INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 6.078
(Volume 6, Issue 1)
Available online at: www.ijariit.com

Performance analysis of Vigilance Control Device (VCD) In electric locomotives of Indian Railways and design of a Drowsiness Detection and Warning system

M. Senthamil Selvan
senselv@gmail.com
Indian Railways

ABSTRACT

A Vigilance control device (VCD) is a safety device designed and installed in Electric locomotive to keep the loco pilots in the vigilant state. These devices are available in all the Electric locomotives in Indian railways since the year 2003. Having served more than 15 years in the locomotive, the performance of the VCD in keeping the loco pilots is critically analyzed. Further, it is proposed the design of an embedded system that will function as an intelligent drowsiness detection and warning system. This proposed system will replace the existing Vigilance control device of the locomotive with an additional and essential feature of detection of drowsiness in early-stage and alert the Crew of the Train operation. The system will have advantages over the existing Vigilance control device it detects the drowsiness for behavioral measures in a non-invasive way, which will be preventing the Signal Passing at Danger (SPAD) in Electric locomotives

Keywords— *Vigilance control device, Drowsiness detection, Signal Passing at Danger*

1. INTRODUCTION

Indian railways operate 20000 trains including passenger and freight trains to connect India. There are more than 60000 loco pilots for operating the locomotives and Motive units. Driverless automatic train operation is not available in India. To keep the driver of any vehicle in a sober state throughout the journey is a challenging job for many decades. The driving the vehicle on road, rail or air develop fatigue in human brain, physically tired and several times leads to drowsiness. Especially the Loco pilots who drive the long-distance train by piloting the Locomotives have a special problem that he has to drive the locomotive in the guided track or rail where he rarely sees a vehicle to negotiate. He has to constantly look for signals to run or stop according to the aspect of the signal. This characteristic of the train piloting makes the work highly monotonous which in turn aggravates the probability of getting drowsiness In order to keep the loco pilots in the alert condition during the train running, an Electronic device called Vigilance Control Device (VCD) was introduced during the year 2003. This device takes operational parameters as the inputs and gives an audio-visual alarm if inputs are not deducted for a predetermined period of time. Further, the non-acknowledgment of the alarm by the loco pilot will lead to the application of Brake to stop the train to safeguard the train and passengers from the occurrence of accidents. The introduction of VCD has served the indented purpose of keeping the driver in alert state to the extent. Even though it has kept the loco pilot in alert conditions, the cases of Signal Passing at Danger (SPAD) continued to occur.

All the trains are driven by the loco pilots and their alertness is the key to ensure the safety of the train. Traditionally Railways enforce stringent rules and regulations for loco pilots to ensure the periodical rest so that loco pilots will not get drowsiness while onboard train operation.

2. PERFORMANCE ANALYSIS OF EXISTING VCD

Signal passing a danger (SPAD) continue to happen while existing VCD is in working condition. This indicates that VCD is not detecting the loco pilot's true alertness or drowsiness at the required level. Train operation and giving input signal to the VCD in the vigilance cycle becomes subconscious activity or reflex for the loco pilots over the period.

2.1 Working of VCD

VCD available in Electric locomotives are designed and manufactured as per the specification published [1] by the RDSO (Research Development and standard organization) vide specification No. RDSO/2008/EL/SPEC/0025/Rev.6 (APR - 2019).

2.1.1 Vigilance cycle/Delay cycle: The cycle has a preset period normally set at 60 ± 2 seconds. This cycle is automatically restarted whenever the vigilance unit detects one of the external inputs derived from some specified vehicle control functions under the Loco Pilot's control from the active cab, the presence of which automatically infers that the Loco pilot has taken some positive action and is therefore vigilant.

These control functions are:

(a) Notch-up/Notch-down by the master controller (MP) or EEC;
(b) Operation of the sander, Train Brake (A-9), Loco Brake (SA9), MPS-1;
(c) Operation of the vigilance pedal (foot) switches available with Loco Pilot.

In normal circumstances, provided that the Loco Pilot is periodically performing some positive action, the cycle shall be continually reset and shall never run to completion. Only if the Loco Pilot fails to perform such inaction within the cycle period, the cycle period shall be completed. When such an event occurs, a second time cycle, i.e. action cycle shall be initiated and audible and visual warnings shall be given to the Loco Pilot.

2.1.2 Action cycle/Warning cycle: This cycle is initiated whenever the Vigilance/delay cycle runs to completion indicating that no positive Loco Pilot action has been detected for the length of the delay cycle period. During this cycle, VCD shall begin flashing yellow warning light for a time period of 8±2 seconds. If by end of this period, an acknowledgment by crew has not been actuated, an audible alarm for a time period 8±2 seconds shall begin in addition to yellow flashing light. In order to maintain normal vehicle operation, the Loco Pilot shall operate the Vigilance footswitch or any other equipment, specified in clause 2.1.1, before the action cycle expires to prove positively that he has not become incapacitated or slept. Once reset in this manner, system operation reverts to the delay cycle and normal vehicle operation is maintained. If for any reason, the action cycle expires without being acknowledged, the brake cycle is initiated to make an automatic brake application.

2.1.3 Penalty brake Cycle: The brake cycle is initiated if the Loco Pilot fails to respond to the audible and visual warnings before the expiry of the action cycle. A brake application is immediately initiated. This ensures that the vehicle is brought to a complete standstill. Vigilance unit initiates a penalty brake, which remains applied for a period of 32±2 seconds and cannot be reset once applied during this period. Only after the expiry of the brake cycle period and then only after the master controller has been set to the off position can the vigilance unit is reset using the reset push button provided at the Loco Pilot desk. The brake application then gets released, the audible and visual warnings are canceled and normal vehicle operation can be re-established.

The working of the existing VCD unit is depicted in the flow diagram in which the vigilance cycle, warning cycles, and penalty cycles are mentioned.

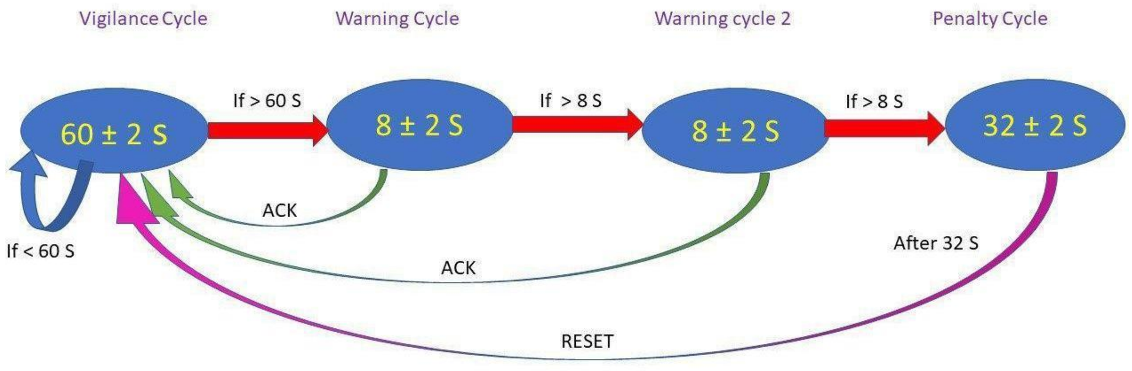

Fig. 1: Schematic diagram for working of VCD

2.2 Performance of VCD during SPAD occurrence

Indian railways accident manual classifies the SPAD as an accident. If the SPAD occurred due to disregard of a signal by the loco pilot, he/she will be removed from railway service in the majority of the cases. Every occurrence of SPAD cases attracts attention from the highest authorities at Railway Board. One of the important performance indexes for the Electrical Operation department is the number of SPAD cases.

The following are the causes of SPAD [2]

(a) Expecting the most restrictive signal aspect will change to a less restrictive aspect before reaching the signal. This is due to the experience of the loco pilots in the same sections
(b) The distraction of loco pilots due to events happening in the station or nearby the track like a passenger fallen on platform etc
(c) Monotonous nature of the working condition, microsleep
(d) Stress and tiredness can reduce the ability to concentrate the driving.
(e) Low brake power of locomotive and coaches
(f) Poor signal sighting and environmental factors like fog and rain etc

SPAD analysis [3] reveals that out of 239 cases of SPAD occurrence over the last five years, the majority of the SPAD occurred with LP availing headquarters rest that is after availing rest at home. In most cases, 70% of cases LP had completed 6 tours of duty or less. This indicates that loco pilot coming to duty after resting at home, had a sleep deficit which may lead to drowsiness onboard or while driving

Data on the occurrence of SPAD for the last 1-year period from 1.1 2019 to 31 12 2019 is taken for study from the Indian Railway website of safety information management system [4]. Out of 67 cases of SPAD, 39 cases are classified as indicated accidents where is 18 cases are classified as consequence accident which lead to derailment of train or collision due to the SPAD

Table 1: Classification of SPAD cases

Type of accident	SPAD cases
Indicative accidents	39
Consequal accidents	18

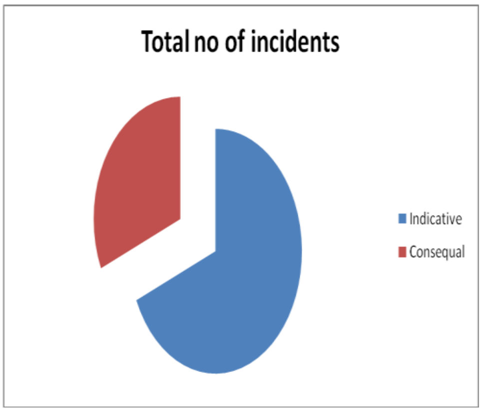

Fig 2: Classification of SPAD cases

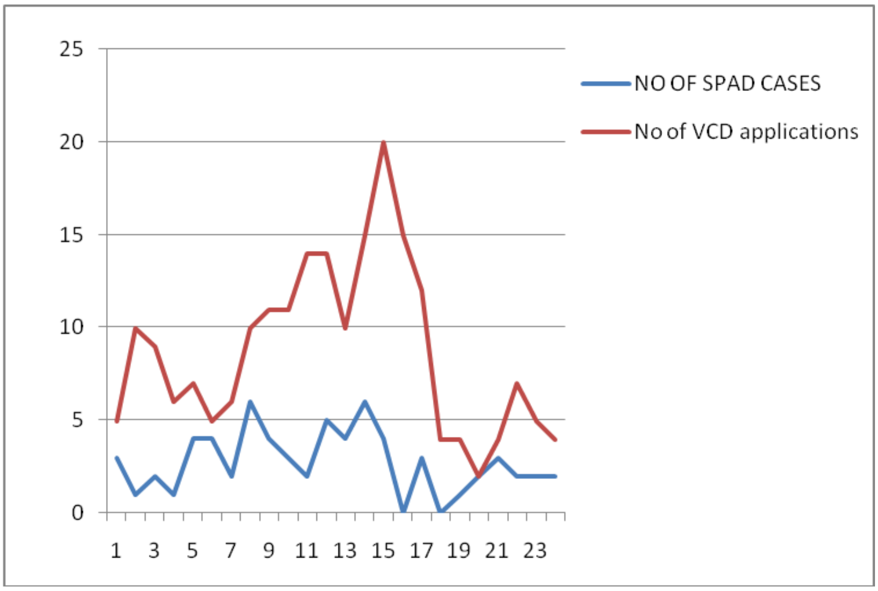

Fig. 3: Hourly distribution occurrence of SPAD cases and VCD penalty brake application

The distribution of SPAD cases and Penalty brake application on an hourly basis is furnished as figure 3. A number of VCD applications and the number of cases of SPAD occurrence are high during the period of 11.00 hours to 17.00 hours in the day time. But it is a commonly known vulnerable period between 2.00 hours 5.00 hours in the early morning. It is seen that SPAD cases are happening throughout the day. it indicates that drowsiness will be felt by loco pilot depends upon the quality or duration of the sleep just prior to joining the train and take over the train operation.

2.3 Analysis of SPAD cases of Southern Railways for the last 10 years

SPAD cases of Southern Railway for the period of 10 years from 1.4 2009 to 21.2 2020 is taken for analysis. Cause of every SPAD occurrence was studied, in all the 40 cases "disregard of the signal aspect by the loco pilot" was the reason. Surprisingly in all the cases, VCD was functioning normally while the SPAD happened. This fact clearly indicates that the alertness of the LP sensed by the existing VCD is not full proof. Or the sensing mechanism is not detecting the true alertness or drowsiness in which the loco pilot was able to operate `routine functions like resetting the VCD etc. But he is not able to do the application of brakes in time. In all the SPAD cases the break was applied after a lapse of some time, this may be taken as an indication of that loco pilots were in micro sleep for a while or drowsiness for a while and wake up to alert state after just a while. Hence it is proposed that the design of VCD may be improved upon to detect the drowsiness of the loco pilot by taking additional inputs of behavioral parameters which will give some indication of fatigue, micro-sleep, and drowsiness.

3. PROPOSED SYSTEM OF DESIGN OF AN DROWSINESS DETECTION AND WARNING

The proposed system for detection and warning will have the following additional sensors

1 Infrared camera
2.High definition microphone

The infrared camera images will be fed into the processor to detect the following behavioral parameters

1. The percentage closer of eyelids PERCLOS
2. Sway the head that is the orientation of the head
3. Yawning of the loco pilot

The schematic of the proposed design is shown in figure 4. The existing VCD inputs are kept and additionally infrared cameras and microphones are used as input devices.

3.1 Functioning of the proposed system

3.1.1 Measurement of PERCLOS: PERCLOS is a proven parameter widely used as drowsiness deduction which is based on eye closure rates. PERCLOS IS defined as the proportion of time in which the eyelids are at least 80% closed over the pupil

$$\text{PERCLOS } P = \frac{E_C}{E_0 + E_C} \times 100$$

Here Ec AND Eo give the counts of closed and open eyes. A higher value of P indicated a higher drowsiness level. Computation of PERCLOS is involved preprocessing, photometric correction, face, and eye detection, eye state classification [5]

3.1.2 Detection of the sway of head yawning: During the onset of drowsiness, the driver's head will move downwards. Computation of the sway of head and yawning also involves processing similar to PERCLOS computation and HAAR like features

3.1.3 Measurement of Voice modulation: PERCLOS gives an authentic indicator of drowsiness but voice-based detection is incorporated as back up sensing as well as a mechanism to ensure the drowsiness. Voiced –Unvoiced Ratio (VUR) for the speech signals have been already validated as a method of drowsiness detection. The microphone captures the speech signals whenever the loco pilot calling out the signal aspect which is mandatory processes the train operation. Suitable noise reduction techniques are applied before the sampling and VUR is calculated.

$$VUR = \frac{\sum_{0}^{N_v - 1} v_s^2(n)}{\sum_{0}^{N_u - 1} u_s^2(n)}$$

Where, $v_s(n)$ is SVM of voiced speech(n) is SVM of unvoiced speech
N_v is the length of voiced speech, Nu is the length of the unvoiced speech.

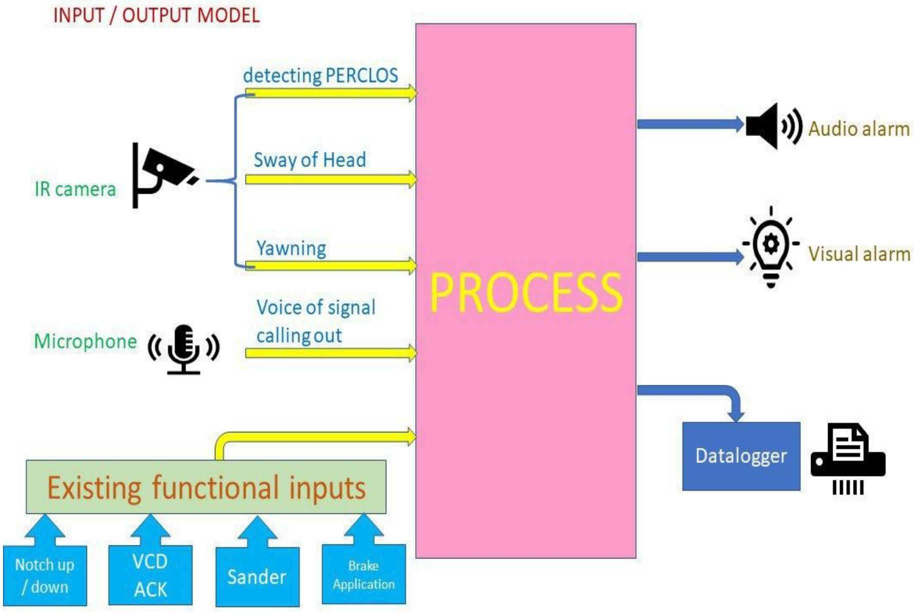

Fig. 4: Proposed system of Design of a Drowsiness detection and warning

3.2 Alarm Generation and data logging

As the system detects the loco pilot is entering to drowsiness state, first a visual alarm (LED blinking) is flashed for 10 seconds. If it is not acknowledged by the loco pilot, then an additional audible alarm (siren) is initiated to alert the driver. If the loco pilot is still not in the state of drowsiness which will be again ensured by the processor, then the penalty brake will be applied by disturbing the pneumatic circuit of a locomotive.

The entire events including acknowledging, resetting, state of drowsiness and penalty brake applications are logged in RAM for future analysis, training, and troubleshooting which can be downloaded in-home shed of locomotives

4. CONCLUSION

With this improved version of existing VCD, the Indian Railways will be able to reduce the number of SPAD cases by keeping the loco pilots in the state of alertness while on board. The proposed system for drowsiness detection and a warning will be helpful for loco pilots for handling the train operation with improved confidence as the drowsiness is beyond the consciousness of a person most of the time which will be detected in non-invasive methods by the proposed system. Voice recording and processing will be helpful in analyzing whether the loco pilot and his assistant is calling out the signals or not. Also, with suitable modification of the design, the voice recording facility can be further converted as a Black box of Aircraft which will be used for investigating the accident causes.

5. REFERENCES

[1] RDSO specification No. RDSO/2008/EL/SPEC/0025/Rev.6 (APR-2019).
[2] A. A. Phadke, "Various stresses on loco pilots ABD SPAD project, IREEN Journal VOL 26 no.2, 2015
[3] S Nayak, S Tripathy and A Dash "A critical analysis of signal passed at danger (SPAD) events of Indian railways" S Nayak *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* 377 012208
[4] Summary of SPAD from 01/12/2018 To 31/12/2019 (For Accident Reporting to All) in http://www.safety.indianrail.gov.in/sims/sims.htm
[5] Anirban Dasgupta, Daleef Rahman, and Aurbinda Routray "A Smartphone-Based Drowsiness Detection and Warning System for Automotive Drivers," in IEEE Trans on Intelligent Transportations system VOL.20 No 11 Nov 2019