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Performance Analysis of Wireless Monitoring Control System for ESP in Cement Plants

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***Abstract* - There is still a deficiency in the field of closed-loop wireless control systems in terms of full real-time implementation and actualization. This paper explores the architecture, design, and implementation of Wireless Networked Control Systems (WNCS), emphasizing their operational problems. In particular, it investigates the implementation of an XBee platform-enabled Wireless Networked Control System to control an Electrostatic Precipitator (ESP) model using PC connection. The architecture of this control system is client-server. A real-world case study about the planning, creation, and implementation of a wireless monitoring control system for ESP is carefully scrutinized and assessed. The True time 1.5 simulator is used to illustrate simulation results, which provide insight into how different system factors affect overall performance and stability. The article also highlights how to use Matlab and Simulink capabilities to improve ZigBee network utilization for comprehensive feedback WNCS.**

Keywords: WNCS, Stability and Performance, Electrostatic Precipitator, ZigBee.

I. INTRODUCTION

The domains of computing, communication, and control engineering have seen tremendous advancements in recent years. They must be able to use computation and communication to carry out sense and actuation between different devices [1-2]. The energy will be provided by the tools to introduce sensible complicated systems that are accepted for effective utilization, improvement of pollution observation systems, and surrounding surveillance. The productivity within the industrial plan can also be improved. Fig.1 represents the relations of the WNCS plan for the common region that laying between controls (C1), Communication (C2), and Computing (C3) engineering fields [3-4]. The Closed-loop distributed control systems at which communications via controllers, sensors, and actuators happen by a share fixed bandwidth data communication network defined as Networked Control Systems (NCS). It can be classified according to the nature of the transmission medium, into two types: wired and wireless systems [5].

The NCSs using extensively to decrease the complexity and the cost. For increased connectivity and also reliability. Recently many schemes have been proposed to increase connectivity and reliability. These schemes are often used with efficiency to observe and control the broad difference processes and systems. In the WNCS, the communication among separate elements of the system builds on the technologies of wireless media. The network by wireless medium could be an appropriate meaningful moment in many fields of applications because of the wide range of benefits like spatial temporality sensing, mobility, and reconfigurability.

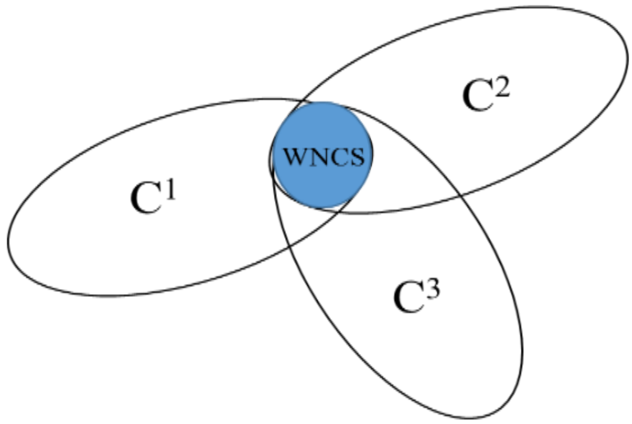

Figure 1: WNCS area by Venn's scheme representation

The wireless transmission is for measuring data by sensor and connection at the origin with Wireless Sensor Networks (WSNs), a new modification has presently been developed that handles an equivalent channel for allowing NCS [5]. The wireless networked control systems study field is mainly classified into three sectors:

1) Controlling on the network: analyze and investigate on the computer network and communication system to make them proper to real-time in the networked control system, routing, congestion flow control, effective transmission, and also protocols.

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2) Control over the network: the area uses control strategies and design guidelines to exert control over the wireless networking medium. The challenges of mitigating the impact of network factors, such as packet loss and network latency, on control system performance and stability.
3) Multi-agent systems: systems treat with the study of agents whereby network structure and intercommunications within network nodes that lead the main control purposes. Besides the exact question here is to know the performance of the single agent influence the complete performance of the NCS [8].

New studies have been directed to improve system accuracy, the Quality of Performance (QoP) and reliability. The installation of those nodes or customs helps the difficulty of convergence because they want a low consumption of energy and possible to communicate for the desired distance. In general, there is a lot of research activities in the area of NCS and WNCSs in the few years ago, an issue into a tremendous amount of papers covering almost all about the problems mentioned so greatly. In the following, the latest publications are explored. In 2005, Tsez et. al. [10] presented a new experimental investigation by a portable (client-server) in NCS.

The shut circle stretches out past a channel association inside the plant hub (server) and regulator hub (client) for universally useful remote help. For remote modern cycle control, Melody et al. [11] introduced a corresponding essential (PI) regulator structure in 2006 and incorporated a fundamental assessment of the regulator's dependability. A multi-bounce caused increment scheduler was proposed by Nikolakopoulous et al. [12] in 2007 for the remote arranged control framework. The proposed control framework is based on the (client-server) system. In 2007, Dritsas et. al. [13] introduced another model for NCSs by different arrangements of various correspondence defer periods are proposed. In 2008, Nikolakopoulous et. al. [14] presented an enhancement technique for a remote correspondence framework, joined inside a tuning strategy for continuous control utilizations of the controlling exhibition. In 2008, Uchimura [15] addressed the WNCS by factor defer way.

To expand the drop or misfortune, the situation depended on a (parcel based) network where bundles make up the forward parcels. Amarawardhana et al. [16] gave a clarification of the principal design of remote sensor organizations, SCADA organizations, and correspondence conventions in 2009. XBee foundation is utilized to lead a contextual investigation. A planning method for a few discrete-time NSC managed to correspondence constraints recently depicted as inertness and bundle drop/misfortune was exhibited by Dai et al. in 2009 [17]. Model prescient control (MPC) was applied in 2010 by Nikolalopoulous et al. [18] to nature control missions of automated quadrotor helicopters for remote transmission and picture decrease.

In 2010, Li et. al. [19] fostered a (remote PLC) framework to deal with the far off region hubs without cabling. by applying XBee modem to foster a remote organization framework inside the regulator hub and plant hub. In 2010, Bemporad et. al. [20] presented the investigation of trial states of MPC of a (half breed dynamical cycle) including remote detecting. In 2010 likewise, Kaltiokallio et. al. [21] examined execution examination inside parcel drop/misfortune and variable postponements of the (PIDPLUS) regulator versus corresponding essential and relative necessary subordinate regulators. In 2011, park et. al. [22] concentrate on the central issues of WNCS through concentrating on the effect of the remote organization on control proficiency boundaries and afterward offered a co-plan method for arriving at the needed control cost while lessening the energy misuse of the organization. In 2011, Lemmon and Hu [23] affirmed an adequate number of necessities for the soundness of the organized control framework with irregular drop/misfortune. Those necessities are related to the burstiness of the drop/misfortune cycle to the ostensible reaction of the controlled framework by the remote transmission.

In 2012, Choi et. al. [24] proposed a bundle misfortune upgrade method for digital actual control past the remote framework. They applied for the Zigbee request as a remote correspondence access and correspondence organization. In 2012 likewise, Qu et. al. [25] examined the adjustment issue for remote arranged control frameworks with motivation impedance in the discrete space. They addressed the parcel misfortune steady with the Bernoulli approach. In 2013, Ulusoy et. al. [26] offered a NCS framework that proposed to as remote portrayal based frequently prescient NCS, and complete a strong framework utilizing IEEE 802.15.4 (ZigBee) as a transmission convention.

They showed reproduction impacts concerning the presentation of the controlled activity underneath gigantic proportions of erratic postpones in organization and parcel misfortune. The logical commitments of this work are the outcomes gotten (with time deferrals and bundle misfortune issues) from exploratory execution of WNCS. The remainder of this paper is organized as follows: in segment II, the framework depiction is performed. In segment III, examination and foundation hypothesis will be surveyed. Reproduction results are given in segments IV and V. The article is finished up in segment VI.

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II. SYSTEM IDENTIFICATION

The data is collected experimentally from the real ESP in the Al-Tahady company; table 1 illustrates the ESP operation data. Figure 2 showed the characteristic of high voltage with fire angle thyristor. Figure 3 represents the input and output data of the transfer function.

Table 1: ESP Operation data

Firing angle (α)	Voltage (Kv)	Current (mA)
0	0	0
360	2	10
720	3	13
1080	4	22
1440	7	23
1800	10	23
2160	12	25
2520	14	26
2880	17	Break down
3240	----	----
3600	----	----

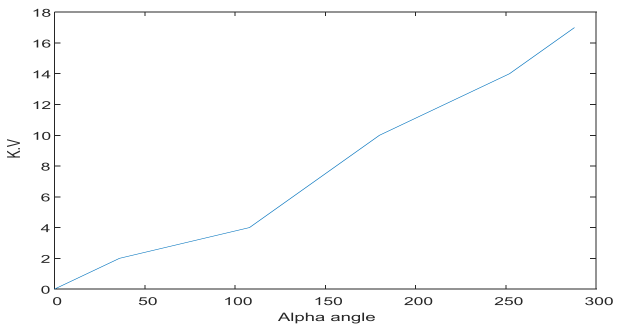

Figure 2: Characteristic of high voltage with Fire angle thyristor

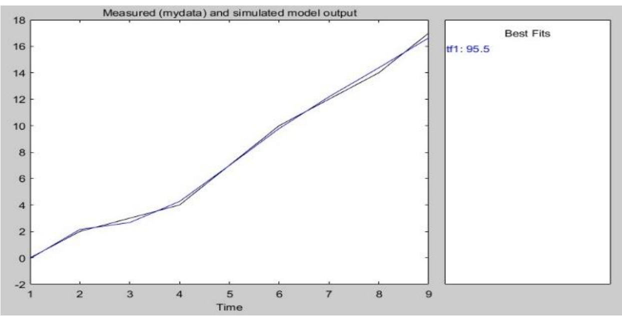

Figure 3: Represent the input and output data of the transfer function

The input and output curve of the real plant is identical to the input and output transfer function curve to 95%.

The final transfer function of the ESP can be written as:

$$T.F = \frac{0.05989\ S^2 - 0.045\ S + 0.11}{S^2 + 0.95\ S + 1.69} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

III. SYSTEM DESCRIPTION

In order to look at the practicability of WNCS, a model reenactment proving ground comprising of an ESP model has been planned, form, and carried out in the current work to make sense of and cover new answers for the plan of control calculations and transmission conventions for remote organized control frameworks working together. An ESP model control framework is utilized in association with remote regulators to drive the ESP power supply. The transformer rectifier unit is constrained by a thyristor unit and a gathering of diodes of the flywheel (delineated in Fig. 4). The arrangement of control is achieved on a one-jump remote medium utilizing four remote detecting units, two remote hubs at the server side (plant), and one more two remote hubs at the client side (regulator) [27]. The numerical model of the ESP is acquired by utilizing framework distinguishing proof toolbo and information got from pragmatic analysis between input terminating point and result KiloVolt.

IV. SYSTEM ANALYSIS

In this part, the analysis and treatment of results for implementing the WNCS using client-server architecture are presented. The analyses include the effects of separate parameters on the stability and performance of the wirelessly controlled ESP model such as time delay, sampling time, and bandwidth and lose channel environment.

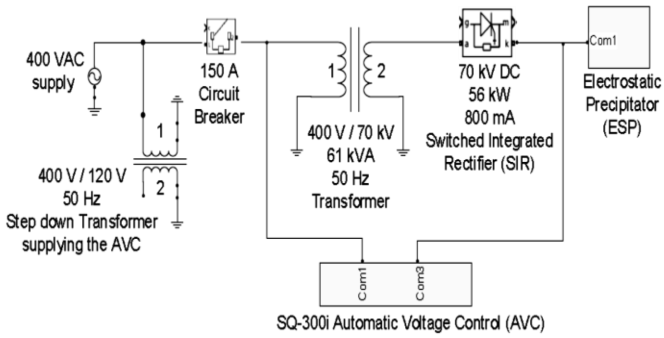

Figure 4: ESP power supply circuit diagram schematic

4.1 System Stability and Performance

Stability may be a very essential notion in systems; however, it's additionally one amongst the toughest performance properties to prove. There are many distinct criteria for system stability; however, the foremost general demand is that the system should produce a restricted output once exposed to a finite input. For the application, if five volts is applied to the input terminals of a DC motor circuit, it will be most if the circuit output (angle) did not approach infinity, and the circuit itself did not soften. This sort of stability is usually known as "Bounded Input, bounded Output" stability, or BIBO. There are a variety of different kinds of stability,

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most of that is supported on the concept of BIBO stability. The stability and performance of the wirelessly controlled ESP model is studied and analyzed by measuring the maximum overshoot (Mp), steady-state error (ess), transient time (tr) and settling time (ts).

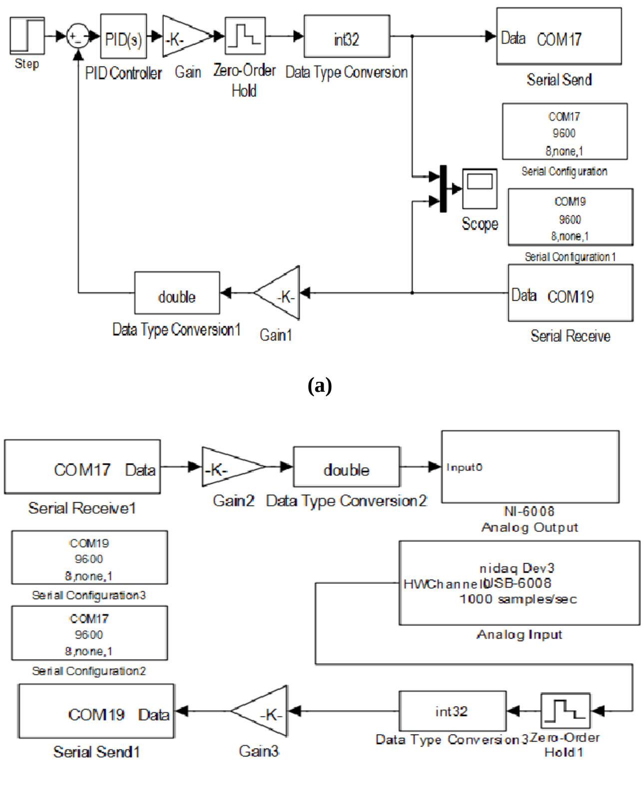

Figure 5: Implementation of WNCS using Simulink, (a) Client-side and (b) Server side

Controller Type: The regulator is fixed on the client side it is utilized to figure the control sign to drive the ESP model to the expected kilovolt and milliampere. There are numerous calculations that have been recommended in [27] to be made in the client side. PID regulator is the most recognizable regulator that we have achieved and it has been seen that PID is awesome for driving the framework to the interest reference signal. Four tests have been convoyed to actually take a look at the framework's strength and execution. The first is finished with P-regulator where Kp=0.039 and both Ki and Kd are equivalent to nothing. The reaction of the framework is depicted in Figure 6. Obviously there is some mistake in the consistent state and profoundly emphasize overshoot in the transient time. Figure 7 and Figure 8 recognized the mistake signal which is taken care of to the regulator and the regulator endeavors separately [28]. The subsequent trial is achieved by utilizing the PI-regulator where Kp=0.04 and Ki=0.012 while Kd=0. The reaction of the framework is delineated in Figure 9. Clearly the consistent state blunder is upgraded and the result attempted to way the expected position. There is as yet a high and rehashing overshoot.

To work on the reaction of the framework, the third test on the ESP model is finished by using the PID regulator. The boundaries of the regulator are speculated relying upon the Z-N technique and Molecule Multitude Improvement (PSO) calculation [30]. Figure 10 shows the framework reaction with Kp =0.05, Ki=0.026, and Kd=0.025. The exhibition of the framework is working on then that of P and PI regulators. The recreations result for all control structures achieved so broadly are dynamic in Table 2 with the undifferentiated from execution angles, for example, consistent state blunder, overshoot, settling time, and rise time.

Table 2: Comparison table from simulation for controller performance parameters

Controller	Rise time (tr)	Settling time (ts)	Overshoot (Mp)	Steady-state error (ess)
P	0.2	>20	35%	0.4
PI	0.15	<12	23%	0.1
PID	0.1	<10	10%	0.09

V. RESULTS AND DISCUSSION

A fourth trial had been achieved by changing the bundle misfortune among client and server. The framework is remade to two stages and the plant is associated with the server. The client-side PC is applied to various parcel misfortunes and the reaction is outlined in the Figure 11. It had been seen that after the moment k=1600 which relates to coming to 15%, the reaction of the remotely controlled is changed and there is fill in the overshoot. Table 3 portrays the communicating and getting impacts of on the soundness and execution of ESP model. This examination can be utilized to construct a lattice ZigBee network between the plant and the regulator [31].

Table 3: Packet loss effect on the wireless ESP model

Packet loss	Controller	Baud rate (Kb/s)	Sampling time (ms)	Performance	Stability
0-5	PI	9600	0.5	Very good	Stable
10-May	PD	9600	0.5	Very good	Stable
15-Oct	PD	11250	0.5	Good	Unstable
>15	PD	11250	0.5	bad	Unstable

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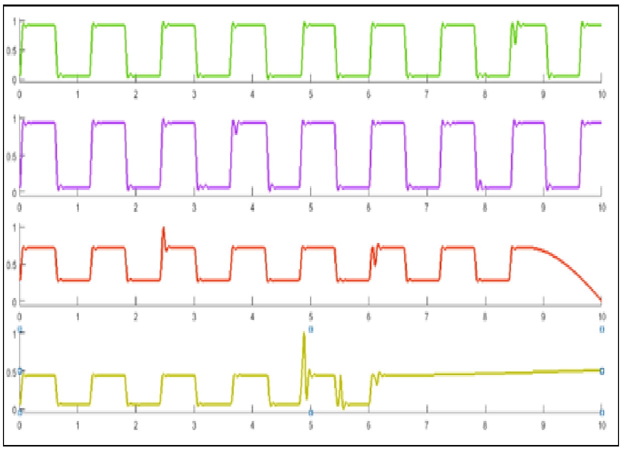

Figure 6: Response of PID-Controller with variable packet losses

There are two ways between the client and server. The first from regulator to the actuator that sends the control sign and input that convey the deliberate sign from sensor to regulator. The organization prompted postpone in the regulator to-actuator and sensor-to-regulator relying upon the organization boundaries and how it guarantees the QoP to keep the exhibition of the NCS as required. The complete shut circle delay τ_total in (2) where τ_sc sensor-to-regulator is, τ_c is regulator calculation and τ_(ca)is a regulator to-actuator delay, successively is introduced in (2).

$$\tau_{total} = \tau_{sc} + \tau_c + \tau_{ca} \quad \text{.......................................}(2)$$

For straightforwardness, the regulator delay is ignored or utilized as a feed of the regulator to-actuator delay since it's insignificant including roughly steady connected with the deferrals. Accordingly, the all out deferral can be acquired by:

$$\tau_{total} = \tau_{sc} + \tau_{ca} \quad \text{...}(3)$$

Time delay was studied by adding the delay Simulink block in different locations. Figure 12 shows the response with different values for delay. It is obvious that the system lost stability and the performance is degraded. The effect of network time delays on ESP model performance is depicted in table 4.

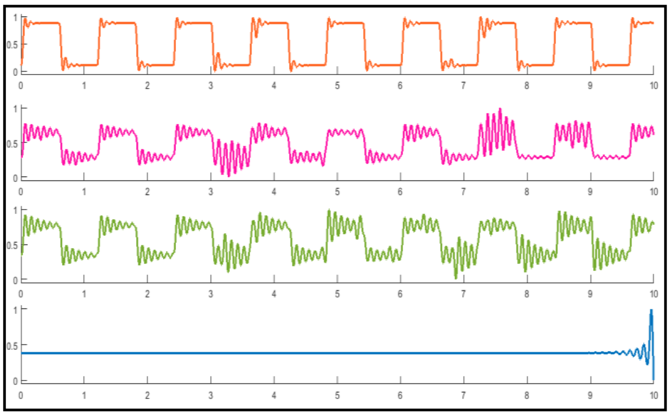

Figure 7: System response for PID-Controller with time delay (1, 2, 4, and 8 ms)

Table 4: Comparison table from simulation for controller performance parameters

WNCS	Normal	Delay			
		1ms	2ms	3ms	4ms
Rise time (tr)	0.168s	0.01866s	0.0176s	>10s	>10s
Delay time(td)	0.084s	0.0093s	0.0088s	>10s	>10s
Settling time (ts)	1.63s	0.556s	0.423s	>10s	>10s
Peak time (tp)	0.445s	0.355s	0.298s	>10s	>10s
Maximum overshot	7.77%	27.3%	42.6%	------	------
Steady-state error	2-4%	5-31%	5-46%	5%->>	6%->>
Peak value (P)	1.08	0.85	1.1	------	------
Output	Bounded	Bounded	Bounded	Unbounded	Unbounded

VI. CONCLUSION

The functional and exploratory consequences of the shut circle remote control framework need a few viewpoints related with practicability for applying remote organization to criticism control frameworks. The plant command over the remote channel with guaranteed shut circle execution guarantee and effective asset use has been made sense of the creators researched the remote organization consequences for the control parts of execution and showed that the decision of testing time a lot of impacts the control execution, security and organization throughput. Some execution issues like the impact of parcel misfortunes, commotion, impediments and course among the client and the server have been tended to and considered. The exhibition investigation and solidness of the control framework have been assessed completely utilizing reproductions under various working circumstances. Information assortment methodologies from the plant utilizing Simulink blocks is likewise proposed and carried out.

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