Modern Applied Science
www.ccsenet.org/journal.html
Vol. 3, No. 11
November 2009

# A New Repetitive Control Strategy in a Liquid Level System

M.Vijayakarthick
Department of Instrumentation Engineering, Annamalai University
Annamalai Nagar-608002, TamilNadu, India
E-mail: vijayakarthick@yahoo.co.in

S.Sathishbabu
Department of Instrumentation Engineering, Annamalai University
Annamalai Nagar-608002, TamilNadu, India
E-mail: sathish3575@gmail.com

P.K.Bhaba (Corresponding author)
Department of Chemical Engineering, Annamalai University
Annamalai Nagar-608002, TamilNadu, India
E-mail: drpkbhaba@gmail.com

**Abstract**

In this research work, a new attempt is made to implement a Repetitive Control Strategy (RCS) in a Liquid Level System (LLS). First, the liquid level system is approximated into a First Order Plus Time Delay (FOPTD) model by step testing method. RCS is incorporated in the conventional level control loop of proportional (P) mode. Ziegler-Nichols Tuning Rule (ZNTR) based proportional controller parameter is considered in the loop. A periodic signal of sine wave in inflow to the level system is generated and real time runs of the LLS are carried out for the periodic input tracking with RCS based P mode control loop. The performance analysis of periodic input tracking is done. A similar run is carried out with the system having conventional P-mode structure in the control loop. A comparison in the performance analysis clearly indicates that the incorporation of RCS in the control loop in LLS provides a better tracking performance than the conventional P mode. The robustness of RCS incorporation in control loop is also justified with another tuning rule.

**Keywords:** Liquid Level System RCS-P, Conventional P, ZNTR, ATR

## 1. Introduction

The basic requirements in control systems is that they have the ability to regulate the controlled variable to the reference commands without steady state error against disturbances. Control of Level process have been widely studied in recent decades due to the importance in many industrial applications. In most level process control applications, P and PI controllers perform reasonably well under constant disturbances .However, consistent regulation performance is not achieved when the process is subject to periodic disturbances. One of the main contributions of the work presented in this paper is precisely implementation of the Repetitive Control Strategy in a level process. Repetitive control is a subclass of learning control systems that achieves low error in systems with periodic exogenous inputs with known period. This is achieved by introducing a highly frequency selective gain through a positive feedback loop containing a time delay element. The delay time is equal to the known period of the exogenous input.

The main applications of the RCS deal with tracking of periodic trajectories in the set point or rejecting periodic disturbances [J. H. Lee, et al,2001] with a known period. In the development of the RCS, the internal model principle (IMP) has played a major role. According to IMP [B A.Francis and W. M. Wonham, 1975] the controlled output tracks a class of reference commands without a steady state error only if the generator for references is included in the stable closed-loop system

The salient features of the RCS are as follows [Rong-Fong et al, 2000]: (i) In order to reduce tracking error in every period of the control system, tracking error in the previous period have to be considered. Therefore, the control method is obviously different from that used in the typical servomechanisms. (ii) Integrator and time delay of the system are combined for achieving the above description.

The concept of RCS has been largely used in different control areas such as CD and disk arm actuators, robotics [Yamada, M et al, 1999] electronic rectifiers [Zhou. K et al, 2000] and pulse-width modulated (PWM) inverters [Zhou.K., & Wang.D, 2001].etc. In particular the RCS have not found any significant application in chemical process because most of the chemical process handling large delays and non linear in nature. In this paper a first attempt is made to implement the RCS in liquid level chemical process. Here the level process behaves linear system with minimum delay

The paper is organized as follows: Section 2 summarizes the process description of Liquid Level Control System. In Section 3, Materials and Methods are described and the structure of Repetitive Control Scheme is also explained. Real time results are analyzed in Section 4 to illustrate the better performance of the proposed RCS in closed loop. Finally, concluding remarks are given in Section 5.

## 2. Process description

### *2.1 Experimental setup*

The experimental setup of Liquid Level System is shown in figure1 and specifications are given in Table1. The setup consists of process tank, collection tank, variable speed motor pump and RF capacitance level sensor. The RF capacitance level sensor is fixed in the process tank to measure the level. The variable speed motor pump is attached to the collection tank and speed of the pump can be controlled by thyristor power control (TPC) unit.

### *2.2 Description*

By means of a variable speed motor pump, water in the collection tank is pumped to the process tank. The level in the tank is measured by RF capacitance level sensor and it converts the physical quantity of level to current signal .This current signal is converted to a voltage signal using I to V converter. A newly designed VMAT01 interface board consisting of a multifunction ,high speed analog to digital converter (ADC) and digital to analog converter (DAC) is interfaced with the PC-AT Pentium 4.The VMAT01 is capable of running the real time control algorithms in simulink tool of MATLAB platform directly. Moreover it is just like DSPACE. The voltage signal is processed and the real time control algorithm is carried out by VMAT01.

## 3. Materials and Methods

### *3.1 Model parameters and Controller settings identification*

Initially the level in the tank is maintained at steady state of 40% (12 cm) of the total height. A step size of 5% in DAC output is given to the system.The variation in level in percentage is recorded against time until a new steady state is attained. From the experimental data the FOPTD model parameters such as process gain ($K_p$), time delay (D) and time constant ($\tau_p$,) of the level process are determined. The identified transfer function model for the Liquid Level System is given as **$G(s) = (4.31 / (22.8s+1)) \exp^{(-1.32s)}$**.Based on these model parameters the P mode controller settings are calculated by considering ZN open loop tuning rules [Ziegler and N. B. Nichols, 1942] (Kc = 4).

### *3.2 Repetitive Control Strategy (RCS)*

Repetitive control is a simple learning control method which was designed especially for tracking a periodic reference signal and rejecting a periodic load signal. The design of repetitive control strategy (RCS) is based on the Internal Model Principle (IMP).The internal model principle **(**IMP**)** proposed by Wonham and Francis plays an important role in the design of the servo system. The IMP states that if any exogenous signal can be regarded as the output of an autonomous system, the inclusion of the model of the signal in a stable closed-loop system can assure perfect tracking or complete rejection of the signal. Hara et al. has developed RCS in the year 1985.

The RCS includes the factor $\frac{e^{-Ls}}{1-e^{-Ls}}$ which has poles at $jk\frac{2\pi}{L}$, k = 0,$\pm$1,…..,$\pm\infty$ (corresponding to the harmonic and sub harmonics of the basic period L), the controller can track any periodic signal and reject any disturbance of period L. Based on this concept, RCS is constructed with a model of $\frac{e^{-Ls}}{1-e^{-Ls}}$. Figure 2 shows the incorporation of RCS in the level control loop.

### *3.3 Periodic Signal Generator*

A periodic signal generator is shown in figure 3.In periodic signal generator, any periodic signal with known period L can be generated by the time delay system. If one single period of any periodic wave is given as an input, the output will generate continuous periodic wave with one period delay. The delay should be the time of one period.

## 4. Results and discussions

A sinusoidal wave with known period (L=62) is generated as discussed in section 3.3. Figure 4 shows the RCS structure in a conventional P mode control loop. Real time runs of the LLS are carried out for sinusoidal periodic tracking in RCS based P mode control and the tracking responses are recorded in figure 5. To compare the RCS based P mode the runs are carried out with conventional P mode control loop and the tracking responses are recorded in figure 6.In both cases the nominal operating point of 40% of liquid level in the tank is maintained. From the figures it is observed that RCS in control loop is capable of tracking dynamic periodic reference trajectories better than the conventional P mode control loop. If the system is linear, the RCS technique can be adopted in chemical process. To analyze the robustness of the proposed structure, an experimental run of the level control system with P mode parameter using Abbas Tuning Rules (ATR) [Abbas, 1997] is carried out. Tracking responses are recorded in figures 7 and 8. The figures 9 and 10 shows the magnified tracking responses of RCS based P mode with ZNTR and ATR. From the result, the RCS based P mode with ZNTR took minimum runs (42 runs) to converge than ATR (47 runs).

## 5. Conclusion

In this paper a Real time implementation of RCS in a liquid level System has been made. Using step testing method the level system has been approximated to first order with delay. The Repetitive controller is developed and implemented. A comparison of the RCS-P controller with Conventional P mode is made. From the results RCS-P gives satisfactory performance over the Conventional P mode controller. Robustness of the proposed control loop is also analyzed.

## References

A.Abbas. (1997). A new set of controller tuning relations, *ISA transactions*, 36(3), 183-187.

B. A. Francis and W. M. Wonham. (1975). Internal Model Principle for Linear Multivariable Regulators, *Journal of Applied Mathematics and Optimization*, 170-194.

J. H. Lee, S. Natarajan, and K. S. Lee. (2001). A Model-Based Predictive Control Approach to Repetitive Control of Continuous Processes with Periodic Operations, *Journal of Process Control*, 11, 195-207.

J.B.Ziegler and N. B. Nichols. (1942).Optimum settings for automatic controllers, *ASME Transactions,* 64, 759-768.

Rong-Fong Fung,Jeng-Sheng Huang,Chung-Gung Chien,Yun-Chen Wang. (2000). Design and application of a continuous repetitive controller for rotating mechanisms. *International Journal of Mechanical Sciences*, 42 , 1805-1819.

S. Hara, Y. Yamamoto, T. Omata, and M. Nakano. (1988). Repetitive Control-System -A New Type Servo System for Periodic Exogenous Signals, *IEEE Transactions on Automatic Control*, 33, 659-668.

Yamada.M., Riadh. Z., & Funahashi.Y. (1999). Design of discretetime repetitive control system for pole placement and application, *IEEE/ASME Transactions On Mechatronics*, 4(2), 110–118.

Zhou. K., Wang. D., & Xu. G. (2000). Repetitive controlled three-phase reversible PWM rectifier, *In Proceedings of the 2000 American control conference*, 1, 125–129.

Zhou.K., & Wang.D. (2001). Digital repetitive learning controller for three-phase CVCF PWM inverter*, IEEE Transactions on Industrial Electronics*, 48(4), 820–830.

Table 1. Specification of Liquid Level System

| **Variable speed motor pump** | | **Process tank** | | **Collection tank** | |
|---|---|---|---|---|---|
| Type | Tullu - 80 | Material | Acrylic | Material | Mild steel |
| Speed | 6500 rpm | Capacity | 3.5 litres | Capacity | 10 litres |
| Discharge | 800 ltr/hr | Height | 30 cm | | |
| | | Diameter | 15 cm | | |

Figure 1. Experimental setup of Liquid Level System

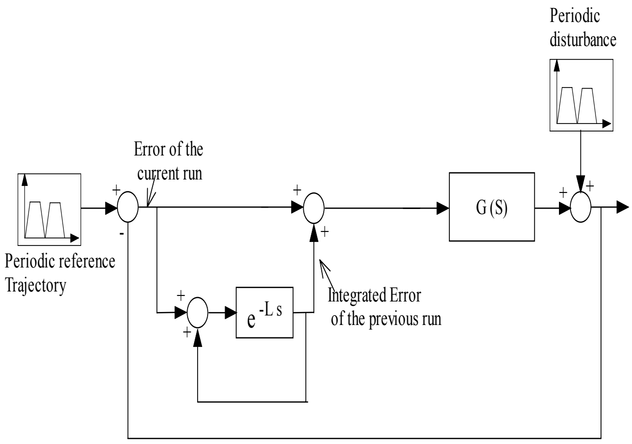


Figure 2. Repetitive Control System

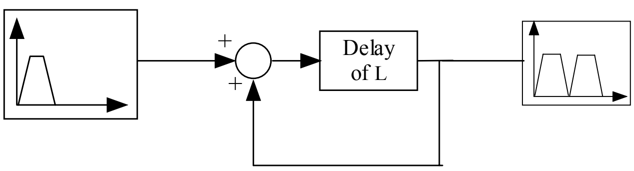


Figure 3. Periodic signal generator

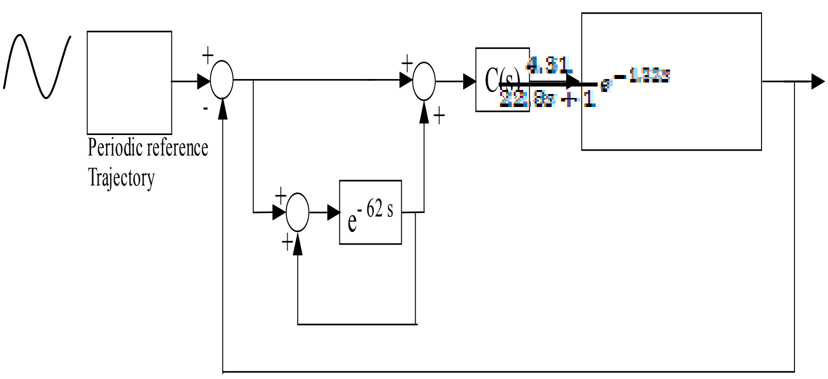


Figure 4. RCS with P mode structure in LLS

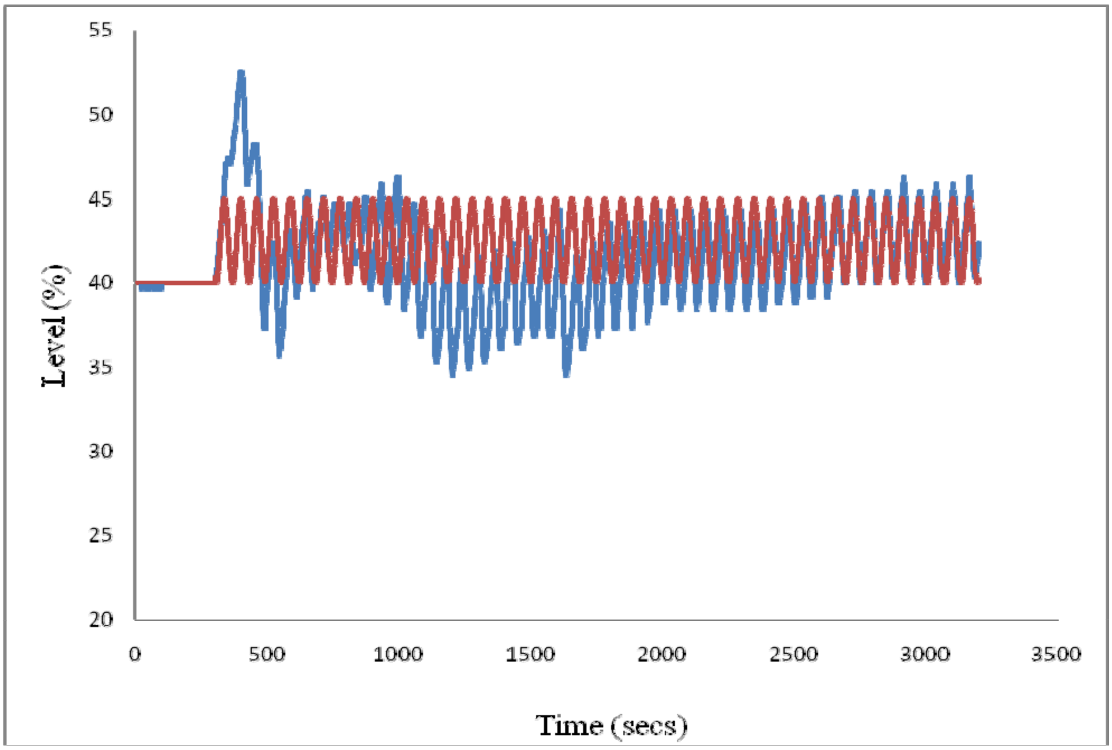


Figure 5. Tracking of periodic reference trajectories with Z-N based RCS-P mode

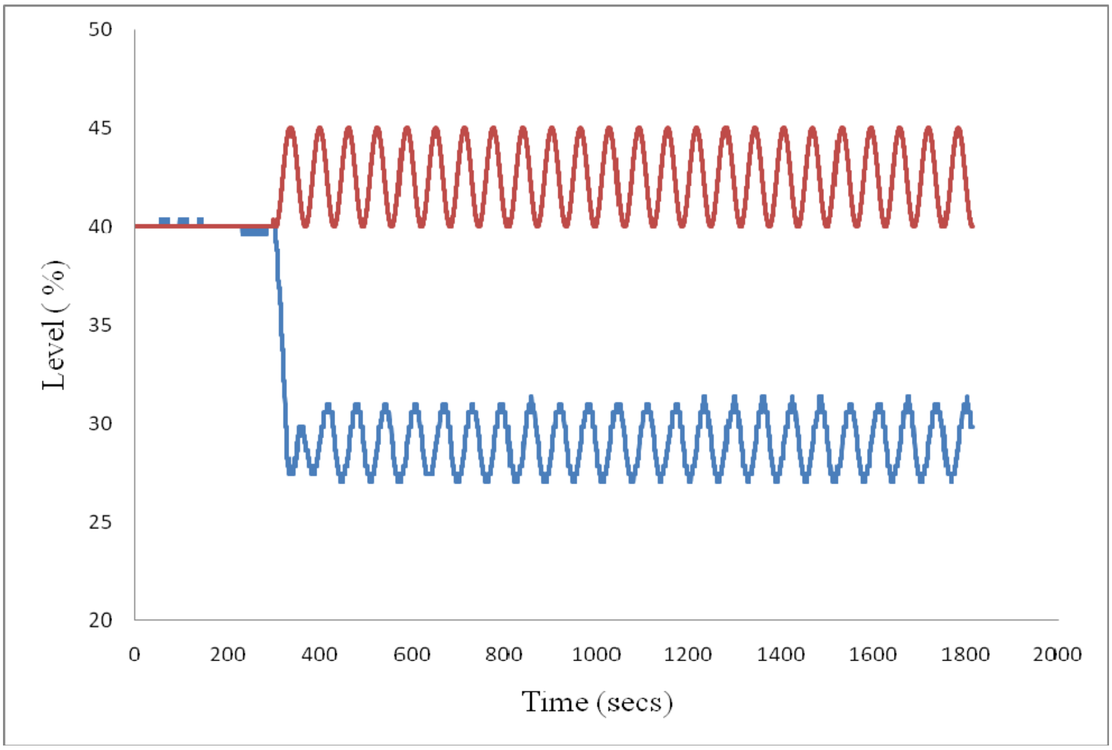


Figure 6. Tracking of periodic reference trajectories with Z-N based P mode

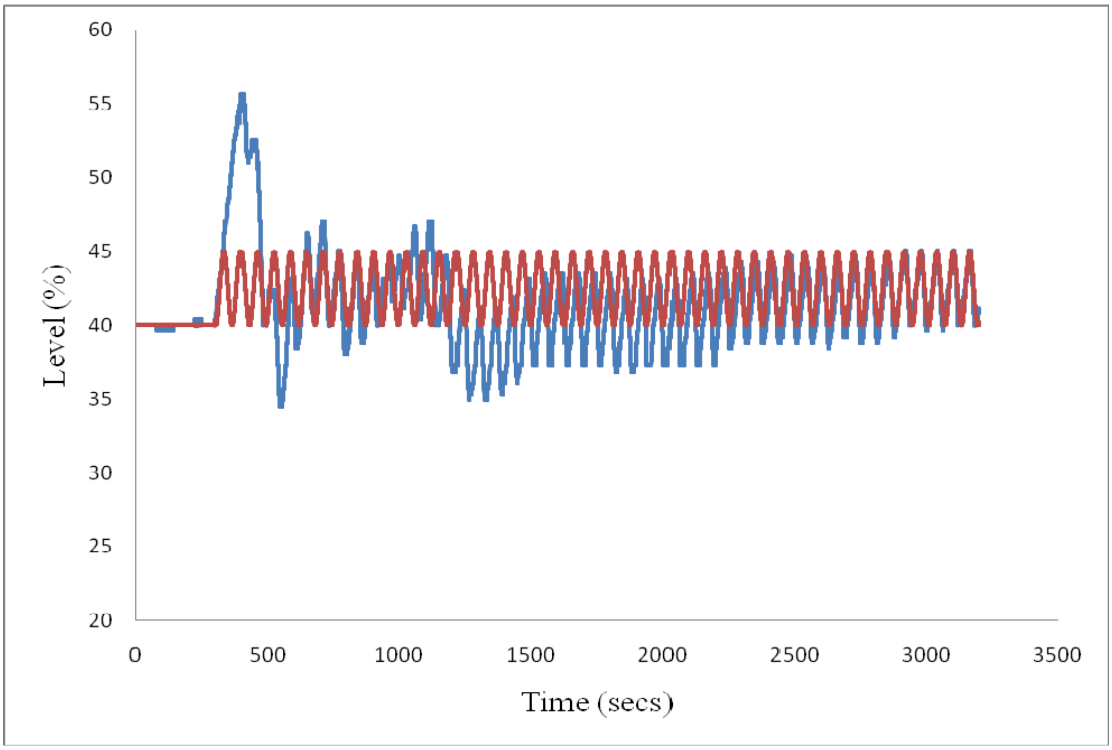


Figure 7. Tracking of periodic reference trajectories with Abbas based RCS-P mode

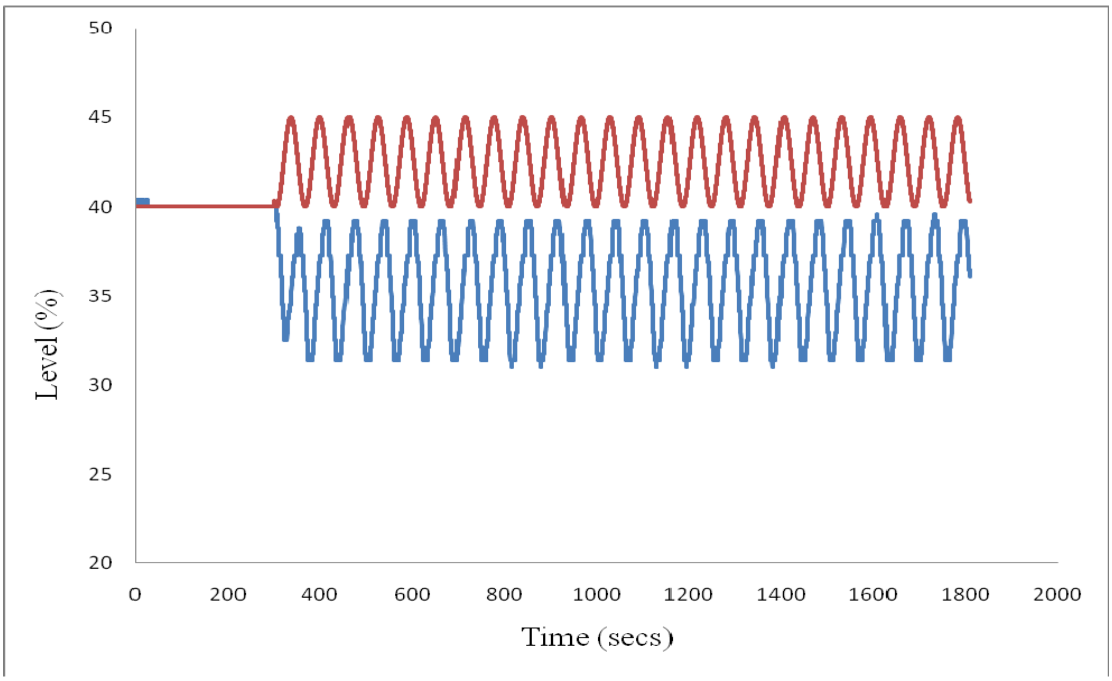


Figure 8. Tracking of periodic reference trajectories with Abbas based P mode

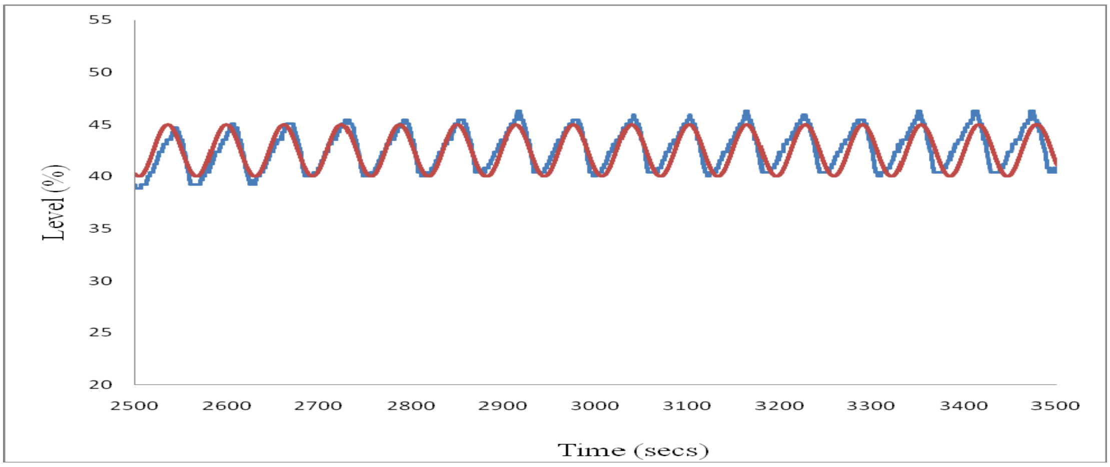


Figure 9. Magnified Tracking response of periodic reference trajectories with Z-N based RCS-Pmode

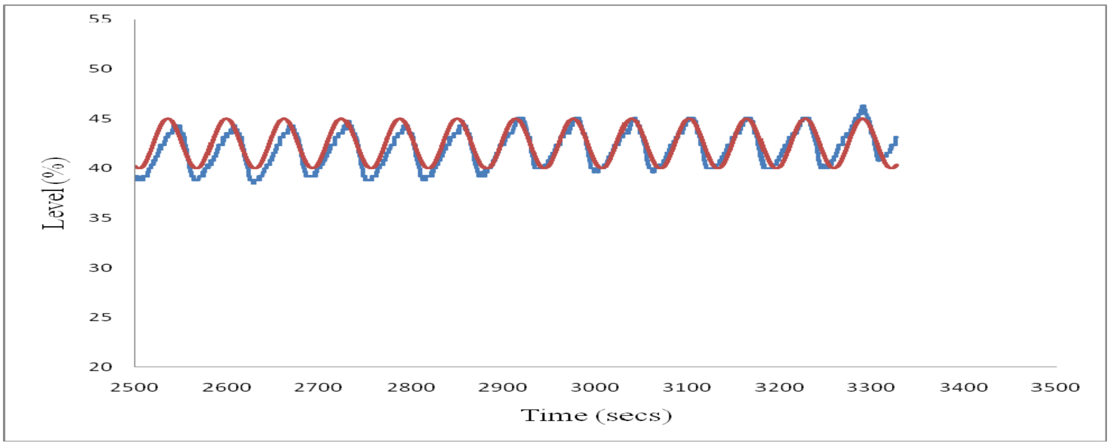


Figure 10. Magnified Tracking response of periodic reference trajectories with Abbas based RCS-P mode