

# Developing PLC based Application Software For Augmentation of Argon System & Process Control in Steel Industry

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## ABSTRACT

Bhilai Steel Plant (BSP) has the capacity to produce 4 MT steel per annum. At present it is producing 5 MT per annum with existing units (which is beyond the rated capacity) and targeting 7 MT per annum around 2009. To achieve this target BSP needs to modernize and expand the existing production & processing units.

One of the very important process units is (OP-II) Oxygen Plant – II, in which Oxygen, Nitrogen, and Argon, are produced. Argon is supplied to existing & expansion units of SMS-II (Steel Melting Shop-II) for *rinsing purpose facilitates continuous casting* [5].

Aim of this project is to develop and implement application software for Augmentation of Argon System using software development platform RSLogix5000 for Controller & RSViewSE for Human Machine Interface (HMI). The hardware platform is PLC (Programmable Logic Controller) ControlLogix system of Rockwell Automation.

## Keywords

PLC, Augmentation, Argon, RSLogix5000, RSViewSE, and ControlLogix.

## 1. INTRODUCTION

To achieve the target BSP needs to modernize and expansion of existing production and processing units is under implementation [6].

It is proposed to install one slab caster, one ladle furnace and one RH degasser SMS –II of BSP with state of art technology. Argon gas is mainly used in SMS-II and its various units viz. VAD, RH, LF, on line purging of ladles and on line rinsing during secondary treatment of steel in order to achieve the required quality. Under the expansion project it is proposed to install one slab caster, one ladle furnace and one RH degasser SMS –II of

BSP with state of art technology [5]. The installation of new units will result in increase in Argon requirement. Therefore the Development of application s/w for the augmentation of argon facilities in SMS-II is required.

## 1.1 Existing System of Cold Converter Process

Liquid Argon from air separation unit in OP-II is stored in 200 Tons of liquid argon tank & is pumped and vaporized at a maximum pressure of 140 kg/cm<sup>2</sup> for filling of argon cylinders at 140 kg/cm<sup>2</sup> and supplying to SMS-II at a reduced pressure of 16 kg/cm<sup>2</sup> as the pipeline in between SMS-II and OP-II is designed for reduced pressure.

Presently pressurizing system of argon from ASU of OP-II consists if 2 streams of pumps & vaporizer; each having capacity of 200 Nm<sup>3</sup>/hr at a discharge pressure of 16 kg/cm<sup>2</sup>. A number of argon cylinders are also connected to the system at 140 kg/cm<sup>2</sup> for storage purpose when the consumption in SMS-II drops. Also the storage capacity at SMS-II consists of 3 receivers viz. 10 m<sup>3</sup> for VAD, 15 m<sup>3</sup> for RH degasser & 10 m<sup>3</sup> for ladle furnace.

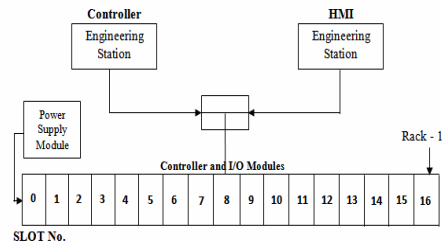


Figure 1. Proposed System Architecture

## 1.2 Proposed Cold Converter System

The proposed system architecture and scheme for augmentation of argon are as mentioned in Figure 1 and Figure 7. Functions of each slot as shown in Figure 1 are provided in section 2.3 (Hardware and Software Architecture). However I have designed the Figure 7 using RSViewSE software to simplify the process and easy to visualize as shown in Figure 2. Figure 7 is actual P/I

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ICAC3'09, January 23–24, 2009, Mumbai, Maharashtra, India.

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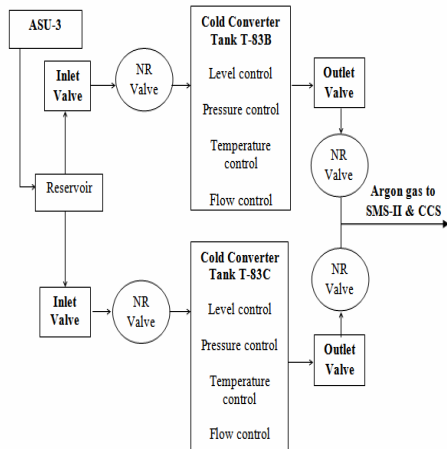


Figure 2. Simplified Diagram of Cold Converter (T-83B & C)

diagram implemented at OP-II for Augmentation of Argon project and is main graphical display at HMI [5].

## 2. CONTROL STRATEGY & METHODOLOGY

### 2.1 Control Strategy of Cold Converter

The whole process is implemented in four steps [5-6] i.e. *Filling*, *Pressurization*, *Feeding*, and *Depressurization*. The tanks T-83B and T-83C operate in synchronization. This is to ensure continuous feeding of gaseous argon into the network. One converter continues to remain in feeding while the other one undergoes the process of depressurization, filling, and pressurization to prepare itself for feeding process as mentioned in Table 1.

Table 1. Steps of Process Control

Steps	POSITION OF VALVES	
	Cold Converter T-83B	Cold Converter T-83C
I	<i>FILLING</i>	<i>FEEDING</i>
	UV 83B-1 open.	UV 83C-1 close.
	UV 83B-2 close.	UV 83C-2 open.
	PV 83 B-2 close.	PV 83C-1 close.
II	<i>PRESSURISATION</i>	<i>FEEDING</i>
	UV 83B-1 close.	UV 83C-1 close.
	UV 83B-2 close.	UV 83C-2 open.
	PV83B-2 under control.	PV 83C-1 close.
III	<i>FEEDING</i>	<i>DEPRESSURISATION</i>
	UV 83B-1 close.	UV 83C-1 close.
	UV 83B-2 open.	UV 83C-2 close.
	PV 83 B-2 close.	PV83C-2 close.
IV	<i>DEPRESSURISATION</i>	<i>FILLING</i>
	UV 83B-1 close.	UV 83C-1 open.
	UV 83B-2 close.	UV 83C-2 close.
	PV83B-2 close.	PV 83 C-2 close.
V	<i>FEEDING</i>	<i>PRESSURISATION</i>
	UV 83B-1 open.	UV 83C-1 close.
	PV83B-1 under control.	UV 83C-2 close.
	PV83C-2 under control.	PV83C-2 under control.

III	<i>FEEDING</i>	<i>DEPRESSURISATION</i>
	UV 83B-1 close.	UV 83C-1 close.
	UV 83B-2 open.	UV 83C-2 close.
	PV 83 B-2 close.	PV83C-2 close.
IV	<i>DEPRESSURISATION</i>	<i>FILLING</i>
	UV 83B-1 close.	UV 83C-1 open.
	UV 83B-2 close.	UV 83C-2 close.
	PV83B-2 close.	PV 83 C-2 close.
V	<i>FEEDING</i>	<i>PRESSURISATION</i>
	UV 83B-1 open.	UV 83C-1 close.
	PV83B-1 under control.	UV 83C-2 close.
	PV83C-2 under control.	PV83C-2 under control.

### 2.2 Inter-relationship and Modeling of Process

Interfacing PLC based controller with HMI to achieve process control and automation is recognized as measuring requirements of instrumentation engineering. The Measuring Requirements are further categorized into *The I/O Assignments* and *The Instrument List*. The inter-relationship among field sensors, controller and HMI is established as shown in Figure 3. The I/O Assignment is further classified into *I/O Configuration*, *Range & Alarm Limits*, *I/O mapping* or aliasing is out of the scope of this paper. Reference [2] might be referred for any detail regarding to measuring requirements. Mathematical modeling of process and related control strategy is characterized by equation (1) to (4), each time whenever there is change in level or pressure.

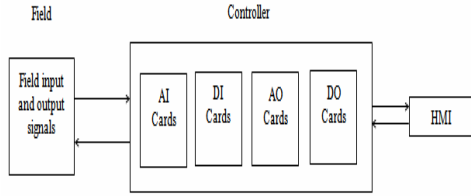
$$\Delta P = \rho gh \quad \dots (1),$$

Where  $\Delta P = P_2 - P_1$  is difference of pressure inside closed liquid argon chamber / cold converter and 'h' is vertical height or level of liquid argon inside cold converter.

$$Q = a \times v \quad \dots (2),$$

Where 'Q' is flow rate of liquid argon, 'a' is area of cylindrical pipe, and 'v' is velocity.

PID (Proportional Integral Derivative) equation / controller is used to change the level of liquid argon at both cold converter T-83B and T-83C followed by mathematical equation.



**Figure 3. Inter-relationship among Field sensors - Controller – HMI**

This is to ensure continuous feeding of gaseous argon into the network. One converter continues to remain in feeding while the other one undergoes the process of depressurization, filling, and pressurization [5]. If  $x(t)$  is input and  $y(t)$  is output in time domain as mentioned in equation (3). While in frequency domain  $X(s)$  is input and  $Y(s)$  is output as mentioned in equation (4).

$$F\{y(t)\} = Y(s) = [K_p + K_D \times \left(\frac{d}{dt}\right) + K_I \times \left(\int_0^t e^{-st} dt\right)]x(t) \quad \dots (3)$$

$$Y(s) = [K_p + sK_D + \left(\frac{K_I}{s}\right)]X(s) \quad \dots (4)$$

Where  $K_p$  is proportional gain,  $K_D$  is derivative gain,  $K_I$  represents integral gain of PID, and integration lies for  $0 \leq t \leq T$ .  $x(t) / X(s)$  represents any level / pressure signal as analog input (AI) from field sensors to PLC based Controller and controller taking necessary actions accordingly based on control strategy and responding to pressure / level sensors as analog output (AO).

As controller senses 4-20 mA / 24 V DC equivalent electrical signal from field on behalf of each I/O signals (particular card & slot number of PLC) for pressure / level / flow / temperature measurement and taking action by the Controller. This might be difficult to understand by an operator sitting at HMI and taking action accordingly.

So we define tag number by alphanumeric character for each service. This is called *aliasing or I/O Mapping*. Table 2 of the instrument list might be referred for briefing.

### 2.2.1 The Instrument List

Once we identify the nature of tags and aliases it, with the help of the Instrument List complete information regarding the tag might be work out very easily. As scope of this paper is to simulate graphical displays of HMI according to control action made by controller (using RSLogix5000 software), when Cold Converter Tank T-83B is in pressurization condition and Cold Converter Tank T-83C is in feeding condition.

In this project Tags are broadly categorized into *Controller Tags* and *HMI Tags*. While we have categorized *Controller Tags* into *H/W Tags & S/W Tags*, but HMI Tags (those are S/W Tags only) into *Device Tags & Memory Tags*. For any further details of

corresponding tags are used in either Controller ladder logic using ControlLogix ControlNet or Ethernet/IP RSLogix5000 or HMI using RSViewSE reference [2 - 4] might be referred. The instrument lists of PLC and HMI could be prepared as shown in Table 2 in (next page).

## 2.3 HARDWARE AND SOFTWARE ARCHITECTURE

As far as programming of process controller (CPU unit) and HMI are concerned; it is required to inter-connect I/O cards, CPU (control / instrumentation H/W) and HMI (display for operator). Number of I/O cards depends on number of signals sensed from field. The proposed system architecture consists of inter-connection among field sensors (related to pressure, level, flow, and temperature signals), controller (using RSLogix5000), and HMI (using RSViewSE) for augmentation of argon in OP-II, Bhilai Steel Plant as shown in Figure 1.

However these field sensors, controller, and HMI are connected via Ethernet. The description of SLOT numbers, corresponding modules of Rack-1 (Controller and I/O modules), and control action of proposed system architecture are as shown in Table 3 (next page). In this project the chassis size of PLC is of 17 slots. For any further details reference [1 - 2] might be referred.

## 2.4 METHODOLOGY – LADDER LOGIC DESIGN

Ladder logic designs have been implemented in OP-II, Bhilai Steel Plant for augmentation of argon system. Ladder logic is one of low-level language option available for PLC programming. Since this section contains the necessary ‘algorithm’ using RSLogix5000 software (real time platform) to keep tank T-83B in pressurization mode and T-83C in feeding mode, only required steps in terms of PLC rungs are produced here as shown in Figure 4, and Figure 5 (next page).

While Figure 6 represents PID controller is taking actions followed by equation (3) sends analog output (AO) signal to field sensors to change level and pressure status of Tank T-83B, according to change in valve positioning as shown in Figure 4. PID might be kept in auto or manual mode. At present it holds manual (.MO) mode. Then it instructs to change valve position of Tank T-83B, and forcing to move into pressurization mode.

## 3. RESULT & DISCUSSIONS

This paper produces simulated graphical displays for Augmentation of Argon system using RSViewSE [4, & 7], Real-time platform in OP-II, BSP (SAIL) as shown in Figure 7. It is a graphical user interface (GUI) for operator / instrumentation engineer to observe the process unit via HMI display and taking necessary action accordingly via GUI / HMI.

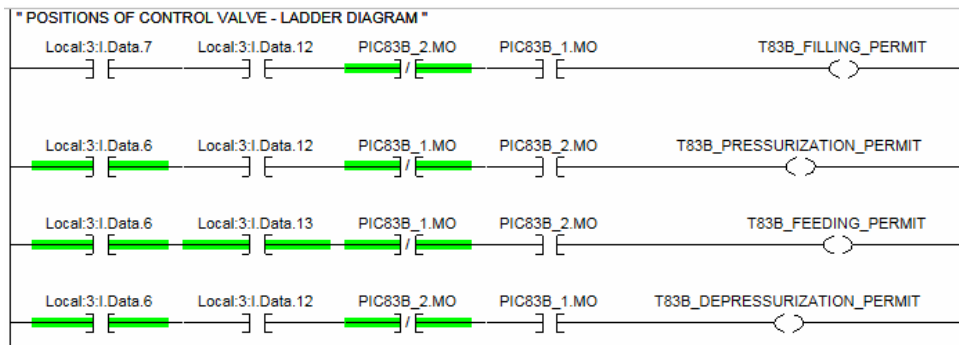
Here three displays are designed for easy observation of different conditions i.e. *The P/I & graphical display of Argon System* (level & / pressure related information of both tanks), and *Trends of Argon System* (having two very important utilities i.e. used to accumulate different parameter conditions and field sensors during troubleshooting, and secondly setting pre-recorded and required parameter values at the time of production of ‘on demand’) as mentioned in Fig. 7, and Fig. 8.

**Table 2. The instrument List of PLC and HMI**

Tag No.	Service	Component (Tag Type)	Instrument Range	Connection To/From	Calibrated as (Module & Slot No.)
LI83B / PI83B	Level / Pressure Indicator of Tank T-83B	I/HMI (S/W)	0-100% (0-760 Hg mm)	At HMI	Device Tag, Local:8:I.Ch0Data / Local:8:I.Ch1Data
ZT83B_1 / ZT83B_2	Position of Pressure Valve PV83B-1 of Tank T-83B	Transmitter/ Control Valve	0-100% (4-20 mA)	From Field	Local:8:I.Ch7Data / Local:8:I.Ch8Data

**Table 3. Briefing of different modules of Proposed System Architecture**

Slot number	Module	Action	Slot number	Module	Action
Isolated	1756-PA75	Power Supply	SLOT 7	1756-OW16I (Spare)	Isolated DO (Spare)
---	1756-PA75R	Power Supply (Redundant)	SLOT 8	1756-IF16	Non-isolated Analog Input
SLOT 0	1756-L55M12	Microprocessor	SLOT 9	1756-IF16 (Spare)	Non-isolated AI (Spare)
SLOT 1	1756-L55M12	Microprocessor (Stand-by)	SLOT 10	1756-OF4	Non-isolated Analog Output
SLOT 2	1756-ENBT	Ethernet module	SLOT 11	1756-OF4 (Spare)	Non-isolated AO (Spare)
SLOT 3	1756-IB16	Non-isolated Digital Input	SLOT 12	1756-IR6I	Isolated RTD Input
SLOT 4	1756-IB16	Non-isolated Digital Input	SLOT 13	1756-IR6I (Spare)	Isolated RTD Input (Spare)
SLOT 5	1756-IB16 (Spare)	Non-isolated DI (Spare)	SLOT 14, 15, & 16	Spare	---
SLOT 6	1756-OW16I	Isolated Digital Output	---	---	---



**Figure 4. On/Off and Control Valve positions of Tank T-83B**



Figure 5. Testing at RUN mode – Tank T-83B

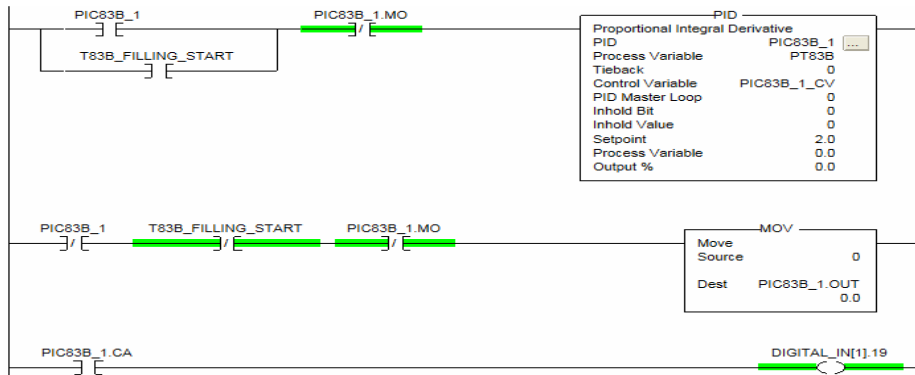


Figure 6. Defining SP, PV, and CV of PID-Tank T-83B

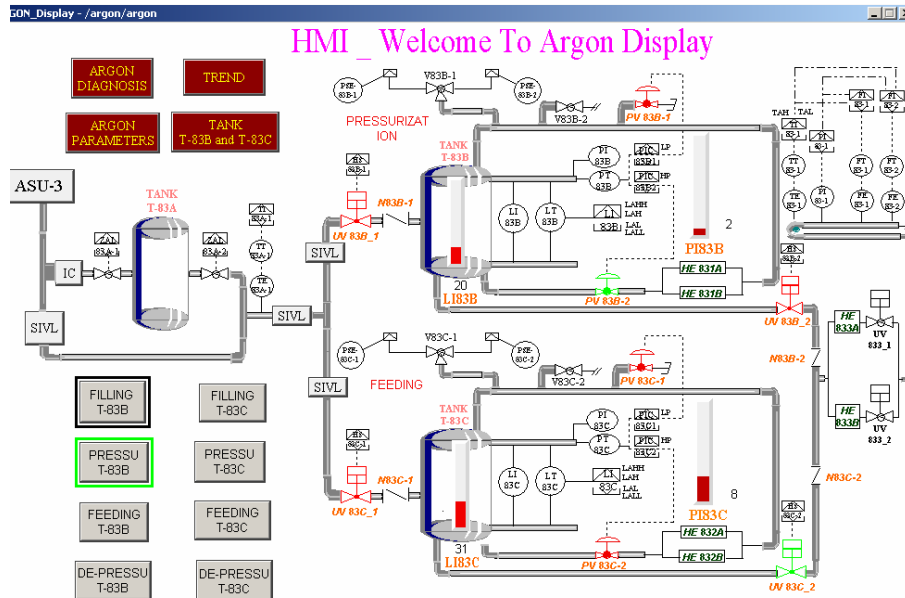
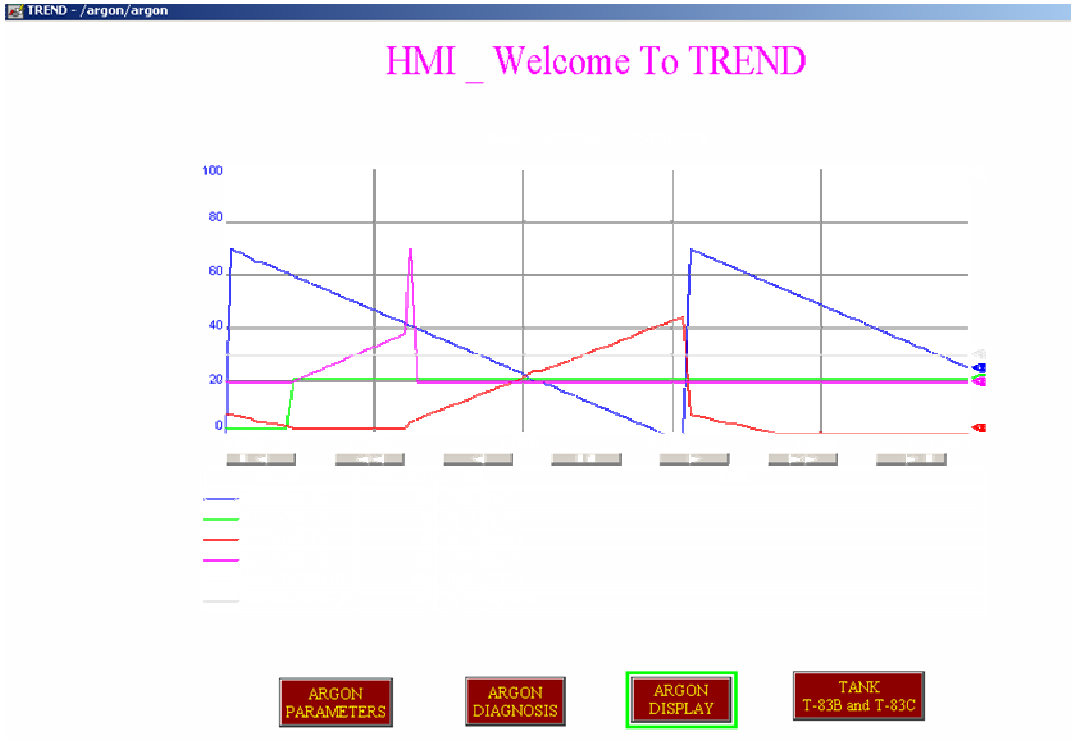


Figure 7. The P/I & Graphical Display of Argon System. Argon Display – It represents actual P/I Diagram of proposed cold converter system and level &/ pressure related information of both tanks. PI83B of tank T-83B goes high during pressurization (PV83B-2 is under control), while LI83C of tank T-83C moves down during feeding to SMS-II.



**Figure 8.** Trends of Argon System - This display is useful for fault identification of specific module of PLC or in field sensors during troubleshooting. It has two very important utilities. First, it is used to accumulate different parameter conditions and field sensors during troubleshooting. And secondly setting pre-recorded and required parameter values at the time of production of 'on demand'.

#### 4. CONCLUSION

There are four important steps have implemented in this project for proposed cold converter system at ASU-III, OP-II, Bhilai Steel Plant. These are configuring PLC, programming of PLC based Controller via ladder logic using RSLogix5000 software, programming of HMI using RSViewSE software, and interfacing Controller with HMI to simulate the process via graphical displays.

Here the Ethernet communication link is used to connect all input, output modules with processor L55M12. As requires budget to install a new 17 slots PLC rack is around 50 lacks rupees. Hence in this project equal amount of cost is saved with the help of *I/O mapping or aliasing* Controller and HMI tags.

For programming of Controller, the PLC based ladder logic is used as like in existing system. Both systems are ControlLogix type. While only 62 rungs are used to program the proposed unit of OP-II for augmentation of argon as compare to 98 rungs of existing system. Hence length of ladder logic program is reduced by 36.73 percent. That's why new ladder logic supports faster execution and takes less time for troubleshooting during run mode. Finally programming of HMI is done by RSViewSE and interfaced with Controller via Ethernet link. All three displays

are user-friendly and interconnected with one another i.e. operator can visit any display, just by clicking one icon available in corresponding display.

#### 5. ACKNOWLEDGMENTS

I am thankful to Mr. G.K. Kundu, Senior Manager (Instrumentation), B.S.P., Bhilai for his priceless support and encouragement to develop this project for the benefit of B.S.P., and many process industries nation & world wide. I also pay my thanks to Prof. S. Karmakar, Computer Application department, BIT-Durg for his valuable guidance to synthesize technical material.

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