supports to lot of devices and user friendly when programming.

Other thing is, there are VFD used to control main fan. Normally withering cycle consumes 78 kWh units as electricity to complete one cycle. Therefore, energy saving can be implement by using VFD when motor does not need to run in full speed.

Servo motors are used to control dampers and proposed leaves mixing mechanism. All servo motors are control by using central servo driver for cost reduction.

Mechanical limit switches are used to sense the movement of the leaves mixing mechanism due to low cost, simple operation and easy maintain.

Design 1 and 2 is most energy consuming design due to DOL start motor.

Design 1 is not cost effective because PLC and HMI devices are expensive.

Therefore, design 3 is the optimum design to implement.

6 Conclusion

7 Further Development

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9 Appendix

9.1 Time frame

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Activity																														
Finalized Project topic	■																													
Prepare/ Submit brief		■	■																											
Literature Survey				■	■	■	■																							
Define 3 Designs								■	■	■																				
Interim Report Writing											■	■	■																	
Interim Report Submission														■																
Optimum Design Planning and Implementation															■	■	■													
Initial Teating and Feasibility																		■	■	■	■									
Metirial Selections																						■	■							
Coding																								■	■					
Build Prototype																									■	■				
Write Final Report																										■	■	■	■	
Check Final Report																													■	■
Submit Final report																														■