GPS AND PLC – HMI BASED LAVATORY FLUSH CONTROL IN INDIAN RAILWAY COMPARTMENTS

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ABSTRACT

This paper emphasize on controlling the process variable parameters such as flow and level with real time implementation of solenoid valve control in lavatory flush outlet in Indian railway compartments. This work uses Trimble GPS (Global Positioning System) studio and B&R Automation studio PLC (Programmable Logic Controller) with HMI (Human Machine Interface). GPS is used to find exact location of the train (whether train is in station or not) and after acquiring data GPS will send digital signal to automated PLC - HMI to open/close the electrical actuator, solenoid valve for controlling the lavatory outlet. When solenoid valve is closed minimum water level is maintained in the storage tank by level switch for cleanliness in the storage tank. Moreover in lavatory motion detector is placed so that if anyone used toilet and left without flush, sensor will detect and send signal to PLC and it will automatically flush out with certain amount of water.

The prototype model is provided with low level in the storage tank and depending on the GPS and motion detector outputs the ladder logic is actuated. This innovative work uses GPS and PLC – HMI with 3 digital inputs and 2 digital outputs to control the miniaturized process depicted in the work. The performance of the proposed scheme is evaluated by simulation and the results of the proposed scheme are highlighted.

Key words: GPS, PLC - HMI, Level switch, flow and level control, solenoid valve, lavatory flush outlet.

1. INTRODUCTION

Gallons of water are utilizing for cleaning the stations. The Indian Government is spending 500 crores for cleaning tracks in Railway stations. Maintenance cost involved is high.
The main objective of this innovative work is to reduce the cleaning process in stations and to decrease the budget included for maintenance in railways and also to give a good eco-friendly environment in stations. This work focuses with the intention of overcome the mentioned problem by maintaining cleanliness in stations and to keep stations tidy by using Trimble GPS (Global Positioning System) studio 1.0.10 and B&R Automation studio version 2.7 PLC with HMI.

Binjammaz et al [1] discussed that GPS receivers are used to provide vehicle position and velocity data. Shoaib et al [2] described that in Current Scenario GPS is very popular device among people for tracking and navigation purpose. GPS data can be further used for analysing the trip, elevation profile etc. There are so many GPS data formats and different GPS receivers support different formats. Bertran et al [3] presented the electromagnetic interference effects on the performance of locomotive onboard Global Positioning System (GPS) receivers due to the railway environment. And he concluded that the reliability of a low-cost GPS receiver for train positioning even if the train equipment has been designed at the threshold of the current normative. Dewang Chen et al [4] demonstrated that Satellites are currently being used to track the positions of trains. And he developed a nonlinear combinational data reduction model for a large amount of railway Global Positioning System (GPS) data to decrease the memory space and, thus, speed up train positioning. Yaping Lei et al [5] designed a new railway crossing warning system based on GPS and GPRS to ensure the railway safety and improve the passing efficiency in railway crossing.

Jiang et al [6] described from the safety requirements of train positioning in high-speed railways, based on the consideration of signal availability and fault-tolerant performance, an integrated train positioning system is formed by integration of GPS and Compass. Gerlach et al [7] described that for certain types of railway lines replacing the equipment for precise train positioning along the track by suitable low-cost sensors and a digital map on the train can result in a more cost-efficient railway operation. Tsunashima et al [8] used a GPS system and a map-matching algorithm to pinpoint the location of faults on tracks.

Fararooy et al [9] identified existing and developing technologies for accurate train localisation in open space and tunnels and their applications, and attempt has done to match appropriate techniques, in terms of their cost and performance specifications, to the applications for different types of railway and other mass transit systems. The location techniques discussed include GPS, track circuits, radio navigation, and magnetic transponders. Wei Shangguan et al [10] described that the research on low-cost train control system is one of the most important part in train traffic field, using GPS data could realized real-time, safe and reliable train positioning. Nejikovsky et al [11] described a recently developed remote monitoring system, based on a combination of embedded computing, digital signal processing, wireless communications, GPS, and GIS technologies. Haitao et al [12] proposed a positioning algorithm based on a Global Positioning System (GPS) and inertial navigation system (INS) is, so that the navigation accuracy of high speed trains is improved. Furthermore, the INS/GPS integrated navigation system based on the information of GPS and INS is modeled and simulated, and the algorithm using Kalman filter (KF) is designed. Stadlmann [13] presented a new kind of train control system for branch lines which are operated by radio-based operational train control. It is based on data radio communication between central computer and trains, cab signalling in the trains, and autonomous determination of train location using GPS and an odometer.

Barmada et al [14] approached first to the design of PLC system onboard trains Durmus et al [15] designed interlocking and signalization design for a sample railway yard is achieved by Automation Petri Nets (APNs) which is an extended type of PNs. They described that once the model is obtained using APNs then it can easily be implemented into a programmable logic controller (PLC). Hai Wan et al [16] represented Programmable logic controllers (PLCs) as a typical class of embedded software systems widely used in safety-critical industrial applications, such as railways, automotive applications, etc. Eris et al [17] described that today the relay based railway
interlocking systems are changing into programmable software interlocking systems. And purposed to develop a Programmable Logic Controller (PLC) program for the signal function blocks by using formal methods and make a comparison between them. Chen et al [18] discussed that Programmable logic controllers (PLCs) have been widely used in safe-critical systems, such as railway, nuclear power stations and petrochemical plants. Mutlu et al [19] explained that Interlocking systems are the core components of railway signalization systems and designed a new environment to test the reliability of the PLC based interlocking systems. Cheung et al [20] demonstrated that the application of solid state relays and programmable logic controller (PLC) has been widely adopted with the development of the power electronic components and became the emerging norm in the railway industry for new generation of passenger train. Gang Xu et al [21] designed a two-lane automatic antifreeze fluid sprinkler of railway coal conveyor. By means of the control of PLC, their device realized the even, automatic, and short-range spraying of antifreeze fluid for five inside surfaces and the coal seam in the train wagon.

In order to utilize the robustness and advantages of the GPS and PLC – HMI, lavatory flush control in Indian Railway compartments using GPS and PLC – HMI is proposed.

The present paper is organized as follows: Section 2 deals with the B&R PLC for Indian Railway compartments. Section 3 deals with GPS. Section 4 deals with visualization. Section 5 deals implementation of prototype model. Section 6 describes the simulation studies of lavatory outlet opening and closing by solenoid valve as actuator for lavatory flush control in Indian Railway compartments. Section 7 gives the summary & conclusions.

2. B&R PLC FOR INDIAN RAILWAY COMPARTMENTS

When train is at 1 km before reaching the station, it receives signal by GPS receiver and GPS receiver will send digital signal to the PLC. Consequently with the automation of PLC, the solenoid valve will close automatically that is lavatory outlet closed. Vice versa when train leaves from the station of about 1km, with the automation of PLC, the solenoid valve will open automatically that is lavatory outlet will open. Using GPS and PLC - HMI, opening and closing of the lavatory outlet by electrical solenoid valve was done with more perfection.

Figure 1 represents the B&R Industrial Automation PLC. Using this PLC the control action is performed. This PLC of B&R Industrial Automation inbuilt with 3 digital inputs and provides 2 potential free outputs to control the miniaturized process depicted in this work. Here this PLC is
utilized for auto operation of Lavatory flush control in Indian Railways so that it can be programmed depending on the operational requirements. Its a digitally operating electronic apparatus which uses a programmable memory for the internal timing, counting and arithmetic to control through digital or analog input/output modules, various types of machines or process.

3. GPS (GLOBAL POSITIONING SYSTEM)

GPS is space-based satellite navigation system and it gives the position of the train on which it is placed with respect to the latitude and longitude of the earth. The basis [22] of the GPS technology is a set of 24 satellites that are continuously orbiting the earth. These satellites are equipped with atomic clocks and sent out radio signals as to the exact time and location. These radio signals from the satellites are picked up by the GPS receiver. Once the GPS receiver locks on to four or more of these satellites, it can triangulate its location from the known positions of the satellites. The system provides critical capabilities to railways and is freely accessible to anyone with a GPS receiver.

GPS Receiver used in this work is Trimble studio GPS module SR 92 and it is shown in figure 3. The GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include
• the time the message was transmitted
• satellite position at time of message transmission
The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite using the speed of light. Each of these distances and satellites' locations define a sphere. The receiver is on the surface of each of these spheres when the distances and the satellites' locations are correct. These distances and satellites' locations are used to compute the location of the receiver using the navigation. This location is then displayed, perhaps with a moving map display or latitude and longitude. The GPS receiver used is a higher performance, low power satellite based model. It is a cost effective and portable system which accurately detects the location. The GPS data sheet and GPS codes gives the features and descriptions of the GPS receiver used is shown in Table I and II.

**Table I GPS Datasheet**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>L1, 1575.42 MHZ</td>
</tr>
<tr>
<td>Channels</td>
<td>20 channels all in view tracking</td>
</tr>
<tr>
<td>Tracking</td>
<td>-159 dbm</td>
</tr>
<tr>
<td>Time</td>
<td>1 microsecond synchronized to GPS time</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>514 meter/second maximum</td>
</tr>
<tr>
<td>Main Power Input</td>
<td>3.0 ~ 5.5 DC input</td>
</tr>
<tr>
<td>Supply Current</td>
<td>&lt; 80 mA</td>
</tr>
<tr>
<td>Back up Power</td>
<td>3 V rechargeable Lithium battery up to 500 hours discharge</td>
</tr>
<tr>
<td>Software</td>
<td>GPS Datum (GPS Coordinate Systems) WGS - 84</td>
</tr>
</tbody>
</table>
GPS programming is done in Trimble GPS studio and it is represented in figure.4. From GPS receiver, data is obtained and it is given as input to the PLC. Obtaining data from GPS is shown in figure.5. Programming part is done in Excel in GPS software is shown in figure 6. Finally GPS is interfaced with PLC using PC is shown in figure.7.

### Table II GPS Codes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC time of the fix hhmmss.dd</td>
<td>hh = hours</td>
</tr>
<tr>
<td></td>
<td>mm = minutes</td>
</tr>
<tr>
<td></td>
<td>ss = seconds</td>
</tr>
<tr>
<td></td>
<td>dd = decimal part of seconds</td>
</tr>
<tr>
<td>Latitude coordinate Xxmm.dddd</td>
<td>xx = degrees</td>
</tr>
<tr>
<td></td>
<td>mm = minutes</td>
</tr>
<tr>
<td></td>
<td>dddd = decimal part of minutes</td>
</tr>
<tr>
<td>Character derothing &lt;N/S&gt;</td>
<td>Either N = North or S = South</td>
</tr>
<tr>
<td>Longitude coordinate yyyymm.dddd</td>
<td>yyy = degrees</td>
</tr>
<tr>
<td></td>
<td>mm = minutes</td>
</tr>
<tr>
<td></td>
<td>dddd = decimal part of minutes</td>
</tr>
<tr>
<td>Character derothing &lt;E/W&gt;</td>
<td>Either E = East or W = West</td>
</tr>
<tr>
<td>Fix valid Indicator V</td>
<td>0 = Fix not valid</td>
</tr>
<tr>
<td></td>
<td>1 = Fix is valid</td>
</tr>
</tbody>
</table>

**Figure. 4. GPS Programming in Trimble GPS Studio**

**Figure. 5. Various types for obtaining data from GPS Receiver**
4. VISUALIZATION

Visualization is the process of designing a Human Machine Interface (HMI) used to operate the PLC with ease. A variety of devices have been in past for interfacing the machine to provide an easy control of the operations. The most modern technique involves the use of touch screen to give the inputs.

Touch screen are considered more superior to the other interfacing devices since it is very easier to give inputs to the PLC. Moreover the prototype model and its operations are visualized in HMI and the advantage is monitoring and supervising the depicted work in trains in an effective and easy way. Whenever any operations are being performed it is displayed on the screen and thus
enables the user to keep track of what is happening. Figure 8 represents start/stop button in HMI for the designed prototype. The process can be start/stop at any time by pressing the button.

Softwares for creating the visualization are specific for a PLC and provided by the B&R Industrial Automation Pvt. Ltd (Austria). Thus the software automation studio proprietary software for the PLC is used along with it. The automation studio provides a user friendly interface for creating and calibrating the touch screens. It has various dynamic features such as profiler, logger, and program watch that helps the user to carry in the programming task as well with ease and it helps for the easy correction of the mistakes made.

5. IMPLEMENTATION OF PROTOTYPE MODEL

The block diagram of Hardware set up and Experimental set up is shown in figure 9 and 10. From lavatory, water and wastes is allowed to pass through the storage tank to drain out by solenoid valve 1 as lavatory flush outlet.
Pure water is taken from main water supply to the lavatory through solenoid valve 2 and finally it is taken to the storage tank. Motion detector, level switch in storage tank and GPS Receiver are the inputs to the PLC. Depending on the motion detector and level switch outputs, the solenoid valve 2 is opened/ closed at various sequence. And also based on the location of the train from GPS Receiver, the solenoid valve 1 is opened/ closed.

6. SIMULATION STUDIES

As trial we took from Avadi to Chennai central. Particularly we selected 5 stations – Avadi, Annanur, Ambattur, Villivakkam and Basin bridge. Keeping Avadi as starting point, from Avadi Annanur, Ambattur, Villivakkam and Basin bridge comes at 2, 3.2, 5.5 and 8.5 kms respectively. The closing and opening of the solenoid valve was done 0.5 km before reaching the particular station and 0.5 km after going ahead of the station respectively. The lavatory flush outlet operation result is shown in figure 11.

![Figure.11. Lavatory Flush Outlet Operation](image)

7. CONCLUSION

The result of this paper highlights the robustness of the GPS and PLC – HMI based lavatory flush control in Indian Railways compartment. The closed loop response of the GPS and PLC – HMI based lavatory flush control shows satisfactory transient response with perfection in control action for the taken 5 stations. Because of this work the cleanliness can be easily and automatically maintained in trains and railway stations which will reduce the budget amount for maintenance in railways and also this system will save gallons of water.

REFERENCES


