بسم الله الرحمن الرحيم

Sudan University of Science & Technology

College of Graduate Studies

Fuzzy Logic Sequence Control for Batch Sugar Centrifugal Machines

المنطق الغامض للتحكم في التسلسل الزمنى بماكينات الطرد المركزى لنفض السكر بالدفعات

A Thesis Submitted for the award of the degree of M.Sc.

In Mechatronics Engineering

By

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Dedication

To the soul of my mother and my father, to my brothers and sisters, and to my wife and to my sons.

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The start Praise be to almighty GOD the Merciful for strength and unlimited gifts which is given, and beside all of these my conduction to this study, sincere thanks to my supervisors Dr **/ Ala Alden Awada** & Dr / **Mohamed Nour A/Allah** for their tips precious and guidance and valuable advices and assistance and also I appreciate follow-up and attention , gratefully and sincerely thank coordinator Dr / **Khawad Elfaki** on the effort Ripper and who suffered hardships to complete the program of mechatronics, which truly is one of the best graduate program , I would also like to make special thanks to **Kenana** Sugar factory for setting up the study and hosting our professors and assistance doctors, and finally thankful be to everyone helped and contributed from the beginning until to the completion of the Master degree, I hope improving reward and success for all.

LIST OF CONTENTS

	Subject	Page
	Dedication	I
	Acknowledgement	II
	List of Contents	III
	List of Figures	VI
	Abstract	VIII
	Arabic Abstract	Viii
	Abbreviation	X
1	Chapter One: Introduction	1
1.1	Background	1
1.2	Problem Statement	2
1.3	Problem Propose	2
1.4	Objective & Significant	3
1.5	Simulation Tools	3
1.6	Methodology	3
1.7	Thesis out Lines	4
2	Chapter Two: Literature review	5
2.1	Sugar Industry Description	5
2.1.1	Harvesting	5
2.1.2	Cane Sugar Production	5
2.2	Batch Centrifugal Description	9
2.2.1	Principles of Operation	11
2.2.2	Basket	12
2.2.3	Main Drive Motor	12

2.2.4	Spindle and Bearing Housing	13
2.2.5	Casing and Support Frame	13
2.2.6	Cooling and Anti-Precession Systems	14
2.2.7	Braking System	14
2.2.8	Feeding System	15
2.2.9	Feed Limiter	15
2.2.10	Plough Discharger	16
2.2.11	Discharge Valve	17
2.2.12	Process Fitments	18
2.2.13	Control Panel (PLC)	18
2.2.13.1	Central Processor Unit (CPU)	19
2.2.13.2	Power Supply Unit (PSU)	19
2.2.13.3	Input Modules	19
2.2.13.4	Output Modules	19
2.2.14	Speed Monitoring System	19
2.2.15	Machine Electrical Equipment	20
2.3	Cycle Operation	21
2.3.1	Cycle Modes	22
2.4	Batch centrifugal drives	23
2.4.1	Centrifugal drive requirements	23
2.4.2	Inverter drives	24
2.5	ASSALAYA Power Generation House	26
2.5.1	Steam Turbine	26
2.5.2	A.C-Generator	26
2.6	Sequence of Centrifugal Machines	27
2.6.1	Connection required for sequence panel	29
2.6.2	Required centrifuge HMI settings with sequence panel	30

2.6.3	Sequence on Acceleration	33
2.6.4	Sequence on Plough	33
3	Chapter three: Method and calculations	34
3.1	Introduction to fuzzy logic	34
3.2	Fuzzy System Components	34
3.2.1	Fuzzification	35
3.2.2	Fuzzy Inference System (FIS)	35
3.2.3	Defuzzification	35
3.3	Tool Used for Sequence Control	36
3.3.1	Fuzzy Logic Toolbox	37
3.3.2	Basic FIS editor	38
3.3.2.1	Spin time	39
3.3.2.2	Last request	40
3.3.2.3	Delay time	41
3.3.3	Fuzzy Rule Base	42
3.4	Model Simulation	45
3.5	Calculation of Delay Time	49
4	Chapter four: Results and Discussions	52
5	Chapter four: Conclusions and Recommendations	62
5.1	Conclusions	62
5.1	Recommendations	66
	References	63
	Appendices	65

LIST OF FIGURES

Fig No	Description	Page
Fig (2.1)	Simplified process flow diagram for cane sugar production	7
Fig(2.2)	General Arrangement of Centrifuge	10
Fig (2.3)	Speed and motor current against time for an inverter drive	26
Fig (2.4)	centrifuge cycle time	29
Fig(2.5)	5/10 BROADBENT SEQUENCE CONNECTION WITH PLC	30
Fig (2.6)	Main Screen	31
Fig (2.7)	Spin Screen	32
Fig (2.8)	Sequence Selecting Icons	32
Fig (3.1)	Fuzzy logic modeling process	36
Fig (3.2)	Fuzzy Inference System Editor	37
Fig (3.3)	Input Variables	39
Fig (3.4)	Spin Time Input Variable	40
Fig (3.5)	Last Request (input variable)	41
Fig (3.6)	Delay Time (output variable)	42
Fig (3.7)	Fuzzy Rule Base	44
Fig (3.8)	A Graphical Representation of the Nonlinear Function	44
Fig (3.9)	Machines Data Entry Dialogue-Box	45
Fig (3.10)	A MODEL OF FUZZY LOGIC SEQUENCE CONTROL FOR BATCH SUGAR CENTRIFIGUAL MACHINES	46
Fig(3.11)	Curve of M/C Speed & Current Vs Time	47
Fig(3.12)	FLOW CHART FOR BATCH SUGAR CENTRIFIGUAL M/C SEQUENCE CONTROL USING FL	48
Fig(3.13)	Delay time Calculation	49
Fig(4.1)	Machines sequence at equal values of spin, feed & plough times	52

Fig(4.2)	Total Current	53
Fig(4.3)	Machines in Sequence at different values of Spin, Feed &Plough	54
Fig(4.4)	Total Current of machines sequence at different values of spin, Feed & plough times	55
Fig (4.5)	M/c's current at (5s,5s,5s) values of feed, spin& plough times	55
Fig4.6)	M/c's current at (10s,10s,10s) values of feed, spin& plough times	56
Fig(4.7)	M/c's current at (15s,15s,15s) values of feed, spin& plough times	56
Fig (4.8)	M/c's current at (15s,20s,15s) values of feed, spin& plough times	56
Fig (4.9)	M/c's current at (20s,20s,20s) values of feed, spin& plough times	56
Fig(4.10)	M/c's current at (20s,30s,20s) values of feed, spin& plough times	57
Fig(4.11)	M/c's current at (20s,35s,20s) values of feed, spin& plough times	57
Fig (4.12)	M/c's current at (20s,40s,20s) values of feed, spin& plough times	57
Fig (4.13)	M/c's current at (15,s40s,20s) values of feed, spin& plough times	58
Fig (4.14)	M/c's current at (20s,40s,15s) values of feed, spin& plough times	58
Fig(4.15)	M/c's current at (15s,40s,15s) values of feed, spin& plough times	58
Fig (4.16)	M/c's current at (10s,40s,10s) values of feed, spin& plough times	58
Fig(4.17)	M/c's current at (10s,40s,5s) values of feed, spin& plough times	59
Fig (4.18)	M/c's current at (5s,40s,10s) values of feed, spin& plough times	59
Fig (4.19)	M/c's current at (10s,40s,15s) values of feed, spin& plough times	59
Fig (4.20)	M/c's current at (15s,40s,10s) values of feed, spin& plough times	59
Fig(4.21)	M/c's current at (15s,40s,5s) values of feed, spin& plough times	60
Fig (4.22)	M/c's current at (20s,40s,5s) values of feed, spin& plough times	60
Fig(4.23)	M/c's current at m/c-1 (20s,40s,20s) , m/c-2 (25s,40s,15s) & m/c3 (15s,40s,25s) values of feed, spin& plough times	61
Fig (4.24)	M/c's current at m/c-1 (20s,40s,20s) , m/c-2 (30s,40s,10s) & m/c3 (10s,40s,30s) values of feed, spin& plough times	61

ABSTRACT

This study is searching for a solution to the rapid oscillation of the current which happened due to the cyclic operation of the batch sugar centrifugal machines, the current oscillation affects the stability of electrical generation produce by steam turbine alternators at ASSALAYA Sugar Factory power station, the solution is focus on sequencing these sugar machines.

Fuzzy logic control and Matlab Simulink are used to make a model of **three** batch sugar machines, the data is taken from Broadbent C46M batch centrifuge at Assalaya sugar factory, and the model represent the current behavior of the machines under working. Organizing the operation of these machines with sequence control is done by selecting the suitable delay time between machines, and this is done when the centrifuge M/C requesting permission from the sequence control to accelerate to the high speed.

Two parameters in fuzzy logic control is used to obtain the desired delay time, the first parameter is depending on the previous machine spinning time duration and the second depend on the time taken between the previous machine get a permission until the current machine requesting permission from sequence control.

When the default values of feed time, spin time & plough time are taken equal to (20s, 40s & 20s) respectively to and be identical for three machines, the total current oscillation has been minimized to 43.75% (compared with peak oscillation of only one machine) and in repeated form, and the total current of the three machines is being less than the current one machine. And in other cases when these parameters has different values the sequence control program also regulate the operation of the machines and the total current not exceed the current taken by one machine.

مستخلص البحث

تبحث هذه الدراسةِ لحَلّ مشكلة تذبذبِ التيار الشديد الذي يحَدثَ بسبب طبيعة العمل الدوري المتغير لماكينات نفض السكر الابيض بالطرد المركزي ، وهذا التذبذب فى التيار يُؤثرُ على استقرار انتاج الطاقة الكهربائية بمولدات التوربينات البخارية في محطةِ كهرباء مصنع سُكّر عسلاية ، الحَلّ إرتكز على التحكم فى التسلسل الزمنى (Sequence control) بهذه الماكينات.

إستخدم التحكم بالمنطق الغامض(Fuzzy Logic Control) وكما تم إستخدام (Simulink Matlab) لعمل نموذج لثلاث ماكينات نفض سكر ابيض ، البيانات مَأْخُوذةٌ مِنْ ماكينات النفض ل Broadbent C46M ، و النموذجَ يُمثّلُ محاكاه لسلوكَ هذه الماكينات اثناء التشغيل، تَنظيم عمل هذه الماكينات تم بواسطة التحكم فى التسلسل الزمنى بإخْتيار فترة تأخير مناسبة بين ماكينة واخرى سابقة لها ، وذلك عندما تطلب ماكينة من التحكم السماح لها بالوصول إلى السرعةِ العالية للنفض.

تم اختيار معاملان في التحكم بالمنطق الغامض للحُصُول على وقتِ التأخير المناسب، المعامل الاول اعتمدُ على فترةَ النفض فى السرعة العالية للماكينةِ السابقة والثانى على الوقتُ المأخوذ بين حصول الماكنةِ السابقةِ على السماح بالوصول للسرعة العالية حتى وقت الطلب با لسماح من التحكم للماكنةِ الحاليةِ.

عندما تم اختيار وقت التغذيةِ للماكينة ، وقتِ النفض ووقتِ لتفضية السكر ب (20 ثانية ، 40 ثانية ،20 ثانية) مساوية لقيم ضبط المصنع و موحد ة للماكينات الثلاث ،انخفض التذبذب الحالي الكليّ إلى 48.38% (مقارنة باعلى قيمةللتذبذعند تشغيل ماكينة واحدة) وكان التيارِ الكليِّ لهذه الماكينات أقل مِنْ التيارالمخذوذ بواسطة ماكينةِ واحدة. وفي حالات اخرى تم اختيار قِيَمُ مختلفةٌ لاوقات التغذيةِ و النفض و تفضية السكر ، أيضاً تم تنظّيمُ عمل هذه الماكينات والتيارِ الكليِّ لم يَتجاوزَ التيارَ لماكنةِ واحدة.

ABBREVIATIONS

- AC : Alternating current
- AVR : Automatic Voltage Regulator
- BOA : Bisector of area
- ^{o}C : Degree centigrade
- CPU : Central Processor Unit
- COG : (Centroid) as centre of gravity
- DC : Direct current
- EMC : Electromagnetic compatibility
- EPROM : Erasable programmable read only memory
- ^{o}F : Degree Fahrenheit
- FIS : Fuzzy Inference System
- FLC : Fuzzy Logic Control
- GUI : Graphical User Interface
- Hz : Hertz, unit of frequency
- IGBT : Isolated-gate bipolar transistor
- Kph : Kilometer per hour
- LED : Light Emitting Diode LED
- LM : Leftmost maximum
- mA : Mille ampere
- M/c : Machine
- MF : The Membership Function
- MOM : Mean of maxima
- Mph : Mile per hour
- PLC : Programmable Logic Controller

- PSU : Power Supply Unit
- PWM : The pulse width modulated
- Rpm : Revolution per minute
- S : Second
- VSD : Variable frequency drive

CHAPTER ONE
INTRODUCTION

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

In the year 2003 Assalaya Sugar factory has established a new project for sugar boiling to increase sugar quality called “A” Additional according to that the old sets of 650 kg/cycle batch sugar centrifugal machines has been replaced by a new one of 1200 kg/cycle which is bigger in numbers and capacity, and it’s use modern technology in the controlling units (PLC) and as well as drive units (inverter) or VSD (Variable frequency drive), these machines take and return back power to the system then the power consumption become unstable.

The batch sugar centrifugal machines operate in cyclic way, and is driven by three phase induction motor, via voltage frequency drive or inverter to control the speed of the machine [15], according to the characteristic of current speed (slip) curve, the induction motor work in tow modes, firstly the **motor mode** which is the most operation of the centrifuge machines, in this mode the machine consume power from system, and secondly the **brake mode** (when machine is de-accelerate from high speed) [2] , in this case the machine produce regenerative power and fed with the aid of inverters back to the system [15].

In order to organize the operation of sugar machines in a battery, so avoiding many machines to accelerate to spin speed or drop sugar in the conveyor at the same time, machines is delayed by constant time between each other with aid of controller called a sequence control.

1.2 PROBLEM STATEMENT

Almost in sugar production power is generated in the factory by steam turbine alternators , the rapid fluctuation due to the cyclic operation of the batch centrifugal machines cause instability in the generated power that produce by steam turbine alternator, so that the governor and actuator of the generator cannot easily compensate the large variation of the loads, the power house operator always keep looking at this fluctuations and sometimes load is reduced manually to solve situation. It is a challenge to obtain mathematical solution to organize the sequence operation of batch sugar machines because there are many variables affecting their work, these parameters varies from one machine to another and also from time to time in the machine itself (i.e. Load, cycle time, speed & etc).

1.3 PROBLEM PROPOSE

In this study Fuzzy Logic Control (FLC) has been used to organize the operation of the machines, rather than constant delay time sequence control, FLC become a common and well known in machine control. However, fuzzy logic is actually very straight forward. And it has a way of interfacing inherently analog processes that move through a continuous range of values, a digital or discrete numeric values [3]. Fuzzy Logic Control methods represent a rather new approach to solve the problems of controlling complex nonlinear systems, the systems whose mathematical model is difficult or impossible to describe, and with the systems which had multiple inputs and outputs and characterized by hardly defined internal interference. It must be said that Fuzzy Logic Control techniques earned more respect from the engineering population after numerous applications on technical and non-technical systems [17].

1.4 OBJECTIVE & SIGNIFICANT

The **objective** of this study is to minimize the current fluctuation during the cyclic operation of the batch sugar centrifugal machines, and the **significance** is to avoid the hazards due to high variation of current taken or fed by the centrifugal machines ,and beside that the study keeping continuous flow of sugar product after dropping it in the grass hopper (sugar conveyor) by arranging the machines sequence so that not more than one machine discharging in the same time, that perform good condition for the coming process like sugar drying weighting and bagging.

1.5 SIMULATION TOOLS

Due to the difficulty to make the study on centrifugal sugar machines in the factory during the crushing season and avoiding delay times and stoppages of the production, and father more to obtain initial result for performance and evaluation, a Matalab Simulink is used to make model of three batch sugar centrifugal machines, the simulation take the data form Assalaya sugar factory when the machines running without mesquite (no load).

Fuzzy logic control with parameters is used to organize the operation of these machines by selecting suitable delay between them.

1.6 METHOGOLOGY

The initially step of research has been began from the **observation** on the rapid current fluctuations in the circuit breaker of centrifugal machines at the power house, trials has been done on adjusting the sequence control for these machines by selecting delay time and operating the machines according to machines number order or arbitrary order, more over the sequence control units has been by replaced new one, it use PLC with additional functions but the oscillation still occur.

The main problem was on the cyclic operation of the centrifugal machines, the solution depend on separation of these machines with suitable delay time to give minimum oscillation, the **hypotheses** based on adding a current of one machine during acceleration to high speed with the current of other machine which is de-accelerate from high speed.

A model is made in Simulink and fuzzy logic is used to control the sequence of these machine, by taking delay or wait time when machine is running to accelerate to high speed, the delay time is get according to the battery and machine condition, the current shooting minimize by coinciding the accelerate period of one machine with the electrical brake or the regenerative period of the previous centrifugal machine.

Tow parameters has been use in Fuzzy logic control to get the desire solution (delay time), these parameters are spin time and time interval between a machine and other proceed it, the **test** has been done to this model by changing the cycle interval time of all machines, this made by decrease or increase the time of feeding, spin or plough.

1.7 THESIS OUT LINES

Chapter one is for introduction showing the problem and it is solutions, objectives etc, and chapter two for literature review give information about sugar factory and about centrifugal mechanics and it's control ,drive units , chapter three showing fuzzy control and sequence calculations, chapter four is results and discussion and finally chapter five for conclusions and recommendations.

CHAPTER TWO
LITERATURE REVIEW

CHAPTER TWO
LITERATURE REVIEW

2.1 SUGAR INDUSTRY DESCRIPTION

Sugarcane processing is a production of sugar from sugarcane, there are byproducts of the processing include bagasse, molasses, and filter cake. Bagasse is the residual woody fiber of the cane, is used as fuel source for the boilers in the generation of process steam, Bagasse also is used as production of numerous papers and Paper board products and reconstituted panel board. Thus, bagasse is a renewable resource. Dried filter cake is used as an animal feed supplement, fertilizer, and source of sugarcane wax. The final byproduct is Molasses is used as edible syrup. And also used to produce ethanol, compressed yeast, citric acid, and rum.

2.1.1 HARVESTING

The primary goal of harvesting is to deliver to the processing mill good quality sugarcane stalks with a minimum of trash. During harvesting, the cane tops and leaves are removed because they contain little sucrose but are high in starch and reducing sugars, which reduces sugar yields.

2.1.2 CANE SUGAR PRODUCTION

A simplified process flow diagram for a typical cane sugar production plant is shown in Figure 2-1. The cane is received at the mill and prepared for extraction of the juice. At the mill, the cane is mechanically unloaded and placed in a large pile. Prior to milling, the cane is cleaned, usually with high pressure water, the milling process occurs in two steps: first is breaking the hard structure of the cane and second is grinding the cane. Breaking the cane uses revolving knives, shredders, crushers, or a combination of these processes. For the grinding, or milling, of the crushed cane, a three-roller mill is most commonly used although some mills consist of four, five, or six rollers in a single mill. Multiple sets of mills are used with combinations of 15 to 18 rollers being predominant. Conveyors transport the crushed cane from one mill to the next. Imbibitions are the process in which water or juice is applied to the crushed cane to enhance the extraction of the juice at the next mill. The common procedure is to send the juice from the crusher and the first two mills for further processing. In imbibitions, water or juice from other processing areas is introduced into the last mill and transferred from mill to mill towards the first two mills while the crushed cane travels from the first to the last mill. The crushed cane exiting the last mill is called bagasse. The juice from the mills is strained to remove large particles and then clarified.

Clarification is done almost exclusively with heat, and lime and phosphoric acid is added. The lime is added to neutralize the organic acids and the temperature of the juice is raised to about 95 ^{o}C (200 ^{o}F). A heavy precipitate forms which is separated from the juice in the clarifier. The phosphate acts as a flocculating agent. The insoluble particulate mass, called "mud", is separated from the limed juice by gravity. Clarified juice goes to the evaporators without additional treatment. The mud is filtered and the filter cake is washed with water; the wash water is added to the juice recovered during filtration. The juice is screened again before going to evaporate water.

Evaporator stations consist of a series of evaporators, termed multiple-effect evaporators. This process typically uses a series of five evaporators.

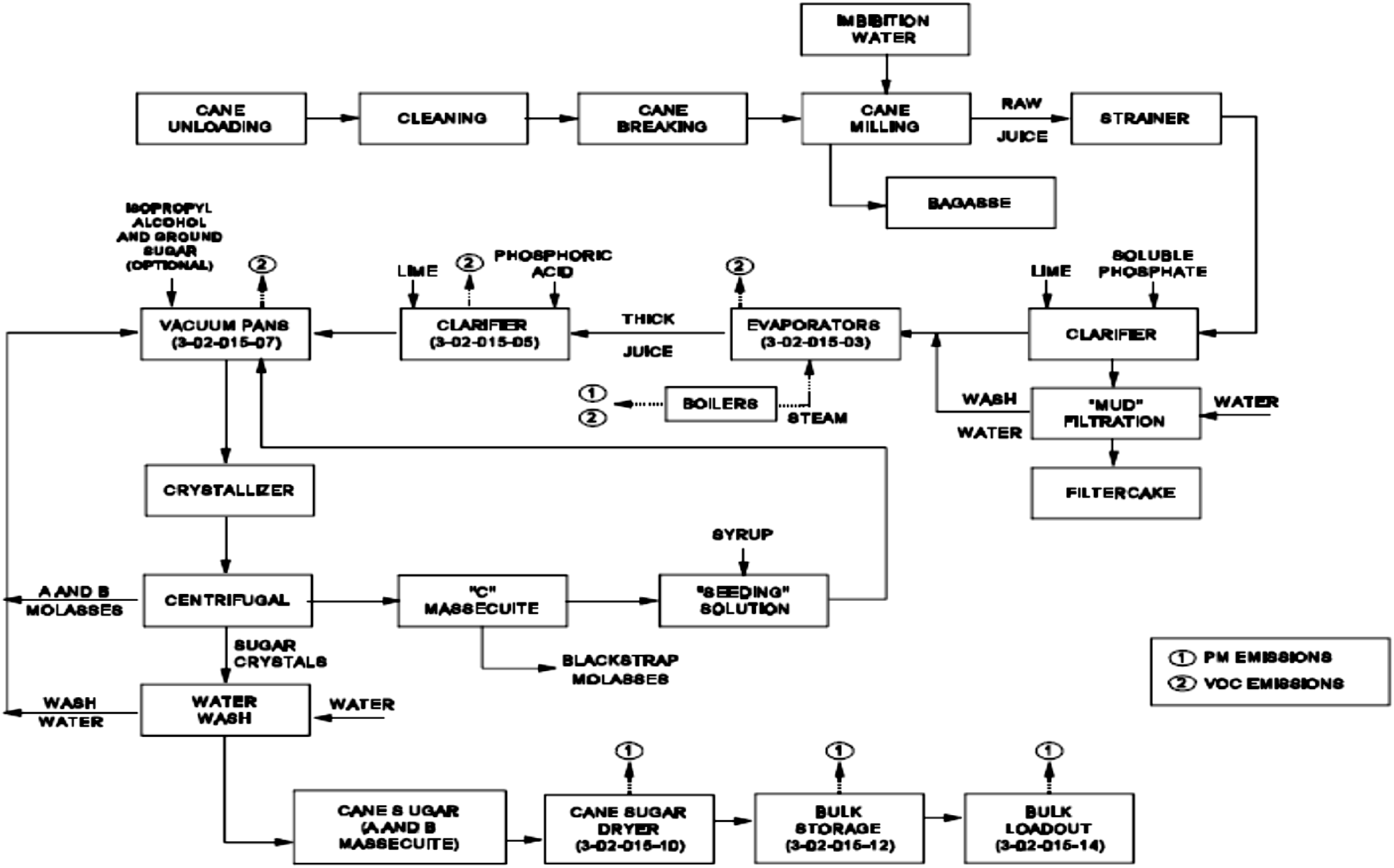


Figure (2.1): Simplified process flow diagram for cane sugar production. *Source*: Food and Agricultural Industry

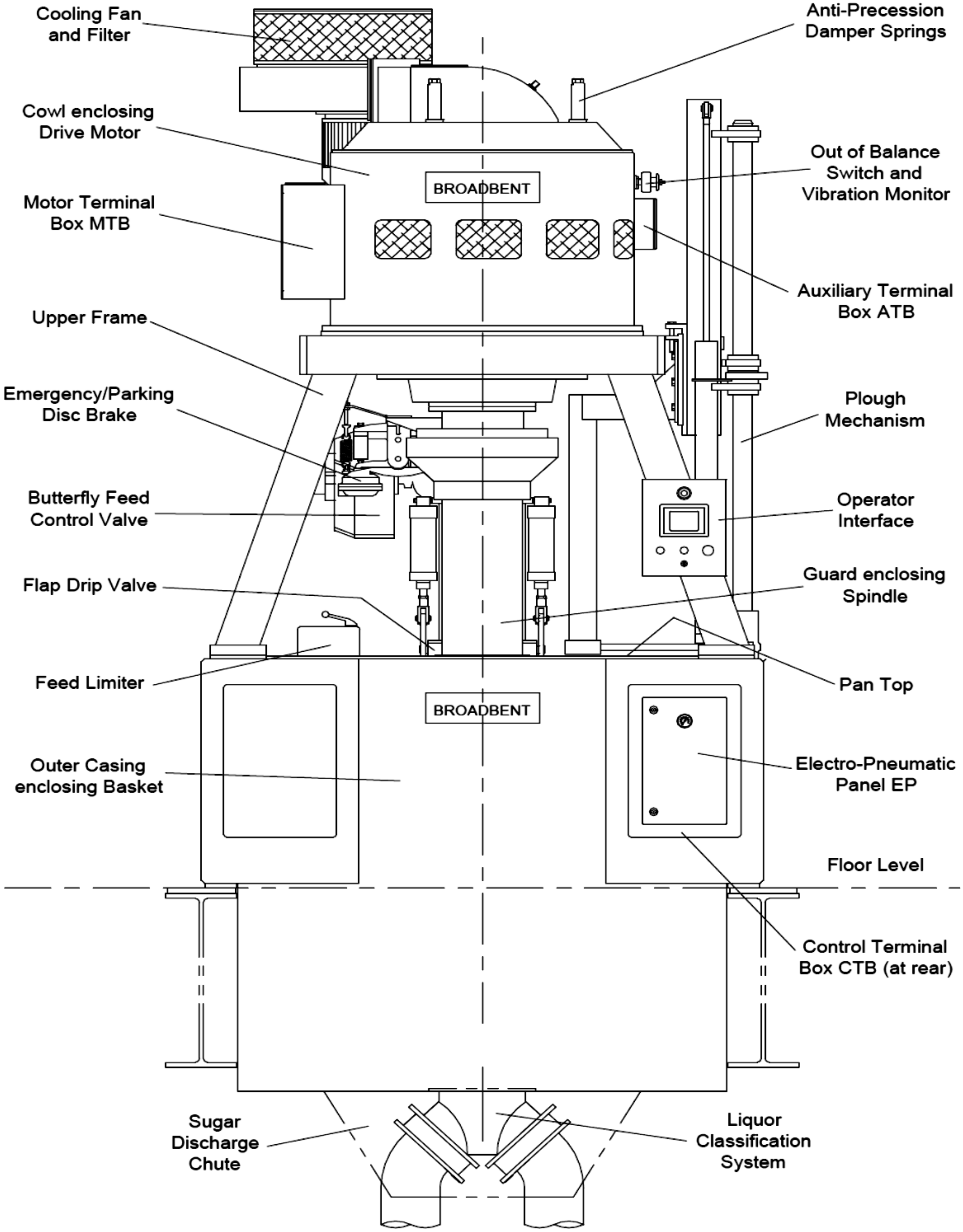
Steam from large boilers is used to heat the first evaporator, and the steam from the water evaporated in the first evaporator is used to heat the second evaporator. This heat transfer process continues through the five evaporators and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator also decreases which allows the juice to boil at the lower temperatures in the subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used in various process heaters in the plant. The evaporator station in raw sugar manufacture typically produces syrup with about 65 percent solids and 35 percent water. Following evaporation, the syrup is clarified by adding lime, phosphoric acid, and a polymer flocculent, aerated, and filtered in the clarifier.

From the clarifier, the syrup goes to the vacuum pans for crystallization. Crystallization of the sugar starts in the vacuum pans, whose function is to produce sugar crystals from the syrup. Batch pan boiling systems is used in the pan boiling process. The syrup is evaporated until it reaches the super-saturation stage. At this point, the crystallization process is initiated by "seeding" solution. When the volume of the mixture of liquor and crystals, known as mesquite, reaches the capacity of the pan, the evaporation is allowed to proceed until the final mesquite is formed. At this point, the contents of the vacuum pans (called "strike") are discharged to the crystallizer. The function of the crystallizer is to maximize the sugar crystal removal from the mesquite. From the crystallizer, the mesquite (A mesquite) is transferred to high-speed centrifugal machines (centrifugals), in which the mother liquor (termed "molasses") is centrifuged to the outer shell and the crystals remain in the inner centrifugal basket. The crystals are washed with water and the wash water centrifuged from the crystals. The liquor (A molasses) from the first centrifugal is returned to a vacuum pan and re-boiled to yield a second mesquite (B mesquite), that in turn yields a second batch of crystals. The B mesquite is transferred to the crystallizer and then to the centrifugal, and the cane sugar is separated from the molasses. This cane sugar is combined with the first crop of crystals. The molasses from the second boiling (B molasses) is of much lower purity than the first molasses. It is re-boiled to form a low grade mesquite (C mesquite) which goes to a crystallizer and then to a centrifugal. This low-grade cane sugar is mingled with syrup and used in the vacuum pans as a "seeding" solution. The final molasses from the third stage is a heavy, viscous material used primarily as a supplement in cattle feed. The cane sugar from the combined A and B mesquites is dried in fluidized bed or spouted bed driers and cooled. After cooling, the cane sugar is transferred to packing bins and then sent to bulk storage [11].

2.2 -BATCH CENTRIFUGAL DESCRIPTION

Batch Centrifuges are filtration machines used to separate sugar mesquite into its constituent crystals and mother liquor under the action of centrifugal force. The product is processed in a cylindrical perforated basket fitted with filtering screens which is hung on the bottom end of a long spindle.

The spindle is suspended from a resilient buffer which allows the rotating assembly to swing slightly to find its own balanced axis of rotation thus reducing transmission of vibration to the support platform. The centrifuge is driven by an electric induction motor running off a variable frequency supply from a solid state inverter which allows a continuously running speed.



Source: (Broadbent 2000)

Figure (2.2): General Arrangement of Centrifuge

All mechanisms used for feeding and discharging product are pneumatically actuated and the whole machine cycle is controlled by a programmable logic controller (PLC).

2.2.1 PRINCIPLES OF OPERATION

The centrifuge processes batches of product in a cyclic manner as follows; the centrifuge accelerates to a low speed. The butterfly feed control valve and a flap valve open allowing product to flow down a feeding chute onto a flinger disc attached to the spindle. This throws the product onto the inside of the basket where it flows under centrifugal force to form a uniform wall. Liquor starts to flow out through the filtering screens and basket perforations and is collected in the outer casing and discharged down pipe-work under the machine. The product thickness builds up inside the basket until the feed detector trips causing the feed control valve to close. The inside of the feed chute is sprayed with water and after a short delay the flap valve closes to prevent any remaining dark colored product dripping onto the product inside the basket. The feeding rate depends on how far the feed valve opens and this can be manually or automatically controlled. On completion of feeding, the centrifuge accelerates to a medium speed hold point to await operator or sequence permission to proceed. The centrifuge then accelerates to its maximum spin speed. During this time, purging of liquor from the product cake continues and water and steam can be sprayed on to remove the final traces of mother-liquor from the crystals. The purity of the run off liquor rises and a classification valve system can be used to direct this liquor down a different discharge pipe. The centrifuge pauses at spin speed for a preset time to dry the crystal cake to the desired level. On completion of spinning, the centrifuge decelerates to a very low speed. A discharge valve plate under the bottom of the basket opens. A plough blade cuts into the top of the cake and moves slowly down the basket screens discharging dried crystals through the basket bottom and down a chute onto a conveyor running beneath the casing. The plough blade moves back to its parked position, the discharge valve shuts, and the machine accelerates to feed speed to begin another cycle. During acceleration, the filtering screens can sprayed with a small amount of water to remove any remaining crystals and thus prevent clogging.

2.2.2 BASKET

The basket is a high integrity fabrication made from materials appropriate to the product being processed. The shell is rolled from plate, seam welded, and perforated. Depending on the operating speed and density of the product, the shell may be reinforced by shrink fitted, high tensile, seamless rolled hoops. The basket bottom includes a hub for attachment to the spindle and a spoked opening for product discharge. The basket top is an annular disc that’s inside diameter or 'lip' determines the maximum possible product cake thickness which can be accommodated. The perforated shell of the basket is lined with 3 screens. The innermost 'working' screen is made from thin metal plate which has many fine perforations and acts as the filter medium. The 'intermediate' screen is fine woven mesh, and the 'backing' screen is coarse woven mesh. The system is designed to optimize support of the working screen whilst allowing easy dispersion of the liquor filtrate.

2.2.3 MAIN DRIVE MOTOR

The cyclic duty induction motor is an induction motor specially designed for high torque variable speed duty. It operates from a variable frequency supply and has much lower headroom requirements than an equivalent conventional motor. The stator is a 3 phase winding in a laminated core with skewed slots to minimize harmonics. The stator frame is of fabricated construction and bolts directly to the spindle bearing housing. The rotor has a low resistance cage in a laminated core and is fitted on a fabricated spoked hub which is attached directly to the spindle. The motor is enclosed by a cowl which provides EMC and noise shielding and includes mesh covered air ducts to allow cooling air to escape. The motor cowl also includes the main motor terminal box. The motor is force ventilated from above by a separate electric motor driven centrifugal fan unit. The air delivered by the cooling fan is drawn through an oil wetted filter to prevent any dust or debris being fed into the internal motor assembly. A rotating baffle on the top of the rotor splits this cooling air flow so that some passes directly across the upper end-windings whilst the remainder passes down the inside of the rotor and across the lower end-windings.

2.2.4 SPINDLE AND BEARING HOUSING

The spindle is a long tubular shaft with the basket attached at the bottom and the motor at the top. The spindle is suspended in a bearing housing just below the motor. The spindle is located radially by two cylindrical roller bearings and vertically by a 4 point angular contact ball thrust bearing which are all retained in a cast bearing housing. All bearings are grease lubricated and rated for long life. Just beneath the bearing housing is a disc brake for parking and emergency duties (In normal operation, the centrifuge is decelerated by regeneration in the inverter). The disc is attached to the spindle by a split taper collar. The caliper is mounted on a bracket attached to the lower bearing cap. The disc and brake shoes are surrounded by a substantial guard. Lower down the spindle is a conical flinger disc to aid distribution of product in the basket. This is also attached to the spindle by a split taper hub.

2.2.5 CASING AND SUPPORT FRAME

The spindle bearing housing is flexibly supported in a conical elastomer bush or 'buffer' which allows the whole rotating assembly to swing slightly. The buffer rests in a conical seating in the top of a rigid support frame which has splayed legs fabricated from square hollow tube. The frame is in turn supported from the casing with intermediate packing plates whose thickness can be changed to adjust the vertical position of the basket. The casing is a fabricated assembly comprising a central cylinder with boxed sides. The cylindrical section surrounds the basket to catch the spun off liquor and incorporates a bottom gutter and bump ring to restrict the lateral motion of the basket. The side frames transfer loads from the upper support frame direct to the supporting foundations.

2.2.6 COOLING AND ANTI-PRECESSION SYSTEMS

The motor cowl supports an auxiliary motor driven fan and filter unit which directs cooling air via a duct into the top of the main drive motor.

An anti-precession system is fitted to control gyration of the rotating assembly during feeding and to prevent gyroscopic precession at high speed. This comprises a damper plate with a friction lining which is pressed down onto the motor top by 3 springs mounted on the motor cowl. The damper plate is held centrally by a rubber ring which is a tight fit on the cooling air duct. When the rotating assembly swings, the motor top is forced to slide against the damper plate giving rise to frictional damping.

2.2.7 BRAKING SYSTEM

In normal operation, the centrifuge is decelerated only by regeneration by the inverter in the Drive Panel. A disc brake is provided as a parking brake and for emergency purposes such as inverter failure or loss of air pressure. The brake caliper has a pair of floating shoes and is supported off a bracket mounted on the lower bearing housing cap. The caliper has a spring on - air off actuator. The brake disc is attached to the spindle by a split taper hub.

2.2.8 FEEDING SYSTEM

Product is fed into the centrifuge via a flow control valve, streamlined feed spout and secondary anti-drip valve. The product falls onto a conical distributor disc or 'flinger' attached to the spindle by a split taper hub. This throws the product onto the basket inner wall approximately halfway up from, where it flows to form a product wall under centrifugal action.

The flow control valve is a butterfly valve with a double acting actuator controlled from an integral electro-pneumatic positioner which responds to a 4-20 mA signal from the PLC. The flow control valve is mounted as close as possible to the mixer tank to avoid plugging. To avoid unsightly drips of colored feedstock onto spun product, a secondary valve is mounted directly onto the casing top. The secondary valve is a flap pulled up onto a soft seating under the spout outlet by a pair of double acting pneumatic cylinders. Mounted locally is an air reservoir with sufficient capacity to allow emergency closing of both valves in the event that the main pneumatic supply fails.

2.2.9 FEED LIMITER

A mechanical feed limiter unit initiates closing of the feed valve when the build-up of product cake inside the basket reaches the desired thickness. This comprises a slipper arm inside the basket connected via a rod to a control box on the casing top. The control box contains a pneumatic cylinder and spring loaded linkages. Just before feeding, the cylinder pushes the slipper close to the basket wall. As the product cake thickens, the slipper rides on the cake surface under spring pressure until the lever arms in the control box move sufficiently to trip a proximity switch. This sends a signal to close the feed valve and releases the cylinder in the control box so that the slipper arm moves well away from the product for the remainder of the cycle. The rod from the slipper arm extends through to a handle on the top of the control box which can be used as a manual override to terminate feeding. The desired product cake thickness is adjusted by rotating the whole assembly on the casing top.

2.2.10 PLOUGH DISCHARGER

Product is ploughed from the basket by a blade which remains within the basket at all times. Its parked position is near the spindle near the top of the basket. For discharging, the blade lifts slightly, moves horizontally to cut into the top of the cake, pauses, and moves slowly vertically down the basket screens, pauses, moves vertically up, moves horizontally back to the spindle and finally drops slightly into the parked position. All plough motions take place with the basket rotating at very slow speeds. The actuating mechanism is mounted to the right of the main support frame and is connected to the blade by an 'L' shaped arm which passes through a curved slot with a sliding cover in the casing top. The heart of the mechanism is a vertical circular shaft on which the carriage supporting the plough arm slides vertically under the action of double acting pneumatic cylinder mounted in parallel with an oil filled dashpot unit. The dashpot allows a slow, adjustable speed downwards during plough. And a fast upwards motion when returning to the parked position. The horizontal motion is obtained by a second double acting pneumatic cylinder pushing on a lever arm attached to the bottom of the plough shaft which rotates the shaft and carriage in bushes at the casing top and at the top of the upper frame. Rollers in the end of the lever arm move the plough arm. The geometry in plan view is such that under cutting action, the blade naturally 'castors' to about half the maximum cake thickness. When first pushing the blade into the cake, the horizontal cylinder operates at full pressure but once on the screens, the pressure is reduced to gently hold the blade lightly against the basket to ensure that all traces of product are removed from the filtering screens. A spring loaded pin engages in cutouts in a locking plate rigidly attached to the plough shaft to hold the mechanism either out towards the screens so that the blade cannot touch the flinger during ploughing or in the parked position close to the spindle during the rest of the cycle. At appropriate points in the sequence, this pin is lifted out of engagement by a lifting ridge on the carriage. When parked, a lug on the carriage rests on a lug on the bracket supporting the upper plough shaft bush. This bracket also supports the proximity switches which sense the position of the mechanism. The solenoid valves controlling the actuators are spring return units and are connected in such a way that if the electrical power fails during ploughing, the plough will naturally tend to return up and in to the spindle towards the parked position.

2.2.11 DISCHARGE VALVE

The discharge valve is a cone which is normally pulled up hard against the underside of the spoked opening in the basket bottom. This cone is lowered away from the basket during ploughing. The discharge valve actuating mechanism is housed entirely within the hollow spindle. It comprises a central pushrod surrounded by a long coil spring which is housed within a tubular hanger attached to the spindle. Spring pressure normally pulls up the pushrod to hold the discharge valve against the basket bottom. However, the top of the hanger houses a single acting cylinder which can compress the spring to depress the pushrod and open the discharge valve. The cylinder air supply is via a rotary union and a flexible hose to the cooling fan duct. To aid assembly the pushrod can be split into two pieces at a joint just below the spring hanger. A sealing plate assembly attached beneath the basket bottom incorporates a bush to guide the pushrod and a lip seal to protect the mechanism against ingress of product.

2.2.12 PROCESS FITMENTS

A static hot water spray pipe protruding into the basket from the casing top allows the screens to be rinsed after ploughing and the product to be washed during spinning. The pipe is short to prevent 'dragging' in the product during ploughing. The spray nozzles sizes, positions and angles have been carefully selected to provide an even wash distribution. The wash is controlled by a pneumatically actuated ball valve attached to the end of the wash pipe. An optional short steam injection pipe protruding into the basket from the casing top allows steam to be added to help dry the product cake. The steam injection is controlled by a pneumatically actuated ball valve attached to the end of the steam pipe. An optional liquor classification unit is attached to the rectangular liquor outlet under the casing. This allows separation of the initial low purity mother liquor spun off immediately after feeding from the wash water containing dissolved product spun off later. It comprises a ‘Y’ splitter box with a pair of pneumatically actuated butterfly valves on the two outlets. The controls are organized such that both valves are never shut simultaneously.

2.2.13 CONTROL PANEL (PLC)

The whole production cycle of the machine, including operation of the inverter, feed valves, plough, and the discharge valve and process fitments is controlled by an electronic Programmable Logic Controller (PLC). The PLC together with its interface devices and auxiliaries is housed in a remote Control Panel cabinet. An isolator, 'Power On' indicator and 'Machine Running' indicator are mounted on the outside of the door. Components inside include the following:

A: \ CENTRAL PROCESS UNIT (CPU)

The CPU is a solid state device consisting of a microprocessor and its support system. It contains the operating program for the machine within its EPROM memory. The program cannot normally be corrupted but changes can be made when required by a suitably qualified and experienced person using a special programming unit. The CPU scans the inputs to the PLC from the various sensors on the centrifuge, acts upon these inputs as determined by the program, and then turns on the appropriate outputs to the inverter and centrifuge actuators in a cyclic manner. A series of indicating LEDs are incorporated on the front of the unit to show the operating status of the unit.

B: \ POWER SUPPLY UNIT (PSU)

This separate unit supplies 24V d.c. to the input/output module mounted on the rack. A light on the PSU indicates when the power supply is active.

C: \ INPUT MODULES

The input modules are all 16 way, low voltage d.c. optically isolated positive logic units. Each input has an associated Light Emitting Diode (LED) on the front of the unit to indicate its status (ON or OFF).

D: \ OUTPUT MODULES

The output modules are all 16 way, low voltage d.c. optically isolated positive logic units. Each output has an associated LED on the front of the unit to indicate its status (ON or OFF).

2.2.14 SPEED MONITORING SYSTEM

The speed of the machine is measured by impulses from two proximity sensors mounted above a series of holes through the brake disc. To guard against faulty speed control, two entirely independent speed monitoring systems are fitted. In the main system, the impulses from one of the sensors are changed to a 4-20 mA analogue signal by a ***frequency to current converter*** and this analogue signal is fed to the main PLC. In the secondary system, the impulses from the second sensor are fed directly to a ***secondary programmable logic controller*** (PLC2) which is of a different type and manufacture to the main PLC. PLC2 is basically a pulse counting unit and is configured to operate 6 sets of contacts corresponding to different speeds. The main PLC continuously scans the status of these contacts and compares these for consistency with its own measurement of speed. If a discrepancy is detected, a fault condition occurs. As a further protection against faults in the main PLC and/or the inverter causing random uncontrolled actions, some of the contacts in PLC2 are hard wired via relays to inhibit dangerous conditions. One set of contacts isolates the plough actuators to prevent the plough deploying above low speed. Another set of contacts isolates the feed valve actuators to prevent feeding above medium speed. A particularly dangerous situation is over speeding the centrifuge. The main PLC is set with a software limit on maximum speed and the inverter is preset with a software limit to the output frequency. In the unlikely event of faults in both these systems occurring simultaneously, two sets of contacts in PLC2 are used as a final protection against over-speeding. The first set removes the inverter enable signal and the second, higher speed, set trips the inverter input contactor and disconnects power.

2.2.15 MACHINE ELECTRICAL EQUIPMENT

The following control equipment is mounted on the centrifuge.

❖ **OPERATOR INTERFACE**

The Operator Interface is mounted on the front of the centrifuge frame. This incorporates a touch sensitive panel with pushbuttons and indicators. It allows operators to monitor and control the machine via the PLC in the Control Panel. The interface allows displays of machine status, interaction with the production cycle, and modification of process parameters.

2.3 CYCLE OPERATION

The sequence of events during a normal operating cycle of the centrifuge is as follows, the centrifuge accelerates to a low speed. The butterfly feed control valve and a flap valve open allowing product to flow down a feeding chute onto a flinger disc attached to the spindle. This throws the product onto the inside of the basket where it flows under centrifugal force to form a uniform wall. Liquor starts to flow out through the filtering screens and basket perforations and is collected in the outer casing and discharged down pipe-work under the machine. The product thickness builds up inside the basket until the feed detector trips causing the feed control valve to close. The inside of the feed chute is sprayed with water and after a short delay the flap valve closes to prevent any remaining dark color product dripping onto the product inside the basket. The feeding rate depends on how far the feed valve opens and this can be manually or automatically controlled. On completion of feeding, the centrifuge accelerates to a medium speed hold point, this is to wait operator or sequence permission to proceed. The centrifuge then accelerates to its maximum spin speed. During this time, purging of liquor from the product cake continues and water and steam can be sprayed on to remove the final traces of mother liquor from the crystals. The purity of the run off liquor rises and a classification valve system can be used to direct this liquor down a different discharge pipe.

The centrifuge pauses at spin speed for a preset time to dry the crystal cake to the desired level. On completion of spinning, the centrifuge decelerates to a very low speed. The discharge valve plate under the bottom of the basket opens. The plough blade cuts into the top of the cake and moves slowly down the basket screens discharging dried crystals through the basket bottom and down a chute onto a conveyor running beneath the casing. The plough blade moves back to its parked position, the discharge valve shuts, and the machine accelerates to feed speed to begin another cycle. During acceleration, the filtering screens can sprayed with a small amount of water to remove any remaining crystals and thus prevent clogging.

A number of different operating modes can be selected by the operator,

2.3.1 CYCLE MODES

A\ AUTOMATIC CYCLE MODE

The centrifuge cycles automatically, with the operator able to change feed, spin, wash, and plough parameters without affecting the centrifuge sequence. The centrifuge continues in this mode unless the *Stop* or *Emergency Stop* buttons are pressed or a fault occurs. Faults will switch the centrifuge into *Manual Cycle Mode* and, depending on the type and severity of the fault, may also stop the centrifuge or shift it to another part of the cycle.

B\ MANUAL CYCLE MODE

The centrifuge cycles in the same way as in *Automatic Cycle Mode* except that the centrifuge pauses awaiting operator intervention at certain parts of the cycle and also comes to rest at the end of each cycle. The operator is required to press the *Start* button at the following points:

(a) To allow feeding to commence

(b) To allow acceleration from holding speed to spin speed

(c) To allow continuation to another cycle

Manual Cycle Mode is useful when commissioning the centrifuge to find the optimum operating parameters and also during fault finding [15].

2.4 BATCH CENTRIFUGAL DRIVES

There are two basic types of induction motor drives - fixed frequency mains supplied and variable frequency inverter supplied.

The developments in motors and controls have provided a variety of induction motor drive systems for batch sugar centrifugals. These include motors with 2 or 3 windings each providing a different speed when supplied by a standard three phase supply. A limited regenerative electrical braking is provided by drives of this type.

Power electronic devices over 20 years ago the growth of inverter technology has formed the basis of an entirely new drive concept. This provides the induction motor with a ‘variable’ supply giving control of both motor torque and speed over a wide range with a reduction in net power usage.

2.4.1 CENTRIFUGAL DRIVE REQUIREMENT

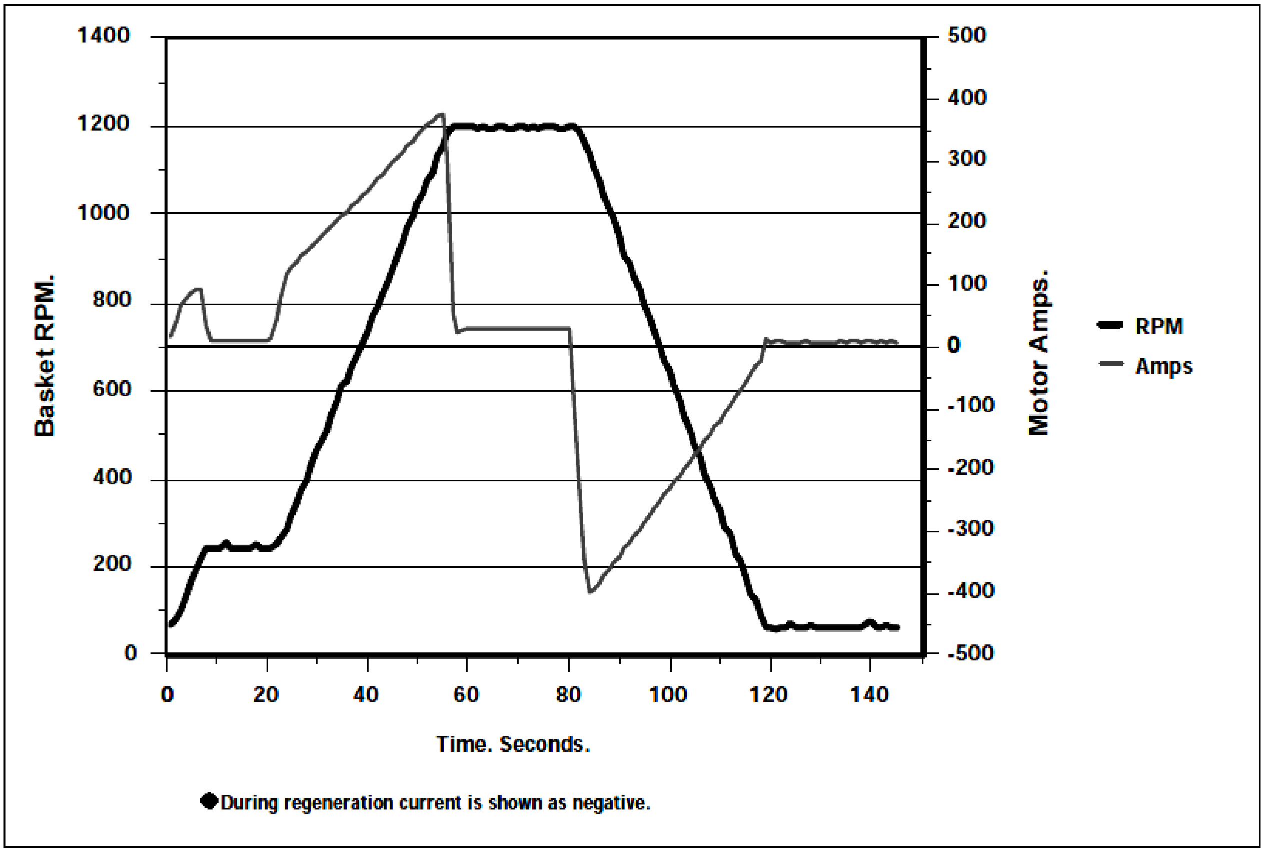
The drive for a batch centrifugal, presents an intriguing problem. The cyclic duty of the centrifugal process requires acceleration from low (discharge) speed through feeding of the massecuite to spin for separation, followed by deceleration to low speed for discharge – typical cycle times [6] .

A large amount of energy is needed to accelerate the centrifugal and most of it is stored in the rotating loaded basket. The energies involved are large - a medium sized centrifugal spinning at 1200 rpm has the same stored energy as a 1.5 tone motor car travelling at 160 mph (250 kph). If a proportion of this stored energy can be returned to the supply during deceleration then the net energy demand is reduced pro rata.

As the centrifugal commences and ends the cycle at the same discharge speed, the energy input has either been recovered by regeneration or dissipated in the losses in the system (controls + motor + windage & friction + energy lost to spun off syrup). Thus the net energy input, that is the energy input minus the energy recovered, equals the system losses. This applies equally to multi-speed and inverter drives.

2.4.2 INVERTER DRIVES

With the advent of electronic power inverters, particularly the pulse width modulated (PWM) type, the induction motor entered a new area. With given a variable frequency/voltage output of the inverter the induction motor could operate at any speed above a few rpm to a top speed fixed by either the inverter maximum frequency or the motor rotor stresses, The centrifuge main drive motor is an induction motor and runs just below the synchronous speed which is determined by the number of poles in the winding and by the frequency of the electrical supply. The motor speed can therefore be changed by varying the frequency of the electrical supply to it. This function is performed by the Drive Panel which is a solid state electronic frequency converter (inverter), Converter is converting electric energy from one form to another, converting between AC and DC, or just changing the voltage or frequency, or some combination of these The fixed frequency alternating current supply to the Drive Panel is first rectified to a direct current which is then electronically switched on and off to construct an output alternating current at the desired frequency. The inverter is housed in a remote cabinet with a door mounted keypad and display for use during setup and fault finding. The inverter driven motor still operates in the cyclic mode described above and therefore both motor and inverter need to be rated to suit this cyclic duty. When applied to a centrifugal, acceleration is controlled by frequency/voltage change or torque/flux control within the allowed power to give the compromise between energy demand and centrifugal product processed. With an inverter capable of regeneration deceleration is controlled in a similar way to the discharge speed and mechanical braking is only needed for emergencies. Inverters are complex and expensive typically 3.5 to 4 times the cost of the three speed induction motor controls and can create substantial harmonic distortion in the electric supply system when using diode/thyristor input power electronics. In the last few years this distortion has been substantially reduced using newer power electronic devices (IGBTs) increasing the cost to 4.5 to 5 times that of the three speed motor controls. Many modern centrifugals, particularly the larger units, are PWM inverter/induction motor driven by the inverter, then the centrifugal motor with 100 electrical units input returns 85 electrical units to the supply, Speed and motor current against time for an inverter drive is shown below for one cycle of 180 seconds on a 440 volts 60 HZ supply and the centrifugal capacity of 1.3 tones mesquite



Source: (ISJ, Dec 1999)

Figure (2.3): Speed and motor current against time for an inverter drive

2.5 ASSALAYA POWER HOUSE GENERATION

The station consist of two back pressure steam turbines, each one produces maximum 6.5 mega watts the description of these equipment explained below:

2.5.1 STEAM TURBINE

Is made by BETER BROTHERHOOD in England, it is multi-stages back pressure steam turbine with 6600 RPM normal full speed, the inlet steam is 24 kg/cm2 and exhaust steam is 1.7 24 kg/cm2. The speed is reduced 1500 RPM by reducing gear with 6580/1300 ratio, and the speed is controlled via WOODWARD type UG.8 speed governor.

2.5.2 A.C-GENERATOR

It is made by PARSONS PEEBLES in England with brushless excitation generate a power of 6.5 mega watts with power factor of 0.78, and three phase rated voltage of 3300 volts ,the maximum full load current is 1456 ampere. The rotor is running with speed of 1500 RPM, and fed with excitation of 33.3 volt & 678 ampere, the voltage is controlled via AVR (Automatic Voltage Regulator) which is ALSTOM Micro-tech DX21 Digital Excitation Controller.

The station contains 17 switch boards and it is ALSTOM vacuum circuit breaker with 3300 volts & 800 ampere.

2.6 SEQUENCE OF CENTRIFUGAL MACHINES

Sequence control refers to user actions and computer logic that initiate, interrupt, or terminate transactions, Sequence control governs the transition from one transaction to the next [14], sequence control is used to coordinate the various actions of the production system (e.g., transfer of parts, changing of the tool, feeding of the metal cutting tool, etc.).

Typically the control problem is to cause/ prevent occurrence of

- ♦ Particular values of outputs process variables
- ♦ Particular values of outputs obeying timing restrictions
- ♦ given sequences of discrete outputs
- ♦ given orders between various discrete outputs [5]

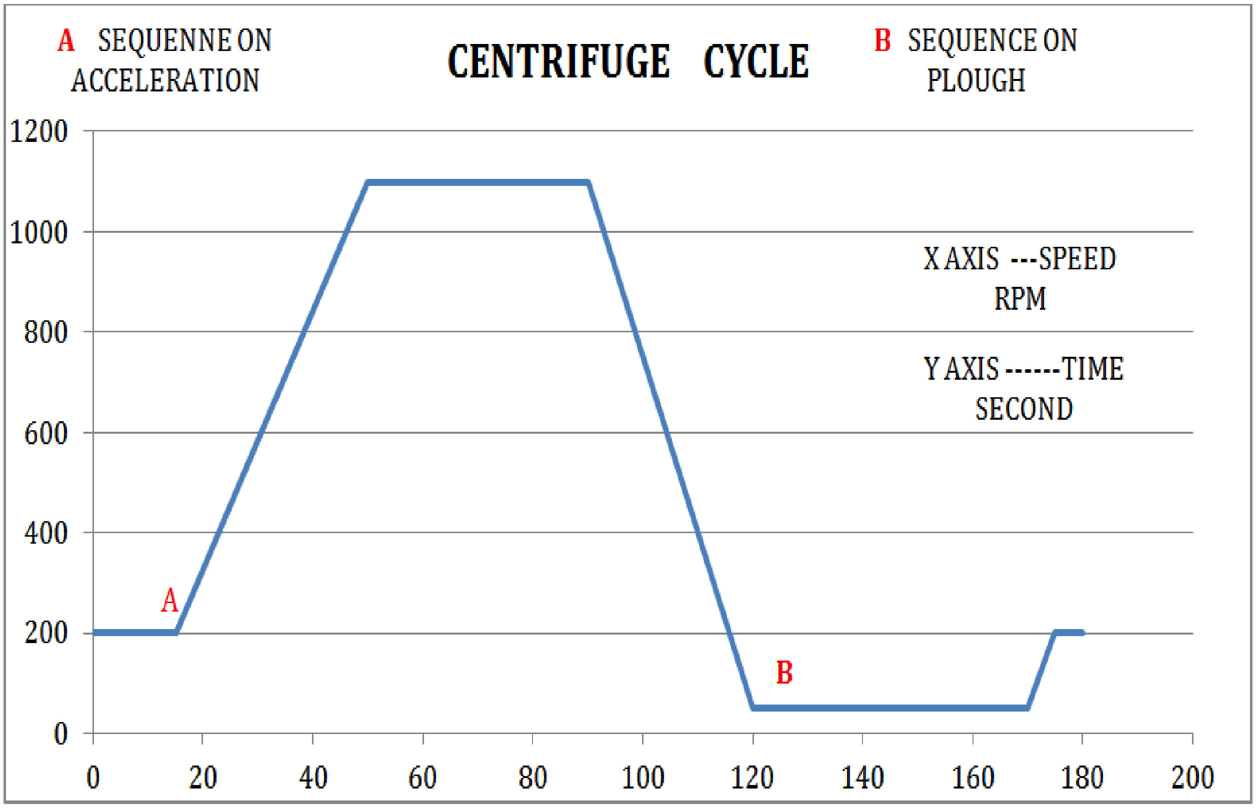
The basic idea of the sequence control is used here to organize the work of the centrifugal machines ,was base on a constant delay time , every machines is wait to take permission either before spinning to cure sugar at high speed, or before discharge to drop the product (plough).

Broadbent is British Company specialist on sugar centrifugal machines manufacturing, applied three types of sequence control in

Assalaya Sugar Factory, all these controls based on the method of delay time, the early one use moving contacts (cams) rotate with constant speed, which is adjust by the operator to control the time delay between machines, the user have a chance to select the request signal of the specific machine to be send when the machine start accelerate to high (spin) speed i.e. sequence at acceleration, or when the machine begin discharge sugar (sequence at plough), if sequence at acceleration is selected the request signal is send to the controller after machine complete feeding, it wait rotating at speed of 500 rpm until the desired contact is closed this let the machine accelerate to 1000 rpm (spin speed) and continue the remaining operations , if sequence at plough is chosen the controller check if the sugar conveyor running or not, in case of conveyor stoppages the machine rotate at 50 rpm (plough speed) and sugar will not be drop until the conveyor running signal come back to the sequence controller, after checking the conveyor signal the machine stay at plough speed until the permission signal send from the sequence controller, beside all these the sequence control can be override by switch inside the machine itself.

The second type of sequence control has the same function of the early one but it used electromechanical relays and on/off-delay timers, the wiring connection of these devices made the desired control, timers is used for the purpose of adjusting the interval times between machines

The last application is used Microcontroller, functionally has the same previous method and behavior, more over the machines can be sequentially operate In ascending or arbitrary order. The sequence control is connected with the programmable logic controller (PLC) of the machine control, and the feature of this application which is cold 5/10 is shown and explained below.

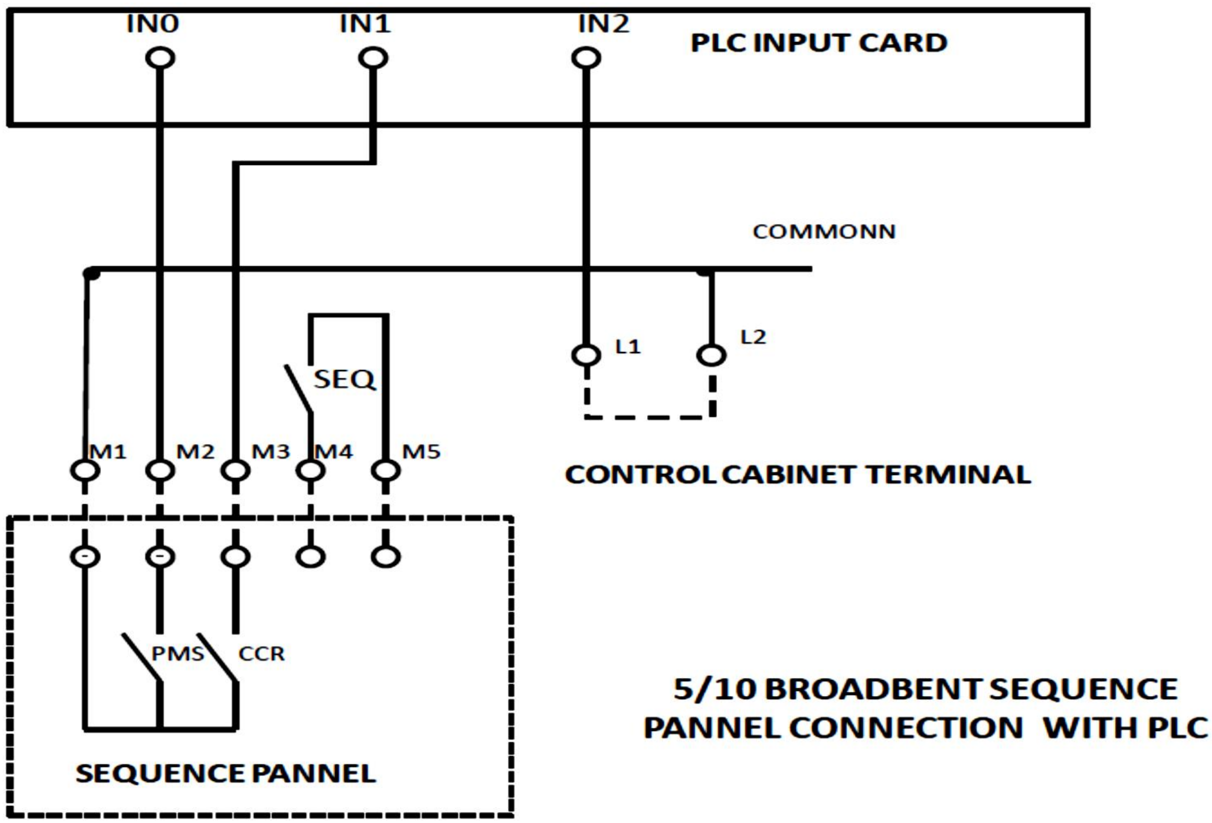


Source :(Broadbent, 2000)

Figure (2.4): centrifuge cycle time

2.6.1CONNECTION REQUIRED FOR SEQUENCE PANEL

Referring to figure (2.5) a five core cable is required to connect each centrifuge to (M1 to M5), when a centrifuge reaches the selected sequence point (either acceleration or plough) then a PLC output is turned on the sequence relay (SEQ) is energized in the centrifuge control panel this send a signal to the sequence panel (on terminals M4 and M5) that the centrifuge is at the sequence holding point. If no other centrifuge is being sequenced then the sequence panel sends a signal back to the centrifuge (on terminals M1 and M2) allowing the centrifuge past the sequence holding point. The sequence panel also has the function of telling the centrifuge if the discharge conveyor is running (if the conveyor is running a signal is sent to each centrifuge on terminals M1and M3) [16].



Source :(5/10 Broadbent)

Figure (2.5): 5/10 BROADBENT SEQUENCE CONNECTION WITH PLC

2.6.2 REQUIRED CENTRIFUGE HMI SETTNGS WITH SEQUENCE PANEL

The first thing required that when the operator decides to use sequence is to ensure sequencing is selected (not overridden).

Sequence selection for each centrifuge can be accessed as follows:

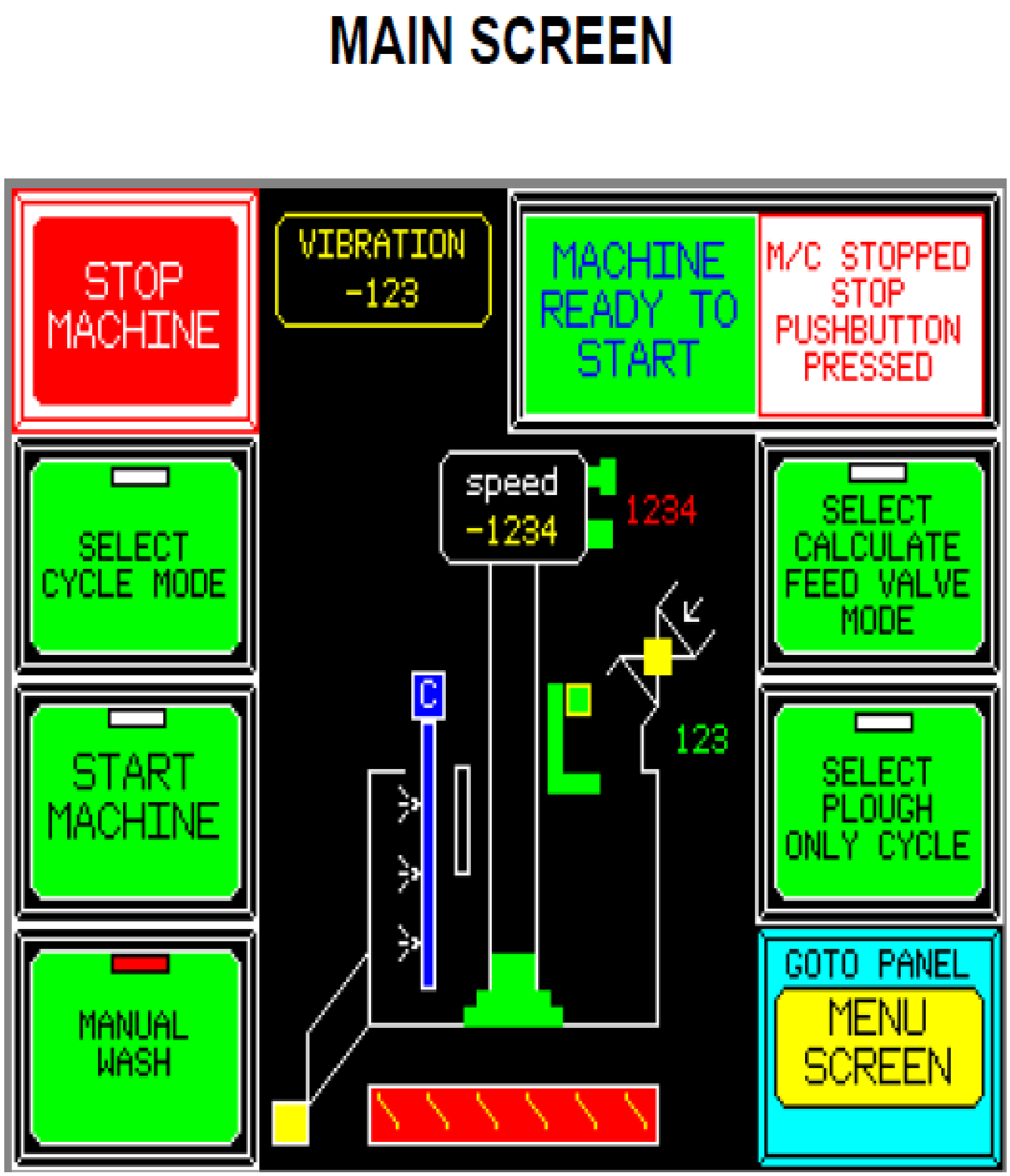
I- From the centrifuges touch screen MAIN SCREEN figure (2.6) select MENU SCREEN.

II- from MENU SCREEN figure (2.7) selects SPIN SCREEN

After selection the following screen appeared figure (2.6).

It can be useful to override the sequence interlock if the sequence panel is turned off or faulty.

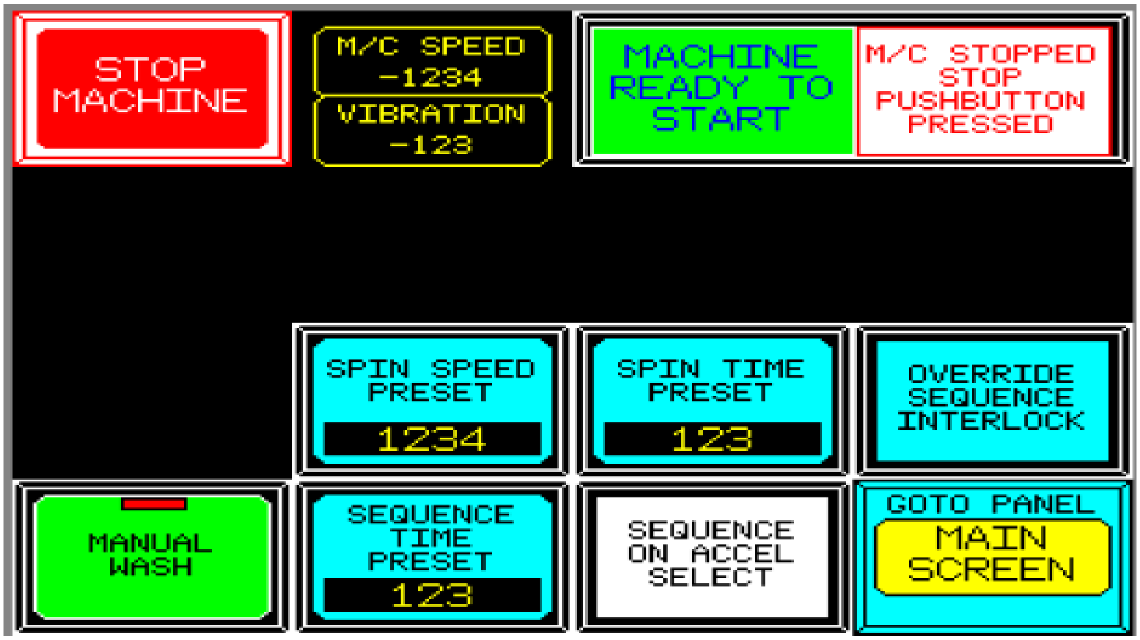
The next consideration is to sequence on acceleration or to sequence at plough, below is brief explanation as to the relative merits of sequencing at each of these points.



Source :(Broadbent, 2000)

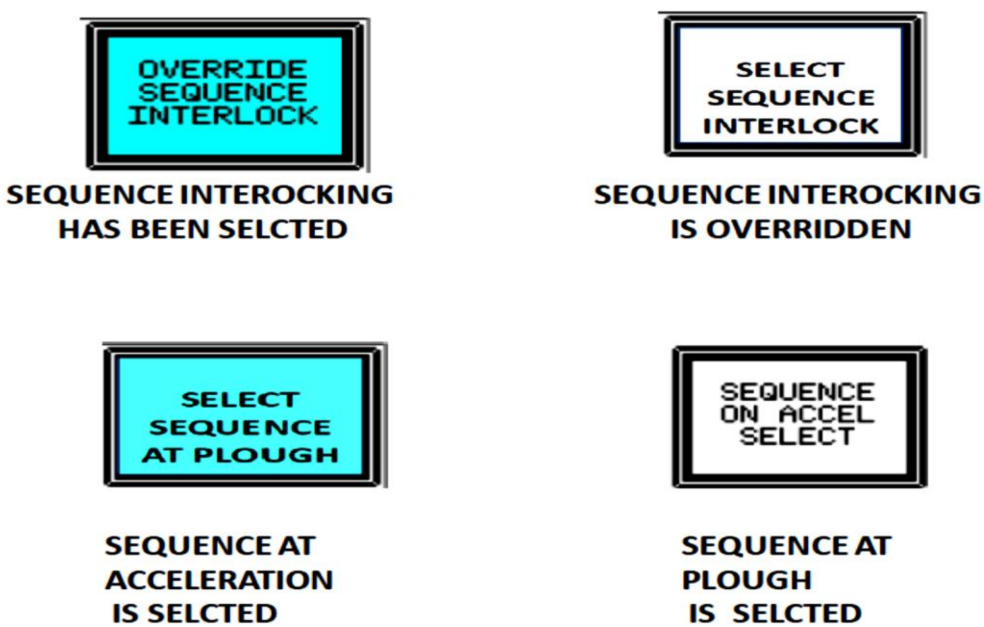
Figure (2.6): Main Screen

SPIN SCREEN



Source :(Broadbent, 2000)

Figure (2.7): Spin Screen



Source :(broadbent, 2000)

Figure (2.8): Sequence Selecting Icons

2.6.3 SEQUENCE ON ACCELEEATION

If there is a need to minimize the peak electrical supply demand then the sequence on acceleration should be selected, this will inhibit more than one centrifuge from acceleration at the same time.

2.6.4 SEQUENCE ON PLOUGH

If there is limitation for the amount of sugar to be discharge in the conveyor, then sequence on plough should this will not allow more than one machine to discharge at the same time.

CHAPTER THREE

METHOD AND CALCULATIONS

CHAPTER THREE

METHOD AND CALCULATIONS

3.1 INTRODUCTION TO FUZZY LOGIC

The pioneering work of Zadeh (1965) has opened a wide range for fuzzy applications in many different fields. It’s include estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, machine vision, pattern recognition, medical computing, robotics, optimization, civil, chemical and industrial engineering, etc. [8].

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasonable approximate rather than precise. In contrast with "crisp logic", where binary sets have binary logic, the fuzzy logic variables may have a membership value it’s not constant value of 0 or 1, the degree of truth of a statement have value between upper and lower limit, Appliances with fuzzy logic controllers provide the consumer with optimum settings that more closely approximate human perceptions and reactions than those associated with standard control systems [13].

A fuzzy system is a mapping between linguistic terms, such as ‘‘medium complexity’’ and ‘‘high cost’’ that are attached to variables. Thus an input into a fuzzy system can be either numerical or linguistic the same thing can be applying to the output [7].

3.2 FUZZY SYSTEM COMPONENTS

A typical fuzzy system is made up of three major components: fuzzifier, fuzzy inference engine (fuzzy rules) defuzzifier as shown in figure (3.1).

3.2.1 FUZZIFICATION

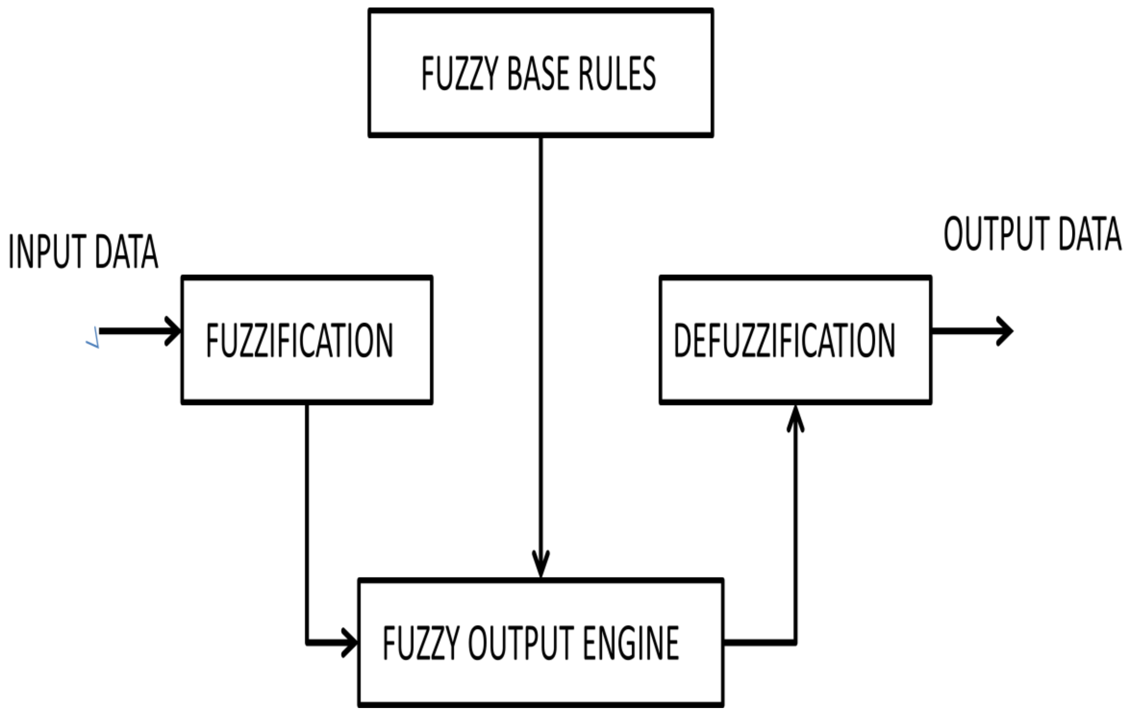
The fuzzifier transforms the input into linguistic terms using membership functions that represent how much a given numerical value of a particular variable fits the linguistic term being considered. All meteorological events are considered as having ambiguous characteristics and therefore their domain of change are divided into many fuzzy subsets, which complete, normal and consistent with each other.

3.2.2 FUZZY INFERENCE SYSTEM (FIS)

This step systematically relates all the factors that take place in the solution depending on the purpose of the problem. In fact, this part includes many fuzzy conditional statements to describe a certain situation. The fuzzy inference engine performs the mapping between the input membership functions and the output membership functions using fuzzy rules that can be obtained from expert knowledge of the relationships being modeled. The greater the input membership degree, the stronger the rule fires, thus the stronger the pull towards the output membership function.

3.2.3 DEFUZZIFICATION

The final result from previous step is in the form of fuzzy statement. A defuzzification method must then be applied to calculate the deterministic value of a linguistic variable. Since several different output membership functions are included in the consequents of rules triggered, a defuzzifier carries out the defuzzification process to combine the output into a single label or numerical value as required. There are many defuzzification methods such as centre of gravity (COG, centroid), bisector of area (BOA), mean of maxima (MOM) leftmost maximum (LM), etc, fuzzy logic modeling process can be given as in figure 3.1 below [8]:



source: (Morteza, 2007)

Figure (3.1): Fuzzy logic modeling process

3.3 TOOL USED FOR SEQUENCE CONTROL

This project has used fuzzy logic toolbox provided by MATLAB. MATLAB is an abbreviation of matrix laboratory. It was developed in late 1970s by the MathWorks Incorporation and provided to users. MATLAB covers different areas of real time implementation like matrix manipulation, data algorithms, user interfaces with languages like C and C++, data analysis and graphical implementations. MATLAB provides separate tools for applications. It is provides toolboxes for signal processing, fuzzy logic, neural networks and many other real time applications project Using MATLAB [10].

Sequence control is made by fuzzy logic. So how to build a simple fuzzy logic system and how to simulate it, is explained in details below.

3.3.1 FUZZY LOGIC TOOLBOX

MATLAB provides inbuilt fuzzy logic toolbox that provides Graphical User Interface (GUI) based implementation of fuzzy systems. The coming is steps for building sequence control model using fuzzy logic.

To start fuzzy logic in MATLAB, open the MATLAB and type fuzzy in the command window. As in figure (3.2) The FIS which is (Fuzzy Inference System) editor browser will be opened.

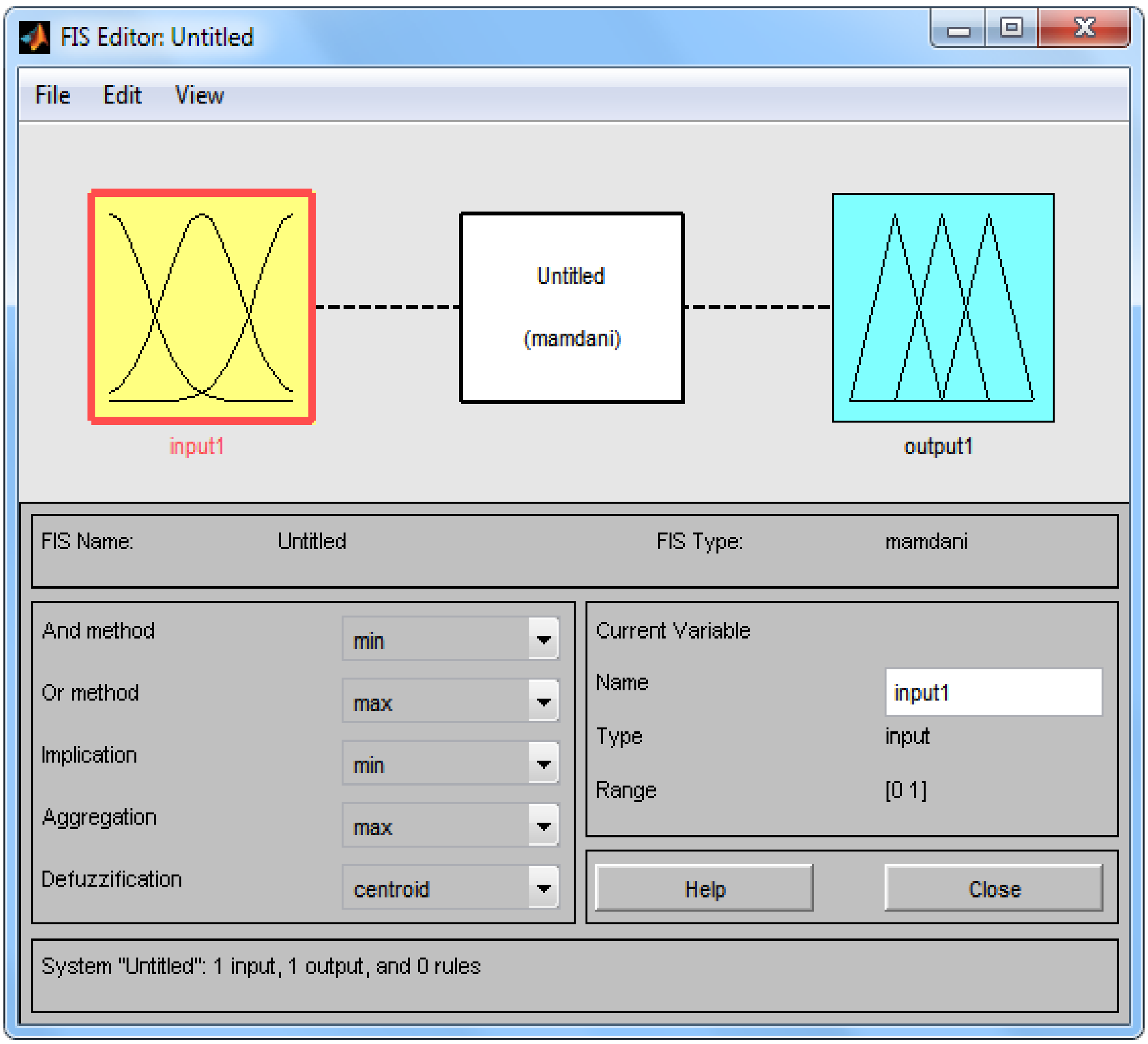


Figure (3.2): Fuzzy Inference System Editor

3.3.2 FUZZY BASIC FIS EDITOR

The FIS Editor displays high-level information about a Fuzzy Inference System. At the top is a diagram of the system with each input and output clearly labeled, by double-clicking on the input or output boxes, will bring up the Membership Function Editor. Double- clicking on the fuzzy rule box in the center of the diagram will bring up the Rule Editor.

Just below the diagram is a text field that displays the name of the current FIS. In the lower left of the window area series of popup menus that allow the user to specify the various functions used in the fuzzy implication process. In the lower-right are fields that provide information about the current variable. The current variable is determined by clicking once on one of the input or output boxes.

The Membership Function (MF) Editor is used to create, remove, and modify the MFs for a given fuzzy system. On the left side of the diagram is a "variable palette" region that is used to select the current variable by clicking once on one of the displayed boxes. Information about the current variable is displayed in the text region below the palette area. To the right is a plot of all the MFs for the current variable. The user can select any of these by clicking once on the line or name of the MF. Once selected, the user can modify the properties of the MF using the controls in the lower right. MFs are added and removed using the Edit menu.

The method used in this model was Sugeno method with two input variables i.e. **spin-time** & **last-request** and only one output called **delay-time,** as shown in figure (3.3) below:

The range and type of input/output variable parameters is entered/selected in the membership functions editor in order to make the suitable desired sequence control model.

The sequence control includes the functions mentioned below.

A. spin time

B. last request

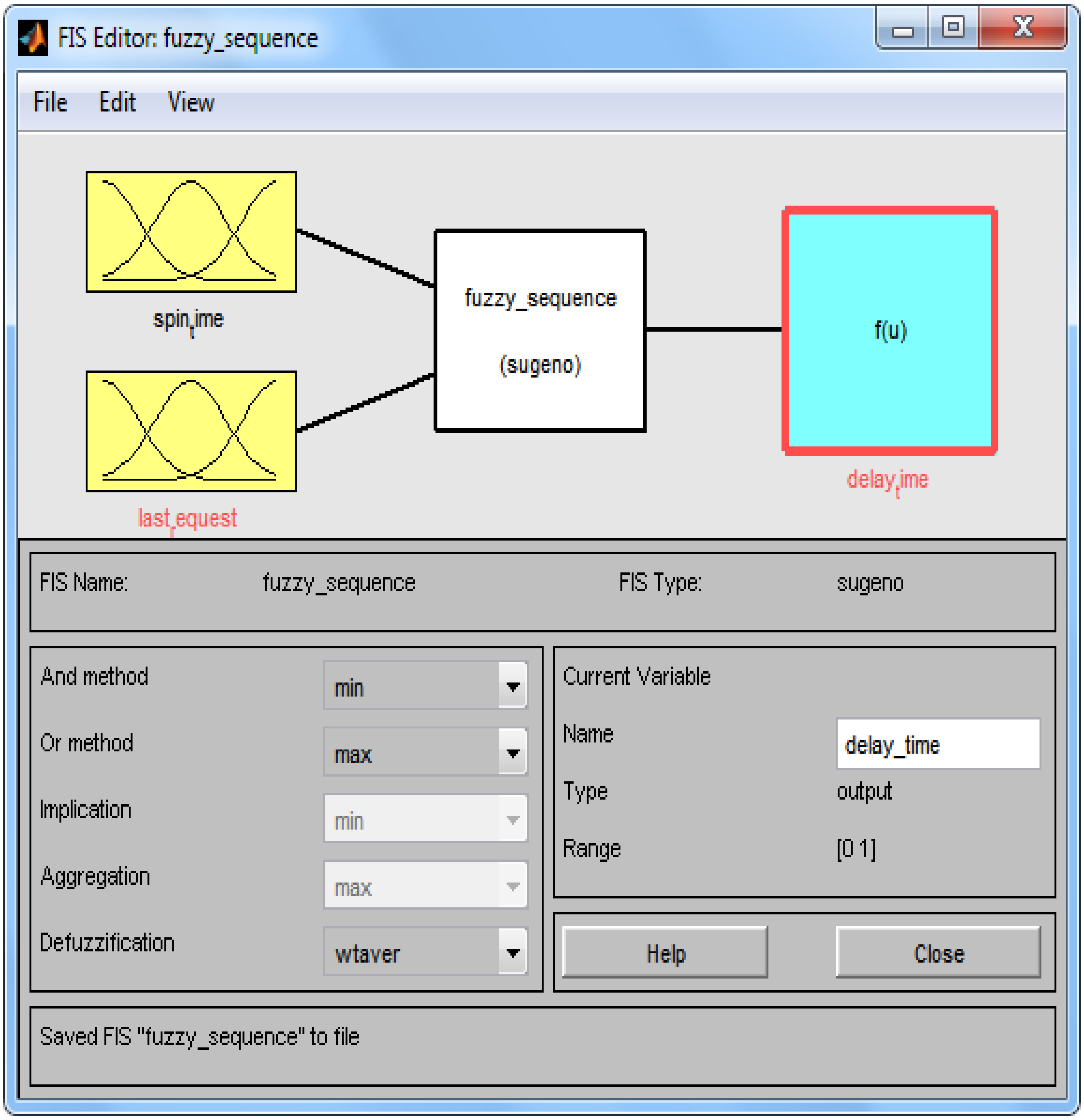


Figure (3.3): Input Variables

A:\ SPIN TIME

It is the time taken to dry the crystal cake to the desired level when the centrifuge rotates at spinning speed, it is a factor to be controlled by the operator. As from Operator Controllable Parameters table, the spin time had a value from 0 to 999 seconds but in normal operation not exceed more than 50 seconds, and the default setting 25 seconds. The spin time variable had only one membership functions which is “normal”, with the universe

U= [0,500 seconds] €Z can be defined as below figure (3.4):

Membership of “normal”

$\mu_n(x)= 0 \qquad x \leq 0$

$\mu_n(x)= x \qquad 0 < x< 500$

$\mu_n(x)=1 \qquad x \geq 500$

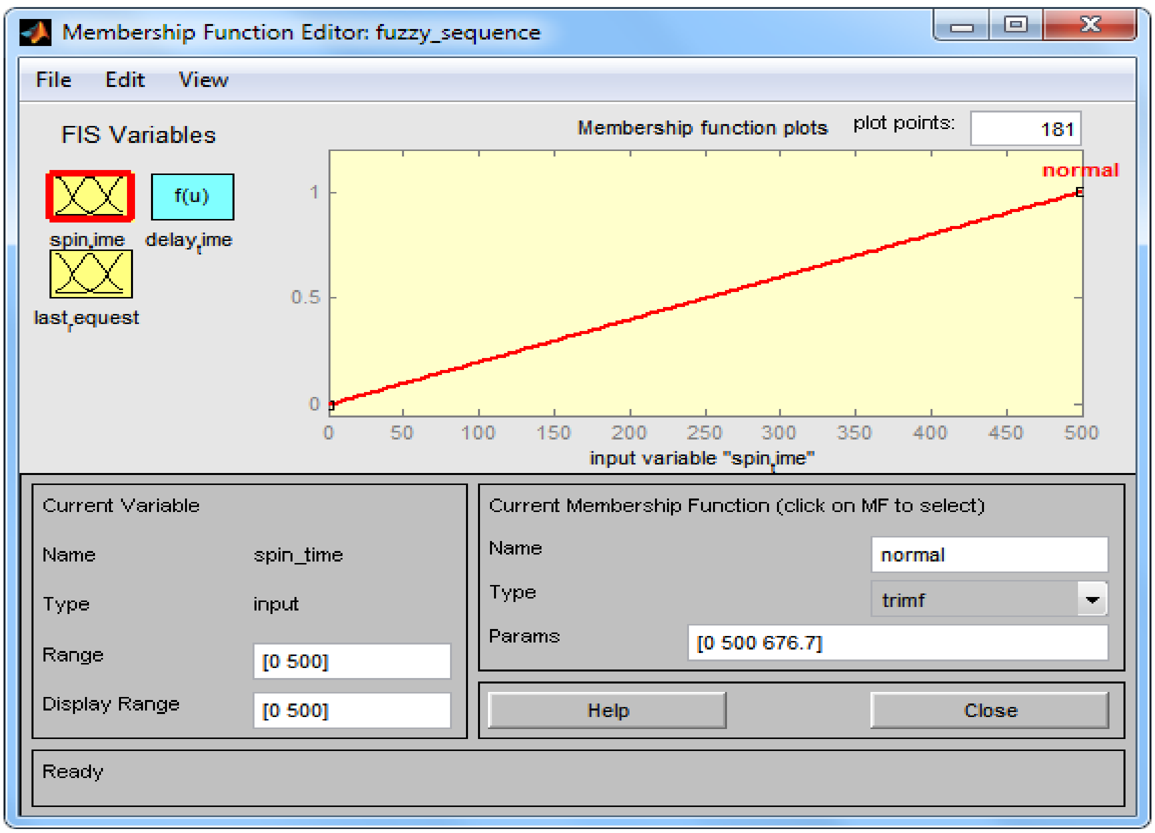


Figure (3.4): Spin Time Input Variable

B:\ LAST REEST

Last request is a time taken since the previous machine send a signal requesting sequence control permission, the membership functions “positive” and “negative” were used, positive it mean that the previous machine had given a permission and passed to accelerate to high speed, in negative case the previous machine still waiting to complete the sequencing delay time. And can be defined as below figure (3.5):

Membership of Positive

$\mu_n(x) = 0 \qquad x \leq 0$

$\mu_n(x) = x \qquad 0 < x < 500$

$\mu_n(x) = 1 \qquad x \geq 500$

Membership of Negative

$\mu_n(x) = 1 \qquad x \leq -500$

$\mu_n(x) = -x \qquad 0 < x < -500$

$\mu_n(x) = 0 \qquad x \geq 0$

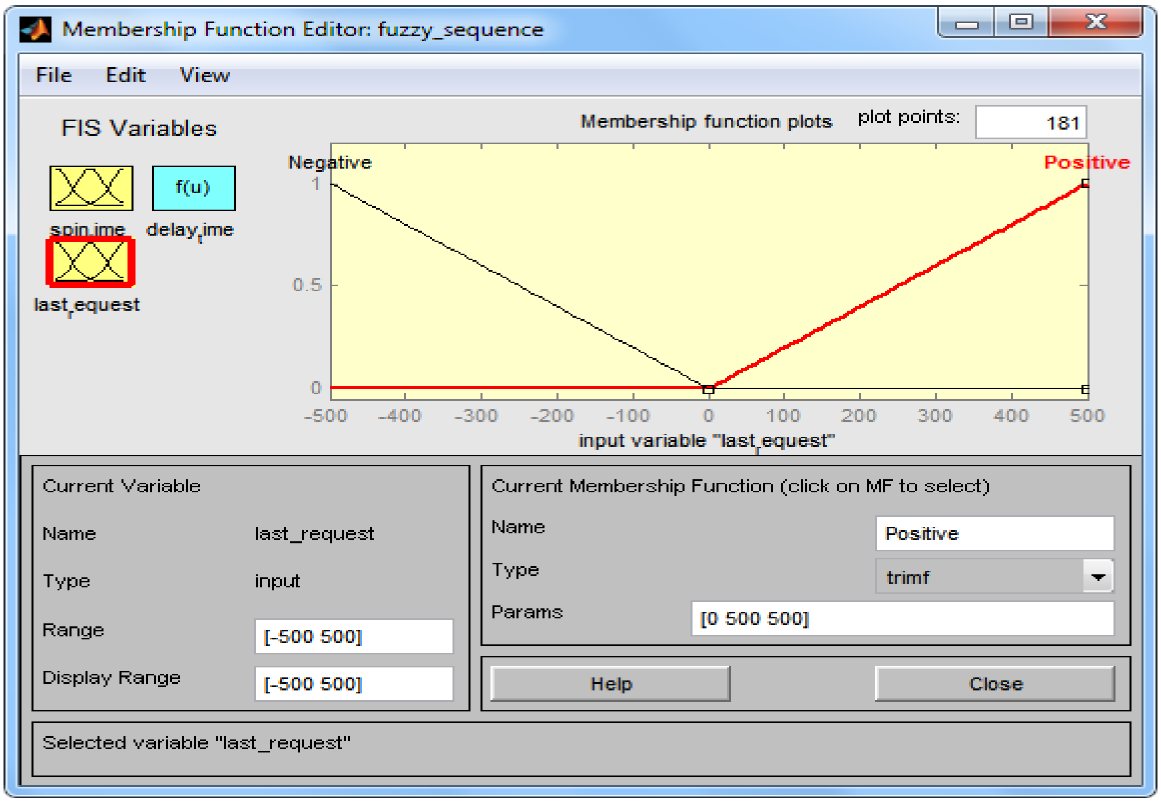


Figure (3.5): Last Request (input variable)

C:\ DELAY TIME

The output has only one variable with one membership function (i.e. mf1) as shown in the figure (3.6):

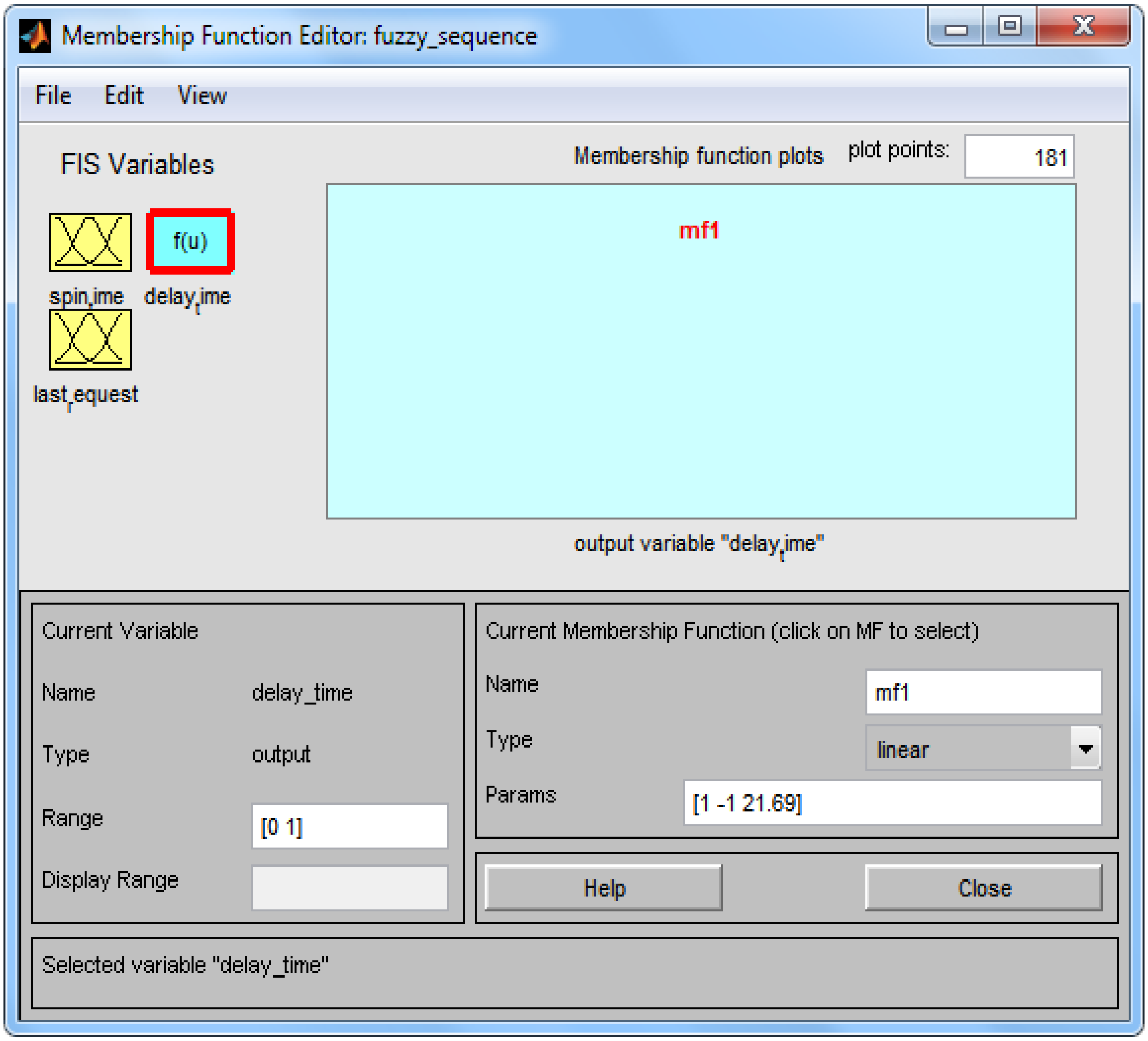


Figure (3.6): Delay Time (output variable)

3.3.3 FUZZY RULE BASE

Fuzzy rule base is created using the two membership functions as mansion before, and the sequence delay time is calculated based on the Sugeno method.

A typical rule in a Sugeno fuzzy model has the form:

If ***Input 1*** = ***x*** and ***Input 2*** = ***y***, then ***Output*** is ***z*** = ***ax*** + ***by*** + ***c***

The output level z_i of each rule is weighted by the firing strength w_i of the rule. for ***AND*** rule with ***Input 1 = x*** and ***Input 2 = y***, the firing strength is being as:

$$w_i = andmethod(F_1(x), F_2(y))$$

Where $F_{1,2}(..)$ are the membership functions for ***Inputs 1 and 2***

The final output of the system is the weighted average of all rule outputs, and computed as:

$$Final\ Output\ = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} w_i}$$

Where ***N*** is the number of rules, here only two rules is used ***(n = 2).*** For this model, the output level ***z*** is a linear with parameters ***(a= -b =1 & C = 21.69)***. The output membership function is selected as shown in figure (3.6).

Now after editing all membership function, the next step is to define rules for the system. Rules can be defined by double clicking on the fuzzy logic medium. It will open the rule editor window. The rules for this model are,

1. If (spin-time is normal) and (last-request is positive) then delay-time is mf1
2. If (spin-time is normal) and (last-request is negative) then delay-time is mf1

It is shown in figure (3.6) below.

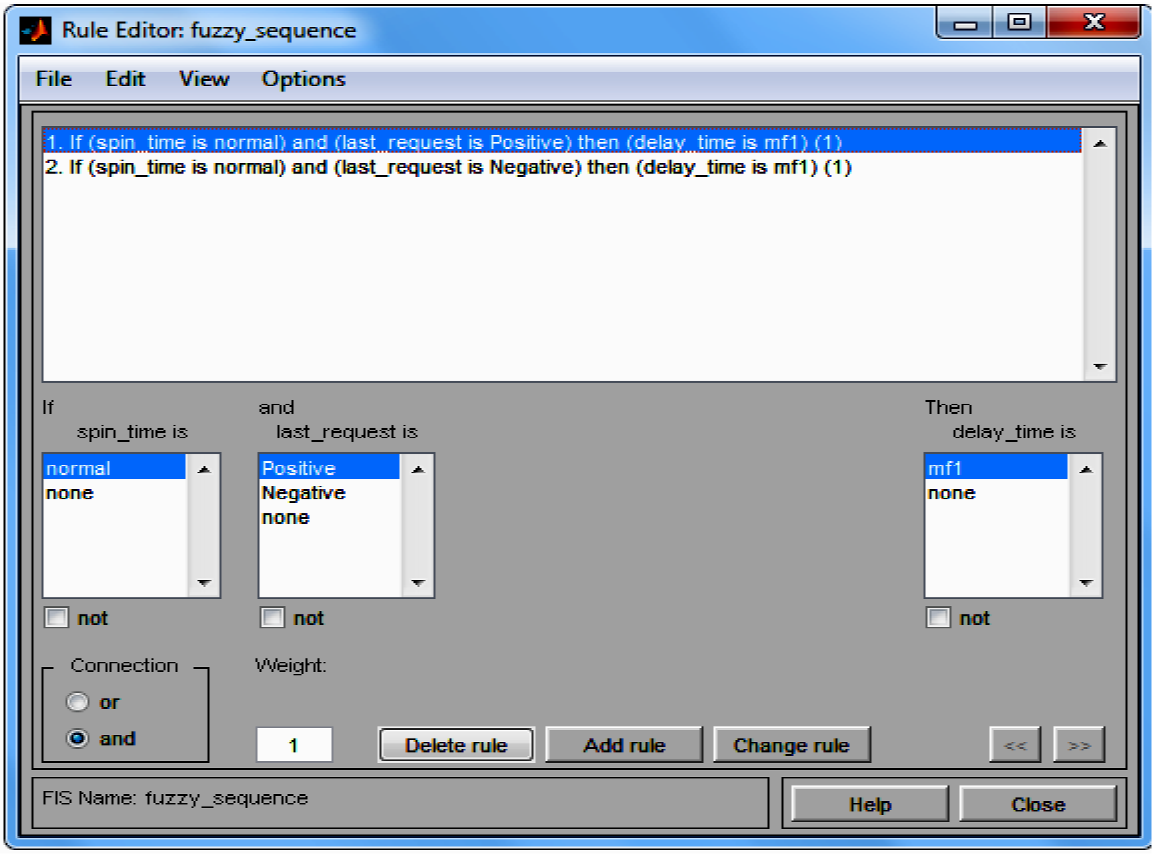


Figure (3.7): Fuzzy Rule Base

Finally Fuzzy controllers based on a linear model and graphically look as figure (3.8) below:

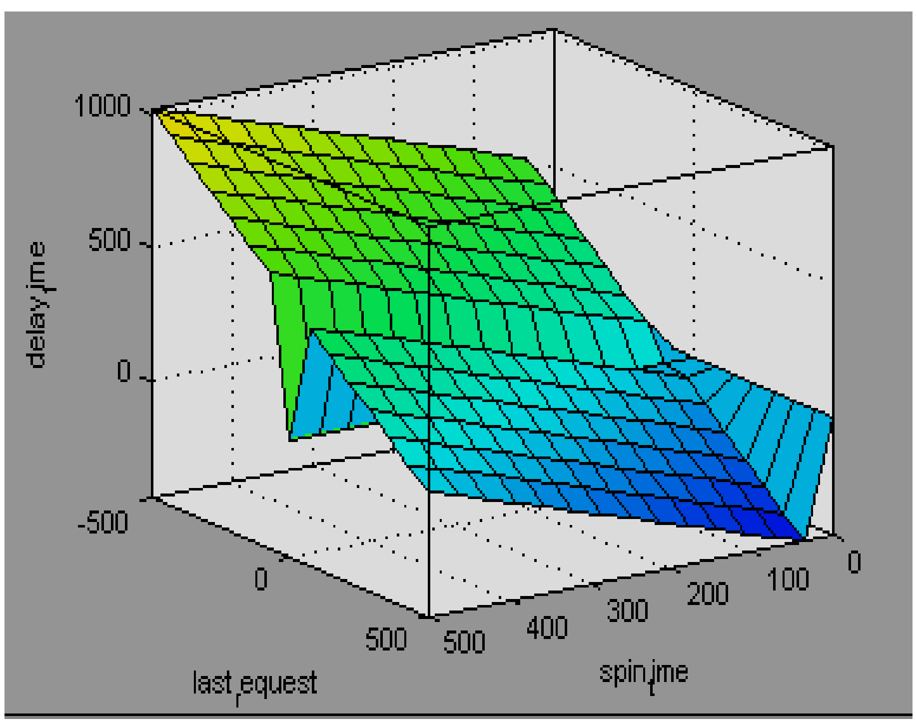


Figure (3.8): A Graphical Representation of the Nonlinear Function

3.4 SIMULATION MODEL:

Matlab Simulink is used to make a model of the sequence control of three batch centrifugal machines using fuzzy interface system as shown in figure(3.10), the current and speed data was entered for simulation of the machines operation figure(3.11), the data is taken from Broadbent C46M batch centrifuge at Assalaya sugar factory when the centrifugal was running on load (Appendix 2), the program considered that the batch centrifugal is operating in cyclic form, more over the machine cycle duration and it is inside intervals (feeding, spinning, plough, etc) varies from time to other.

For simulation the feeding speed, spin speed and plough speed is selected at 250, 1150, 50 respectively, the time duration of feed, spin and plough is entered into machines dialogue-box as below:

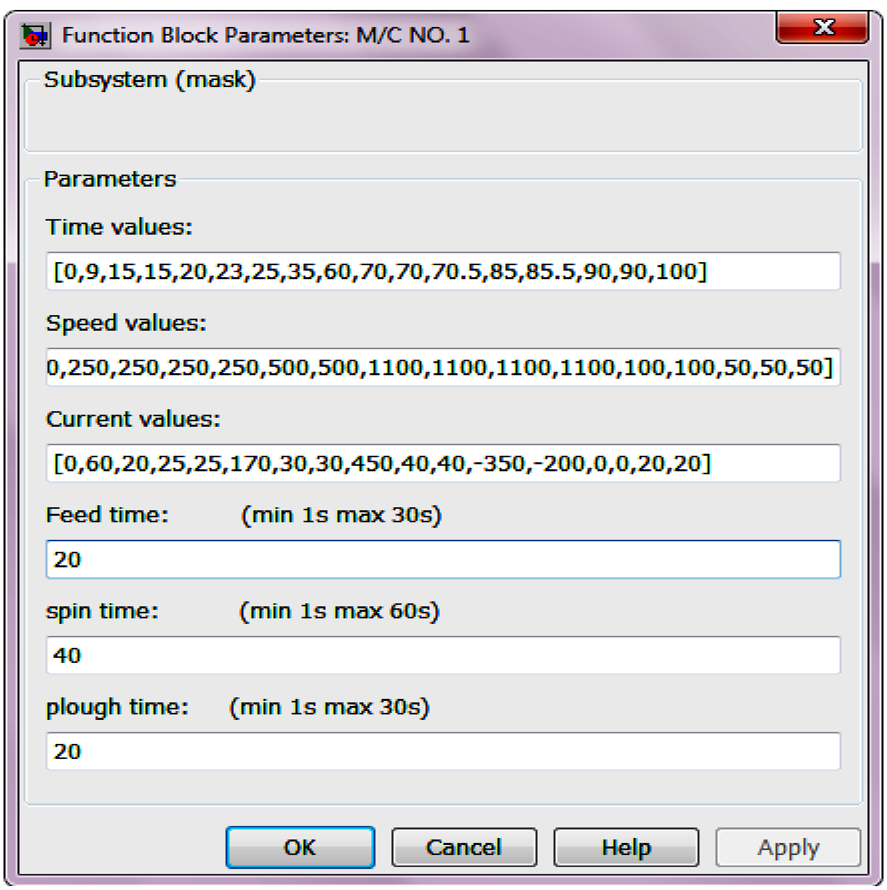


Figure (3.9): Machines Data Entry Dialogue-Box

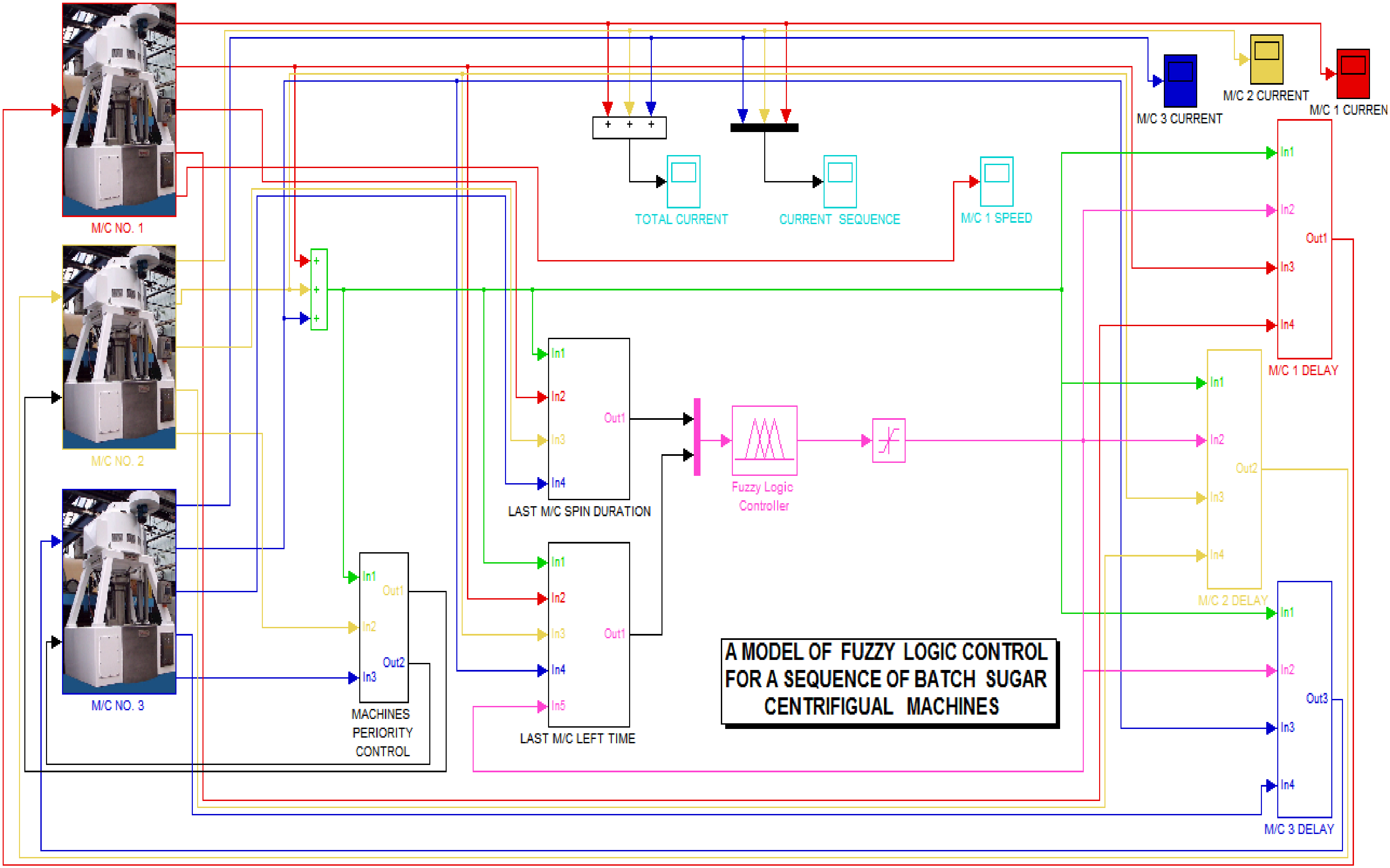


FIGURE (3.10): AMODEL OF FUZZY LOGIC SEQUENCE CONTROL FOR BATCH SUGAR CENTRIFIGUAL MACHINES

By the above dialogue-box figure (3.9) the data for speed Vs time and current Vs time to the batch centrifugal machines is added, same like the simulation showing an induction motor current and time characteristic curves, which has represented linearly and showing a proportional relation. The current increase when speed is increase on acceleration, and the current has negative sign to represent the generative power when in brake mode during de-acceleration as shown in the figure (3.11).

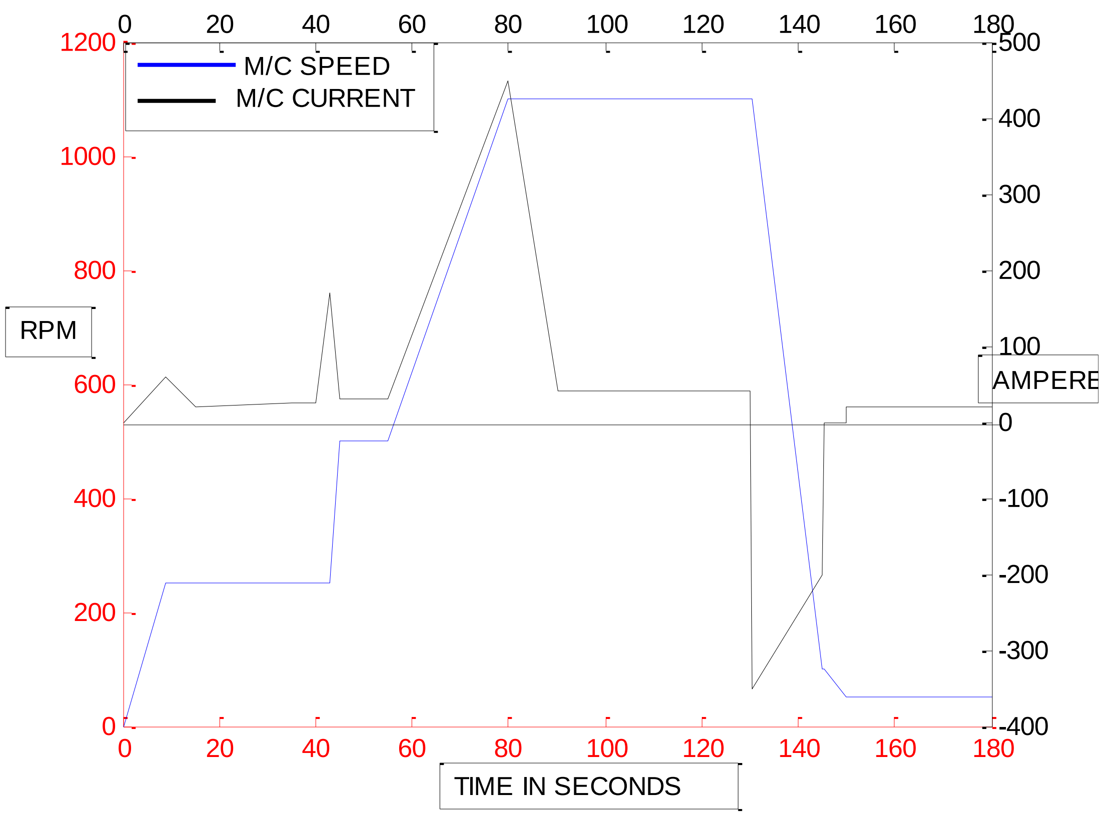
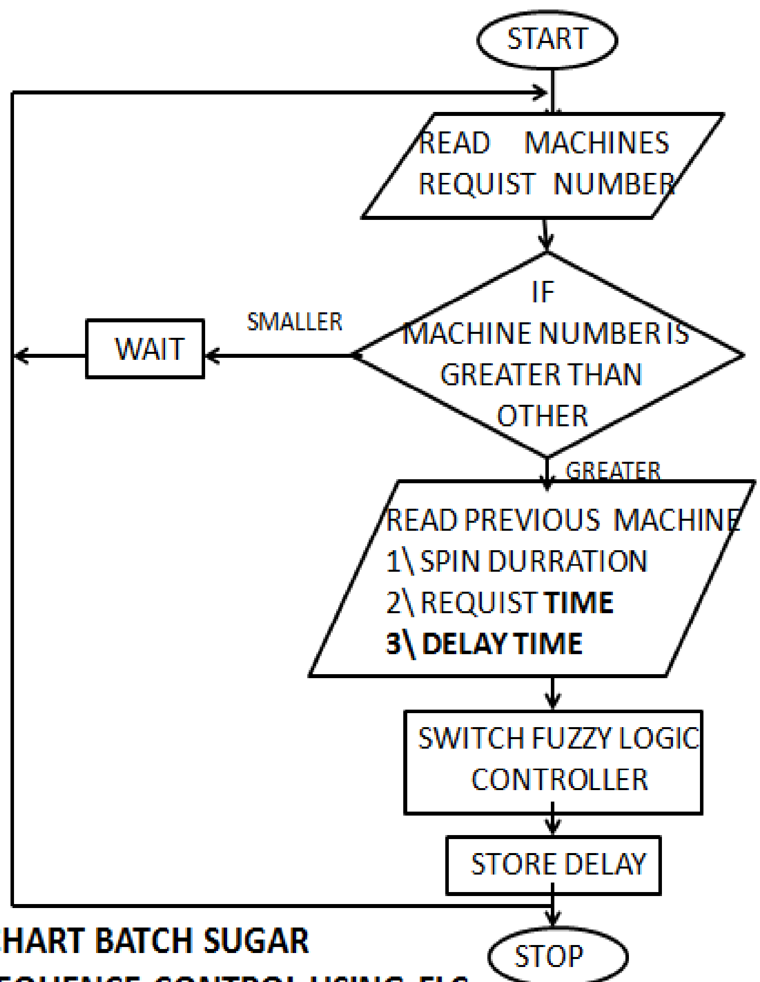


Figure (3.11): Curve of M/C Speed & Current Vs Time

The program was simulate the machine current in all over the cycle during machine running as shown in the flow chart of figure(3.12), the cycle begin to start the machine from the initial point with zero speed and current to reach the feed speed of 250 RPM, the feeding duration time was consider and should be entered in data (figure(3.9)) because of its affect in the cycle length, after feeding complete the machine accelerate to 500 rpm and a current will be more than 30 ampere when this speed reached the machine send a request signal to the sequence control, each machine has specific signal ,the values of these signals equal to the machine order number in the battery, these signal values used for checking the priority ,and according to that the sequence control give a permission to the desired machine after calculating the delay time, this happen when more than one machine send a request signal at the same time, the priority check is done by comparing the values of machine order numbers is and the allowance is given to the machine which had a lowest order number, machines which had higher order is waiting 1 second and also rotate with same 500 rpm, after waiting time is complete the priority also is checked, if allowance is given then the machine data will be entered to fuzzy interface system .



FIGURE(3.12): FLOW CHART BATCH SUGAR CENTRIFIGUAL M/CS SEQUENCE CONTROL USING FLC

After the delay is calculated is stored in the fuzzy logic controller so as to be use in the calculating the delay time of the coming machine. And the sequencing cycle start to continue again for a new calculation of another machine.

3.5 CALCULATION OF DELAY TIME:

The main idea in order to calculate a delay time base on minimizing current shooting by coinciding the accelerate period of one machine with the electrical brake or the regenerative period of the previous centrifugal machine. With aid of the Curve of M/C Speed & Current Vs Time Figure (3.11),

Consider figure (3.13) and the observations for calculating delay time have been taken as follows:

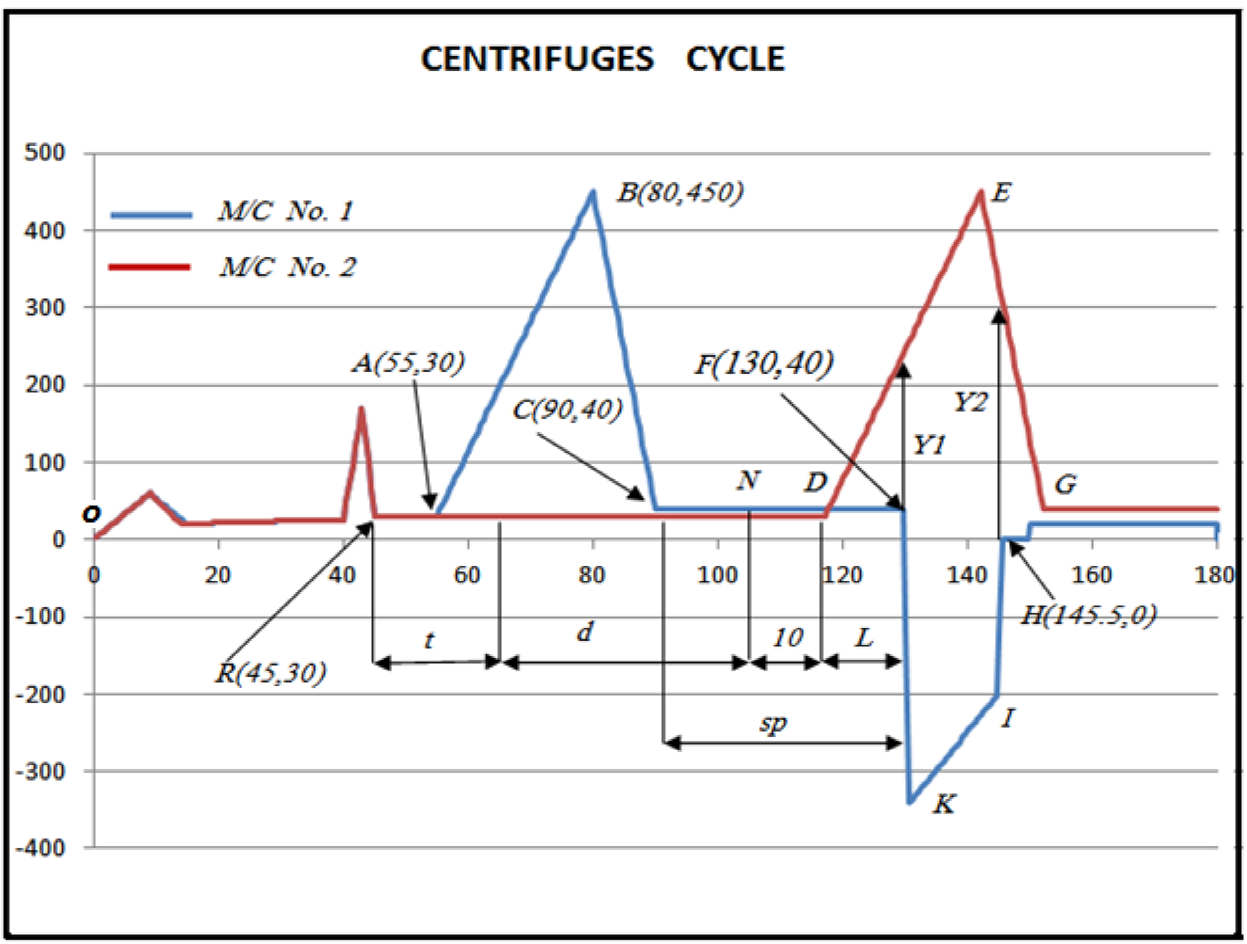


Figure (3.13): Centrifuges Cycle & Delay Time Calculation

from figure (3.13) above the 1st machine is representing with blue color and the 2nd machine is representing with red color.

At ***R*** (45s) the 1st machine (previous machine) request a permission.

2nd machine request after 1st machine by a time of ***t*** second.

sp spins duration of the1st machine (40 second).

d is the time delay for the second machine.

L is a difference between point ***D & F.***

 # RA = ND= 10s is the waiting time before spinning from medium to high speed.

From the above graph the 1st machine request permission at point ***R*** (45s) and start to accelerate from point ***A*** up to point ***B*** and then reach the rated speed the current fall after ***B*** and then be at constant value as between points ***C & F***, then the 1st machine be at brake mode or a regenerative power at points ***F, K, I & H***.

For simplification the program has been made on the assumption that all machines had the same current speed characteristic curve, hence in order to get minimum current shooting, then the positive portion of the second machine (***D E F***) should over lab with negative portion of the 1st machine , above figure the below equation was obtain as:

$$\boldsymbol{OA + t + d + ND + L = OC + sp} \qquad \ldots\ldots\ldots\ldots(3,1)$$

According simulation data ***OA = 45s, ND =10s & OC = 90s*** then the above can be written as:

$$\boldsymbol{45 + t + d + 10 + L = 90 + sp} \qquad \ldots\ldots\ldots\ldots(3,2)$$

$$\boldsymbol{d = sp - t + (35 - L)} \qquad \ldots\ldots\ldots\ldots(3,3)$$

The slope $\boldsymbol{m1}$ of line ***AB*** is equal to the slope of line ***DE***

$$\boldsymbol{m1 = \frac{450 - 30}{80 - 55} = 16.8} \qquad \ldots\ldots\ldots\ldots(3,4)$$

The slope $\boldsymbol{m1}$ of line ***AB*** is equal to line ***DE***

And similarly the slope $\boldsymbol{m2}$ for lines ***BC & EG*** are equal

$$\boldsymbol{m2 = \frac{450 - 40}{80 - 90} = -41} \qquad \ldots\ldots\ldots\ldots (3,5)$$

Equation (3, 3) is linear and the value of the delay time ***d*** is varies proportionally depend on ***t*** and ***sp, L*** is assumed to constant and calculated as follows:

The equation of ***DE*** line is

$$\boldsymbol{y - 30 = 16.8(x - (130 - l))} \qquad \ldots\ldots\ldots\ldots (3,6)$$

$$\boldsymbol{y = 16.8(x + l - 130) + 30} \qquad \ldots\ldots\ldots\ldots (3,7)$$

The equation of ***EG*** line is

$$\boldsymbol{y - 450 = -41(x - (130 - l + 25))} \qquad \ldots\ldots\ldots\ldots (3,8)$$

$$\boldsymbol{y = -41(x + l - 155) + 450} \qquad \ldots\ldots\ldots\ldots (3,9)$$

In order to get minimum over shooting referring to above figure consider the coming equation

$$\boldsymbol{y_1 + 40 = y_2} \qquad \ldots\ldots\ldots\ldots (3,10)$$

To obtain value of ***y1*** substitute ***x=130*** in equation-(3, 7)

$$\boldsymbol{y_1 = 16.8(130 + l - 130) + 30} \qquad \ldots\ldots\ldots\ldots (3,11)$$

$$\boldsymbol{y_1 = 16.8l + 30} \qquad \ldots\ldots\ldots\ldots (3,12)$$

For ***y2 , x=145.5***

$$\boldsymbol{y_2 = -41(145.5 + l - 155) + 450} \qquad \ldots\ldots\ldots\ldots (3,13)$$

$$\boldsymbol{y_2 = -41l + 839.5} \qquad \ldots\ldots\ldots\ldots (3,14)$$

Substitute equations (3, 12) & (3, 14) in (3, 11) then

$$\boldsymbol{16.8l + 30 + 40 = -41l + 839.5} \qquad \ldots\ldots\ldots\ldots (3,15)$$

$$\boldsymbol{l = 13.31} \qquad \ldots\ldots\ldots\ldots (3,16)$$

Finally equation (3, 3) can be written in the form

$$\boldsymbol{d = sp - t + 21.69} \qquad \ldots\ldots\ldots\ldots (3,17)$$

This equation used in FIS as in figure (3.6) to represent the main formula for the solution of sequence control simulation.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

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The sequence control simulation program show the working of three batch machines, the parameter values of these machines i.e.(feed, spin & plough) times has take the default values of (20s, 40s & 20s) respectively (Table 1). The sequence delay time is obtained by overlap the positive spin acceleration current curve of one machine with negative portion of the proceeding one as shown in figure (4.1) below.

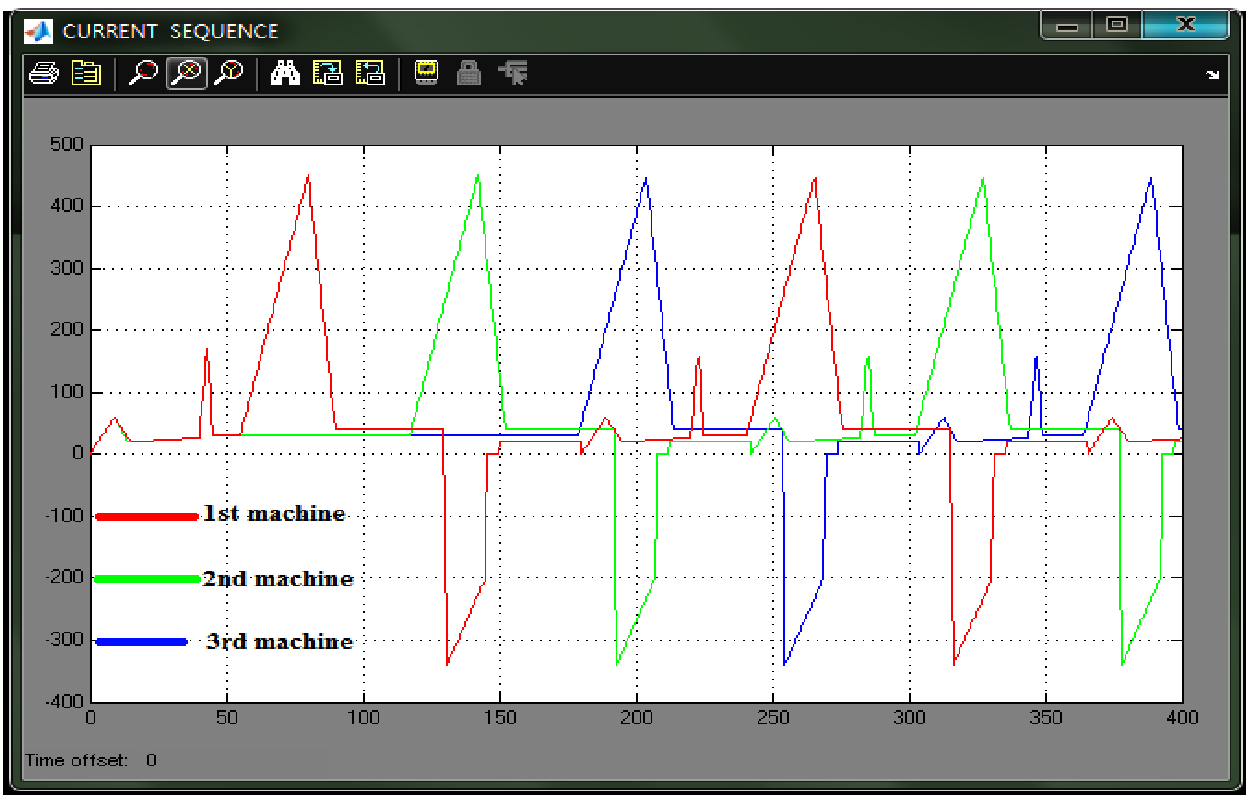

Figure (4.1): Machines sequence at equal values of spin, feed & plough times.

The above figure showing equal interval between machines cycles at all the time after sequencing them, so machines ploughing has separated by equal time interval this prevent more than one machines to discharge at same time.

Figure (4.2) show that the total current is being minimize and, the rapid oscillations and the power taken is appear less than the current of one machine.

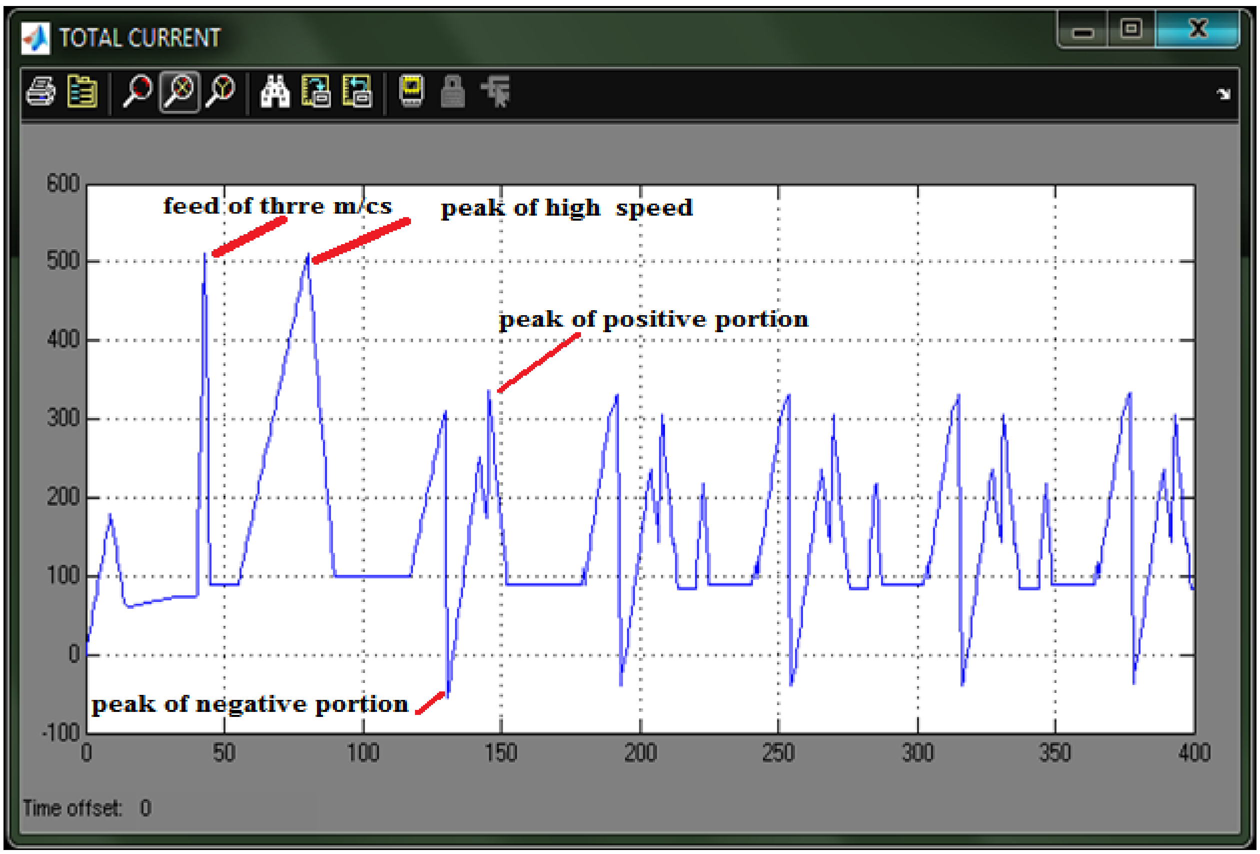

Figure (4.2): Total Current

From figure(4.2) it's appear that the total current reach the maximum value 500A firstly when the three machines were feeding and secondly when the first machine arrive spinning, after that the peak in the positive portion is decrease from 450A (the positive peak current of high speed of one machine) to 325A, here the total current 500A at this time due to the feeding of three machines at same time and secondly is increased to 500A due to spin of the first machine, then sequence controlling the total current and the negative portion increase for -350A (the negative peak current of high speed of one machine) to -50A, this mean that the rapid oscillation of the current is minimized compared with oscillation of one machine and in repeated form, and the total current of the three machines is being less than one machine.

In the second case when the parameters of feed, spin & plough for these machines has different values (i.e. m/c-1 is (30s, 40s, 15s), m/c-2 is (20s, 35s, 10s) & m/c-3 is (25s, 20s, 30s)) the sequence control program regulate the operation of the machines and the total current not exceed the current of one machine as shown in the figure (4.3) and figure (4.4).

Figure (4.1) and figure (4.3) show that the rising end of any negative portions is the starting of discharge of sugar, it separated in organize times intervals, and then the flow sugar be in continues and steady form.

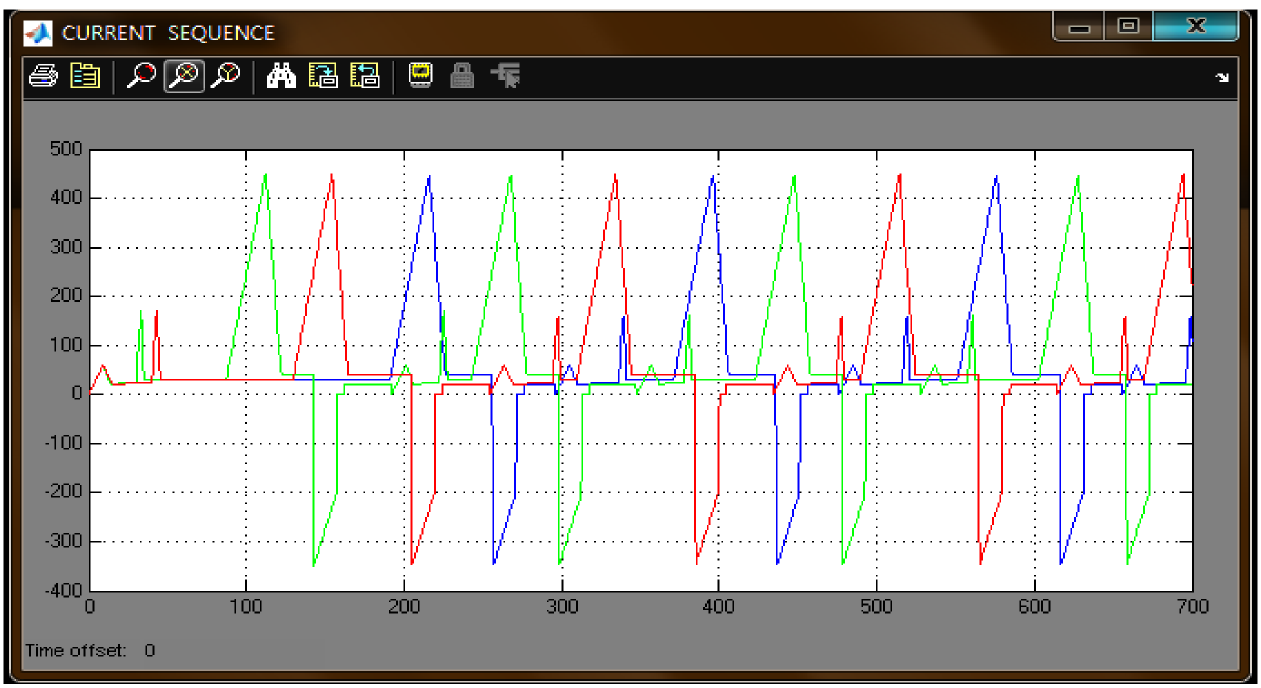

Figure (4.3): Machines in Sequence at different values of Spin, Feed & Plough times.

The above figure show reasonable interval between machines at ploughing which is sufficient enough to prevent more than one machines to discharge at same time.

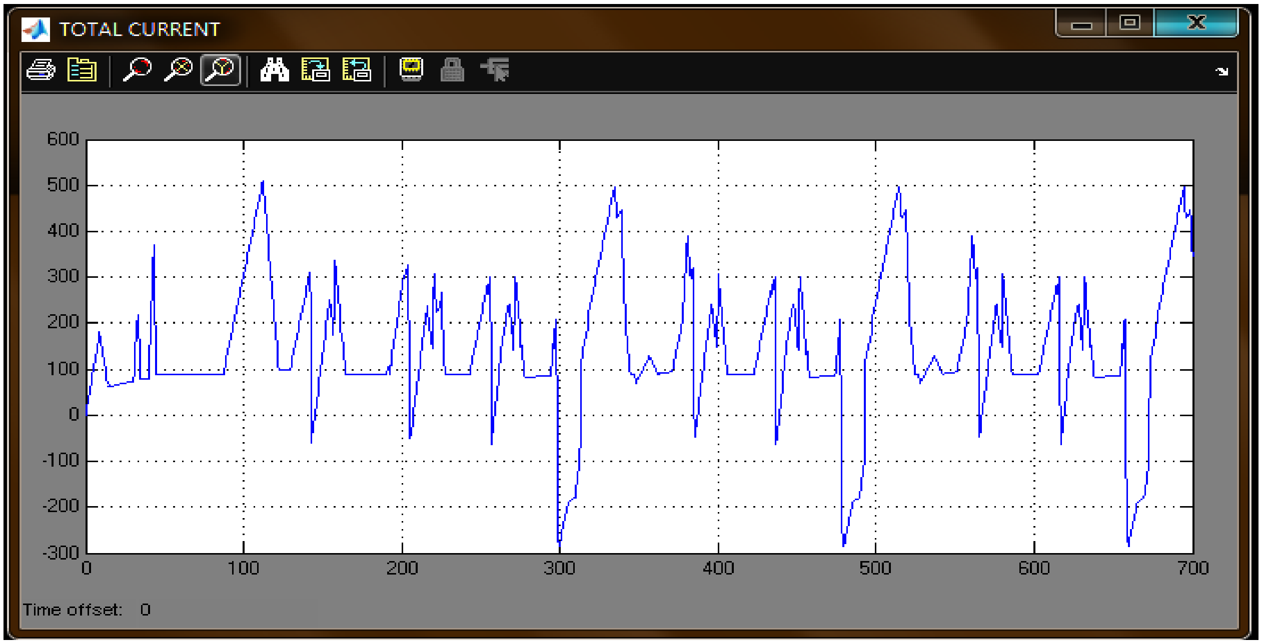

Figure (4.4): Total Current of machines sequence at different values of spin, feed & plough times

The coming figure give the total current of centrifugal machines for different values of feeding, spin and plough times in the simulation program, and in all cases it shown that the total current not more than+500A and less than -350A which is the oscillation that due to the operation of one machine

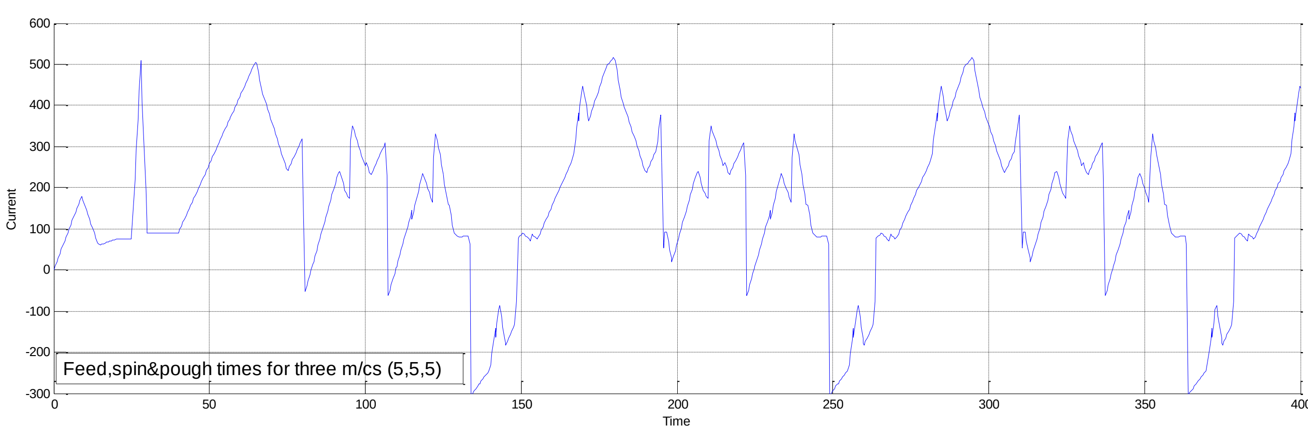

Figure (4.5): Machines current at (5s,5s,5s) values of feed, spin& plough times

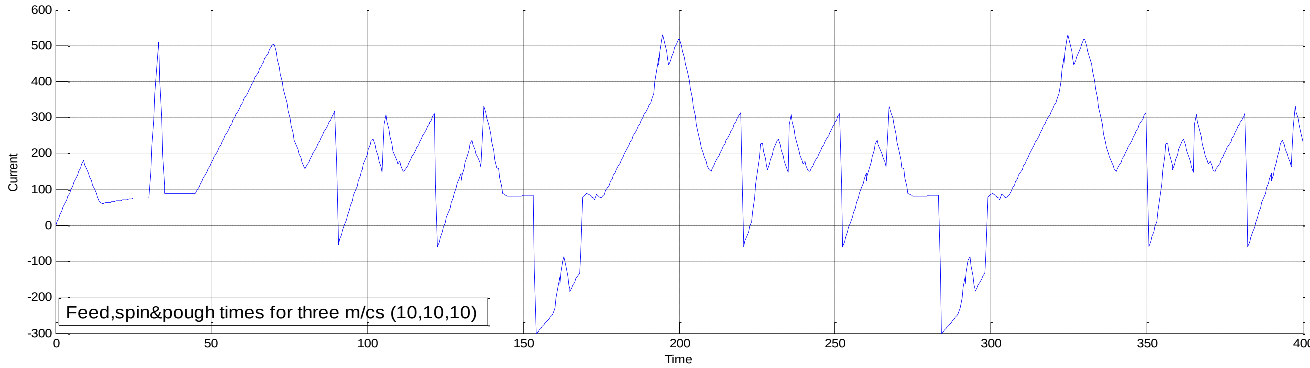

Figure (4.6): Machines current at (10s,10s,10s) values of feed, spin& plough times

Figure (4.7): Machines current at (15s,15s,15s) values of feed, spin& plough times

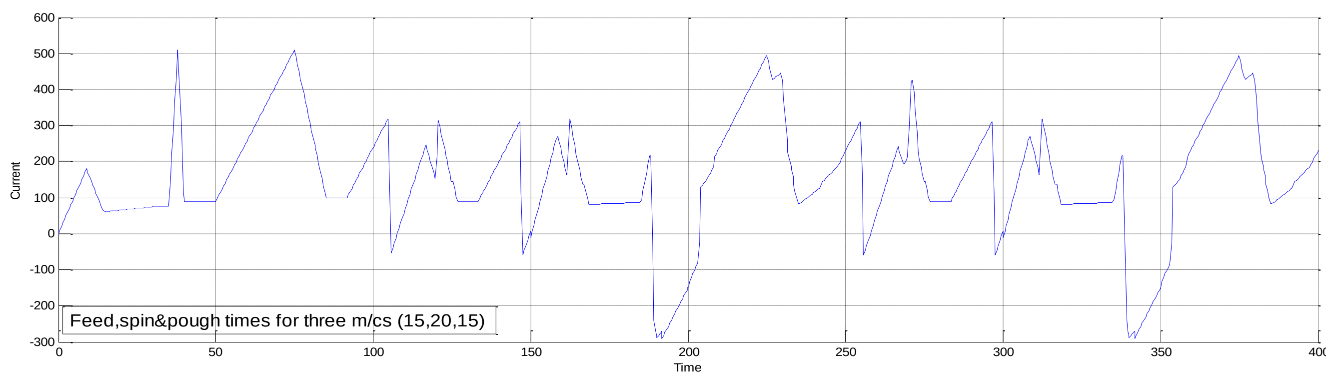

Figure (4.8): Machines current at (15s,20s,15s) values of feed, spin& plough times

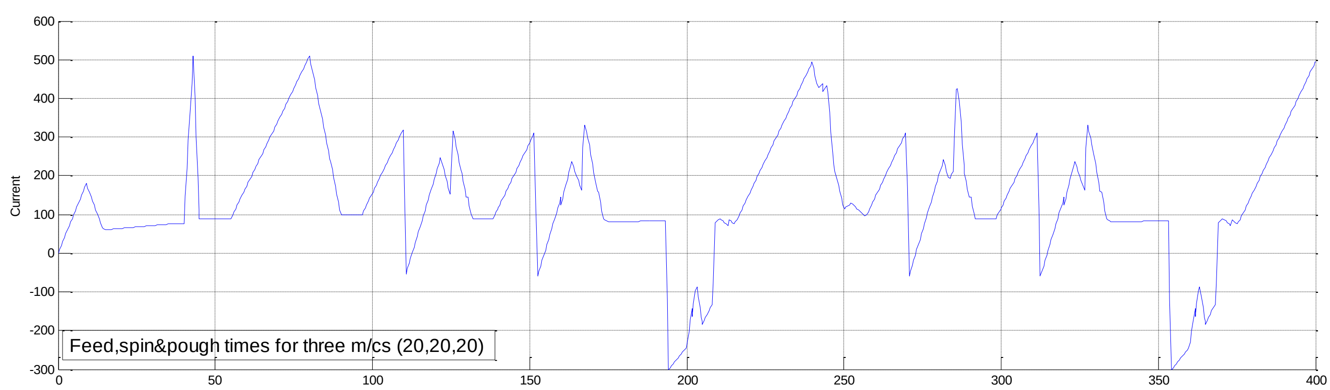

Figure (4.9): Machines current at (20s,20s,20s) values of feed, spin& plough times

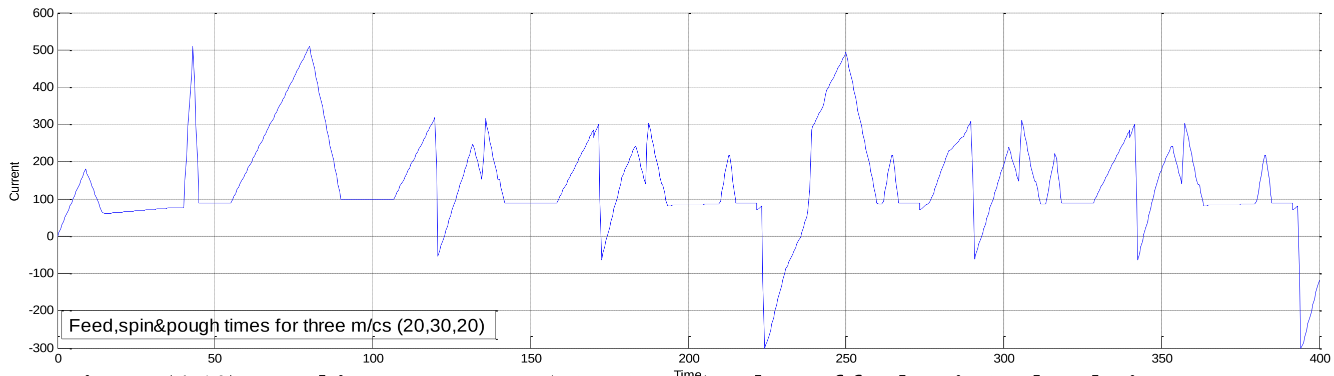

Figure (4.10): Machines current at (20s,30s,20s) values of feed, spin& plough times

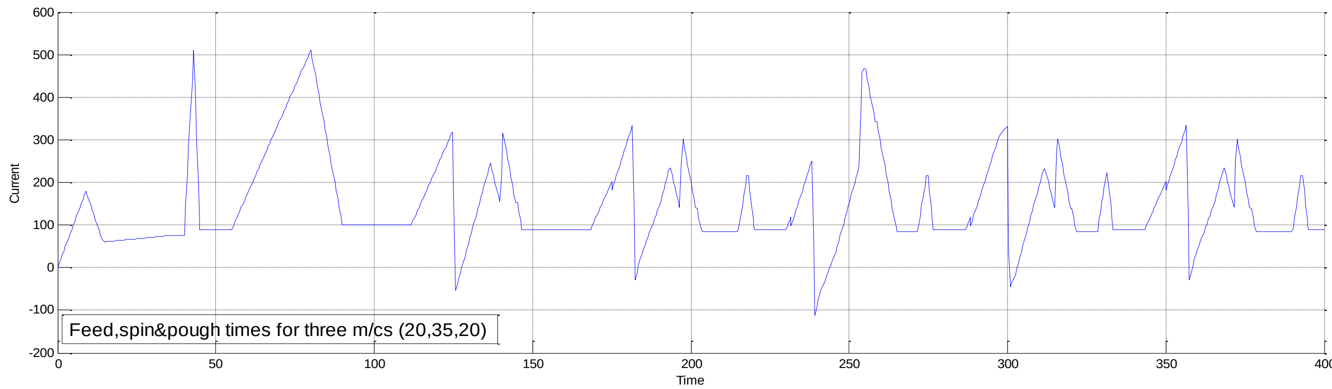

Figure (4.11): Machines current at (20s,35s,20s) values of feed, spin& plough times

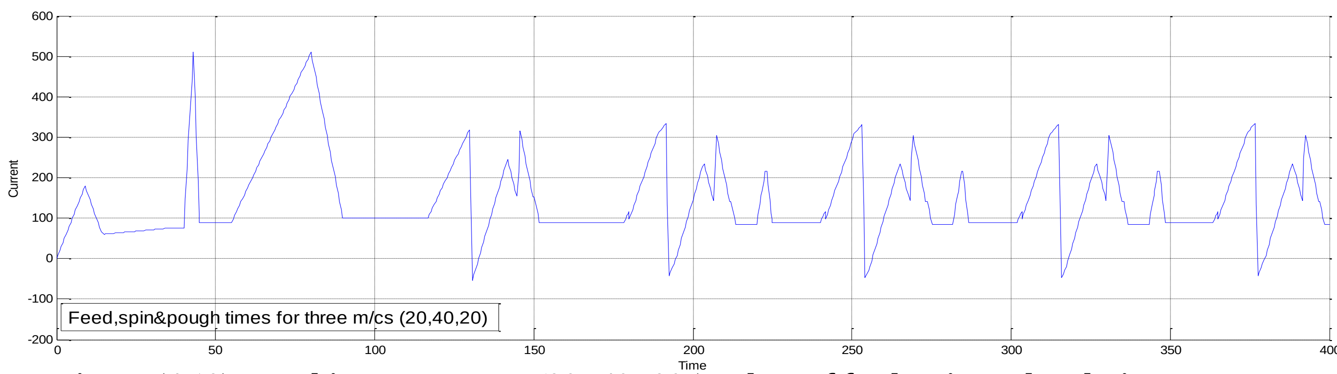

Figure (4.12): Machines current at (20s,40s,20s) values of feed, spin& plough times

The centrifugal machine default spin time for is 40s, from figure (4.5) to figure (4.12) the current oscillation after feeding of three machines & spin of the first one machine, the current has been in high oscillation when the spinning the time for the machines is less than the default value, and vice versa this mean that the sequence control regulation depend on the spin time of the machines.

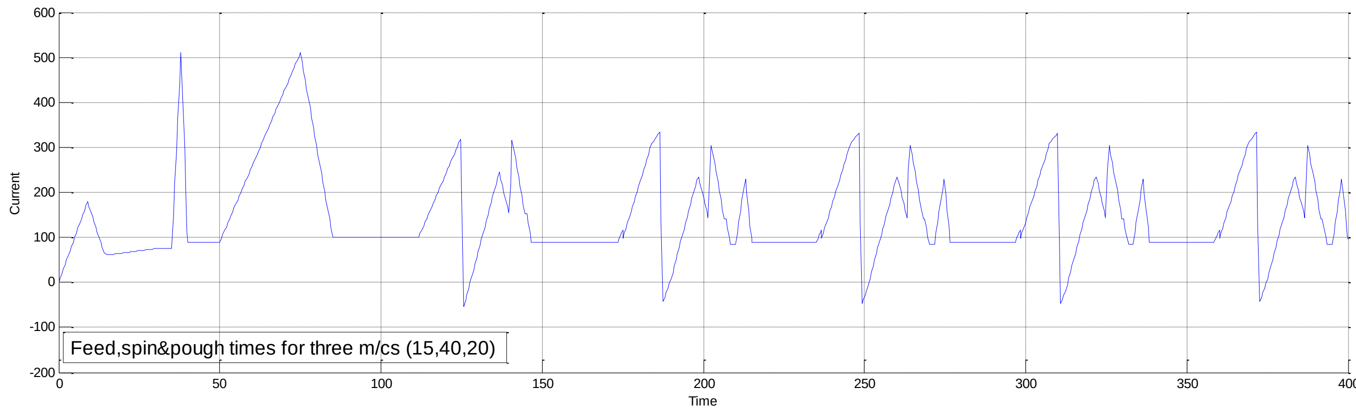

Figure (4.13): Machines current at (15,s40s,20s) values of feed, spin& plough times

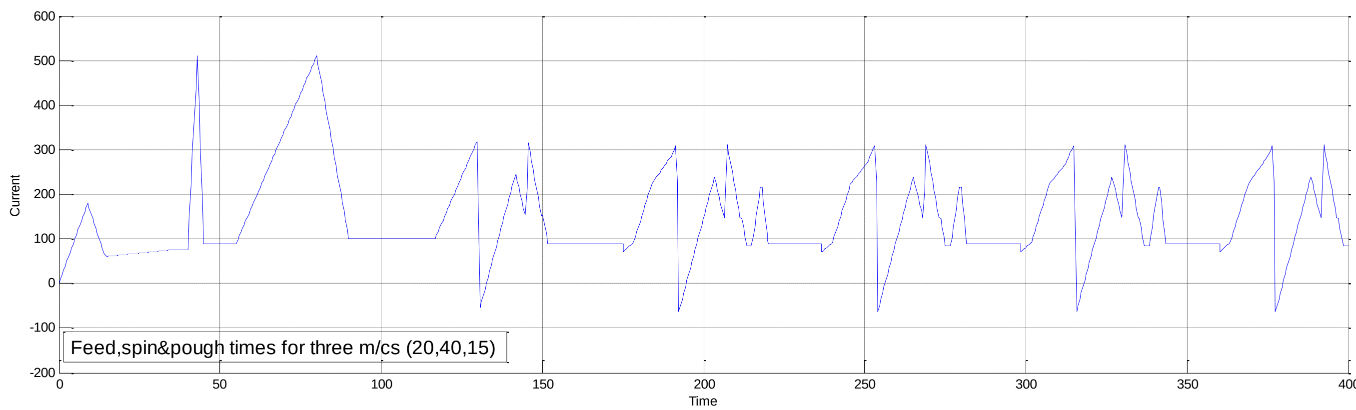

Figure (4.14): Machines current at (20s,40s,15s) values of feed, spin& plough times

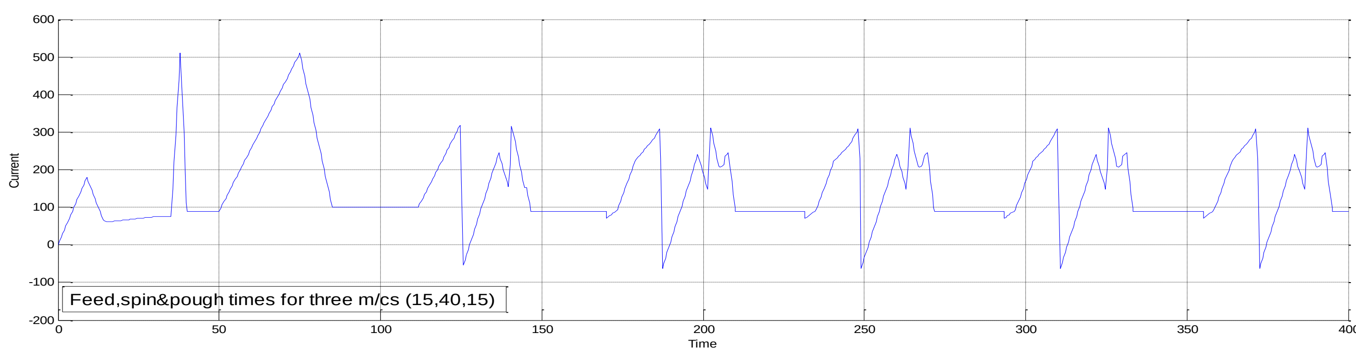

Figure (4.15): Machines current at (15s,40s,15s) values of feed, spin& plough times

Figure (4.16): Machines current at (10s,40s,10s) values of feed, spin& plough times

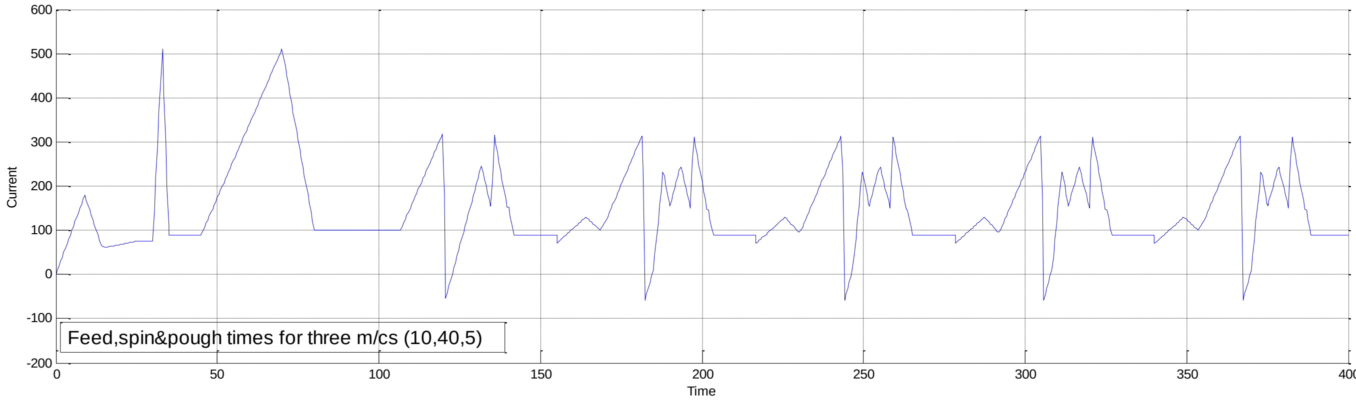

Figure (4.17): Machines current at (10s,40s,5s) values of feed, spin& plough times

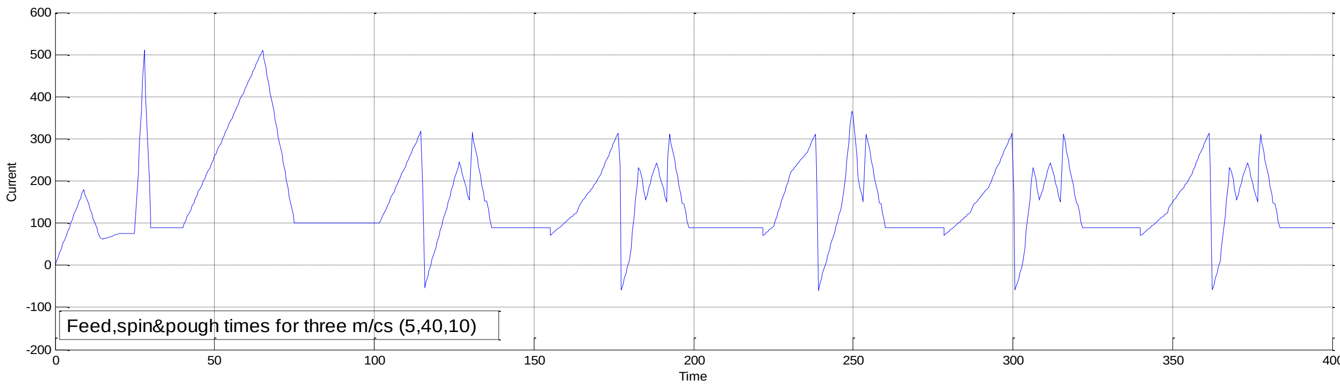

Figure (4.18): Machines current at (5s,40s,10s) values of feed, spin& plough times

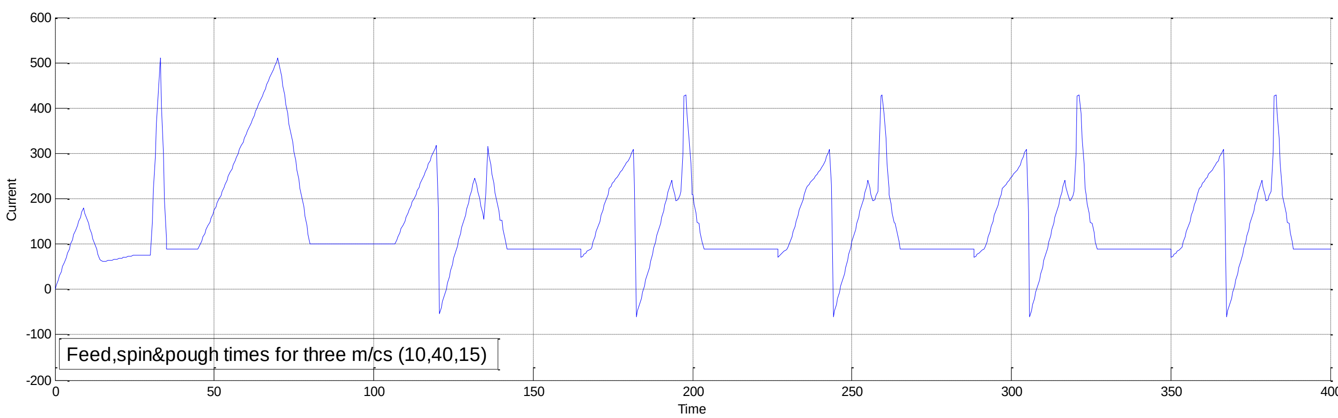

Figure (4.19): Machines current at (10s,40s,15s) values of feed, spin& plough times

Figure (4.20): Machines current at (15s,40s,10s) values of feed, spin& plough times

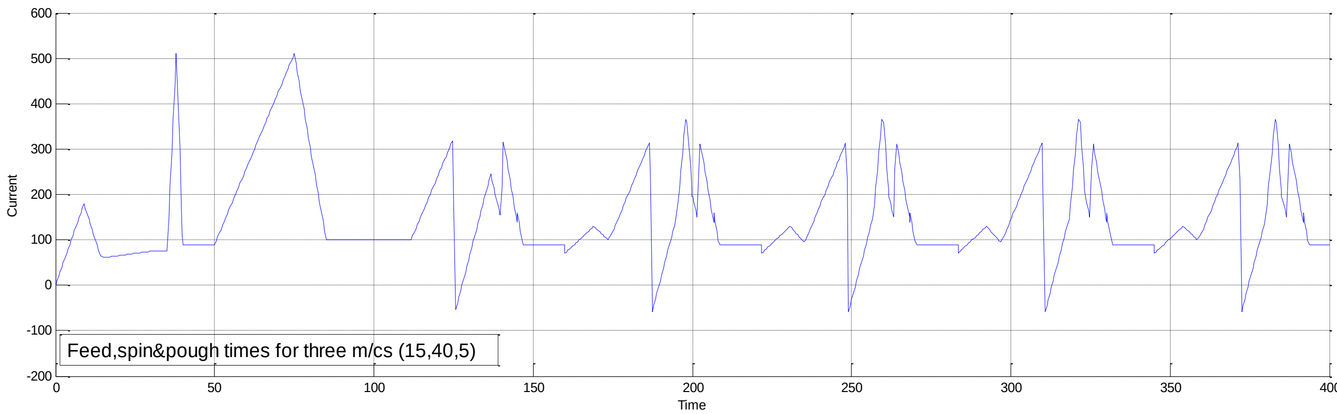

Figure (4.21): Machines current at (15s,40s,5s) values of feed, spin& plough times

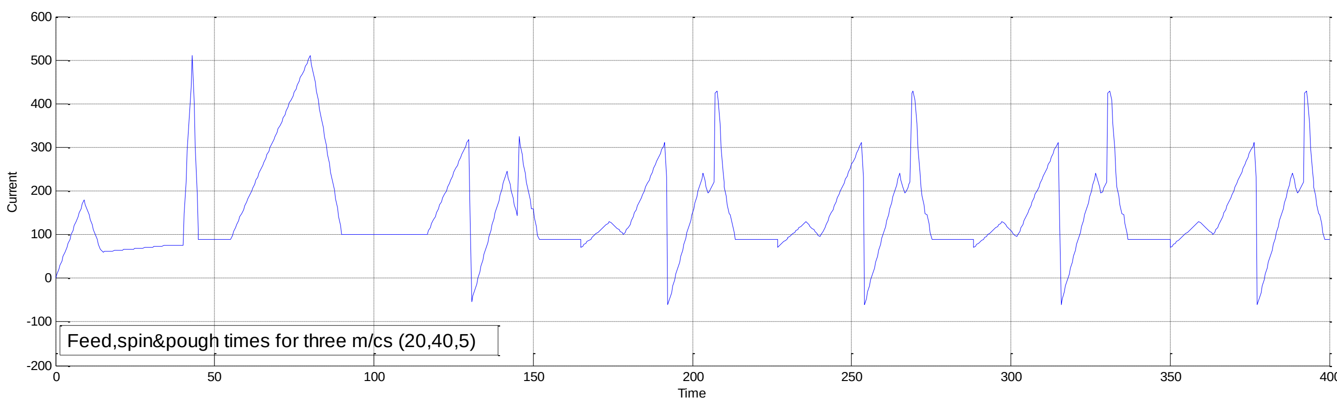

Figure (4.22): Machines current at (20s,40s,5s) values of feed, spin& plough times

The default cycle time for centrifugal machine is 180 and the default time for feeding, spinning and plough is 20s, 40s&20s respectively, the other reset of cycle is assume to be constant due operation of machine without load, from figure (4.13) to figure (4.22) the current oscillation after feeding of three machines & spin of the first one machine, the current has been in high oscillation when the cycles of machines is less the default cycle length ,this mean that the sequence of machines will not regulate the currents when the machines cycles less than 180s.

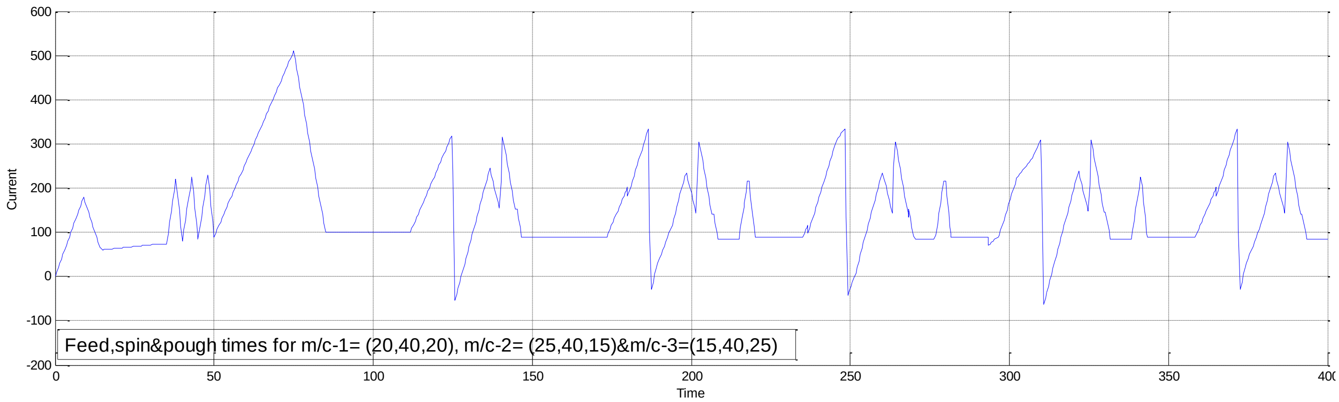

Figure (4.23): Machines current at m/c-1 (20s,40s,20s) , m/c-2 (25s,40s,15s) &m/c3 (15s,40s,25s) values of feed, spin& plough times

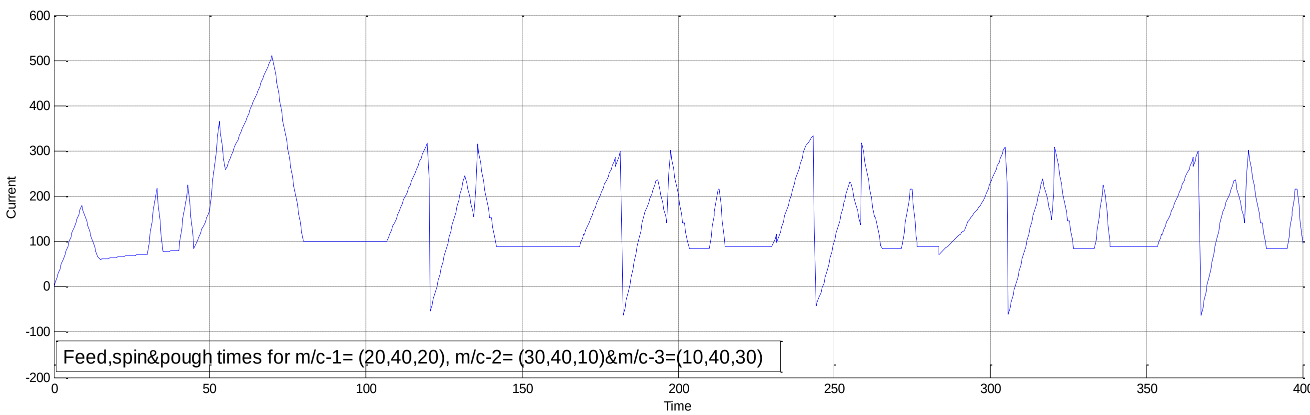

Figure (4.24): Machines current at m/c-1 (20s,40s,20s) , m/c-2 (30s,40s,10s) &m/c3 (10s,40s,30s) values of feed, spin& plough times

In figure (4.23) & figure (4.24) showed that for different values of spin, feeding and plough for the three machines, but these value near to each other and also the machines cycles are equal, the sequence control regulate the oscillation in good manner and minimize the total machines current and not increase more than +300A and not lower -50A.

Chapter five

CONCLUSSIONS AND RECOMONDATIONS

CHAPTER FIVE

CONCLUSSIONS AND RECOMONDATIONS

5.1 CONCLUSSIONS

- The delay time selected by the sequence control to regulate a machine is depending on the previous one spin time, and the time interval between the required machine and that left the sequence control.
- In all case when varying values of feed spin & plough cycle time, the sequence was control the centrifugal machines and the current oscillations of these machines not exceed the oscillation of only one machine
- The sequence control has better performance when the values feeding, spin, plough & cycle time for any machine is equal or nearly to the values of other machines.

5.2 RECOMONDATIONS

- The three machines model can be generalize to include many machines in a battery and the regulation of the machines sequence can be obtain according to the number of the working machines at that battery.
- In order to get more precise solution in addition to the two parameters used (i.e. spin time & last machine request) more parameters can be added like number of the machines working, other machines position in their cycles (request time taken for every machines) and the load of current of the machines, more over the current of the induction motor of the centrifugal machine can be representing by its equivalent circuit diagram.
- Neural network can be used instead of fuzzy control in order to get more accurate solution in sequence control.

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APPENDICS

APPENDIX 1

NO.	Description	Limits	Initial Setting
1	Feed Speed (rpm)	150 to 450	250
2	Valve Opening Preset in *Preset Feed Mode* (%)	0 to100	20
3	Target Feed Time in *Calculate Feed Mode* (seconds)	5 to 40	20
4	Fail Feed Time (seconds)	5 to 40	25
5	Feed Chute Rinsing Time (seconds)	0 to 10	1
6	Cake Settling Delay Time (seconds)	0 to 60	0
7	Speed for Primary Wash to start (rpm)	250 to 1100	650
8	Duration of Primary Wash (seconds)	0 to 30	5
9	Liquor Classification Changeover Delay (seconds)	0 to 999	10
10	Speed for Secondary Wash to Start (rpm)	250 to 1100	800
11	Duration of Secondary Wash (seconds)	0 to 30	5
12	Time for Wash C to start after start of spin (seconds)	0 to 999	5
13	Duration of Wash C (seconds)	0 to 30	0
14	Time for Steaming to start after start of spin (seconds)	0 to 999	5
15	Duration of Steaming (seconds)	0 to 30	5
16	Spin Speed (rpm)	1000 to 1150	1150
17	Spin Time (seconds)	0 to 999	25
18	Ploughing Speed (rpm)	40 to 60	45
19	Plough Dwell Time in Top of Basket (seconds)	0 to 10	1.5

Source: (Broadbent, 2002)

Table 1 : Operator Controllable Parameters

APPENDIX 2

Step no.	Time in Seconds	Speed in RPM	Current in Ampere
1	0	0	0
2	9	250	60
3	15	250	20
4	15	250	25
5	20	250	25
6	23	250	170
7	25	500	30
8	35	500	30
9	60	1100	450
10	70	1100	40
11	70	1100	40
12	70.5	1100	-350
13	85	100	-200
14	85.5	100	0
15	90	50	0
16	90	50	20
17	100	50	20

Source: (Data from Assalaya Sugar Factory working machines)

Table 2 : Batch Centrifugal M/C speed &current Vs time Data