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Automatic Control System for Spray Drier Pilot Plant

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Abstract— **In this paper we describe the software implementation for complete automation of spray drying pilot plant using PLC and also the SCADA representations of particular plant. The software is implemented using RX Logics 5000 software. Paper contains the plant specifications and the flow chart used for software implementation. This pilot plant can be operated and different control strategies can be tested from PLC, DCS, Local Console as well as Remote Location over Internet depending upon the position of hard selector switch. This plant is readily available at College Of Engineering, Shivajinagar, Pune, Maharashtra, India**

Index Terms— **Pilot plant, PLC, Control strategies, DCS.**

I. INTRODUCTION

Spray drying is a removal of moisture from liquid feed by breaking into droplets in a hot medium to convert into powder form. In order to ensure the product quality is at the desired specification, a good control system and good understanding on the dynamic behaviour should be considered. The aims of this study are to develop model of spray drying process and improve the process by implementation of PI controller.

Spray drying is a method in which a fluid mixture usually being sprayed into a hot dry air. Spray drying can only be done only when the dried final product behaves as a non-sticky solid (not a liquid). The mixture being sprayed can be a solvent, emulsion, suspension or dispersion. It is atomized into millions of individual droplets by a nozzle or a rotary wheel. This process increases the surface area of the sprayed solution. The solvent is vaporized immediately by the hot air. This vaporization process rapidly removes heat so that the product is dried gently without thermally shocking it. The product is turned into a powder, granulate or agglomerate within seconds.

Spray drying consists of three process stages:
- Atomization
- Spray-air mixing and moisture evaporation
- Product recovery

Each stage is carried out according to the dryer design and operation and together with the physical and chemical properties of the feed determines the characteristics of the final product.

The paper is organized as follows. In Section II we present the Literature survey. Section III presents the model of the spray dryer. In Section IV we present a software implementation to show the benefit of optimizing the operation. Results and Conclusions are given in Section V and Section VI. Section VII represents future scope and Section VIII references used in this paper.

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II. LITERATURE SURVEY

A. Spray Drying

Spray drying is an important unit operation in many industries such as pharmaceuticals and food. In spray dryer an atomized stream is to be dried with a hot air or gas stream which is at higher temperature than the liquid stream. The higher temperature of a heating media causes evaporation of liquid from the droplets which lead to form particles. It is by definition transformation of feed from fluid state into a dried particulate form.

The development of spray drying process has been intimately associated with the dairy industry and the demand for drying of milk powders. Spray drying used in dairy industry dates back to around 1800, but it was not possible until 1850 that it became possible in industrial scale to dry the milk. However, this technology has been developed and expanded to cover a large food group that is now successfully dried. Nowadays spray dryer extensively used in food industry for example manufacturing of milk powder, tomato powder and the pharmaceutical industries to form powders.

B. Design Of Spray Dryers

Chemical processes are concerned with using known chemistry, kinetics and thermodynamics to manufacture different products based on specified requirements. Process design for chemical processes involves such activities as different unit operations, generating the process flow sheet, and optimizing the flow sheet to improve the economics.

Here we are concerning more on process design rather than flow sheet synthesis. The flow sheet may be optimized for particular objective function, such as profit or loss. The process optimization problem may consist of continuous variables such as equipment sizes, flow rates and concentrations. The process design is carried out in steady state to achieve nominal design conditions. The dynamics associated with start-ups and operability is addressed in process control part by parameter sensitivity analysis but the selection and placement of actuators and sensors, which are used to develop an effective control strategy, should be elected in process design itself. Different spray dryer designs can be obtained by passing the heating gas either co-currently or counter-currently to the feed solution [1], by a different choice of atomizer. Mujumdar [2, 3] have investigated horizontal spray dryers using computational fluid dynamic simulations. Masters [4] discusses three different control schemes and has provided some guidelines for the design of a control system for a general spray dryer. The heating gas flow rate or heating gas temperature is chosen to regulate the amount of solvent that remains in the particle. Shrishail

Kattimani [5] discussed the design of the lab scale pilot plant of Spray Dryer.

C. Remote Triggering

Over the past decade several RT experiments have emerged in different parts of the world including those developed under Govt. of India's National Mission on Education through ICT as part of Right to Education (RTE) Program. However, as the technology to build RT labs evolves there is a growing concern at high cost of RT labs compared to real labs [6]. The availability of hands-on labs in engineering and science education that require costly equipment and instruments is restricted for little and limited periods of time for a huge number of students. Solutions to bypass these problems are through the introduction of augmented reality (AR) remote labs and virtual labs. A comparison between three different types of labs, namely augmented reality remote labs, virtual labs and hands-on is carried out [7].

III. SYSTEM MODEL

A. Hardware Requirements

FD fan speed – 50% of its max speed in order to get 30ml/sec speed of fluid

PSLL (Pressure Switch Low Level)-100mm WC

PSHH(Pressure Switch High)-450mm WC

TT1(Temperature Transmitter1)- between 100°C to 120°C

TT2(Temperature Transmitter2)- around 60°C

VI(Vacuum Indicator)-110-120 mm WC

PI(Pressure Indicator)-1-1.5 kg/cm²

ID fan- max speed

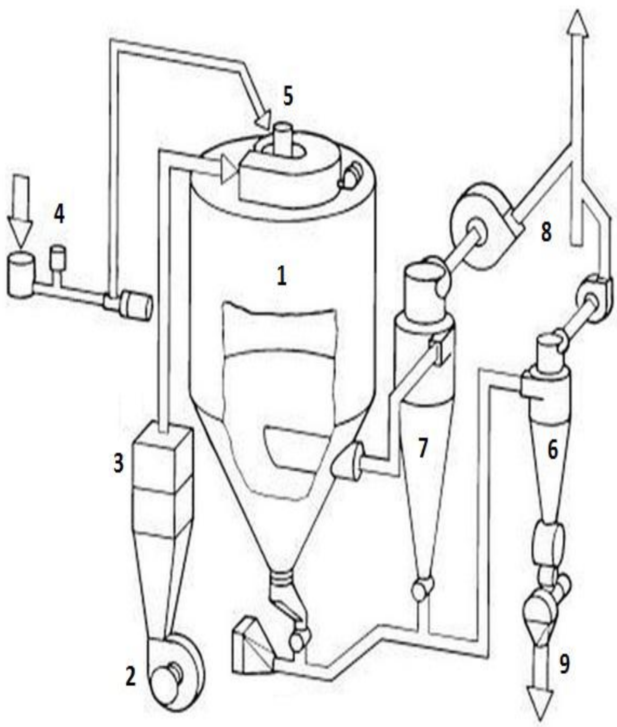


Figure 3.1: Spray drying process

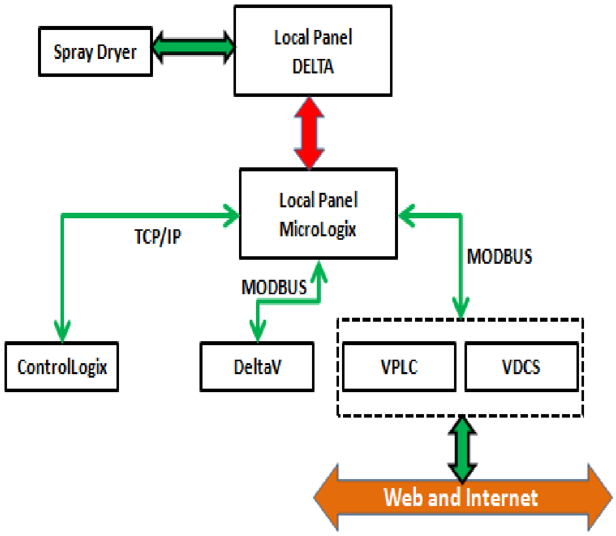
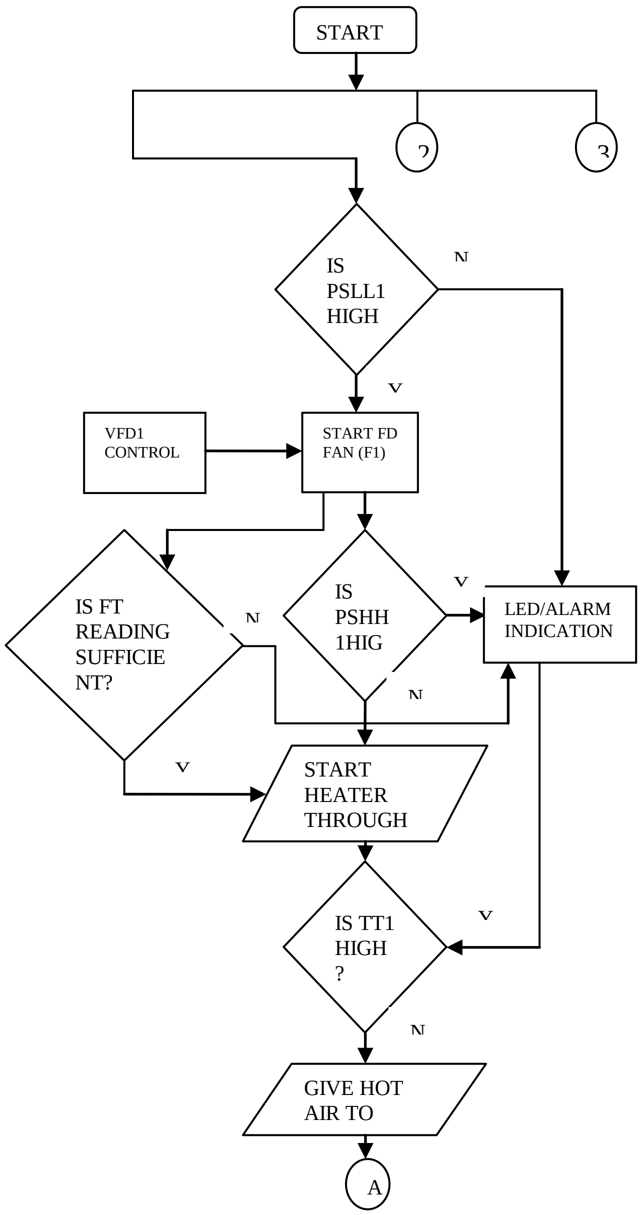
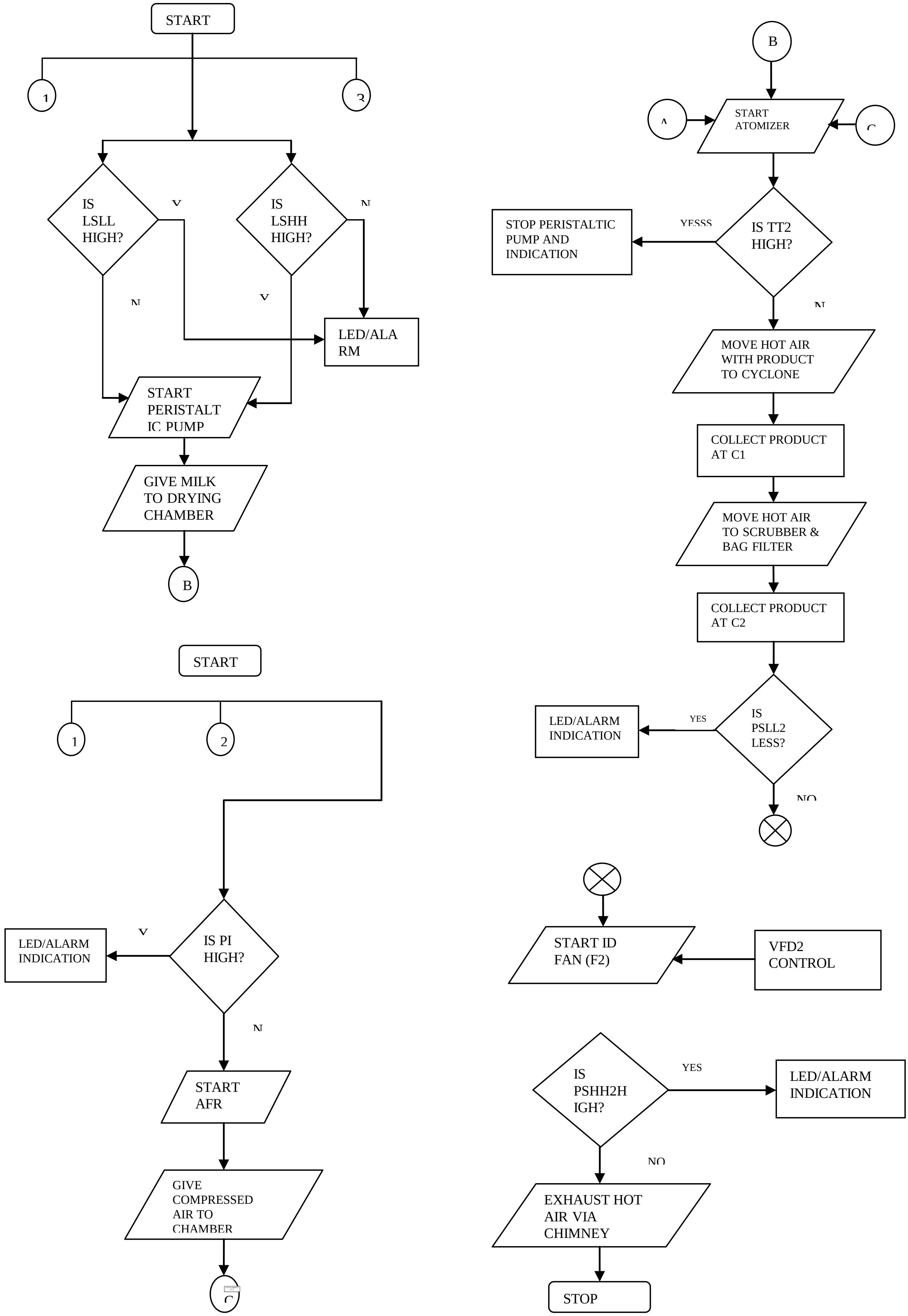


Figure 4.1: Spray dryer proposed network

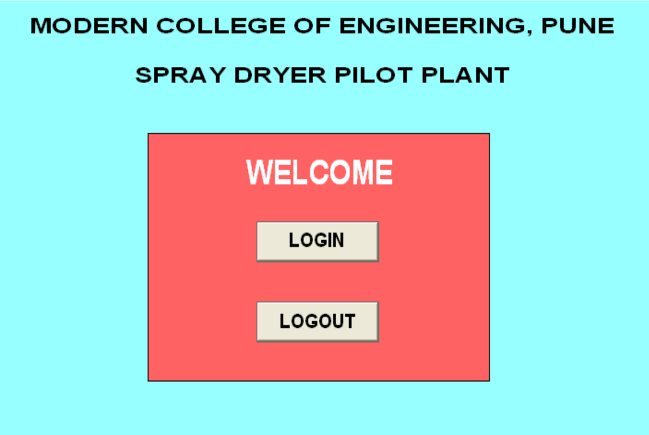
IV. SOFTWARE IMPLIMENTATION



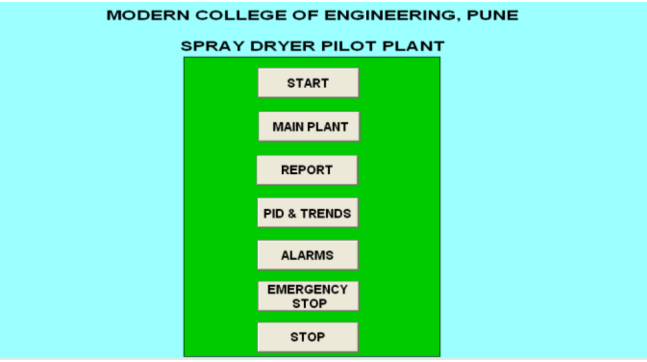

START
1
3
IS LSLL HIGH?
Y
IS LSHH HIGH?
N
N
Y
LED/ALARM
START PERISTALTIC PUMP
GIVE MILK TO DRYING CHAMBER
B
START
1
2
IS PI HIGH?
Y
LED/ALARM INDICATION
N
START AFR
GIVE COMPRESSED AIR TO CHAMBER
C
B
A
START ATOMIZER
C
IS TT2 HIGH?
YESSS
STOP PERISTALTIC PUMP AND INDICATION
N
MOVE HOT AIR WITH PRODUCT TO CYCLONE
COLLECT PRODUCT AT C1
MOVE HOT AIR TO SCRUBBER & BAG FILTER
COLLECT PRODUCT AT C2
IS PSLL2 LESS?
YES
LED/ALARM INDICATION
NO
START ID FAN (F2)
VFD2 CONTROL
IS PSHH2HIGH?
YES
LED/ALARM INDICATION
NO
EXHAUST HOT AIR VIA CHIMNEY
STOP

V. Simulation Results

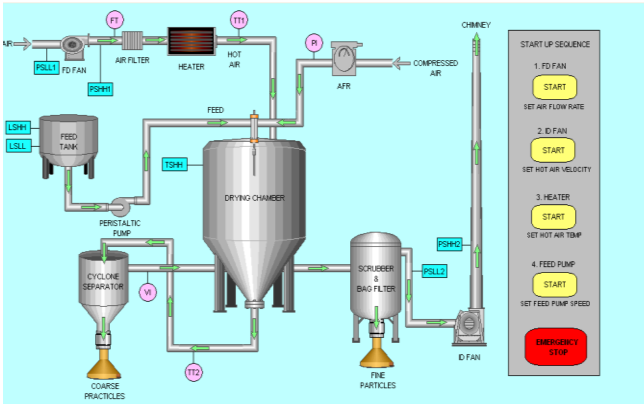
B. SCADA



Display1: Welcome Screen

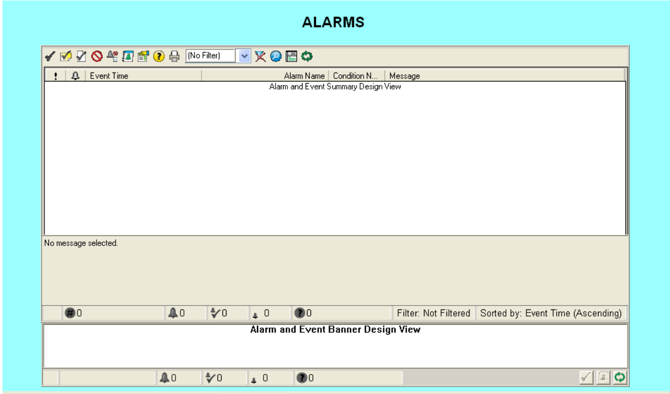


Display2: Control Buttons



Display3: Main Plant

Display 4: Trends



Display5: Alarms

C. Product

The objective of the spray drying process is to produce dried product of a desired quality regardless of the disturbances in the drying operation and variations in feed supply. In order to check the performance of spray dryer we have tested the plant on milk and got satisfactory results. The product quality was satisfactory.

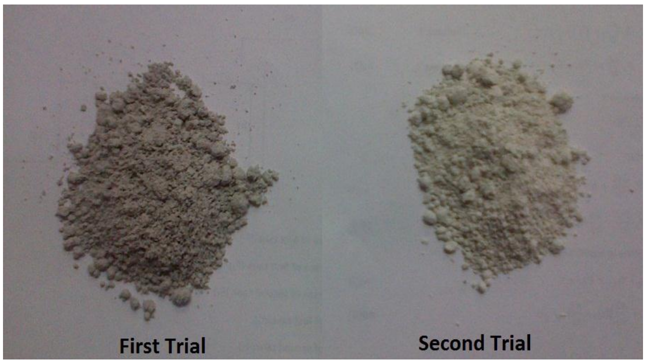
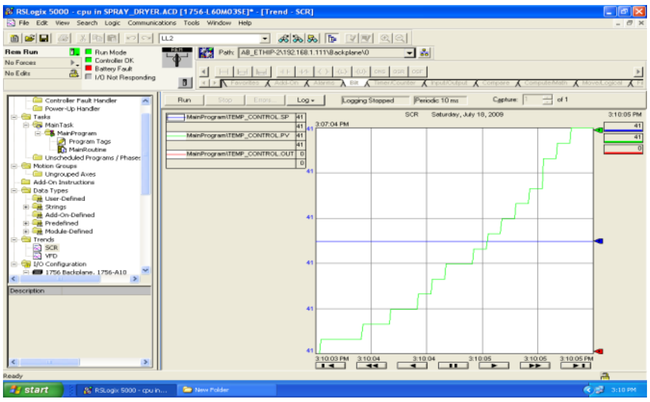


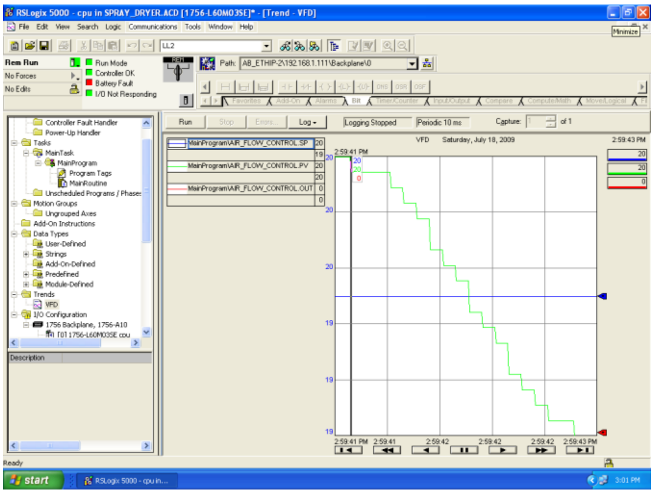
Figure 6.1: Product - milk powder

The most important result of this work is a single pilot plant can be operated and controlled from variety of places depending up on position of hard selector switch located on master local panel which results in comparative study of different control environments with respect to plant performance as well as product quality. Giving remote access to the plant in unknown persons hand may be disastrous but we have taken in account this problem by having hard wired interlocks on our master local panel to ensure safety on plant as well as lab environment.

D. PID Tunning Waveforms



Trends of PID tuning Used in Ladder Diagram for Heater Control



Trends of PID tuning Used in Ladder Diagram for ID fan Control

VI. CONCLUSION

It is common in many cases where process technology has been successfully implemented on pilot plants and the savings at the commercial scale resulting from pilot testing significantly outweighs the cost of the pilot plant itself. So in any new product development we can test the product on pilot plant with minimum changes in plant parameters and depending on the results we can scale up the process which ensures successful, more efficient and optimised process.

The most important process variables like vacuum in drying chamber, feed flow rate or inlet air temperature and flow rate which can be controlled are ignored over a long period of time may be because of unavailability of measurement systems and faith over manual control by experience. Here in this plant we can measure and control almost each and every parameter which is ignored by industrial people which will result in increased efficiency of plant. The remote access to plants in various fields of engineering and science will share the costly equipment and resources, which are otherwise available to limited number of users due to con-strains on time and geographical distances. Remotely triggering an experiment in an actual lab and providing them the results of the experiment through the computer interface. This would entail carrying out the actual lab experiment remotely.

VII. FUTURE SCOPE

E. Spray Dryer Modelling

First principle modelling is always a tedious job. Thus to understand any process the grey box modelling can be done. The modelling work for spray dryers hampered due to lack of experimental data to validate the models. Thus now the data for all parameters is available one can do data driven modelling as well as he can implement system identification techniques.

F. Spray Dryer Control

Now while the plant is running, all the process data is available to multiple users at the same time so they can build their own controller and test it on the plant (depending on user selection by Master Local Controller) and have a comparative study between control technologies like PLC, DCS etc.

Almost in every industrial spray dryer the heater is being controlled using a ON-OFF controller so now here we can improve plant performance by using a SCR Controller for Heater. As well as the vacuum and air flow rate can be also controlled to increase the efficiency of plant.

If model is developed we can implement MPC (Modern Predictive Control) or using the data from plant we can go for data driven control strategies like artificial neural networks (ANN) or Fuzzy based controllers.

G. Process Improvement

To test the plant on multiple products we need to clean the plant to avoid the contamination. So implementing a Clean in Process (CIP) system will be interesting which a mandatory is also as per FDA norms. This plant is a open loop spray dryer. We can modify it and make it closed loop by installing an Inert Loop system at exhaust. The advantages of this would be,

• If solvent is not water e.g. Methanol or Malt dextrin then it is possible to recover solvent from the exhaust gases.

• The fresh air outlet from inert loop will be again fed to FD fan so it is recycled for drying purpose.

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