ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

Wireless Control System with Model Based Control

Xiankleber C. Benjamim[1], Felipe O. S. Gama[2], Andrés O. Salazar[3], Luiz F. Q. Silveira[3]

Universidade Federal do Rio Grande do Norte

PhD Student, Engineering of Computation and Automation, UFRN, Natal/RN, Brasil[1]

Master Student, Engineering of Computation and Automation, UFRN, Natal/RN, Brasil[2]

PhD Professor, Engineering Department of Computation and Automation, UFRN, Natal/RN, Brasil[3]

ABSTRACT: There are control systems in which sensors, actuators and controllers can't communicate by wired networks. In these environments, the use of wireless communications system is an alternative, but this can create other problems in the system, like delay and information loss. This paper investigates the performance of technique a Model Based Control (MBC) used to improve the response of a nonlinear invariant system, using a analogic circuit to simulate a tank level control, and analyzing the control behavior considering a communication with information loss. The results demonstrated that the technique improves the wireless control system.

KEYWORDS: Control System, Wireless Communications, Model Based Control, Information Loss.

I. INTRODUCTION

The traditional communication architectures in control systems are generally defined on a wired infrastructure. This type of centralized communication architecture doesn't support some requirements, such as modularity and decentralized control[1].An alternative to this scenario is the use of Wireless Sensors Networks (WSN) to interconnect sensors, actuators and controllers in a remote control environment [2].

On the other hand, the use of WSN at industrial environment can cause problems as information loss and jitter, affecting the Control System Stability [3]. In this sense, there are several techniques to minimize the degenerative effects that information loss can cause in control systems, amongst them it can be cited the MBC.

The MBC is a strategy of control where control signals are based on the plant model[4]. Its main feature is to use the process model to predict the future behavior of the controlled variables [5]. When using MBC techniques in WSN is assumes that the lost information due to miscommunication can be estimated by simulating these models [6].

MBC, using the mathematical model of the plant for treating loss of information in the network problems [7] In the control based on model, a mathematical model of the process dynamics is explicitly incorporated into the process control system, in orderto improve the performance system [8], [9], [10] and [11].

The strategy adopted in this paper considers the use of MBC to simulate the system process output when occurs a packet loss, and then use the obtained results to feed a Proportional Integrative Derivative Controller (PID).

This paper is organized as follows. Section II presents a review of the control technique used in this study. Section III shows the system used in the tests and the project details. Section IV illustrates the implementation of MBC technique. The results are shown and discussed in Section V. Finally, Section VI presents the conclusions.

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II. SYSTEM MODEL

The mathematical model of the first order invariant system used in this work is illustrated in Figure 1. The system has one input and one output, and is nonlinear. This model is important for the development of a WSN system that use the MBC control strategy.

It was used a single tank system, with the main objective to control the fluid level of the tank.It is a system commonly used in industrial plants[5] and [12]. The system has a reservoir, a pump and one vertical tanks, configured such that the liquid is pumped from the reservoir to the tank, the orifice at its base enabling this fluid flow into the reservoir to be pumped again.

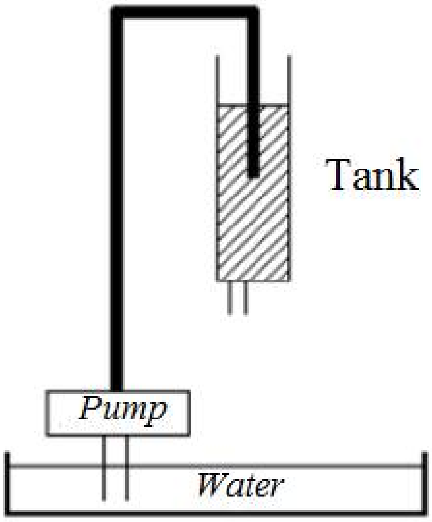

Fig. 1.Coupled tank System.

The Equation (1) represents the tank level system dynamics.

$$\dot{L} = -\frac{a}{A}\sqrt{2gL} + \frac{K_m}{A}\cdot V_p$$
)

Where $\dot{L}$ is the tank level variation, a is the output orifice area of the tank, A bottom area of the tank, g gravity acceleration, $K_m$is the water pump constant and $V_p$is the applied pump voltage.

The Table 1 presents the parameters of the system describes by Equation (1).

TABLE I. USED PARAMETRES

Parameters	Values
A	15.518 cm^2
a	0.178 cm^2
K_m	4.6 cm^3 / s . V
g	981 cm / s^2

Since the model is nonlinear, it is necessary to obtain a linear equation that represents the system in an operation point. This equation is necessary to design a process controller based in linear control techniques. The Equation (2) represents the system in discrete state space for sample period of T = 0.1 seconds and linearized at L = 15 cm.

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$$L(K+1) = 0,9935L(K) + 0,01477V_p(K) + 0,01477V_p(K-1) \quad (2)$$

The system was implemented by an analogic circuit using operational amplifiers presented in section III.

III. METODOLOGY

The main objective of predictive technique implemented in this work is to keep the regulation of the same tank level 1 in the event of packet loss between the parts of the system.

The composition of the experimental bench used in the execution of the project consists of a circuit based on operational amplifiers(Figure2) responsible by for emulation of the first order plant, ATMEGA328P microcontrollers, representing the sensor element, the actuator and controller, and wireless communication modules NRF24L01 to perform the communication link. An overview of the structure isrepresented in Figure 3.

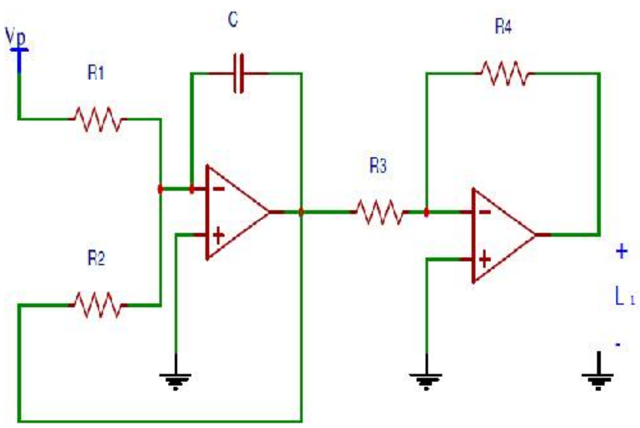

Fig. 2.Eletronic circuit that simulate a tank level system.

The sensor element measures the tank level. The generated signal is transmitted via the RF module to the controller, which performs a PID control routine with reference to the value that is passed by the computer.

The actuator receives the control action from the controller module, via RF, and produces the PWM signal to be injected into the pump.

In order to simulatea communication environment withpacket loss, the transmission power is setat-18 dBm, and the packet size is set at 16 bytes.Besides, the Cyclic Redundancy Check (CRC) is turned off to avoid error checking in the wireless link.

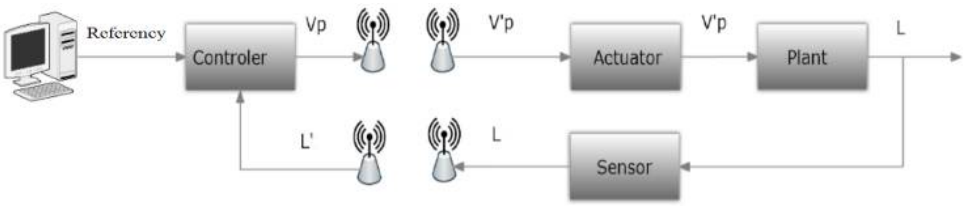

Fig. 3.System diagram to experimental tests.

IV. MBC IMPLEMENTATION

In this work, when a packet loss is detect the MBC technique estimates the tank level through the transfer function presented in Section II. In order to detect a packet loss, it was used the timer of a microcontroller configured to create an

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interruption warning every time a predefined time threshold has been exceeded. After the packet loss detection, rather than waiting for the next packet to perform the control signal calculation, the controller receives the plant level estimated value obtained through simulation based on the transfer function presented in Section II.

Figure 4 illustrates the used control strategy, where the"overflow key" is the logic to detect the packet loss, if the packet loss it detected the signal sent to the controller and obtained by system transference function discussed in Section II. Otherwise, the signal sent to the controller level is measured by the sensor.

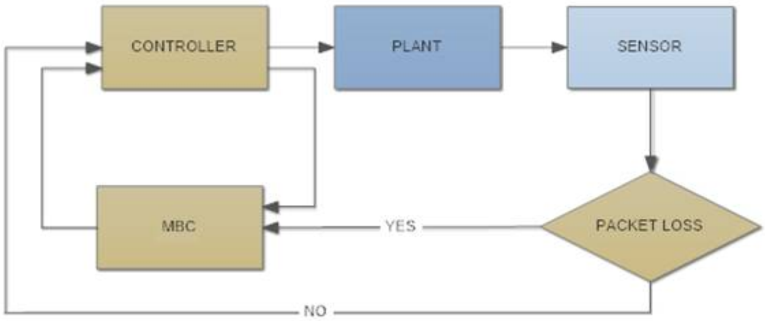

Fig. 4.Block diagram of MBC strategy.

V. EXPERIMENTAL RESULTS

This section presents performance results obtained from experiments in a control loop where the controller is five meters from the sensor modules and actuator. The system counts the numbers of packet loss that occurred in a period of 120 s. The Figure 5 shows the results obtained from various experiments without the MBC technique, which is observed the packet loss degenerative effect can cause the control system.

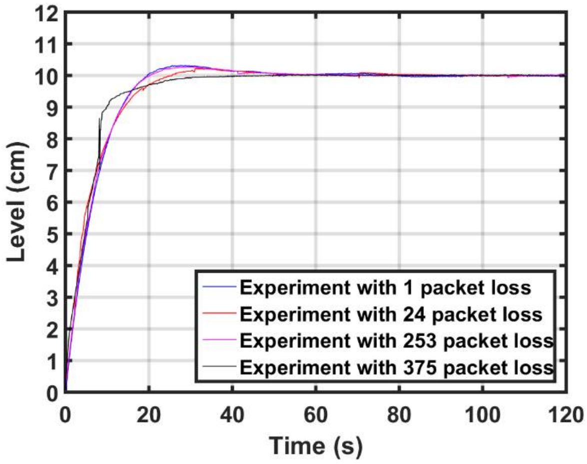

Fig. 5.System response without the MBC technique.

Figure 6 presents the results obtained through experiments performed with MBC technique, which is observed that the packet loss effects in the control system are minimized.

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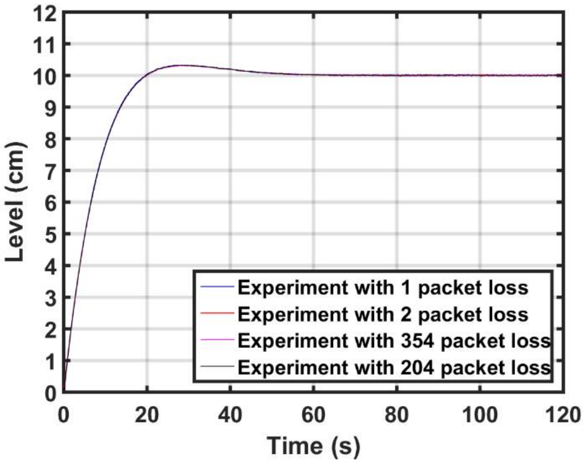

Fig. 6.System response with the MBC technique.

The Figure 7 shows the comparison between a control system with and without MBC technique, both with an approximate amount of packet loss, 354 and 375 respectively. It can be observed that the system response with MBC have less noise and less oscillation than the system response without the technique.

VI. CONCLUSIONS

This paper presented a methodology to improves the packet loss impact in a wireless control system and a control strategy which aims to minimize the degenerative effects that can occur with packet loss. With the insertion of MBC technique in a control system with wireless communication, it achieved a performance superior to systems

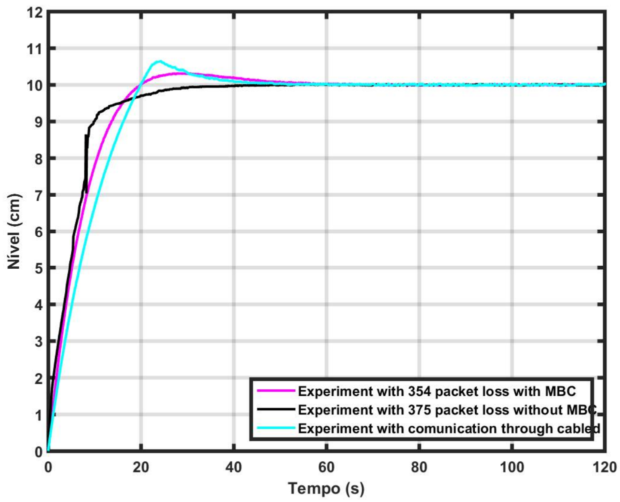

Fig. 7.System Wired systemresponse with the MBC technique.

without the MBC technique. These results show the increased performance of the controller to the technique used in this work.

Given the results, the main contribution of this work was to propose and consolidate the insertion of MBC technique in control systems with wireless communication.Future works can test in superior orders systems, and change the system parameters to obtain fasters system and detect the fastest system that can be optimized by MBC technique. Also the

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MBC technique can be compared with other techniques of predictive control to estimate the best approach to solve this problem.

ACKNOWLEDGMENT

The authors thank Capes, the support received for this work.

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