Solid State Block Proving By Axle Counter (Digital)

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ABSTRACT

SSBPAC is a solid state system used for controlling the coordinated movement of the train in the block section working on absolute block working principle. The system has been developed as per RDSO/SPN/175/2005 both for single line working and double line working. The SSBPAC (D) is of 2 out of 3 hardware architecture with implementations of the fail safety principles. It complies with the CENELEC standards and conforming to Safety Integrity Level - 4 (SIL-4). The system incorporates auto features and eliminates manual co-operations from other end for Line Clear and Line Close operations. Emergency cancellation at the receiving station. Automatic Train On Line. Automatic Line Close after sequence proved at receiving end and section is free. Simplified Block Back / Block Forward Operations. Cooperative Cancellation. Line Clear Block Key (LCB Key) to prevent automatic granting of Line Clear. Station Master Key (SM Key) to prevent unauthorized panel operations. Fully solid state and relays are only for final vital outputs. Single Line Working with provisions for shunting with shunt key EKT Event logging operations and data storage in built in the system. Data logger network interface. Communication media: (1 pair cable in quad or on voice channel in OFC.) Block bell and telephone on separate pair of quad or voice channel of OFC. Two repeater relays to repeat input status at the other end. To implement SSBPAC we used PTHMU SOFTWARE to get the results.

Keywords: SSBPAC, SM, LCB, **CENELEC, PTHMU SOFTWARE**

I. INTRODUCTION

An axle counter is a device on a railway that detects the passing of a train in lieu of the more common track circuit. A counting head (or 'detection point') is installed at each end of the section, and as each axle passes the head at the start of the section, counter increments. A detection point comprises two independent sensors; therefore the device can detect the direction of a train by the order in which the sensors are passed.

As the train passes a similar counting head at the end of the section, the counter decrements. If the net count is evaluated as zero, the section is presumed to be clear for a second train. This is carried out by safety critical computers called 'evaluators' which are centrally located, with the detection points located at the required sites in the field. the detection points are either connected to the evaluator via dedicated copper cable or via a tele communications transmission system. This allows the detection points to be located significant distances from the evaluator. This is useful when using centralized interlocking equipment but less so when signaling equipment is distributed at the line side in equipment cabinets.

Fig. 1 An axle counters detection point in the UK

The system (SSBPAC (D)) will require the following subsystem for its working as per scheme depicted:

- Block Panel
- Block Telephone
- Electronic interlocking and communication module (SSBPAC(D))
- Single section Digital Axle Counter
- Relay rack with relays
- Battery Set
- Battery Charger / IPS module
- Quad Cable or Voice channel

It should work for both single line and double line with minimum changes in the software as well as in the hard ware. Double line panel design will be as per RDSO's Drg No. RDSO/S/32025. Single line panel design will be as per RDSO's Drg No. RDSO/S/32023. The system will itself capable to handle communication between two stations. It doesn't need any multiplexer for repeating purpose. The distance between housing rack and operation panel will be maximum of 50meters.The MTBF (Mean Time between the Failures) will be more than 20,000 hour [3].

Objective:

Objective of the system is to provide interlocking functions of block signaling according to approved method of working. And the very main objectives of the system are listed below:

- To ensure high degree of safety to avoid accidents.
- To increase the mean time between wrong side failures (MTBWSF) of the relays.
- To avoid the complete tracing of every logical condition around Control Philosophy in trouble shooting.
- To reduce the manual errors.
- To replace the electro mechanical controlling of railway signals.
- To avoid the problems with microprocessors based systems.
- To use the advantages of embedded systems.
- To avoid Problems with Hard-Wired Relay Logic:-
  - Trouble-shooting the failures is difficult.
  - Trace every logical condition around Control philosophy
  - More down time.
  - Indulges to by-pass the error with safety at stake to, cut revenue loss.

II. CLASSIFICATION OF SYSTEMS

Coming to the classification of systems the ***Systems of block working*** divided into two types:

1) Automatic block working
2) Absolute block working

1) Automatic block working:

This automatic block working is all about All the signals display PROCEED aspect normally and displays STOP when train occupies the controlling track as shown here [1].

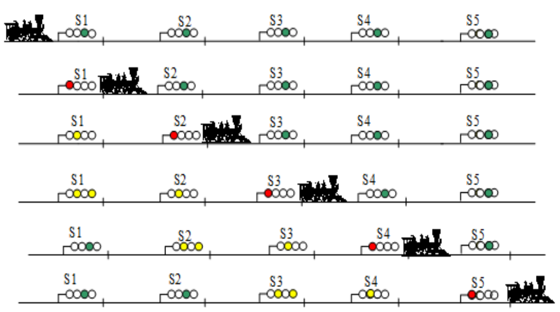

Fig. 2 Sequence of the signal change in Automatic Block Signaling

2) Absolute block working:

In automatic block working, dispatch signals display ON aspect normally and changes to OFF when permission given to enter the block section. This is normally achieved through SSBPAC (which is interlocked with advanced starter signal) operated by either station masters. The following figures depict the operational content [1].

Fig. 3 Showing signals and relays on the block just after getting line clear

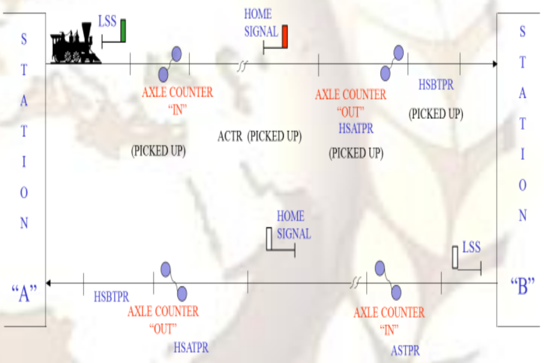

Fig. 3.1 The train is ready to enter the block (sequence 1)

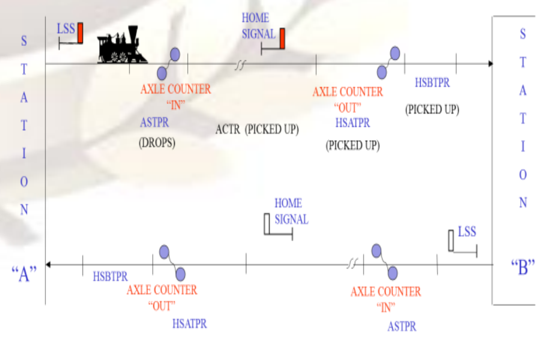

Fig. 3.2 The train is ready to enter the block (sequence 2)

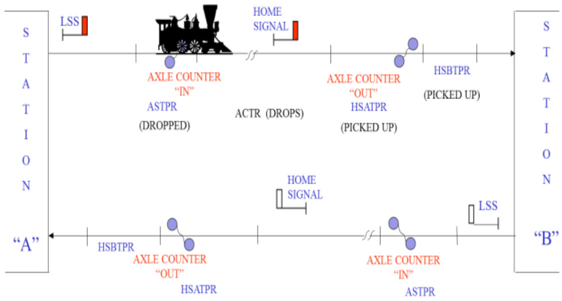

Fig. 3.3 The train is ready to enter the block (sequence 3)

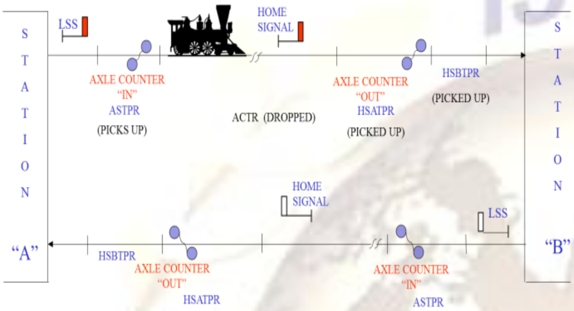

Fig. 3.4 The train is ready to enter the block (sequence 4)

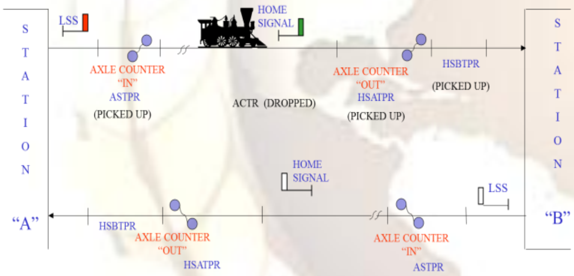

Fig. 3.5 The train is ready to enter the block (sequence 5)

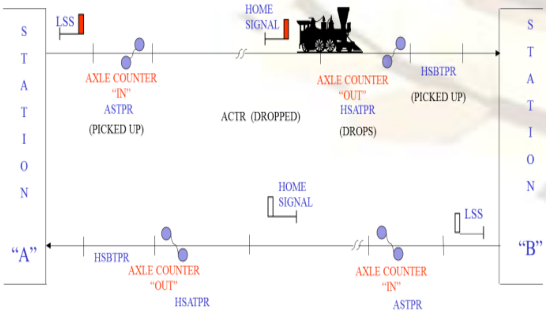

Fig. 3.6 The train is ready to enter the block (sequence 6)

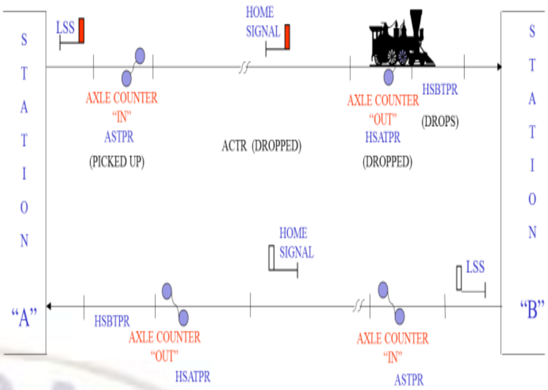

Fig. 3.7 The train is ready to enter the block (sequence 7)

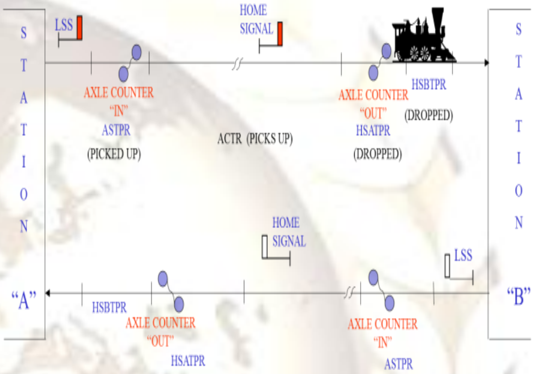

Fig. 3.8 The train is ready to enter the block (sequence 8)

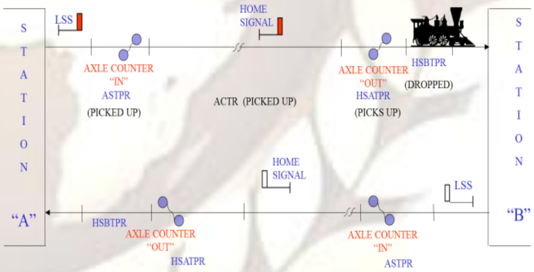

Fig. 3.9 The train is ready to enter the block (sequence 9)

III.SSBPAC[D] ARCHITECTURE:

Basically Block Working of SSBPAC[D] is required as following:

The SSBPAC system is based on two-out of-three architecture. This means that, the system has three identical processing hardware Units (CPU modules) and run the identical firmware.

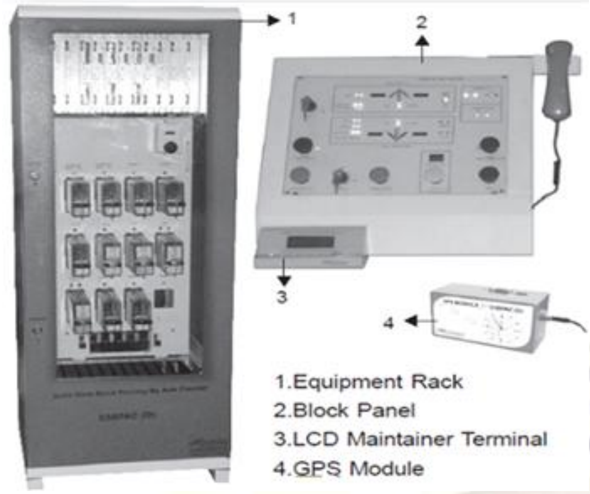

Fig. 4 SSBPAC(D) Architecture

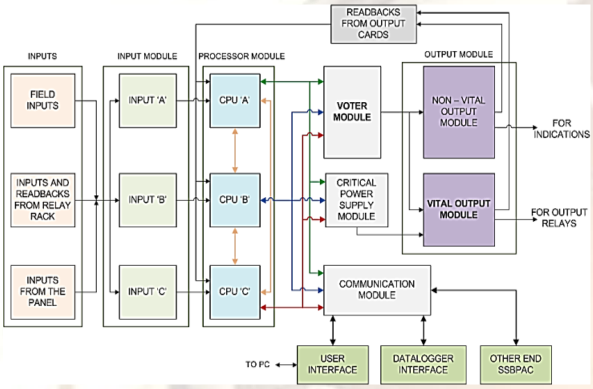

Fig. 5 Block Diagram of SSBPAC

Principle of working:

The trains generally are worked on the Absolute Block system. The block section is provided with an axle counter to verify the occupation or clearance of block section and indicated on Block Panel. It is not possible to take the Last Stop Signal to 'OFF' unless LINE CLEAR has been obtained from station in advance.

It is not possible to obtain LINE CLEAR unless block section and an adequate distance beyond first stop signal of station in advance is clear of trains. The Last Stop Signal assume 'ON' aspect automatically on entry of train into block section and when so replaced, is maintained in its 'ON' position, till a fresh LINE CLEAR is obtained on block panel. Block section show automatically Train on Line on panel when train enters into the block section on line clear. Train entry/exit buzzer to/ from block section are provided and to be acknowledged. Block section automatically closes on complete arrival of train at the receiving station.

A control to prevent the station in rear to take LINE CLEAR on its Block Panel without taking consent of receiving station. A control to cancel the LINE CLEAR, already taken by station in rear. It is possible to close the block section only, if no train has entered the Block Section for at least 120 seconds after application of cancellation with a co-operation from station in rear.

All the three CPUs are provided with the same set of inputs and generate individual outputs to the corresponding output modules. The main architecture is based on the triple electronic structure. The total architecture of PCB's present in a rack known as "EURO RACK" can be decomposed into two major categories as explained in the following chapter.

IV. Euro Rack Module

The below figure can represents the Euro Rack Module

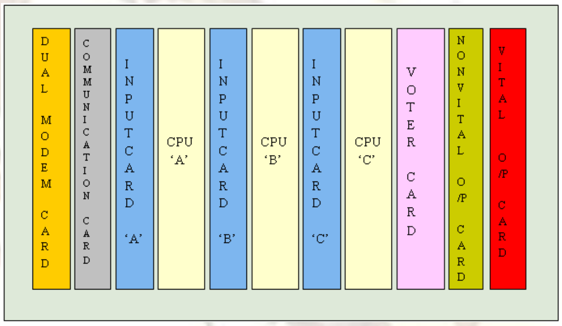

Fig. 6 Euro Rack Module

Here we can see the discussion about Safety Related Modules and Different Modules for our design.

1) Safety related modules:

The Following Modules Come under Safety related Modules.

C.P.U module: CPU module will comprise of Motorola 68000 Processor. Total three CPUs are present in SSBPAC system, which are of same hardware and software.

This architecture will provide Composite fail safety in which all the three CPUs will be dependent from each other to avoid common mode faults. Non restrictive activities are allowed, if at least any of the two CPUs agree for the same decision. The three CPUs are synchronized by the external event pulse generated by the hardware voter module. The CPUs poll for this synchronizing pulse once in every main loop.

So, at most, the three CPUs may have a synchronization difference of one main loop cycle time. Hence, the three CPUs are loosely coupled.

Three CPUs will read inputs from input module through software controlled I/O bus and process the same inputs separately.

Three CPUs will generate the outputs parallelly. These outputs will be indications such as Panel indications, buzzers, video counters, output relays and output commands. Three CPUs will mutually exchange inputs and outputs among them for validation through inter processor communication.

Three processors will also exchange their health, status and control bytes. Three CPUs will place the outputs onto the hard wired voter module through software controlled I/O bus. CPUs will place its evaluated output to the voter module if its outputs are matched with at least any one of the other CPU. If output of any CPU doesn't match with the other two CPUs it will place the fail safe output onto the voter module and it will display the error code. Fail safe outputs are the outputs where all the indications are OFF and output relays are in drop state. CPU module will maintain health by using hardware mono shot. It will check the health status before placing the output onto the voter module in every cycle. It will have an external Watchdog timer for monitoring the CPU processing. It will also have the internal soft ware watch dog timer which will monitor the program flow and the time of these watch dog timers will be in the multiple of 5milliseconds. Each CPU module will provide the trigger to the Critical Power Control Unit, which will provide power supply to the vital output module.

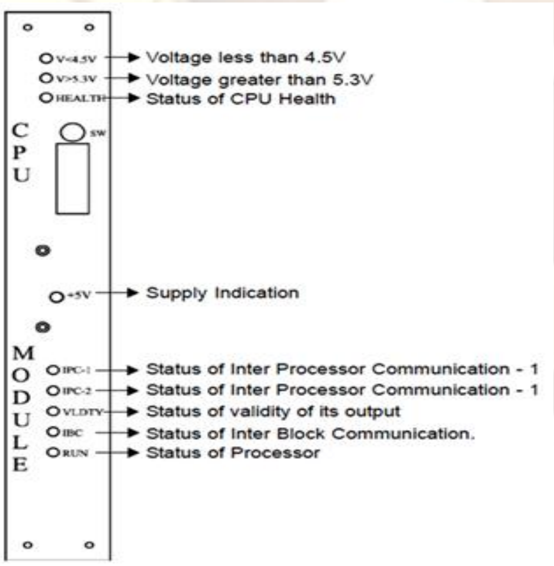

Fig. 6.1 CPU Module

Each CPU will have the serial port drivers for the Inter Processor communication, Inter Block Communication, Data logger communication and communication with User Interface module. CPU module will have power supply failure indications when supply falls below 4.5Volts or above 5.5Volts.

In SSBPAC system CPU modules will have ***Two Options*** one is the common power supply and other is the individual onboard power supply. Each CPU will have its own individual input and output modules. Supply Pins of all digital ICs will be decoupled with a high frequency capacitor.

2) Input module:

Three input modules will be provided for three CPU modules which are of identical hardware. Input module will have the provision for 64 inputs maximum. Input mo- dule will periodically read the inputs from field relays, relays in relay rack, panel buttons and keys.

Both front and back contacts of all input relays, output relays and panel buttons will be connected to the input module. all the inputs will be electrically isolated by using opto couplers so that it can give isolation voltage more than 2000v and it will draw less than 10 mA for each input. Inputs will be scrambled in three different patterns and then given to processor modules to avoid common mode faults like any adjacent shorts between inputs.

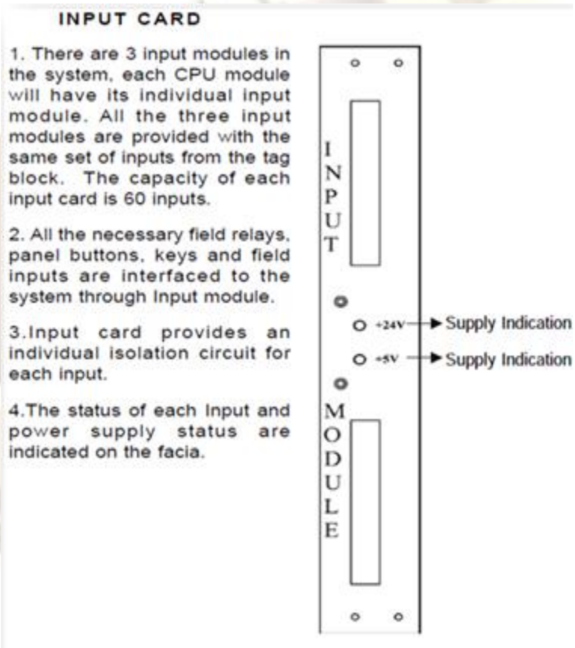

Fig. 6.2 Input Module

While scanning the inputs, de bounce checking and chatter checking will be performed. Input module will also check for the bi state validity. Input module will consist of surge protection circuits and transient voltage suppressors.

Input module will consist of LEDs to indicate the status of all inputs. All the inputs at the input module are of positive switching type with +24V to front and back.

3) Voter module:

Hardware voter module is provided for voting the outputs of three CPUs. Voter will not accept outputs from CPU module if health of the CPU is not available. Voter compares the outputs of three CPUs and will place final outputs on to the output module. Final outputs will be the outputs which are same for at least two CPUs. If none of the CPU outputs match then voter will place failsafe output on output module, thereby it will ensure inherent fail safety. Voter module will provide synchronizing pulse for all the three CPUs. This is known as system clock cycle.

This cycle time will be 500ms. Each CPU will poll for the start pulse and starts processing only when it detects start pulse. If start pulse is not detected it will stop further execution.

After placing the evaluated output onto the voter the CPU will place the end pulse. If the end pulse is not placed the output of that particular CPU is not considered. Thus, voter module will be continuously tested by the three CPU modules. Voter module will provide changeover indication for the critical power control unit.

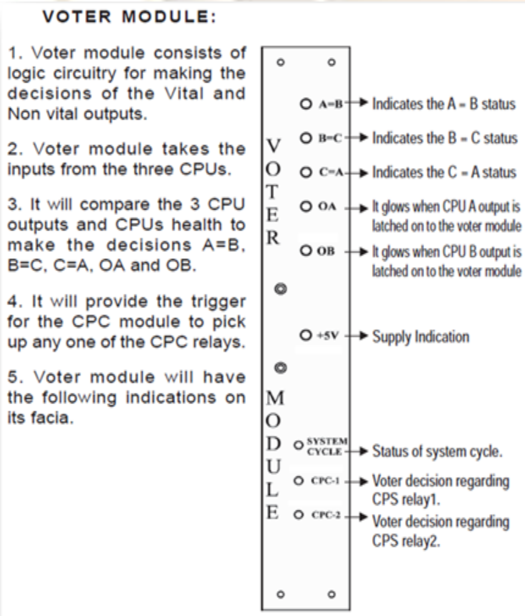

Fig. 6.3 Voter Module

4) Communication module:

This module will accommodate common hardware for all three processors. Communication module will have driver interface for Data logger communication and user interface communication.

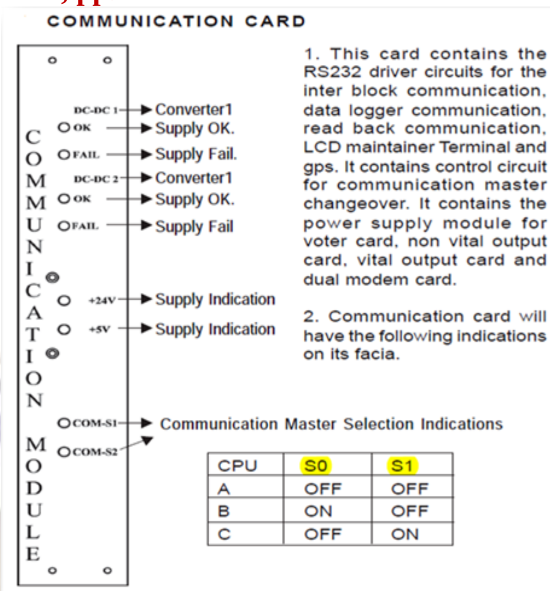

Fig. 6.4 Communication Module

It will provide driver interface for inter block communication as per CCITT standard at baud rate 1200 minimum. Inter block communication will provide inputs for processing module which are used for decision making. Data logger communication is used for event logging, which will be discussed in non safety modules. User Interface module will provide the communication between SSBPAC and user. Though three processors are present in system only one CPU will communicate with other SSBPAC or Data logger. This CPU module will act as the communication master. Selection of communication master will be handled by communication module. If the master CPU fails, then switching to other CPU is done automatically. This is called the Automatic Communication Changeover. The communication module will consist of all the hardware required to perform these communications and the automatic changeover.

The three CPUs also have the provision to communicate among themselves. Inter process communication speed will be sufficiently high to meet cycle time requirements. The SSBPAC will be capable of working on Telecom Cable as well as on Voice/data Channel provided over Optical Fibre. The Inter block communication will work with a communication pair or voice /data channel. And a separate communication pair or voice/data channel will be used for the block telephone. The data packets of IPC, IBC and Data Logger communication will be protected with error detection codes like CRC having minimum hamming distance of 5.

In each system two ids will be specified, one is the self ID and other is the remote ID. The communication between two systems establishes when self and remote IDs are properly configured in both stations by using DIP switches. The system will give the error when these IDs are not matched during communication and if it receives continuously the system will display error and go to the safe shutdown mode. The SSBPAC will have the provision of section ID configuration. The communication between the two systems establishes when section ID is same in both systems.

This ID will be hard wired. The system will give the error when these IDs are not matched during communication. Dual modems will be used to communicate between the two systems. This modem will work up to 15 km. This modem will meet the RDSO specifications [2] [4]. The systems in the two station will exchange the system status, IDs, health and also control bytes in regular intervals i.e. once in a system cycle. Master ship of CPU will given to adjacent CPU if it is not participating in voter decision.

5) Output module:

Output Module Can Be Decomposed In Two Types

5.1) Vital output module:

Vital output module will have 8 vital relays as outputs and each output will be capable to drive relay of 100 ohms to 1000 ohms at 24 V. Vital outputs will drive Q series relays.

The relays shall be driven through AC coupled drivers with optical/galvanic isolation and transient free supply.

Power supply to this module will be provided by critical power control unit. Output card will have short circuit protected 24V supply for driving external Q series relays. At power on condition all vital outputs are in off condition. In safe shut down mode also all vital outputs will be in off condition. Two stages of read backs are provided from vital output module to CPU module. First stage read backs are from vital relay driver inputs and second stage read backs are from vital relay driver outputs. Vital relay outputs will be given as inputs to input module.

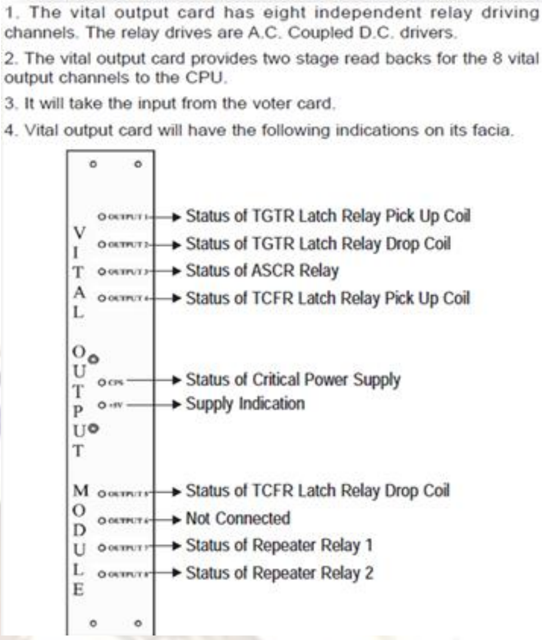

Fig. 7.1 VITAL Output Module

5.2) Non vital output module:

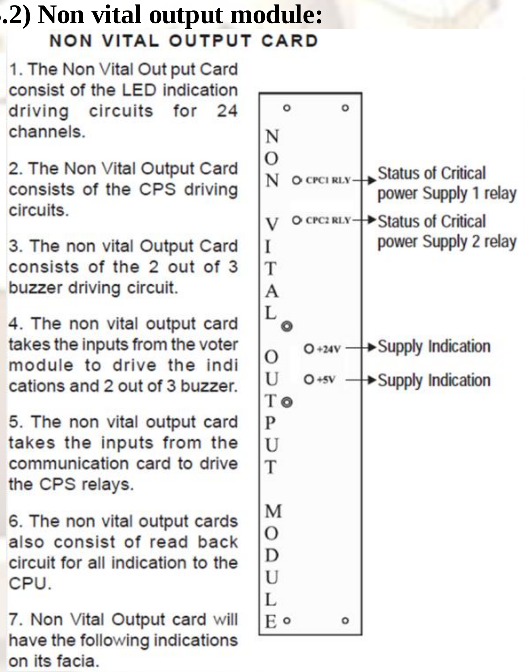

Fig. 7.2 Non-VITAL Output Module

Non vital output module will have 24 non vital outputs. Non vital output module will drive all panel indications, buzzers, veedo counters. One stage read back will be provided from non vital outputs to CPU modules.

Critical power control unit:

Critical power control unit will provide power supply to the vital output module. CPC unit will cut the power supply to the system under fault condition. CPC unit will be triggered by three CPU modules. The trigger of CPU will be invalid if CPU health is not available. When two CPUs are failed to give the trigger to CPC module then the CPC module will not provide the supply to the output module. So this is represents as system health.

For every 10ms three CPUs will give trigger to the CPC unit. CPC will provide power to vital output module if it is triggered by at least two CPU modules. Otherwise it will cut down the supply to the vital output module. CPC unit will have the provision to self diagnose at periodic intervals so that reactive fail safety can be assured to avoid the hazardous conditions.

V. METHOD OF SIGNALING

Method of Signaling Trains from Block Station to Block Station for Single Line:

SM of the station intending to send a train from his station has to obtain verbal consent from station at other end before taking LINE CLEAR on its Block Panel.

a) Before a request for IS LINE CLEAR is sent to station at other end, SM shall ensure the following on its Block Panel:
   i) LINE CLOSED indication YELLOW &
   ii) LINE FREE indication GREEN &
   iii) SNK indication YELLOW &
   iv) SNOEK indication YELLOW &
   v) SHUNT KEY indication GREEN
b) The station at other end while granting his consent shall ensure the following on its Block Panel;
   i) LINE CLOSED indication YELLOW &
   ii) LINE FREE indication GREEN &
   iii) SNK indication YELLOW &
   iv) SNOEK indication YELLOW &
   v) SHUNT KEY indication GREEN
c) Thereafter SM of sending station presses BELL & TRAIN GOING TO buttons.
d) The directional arrowhead, TRAIN GOING TO/ TRAIN COMING FROM lights up green at sending/receiving station respectively.
f) SM of sending station releases BELL & TRAIN GOING TO buttons on getting TRAIN GOING TO green indication.

g) The sending station SM, after obtaining LINE CLEAR on its Block Panel, can send a train into Block Section by taking the LSS to `OFF'. On entry of train into section, TRAIN ON LINE lights up at both the stations near arrowhead indication. The TRAIN GOING TO / TRAIN COMING FROM Arrow Head Indications turns RED in respective stations. SECTION buzzer sounds at both the stations along with ACKN indicator near ACKN button. Pressing of ACKN will turn off the buzzer and ACKN indicator.
h) The train is received at receiving station on proper reception signals. On complete arrival of train, TRAIN COMING FROM indicator changes to FLASHING GREEN & LINE FREE indicator turns to GREEN at both the stations. TRAIN GOING TO /TRAIN COMING FROM indicator continues FLASHING GREEN at sending / receiving station respectively if reception & departure signals and their controls are not at normal or SHUNT KEY of EKT is `OUT'. In case reception & departure signals and their controls are at normal & SHUNT KEY of EKT is `IN' at sending/ receiving station, TRAIN GOING TO/ TRAIN COMING FROM turns off and LINE CLOSED indicator lights up YELLOW.

Method of Signaling Trains from Block Station to Block Station for Double Line:

SM of the station intending to send a train from his station has to obtain verbal consent from station in advance before taking LINE CLEAR on its Block Panel. Before a request for IS LINE CLEAR is sent to station in advance, SM of sending station shall ensure the following near TRAIN GOING TO arrowhead on its Block Panel:

i.) LINE CLOSED indication YELLOW &
ii.) LINE FREE indication GREEN &
iii.) SNK indication YELLOW.

The station in advance while granting his verbal consent shall ensure the following near TRAIN COMING FROM arrowhead on its Block Panel:

i.) LINE CLOSED indication YELLOW &
ii.) LINE FREE indication GREEN &
iii.) SNK indication YELLOW &
iv.) SNOEK indication YELLOW
v.) Then inserts and turns LCB key.

Thereafter SM of sending station presses BELL & TRAIN GOING TO buttons. The arrowhead, TRAIN GOING TO/ TRAIN COMING FROM lights up green at sending/receiving station respectively. SM of sending station releases BELL & TRAIN GOING TO buttons on getting TRAIN GOING TO green indication.

The sending station SM after obtaining LINE CLEAR on its Block Panel can send the train into Block Section by taking the LSS to `OFF'. On entry of train into section, TRAIN ON LINE lights up RED at both the stations in arrowhead indication. SECTION buzzer sounds at both the stations along with ACKN indication near respective ACKN button. Pressing of ACKN button of concerned line (Dispatch/Receive) will turn off the buzzer and ACKN indication.

The train is received at receiving station on proper reception signals. On complete arrival of train, TRAIN GOI-NG TO /TRAIN COMING FROM arrowhead indication turns to FLASHING GREEN & LINE FREE indication turns to GREEN at both the stations. TRAIN GOING TO /TRAIN COMING FROM arrowhead indication continues FLASHI-NG GREEN at sending / receiving station respectively till reception & departure signals and their controls are not at normal or LCB Key is not `IN'. In case reception & departure signals and their controls are at normal & LCB key is IN, TRAIN GOING TO /TRAIN COMING FROM arrowhead indication turns off and LINE CLOSED indication lights up YELLOW.

VI. PTHMU SOFTWARE

Point Machine Health Monitoring Unit:

Fig. 8 Point Machine Health Monitoring Unit

DC Track Circuit health monitoring unit is used for detecting the electrical energies at feed and relay ends of the track circuit. It is possible to have an early warning before the track relay drops and cause signal failure or over energized beyond maximum limit and cause unsafe side failure. Point Machine Health monitoring unit indicates the point machine's health by monitoring its current along with status of point control, operating and detection relays. By this signal technician can reduce the down time of the point in case of failure as the failure state is already made available by the system. He can plan for need based maintenance which reduces the disconnection time.

In case of simple obstruction the station master is guided by the system i.e. on which end to check for obstruction. DC Track circuit and Point Machine Health monitoring unit enables signal Technician to perform status based maintenance. Reduces the down time of points and track circuits by eliminating down time due to frequent disconnections for maintenance and improves MTTR.

VII. CONCLUSIONS

- Less maintenance and requires no periodical over-hauling in consideration with the electromechanical systems.
- It considers signal overlap distance for granting line clear, which is not available in some of the present systems.
- It has inbuilt data logging capability which logs all the panel operations, events, relays status and other information.
- All the panel indications are with LEDs.
- No need for next train on PLC after push back operation.

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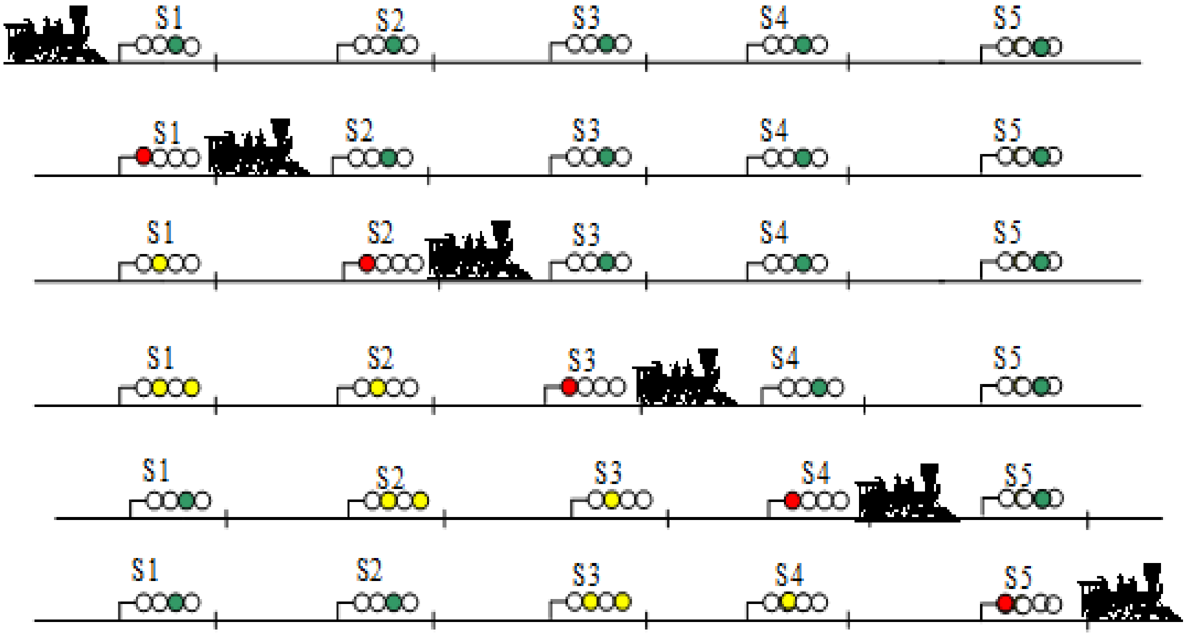

Fig. 9 Sequence of the signal change in Automatic Block Signaling