Global Scientific JOURNALS

GSJ: Volume 7, Issue 1, January 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

DESIGN AND SIMULATION OF AN AUTOMATED POULTRY FEED MIXING MACHINE USING PROCESS CONTROLLER

Isife Joseph K.[1], Ukwani Chijioke[2], Sani Godwin[3].

1Masters degree student in Machine Design and Mechatronics Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria. E-mail: joeyisife@yahoo.com.
2Animal Health and Production Department, Enugu state Polytechnic Iwollo, Nigeria.
3Post Graduate student, Department of Mechatronics and System Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria.

ABSTRACT

Mixing plays a crucial role in the whole production processes of many industries (ranging from feed mills for poultry birds and other animals, to cement, pharmaceutical, dairy, food etc) in meeting their demand expectations. The aim of this research is to develop in a continuous blending system an automated poultry feed mixing process using process controllers. The methods followed the controlled process includes; feeding of the individual ingredient hoppers via bucket elevator with their respective ingredients, determining the time of discharge and the rate of discharge that will make for 25 kilogram mass feed per mix, the adoption of virtual multipoint Near Infrared spectroscopy (NIRS) with it accompanying sensor probes that monitors the mixing real time analyzing along as the mixing progresses the various ingredient percentage nutrients classes (i.e. fat, fibre, crude protein etc.) and the controller collects the analyzed values and calculate (as the sensor keep updating the values) for the blend uniformity (i.e. the CV) of the mixing process until the threshold value of the coefficient of variation (CV) or the relative standard deviation (RSD) is reached (the final CV set point value, i.e. $F\_CV \leq 4.00\%$) which will terminate Multipoint NIRS analysis and activate for output of processed feed. STEP7 in-built PID controller block (FB41 CONT_C) is used for achieving this task. The whole system were PLC (Programmable Logic Controller) controlled and programmed in Siemens SIMANTICS step7 300 software with WINCC HMI operator-panel that enables parameter adjustments and results monitoring in real-time. The performance of the mixing process was also simulated using MATLAB/Simulink, the responses of the mixer speed were determined having 0.175seconds, 0.33 and 0.3902seconds rise time, overshoot and settling time respectively . And finally the outlooks of the work were modeled with AUTOCAD.

Keywords: Mixing, Automated, Discharge rate, Hoppers. Process, Feeding, Ingredient, Spectroscopy, Blend uniformity, Coefficient of Variation.

CHAPTER ONE

1. INTRODUCTION

There are six main nutrients in animal feed, these comprises of water, protein, carbohydrate, fats, mineral elements and vitamins. These six nutrients are vital to animal survival. Variations therefore exists in nutrient requirements for different farm animals, but the level of dietary energy and associated nutrient should be high enough to allow expression of animal potentials under certain environmental circumstances within the economic limitations [1]. These have to be combined in such a proportion that the feed produced will contain the requirements for the different classes and ages of poultry without any waste and at the cheapest cost. Machineries are required for the purpose of mixing of ingredients for animal feed. Traditionally, small scale poultry breeder uses manual or hand to mix the crushed feed. In the medium scale production, feed mixing can be done either manually or mechanically. The manual method of mixing feed entails the use of shovel to intersperse the feed's constituents into one another on open concrete floors [2]. The manual method of mixing feed ingredients is generally characterized by low output, less efficient, labor intensive and may prove unsafe, hence, hazardous to the health of the intended animals, birds or fishes for which the feed is prepared. The mechanical method of mixing is achieved by using mechanical mixers developed over the years to alleviate the shortcomings associated with the manual method. A satisfactory mixing process produces a uniform feed in a minimum time with a minimum cost of overhead, power, and labour. Some variation between samples should be expected, but an ideal mixture would be one with minimal variation in composition [3].

A wide variety of mixers are available for use in mixing components, the selection of which depends mainly on the phase or phases the components exists such as solid, liquid or gaseous phases. Some commonly used solid mixers as discussed by [4] includes: Tumbler mixers**,** Horizontal trough mixers, Vertical screw mixers etc. These are quite quick and efficient particularly in mixing small quantities of additives into large masses of materials. [5] observed that regardless of the type of mixer, the ultimate aim of using a mixing device is to achieve a uniform distribution of the components by means of flow, which is generated by mechanical means. Nevertheless, the control of these processes by electromechanical means (guided by the micro-controllers) gives rise to more efficient and faster feed mix and through put of the feed mill at minimal cost and labour.

The feed production processes proposed in the context of this research for automation include (as shown in figure1 [6]);

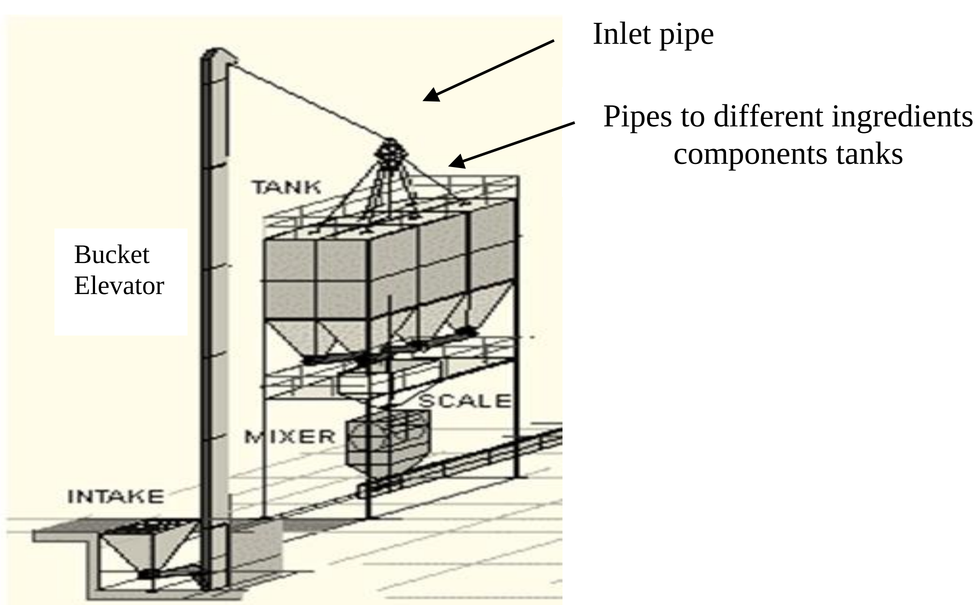

Figure 1: Feed Production Process

i. Feeding in the ingredients to their various silos (i.e. hoppers/tanks) via bucket elevator.

ii. Discharging of the measured (in kg of mass) ingredients into the collection silo and subsequently into the mixing chamber.

iii. Efficient mixing of the measured ingredients into feed at a minimum time interval and output of the finished feed.

At every stage of the production process various components parts or instruments or equipment will be put to use, these include: bucket elevator, hoppers, control valves, level sensors, mixing chamber etc.

CHAPTER TWO

2. LITERATURE REVIEW

Research on feed mixing machine has been carried out by many researchers in the areas of mechanical systems, process control systems as well as full automation and control systems. The work on the area of mechanical systems seems to be more extensively done because of the availability of their materials and analysis for modifications and reference studies. However reviewing of the literatures in the various processes of mixing and in automations with programmable controller were categorized as follows; Manual, Mechanical, Process controlled, Near Infrared spectrometry (NIR) controlled and Automations with Programmable Controllers (PLC).

2.1 Manual feed mixing process.

Most of the poultry farmers still employ crude techniques for processing their poultry feeds. For example, some still use hand and basins to mix already crushed poultry, some also use shovel to intersperse the feed's constituents into one another on open concrete floors (as represented in figure 2 below [7]), all of which are labour intensive and hazardous.

Figure 2: Mixing feed with shovel on open floor (Volosciuc, 2015).

While other categories of local farmers, according to the work of [8], uses drum mixer to mix their poultry feed. This aspect of manual mixing (as represented in figure 3 [8]) is much healthier for the birds and better in efficiency and output, than the use of shovel or hands and basin. Nevertheless, their outputs and efficiencies are not to be reckoned with in production of poultry feed in a proper commercial poultry farm. Besides, the drum mixer encourages segregation of feed particles.

Figure 3: Mixing feed with drum mixer .

2.2 Mechanical Mixing Process.

Mechanical mixing is one of the most important unit operations in livestock feed manufacturing. The purposes of which, after size reduction of different feed ingredients, is to aid palatability of feed, minimizes waste during animal feeding, facilitates easy packaging, and enhances post-production storage and preservation. The mechanical method of mixing as described earlier is achieved by using mechanical mixers or machineries for the purpose of mixing feed.

The work by [9] developed and tested an animal feed mixing machine which was tested using a feed components divided into three equal measures of 50 kg for ground corn, 0.265 kg for cassava flour and 2.65 kg for shelled corn replicated thrice (according to the standard test procedure developed by [10]) at four mixing durations of 5, 10, 15 and 20 min. A mixing performance of up to 95.31% was attained in 20 minutes of operation and evacuation of mixed materials from the mixer was observed to be almost complete and was accomplished in 9 minutes with the mixer at full capacity (60 kg of feed ingredients or two-third of the mixing chamber filled) while the average value of coefficient of variation for the three replicates was 4.69%. The performance test at the end of each test run, ten samples of 500 g were drawn from the mixed components and the coefficient of variation among blended samples and mixing levels, were computed using the expressions below [11]:

$$CV = \frac{S}{x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\%D_M = (1 - CV) \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$S = \sqrt{\frac{\sum(X-x)^2}{(n-1)}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where: CV = Coefficient of variability; D_M = Percent mixing level; S = Standard deviation; X = Weight of shelled corn in the samples; x = Mean value of shelled corn in the samples; n = Number of samples

2.3. Process controlled mixing

Process control refers to the methods used to maintain the output of process variables- such as temperature, pressure, flow, or level- within a desired range. It is part of a closed loop system in which a process variable is measured, compared to a set point, and action is taken to correct any deviation from the set point. Closed loop control is feedback-dependent; receiving feedback from sensors monitoring the process variable and providing feedback to the final control element that corrects any deviation from the set point. By carefully monitoring and correcting process variables, controllers greatly assist in reducing variability, increasing efficiency, and ensuring safety. Any equipment that requires constant monitoring of a process variable can benefit from a process controller [12].

2.4 Near infrared (NIR) spectrometry controlled

Two kinds of analytical techniques are seen in powder blending research. The first set of monitoring technique is used for monitoring powder flow behavior in blenders include techniques like positron emission and particle tracking and magnetic resonance imaging. These complicated monitoring techniques usually are unfavorable to be used in control systems for industrial application but are useful research tools for understanding the fundamental behavior of powders in blenders. Another set of analytical techniques are those that can be implemented as a process analytical tool in an industrial manufacturing line process. These include technologies like light induced fluorescence (LIF), NIR spectrometry and optical reflectance [13]. NIR is a useful analytical tool for both qualitative and quantitative analyses, i.e., it has the ability not only to identify a certain compound, by comparing it with those existent in the “spectral library” (qualitative method), but also to determine the amount of compound present in a sample (quantitative method).

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

Multi Check NIR

The multi check NIR is a near-infrared spectrometer which is used to analyze composition of samples using infrared absorbency characteristics of the sample spectra. The NIR multi-check is a compact unit with display at the front end. The instrument control and calculation is performed by the integrated PC and menu driven OMEGA software, running under windows. An integrated dialog display serves as user interface with interactive touch screen.

It is suitable for compositional analysis of a wide variety of products like grain, oilseeds and meal. An unlimited number of chemicals and physical parameters and properties of products, such as protein, moisture and fat can be analyzed simultaneously.

Figure 4: Multi check NIR spectrometer [14].

Figure 5: NIRS™ DS2500 F integrated with a PC .

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

Principle of operation:

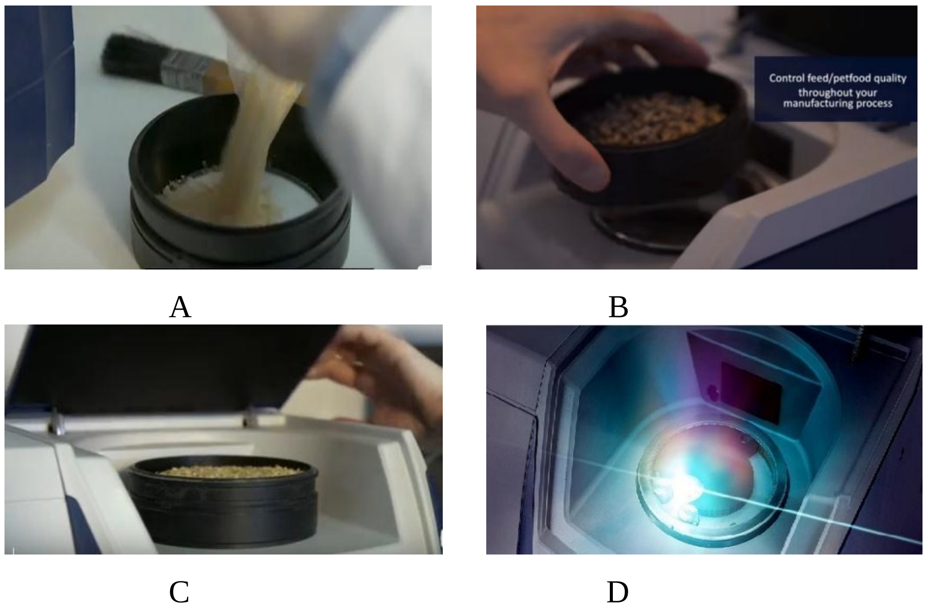

Figure 6: Sample mixed feed in sample theif and Near Infrared Spectrometer[15]

The pouring of the mixed feed sample into the sample thief or cup (figure 6 A) and then positioning well the cup onto the optical lens of the NIRS^{TM} DS2500 F for analysis (figure 6 B).The cup is covered (figure 6 C) and light of full wavelength range of 850 to 2500nm (figure 6 D) is passed across the sample for analysis [15].

The light passes through the cup window, strikes the sample surface, interacts with sample molecules and partly absorbed and partly reflected. The reflected light is collected in an integrating sphere beneath the sample window and finally measured by a detector located in the sphere [14]. The detector measures the spectral absorbance or reflectance of a sample. Identification involves comparing this unknown spectrum to a reference spectrum, the differences between the unknown and the reference spectrum are then evaluated according to given criteria and a decision is made on the identity of the unknown [16]. The amount of light absorbed by the sample at different wavelengths is directly related to the concentration of chemical functional groups, such as C-H, O-H and N-H. As these concentrations are in turn related to concentrations of the properties of interest, for example fat, protein, moisture etc, property values can be determined.

Mode of analysis:

The technique of interest for analysis of raw materials, intermediates and products is diffuse reflectance mode of analysis.

In diffuse reflectance the monochromatic NIR radiation leaving the monochromator hits the sample filled into the sample cup. After interaction with the sample the reflected light leaves the sample cup in all directions. A large portion of this light is collected under a wide angle in an integrating sphere behind the sample window, finally generating a corresponding photometric signal. From the ratio of sample reading/reference reading the absorbency values is calculated, which provide the basis for calculating values of the sample (crude protein, ash, fat etc.) [14].

On-line monitoring systems using NIR is an alternative to the use of sample thieves. NIR is quite attractive for this type of application because it is a nondestructive method that usually does not require sample preparation, is noninvasive, and offers the possibility of remote sampling with fiber optic probes (as represented in figure 7 [19]) with light of full wave length of the range 1100 – 1650 [15]. The principal means of judging blend uniformity with on-line measurements is on the basis of the standard deviation of the spectra obtained, even though other chemo metric methods have been explored. The mixture is termed homogeneous when the standard deviation of the NIR spectrum reaches a minimum value

[17,18].

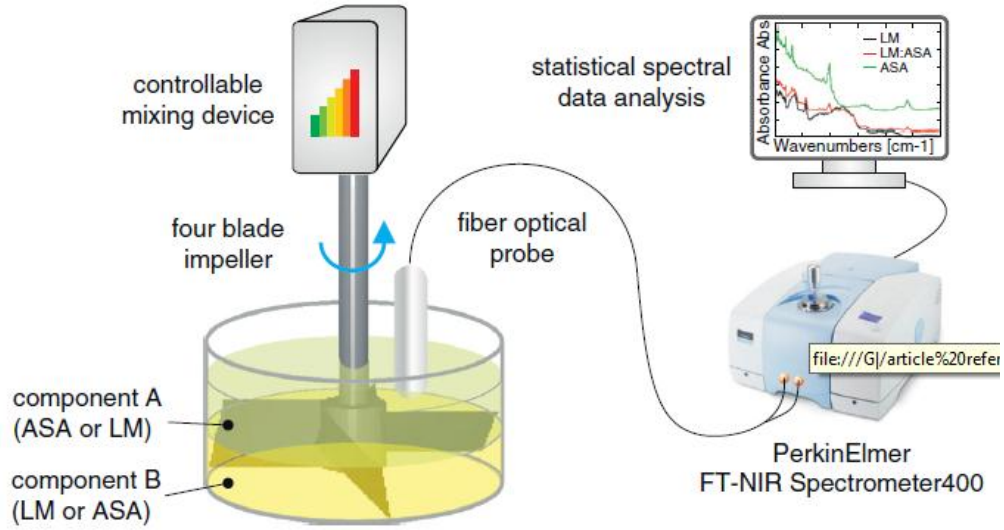

Figure 7: Schematic of the experimental setup with a four-bladed mixer connected to a controllable mixing device. The fiber optical reflectance probe of the FT-NIR spectrometer was in direct contact with the powder during the mixing process[44] .

2.7 Automations with Programmable Controllers (PLC)

A Programmable Controller as a specialized computer has all the basic component parts that any other computer has. A typical programmable controller block diagram is shown in figure 8 [19]. The Central Processing Unit (CPU) is the control portion of the PLC. It interprets the program commands retrieved from memory and acts on these commands. Memory in the system is generally of two types; ROM and RAM. The ROM memory contains the program information that allows the CPU to interpret and act on the Ladder logic program stored in the RAM memory. RAM memory is generally kept alive with an on-board battery so that ladder programming is not lost when the system power is removed [19].

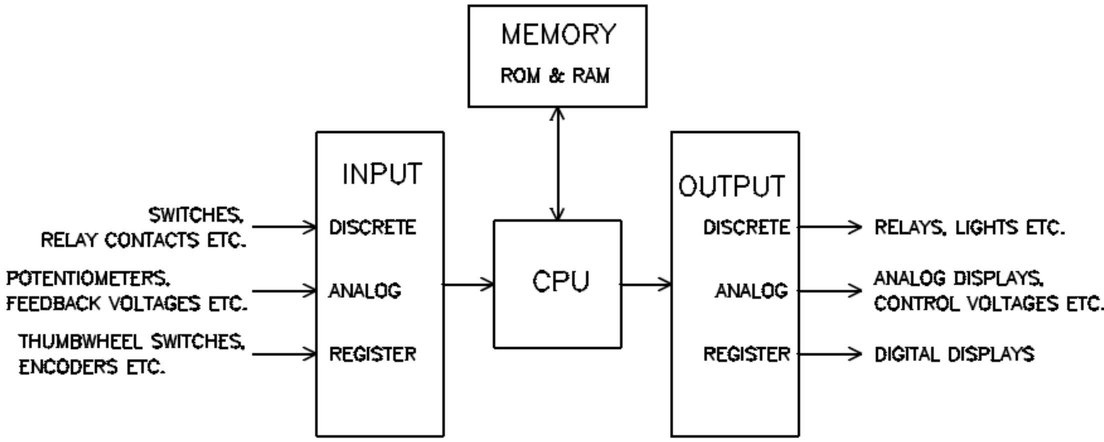

Figure 8: Programmable Controller Block Diagram

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1. Introduction

In this chapter, various methods adopted in the course of the analysis of this research work were guided by the materials/equipments operation principles which were considered below. These methods include;

1. The startup process, with its accompany logic and flow chart which the controller used to regulate the input of the raw materials (ingredients) from bucket elevator into the individual hoppers.
2. The design analysis of the system, like; the bucket elevator, the discharge rate of the hoppers (silos) and mass flow rates of the crushed solid raw material, the mixing chamber.
3. The design of the transfer function of the plant (i.e. the electric motor performance on the mixing process), the PID controller and the plant design with its feedback, HODFC and the plant design and then the simulation with Matlab and Simulink of the performance responses of the two controller to make comparison of the better controller for the plant.
4. Finally, the programming and simulation of the entire processes (i.e. from B.E ingredients discharge into the hoppers to the feed output from the mixing chamber) and performance check at various discharge points using SIMANTICS STEP7 300 with the WinCC HMI as the running display implementation of the processes, as guided by the various input and output flows in the process flow diagram (PFD).

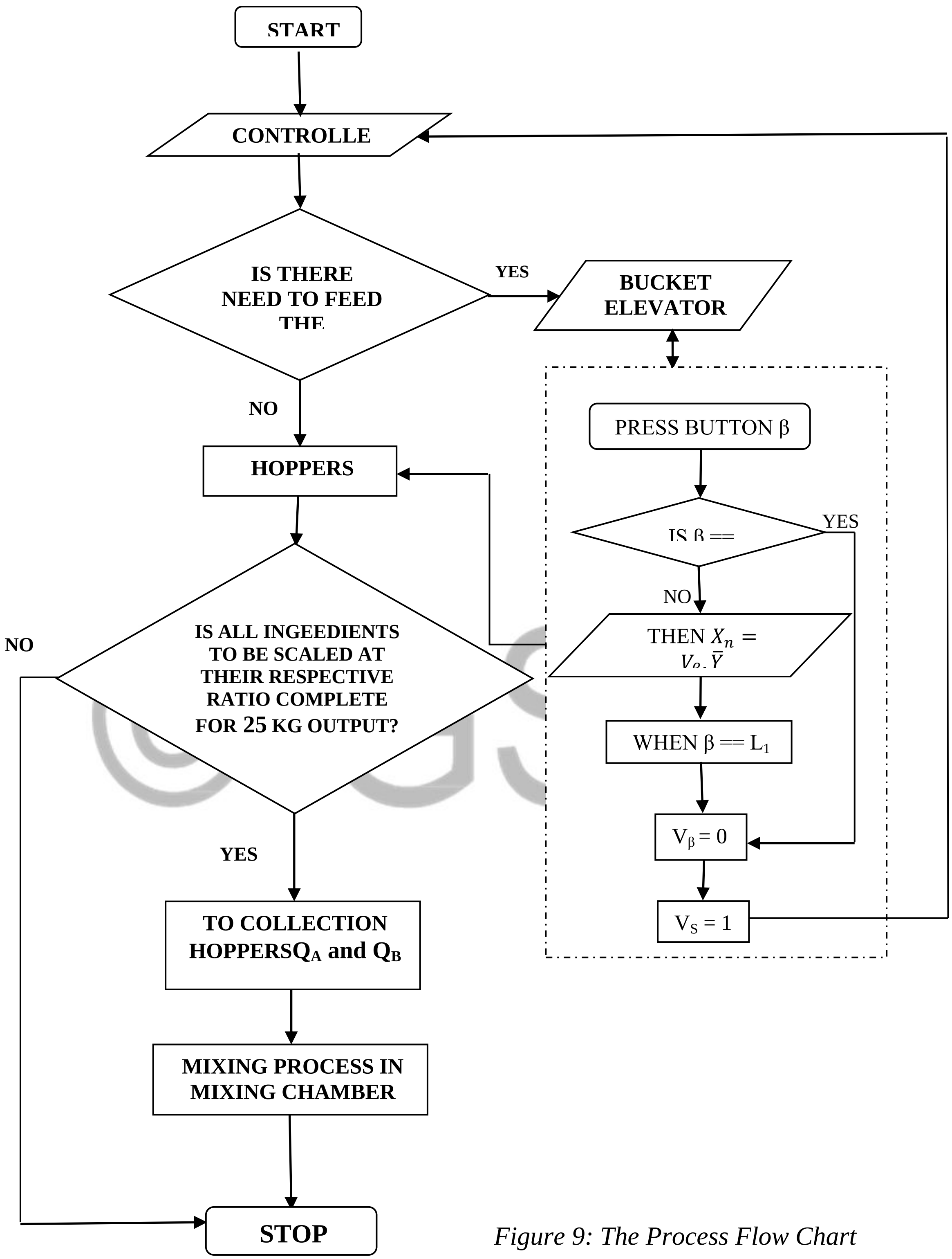

Figure 9: The Process Flow Chart

3.2 The Startup Process

The schematic flow pattern of the System from ingredient inlet, the Bucket Elevator, feed input through the valves down to the Hoppers.

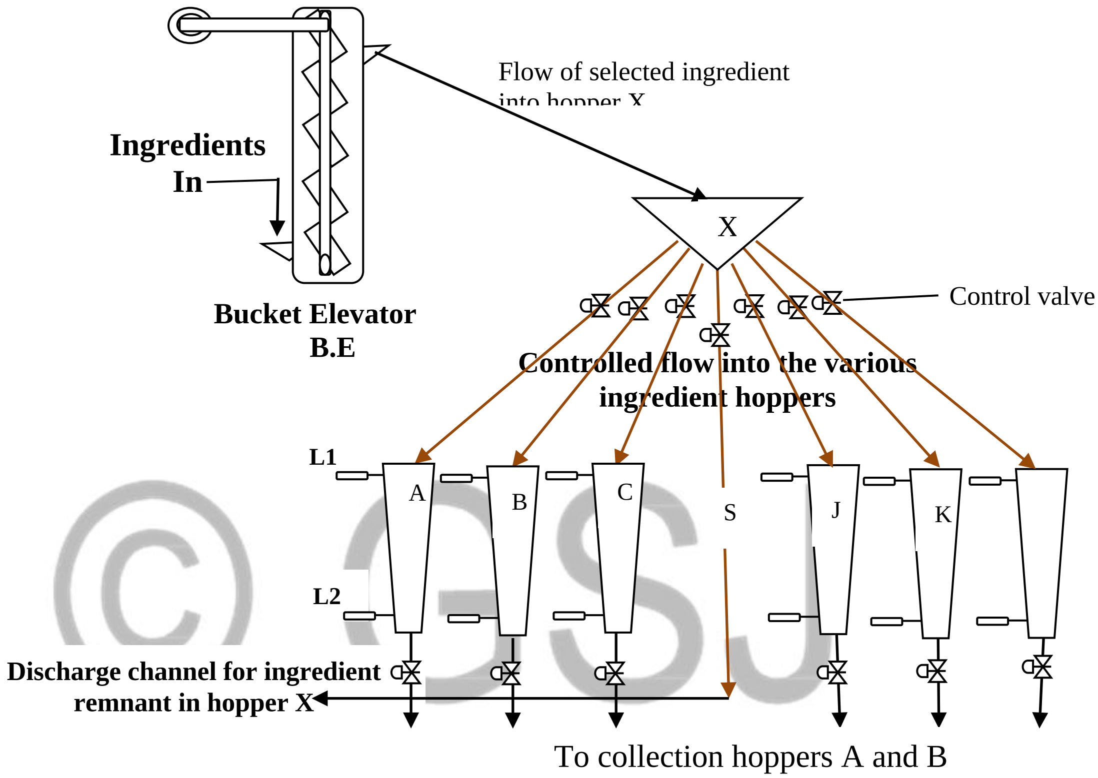

Figure 10: Schematic Flow Pattern from B.E to the Individual Hoppers

The detailed description of the logics for the operation of the bucket elevator is in Appendix.

Where, **β** represents A//B//C//D//E//F//G//H/ to N [20]; $\mathbf{L_1}$ and $\mathbf{L_2}$ represent Level Sensor 1and Level Sensor 2 respectively.

Feed ration formulation involves combining different ingredients in proportions necessary to provide the animal with proper amounts of nutrients needed at a particular growth stage. There are classes of food nutrients essentially considered in feed production for the feed formulation, the table 1 below detailed those essential nutrients with its' percentage content in each of the ingredients considered in this work. The table is also an excel chart showing the result of my evaluated feed formulation from 1tonne to 25kg processed feed output with 35% value of the mass as tolerance, according to the feed formulation chart of [14].

Table 1: Ingredients with their Respective Percentage Nutrients Classes

			Nutrient levels of ingredients							
	Materials	Weight (Kg)	crude protein %	ether extract %	crude fiber %	lysine %	methionine %	calcium %	phosphorus %
1	Maize	11.5	9	4	2	0.25	0.18	0.01	0.09
2	Guinea corn	8.75	11	3	2	0.35	0.1	0.04	0.32
3	Maize offal	1.25	11	2.8	12	0.25	0.18	0.01	0.09
4	Rice bran	1.25	11.8	12.5	12.5	0.5	0.24	0.04	0.46
5	Wheat middlings	2.5	17	3.5	8.5	0.9	0.25	0.1	0.3
6	Groundnut cake	2.5	46	6	5	1.6	0.48	0.2	0.2
7	Soya bean meal	2.5	44	3.5	6.5	2.8	0.59	0.2	0.6
8	Fish meal	0.75	65	4.5	1	4.5	1.8	6.1	3
9	Oyster shell	2.375						35	
10	Salt	0.1							
11	DCP	0.375						18	18
12	Methonine	0.025							
13	Lysine	0.0375							
14	Toxin binder	0.05							
	Total	33.7							

(Source: [14]).

The ladder programs as executed in STEP7 of figures 11 and 12 below, described one of the logic (e.g. $X_1 = V_A.\overline{Y_1}$ in appendix 5) of startup process for one of the hoppers. The program controls the ingredient level in the hopper by using the high and low level sensors to signal the controller when to halt every other processes for the push button to be pressed to open the valve of the specific hopper for its filling and when the hopper is filled to close the valve.

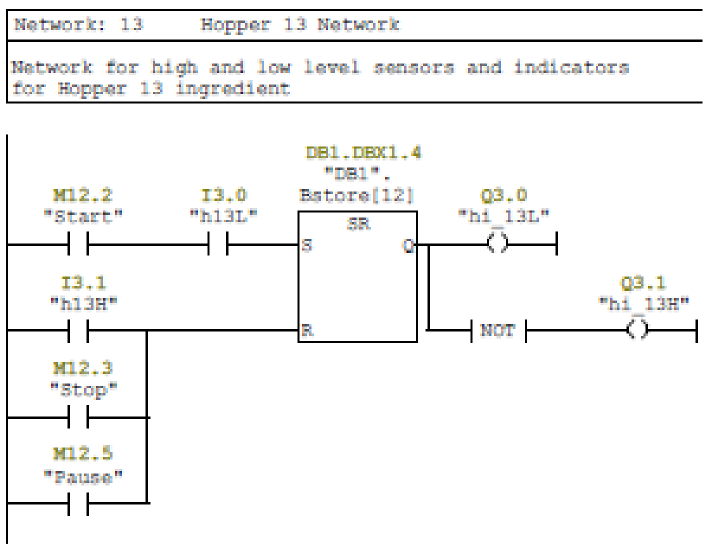

Figure 11: Program for High and Low level sensor indicator

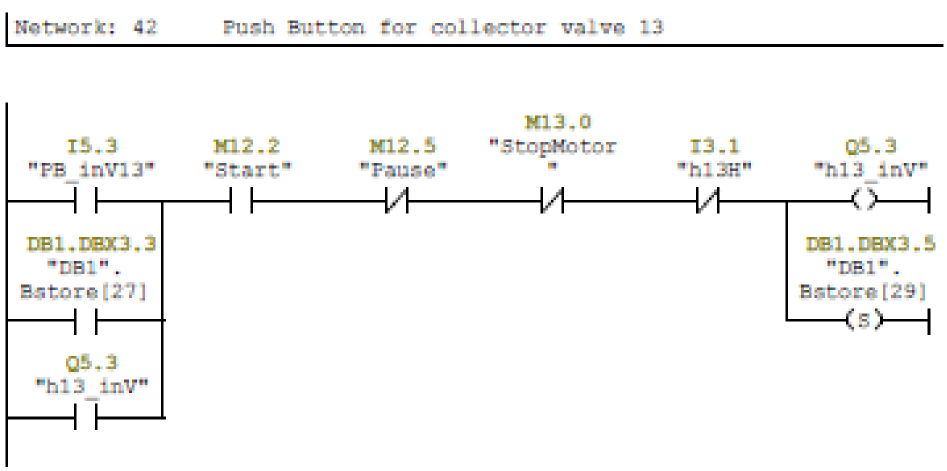

Figure 12: Program to active the opening of hopper 13 valve by press the push button

3.3 The Discharge Rate of the Hoppers (Silos).

Coarse Particles [21]

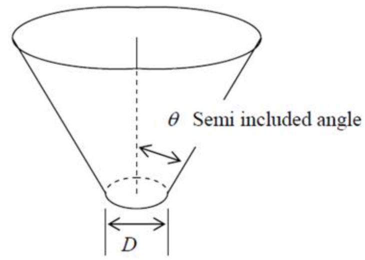

Figure 13: Conical hopper with outlet size, D, and semi included angle θ.

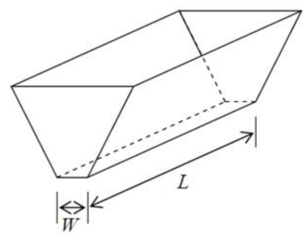

Figure 14: Symmetrical slot outlet hopper of opening size W x L .

For coarse particles, that is, particles > 500 microns in diameter. This analysis considered only the mass flow equation.

The Modeled Equation for the Mass Flow type of Hopper, as explained in the introduction is as follows;

The Johanson equation [43], derived from fundamental principles is,

$$\dot{m} = \rho^0 A \sqrt{\frac{B_g}{2(1+m)\tan(\theta)}}$$

…..……..………4

Where, θ = semi included angle of the hopper,

$\dot{m}$ = discharge rate (kg/sec),

ρ^0 = bulk density (kg/m^3),

g = gravity acceleration (9.807 m/s^2).

g_c = gravity constant conversion factor to convert the result from units of mass to unit of force.

Depending on whether a conical or symmetric slot opening hopper the remaining parameters in the equation are given in Table in the appendix 1.

To determine the time t (in seconds) it will take each of the ingredients to discharge their required Mass (in kg), the modeled equation (since, $\dot{m} = \frac{dM}{dt}$) becomes;

$$M = \rho^0 A \sqrt{\frac{B_g}{2(1+m)\tan(\theta)}} \int dt \quad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

$$t = \frac{4M}{\rho^o \pi D^2 (Dg(2(1+m)\tan\theta)^{-1})^{\frac{1}{2}}} \quad \ldots\ldots\ldots\ldots 6$$

Table 2: The Result Values of the Individual Ingredients Hopper Parameters.

	Ingredients	Mass (Kg)	Outlet diameter of Hopper, D (m)	Bulk density, ρ^o (Kg/m^3)	Particles diameter, D (microns)	Semi-included angle, θ (^{0}).	Time of discharge, t (secs.)
1.	Maize	11.25	0.637	640	708	41.15	7.34

2	Guinea corn	8.75	0.612	630	680	23.46	4.15
3	Maize offal	1.25	0.819	192.2	710	33.29	1.141
4	Rice bran	1.25	0.887	417	520	24.30	0.6174
5	Wheat middlings	2.5	0.819	350	590	33.29	1.6915
6	Groundnut cake	2.5	0.639	460	504	35.97	1.7567
7	Soya bean meal	2.5	0.637	640	570	41.15	1.6363
8	Fish meal	0.75	0.819	609	350	33.29	0.0198
9	Oyster shell	2.375	0.032	860	200	14.10	5.140
10	Salt	0.1	0.279	1120	184	12.72	0.2266
11	DCP	0.375	0.032	640	127	14.10	1.8729
12	Methonine	0.025	0.020	550	127	31.04	0.4507
13	Lysine	0.0375	0.020	600	127	31.04	0.2371
14	Toxin binder	0.05	0.020	630	127	31.04	0.6718

(Sources: Mass of Ingredients [14], Outlet diameter of hoppers and Semi-included angles [22], Bulk density [23-25], Particle diameters [26-34]).

Other parameters include, the standard values of these atmospheric properties [35];

Kinematics Viscosity (υ_{air}) = 1.460 $\times 10^{-5}$ m^2/s

Density (ρ_{air}) = 1.225 Kg/m^3

Viscosity (μ_{air}) = 1.789 $\times 10^{-5}$ Kg/m/s

Fine Particles

Fine particles (d_p (particle diameter) < 500 microns

Carleton gives an expression for predicting the velocity of the solids [36] as;

$$\frac{4V_0^2 \sin\theta}{B} + 15\frac{\rho^{1/3}\mu^{2/3}V_0^{4/3}}{\rho_p d_p^{\frac{5}{3}}} = g \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 7$$

To solve out $V_0$from the equation, equation (7) was evaluated into these 3rd degree polynomial equations:

$$4\rho_p d_p^{\frac{5}{3}} V_0^{\ 3} \sin\theta + 15Be^{\frac{1}{3}}\mu^{\frac{2}{3}} V_0^{\ 2} - gB\rho_p d_p^{\frac{5}{3}} = 0 \quad \dots\dots\dots 8$$

After substituting in the standard atmosphere characteristics values the becomes;

$$4\rho_p d_p^{\frac{5}{3}} V_0^{\ 3} \sin\theta + 0.0109785BV_0^{\ 2} - 9.81B\rho_p d_p^{\frac{5}{3}} = 0 \ \dots\dots\dots 9$$

$$\dot{m} = \rho^0 A V_0 \qquad \dots\dots\dots\dots\dots 10$$

Therefore, to determining the time t in seconds (having $\dot{m} = \frac{dM}{dt}$):

$$M = \rho^0 A V_0 \int dt \qquad \dots\dots\dots\dots\dots\dots\dots\dots 11$$

$$t = \frac{4M}{\rho^0 \pi D^2 V_0} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..12$$

Where, V_0 = average velocity of solids discharging (m/s)

A,B = given in Table above

μ,ρ = viscosity and air density

ρ_p = particle density

ρ^0 = bulk density of the powder bed.

3.4. PID Controller

Open loop control system of my plant model

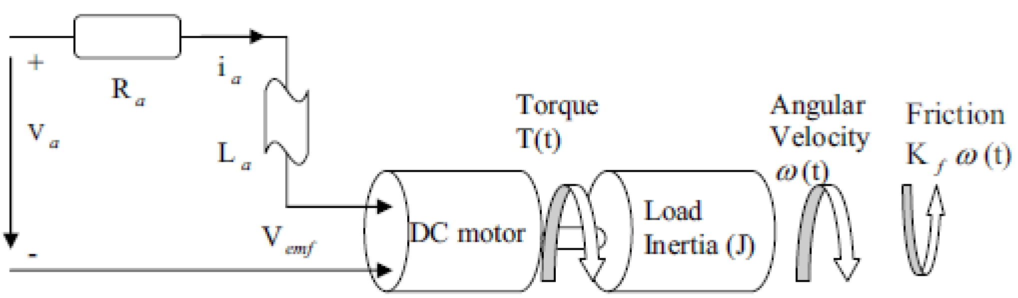

Figure 15: General model of DC motor [37]

The mathematical model of the system is;

$$V_a = L_a \frac{di_a(t)}{dt} + R_a i_a(t) + V_e mf(t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.13$$

$$T_m = J \frac{d\omega_m(t)}{dt} + B\omega_m(t) + T(t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots14$$

But $V_e mf(t) = K_r \omega(t)$, $T_m = K_m(t)$, $T(t) = F \times r$, $M_{shaft} + M_{feed} = M_{eq}$,

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

and $F = M_{eq} \times \omega r(t)$. Hence equation (14) becomes;

$$K_m i(t) = J\frac{d\omega_m(t)}{dt} + B\omega_m(t) + r^2 M_{eq}\omega(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots 15$$

Again, $K_r\omega(t) = K_m(t) = K$

The Transfer function becomes;

$$\frac{\Omega(s)}{V(s)} = \frac{K}{JLS^2 + \left(RJ + LB + Lr^2 M_{eq}\right)S + (RB + Rr^2 M_{eq} + K^2)} \quad \ldots\ldots\ldots\ldots 16$$

Or

$$\frac{\Omega(s)}{V(s)} = \frac{D}{AS^2 + BS + C}$$

$\ldots\ldots\ldots\ldots\ldots\ldots 17$

Where; J – Moment of inertia of load and rotor; r – Shaft radius; ω – Angular speed (rad/s); V_e - Back emf; V_a – Applied armature voltage; L_a – Armature inductance; I_a - Armature current; R_a - Armature resistance; M_{eq} – Equivalent Mass of shaft (M_{shaft}) and Mass of feed (M_{feed}); B – Damping coefficient; F – Force; T – Load torque.

Table 3: The Parameters Values for the Transfer Function (adopted).

No	DC Motor parameters	Values and Units
1	R	$15.31e^{-2}$ ohms
2	L	0.48 H
3	J	0.088 kgm^2

4	B	0.2 Nm.sec/rads^{-1}
5	K	0.06 Nm/A
6	D	0.12 m
7	R	0.06 m
8	M_{shaft}	40 kg
9	M_{eq}	65 kg

(Source: [38])

Table 4: HODFC parameter values as evaluated by Matlab

1	K_{hod}	6.75
2	m	3
3	a_0	2
4	a_i	[6.75 27 27]

A typical structure of a PID control system is shown in figure below [39];

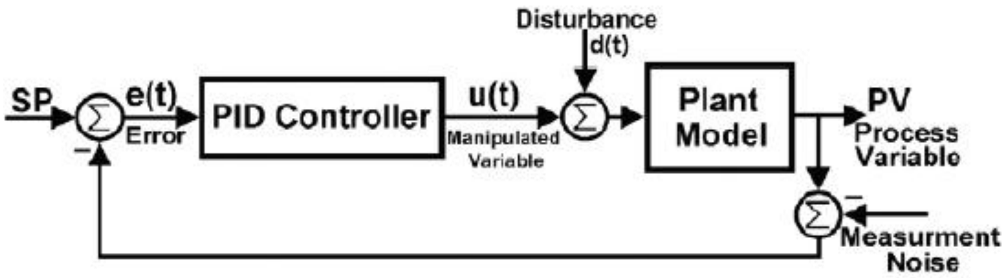

Figure 16: A typical PID control structure

Four main features of the closed–loop step response are:

Rise time – the time it takes for the process variable to rise above 90% of the set point for the first time.

Overshoot – the maximum swing above the set point.

Settling time – the time it takes for the process variable to fall within a certain percentage (i.e. 2%) of the steady state value for a step input.

Steady-state error – the difference between the steady-state variable and the set point.

The transfer function of my plant model in equation (17) is then evaluated with Matlab as;

$$G_S\_OL = \frac{\Omega(s)}{V(s)} = \frac{1.42}{S^2 + 5.251S + 1.573}$$

Again the evaluated poles of the transfer function using this command "pole (G_S_OL)" generated these negative real numbers, -4.9318 and -0.3190 (values of S for which the denominator equal to zero). Moreover the poles of the transfer function are the eigenvalues of the system matrix A and the negative signs shows that the poles are placed at the Left-half plane.

The Simulink of figure 17 is the representation of the mathematical models in block diagram of the mixing processes of the mixer (my plant), with PID controller and HODFController controlling the plant processes.

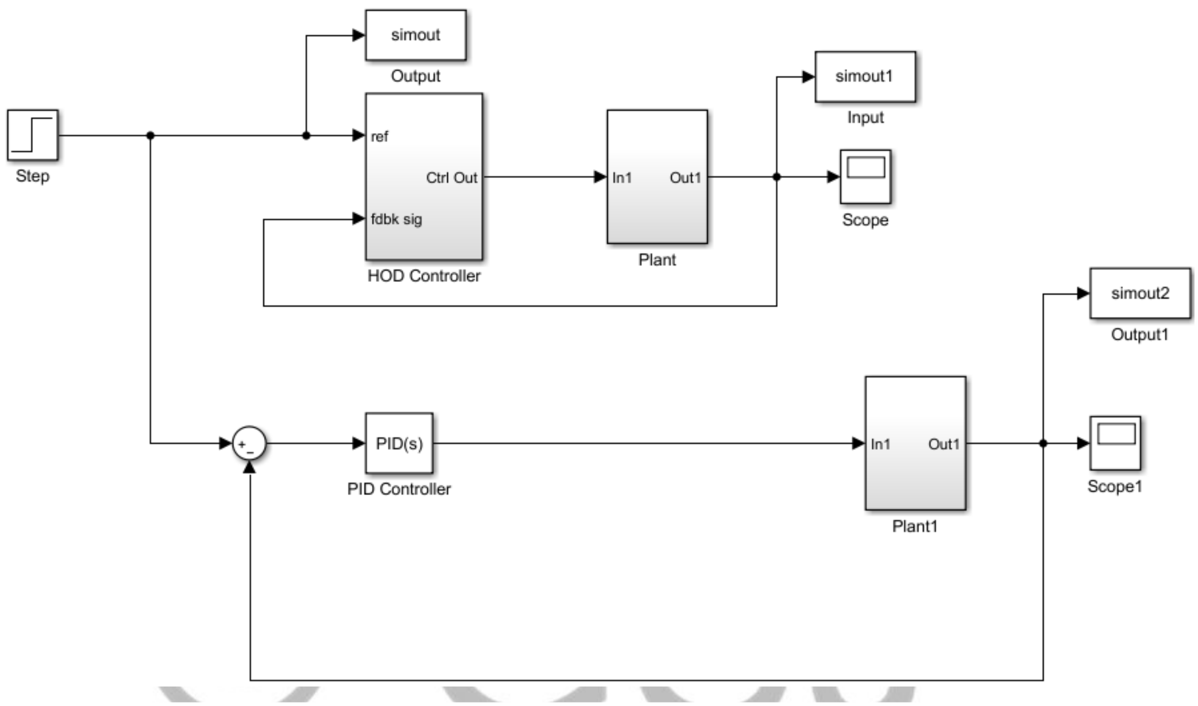

Figure 17: Simulink representation for the two the controlled closed loop of the system, one with PID controller and another with HODFC.

The continuous transfer function model of the two controllers for the mixing processes as evaluated by Matlab are:

1. For HODFC, with the Higher Order Differentiator [40] given as;

$$K_{hod} = \frac{m^m}{(m-1)^{m-1}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..18$$

$$a_i = a_0^{i-1} K_{hod} C_{m-1}^{i-1}; \;\; i = 1, 2, \ldots \ldots m \qquad \ldots\ldots\ldots\ldots\ldots\ldots..19$$

Where m is the order of the differentiator system, the HODFC closed loop control system then becomes;

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

$$Gs_{hod} = \frac{9.585}{S^2 + 5.251S + 1.573}$$

2. For the PID controller closed loop control of the system we have;

$$Gs_{CLC} = \frac{12.78S^2 + 65.34S + 25.57}{S^3 + 18.03S^2 + 66.91S + 25.57}$$

Where; Table 5: The tuned parameter values

K_P	46
K_I	18
K_D	9

PID control in simantics step7

The actual version of the algorithm used in PLCs to achieve PID control is sample with Δt intervals [41] can be expressed as:

$$CV = k_p\left[(SP - PV) + \frac{1}{T_i}\sum_{0}^{t}(SP - PV)\Delta t + T_d\frac{\Delta(SP - PV)}{\Delta t}\right]$$

………………….20

The function Blocks (FBs) of the PID control package consist of controller blocks for Continuous Control FB41 (CONT_C), for Step Control FB42 (CONT_S), for Pulse Duration Modulation FB43 (PULSEGEN), for Continuous Temperature control FB58

(TCONT_CP) and for Temperature Step Control FB59 (TCONT_S). These controllers must be called at exactly equal intervals. A cyclic interrupt OB, e.g. OB35, can be used as a “container” of the PID blocks. This avoids errors and gives high accuracy in the internal calculations of the PID dynamics. The PLC programmer can choose the PID parameters needed for a certain plant control by activating or deactivating the relevant PID parameters (for example PI-control only).

PLC Simulation of the Ingredients Mixing Homogeneity.

The degree of homogeneity of a mixed product can be measured by statistical analysis of a number of samples of the mixture as summarized below [42]:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \dots\dots\dots\dots\dots\dots 21$$

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n} (x_i - \bar{x})^2 \qquad \dots\dots\dots\dots\dots 22$$

$$RSD = CV = \frac{s}{\bar{x}} \qquad \dots\dots\dots\dots\dots\dots\dots\dots 23$$

Where, RSD = Relative Standard Deviation; CV = Coefficient of variability; $\%D_M$ = S = Standard deviation; X_i = the composition of the key component in the i^{th} sample; $\bar{x}$ = Sample mean; n = number of samples, RSD = Relative Standard Deviation; CV = Coefficient of Variation (%).

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

Table 6: Mixing Validation Data Sheet of NIRs evaluated from 1ton to 25kg values.

		Date	Sample name	Batch No.	% Cp	% Fat	% Fibre
		28-09-15	**LAYMORE MASH**	02092015-13	0.523	0.05	0.1
Mean =	***0.52***			02092015-19	0.52	0.08	0.1
S.D =	***0.0024495***			02092015-25	0.52	0.07	0.1
% Variation=	***0.4710557***			02092015-38	0.517	0.11	0.08
		28-09-15	**LAYMORE MASH**	10092015-15	0.53	0.05	0.08
Mean =	***0.5275***			10092015-20	0.528	0.09	0.09
S.D =	***0.0025166***			10092015-30	0.528	0.13	0.1
% Variation=	***0.4770827***			10092015-40	0.524	0.1	0.06
		28-09-15	**LAYMORE MASH**	18092015-11	0.54	0.13	0.08
Mean =	***0.5374929***			18092015-18	0.515	0.12	0.09
S.D =	***0.0102429***			18092015-25	0.526	0.09	0.1
% Variation=	***1.905678***			18092015-37	0.528	0.13	0.1
		28-09-15	**LAYMORE MASH**	24092015-28	0.509	0.03	0.09
Mean =	***0.5062***			24092015-39	0.513	0.03	0.07
S.D =	***0.0073258***			24092015-44	0.496	0.06	0.12
% Variation=	***1.4472054***			24092015-53	0.504	0.06	0.1

Descriptive Statistics

	N	Minimum	Maximum	Mean	Mean Variation %
Percent Crude protein	4	0.496	0.54	0.522798221	1.075255466

(Source: [14])

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

3.5. Material/Software that were Used for this Work

The following software were used;

1. SIMANTIC STEP7 Professional
2. SIMANTIC WINCC
3. Matlab/SIMULINK
4. CAD Application; AUTOCAD 2015 (Appendix 6)

The Hardware used;

1. PLC STEP7 300 (i.e. SIMANTIC 300 Station /Module – CPU314C-2 DP)

3.6. Process Flow Diagram

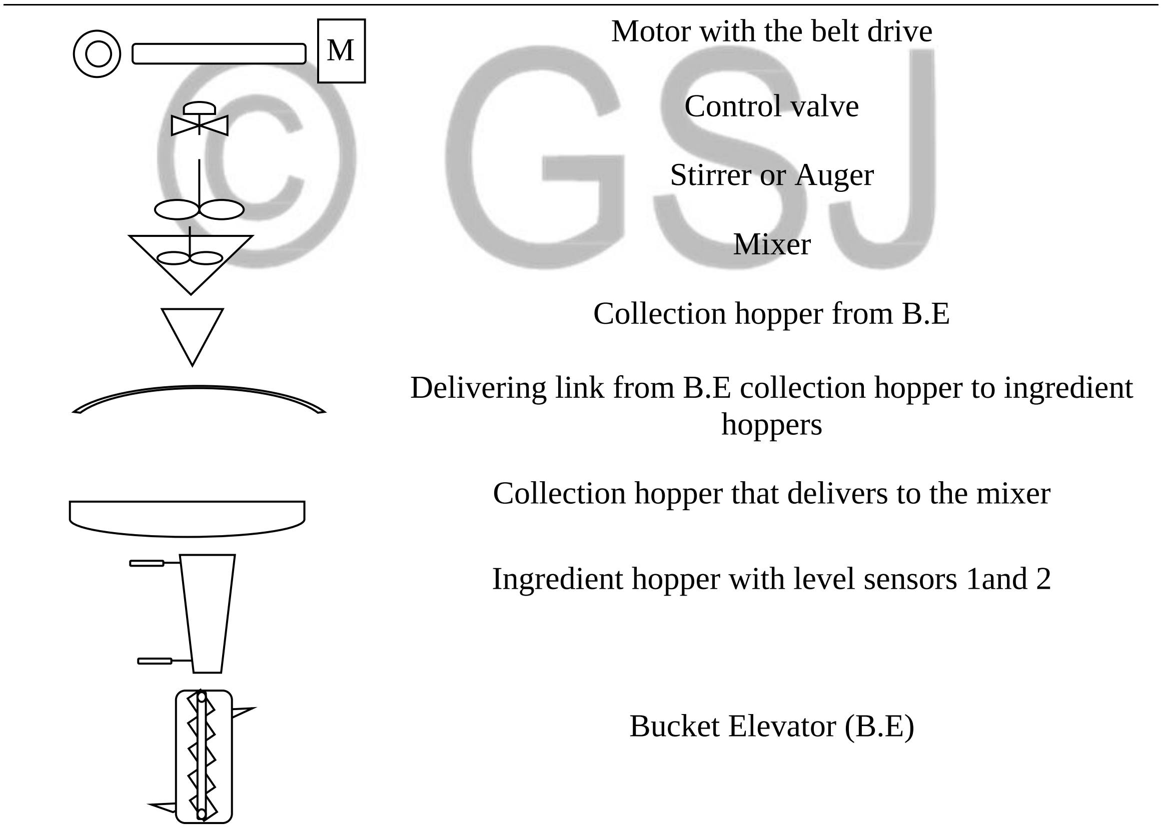

Figure 18: Process flow diagram legends

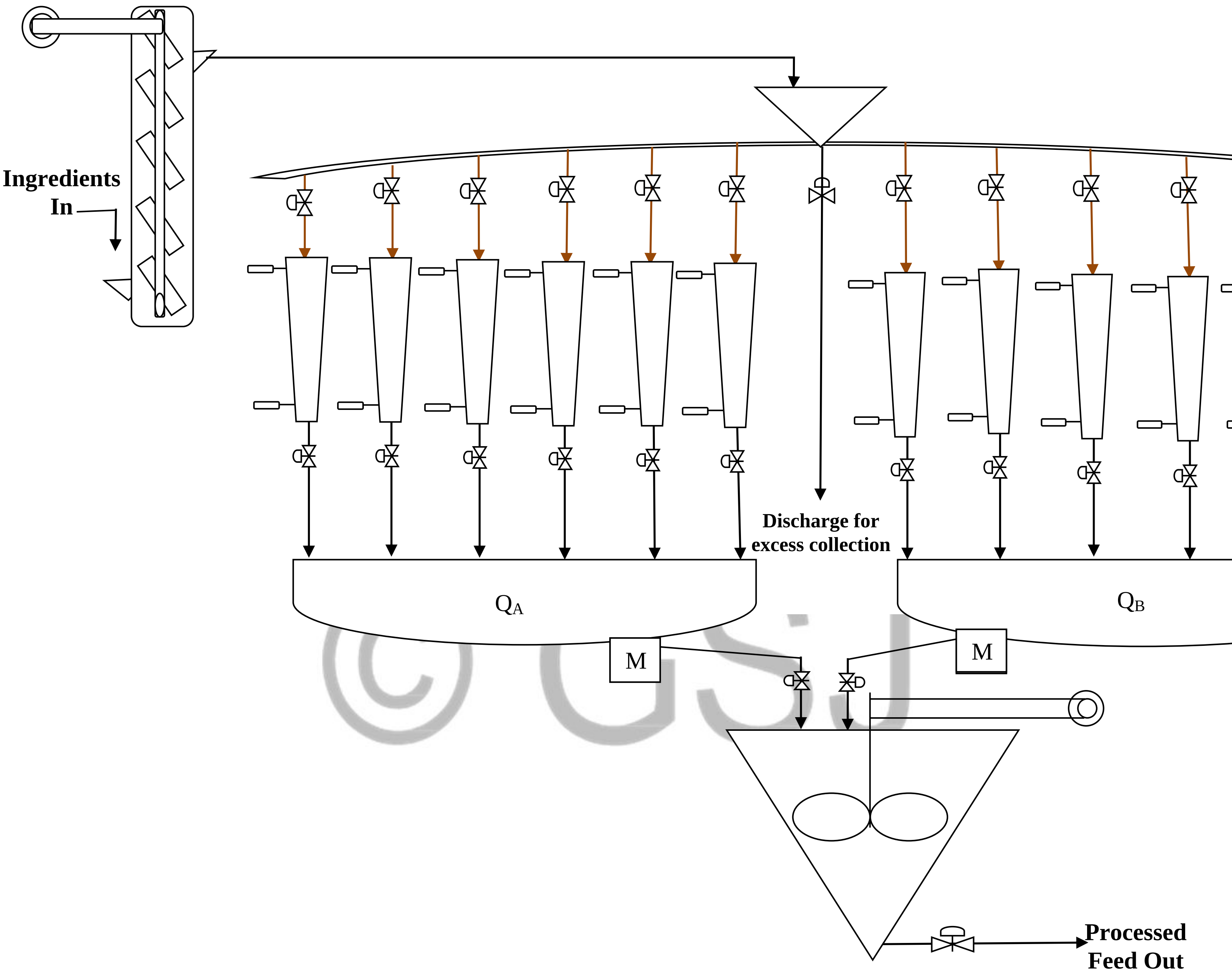

Figure 19: Process Flow Diagram

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter described the different stages of the process designs and execution through simulations achieved. In the case of SIMANTIC STEP7 PLC, it described the major program designs, compared the results of hardware simulations with the HMIs and the effects to the efficient performance of the process, while in Matlab and Simulink the results responses were shown, the effect of PID controller applied as part of the control system apparatus were and discussed. Finally, the stability response and the disturbance rejection of the PID controller on the mixing process were compared with HODF Controller and there results discussed.

Simantic Simulation Results for Program Designs and their HMI

In figure 20 call for the controller to EITHER output hi_13L (i.e. red indication signal for hopper 13 low level sensor) to be ON when start is ON and sensor sensed that ingredient in the hopper 13 (i.e. h13L) is low, OR output hi_13H (i.e. green indication signal for hopper 13 high level sensor) when sensor (h13H) sensed that ingredient level in the hopper 13 is high. While Plate I is the HMI implementation, here the implementation for program of figures 20 were displayed, that is, push button for hopper 13 is pressed and the valve for 13 opened to discharge ingredient into hopper13 as the low level sensor indicated.

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

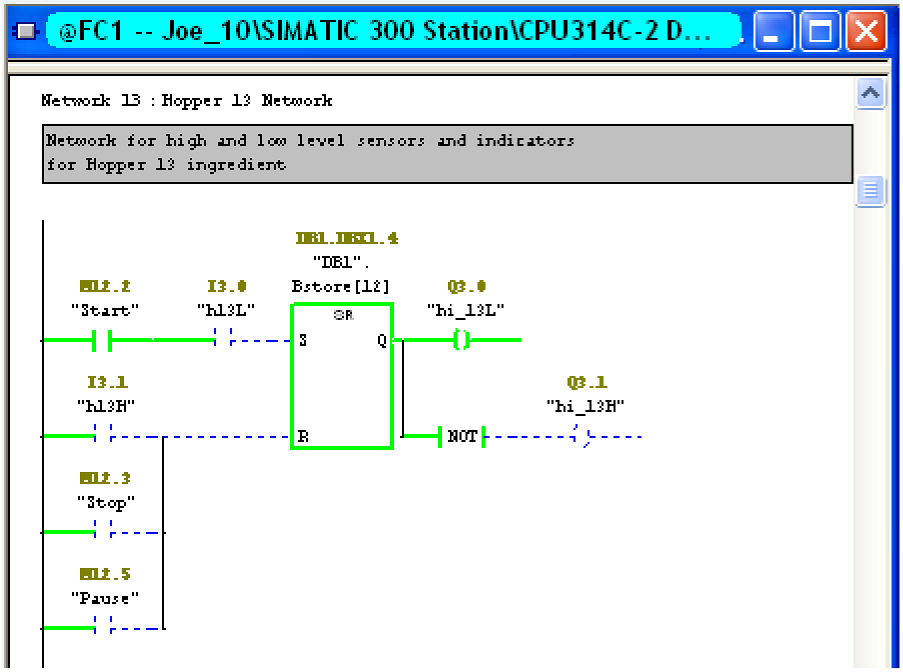

Figure 20: Simulation for low level sensor indicator for hopper 13 activated

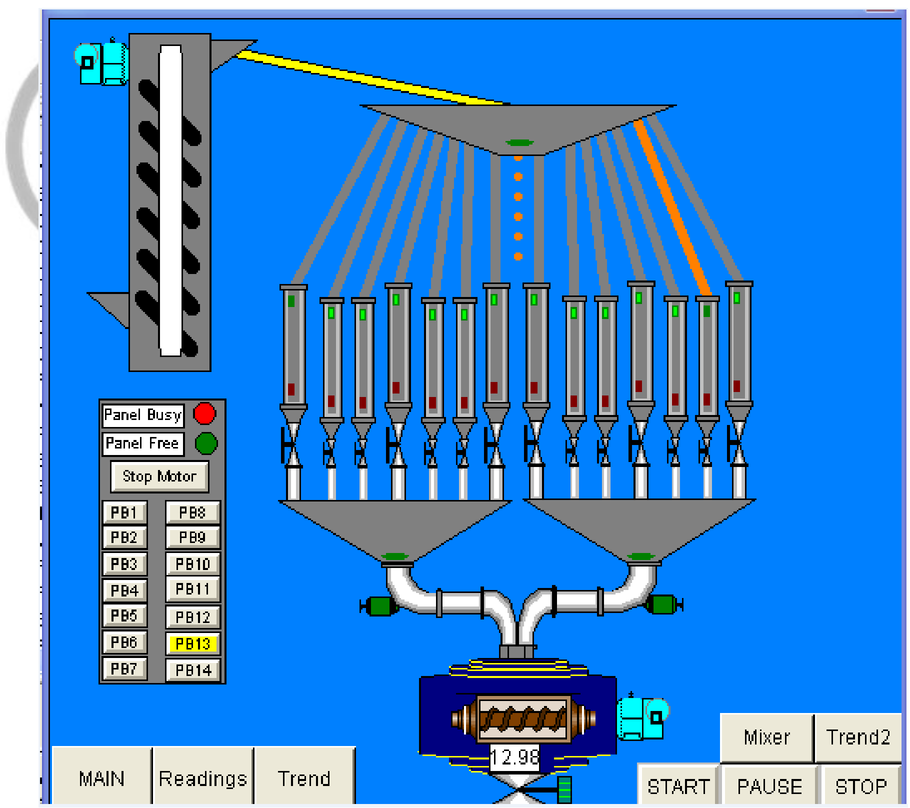

Plate I: HMI Process implementation of the program designed

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

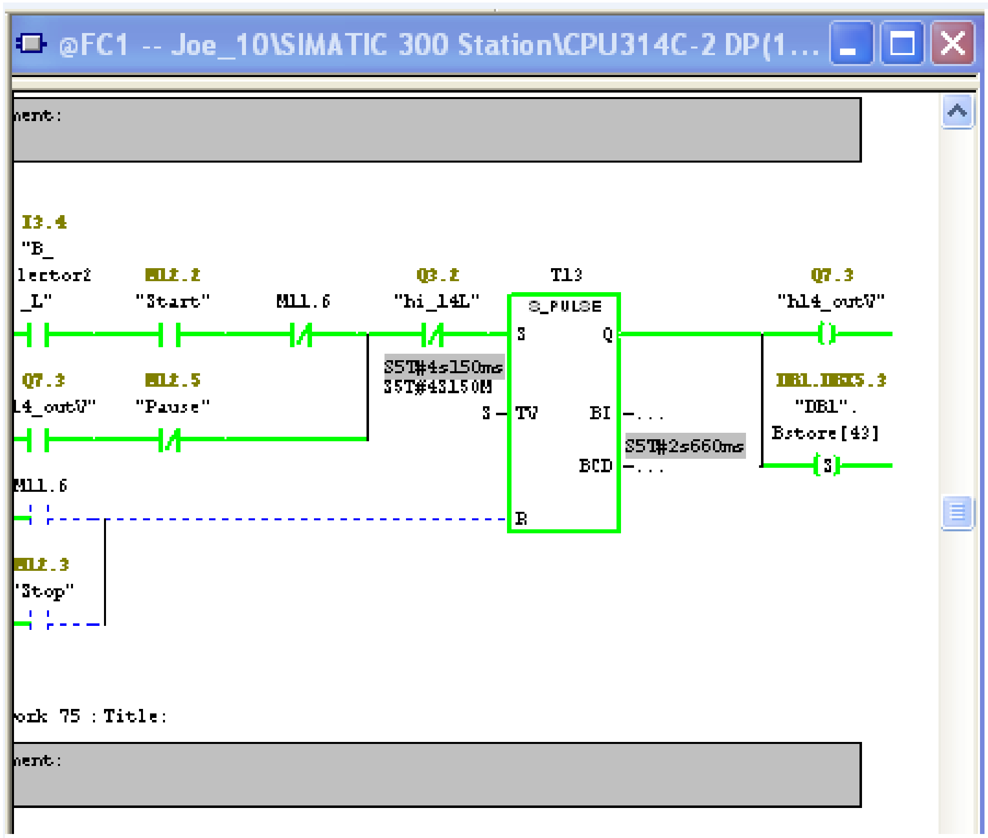

Plate II: Program that executed opening of hopper 14 discharge valve and times out its closing for estimated mass to be discharged.

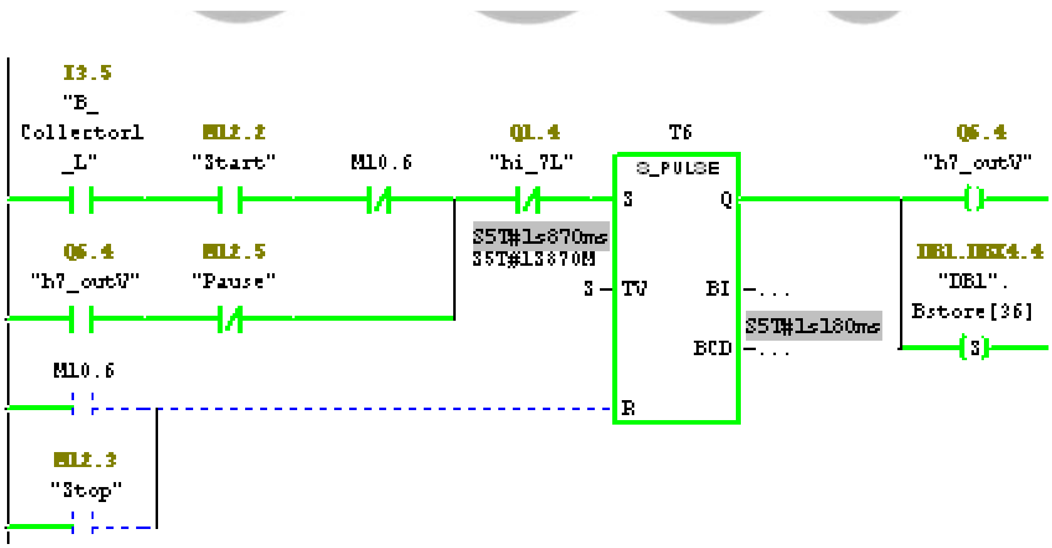

Plate III: Execution of Hopper 7 discharge timing

In the ladder program of plate II, it described the discharge rate of ingredient in one of the hoppers (with ingredients which particle diameter is of coarse texture) into the collector that discharge for mixing to the mixer. The time of discharge value gotten from the evaluated modeled equation for the discharge rate in chapter 3 was used to accomplish this. The same goes for every other hopper. Nevertheless, the program executed for hopper 14 of which the discharge time value was for Guinea corn and was achieved as follows;

$$t = \frac{4(8.75)}{(630)\pi(0.612)^2(0.612(9.81)(2(1+1)\tan 23.46)^{-1})^{1/2}}$$

$$t = 4.15\ seconds.$$

The delay time T13 at the input TV of S_PULSE from the program, as its executing, was set and meant to hold output active as it timed down to zero at BCD. Here in the program the hopper 14 discharge valve (h14_outV) opened, had to remain opened for 4seconds 150milliseconds for the estimated quantity (in mass) of ingredient to discharge and the time set to zero by DB1 ready for another process. The same discussion goes for Plate III for hopper 7 containing DCP (Di-calcium Phosphate) which represents for fine particles, has its discharge time value solved out from equations (9) and (12) as follows:

$$4(640)(1.27e^{-4})^{\frac{5}{3}}{V_0}^3 \sin 14.10 + 0.0109785(0.032){V_0}^2 - 9.81(640)(1.27e^{-4})^{\frac{5}{3}}(0.032) = 0$$

$$4.1889e^{-4}{V_0}^3 + 19.640536e^{-3}{V_0}^2 - 3.6041168e^{-3} = 0$$

$V_0 = 0.389$, Therefore; $t = \frac{4(0.375)}{(640)\pi(0.032)^2(0.389)}$

$$t = 1.8729$$

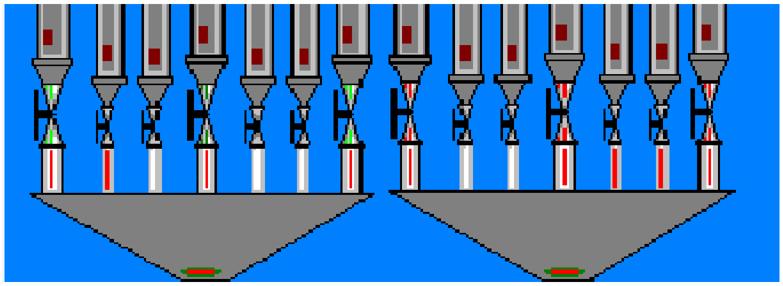

Plate IV: HMI implementation of valve discharging process

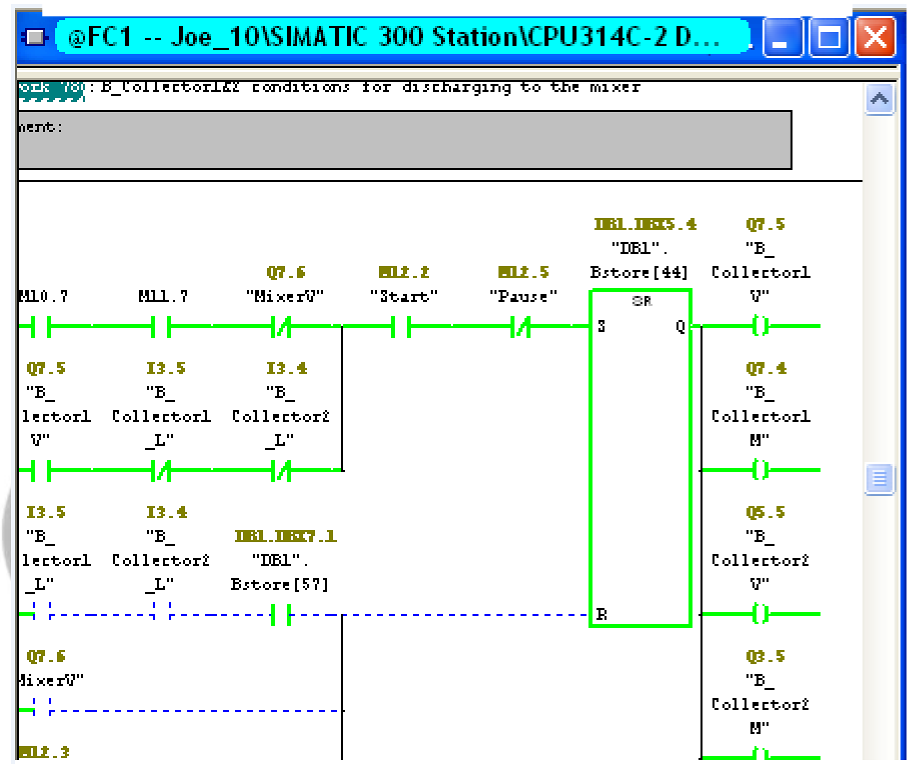

Plate V: Program executing discharge from the two big collector hoppers into the mixing chamber.

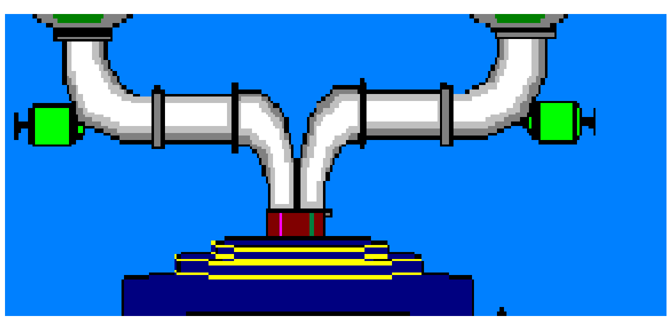

Plate VI: HMI implementation of the big collectors discharge

The simulation of the program of Plate V was an execution that certifies that all ingredient hoppers have successfully discharged their estimated quantities in mass into the collector hopper, for onwards discharge into the mixer. And as this is achieve, the output activates the indication for the hoppers' high level sensors and activates opening of the screw valve by powering ON the screw valve motors. From the program input, we can see M10.7, M11.7 (which were assign memory byte outputs that only activate when all the 14 discharge hopper valves must have opened and closed), Mixer Valve (Mixer V), start and pause, must all activate to output for big collector 1 & 2 motors and valves opening by keeping them active. Plate VI is the HMI implementation, as we can see from the display.

The simulation programs of plate VII & VIII scales the speed and updates the timing of the mixer. The discussion goes thus; PIW 256 is the default start addressing for the analog input WORDs in PLC module. Analog values are inputted as WORD with the integer (INT) data type format in the PLC. The PIW 256 working as the potentiometer, accepts the analog values (4mA – 20mA as described in the review) and gives a digital output value of the range 0 – 27648 for unipolar. The analog values scaling are done with the PLC inbuilt scaling function FC105. The function takes an input IN as an INT and converts it to a real value between two limits, a low and a high limit (LO_LIM and HI_LIM).

The equation used is:

$$OUT = \left[\frac{(FLOAT(IN) - K1)}{(K2 - K1)} \times (HI_{LIM} - LO_{LIM})\right] + LO\_LIM$$

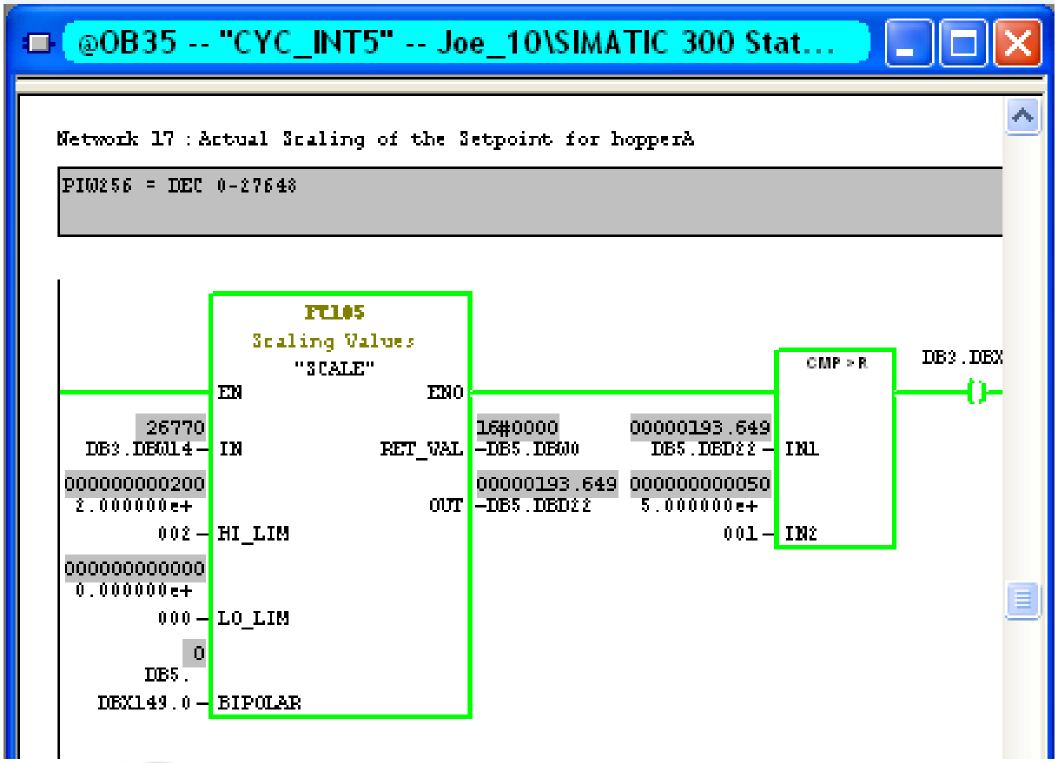

Plate VII: Actual scaling of the speed limit

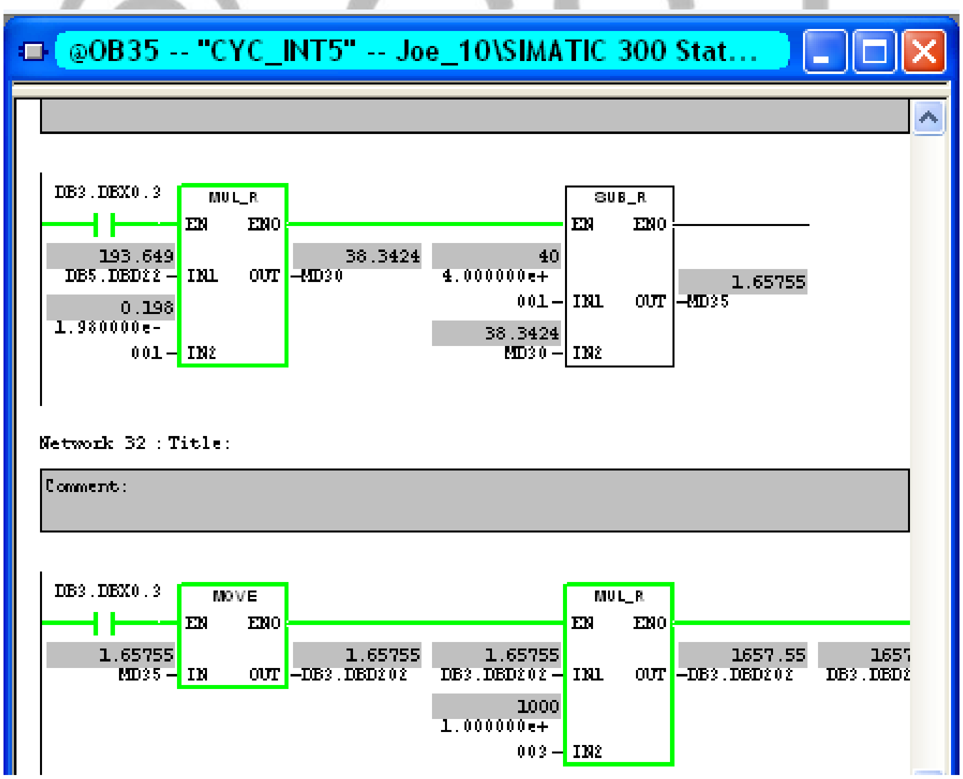

Plate VIII: Mixing time updating

In this simulated program of plate VII, analog input was the set point within the range of 0 – 200rpm. The constants K1 and K2 were set based upon whether the input value is bipolar or unipolar. Since this is unipolar, the K1 = 0.0 and K2 = 27648.0 while the HI_LIM = 200 and LO_LIM = 0.0. Then the comparator was applied to keep the speed between 50 – 198rpm. In the simulation of Plate VIII, the program executed the updating of the mixing timing in such a way that as the speed is increases the timing reduces and vice versa.

In figures 21, Plates IX, X, XI and XIII program simulation part (which is the mixing process in the mixer) the virtual sensor probe readings were provided for, to replicate the different four sets of readings in the excel chart of table 6 and their Mean (X), Standard deviations (SDs) and CVs (RSDs), automatically calculated, as made to, by the chart using Crude Protein (CP) values generated by the NIR analysis as the key sample composition (X_i) as in equations (21), (22) and (23). The same way provisions were made for the four different sets of reading in the program which were displayed as CH1, CH2, CH3 and CH4 (i.e. Channels 1, 2, 3 & 4 respectively). Each of this Channels have their four different readings of which as in the program of figure 21 (i.e. Channel 4 readings) were display as CH4_CP1, CH4_CP2, CH4_CP3 and CH4_CP4 (i.e. probe slot for Channel 4 Crude Protein 1 reading (CH4_CP1) and so on.), they are all sensor probe slots. Just as the excel table 6 chart has been programmed to calculate for the X, SDs and CVs whenever the sample analyzed Crude Protein (CP) values are inputted, as well the Structured Control Language (SCL) in the appendix 5 runs the calculations for the four channels and as well the calculations for the final average cumulative CV (F_CV) in the controller as all the virtual sensor probes keep generating (analyzed) random CP values (as represented in the simulations of Plates XI and XIII).

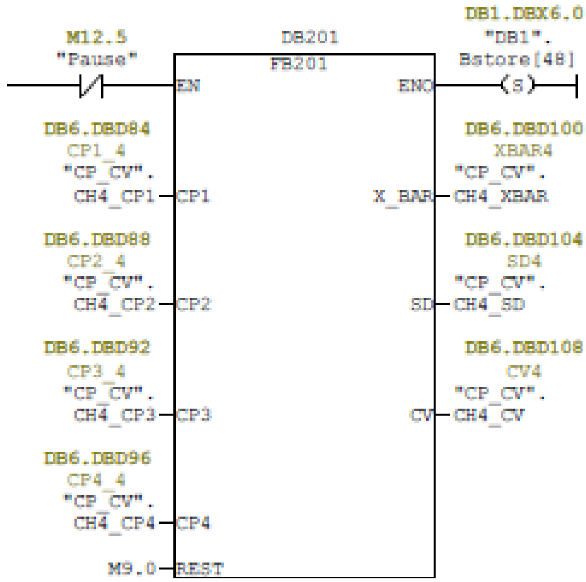

Figure 21: Mixing chamber location with probes 13, 14, 15 and 16

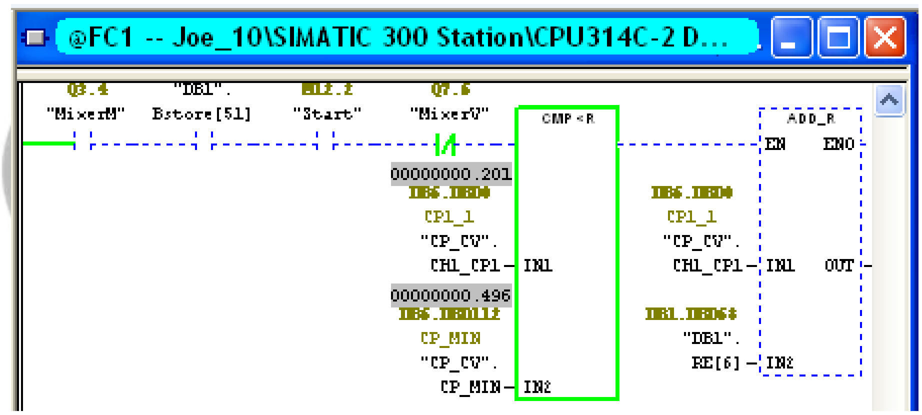

Plate IX: Compares actual values with minimum CP values and add random values when required

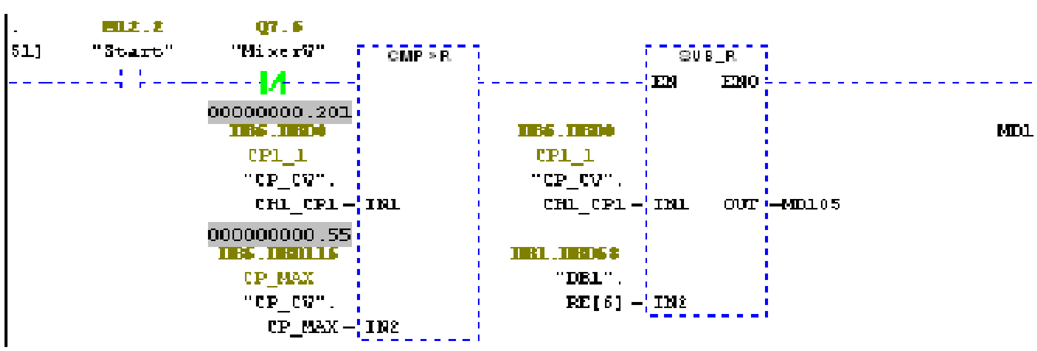

Plate X: Compares actual values with max. CP values and subtract from random values

According to the excel chart of table 6 the CP has a minimum value of 0.496 and maximum value of 0.54, the simulations of Plates IX and X used SCL codes in the appendix 4 to execute for the minimum and maximum values. While simulation of Plate IX takes the actual values, compare it with the set minimum value, add random value if less than the set minimum, terminate random number generation and output value as soon as it get to the set minimum value. Plate X takes the actual values compare it with the set maximum value, subtracts random values that generates from the actual, if more than the maximum set value and terminate all number generation and output value as soon as the actual value gets to set maximum value.

The HMI implementation of Plate XII displayed the executed simulations of Plates VI & VII which are where mixing speed and time updating values were scaled from there analog values to digital values, also displayed are the virtual sensor probes (analyzed by NIRS) reading of CP for each and every channels. And the executed CVs for the four channels in Plate XI with the F_CV output.

Nevertheless at this point (i.e. during the process of mixing) the virtual Multipoint NIRS (with its virtual light emitting fibre optics sensor probes which were positioned four different location each at every four sides of the mixing chamber) runs on line continuous analysis of the mixture blend of the various feed ingredients (as the mixing process is in progress) generating continuously percentage nutrient content values (for majorly crude protein, ether extract i.e. fat & oil and fibre) from the locations of each and every one of the sensor probes. These continuous values of the percentage nutrient content for any of the major nutrient constitute (here we used (CP) Crude protein) are what the controller collects real-time as they updates and keep evaluating for X, SDs and CVs or RSDs (as in equations

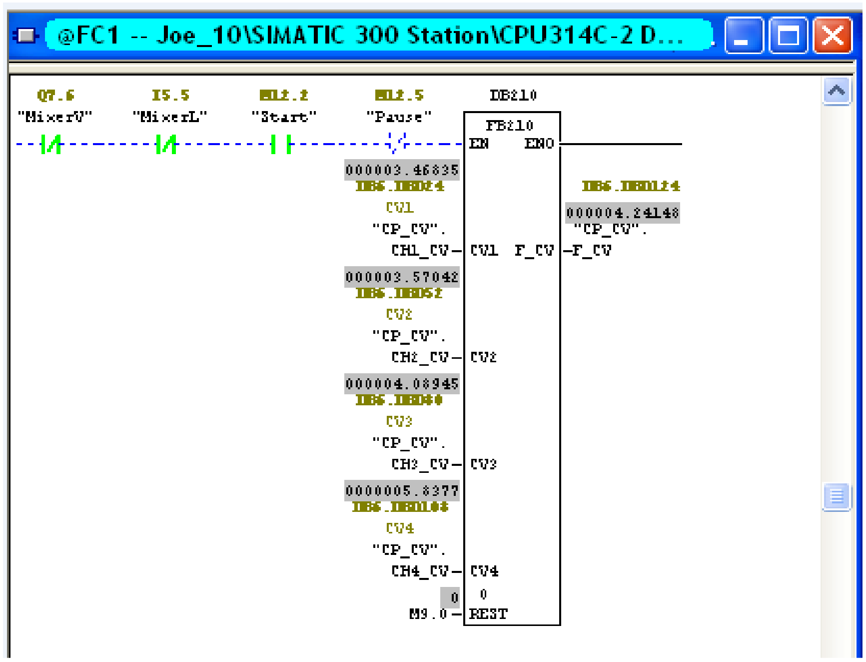

Plate XI: Coefficient of Variations for each of the four channel probe readings and the F_CV

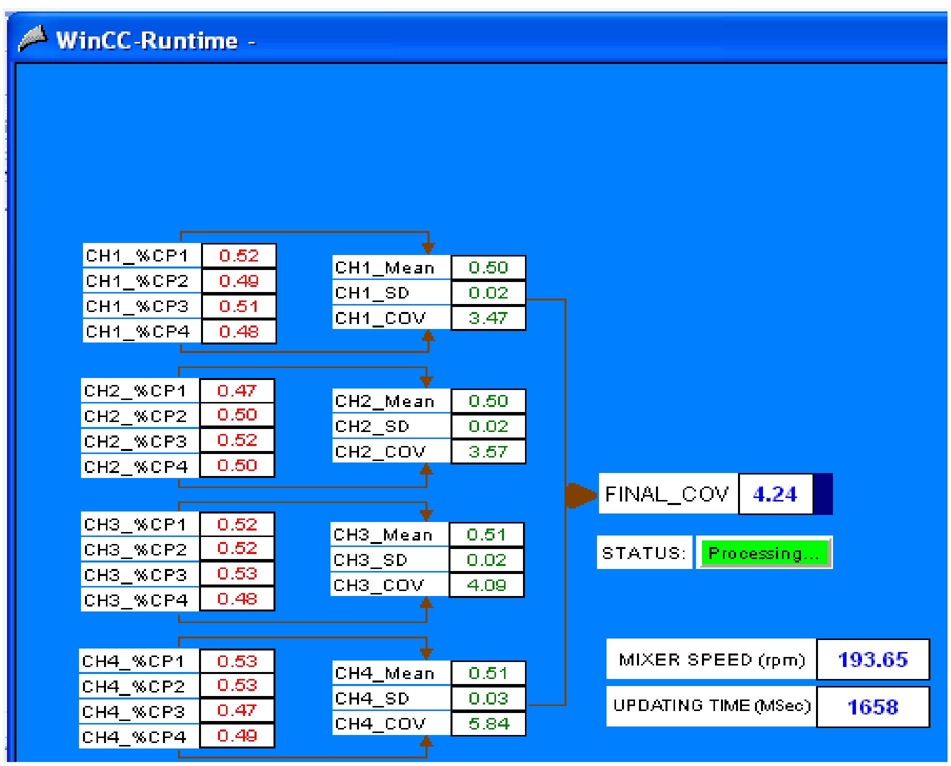

Plate XII: HMI simulations for all the process readings

21, 22 and 23) and then the Average Cumulative X and CV or RSD of the final mixture (as represented in excel chart of table 6), using the Structured Controlled Language (SCL) in appendix 2 and 3. The in built PID controller collects the calculated values and updates them (as the process is in progress) varying the process variables (i.e. $\bar{x}$ and RSD) with the set point (≤ 4%) until zero error is hit by the controller. Also from the excel chart of table 6 the CV for this continuous mixing process (since table 6 was for batch process) was set at a set point of 4.00%, meaning that the value of the Final CV must be less than or equal to 4.00 (F_CV ≤ 4.00%), this is where the plant model and PID block comes in.

Nevertheless, the simulation of Plate XIII program executed termination of a mixing process as the average cumulative of the four channels CV (i.e. final CV or F_CV) reaches 3.32677 (approximately 3.33).

The PID were programmed in OB35, the implementation of the controller was done by activating the P, I, and D parameters in the PID block FB41 CONT_C. But first these addresses PVPER_ON was set FALSE and MAN_ON set TRUE to allow for external process variables to be given manually on the input PV_IN address of FB41 CONT_C block since we are in simulator mode. This means that in the manual mode, the Manipulated Variable (MV) is adjusted to a selected value manually. However the PID controller was programmed to control the adjustments of the motor speed of the mixer (MV) and use the plant model and its SCL to update and stabilize the Controlled Variable below the set point of 4.00. The PID block FB41 CONT_C, the table for all the digital input/output and analog input/output (including the values for the gains, i.e. P, TI, and TD), the plant model block and the SCL of the plant model are all in the appendix 4.

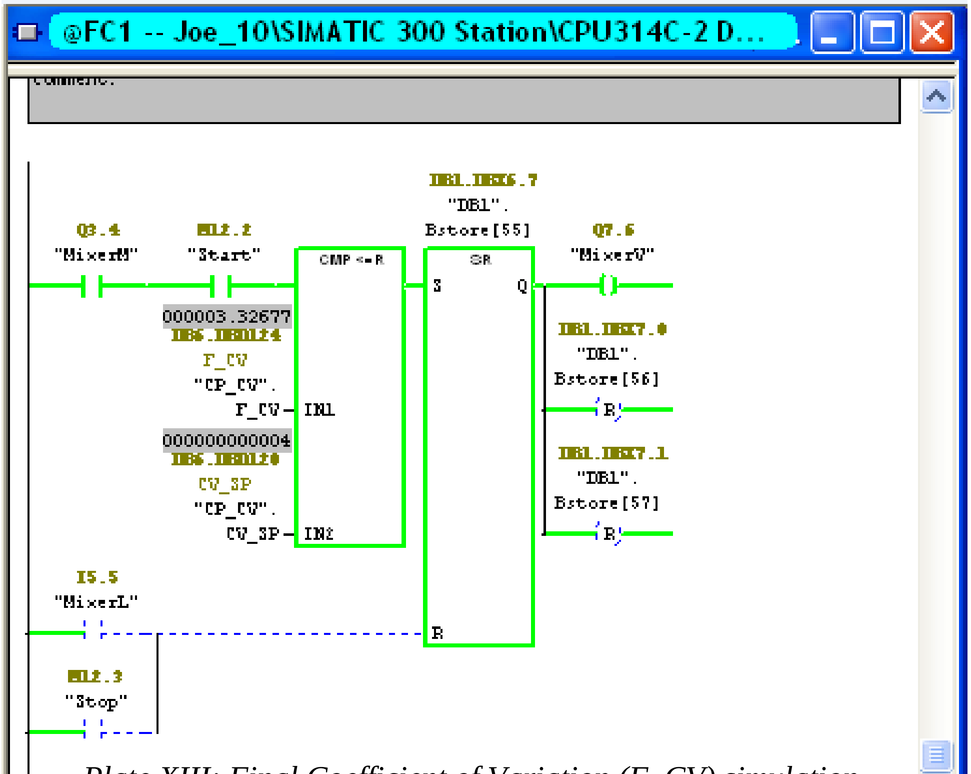

Plate XIII: Final Coefficient of Variation (F_CV) simulation

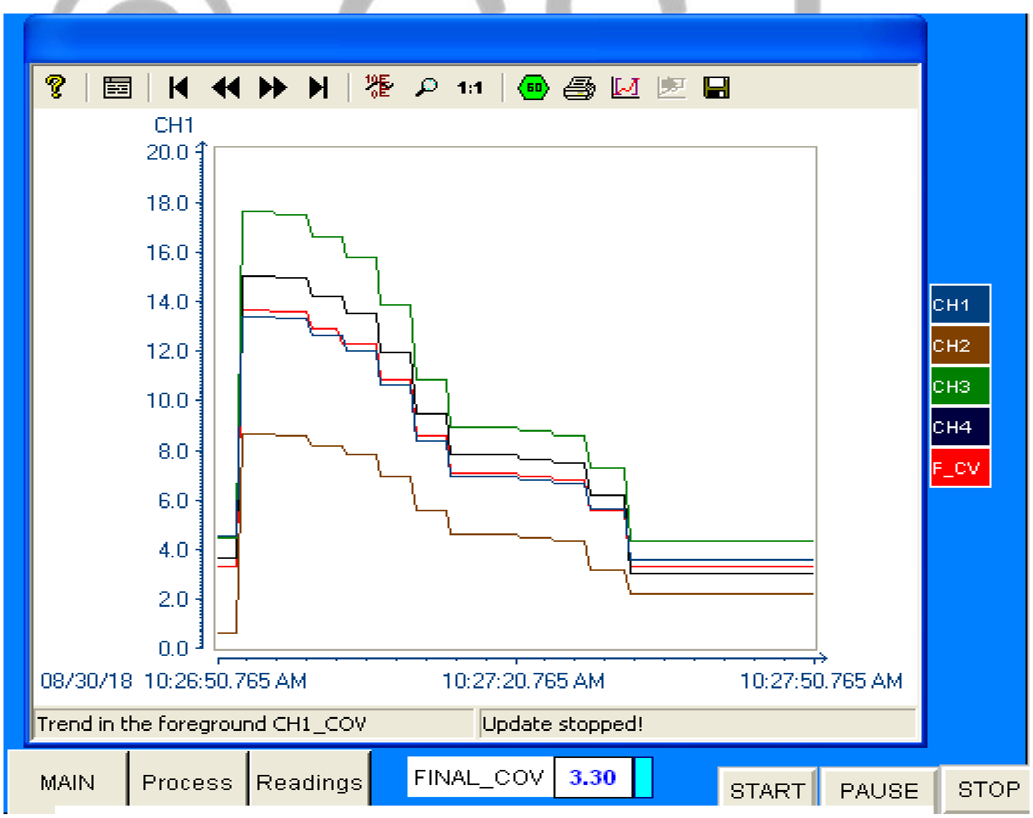

Plate XIV:HMI real-time plotting of the coefficient of variations

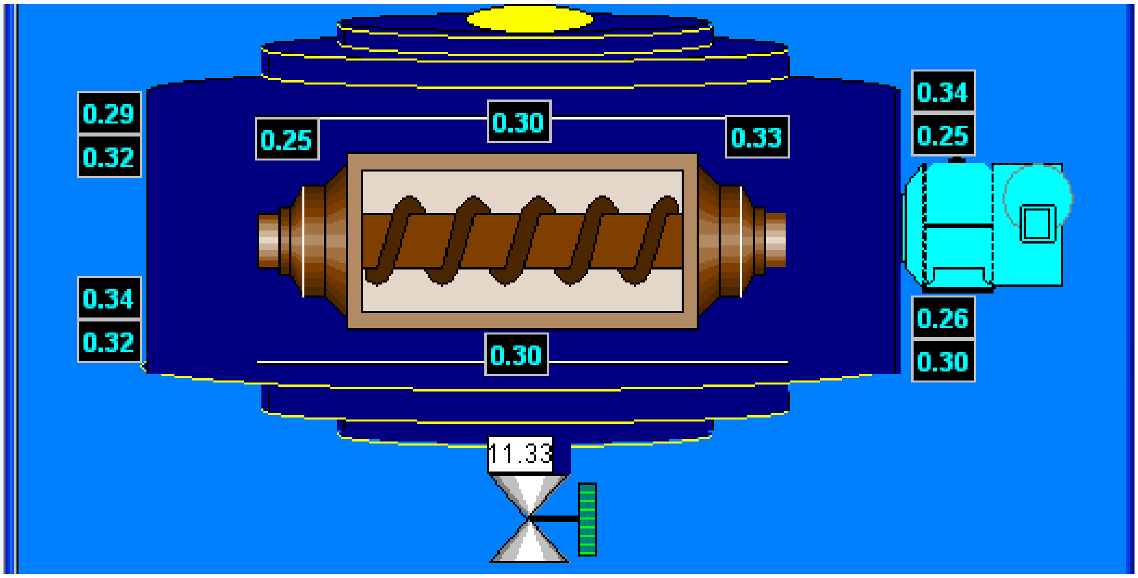

Plate XV:HMI display for the location of the Virtual sensor probes on the sides of the mixing chamber

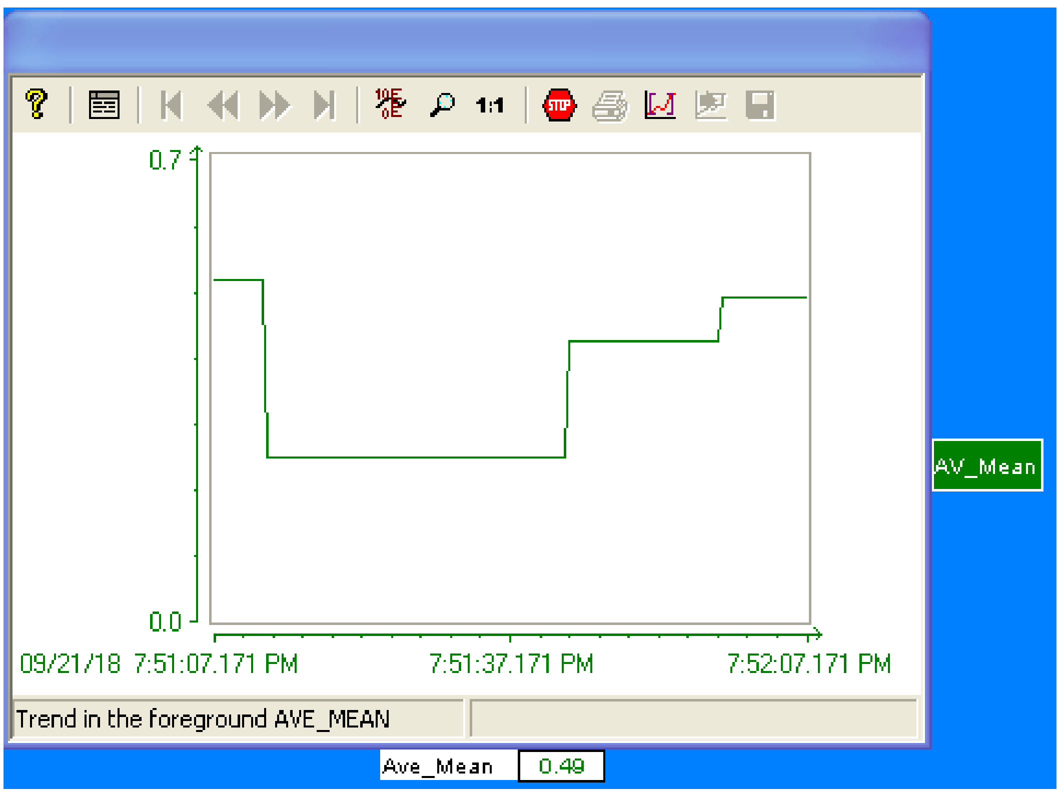

Plate XVI: HMI real-time update plotting of the average cumulative Mean for the four Channels until set point ($F\_CV \leq 4.00$) is reached.

In plate XIV, the full HMI implementation of Plates XI and XIII and (especially) XIII is displayed. It shows the online trending, or the real-time time plotting, of the results of the update calculation of the CVs in the four Channels (i.e. CH1, CH2, CH3 and CH4) and the calculation of their average cumulative (i.e. F_CV) as the mixing process is in progress until it terminate at the set point of F_CV ≤ 4.00%. From the trend the final coefficient of Variation (CV) or average cumulative CV (F_CV) shown in red line in the plot terminates at F_CV of 3.30, as well in the simulation of Plate XIII.

The Channels discussed for figures 19, Plates IX, X and XI as virtual sensor probes from virtual Multipoint NIRs were positioned four location at each of every four sides of the mixing chamber as displayed in Plate XV.

4.2 MATLAB/SIMULINK

The simulation of figure 22 compared the performance of the two controllers (i.e. PID and HODFC) on the plant and these were there performance parameter responses:

1 The PID controller had a faster rise time at 0.175 seconds with very little overshoot of 0.33 and a settling time of 0.3902 seconds.
2 The HODF Controller had a fast rise time of 3.53seconds but not as fast as the PID controller, though with no overshoot but a settling of 6.22 seconds.
3 The disturbance rejection for PID, of figure 43, which overshoots to 0.019 amplitude values before settling to a steady state at 3.8 seconds, gave much efficiency to its performance.

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

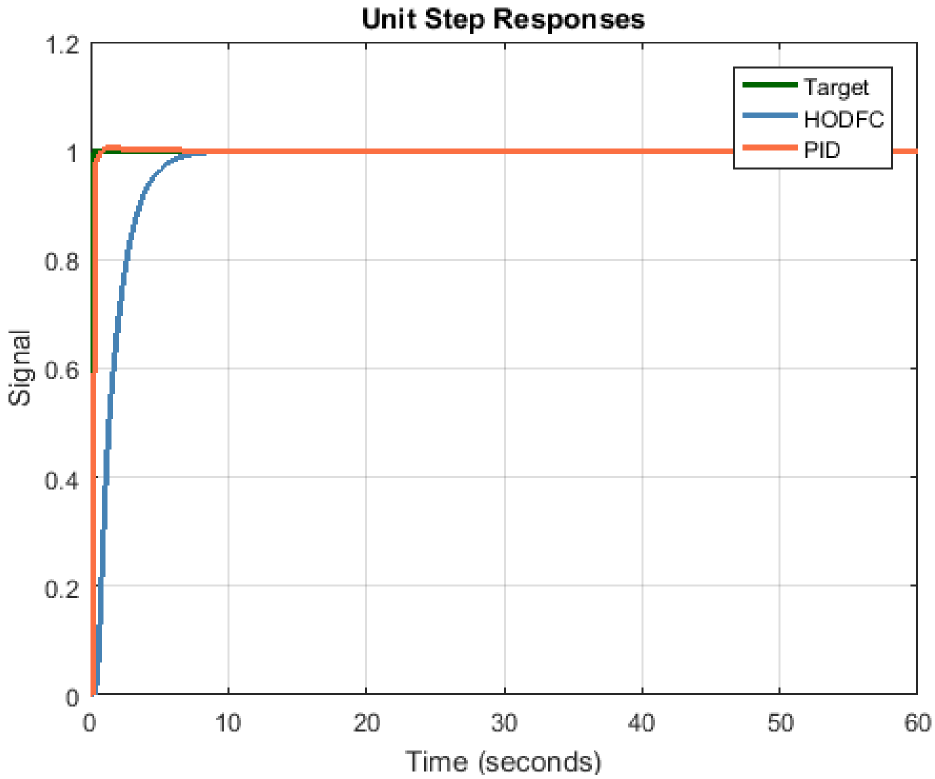

Figure 22: The Responses of the two controllers on the system

Figure 23: PID controller disturbance rejection for the plant

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

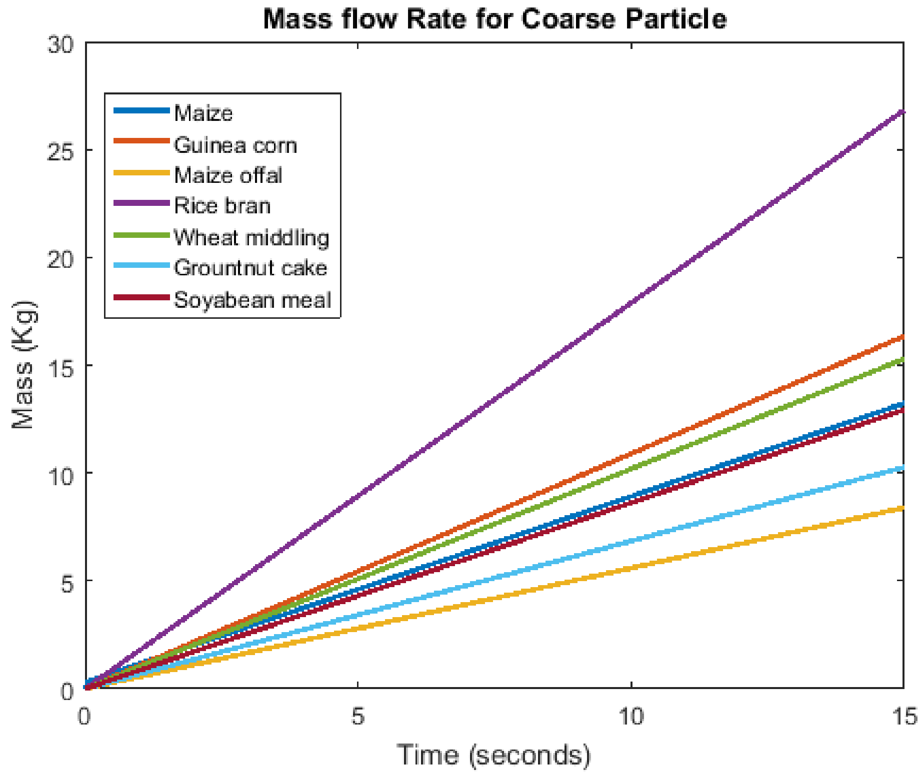

Figure 24: Mass flow rate for Coarse particles

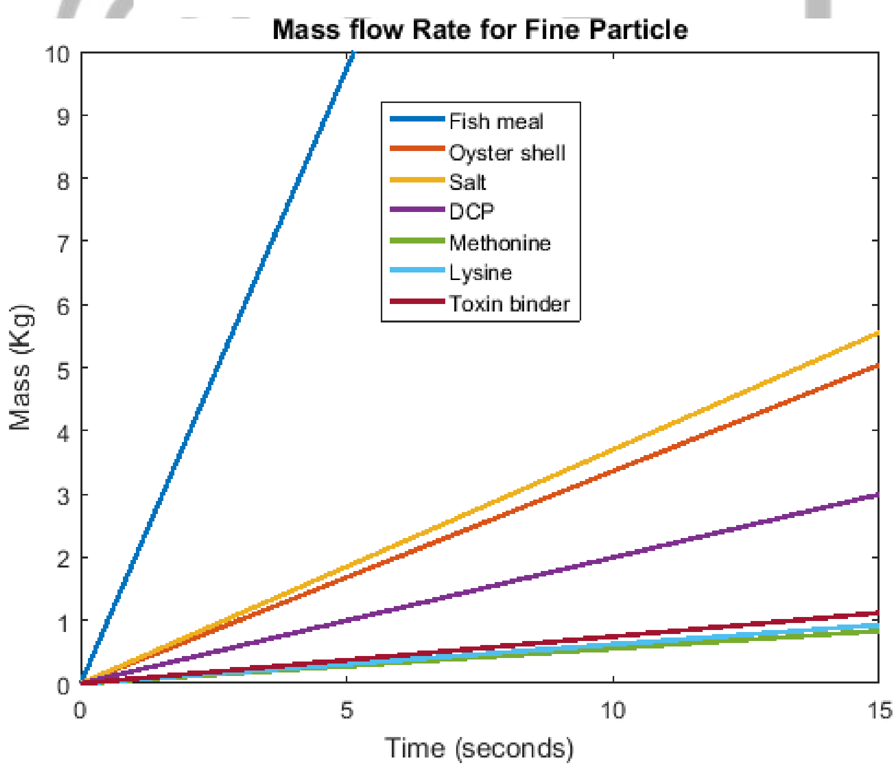

Figure 25: Mass flow rate for fine particles

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

In Plate I the HMI provided for a display of the entire system outlook:

The Bucket elevator (B.E) that conveys the ingredients to fill the hoppers. The push button panel activates the B.E motors and opens the valve of the respective push button number pressed ON. Hopper filling terminates immediately the high level sensor indicator activates (i.e. start to blink green light), this is achieved in simulator mode by the inbuilt simulator application (PLCSIM) provided by STEP7. The 'Stop Motor' button in the panel deactivates the B.E motor.

The fourteen ingredient hoppers which must be filled to high level sensor before the discharge process of the hoppers commences, the high level sensors remains active until low level sensors indicate that ingredient level is at their spot then high level sensor indicator deactivates while low level own activates, the hoppers valves open for discharge at the same time but closes at their individual calculated time equivalent to their estimated Mass and all the hoppers must discharge completely at the estimated rate before the level sensor in the two big hoppers that collects from the fourteen hoppers signal for valve opening to discharge into the mixer.

Since the program executes for continuous mixing processes, the mixer motor activates and keep running as the 'start' button is ON. The virtual Multipoint NIRs analyses with the aid of its sensor probes real time mixing process together with the controller which continuously collects generated values of the probes and evaluate for the best uniformity blend (i.e. the CV) of feed mixed, which when reached, activates for the opening of the outlet valve of the mixing chamber to discharge the feed while the mixer keeps rotating.

In this continuous automated mixing process of feed, quality nutrient blend poultry feed are produce continuously and faster without any interruption to the plant until complete processing of the required feed. But in batched processes which are prevalent in our industries, the plant process is intermittently interrupted to collect samples to check for mixture homogeneity.

However the results of the compared performance parameters of the two controllers responses in the Matlab simulation shows evidently that PID controller performed better with the system than HODFC.

5.2 Conclusion

The objectives of this project was achieved, the mass flow rate timings of the two particle categories (Coarse and Fine particles) of the various ingredient were analyzed and calculated for, using their modeled equations, adopted parameter values from different experiments done on analysis of mass flow hoppers and the standard feed formulation chart that was used to evaluate for the various ingredients Masses to make for a 25kg of mass feed. The analyses of the system from bucket elevator to the design of the mixing chamber were carried out. And finally the simulation of the whole processes of mixing in the system and the various performances were done with the required SIMANTICS STEP7 300 apparatus and implemented in WINCC HMI. The mixing process in the mixing chamber as its being controlled by PID controller was also simulated and performance rate compared with Higher Order Differential Feedback Controller (HODFC) in Matlab and Simulink and PID controller performed best.

5.2. Recommendation for future work

My recommendation is to consider finding or designing sensor(s) that will posses parameters for analyzing the differences in the properties of each of the various ingredients especially those of them with similar characteristics (like color, particle sizes etc) and identifying them with ease using such parameters. This will enhance further development of the PLC controller program that will give the controller avenue to make decisions on the choices of the feed ingredients with better nutrients quality to add and others to improvise in order to produce animal feed with optimal nutrient classes with limited raw materials.

REFERENCES

[1] Wilson, J. E. (1990). Raw Materials – Animal Protein. Feed Tech V Revised (Ist ed.)

[2] Grafman, L. (2007). Original: Small scale Manufacture of Compound Animal Feed 7 http://www.appropedia.org/Original:Small_scale_Manufacture_of_Compound_Animal_Feed_7

[3] Lindley, J. A. (1991). Mixing Processes for Agricultural and Food Materials, *Journal of Agricultural Engineering Research* **48**:153-170.

[4] Brennan J. G, Butters, J. R, Cowell, N. D. & VLilley, A. E. (2008). Food Engine operations, (3rd ed.). *Elsevier Applied Science*, London. pp. 91 – 107 and 287 – 89.

[5] New, M. B. (2007). Feed and Feeding of Fish and Shrimp, ADCP/REP/87/26, FAO/UNDP, Rome.

[6] Galim Engineering (2003). Article on Plant Feed mill. Website: http://garlim.com/

[7] Volosciuc, P. (2015). Granulator 300kg/h. www.youtube.com/watch?v=ELTmmy4x14g

[8] Peter, K. I. (2013). The organic farmer, (biovision). The magazine for sustainable agriculture in East Africa, No. 102. November 2013. http://www.biovision.ch/fileadmin/pdf/d/services/downloads/organic_farmer/org_farmer102_13_red.pdf

[9] Balami, A. A, Adgidzi, D, & Mua'zu, A. (2013). Development and Testing of an Animal Feed Mixing Machine, *International Journal of Basics and Applied Sciences*, Insan Akademika Publications, P-ISSN: 2301 – 4458; E – ISSN: 2301-8038.

[10] ASAE Standards, (ASAE S380 DEC1975 R2006). Test Procedure to Measure Mixing Ability of Portable Farm Batch Mixers, pp. 261 – 262.

[11] Ibrahim, S. O. & Fasasi, M. B. (2004). Design and Development of a Portable Feed Mixer for Small-scale Poultry Farmers. Proc. NIAE 26, Nov. 28 – Dec. 2, Ilorin.

[12] Instrumart (2018) "Process Controller Resources", https://www.instrumart.com

[13] Lakshman, P. (2008). Continuous blending of dry pharmaceutical powders. Unpublished Doctoral dissertation, Massachusetts Institute of Technology, 2008

[14] Oghene, O. O., (2018). Feed Analysis and Quality Laboratory Asaba. Animal Care Services Konsult (Nigeria) Ltd. www.animalcare-ng.com

[15] Foss, (2018). NIRS™ DS2600F, The dedicated analyser providing full confidence in flour and grain analysis. Foss analystics. May 2018. https://www.fossanalytics.com.

[16] Debanian, D. (2010). Analytical Techniques in Online Blend Uniformity in Powder Technology. Published on 24 October 2010. Formation & Process Development (small molecules & biologics manufacturing), Manager, R & D.

[17] Popo, M., Torres, R. S., Conde, C. & Romanach, R.J. (2002). Blend Uniformity Analysis using Stream Sampling and Near Infrared Spectroscopy, AAPS PharmSciTech 2002; 3(3) article 24 http://www.aapspharmsci.org

[18] Wenlong, L. & Haibin, Q. (2013). Characterization of herbal powder blends homogeneity using near-infrared spectroscopy. *Journal of innovative optical health sciences*, Vol. 7, No. 6 (2014) 1450004 (7 pages). DOI: 10.1142/S179354581 4500047.

[19] John, R. H. & Federick D. H. (2004). Programmable Logic Controllers: Programming Methods and Applications

[20] Sedgewick, R. & Wayne, K. (2016). Computer Science: An Interdisciplinary Approach Last Modified on July 25, 2016.

[21] Chase, G. G., (2001) Solids flow ability. The University of Akron. Uploaded by Ellantidinesh on Jul 13, 2012. Source: http://chemical.uakron.edu/fclty/chase/Solids/SolidsNotes10%20Hopper%20Design pdf

[22] Oko, C. O. C., Diemuodeke, E. O. & Edet, D. (2015). Conical hopper design parameters for selected food powders using ms excel add-in. *international journal of computer applications* (0975 - 8887), Volume 113 – No. 11, March 2015.

[23] Pacheco, W. J., Stark, C. R., Ferket, P. R., & Brake, J., (2013). Evaluation of soya bean meal source and particle size on broiler performance, nutrient digestibility and gizzard development. Poultry Science, Volume 92, Issue 11, pages 2914 – 2922. https://doi.org/10.3382/ps.2013-03186

[24] Feedipedia, (2016). Animal feed resources information system, on groundnut cake particle diameter. http://www.feedipedia.org/node/699. 12 August 2016.

[25] Sujeewa, A. (2000). The Evaluation of functional properties of fish meal. Icelandic fisheries laboratories, final project 2000. United Nation University, fisheries training program. P.O. Box 1390, Skulagata 4 120 Reykjavik, Iceland. http://www.unuftp.is/static/fellows/document/sujeewa3.pdf

[26] Gautério, C., Eliana, S. & Furlong, B. (2012). Effect of particle size and ammonium sulfate concentration on rice bran fermentation with the fungus *Rhizopus oryzae*. Under an *Elsevier* user license. Volume 123, November 2012, Page 36 – 41. https://doi.org/10.1016/j.biortech.2012.07.081Get rights and content

[27] Evonik Nutrition & Care, (2015). DL-Methionine for Aquaculture™ Production information. Evonik Nutrition & care GmbH, July 2015.

[28] Hwang, R. & Gretchen, R. P. (2001). A systematic evaluation of the compression and tablet characteristics of various types of lactose and dibasic calcium phosphate. Pharmaceutical technology, June 2001.

[29] Engineering tool box, (2005). Particle Sizes. [online] Available at: https://www.engineeringtoolbox.com/particle-sizes-d_934.

[30] Caltron, (2015). Caltron's DCP / Dicalcium Phosphate as an Animal Feed Supplement. © 2015 Caltron Clays & Chemicals Pvt. Ltd. http://www.caltronclays.com/dicalcium-phosphate.html

[31] Merck KGaA, (2018). 816010 | L-Methionine: L- Methionine for synthesis. CAS 63-68-3, pH 5-7. 2018 Merck KGaA, Darmastadt, Germany and / or its affiliates. All rights reserved. http://www.merckmillipore.com/INTL/en/product/L-Methionine

[32] Dale, A. B., Carl L. R., Gerry L. K., Dionisia, M. T., Jim, S. D., Keith, C. B. *et al*. (1998). Wheat middlings composition, feeding value, and storage guidelines, Kansas State University, August 1998. https://www.bookstore.ksre.ksu.edu/pubs/mf2353.pdf

[33] Gwirtz, J. A., Nieves, M. & Casal, G. (2013). Processing maize flour and corn meal food products. Annals of the New York Academy of Sciences. First published: 11 December 2013. https://doi.org/10.1111/nyas.12299 [34] ADCP (1980). Bulk density, pelletability and particle size. Appendix XI. http://www.fao.org/docrep/s4314e/s4314e0q.htm

[35] Evans, P. (2015). Properties of air at atmospheric pressure. The Engineering mind set.com. Published 29 March 2015. http://theengineeringmindset.com/properties-of-air-at-atmospheric-pressure/

[36] Carleton, A. J. (1972). "The Effect of Fluid-Drag Forces on the Discharge of Free-Flowing Solids from 23 Hoppers. " Powder Tech. 6, 91-96.

[37] Inwelegbu, J. O. & Nwodoh, T. A. (2011). FPGA controller design and simulation of a portable dough mixing machine. Department of Electrical Engineering, faculty of Engineering, University of Nigeria Nsukka. *Nigerian journal of technology*, Volume 30. No.1, March 2011.

[38] Sani, G. Shehu, A., Maijama'a, L. & Shehu, Y. (2018). Holonic control of poultry house travelling hopper feeders and comparative cost analysis. *International Journal of Engineering Technologies and Management Research (IJETMR),* DOI: 10.5281/zendo. 1304420. ISSN: 2454-1907. Page 36. June 2018.

[39] Bakar, R.& Reddy, P. L. (2015). Concept and application of PID control and implementation of continuous PID controller in Siemens PLCs. Department of Electrical Engineering, University college of Engineering, Osmania University, Hyderadad – 500007, Telangana, India. *India journal of science and technology,* Vol. 8 (35), DOI: 10.17485/ijst/2015/v8i35/82262. ISSN (Online): 0974-5645.

[40] Nyabundi, A. S., Qi, G., Hamam, Y., & Munda, J. (2009). DC motor control via High Order Differential Feedback Control. *IEEE Africon* 2009, 5 Pages.

[41] Eli, A. (2011). Development of a continuous blending system, controlling a blending system. (Master's Thesis, Division of Industrial Electrical Engineering and Automation, Faculty of Engineering, Lund University)

[42] Xiaojuan, Z. (2014). Contribution to the Implementation of a Process Control System for Continuous Powder Mixing. HAL Id, https://tel.archives-ouvertes.fr/tel-00975251

[43] Johansson, J. R. (1966). The Use of Flow-corrective Inserts in Bin. Transactions of the ASME Journal of Engineering for Industry. 88: 224-230.

[44] Koller, D. M., Posh, A., Horl, G., Voura, C., Radl, S., Urbanetz, N. et al. (2010). Continuous quantitative monitoring of powder mixing dynamics by near-infrared spectroscopy. Powder technology 205 (2011) 87-96. Published by *Elsevier* B.V. doi: 10.1016/j.powtec.2010.08.07.0.

APPENDIX 1

Table 11. Parameters in the Johanson Equation.

Parameter	Conical hopper	Symmetric slot hopper
B	D. diameter of outlet	W
A	$\frac{\pi}{4}D^2$	WL
m	1	0

(Source: Chase, 2012)

APPENDIX 2

The Structured Controlled Language (SCL) that generate random numbers to represent the virtual multipoint NIRs process analyzed values for the CPs which continuously is declared and assigned to X_BAR (i.e. the mean).

SIMATIC   Joe_study\   09/05/2018 04:51
SIMATIC 300 Station\CPU314C-2 DP(1)\...\FB205

```
FUNCTION_BLOCK FB205

    VAR_INPUT
        CP1:REAL:=0.2;
    END_VAR

    VAR_IN_OUT
        REST:BOOL:=FALSE;
    END_VAR

    VAR_OUTPUT
        X_BAR:REAL;

    END_VAR

    VAR
        TEMP:REAL:=0;
    END_VAR

    IF REST=1 THEN
        X_BAR:=0;
    ELSE
        X_BAR:=CP1+0.0101;
    END_IF

    ;
END_FUNCTION_BLOCK
```

APPENDIX 3

The Structured Control Language (SCL) of SIMANTICS controller that runs the calculation of the Xs, SDs and the CVs for each of the four channels.

SIMATIC　　　Joe_study\　　　09/05/2018 07:06
SIMATIC 300 Station\CPU314C-2 DP(1)\...\FB201

```
FUNCTION_BLOCK FB201

    VAR_INPUT
        CP1:REAL:=0.2;
        CP2:REAL:=0.2;
        CP3:REAL:=0.2;
        CP4:REAL:=0.2;
    END_VAR

    VAR_IN_OUT
        REST:BOOL:=FALSE;
    END_VAR

    VAR_OUTPUT
        X_BAR:REAL;
        SD:REAL;
        CV:REAL;
    END_VAR

    VAR
        TEMP:REAL:=0;
    END_VAR
    IF REST=1 THEN
        X_BAR:=0;
        SD:=0;
        CV:=0;
    ELSE
        X_BAR:=(CP1+CP2+CP3+CP4)/4;
        TEMP:=(CP1-X_BAR)*(CP1-X_BAR) + (CP2-X_BAR)*(CP2-X_BAR) + (CP3-X_BAR)*(CP3-X_BAF
(CP4-X_BAR)*(CP4-X_BAR);
        SD:=SQRT(TEMP/3);
        CV:=100*(SD/X_BAR);
    END_IF

    ;
```

The SCL that evaluate and calculates the average CV (i.e. final CV) of the cummulative CVs of the four channels.

SIMATIC Joe_study\ 09/05/2018 07:10
SIMATIC 300 Station\CPU314C-2 DP(1)\...\FB210

```
FUNCTION_BLOCK FB210

    VAR_INPUT
        CV1:REAL:=0;
        CV2:REAL:=0;
        CV3:REAL:=0;
        CV4:REAL:=0;
    END_VAR

    VAR_IN_OUT
        REST:BOOL:=FALSE;
    END_VAR

    VAR_OUTPUT
        F_CV:REAL;
    END_VAR

    VAR
        TEMP:REAL:=0;
    END_VAR
    IF REST=1 THEN
        F_CV:=0;
    ELSE
        F_CV:=(CV1+CV2+CV3+CV4)/4;
    END_IF

    ;
END_FUNCTION_BLOCK
```

APPENDIX 4

The plant model block and the SCL of the plant model.

SIMATIC   Joe_10\   09/21/2018 08:01:
SIMATIC 300 Station\CPU314C-2 DP(1)\...\FB300

```
FUNCTION_BLOCK FB300

// Block Parameters
VAR_INPUT
  // Input Parameters
  R:REAL;
    A:REAL:=1.0;
      B:REAL:=1.0;
      C:REAL:=1.0;
      D:REAL:=1.0;
      //E:REAL:=1.0;
  INTERVAL:TIME:=T#1S;
END_VAR

VAR_IN_OUT
 REST:BOOL:=FALSE;
END_VAR

VAR_OUTPUT
 // Output Parameters
 Y:REAL;
END_VAR

VAR_TEMP
  // Temporary Variables

END_VAR
VAR
  // Static Variables
X1:REAL:=0.0;
X2:REAL:=0.0;

X1OLD:REAL:=0.0;
X2OLD:REAL:=0.0;

DELTA1:REAL:=0.0;
DELTA2:REAL:=0.0;
T_INTERNAL:REAL:=1.0;
ROLD:REAL:=0.0;
RNEW:REAL:=0.0;
END_VAR

  // Instruction Section
T_INTERNAL := (DINT_TO_REAL(TIME_TO_DINT (INTERVAL)))/1000.0;
IF REST=1 THEN
    X1:=0.0;
    X2:=0.0;
    X1OLD:=0.0;
```

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186


```
   _

  // Instruction Section
T_INTERNAL := (DINT_TO_REAL(TIME_TO_DINT (INTERVAL)))/1000.0;
IF REST=1 THEN
    X1:=0.0;
    X2:=0.0;
    X1OLD:=0.0;
    X2OLD:=0.0;
    ROLD:=0.0;
    RNEW:=0.0;
    T_INTERNAL := (DINT_TO_REAL(TIME_TO_DINT (INTERVAL)))/1000.0;
    //REST:=0;
    Y:=0;
ELSE
    RNEW:= R;
    DELTA2 :=((D*RNEW)- (C*X1OLD) - (B*X2OLD))/A;
    X2:= X2OLD + (DELTA2 * T_INTERNAL);
    DELTA1 :=X2;
    X1 := X1OLD + (DELTA1 * T_INTERNAL);
    X2OLD:= X2;
    X1OLD:=X1;
    Y:=X1;
    ROLD:=RNEW;
    T_INTERNAL := T_INTERNAL + (DINT_TO_REAL(TIME_TO_DINT (INTERVAL)))/1000.0;;
        ;
END_IF;
  ;
END_FUNCTION_BLOCK
```

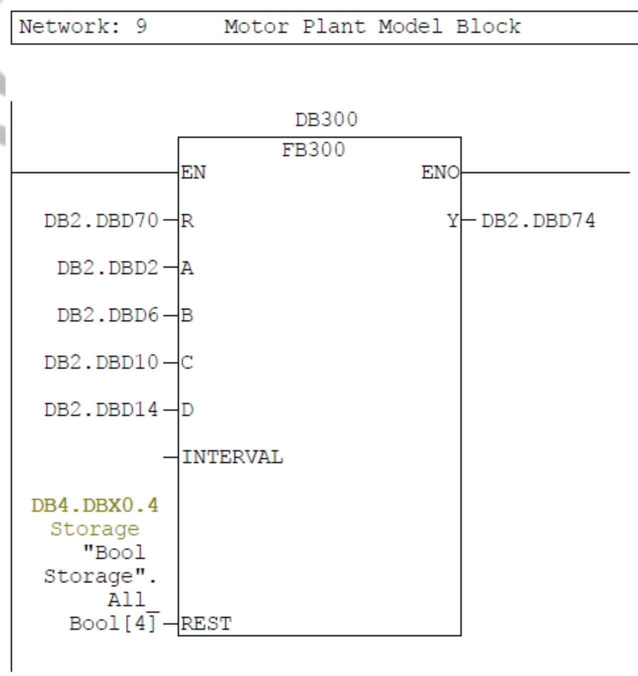

Figure 46: Plant model block

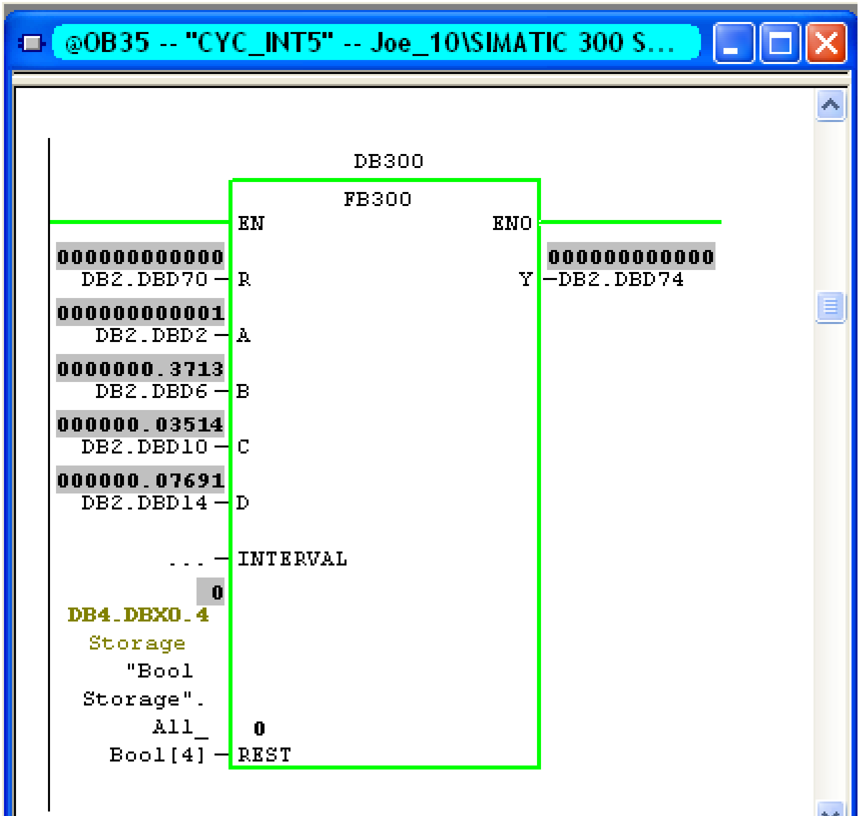

Plate XVII: Motor Plant model block simulation

APPENDIX 5

The conditions and logics that guided the implementation of the startup processes as represented in the flow chart of the process flow chart (figure 21) with dotted lines.

For the operation of the Bucket Elevator (B.E) these logics go:

The valves of the various hoppers (Tanks) that are to collect inputs directly from the B.E were labeled, recorded and identified by the controller as V_A, V_B, …..,V_N & V_S, in accordance to their respective alphabets, that is, V_A is the valve for hopper A; V_B is the valve for hopper B and so on.

The flow of ingredients in and out of the hoppers will be guided by two different sets of valves which will be represented as; $\mathbf{X_n}$, will be set of the inlet valves and $\mathbf{O_n}$, will be set of the outlet valves.

Where, **n** is the various numbering (from 1 to 15) indicating, for example during start up, if only valve for hopper A (V_A) is logically meant to be opened in the set of 15 inlet valves while other valves remain closed, that particular outcome in that set will be assigned X_1 and if the same applies for V_B, the set will be assigned X_2 and so on for the 15 valves (as illustrated below and elaborated in the logic table 7). V_S will be the discharge for the excess ingredient.

$$X_n = V_\beta . \overline{Y_n} \qquad \text{…………………84}$$

Example; $X_1 = V_A . \overline{Y_1}$ …………...…….85

Where, $\overline{Y_1} = \overline{V_B . V_C . V_D . V_E . V_F . V_G . V_H . V_I . V_J . V_K . V_L . V_M . V_N . V_S}$

And, $Y_1 = V_B . V_C . V_D . V_E . V_F . V_G . V_H . V_I . V_J . V_K . V_L . V_M . V_N . V_S$

GSJ: Volume 7, Issue 1, January 2019
ISSN 2320-9186

Since valves can either be open or closed, If the logical 1 indicates ON signal, then logical 0 represents OFF (that is ON = 1 and OFF = 0). Where ON also indicates valve Opened and OFF indicates valve closed. When for example, valve for hopper A (V_A) is open V_A = 1 and if the valve is NOT ($\overline{V_A}$) open, then V_A = 0 and $\overline{V_A} = 1$ (implying it's closed), the same applies to other valves. According to the logic symbols and table of Parag (2002) and Muhamed (2017) in their Boolean algebra and logic gates presentations the following logic tables were formed;

Table 13. The Logic Table,

INPUTS Y_n																OUTPUT X_n		
n	V_A	V_B	V_C	V_D	V_E	V_F	V_G	V_H	V_I	V_J	V_K	V_L	V_S	Y	$\bar{Y}$	V_β	$V_\beta.Y$	$V_\beta.\bar{Y}$
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	V_A	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	V_B	0	1
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	V_C	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	V_D	0	1
5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	V_E	0	1
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	V_F	0	1
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	V_G	0	1
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	V_H	0	1
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	V_I	0	1
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	V_J	0	1
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	V_K	0	1
12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	V_L	0	1

APPENDIX 6

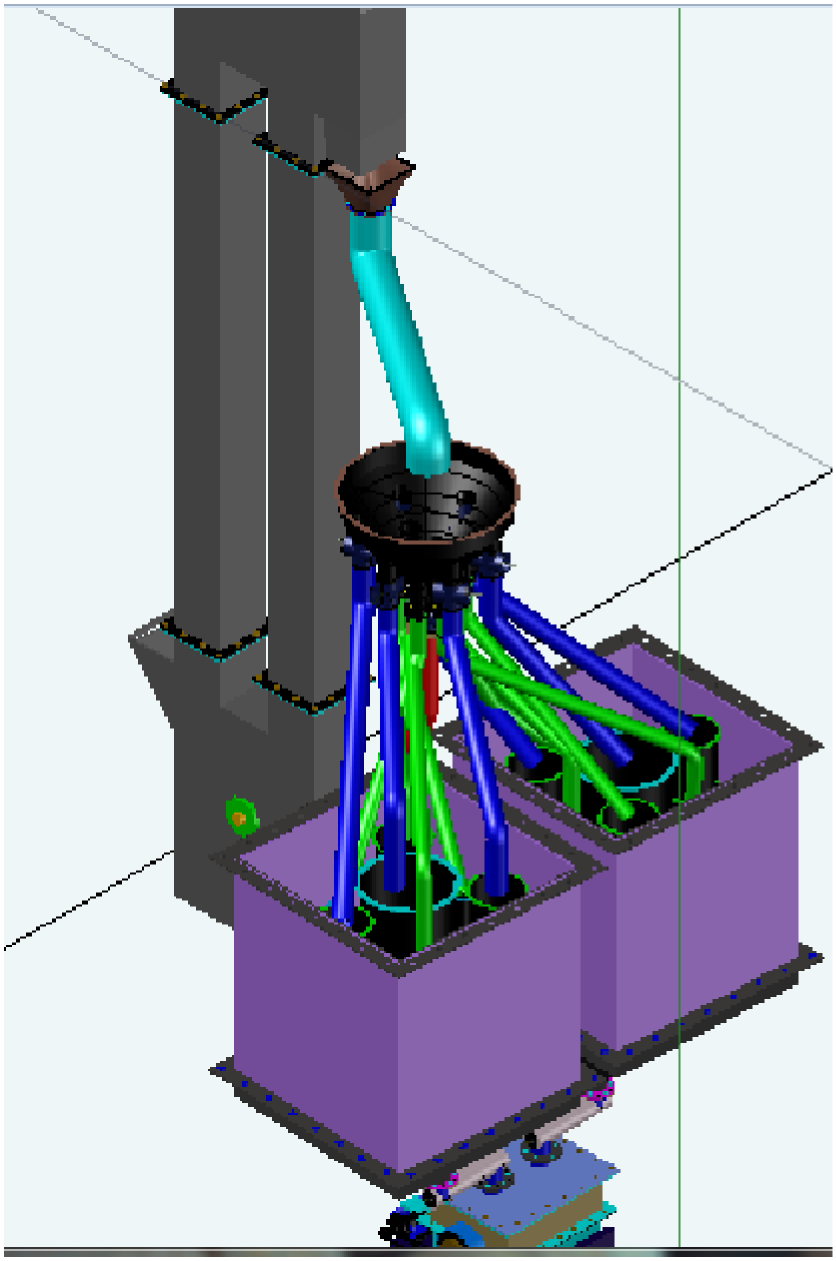

Figure 47: Autocad Model of the Plant