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Real Time Train Tracking System with On-Board Colour Light Signals.

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Abstract:- Knowing the location and being able to track trains in real time is of high importance to cus-tomers and train owners. Train planning and scheduling can be optimized if train location is known in real time. An increase in signalling track circuits and signals failures due to signalling cable thefts has had a sig-nificant impact on railway companies delivering services to customers. Thus this paper presents a real time tracking system for locomotives as a secondary/ replacement for track circuits. The system uses 5G as com-munication means to send data between remote train control system and locomotive(s); the location of the train is obtained through GPS, RFID. An artificial neural network is used for processing, switching between the various methods of obtaining location and communicates with remote train control system. The on-board colour light display unit is in sync with signals in the field and it acts as a backup for signals failure. The sys-tem can be used as either a primary or secondary system since it will be incorporated with interlocking. The information of train location will be sent to the relay room for incorporation with interlocking, and sent to centralised traffic control (CTC) through fibre optic or 5G.

I. INTRODUCTION

Railway companies across the world are experiencing gradual increase in signalling copper cable thefts every year. Railway transport is a major enabler of economic growth as it transports freight in bulk and transports people in high numbers, thus reducing road traffic. Increase in signalling cable theft has had a negative impact on railways due to the increase in system down-time, which has resulted in customer dissatisfaction and loss of revenue. There has been an increase of rail freight on South African roads due to the uncertainty of the railway system due to increase in system failures and down-times.

Safety of private and public vehicle has been a major concern over the years, therefore there is an increase in research on real time tracking of vehicle through the use of Global Positioning System (GPS). GPS together with Global System for Mobile Communication (GSM) is mostly used on vehicles for theft prevention and as a retrieval device (Punekar at al. 2013). GPS and GSM will be discussed in chapter 3.2 and 3.3 of this article. Track circuits are used for track vacancy detection. Track circuits failures will result in stoppage of train movements through that track section until the section is verified and declared safe for train movements. Thereafter, trains can be authorized through that section. When there is a failure on colour light signals that also results in train authorizations on those signals until the fault is fixed. Train authorization relies on oral communication through telephonic conversations, hence, miscommunication between train driver and operator may lead to train collision on railway system. This paper presents a system of train tracking and locating through RFID technology, GPS. Communicate with relay room, and CTC is through GSM on the locomotives and Radio Frequency. Train scheduling will be optimized as each train location is known and failure on track circuits and signals can be mitigated by this system.

II. SYSTEM OVERVIEW

A. System Block Diagram

The proposed system block diagram is illustrated in Fig. 1. and Fig. 2. The system consists of two units, namely an on-board unit and relay room unit. The on-board unit is installed in locomotives, and is used for processing locomotive location data and controlling the colour light display unit on the locomotive(s). More-over, it also communicates with the relay room and remote control office. The relay room unit is used for sending the location data to the interlocking in the relay room and also for sending data to rail vehicle in the station. The relay room (RR) unit has a controller that performs the processing of data received from on-board unit either through GSM or Radio Frequency RX/TX module. The RR controller maps rail vehicle location(s) with track circuits position and then sends the data to the interlocking interface unit.

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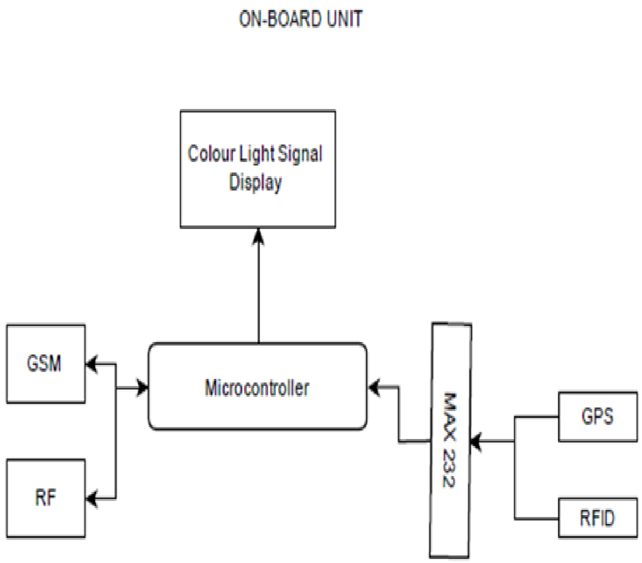

Fig 1:- Block diagram for on-board unit

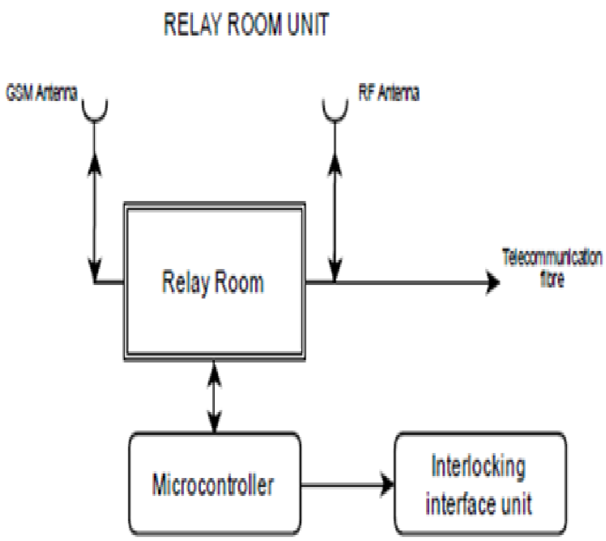

Fig 2:- Block diagram for Relay Room unit

B. System Flow Chart

Fig.3. illustrates the flow chart of the proposed system. Location data of the rail vehicle is obtained through the RFID network and GPS. When GSM connection has been established, the system first initialises all its function by first running a system communication test with dummy location and RFID tag data. Radio Fre-quency communication test between the rail vehicle with the nearest station follows. Then system operation starts, scan RFID tags and get GPS data, with the information on the RFID tag or GPS data the processing of the data is done by an artificial neural network and the result is sent to the relay room unit via GSM or RF module. The artificial neural network will send data to the relay room only if there is a change on the infor-mation or it will send a 'previous state message' to the RR unit.

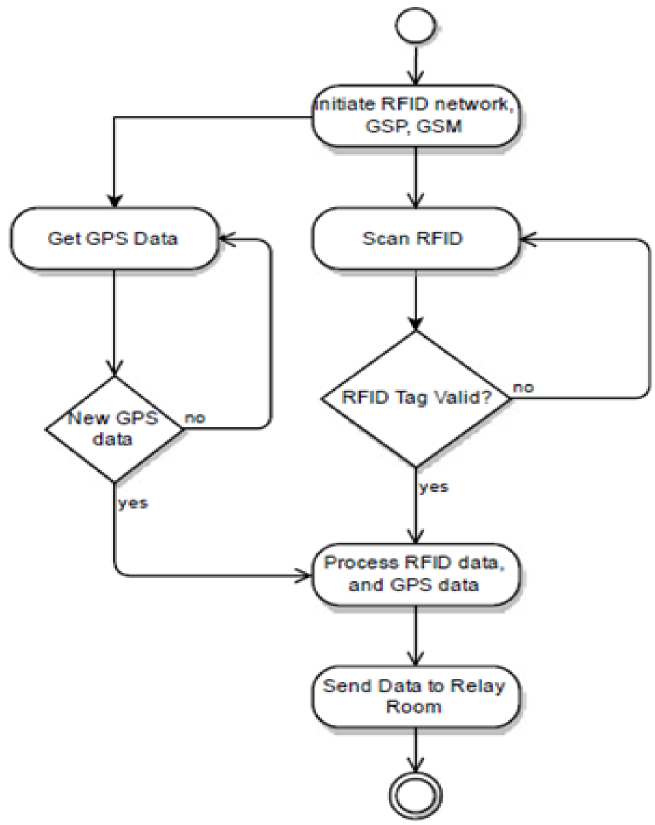

Fig 3:- Flow chart for the on-board unit

III. ON-BOARD UNIT

A. RFID Network

RFID Network system consist of three units/ components, namely an RFID reader, RFID antenna and RFID tags. In Figure 4, is a network of RFID tags installed at every 500m sleeper. Each tag is associated with a par-ticular track circuit, therefore once a tag is scanned the associated track circuit will drop as the train moves. The system uses passive tags which do not have an internal power source. Passive tags are powered by the electromagnetic energy transmitted by the RFID reader, when the tag is in the 'read zone'. RFID reader is in-stalled on the train and the tags are installed on the sleepers since tags are not expensive as compared to read-ers.

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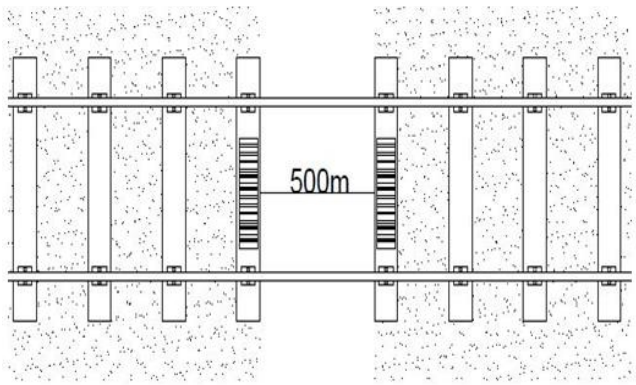

Fig 4:-Railway line with RFID Tags installed

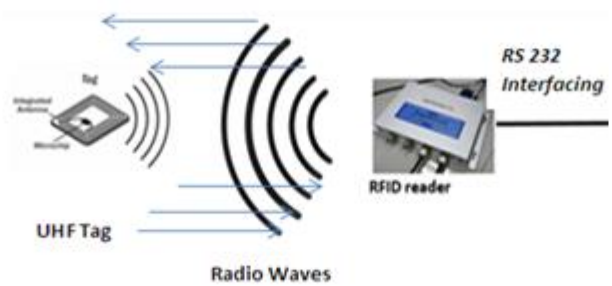

Fig 5:- Interface between Tag, Reader (Autodesk)

The network losses may also be accounted for in the value of the tag antenna gain, GT. Both the reader anten-na gain, GR. and the tag gain GT. are then expressed relative to an isotropic antenna (Lee at al. 2008). From the observations of power flux density at the tag, considering λ as the wavelength, we get both the tag voltage as power as illustrated in the equations relating to RFID power and voltage equations:

$$Ptag = \left(\frac{E^2}{120\pi}\right) * \left(\frac{\lambda^2}{4\pi}\right) * G_T = V_{tag}^2/Rc \quad (1)$$

$$\frac{E^2}{120\pi} = P_{R*} G_R/4\pi^2 \quad (2)$$

$$P_{tag} = \left(\frac{P_{R*} G_R}{4\pi r^2}\right) * \left(\lambda^2 * \frac{G_T}{4\pi}\right) = \frac{P_R G_R G_T \lambda^2}{(4\pi r)^2} \quad (3)$$

$$V_{tag} = \left(\frac{\lambda}{4\pi r}\right) * \sqrt{(\Pr * G_R * G_T * R_C)} \quad (4)$$

B. Global Positioning System (GPS)

The Global Positioning System is a network of satellites orbiting the earth at altitudes of 20 000 km. Each of the GPS satellites transmits information about its position and time at regular intervals. These signals are in-tercepted by GPS receivers, which calculates how far each satellite is based on the time it took for the mes-sage to arrive. The GPS receiver must get information on at least three satellites for it to calculate 2D move-ment, to pinpoint its location through the process called trilateration (Kalpan 1996). When there are four or more satellites visible, the GPS receiver can determine the devices 3D position (latitude, longitude and alti-tude) (Marais at al. 2000).

A GPS receiver is installed on the rail vehicle for the purpose of determining the vehicles location and speed. The location data of the rail vehicle is transmitted to the rail room via GSM and RF modems.

C. Communication GSM and RF

The Global system for Mobile Communication (GSM) is a cell phone based technology used in different parts of the world. GSM modem operates in the same principle as mobile phone, it accepts sim card and operates over a subscription of a mobile operator. GSM networks operate in different frequency band, and the most common operating frequencies are 850MHz, 900MHz, 1800MHz and 1900MHz (Punekar at al. 2013). GSM modem use AT commands for sending and receiving SMS messages through a process called circuit switch-ing. Short Message Service (SMS) allows users to send up to 160 characters and it is the cheapest form of communicating. In the proposed system GSM is used for communicating with the nearest relay room and also with the CTC in case the whole station is out meaning there is no power in the station. In such an event the GSM communicates directly with CTC interlocking interface.

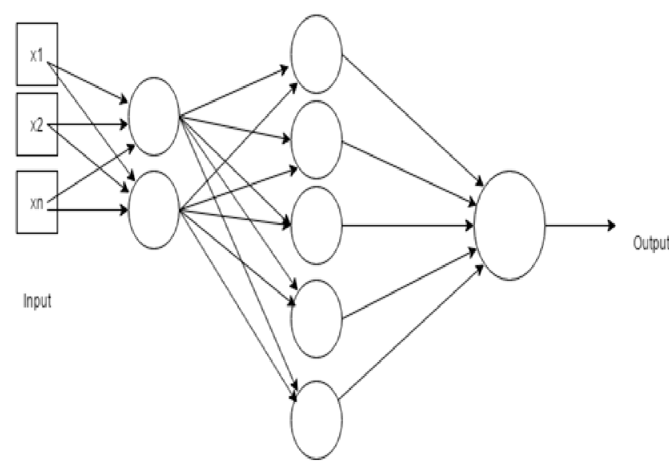

Fig 6:- SIM900A GSM Modem (Pantechsolutions)

Radio frequency is any electromagnetic wave frequencies that lie in the range extending from around 3 kHz to 300 GHz. The most common wireless technologies use radio waves. Examples of applications of radio wireless technology include GPS units, wireless computer mice, keyboard, broadcast television, etc. (Agarwal 2014). The use of wireless communication increases the likelihood of data unintentionally being received at the receiver which may be from other external sources with wireless transmission capability. An authentication protocol must be incorporated into the transmitted data so that the receiver can reject unauthenticated transmissions from other wireless sources and this protocol also protects against random noise in the relevant frequency range. There are different authentication protocols but in this design encapsulation of data within a "data packet" is used as an authentication protocol.

D. Microcontroller and Display Unit

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals, it can be used as an embedded system (Mazidi at al.). Microcontrollers are designed for embedded applications, in contrast to microprocessors used in personal computers or other general-purpose applications processors. The colour light display system consists of two LED clusters, one RGB cluster for red, yellow, and green signal aspect and another RGB for yellow two, white and other aspect. The RGB cluster are controlled by Pulse Width Modulation of the microcontroller in order to obtain the required signal aspects.

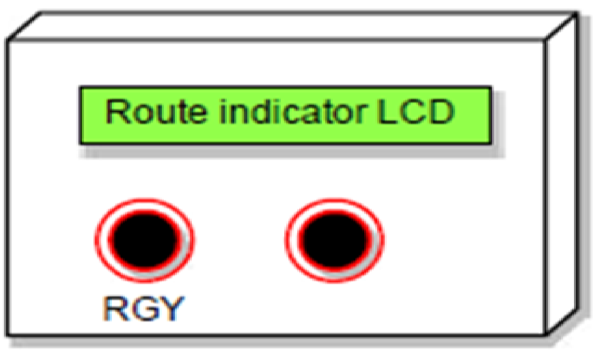

Fig 7:- Colour Light Signals Display Unit

The LCD on the colour light display unit displays the signal number and route indication. This unit will be the visual display for train drivers when there are cable thefts and other cable related failures.

The microcontroller performs the function of processing data from GPS and RFID network, and encapsulate the data before sending it to the RR unit via RF module or GSM modem.

IV. RELAY ROOM UNIT

A. Artificial Neural Network

An artificial network is composed of large number of interconnected units called neurons that have a certain natural tendency for learning information from the outside world. Neural networks are good in estimating or approximation of functions that may depend on a lot of variables (Gardner at al. 1998). The neural network must be trained in order to learn and understand the system and because of non-linearity capability it can ap-proximate any function.

Fig 8:- Neural network structure

In the proposed system an Artificial Neural Network (ANN) is used for processing, switching between the various methods of obtaining location and communicates with remote train control system. Moreover, the neural network will be train to detect failures on the current system and prompt the system to start operating until the failure is fixed. The ANN will perform the mapping of location and RFID data with the associated track circuits. Relay room will communicate with on-board unit on a train(s) in the station; it is important for the ANN to send an 'end of station' signal to the on-board unit for the on-board to start communicating with the RR unit on the next station.

B. Interlocking Interface Unit

The basic operation of the interlocking interface unit is based on the type of interlocking used on a specific station, either mechanical or electronic. The station is operating/ running on electronic interlocking; the system will be easily interfaced as there is no need for converting the data into equivalent electrical signals to pick relevant relays as is the case with spoorplan interlocking. In the case of mechanical interlocking, the interface unit will have the capability to convert all the electronic data to electrical power for the interlocking to complete.

V. CONCLUSIONS

This paper documented the proposed real time tracking of trains as a mitigation for cable theft or fault. Im-plementation of this system will results in improving railway operation and increase freight railed as it will ensure optimum planning, and usage of resources. The system utilises GPS, GSM, and RFID technologies on the track and on the rail vehicle. From the feasibility study of the system it clear that the system will improve the current system by ensuring continuous train movement in the event of system breakdown.

RECOMMENDATIONS

It is recommended that the system communicates the train speed with the centralised traffic control office, as this information can be used to estimate the time of arrival of the train and improve train scheduling. Custom-ers can be given a more accurate estimate on the arrival of their freight, therefore increasing customer confi-dence.

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