## 2.3 Voltage Current and Temperature Monitoring (VIT Monitoring)

**2.3.1 Feature Objective:**

VIT monitor will provide filtering and diagnostic features of the voltage, current and temperature data from all sensors connected to BMS. This feature will check if all cell voltages, pack current and pack temperature are within their respective upper and lower limits, and will raise flags to indicate which sensor signal is out of its range. The filtered signals and diagnostic signals will be used by other BMS features.

**2.3.2 Functional Description:**

**2.3.2.1 Filtering Logic:**

The VIT raw sensor signals will be first filtered to get the filtered signals. For example, the i-th cell voltage filtered signal is

where is the raw sensor signal of the i-th cell voltage, and . For the pack current, the filtered signal is

where is the raw pack current sensor signal, and . For the pack temperature, we assume there is one sensor signal, if multiple pack temperature signals are available (e.g., coolant inlet and coolant outlet temperature), we can apply the same method to all the temperature signals. The filtered temperature signals is given by:

where is the raw pack temperature signal, and . The coolant inlet and coolant outlet temperature sensor signals will use the same filtering constant .

**2.3.2.2 Cell Temperature and Cell Voltage Statistic Quantities:**

We assume the cell temperature and cell voltages are available through CAN bus that connected with slave boards that connects to battery cell sensors. For cell temperatures, we calculate the cell statistical quantities (maximum, minimum and average) as:

To calculate the pack temperature, we use the following logic.

Max cell temperature = maximum of all cell temperatures

Min cell temperature = minimum of all cell temperature

If max cell temperature > Calibrated high temperature

Pack Temperature = max cell temperature

Else if min cell temperature < Calibrated low temperature

Pack temperature = min cell temperature

Else

Pack temperature = average cell temperature

The statistical quantities of cell voltages can be computed the same way as cell temperatures except we have a physical measurement of pack voltage and do not need the average of all cells to approximate it.

**2.3.2.3 Diagnostic of VIT**

To detect if the sensor signal is out of normal range, we can apply the diagnostic logic on the filtered signals as following:

If sensor\_signal > upper\_lim or sensor\_signal < lower\_lim for calibratable amount of time

Flag = FALSE (1)

Else

Flag = TRUE (0)

End

We will apply this logic to pack current, coolant inlet and outlet temperature, and pack temperature. For cell voltages, we can apply the logic that

If max cell value > upper\_lim or min cell value < lower\_lim for calibratable amount of time

Flag = FALSE (1)

Else

Flag = TRUE (0)

End

For the pack voltage, we can detect if it is equal to the sum of the cell voltages to determine if it is a valid value.

If abs (sum of cell voltages – pack voltage measured ) < Tol

Flag = FALSE (0)

Else

Flag = TRUE (1)

End

In case we do not have pack voltage sensor reading as input to the feature, we can ignore the diagnostics of the pack voltage and use the sum of cell voltages as the estimation of pack voltage.

**2.3.3 I/O description:**

The VIT\_Monitor module requires the dynamic I/O shown in the following table

|  |  |  |  |
| --- | --- | --- | --- |
| **Signal(s)** | **I/O** | **Description** | **Units/comments** |
| vitm\_Input\_CellV | Input | All the cell voltage values (in a vector form) | V |
| vitm\_Input\_CoolantInletT | Input | Coolant inlet temperature | °C |
| vitm\_Input\_CoolantOutletT | Input | Coolant outlet temperature | °C |
| vitm\_Input\_CellT | Input | temperature of all cells | °C |
| vitm\_Input\_PackCurrent | Input | pack current | A |
| vitm\_Input\_PackVoltage | Input | pack voltage | V |
| vitm\_Input\_VehSideVoltage | Input | Vehicle side voltage | V |
| vitm\_CellsMaxTemperature | Output | max cell temperature | °C |
| vitm\_CellsMinTemperature | Output | min cell temperature | °C |
| vitm\_CellsAvgTemperature | Output | average cell temperature | °C |
| vitm\_CellsTemperatureFiltered | Output | filtered cell temperature | °C |
| vitm\_CellsTemperatureLowFault | Output | cell temperature Low fault, 0 mean no fault and 1 means cell temperature too low | unitless |
| vitm\_CellsTemperatureHighFault | Output | cell temperature high fault, 0 mean no fault and 1 means cell temperature too high | unitless |
| vitm\_CellsVoltageFiltered | Output | filtered all the cell voltage values (in a vector form) | V |
| vitm\_CoolantInletTFiltered | Output | filtered coolant inlet temperature | °C |
| vitm\_CoolantOutletTFiltered | Output | filtered coolant outlet temperature | °C |
| vitm\_PackCurrentFiltered | Output | filtered pack current | A |
| vitm\_PackVoltageFault | Output | cell voltage diagnostic flag, 0 is normal, 1 means fault | unitless |
| vitm\_CellsVoltageLowFault | Output | cell voltage diagnostic flag, 0 is normal, 1 means too low fault | unitless |
| vitm\_CellsVoltageHighFault | Output | cell voltage diagnostic flag, 0 is normal, 1 means too high fault | unitless |
| vitm\_PackCurrentFault | Output | pack current diagnostic flag, 0 is normal, 1 means too high fault | unitless |
| vitm\_CoolantInletTempFault | Output | Coolant inlet temperature diagnostic flag, 0 is normal, 1 means fault | unitless |
| vitm\_CoolantOutletTempFault | Output | Coolant outlet temperature diagnostic flag, 0 is normal, 1 means fault | unitless |
| vitm\_CellsMaxVoltage | Output | max cell voltage | V |
| vitm\_CellsAvgVoltage | Output | average cell voltage | V |
| vitm\_CellsMinVoltage | Output | minimum cell voltage | V |

**2.3.4 Fault Management:**

When any of the VIT fault signal is not zero, the signal will trigger some fault process.

1. When the pack voltage fault occurs, this fault signal will trigger state of power (SOP) feature to reduce the dis-charging power limit.
2. When the pack current fault occurs, this fault signal will trigger state of power SOP to reduce the dis-charging power limit.
3. When the cell temperature high fault occurs, this fault signal will trigger state of power SOP to reduce the dis-charging power limit.