

# SENSORS & TRANSDUCERS **12** vol. 147 /12

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## Sensor Market Trends

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# Contents

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## Research Articles

<b>Constantly Evolving Smartness, Intelligence and Innovation Ensure Seamless System Integration</b> <i>Dr. Rajender Thusu</i> .....	1
<b>An Intelligent Temperature Measurement Technique Using J Type Thermocouple with an Optimal Neural Network</b> <i>Santhosh K. V., B. K. Roy</i> .....	6
<b>Thermal Sensitivity of Solid Polymer Coated Surface Transverse/Love Wave Based Resonators on AT-cut Quartz for Sensor Applications</b> <i>I. D. Avramov and K. D. Esmeryan</i> .....	15
<b>Effect on Passive Localization from the Shape Distortion of Triplet Linear Array Based on Piezoelectric Transducers</b> <i>Fei Xu, Xianlong Liu</i> .....	27
<b>Detecting Water Content in Hydrocarbon Emulsion Using Acoustic and Ultrasonic Detectors</b> <i>Rateb Issa, Ibrahim Al-Abbas and Hussein Sarhan</i> .....	36
<b>Study of Vibration Characteristics of a Multi Cracked Rotating Shaft Using Piezoelectric Sensor</b> <i>Rajeev Ranjan, N. K. Mandal</i> .....	45
<b>An Insole Device Based on Piezoelectric Sensor to Assess Plantar Pressure during Daily Human Activity</b> <i>Yemin Guo</i> .....	53
<b>A Novel Tuning Method for Repeatability Problem Solving of RF MEMS Disk Resonators</b> <i>Masoud Baghelani, Habib Badri Ghavifekr, Afshin Ebrahimi</i> .....	61
<b>FEM Based Optimization of Thin Membrane for Thermoelectric Energy Harvesting Devices</b> <i>Divya Jatain, Monoj Kumar Singha, Ajay Agarwal, Manoj Taleja</i> .....	68
<b>Visual Odometry in Dynamical Scenes</b> <i>Dong Zhang and Ping Li</i> .....	78
<b>An Experimentation on Anti-Reset Windup Scheme for Level Process Station</b> <i>I. Thirunavukkarasu, Mohammed Ibrahim Fareed Abuaiah, V. I. George, S. Shanmuga Priya</i> .....	87
<b>Design and Development of an Instrument to Determine the Fluoride Ion Concentration in Certain Tooth Pastes</b> <i>Saraswathi Parigi, Sreelekha Kande, Nagaraju Boya, Raghavendra Rao Kanchi</i> .....	95

<b>Data Mining Approach to Polymer Selection for Making SAW Sensor Array Based Electronic Nose</b> <i>Sunil K. Jha and R. D. S. Yadava</i> .....	108
<b>Development of a Non-invasive Micron Sized Blood Glucose Sensor Based on Microsphere Stimulated Raman Spectroscopy</b> <i>Alireza Bahrampour, Neda Jahangiri, Majid Taraz</i> .....	129
<b>MOS Device Chemical Response to Acceptor Stimuli</b> <i>Rina Lombardi, Ricardo Aragón and Héctor A. Medina</i> .....	143

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## Digital Sensors and Sensor Systems: Practical Design

Sergey Y. Yurish



The goal of this book is to help the practitioners achieve the best metrological and technical performances of digital sensors and sensor systems at low cost, and significantly to reduce time-to-market. It should be also useful for students, lectures and professors to provide a solid background of the novel concepts and design approach.

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*Digital Sensors and Sensor Systems: Practical Design* will greatly benefit undergraduate and at PhD students, engineers, scientists and researchers in both industry and academia. It is especially suited as a reference guide for practitioners, working for Original Equipment Manufacturers (OEM) electronics market (electronics/hardware), sensor industry, and using commercial-off-the-shelf components

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## An Experimentation on Anti-Reset Windup Scheme for Level Process Station

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**Abstract:** This paper represents how to eliminate the undesired effect occurred in the PI or PID controller called integrator-windup by using four different methods. These different methods are known as anti-windup strategies. A Simulink-Matlab program has been used to investigate the results and the performance of the four anti-windup strategies, using the parameters and values from two published papers [1-2]. The controller, actuator, saturation and plant transfer function are used to build the general structure of a control feedback system. Finally, the modifications were made in the “Level Control Trainer” program that was made by InTouch-windows maker program to solve the problem that happens by the integrator windup in a real time system for level control station was done experimentally. *Copyright © 2012 IFSA.*

**Keywords:** PID controller, Anti-reset windup, Actuator saturation, Conditional integrator.

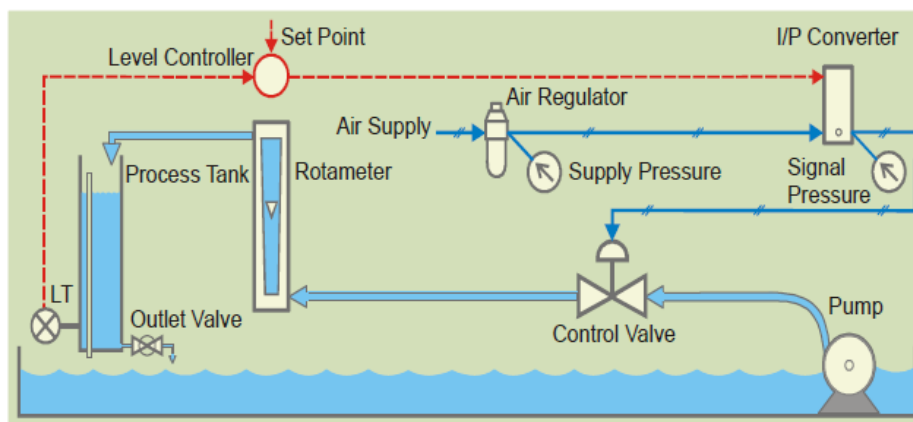
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### 1. Introduction

In this experiment the modifications were made on “Level Control Trainer” program that was made by InTouch-windows maker program. This program is responsible to control the water level in a tank by using PID controller. The aim of this experiment is to add saturation level to obtain the integrator windup (for studying research) [3]. After that we measured the saturation level in real time by using millimeter, to know the maximum and minimum saturation ( $U_{\max}$  and  $U_{\min}$ ) for the water level. Finally we added anti-windup controller to solve the problem that happens by the integrator windup.

### 1.1. Level Controller Station Description [5]

Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting. Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.



**Fig. 1.** General scheme for level control station.

### 1.2. InTouch-windows Maker Program [6]

A Human Machine Interface (HMI) software application shows a graphical representation of a manufacturing environment. The tools, materials, and processes used to create a product appear as visual elements in an HMI application's windows. Plant operators interact with an application's graphical interface to monitor and administer the manufacturing processes.

Fig. 2 shows the core components of the InTouch HMI that you use to build and run applications.

As its name suggests, you use Application Manager to create and manage InTouch applications. The application development environment, called WindowMaker, includes a set of graphic and other development tools to build your applications. You run your applications using WindowViewer.

## 2. Experimental Process

### 2.1. Level Control Station

The Level Control Station is shown in Fig. 3. This station is responsible to control the water level in a small tank by using PID controller (UT321 – YOKOGAWA shown in Fig. 4) connected to a computer by ADAM USB wire connection. The water level in the tank can vary between 0 to 100 cm. The

simulation program that is responsible for sending the variable data to the PID controller is In-Touch-windows maker as shown in Fig. 5.

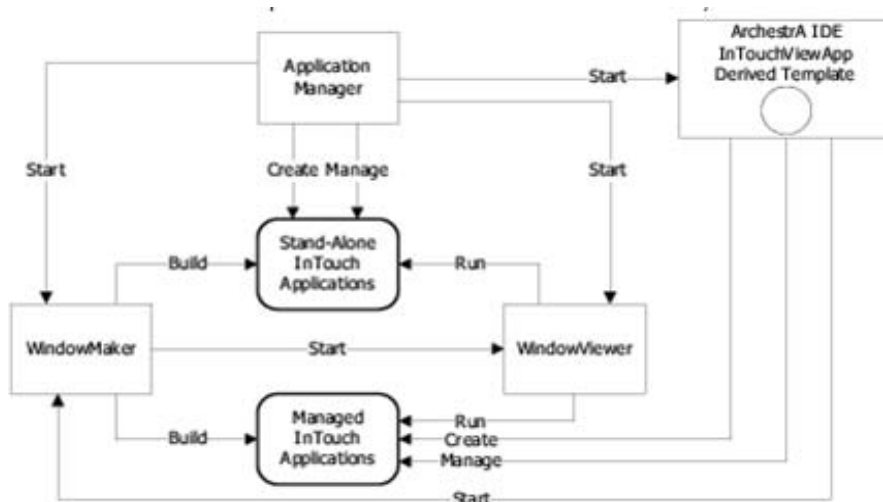


Fig. 2. Flow chart of In-touch Software.



Fig. 3. Level control station.

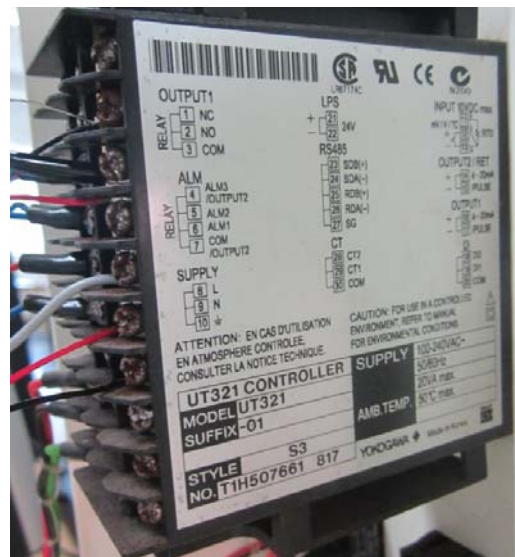


Fig. 4. UT321 PID Controller.

Table 1 shows the variable and the modes in the 'Level Control Trainer' program that used for controlling the PID.

### 2.1.1. Current Measurement

Before making an Anti-Windup mode in the level control program we must measure the output current from the PID controller in different water level (0 cm to 100 cm) to define the maximum and minimum saturation level ( $U_{max}$  &  $U_{min}$ ). We disconnect the positive output wire from the PID and the connected the multimeter (AC mA) as shown in Fig. 6. Table 2 shows the current value in different water level.

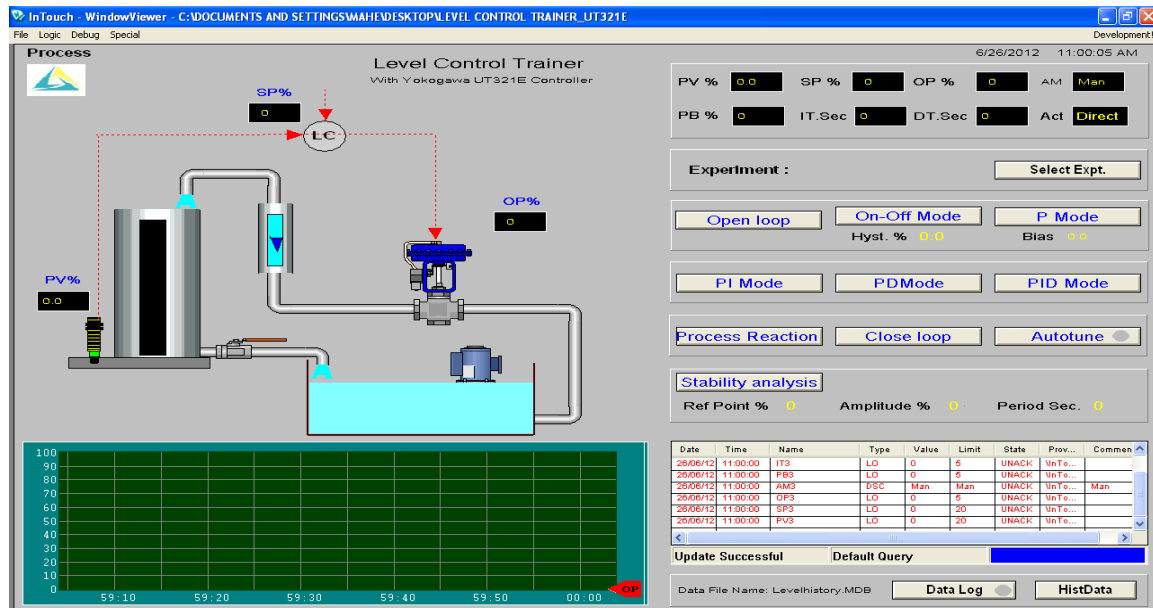


Fig. 5. InTouch-windows maker 'Level Control Trainer'.

Table 1. Level Control Trainer program Mode & Variable.

Mode/Variable	Details
<b>Open-Loop</b>	Study of open loop response (manual control)
<b>On-Off Mode</b>	Study of on/off controller
<b>P Mode</b>	Study of proportional controller
<b>PI Mode</b>	Study of proportional integral controller
<b>PD Mode</b>	Study of proportional derivative controller
<b>PID Mode</b>	Study of proportional integral derivative controller
<b>Process Reaction</b>	Tuning of controller (open loop method)
<b>Close loop</b>	Tuning of controller (closed loop method)
<b>Autotune</b>	Tuning of controller (using auto tuning method)
<b>Stability analysis</b>	To study stability of the system (bode plot)
<b>PV</b>	Process value
<b>SP</b>	Step point
<b>AM</b>	Auto/manual
<b>PB</b>	Proportional band
<b>IT.sec</b>	Integral time
<b>DT.sec</b>	Derivative time

Table 2. Current value for different water level.

Water level (cm)	Current value (mA)
0	4
10	5.5
20	7.2
30	8.8
40	10.3
50	11.9
60	13.5
70	15.5
80	16.8
90	18.9
100	20.01

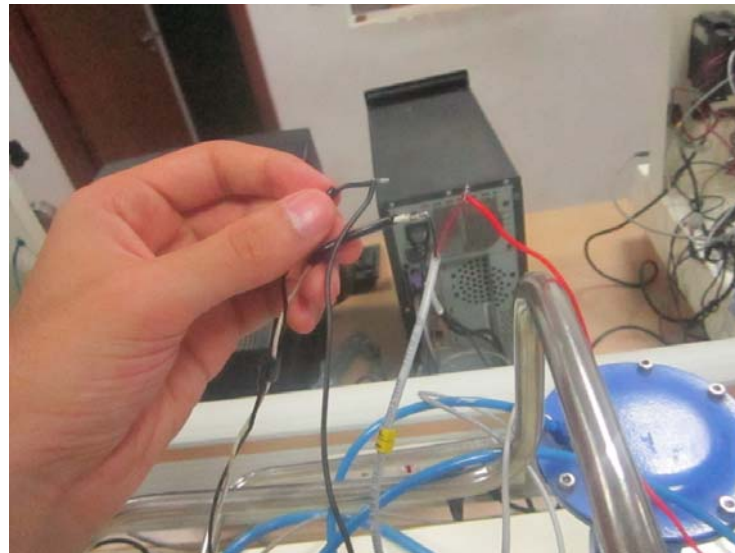


Fig. 6. Measure the output current value from the PID controller.

### 2.1.2. Reprogramming

After we study and collect the information about integrator windup problem we modified the level controller program to obtain the Anti-Windup strategy in real time implementation [6, 7]. This done by added the Anti-Windup mode and saturation level to the main program as shown in Fig. 7. Then we reprogramming the original code to controlling the hardware actuator by calculate the error between PV and SP, then we take this error as a feedback to the controller to limit the actuator movement between defined  $U_{max}$  and  $U_{min}$  automatically.

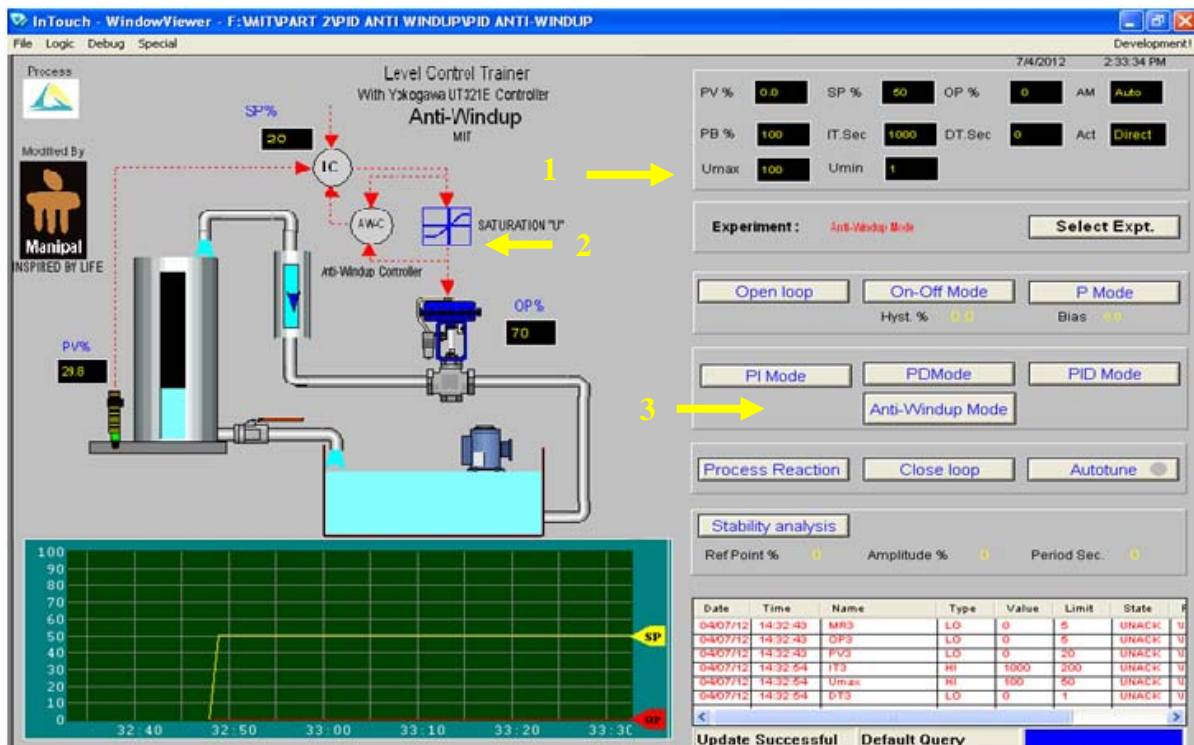


Fig. 7. Level controller program with Anti-Windup controller. (Umax & Umin '1', saturation and Anti-Windup graph '2', Anti-Windup Mode '3').

### 2.1.3. Final Result

Fig. 8 and Fig. 9 are showing the difference between PID and Anti-Windup result for the real time processing value (PV), step point (SP), and operating response (OP). And Fig. 10 and Fig. 11 are showing the current output at two saturation levels (10 and 80).

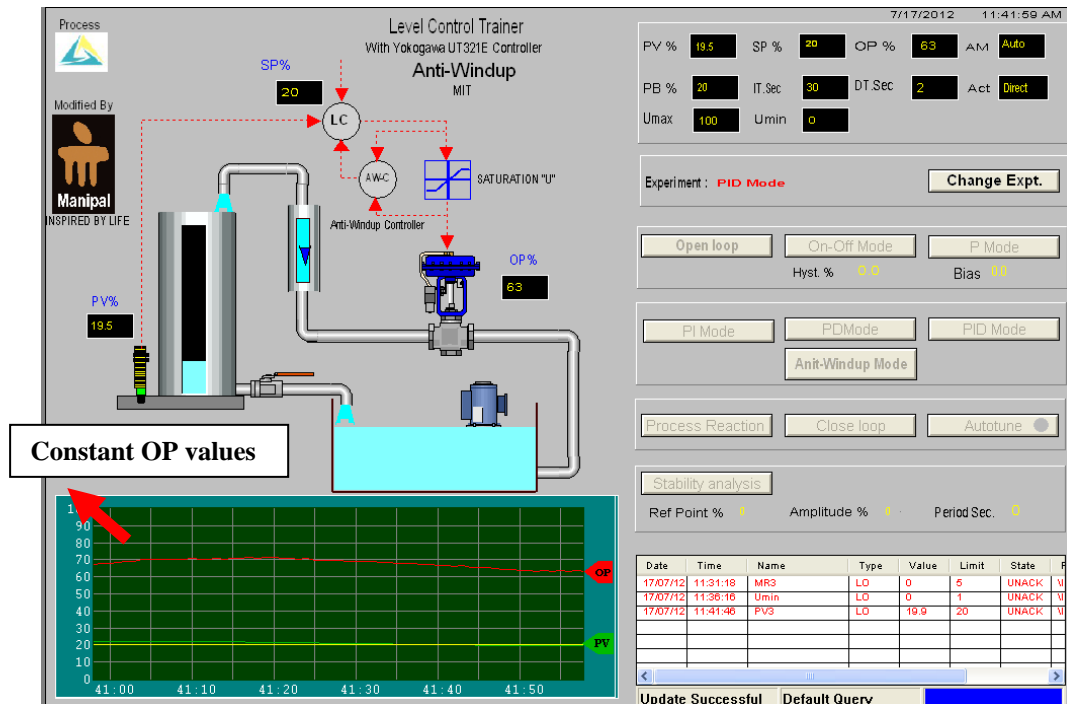


Fig. 8. OP, PV and SP response in PID Mode.

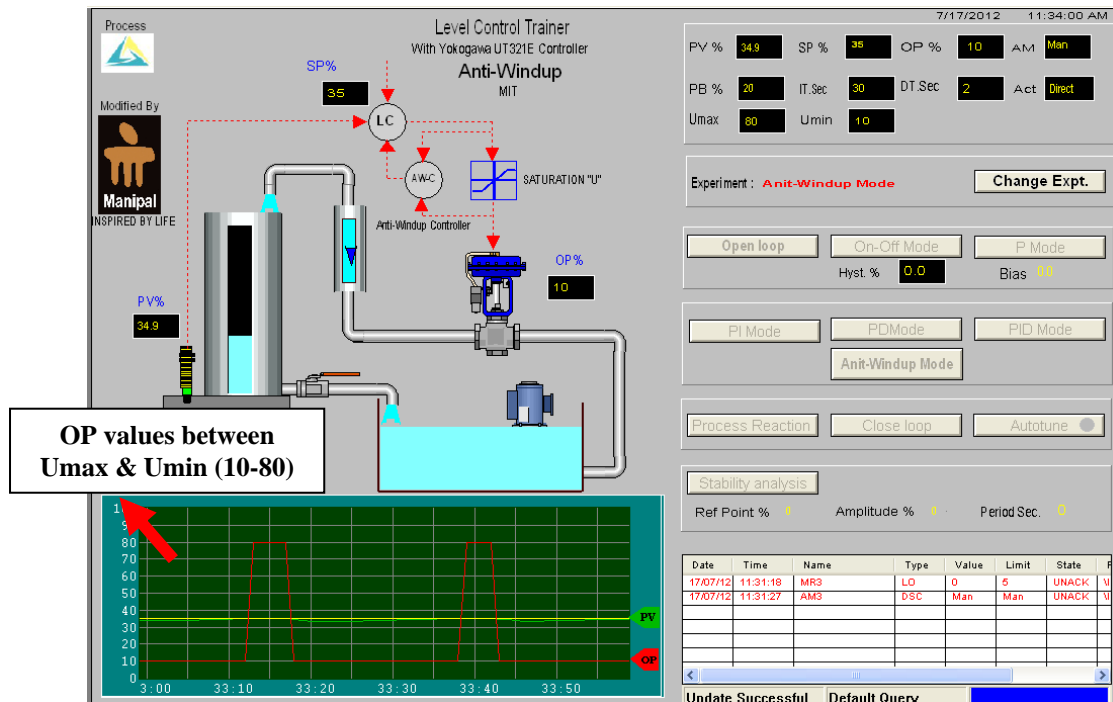


Fig. 9. OP, PV and SP response in Anti-Windup Mode.

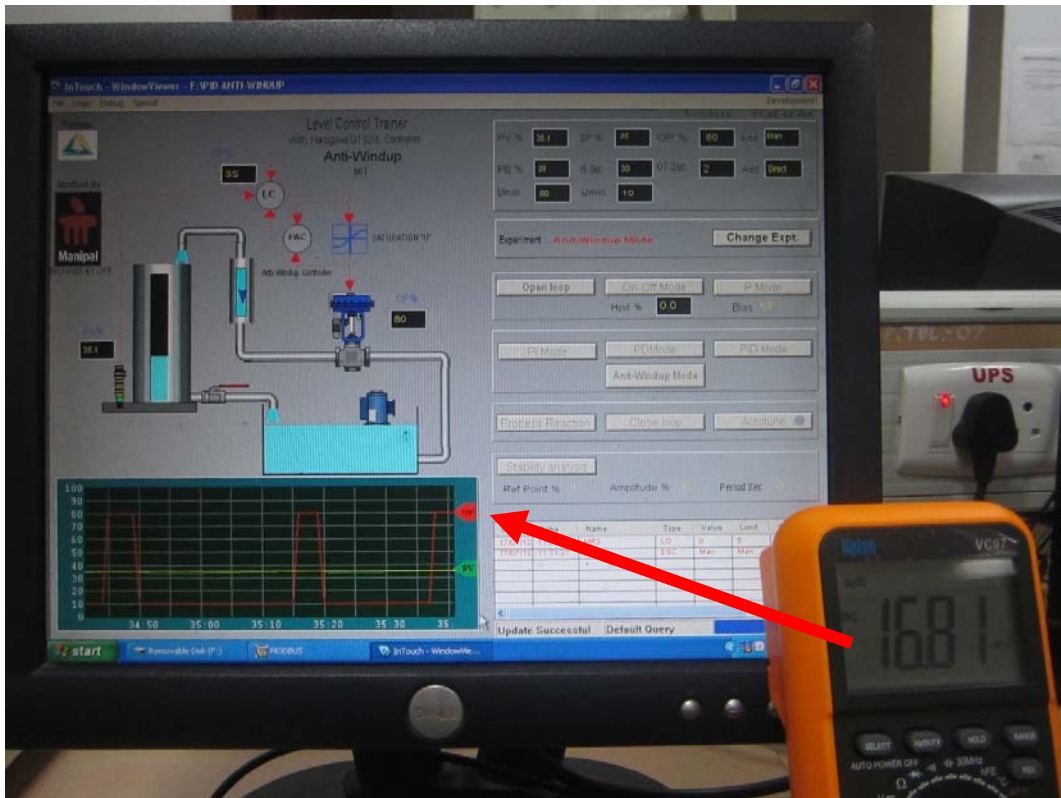


Fig. 10. The output current value at  $U_{max} = 80$ .

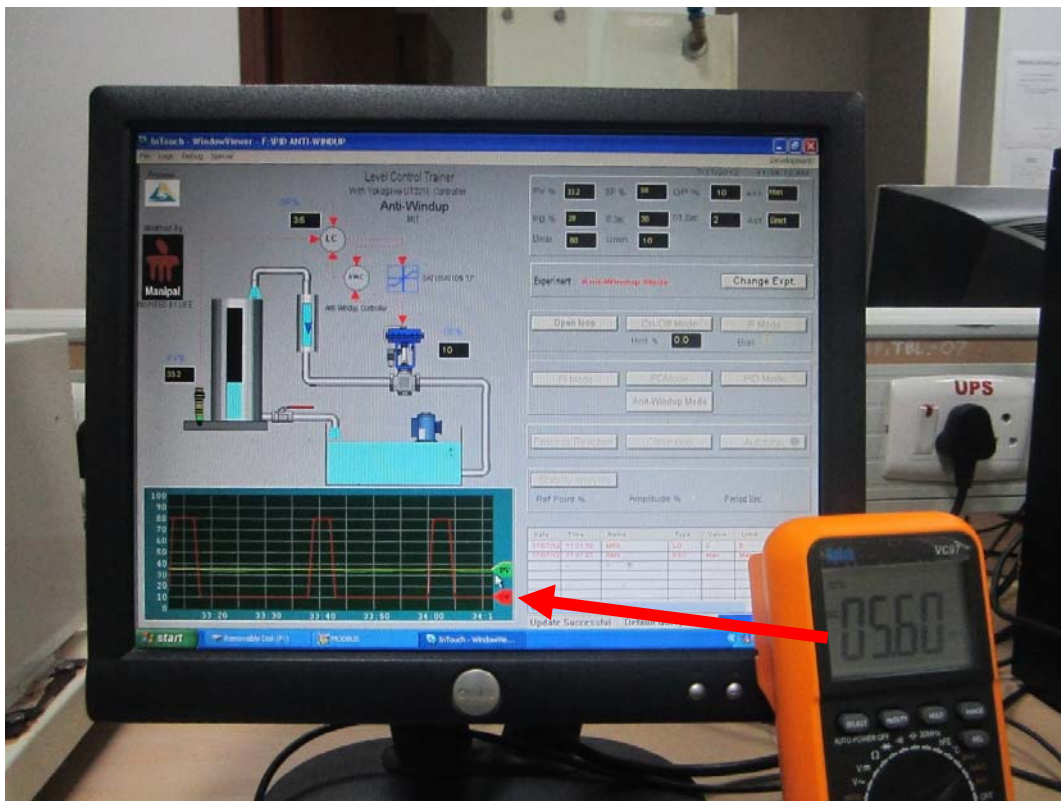


Fig. 11. The output current value at  $min = 10$ .

### 3. Conclusion

The integrator windup is a very common problem in the PID controller system, accrued when we have actuator saturation. There are four different methods called anti-windup strategy to solve this problem, each strategy has its own advantage and disadvantage at the same time, e.g. the limited integrator give the high overshoot compared with the other method, so it's the least desirable method. The proposed method gives a very good response, because it takes the advantages of the two anti-windup strategies (conditional integrator and back-calculation). Also the response of the controller with and without Anti-Windup in real time system and how it use to limit the actuator and prevent him to exceed a defined values ( $U_{max}$  &  $U_{min}$ ) when a saturation is accrued.

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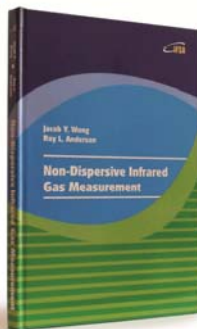
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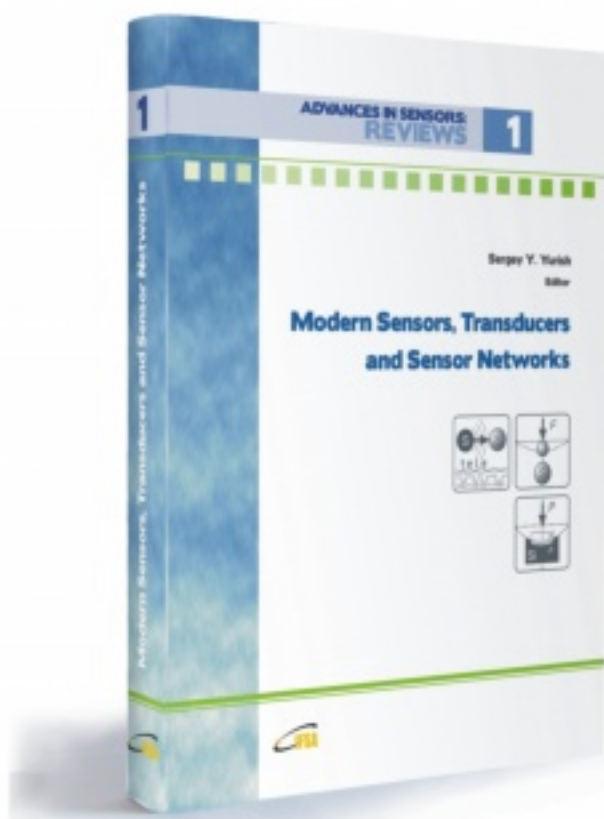
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