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SIMULATION BASED DESIGN OF RETENTION TANK OF MODULAR CONTROLLER DISCHARGE SYSTEM (MCDS) FOR TRAIN COACHES

Rajesh Kumar Garg
Lecturer, Electronic & Communication Engineering
Seth Jai Parkash Polytechnic
Damla, Yamuna Nagar-135001 ,Haryana (INDIA)

Vikram Singh
Professor & Chairperson
Deptt of Computer Science & Applications
Chaudhary Devi Lal University, Sirsa Haryana (INDIA)

Abstract: As increasingly more complex embedded systems are being considered for design, their design and validation is proving a Herculean task. Innovative applications demand stringent requirements, necessitating improvements in technologies and system design methodologies. It is where simulation and modeling come in to picture. Modern embedded system design philosophy is heavily dependent on simulation. Simulation provides a means to model an embedded system, perform experiments with the model, test, and evaluate the designs prior to committing to implementation, thus allowing design flaws to be detected and corrected early in the design process. In this paper, the design for retention tank of Modular Controller Discharge System (MCDS) is proposed which is a modernized toilet system for trains to avoid the spillage at undesired places or at railway platforms. Speed sensors help to dump the waste at a suitable distance from the railway station. Intermediate tank is used under the toilet seat and it is designed using simulation. A Programmable Logic Controller is used to control the action of storage tank.

Keywords: Embedded system, Programmable logic controller, design process, simulation, and retention tank

I INTRODUCTION

Maintaining the sanitation in train bogies and on the platforms is high on the agenda of railway networks all over the world. Travelers are advised not to use the lavatories while a train is stationed on a platform or is approaching/leaving the platform. But owing to the call of nature, must someone use latrine or urinal; it must not be spilt on or near the platform. This necessitates an intermediate storage for the excreta, which could be dumped once the train is well past the platform. It is also desired that the commode be tightly sealed with an efficient flushing system of stainless steel in order to be acid resistant. The pneumatic slide valves are made of a polymer. The overall system is controlled by a programmable logic controller (PLC). The PLC used here operates at 24 volts DC and has 4 digital inputs and 4 digital outputs. Fully controlled discharge toilet retains human waste to avoid dumping at stations and discharge it away from stations and city areas. The control unit is programmable and might be programmed according to the requirements of the system.

A programmable logical controller can be programmed to control devices such as limit switches, push buttons, proximity or photoelectric sensors, float switches, or pressure switches etc. [1]. The instructions specified in the user ladder program direct the PLC how to react to the control signals coming from field sensors

After processing the input signals coming from sensors the PLC sends a signal to the field device to control its working. Resultantly, the field-controller devices are turned on or off [2]. The sequence of instructions specified by the programmer and burnt in to the PLC ROM is called the user ladder program. Before a user ladder program is loaded the processor must be in program mode. Thereafter, if all input and output signals are wired to the correct screw terminals, the processor can be put in run mode, wherein, the program will continuously run the user ladder program instructions [7].Continual running of the program specified in a PLC is called scanning. As part of the processor's problem-solving routine, the PLC scans the incoming signals, follow the preprogrammed instructions associated with each input signal, and control the programmed output field devices [4].

II SIMULATION IN SYSTEM DESIGN

The high-level concept of how the *modular controller discharge system* will be constructed is documented in the form of architecture diagram and system-level block diagrams. The steps involved in the detailed system design are depicted in Figure 1. In the first step, a developer constructs a simulation of all or parts of the initial high-level system architecture, with the intent of not only visualizing the system, but of verifying the high-level design against the system requirements. Simulation is utilized early in the design process, to ensure the initial design is correct at a high level. Another purpose of simulation at this stage is to gather sufficient information about the system to allow rough analyses of design approaches and tradeoffs. Simulations are designed to provide sufficient accuracy and detail to allow the detection of design flaws. There are two basic types of simulation: performance and functional. A performance simulator abstracts the details of how a system performs its tasks in favor of simulating the temporal aspects of the system. A functional simulation captures the behavior of a system, allowing the designer to verify whether a system meets functional requirements. Simulators also vary in their level of detail and accuracy. A high-level simulator offers a less detailed, less accurate view of a system in favor of a rapid execution time. A high-level simulation is used when low-level system details are not needed or are not known. A low-level simulator provides fine-grained, more accurate details at the cost of longer simulation times. [7,8]After simulating the initial design architecture, the designer proceeds to design the system components. Components form the fundamental building blocks of the application. Each component is designed individually

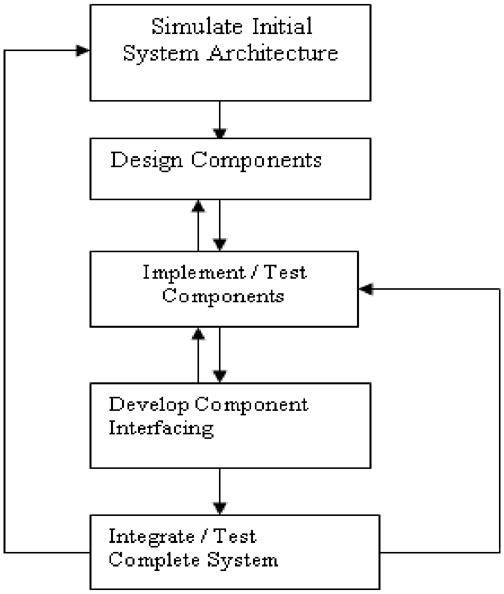

Figure 1 A typical embedded system development process.

. Good design practice dictates that components should conform to well-defined and documented interfaces, and should provide specific entry points. A first step in the development of a component is to construct a simulation of the component's behavior. The purpose of the component simulation is the same as the simulation of the initial design architecture, to verify the design against the system requirements, or to verify that the component does what it is intended to do. Only after this verification through simulation has been performed should the designer proceed to the more tedious and expensive step of component implementation. Upon completion of the component implementation, the developer tests the component by simulating the inputs and execution environment of the component. The behavior of the component implementation can be compared against the component simulation to verify proper functionality. The developer iterates over this process until all components have been implemented and verified. The next step in the design process is system integration. At a high level, integration involves properly connecting components together to form the final system. [9, 10]

III. MODULAR CONTROLLER DISCHARGE SYSTEM

It is often seen on busy railway stations of Indian Railways that there is spillage of human excreta on the railway tracks near the platforms. It becomes suffocating and unhygienic for the persons to stand there even for a short duration [6]. Retention tank which one main component of modular control discharge system (MCDS) – has been designed and described in this paper. The objective of the system described here is to provide healthy and clean environs at railway stations. Modus operandi of proposed system is given as under:

1. *Block Diagram*

With the press of start button, the input I_1 goes high and the various valves operate according to the timing diagram as shown in the fig 3. The first valve to operate is pressuriser valve i.e. valve Q_2. This valve operates for 1.5 sec. The purpose of the valve is to give additional pressure to the Inlet water. The second valve operates water inlet valve. As the valve opens, high-pressure water enters the basin whose purpose is to flush and clean the basin. The valve operates for 5 seconds. The quantity of water used is dependent upon the opening timing of the valve Q_1. This timing can be changed as per the requirements. After 2 seconds from the time of start the outlet valve Q_4 operates and it remains open for 8 seconds. The opening of the outlet valve is dependent upon the velocity of the train. If the speed of the train is above the designated speed for e.g. 30 km/hr, then only the outlet valve will open. If the speed of the train is less or if the train is stationary then the outlet valve will not operate and the outlet shutter will remain closed. The inlet valve for the intermediate tank will operate after 4.5 sec. and will remain open for 5.5 second. The effluent remains stored in the intermediate tank till the train reaches a speed above the designation speed i.e. 30 km/hr. The intermediate tank is provided with a overflow hose i.e. if the train is stationary and the toilet has been used continuously say more than 8 times then the effluent will overflow through the over flow hose even if no person is using the toilet and speed increases above say 30 km/hr. The outlet valve Q_4 will perform its cycle once and will remain closed afterwards whole cycle will complete in 10 seconds. Before 15 seconds, the new cycle will not start even if the user presses start button more than once during the cycle. . The inlet and outlet valve can also be operated manually by pressing manual inlet switch and manual outlet switch. This is done to make input I_4 and I_3 high. The switches manual inlet and manual outlet are pressed to lock and then pressed to release. In case there is a failure of electricity or air pressure. [11,12]

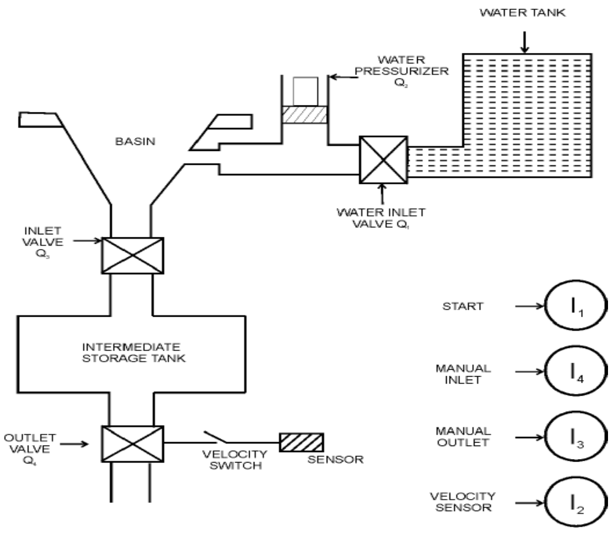

Figure 2 Block diagram of Modular Controller Discharge System (MCDS)

The valves Q_4 and Q_3 will open automatically. The PLC is programmed using ladder technique and its specified syntax [9, 10, 11].

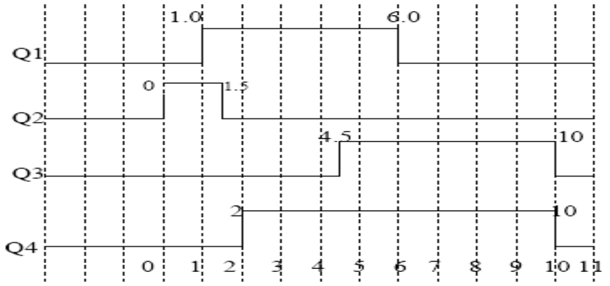

FIGURE 3
Timing Diagram showing the opening and closing of valves of MCDS

Speed Sensor**:** The speed sensor is an inductive proximity switch whose function is to sense the train speed [5]. As the wheel of the train rotates it sends a pulse to the PLC on each rotation. The PLC counts the number of pulses per minute and since the number of pulses is dependent upon the speed of the train therefore when the number of pulses is more than the set value the PLC operates the output $Q_{4\ \text{the}}$ outlet valve. The diameter of wheel is 920 mm i.e. 0.92 meters. If the train moves with a speed of say 30 km/hr. Then N (number of pulses per minute) is as follows:

V = r x w (where r is radius & w is angular velocity)
30 km/hr = (0.92 x 2 л N) / 2
N=172 pulse/minute

IV *DESIGN OF RETENTION TANK–SIMULATION BASED APPROACH*

The modular controller discharge system has least operation and maintenance free. Effluents are not flushed on the tracks directly instead stored in a retention tank, discharged at an instant when the train achieves a predetermined speed. Simulation is used to calculate the optimum size of the retention tank. Let us consider the following proposal for designing a retention tank.. In reality no reasonable finite sized retention tank can provide an absolute guarantee of meeting the demand 100% because the human waste and water, inter arrival and using toilet time all are random variables. To build such a tank which will never fail through its entire life will generally be uneconomical. Therefore, in practice one determines the tank size which will meet the demand with a specified risk of failure. For example 0.002% failure (per year) means that once in a year the tank would become overflow. Hence to prevent the tank from the overflow we find the optimum size of the tank. The tank is empty when the train speed is more than specified speed and the tank is open at that time, the waste is dropped on the railway track away from the city/platform.

We can find the optimum size of the tank, assuming the following parameters:-

Let the amount of the waste may vary from 00 ml to 300ml per person.

The maximum water used by a single person is 4000ml.

The maximum time for standing of a train at a railway station is one hour and the single user can take 4 to 10 minutes in the toilet. So, the maximum 15 person can use continuously the flush in that hour.

Then
For i=1,2,3,4,….,15 ; Weight of waste - w_i ((randomly generated)
where i= 1, 2, 3… 15 ; let water used at once= L litres
Then total size of tank = > $S=\sum_{i=1 \text{ to } 15} (w_i + 15.L)$

But this is theoretical concept. To make it more realistic we will follow following procedure

The Tank has been designed for stochastic values of train stoppage time, service time and inter arrival gap in between and human excreta.

ALGORITHM

Let T = total time; TS_i = service time for the ith user ; TI_i inter arrival time for the ith user.
Let service rate (mu) = 4 mins/person ; Inter arrival rate(lamda) =8mins/person
W_i = waste for the ith user.; TT = Stoppage Time of the train
L = water amount in liters for the per user.

K = Time before stoppage and after running the train (less than specific speed) near by Railway Station

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 i=0; T=0; W=0
 If   T < (TT +K)   then
  $T= T+TS_i+TI_i$
$TS_i$ -Generated using Expontial Distribution ; $TI_i$ Generated using Expontial Distribution ; TT Generated using uniform distribution (from max. stoppage time at particular station in the way of the train, data collected from Railway Deptt)
W – Waste generated randomly
  $W= W + W_i$
   i++
 else
  print  i" is the no of users"
  end if
  S= W+i.L    (Where S   is the size of tank)
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V. *Result & Discussion*

The figure 4 shows the graph between day and max stoppage time at a particular station in the way. Table 2 shows the different sizes of the tank during 1000 runs.

Table 1. Max Stoppage Time of the Train at a Particular Railway Station in one Month

S. No	Stop Time (minutes)	Day	S. No	Stop Time (minutes)	Day
1	35	1	16	30	16
2	34	2	17	36	17
3	35	3	18	38	18
4	33	4	19	33	19
5	32	5	20	40	20
6	30	6	21	38	21
7	31	7	22	33	22
8	32	8	23	32	23
9	36	9	24	36	24
10	38	10	25	35	25
11	40	11	26	32	26
12	36	12	27	30	27
13	37	13	28	30	28
14	38	14	29	30	29
15	32	15	30	40	30
Mean = 34.4 Standard Deviation =3.25					

From the above mentioned parameters the optimum size of the Tank is 32.780 liters(Graph 2) and number of passengers in the given time is 08 if service rate (mu) = 4 mins/person ; Inter arrival rate(lamda) =8mins/person .The max stoppage time during its journey for one month of the train is given in Table 1 .The average time and standard deviation is calculated from the given data and TT is generated using Normal Distribution. The program is run 1000 times (Table 2). The input of the tank is human waste and water used by the user of the tank. In reality no reasonable finite sized retention tank can provide an absolute guarantee of meeting the demand 100% because the human waste and water, inter arrival and using toilet time all are random variables. To build such a tank which will never fail through its entire life will generally be uneconomical. Therefore, in practice I have determined the tank size which will meet the demand with a specified risk of failure of 0.004% failure/per year means that approx. one to two times failure in a year the tank would become overflow

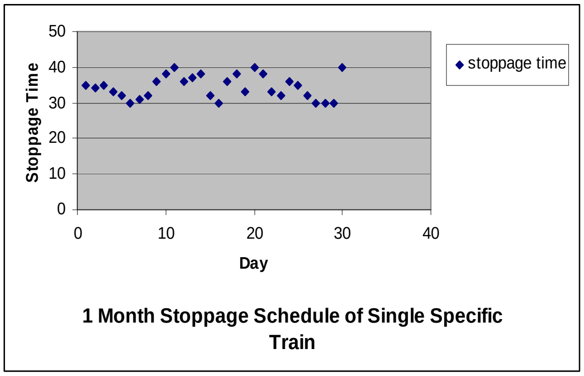

Figure 4: 1 Month Stoppage Schedule of Single Specific Train

. By taking the size 32.900 liters the risk of failure is reduced to 0.003% failure/per year means that one times failure in a year the tank would become overflow.

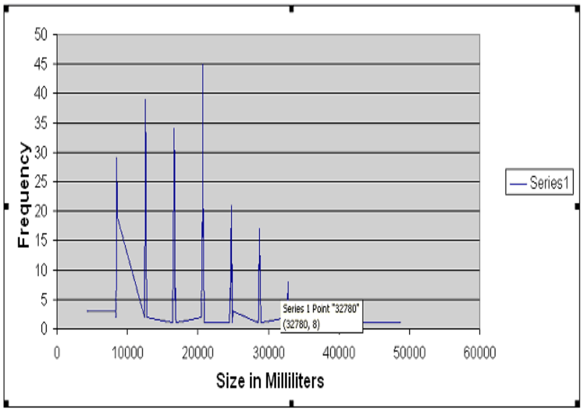

Figure 5 Graph for Size of Tank v/s Frequency

Table 2 Size of Tank V/S Frequency

S.No.	Size (ml)	Freq.	S.No.	Size (ml)	Freq.
1	0	0	58	24600	6
2	4270	3	59	24630	5
3	8330	3	60	24660	17
4	8360	2	61	24690	12
5	8390	6	62	24720	21
6	8420	7	63	24750	9
7	8450	21	64	24780	8
8	8480	29	65	24810	11
9	8510	21	66	24840	6
10	8540	19	67	24870	7
11	12390	2	68	24900	1
12	12420	3	69	24930	3
13	12450	12	70	28510	1
14	12480	16	71	28570	1
15	12510	32	72	28600	2
16	12540	39	73	28630	7
17	12600	28	74	28660	6
18	12630	18	75	28690	16
19	12660	11	76	28720	10
20	12690	6	77	28750	17
21	12720	2	78	28780	8
22	16390	1	79	28810	10
23	16420	2	80	28840	5
24	16450	4	81	28870	5
25	16480	9	82	28900	3
26	16510	15	83	28930	1
27	16540	20	84	28960	1
28	16570	20	85	28990	1
29	16600	34	86	32630	2
30	16630	33	87	32660	6
31	16660	28	88	32690	3
32	16690	15	89	32720	1
33	16720	13	90	32750	4
34	16750	5	91	32780	8
35	16780	7	92	32810	4
36	16810	5	93	32840	4
37	16840	2	94	32870	3
38	16870	1	95	32900	4
39	20450	2	96	32930	1
40	20480	3	97	36630	2
41	20510	2	98	36690	2
42	20540	11	99	36720	2
43	20570	18	100	36750	2
44	20600	12	101	36780	1
45	20630	19	102	36810	3
46	20660	45	103	36930	1
47	20690	25	104	36990	2
48	20720	26	105	37020	1
49	20750	15	106	40720	1
50	20780	13	107	40750	2
51	20810	8	108	40810	1
52	20840	5	109	40900	1
53	20870	3	110	40960	1
54	20900	1	111	40990	1
55	24480	1	112	44780	1
56	24540	4	113	48810	1
57	24570	7	114	48840	1

IV CONCLUSION

We have given the above mentioned simulation based designed to determine the tank size with a specified risk of failure of 0.003% failure (per year) means that once in a year the tank would become overflow with a aim to make the railway platform hygienic, when the train stops at the railway platform then no human waste is dropped on to the railway tracks. So, to clean the railway platform we use the retention tank. In future human excreta can be used as a source of energy means as fuel or agricultural manure. It can also be used to generate the bio gas which can be utilized for cooking and lighting purposes at railway platforms

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