

"If I is equal or higher than 600 A(RMS) during at least a period of  $t_{filt} = 100 \text{ ms}$  (filter-time implemented in software that short high current peaks don't generate a disturbance), a disturbance is detected and then after a defined time of **protective action**  $\leq 250 \text{ ms}$  a protective action VCB off / contactor off (software delay time measured from the disturbance is triggered until the VCB Off command goes on) must happen.

Because all the monitored values are sampled by a digital control system a time of **sample**  $= 100 \text{ ms}$  must be added to the filter-time. That means in worst case the current must be higher than 600 A(RMS) about a time of  $t_{filt} + t_{sample} = 200 \text{ ms}$  to generate a disturbance and a protective action.

An exception exists for the primary current. Switching off a high primary current should be done very fast. To reduce the sample time, the input signal is differenced to get a faster rise time. The resulting filter time and sampling time is approx. 50 ms (see SLG segment 0104)

Traction effort value:

"TE = 100%" means (e.g. 5.6.C) 1) a) Protective limits vehicle speed WAP-5)

"Traction effort is 100% of the maximum possible traction effort  $T_{Emax}$  given by traction speed diagram (e.g. BoBo-loco by  $v=0\text{km/h} \rightarrow T_{Emax}=258\text{kN}$ ,  $v=80\text{km/h} \rightarrow T_{Emax}=180\text{kN}$ ) or by power reduction in case of a protection action (e.g. temperature in traction motor to high)"

Parameternames for limit values are built as: (*Processorname* , *Parametername* , *Scaling*)

## 5. MONITORED VALUES

### 5.1. AC Primary Voltage

There are two different protective mechanism implemented. The first one described in 5.1.1. is only active in the cooling mode, where the control electronics are inactive. The second one described in 5.1.2. is active in the driving mode during normal operation.

#### 5.1.1. AC Primary Voltage (Cooling Mode)

Monitoring and protective actions:

- Primary-voltage monitoring
- Switch-off VCB if minimum voltage drops below the lower limit.

A) Available sensors and transformers:

Primary voltage transformer	: Pos. 3	MWB-VGF 36
Ratio	: 125:1	
Minimum voltage relay	: Pos. 86	MES-VSA/5R
Primary voltage	: nominal 25 kV AC	

B) Inputs to control system:  
not available

C) Limit-value monitoring, protective actions (U-Relay, hardware):

Minimum-voltage monitoring:

Trigger level 17,5 kV(RMS) (+/- 0.5 kV, no hysteresis) : VCB off  
Time delay switch off 2 sec (+/- 0.6 sec)  
Time delay switch on 0 - 1 sec

D) Implementation:

Hardware Function: The minimum voltage relay (Pos. 86) interrupts the power supply to the VCB's closing/holding coils.

**5.1.2. AC Primary Voltage (Driving Mode)**

Monitoring and protective actions:

- Primary-voltage monitoring and power limiting by power reduction according to protective characteristic curve in document 3EHP 551 009 (WAP-5) & 3EHP 551 010 (WAG-9) 'Specification ALG-Software'
- Switch-off VCB if minimum voltage drops below or if maximum voltage is exceeded.

## A) Available sensors and transformers:

Primary voltage transformer	: Pos. 3	MWB-VGF 36
Transformation ratio	: 125:1	
Transformer module	: Pos. 224.1	ABB-UU A225 A11
Transformation ratio	: 50:1	
Primary voltage	: nominal 25 kV AC	
Ratio total	: 6250:1	

## B) Inputs to control system:

Transformer 224.1/1 to BA 5/6 NSC1  
Transformer 224.1/2 to BA 5/6 NSC2

## C) Limit-value monitoring, protective actions:

## 1) Power limiting:

according to protective characteristic curve 1a network B1 in document 3EHP 551 009 (WAP-5) & 3EHP 551 010 (WAG-9) 'Specification ALG-Software'

## 2) Minimum-voltage monitoring:

$U \leq 17 \text{ kV(RMS)} / t_{\text{filt}} = 2 \text{ s} : \text{ VCB off}$   
(SLG: PA09\_P0903-GWUpMin / 100% = 10kV) / (SLG: PA09\_P0903-GWZeiUMin / 1G = 0,1s)

closing of VCB inhibited if  $U \leq 17.5 \text{ kV}$   
(FLG: PA09\_P0901-UprimLoLim / 100% = 10kV)

## 3) Maximum-voltage monitoring:

$U \geq 30 \text{ kV(RMS)} / t_{\text{filt}} = 1 \text{ s} : \text{ VCB off}$   
(SLG: PA09\_P0903-GWUpMax / 100% = 10kV) / (SLG: PA09\_P0903-GWZeiUMax / 1G = 0,1s)

closing of VCB inhibited if  $U \geq 29 \text{ kV}$   
(FLG: PA09\_P0901-UprimUpLim / 100% = 10kV)

## D) Implementation:

- The limit-value monitoring and the protective actions are implemented in both SLGs.
- The limit values shall be implemented as constants.

## 5.2 AC Primary Current

Monitoring and protective actions:

- Monitoring and limiting of primary current
- Switch-off VCB if maximum current exceeded (primary input current)

### 5.2.1 AC Primary Input Current (Hardware Function)

#### A) Available sensors and transformers:

Primary Current Sensor	: Pos. 6.1	Pfiffner G-IEBL1
Ratio	: 100 A ac : 1 A ac	
Maximum Current Relay	: Pos. 78	Sécheron DI/Pos.12
Auxiliary contact of maximum current relay		

#### B) Inputs to control system:

Auxiliary contact 78 to LD 4 STB1

#### C) Limit-value monitoring, protective action (I-Relay, hardware):

- 1) Maximum-current monitoring within 1 sec (+/- 0.2 sec) after switch-on of VCB (inrush current of transformer):  
Trigger level 990 A<sub>peak</sub> (+ 0 A / - 100 A): VCB off
- 2) Maximum-current monitoring during normal operation:  
Trigger level 360 A<sub>RMS</sub> (+ 0 A / - 20 A): VCB off

#### D) Implementation:

- Hardware Function: The maximum current relay (Pos. 78) interrupts the power supply to the VCB's closing/holding coils. In driving mode the auxiliary contact of Pos. 78 triggers a priority 1 fault message.
- In case of exceeded current in driving mode only one renewed switch-on attempt is permitted. Thereafter, the VCB remains in the open position and the vehicle is shut down.

### 5.2.2 AC Primary Return Current

#### A) Available sensors and transformers:

Primary Current Sensor	: Pos. 6.2	LEM LT 1000-SI/SP59
Ratio	: 5000:1	

#### B) Inputs to control system:

Sensor 6.2/1 to AA 6 SLG1  
Sensor 6.2/2 to AA 6 SLG2

#### C) Limit-value monitoring, protective action:

- 1) Maximum-current monitoring within 1,25 sec after switch-on of VCB (inrush current of transformer):  
 $I \geq 800 \text{ A(RMS)} / t_{\text{filt}} \text{ approx. } 50 \text{ ms: VCB off}$   
 (SLG: PA09\_P0903-GWlprEin / 100A = 10%) / (SLG: PA09\_P0903-GWZeIHSA0D / 1G = 0.1s)
- 2) Maximum-current monitoring during normal operation:  
 $I \geq 330 \text{ A(RMS)} / t_{\text{filt}} \text{ approx. } 50 \text{ ms: VCB off}$   
 (SLG: PA09\_P0903-GWlpr2DG / 100A = 10%) / (SLG: PA09\_P0903-GWZeIHSA0D / 1G = 0.1s)

#### D) Implementation:

- The maximum-current monitoring is implemented in both SLGs.
- One renewed switch-on attempt is permitted. Thereafter, the VCB remains in the open position and the vehicle is shut down.
- The limit values shall be implemented as constants.

### 5.3 Harmonic Filter Current

Monitoring and protective actions:

- Monitoring and limiting of harmonic filter current
- Switch-off VCB and harmonic filter contactor 8.1 if maximum current exceeded

A) Available sensors and transformers:

Harmonic Filter Current Sensor	: Pos. 8.5	LEM LT 1000-SI/SP59
Ratio	: 5000:1	

B) Inputs to control system:

Sensor 8.5/1 to AE 6 SLG1  
Sensor 8.5/2 to AE 6 SLG2

C) Limit-value monitoring, protective action:

1) Maximum-current monitoring within 1 sec after switch-on of harmonic-filter:

$I \geq 600 \text{ A(RMS)} / t_{\text{filt}} = 0 \text{ ms}$  : VCB off, contactor harmonic filter off  
(SLG: PA09\_P0903-GWIFiltEin / 100A = 10%) / (SLG: PA09\_P0903-GWZeiHSAFE / 1G = 0.1s)

2) Maximum-current monitoring during normal operation:

$I \geq 410 \text{ A(RMS)} / t_{\text{filt}} = 0 \text{ ms}$  : VCB off, contactor harmonic filter off  
(SLG: PA09\_P0903-GWIFilt / 100A = 10%) / (SLG: PA09\_P0903-GWZeiHSAIF / 1G = 0.1s)

D) Implementation:

- The maximum-current monitoring is implemented in both SLGs.
- One renewed switch-on attempt is permitted. Thereafter, the harmonic filter contactor 8.1 remains in the open position.
- The limit values shall be implemented as constants.

### 5.4 Hotel Load Current

Monitoring and protective actions:

- Monitoring and limiting of hotel load current
- Switch-off VCB and contactor hotel load supply (Pos. 32) if maximum current exceeded

A) Available sensors and transformers:

Current Sensor Hotel Load Supply	: Pos. 33	LEM LT 2000-S/SP20
Ratio	: 5000:1	
Range	: 0-2000A	

B) Inputs to control system:

Sensor 33/1 to AG 6 SLG1  
Sensor 33/2 to AG 6 SLG2

C) Limit-value monitoring, protective action:

1) Maximum-current monitoring:

$I \geq 1380 \text{ A(RMS)} / t_{\text{filt}} = 0 \text{ ms}$  : VCB off, contactor hotel load off with 500ms delay  
(SLG: PA09\_P0903-GWIZSS1Max / 100A = 10%) / (SLG: PA09\_P0903-GWZeiHSAIZ / 1G = 0.1s)

D) Implementation:

- The maximum-current monitoring is implemented in both SLGs.
- The contactor hotel load is controlled by STB1.
- One renewed switch-on attempt is permitted. Thereafter, the contactor hotel load supply 32 remains in the open position.
- The limit values shall be implemented as constants.
- To prevent the contactor hotel load supply (Pos. 32) from switching of high currents, the VCB shall always be switched off before the contactor is opened.

## 5.5 Auxiliary Current

Monitoring and protective actions:

- Monitoring and limiting of auxiliary converter current
- Switch-off VCB if maximum current exceeded

A) Available sensors and transformers:

Current Sensor	: Pos. 42.3	LEM LT 1000-SI/SP59
Ratio	: 5000:1	
Range	: 0-1000A	

B) Inputs to control system:

Sensor 42.3/1 to AC 6 SLG1  
Sensor 42.3/2 to AC 6 SLG2

C) Limit-value monitoring, protective action:

1) Maximum-current monitoring:

$I \geq 400 \text{ A(RMS)} / t_{\text{filt}} = 0 \text{ ms}$  : VCB off  
(SLG: PA09\_P0903-GWIBURMax / 100A = 10%) / (SLG: PA09\_P0903-GWZeHSAIB / 1G = 0.1s)

D) Implementation:

- The maximum-current monitoring is implemented in both SLGs.
- One renewed switch-on attempt is permitted. Thereafter, the VCB remains in the open position and the vehicle is shut down.
- The limit values shall be implemented as constants.

## 5.6 Vehicle Speed, Motor Speed

Monitoring and protective actions:

- Monitoring of maximum vehicle speed and maximum motor speed
- TE/BE-reduction if speed limits exceeded.

### A) Available sensors and transformers:

Speed Sensor Traction Motor	: Pos. 93.2	ABB
No. of pulses	: 120 pulses/revolution	
Measuring range	: + / - 6000 rpm	

Auxiliary contact HASLER-Memotel (Pos. 94.2) "v >= 105% max service speed"

Auxiliary contact HASLER-Memotel (Pos. 94.2) "v >= 110% max service speed"

### B) Inputs to control system for motor speed:

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- 1) Bogie 1 Motor 1 93.2/1 to HA 6/7 ASC 1 + HC 6/7 ASC1
- 2) Bogie 1 Motor 2 93.2/2 to HE 6/7 ASC 1 + HG 6/7 ASC1
- 3) Bogie 2 Motor 3 93.2/3 to HA 6/7 ASC 2 + HC 6/7 ASC2
- 4) Bogie 2 Motor 4 93.2/4 to HE 6/7 ASC 2 + HG 6/7 ASC2

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- 1) Bogie 1 Motor 1 93.2/1 to HA 6/7 ASC 1
- 2) Bogie 1 Motor 2 93.2/2 to HC 6/7 ASC 1
- 3) Bogie 1 Motor 3 93.2/3 to HE 6/7 ASC 1
- 4) Bogie 2 Motor 4 93.2/4 to HA 6/7 ASC 2
- 5) Bogie 2 Motor 5 93.2/5 to HC 6/7 ASC 2
- 6) Bogie 2 Motor 6 93.2/6 to HE 6/7 ASC 2

Inputs to control system for vehicle speed:

Vehicle-speed information of HASLER-Memotel speed recorder via FLG2

- a) Binary signal "v >= 105% max service speed" to JD 3 STB2
- b) Binary signal "v >= 110% max service speed" to JD 11 STB2

Type	max service speed	max test speed
WAP-5	160 km/h	180 km/h
WAG-9	100 km/h	110 km/h

### C) Limit-value monitoring, protective actions:

- 1) Protective limits vehicle speed v [km/h] and motor speed n [rpm].

The vehicle speed limits refer to half-worn wheels (d = 1054 mm):

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- a)  $0 \leq v \leq 160 \text{ km/h}$  : 100% TE
- b)  $160 \text{ km/h} < v \leq 178 \text{ km/h}$  : Linear TE reduction from 100% to 0% in FLG  
(FLG: PA53\_P5302-VmaxLimBoB / 100% = 100km/h)
- c)  $v > 178 \text{ km/h}$  : TE inhibited in SLG (SLG: PA09\_P0905-GWvmax / 100% = 100km/h)
- d)  $n > 3705 \text{ rpm}$  : TE inhibited in ALG, gear ratio 1:3.941  
 $v = 187 \text{ km/h}$
- a.) and b.) for shunting mode : 15 km/h (FLG: PA53\_P5302-VmaxShBoBo / 100% = 100 km/h)

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- a)  $0 \leq v \leq 100 \text{ km/h}$  : 100% TE
- b)  $100 \text{ km/h} < v \leq 110 \text{ km/h}$  : Linear TE reduction from 100% to 0% in FLG  
(FLG: PA53\_P5303-VmaxLimCoC / 100% = 100km/h)
- c)  $v > 112 \text{ km/h}$  : TE inhibited in SLG (SLG: PA09\_P0905-GWvmaxCoCo / 100% = 100km/h)
- d)  $n > 2948 \text{ rpm}$  : TE inhibited in ALG, gear ratio 1:5.133  
 $v = 114 \text{ km/h}$
- a.) and b.) for shunting mode : 15 km/h (FLG: PA53\_P5302-VmaxShCoCo / 100% = 100 km/h)

2) Monitoring of maximum vehicle speed in HASLER-Memotel and FLG2:

- 1)  $v \geq 105\%$  max service speed : acoustic warning on buzzer Pos. 238
- 2)  $v \geq 110\%$  max service speed : emergency brake application (hardware function)

D) Implementation:

- The vehicle speed limits and the corresponding protective actions are implemented in FLGs, SLGs and ALGs as described in clause C1.
- The limit values shall be implemented as constants.
- It shall be possible to inhibit the vehicle speed limits in SLG and FLG in a simple way to enable test runs at speeds above these limits.
- The monitoring of " $v \geq 105\%$  max service speed" is implemented in HASLER-Memotel.  
The FLG2 activates the buzzer.
- The monitoring of " $v \geq 110\%$  max service speed" is implemented in HASLER-Memotel.  
It interrupts the power supply to the EP valve emergency braking (ABB Pos. 243 / D&M Pos. 72).
- The limit values shall be implemented as parameters in the HASLER-Memotel software.



## 5.7 Traction Motor Temperatures

Monitoring and protective actions:

- Monitoring of motor temperature
- TE/BE reduction, increase of ventilation

A) Available sensors and transformers:

Temperature Sensor Traction Motor	: Pos. 98	CAG Pt100
Element	: Pt100	

B) Inputs to control system:

WAP-5:

Bogie 1 Temperature 1.1 98/1	to DA 6/1 SLG1
Bogie 1 Temperature 1.2 98/2	to DA 5/9 SLG1
Bogie 1 Temperature 2.1 98/3	to DC 6/1 SLG1
Bogie 1 Temperature 2.2 98/4	to DC 5/9 SLG1
Bogie 2 Temperature 3.1 98/5	to DA 6/1 SLG2
Bogie 2 Temperature 3.2 98/6	to DA 5/9 SLG2
Bogie 2 Temperature 4.1 98/7	to DC 6/1 SLG2
Bogie 2 Temperature 4.2 98/8	to DC 5/9 SLG2

WAG-9:

Bogie 1 Temperature 1.1 98/1	to DA 6/1 SLG1
Bogie 1 Temperature 1.2 98/2	to DA 5/9 SLG1
Bogie 1 Temperature 2.1 98/3	to DC 6/1 SLG1
Bogie 1 Temperature 2.2 98/4	to DC 5/9 SLG1
Bogie 1 Temperature 3.1 98/5	to DE 6/1 SLG1
Bogie 1 Temperature 3.2 98/6	to DE 5/9 SLG1
Bogie 2 Temperature 4.1 98/7	to DA 6/1 SLG2
Bogie 2 Temperature 4.2 98/8	to DA 5/9 SLG2
Bogie 2 Temperature 5.1 98/9	to DC 6/1 SLG2
Bogie 2 Temperature 5.2 98/10	to DC 5/9 SLG2
Bogie 2 Temperature 6.1 98/11	to DE 6/1 SLG2
Bogie 2 Temperature 6.2 98/12	to DE 5/9 SLG2

C) Limit-value monitoring, protective actions (T = actual motor temperature, see E):

1) Ventilation control (increasing ramp = 5Hz/s, decreasing ramp = 2Hz/s):

Ventilation off T < 55°C and TE/BE < 70% and no ventilation afterwards demanded

Level 1      ↑ T = 60°C ↓ T=55°C (Hyst. 5°C) (SLG: PA09\_P0902-GWTmpMotL1 / 100°C= 100%)

Level 2      ↑ T = 80°C ↓ T=75°C (Hyst. 5°C) (SLG: PA09\_P0902-GWTmpMotL2 / 100°C= 100%)  
or [TE/BE > 50%\* and v < ↑30km/h, ↓25km/h (Hyst. TE/BE=10%, v=5km/h)] (30 sec  
ventilation afterwards if TE/BE was > 50%). Rules only valid for speed > 30 km/h; for  
speed < 30 km/h level 1.

Level 3      ↑ T = 100°C ↓ T=95°C (Hyst. 5°C) (SLG: PA09\_P0902-GWTmpMotL3 / 100°C= 100%)  
or [TE/BE > 50%\* and v > ↑30km/h, ↓25km/h (Hyst. TE/BE=10%, v=5km/h)]  
or level 2 longer than 20 sec because of TE/BE > 50%  
(30 sec ventilation afterwards if TE/BE was > 50%) Rules only valid for speed > 30  
km/h; for speed < 30 km/h level 2.

Remark: Due to redistribution of BUR loads, traction motor blowers are always running in  
level 3 (fixed frequency). But software managing ventilation levels remains untouched.

2) Reduction of TE/BE:

TE/BE 100%	T < 210°C (SLG: PA09_P0902-LRTmpMot / 100°C= 100%)
TE/BE reduction from 100% to 0%	210°C < T < 230°C

GTO-pulsing inhibited:

(SLG: PA09\_P0902-GWTmpMot / 100°C= 100%)

T ≥ 230°C longer than 10 sec

(SLG: PA09\_P0902-GWTmpMot / 100°C= 100%)

\* 50% means here 50% TE/BE of TE/BE max. in kN of BoBo or CoCo loco (not dependent on speed)

#### D) Implementation:

- Normally, the maximum value is formed by the two temperature sensors for each motor.
- If the two values of a motor differ by more than 10 K, then a diagnostic data set (DDS) will be issued. If an open circuit or short circuit is detected of one sensor, the value of this sensor won't be monitored anymore and a diagnostic data set (DDS) will be issued likewise.
- If in both sensors (PT-100) of one motor an open or a short circuit is detected a traction interlock of this bogie (TE/BE = 0) and ventilevel 3 is generated.
- If the difference between the maximum and minimum temperature values within the motors of one bogie is more than 50 K, a diagnostic data set (DDS) will be likewise issued.
- The monitoring of the traction-motor temperature, the TE/BE-reduction and the GTO-pulsing inhibition are implemented in both SLGs.
- The limit values shall be implemented as parameters.
- The control of ventilation levels is implemented in SLG1 and SLG2.
- The limit values shall be implemented as parameters.

#### E) Gradient function

The time delay between stator iron core and winding head is taken in consideration by the following formula:

T (actual motor temperature) = measured motor temperature +  
temperature increase during one minute x 10 (offset is limited on 200 Kelvin)

## 5.8 Transformer Oil Pressure

Monitoring and protective actions:

- Monitoring of difference of pressure from the oil cooler In-/Output in the circuit developed by the oil pumps
- Power reduction, VCB off, increase of ventilation, hotel load off

A) Available sensors and transformers:

Pressure Sensors Transformer Oil Circuit	: Pos. 213.5	Baumer PDRB K005W22B240
Scale: 4-20mA	: 0-4bar	
Amplifier: different pressure oil cooler In-/Output	: Pos 214	Baumer
Scale: 4-20mA	: 0-4bar (250 mbar = 1 mA)	

B) Inputs to control system:

Amplifier pos.214/1 to AI 6/3 SLG1  
Amplifier pos.214/2 to AI 6/3 SLG2

C) Limit-value monitoring, protective actions:

- 1) failure of measurement transformer oil circuit, while oil pump is off:  
monitoring active only before the oil pump is switched ON for the first time:  
if signal > 6 mA (0.5 bar) (SLG:  $PA09\_P0902-GWDruEinTR / 2 \text{ bar} = 100\%$ )  
--> power reduction to 70% per bogie + ventilation level 3, hotel load off
- 2) failure of one transformer oil circuit while oil pump is on:  
monitoring active 20 sec after the oil pump is switched ON:  
if signal < 7 mA (0.75 bar) (SLG:  $PA09\_P0902-GWDruMinTR / 2 \text{ bar} = 100\%$ )  
or signal > 14 mA (2.5 bar) for more than 10 seconds (SLG:  $PA09\_P0902-GWZei2TSTR / 1G = 1s$ )  
--> power reduction to 70% per bogie + ventilation level 3, hotel load off
- 3) failure of both transformer oil circuits:  
failure of both pumps (both signals not correct or missing)  
--> power reduction to 0% + VCB off + hotel load off

D) Implementation

- The oil pressure monitoring is implemented in both SLG.
- The control of ventilation-levels is implemented in SLG1 and SLG2.
- The hotel load is switched off by STB1.
- The limit values shall be implemented as parameters.

## 5.9 Transformer Temperature

Monitoring and protective actions:

- Monitoring of transformer oil temperature
- Increase of ventilation, TE/BE-reduction, GTO-pulsing inhibit, VCB off

A) Available sensors and transformers:

Temperature Sensor Transformer Oil Circuit	: Pos. 210.51	Allmetra 2Pt100/B/2
Element	: Pt100	

B) Inputs to control system:

Sensor 210.51/1 Temperature 1 to DI 5/9 SLG 1  
 Sensor 210.51/1 Temperature 2 to DI 6/1 SLG 1  
 Sensor 210.51/2 Temperature 1 to DI 5/9 SLG 2  
 Sensor 210.51/2 Temperature 2 to DI 6/1 SLG 2

C) Limit-value monitoring, protective actions

1) Ventilation control (increasing ramp = 5Hz/s, decreasing ramp = 2Hz/s):

Ventilation off  $T < 47^{\circ}\text{C}$

Level 1  $\uparrow T = 50^{\circ}\text{C}$   $\downarrow T = 47^{\circ}\text{C}$  (Hyst. 3 K) (SLG: PA09\_P0902-GWTmpTRL1 /  $100^{\circ}\text{C} = 100\%$ )

Level 2  $\uparrow T = 55^{\circ}\text{C}$   $\downarrow T = 52^{\circ}\text{C}$  (Hyst. 3 K) (SLG: PA09\_P0902-GWTmpTRL2 /  $100^{\circ}\text{C} = 100\%$ )

Level 3  $\uparrow T = 60^{\circ}\text{C}$   $\downarrow T = 57^{\circ}\text{C}$  (Hyst. 3 K) (SLG: PA09\_P0902-GWTmpTRL3 /  $100^{\circ}\text{C} = 100\%$ )

2) Reduction of TE/BE:

TE/BE 100%	$T < 80^{\circ}\text{C}$ (SLG: PA09_P0902-LRBTmpOITR / $100^{\circ}\text{C} = 100\%$ )
TE/BE reduction from 100% to 0%	$80^{\circ}\text{C} < T < 84^{\circ}\text{C}$
GTO-pulsing inhibited:	$T \geq 84^{\circ}\text{C}$ (SLG: PA09_P0902-GWTmpOeITR / $100^{\circ}\text{C} = 100\%$ )

3) VCB Off:  $T \geq 84^{\circ}\text{C}$  longer than 10 sec

D) Implementation:

- Monitoring starts 40 sec after switch-on of VCB.  
The maximum of the oil-temperature measurements is decisive.
- Plausibility-check in SLG1/2: diagnostic data set (DDS), if temperature difference  $> 10^{\circ}\text{C}$  in one sensor. If an open circuit or a short circuit is detected in one sensor, the temperature in this sensor will not be taken into consideration and a diagnostic data set (DDS) will be issued likewise.
- If in both sensors of a bogie an open or a short circuit is detected, the same protective actions will be triggered as if the corresponding oil pump would not be working (TE/BE reduction to 70% per bogie). The temperature is only valid, if the corresponding oil circuit is normally operating.
- The temperature monitoring and the protective actions (TE/BE-reduction, GTO-pulsing inhibition, VCB tripping) are implemented in both SLGs.
- The control of ventilation-levels is implemented in SLG1 and SLG2.
- The limit values shall be implemented as parameters.

## 5.10 Converter Oil Pressure

Monitoring and protective actions:

- Monitoring of the pressure in the circuit developed by the oil pumps
- GTO-pulsing inhibition, VCB off

A) Available sensors and transformers:

Pressure Sensor Converter Oil Circuit	: Pos. 210.62	Baumer PDRB K005W22B240
Scale: 4-20mA	: 0-4 bar linear	

B) Inputs to control system:

Sensor 210.62/1 to DK 7/3 SLG 1  
Sensor 210.62/2 to DK 7/3 SLG 2

C) Limit-value monitoring, protective actions:

1) Oil-pressure monitoring:

a) Converter oil temperature < 50°C

pressure < 1.3 bar / 20 sec: VCB off

(SLG: PA09\_P0902-GWDruck1SR / 1bar = 100%) / (SLG: PA09\_P0902-GWZeitSSR1 / 1G = 1s)

b) Converter oil temperature > 50°C

pressure < 1.5 bar / 20 sec: VCB off

(SLG: PA09\_P0902-GWDruck2SR / 1bar = 100%) / (SLG: PA09\_P0902-GWZeitSSR1 / 1G = 1s)

D) Implementation:

- Monitoring starts 40 sec after switch-on of VCB.
- The oil pressure monitoring is implemented in the SLG of the converter.
- In case of failure the bogie has to be isolated after the second switch-on attempt.
- The limit values shall be implemented as parameters.

## 5.11 Converter Oil Temperature

Monitoring and protective actions:

- Monitoring of the converter oil temperature
- increase of ventilation, TE/BE-reduction, GTO-pulsing inhabitation, VCB off

A) Available sensors and transformers:

Temperature Sensor Converter Oil Circuit : Pos. 210.61 Allmetra 2Pt100/B/2  
Element : Pt100

B) Inputs to control system:

Sensor 210.61/1 Temperature 1 to DG 1/6 SLG1

Sensor 210.61/1 Temperature 2 to DG 9/5 SLG1

Sensor 210.61/2 Temperature 1 to DG 1/6 SLG2

Sensor 210.61/2 Temperature 2 to DG 9/5 SLG2

C) Limit-value monitoring, protective actions:

1) Ventilation control (increasing ramp = 5Hz/s, decreasing ramp = 2Hz/s):

Ventilation off  $T < 42^{\circ}\text{C}$

Level 1  $\uparrow T = 45^{\circ}\text{C}$   $\downarrow T = 42^{\circ}\text{C}$  (Hyst.  $3^{\circ}\text{C}$ ) (SLG: PA09\_P0902-GWTmpSRL1 /  $100^{\circ}\text{C} = 100\%$ )

Level 2  $\uparrow T = 50^{\circ}\text{C}$   $\downarrow T = 47^{\circ}\text{C}$  (Hyst.  $3^{\circ}\text{C}$ ) (SLG: PA09\_P0902-GWTmpSRL2 /  $100^{\circ}\text{C} = 100\%$ )

Level 3  $\uparrow T = 55^{\circ}\text{C}$   $\downarrow T = 52^{\circ}\text{C}$  (Hyst.  $3^{\circ}\text{C}$ ) (SLG: PA09\_P0902-GWTmpSRL3 /  $100^{\circ}\text{C} = 100\%$ )

2) Reduction of TE/BE:

TE/BE 100%

$T < 62^{\circ}\text{C}$  (SLG: PA09\_P0902-LRBTmpOISR /  $100^{\circ}\text{C} = 100\%$ )

TE/BE reduction from 100% to 0%

$64^{\circ}\text{C} < T < 66^{\circ}\text{C}$

GTO-pulsing inhibited:

$T \geq 66^{\circ}\text{C}$  (SLG: PA09\_P0902-LRETmpOISR /  $100^{\circ}\text{C} = 100\%$ )

3) VCB Off:

$T \geq 80^{\circ}\text{C}$  longer than 10 sec

(SLG: PA09\_P0902GWTmpOelSR /  $100^{\circ}\text{C} = 100\%$ )

D) Implementation:

- Monitoring starts 5 sec after switch-on of VCB.
- The maximum of the two oil-temperature measurements is decisive.
- Plausibility-check in SLG1/2: diagnostic data set (DDS), if temperature difference  $> 10^{\circ}\text{C}$  in one sensor. If an open circuit or a short circuit is detected in one sensor, the temperature in this sensor will not be taken into consideration and a diagnostic data set (DDS) will be issued likewise.
- If an open or a short circuit is detected in both PT100 sensors VCB off is generated. The limit values are implemented as parameters.
- The control of ventilation is implemented in SLG1 and SLG2.
- The limit values of clauses C)1) and C)2) shall be implemented as parameters.  
The limit value of clause C)3) shall be implemented as constant.
- real temperature = measured temperature – 3.5 K  
(to get the same temperature as measured with a calibration equipment)

## 5.12 DC-Link Voltage Main Converter

Monitoring and protective actions:

- Monitoring the DC-link voltage of the main converter
- Definition of the two DC-link status (discharged, charged)
- If charging process failed then switch-off:
  - VCB,
  - contactor converter precharging (Pos. 12.3)
  - contactor converter (Pos. 12.4)

Definitions:

Udc = DC Link Voltage

A) Available sensors and transformers:

Voltage sensor DC-link	: Pos. 15.6	KUK-Elektronik PV C000 A01
Ratio	: 400:1	
Range	: 4000 V .. 10 V	

B) Inputs to control system:

Sensor 15.6/1 to CI 6/5 ASC1  
 Sensor 15.6/2 to CK 6/5 ASC1  
 Sensor 15.6/3 to CI 6/5 ASC2  
 Sensor 15.6/4 to CK 6/5 ASC2

C) Limit-value monitoring, protective action:

Udc < 150 V : DC-link discharged (SLG: PA09\_P0904-GWUDleer / 1000V = 100%)  
 Udc > 2100 V : DC-link charged (variable DC-link voltage: 2100 - 2800 V)  
 2100 V: (SLG: PA09\_P0904-GWUDmin / 1000V = 100%)  
 2800 V: (SLG: PA09\_P0904-GWUDmax / 1000V = 100%)  
 Udc > 3200 V : MUB firing till DC-link voltage reaches 2800 V, if DC-link voltage doesn't lower MUB to hot will be detected and a protective shutdown is generated

Udc < 400 V (experienced value), 1 sec after contactor precharging (12.3) is closed:  
 Switch-off VCB, contactor converter precharging (Pos. 12.3) and contactor converter (Pos. 12.4)

D) Implementation:

- The monitoring of the DC-link voltage is implemented in the SLG of the converter.
- In case of failure during charging, the converter shall be isolated by opening 12.3 (contactor converter precharging) and 12.4 (contactor converter).
- If there is a difference between the two DC-link sensor values a diagnostic data set (DDS) is generated.
- The limit values shall be implemented as constants.

### 5.13 Earth fault Detection Main Converter

Monitoring and protective actions:

- Monitoring of the isolation of the main converter

Definitions:

$U_e$  = Earth fault-Voltage

$U_{dc}$  = DC Link Voltage

A) Available sensors and transformers:

Earth fault detection DC-link main converter	: Pos. 89.4	KUK-Elektronik PV C000 A01
Ratio	: 400:1	
Range	: 4000 V .. 10 V	

Voltage sensor DC-link	: Pos. 15.6	KUK-Elektronik PV C000 A01
Ratio	: 400:1	
Range	: 4000 V .. 10 V	

B) Inputs to control system:

Sensor 89.4/1 to AK 6/5 SLG1

Sensor 15.6/1 to CI 6/5 ASC1

Sensor 15.6/2 to CK 6/5 ASC1

Sensor 89.4/2 to AK 6/5 SLG2

Sensor 15.6/3 to CI 6/5 ASC2

Sensor 15.6/4 to CK 6/5 ASC2

C) Limit-value monitoring, protective action:

$U_e/U_{dc} < 0.35 / 20 \text{ sec}$  : DDS 'earth fault on the positive potential of the DC-link'

(SLG: PA09\_P0904-GWESZK1OG / 1000V = 100%)

$0.35 < U_e/U_{dc} < 0.65 / 20 \text{ sec}$  : DDS 'earth fault in the AC-part of traction circuits'

e.g. traction winding of the transformer or traction motor

(SLG: PA09\_P0904-GWESZK2UG / 1000V = 100%)

(SLG: PA09\_P0904-GWESZK2OG / 1000V = 100%)

$0.65 < U_e/U_{dc} < 0.85$  : normal operation

$0.85 < U_e/U_{dc} / 20 \text{ sec}$  : DDS 'earth fault on the negative potential of the DC-link'

(SLG: PA09\_P0904-GWESZK3UG / 1000V = 100%)

Description of earth fault measurement:

Normal operation  $U_e = U_{dc} \cdot R1 / (R1 + R2)$ ,  $R1 \neq R2$

Earth fault AC part  $U_e = U_{dc} / 2$

Earth fault positive potential  $U_e = 0$

Earth fault negative potential  $U_e = U_{dc}$

D) Implementation:

- The earth fault monitoring starts as soon as a contactor in the converter is closed, either Pos. 12.3 (contactor converter precharging) or Pos. 12.4. (contactor converter). It is implemented in the SLG of the converter.
- The limit values shall be implemented as constants.



## 5.14 Pressure Capacitor DC-Link

Monitoring and protective actions:

- Monitoring of the pressure of the DC-link capacitors

A) Available sensors and transformers:

Pressure switch capacitor DC-link : Pos 15.52 CONDIS

B) Inputs to control system:

Binary input of 15.52/ 1..14 to WD 11 SLG1

Binary input of 15.52/15..28 to WD 11 SLG2

C) Limit-value monitoring, protective action:

binary signal 1 : normal operation

binary signal 0 / 5 sec : diagnostic data set (DDS) 'overpressure in capacitor DC-link'  
(there's no selfprotection from over pressure through the pressure switch,  
only message to the driver will be generated)

(SLG: PA09\_P0904-GWZeiC / 1G = 0.1s)

D) Implementation:

- The pressure of the DC-link capacitors is monitored as soon as a contactor in the converter is closed, either Pos. 12.3 (contactor converter precharging) or Pos. 12.4. (contactor converter). It is monitored by the SLG of the converter.
- The limit values shall be implemented as constants.

## 5.15 Earth fault Battery Circuit

Monitoring and protective actions:

- Monitoring the earth fault current of the battery circuit

A) Available sensors and transformers:

Earth fault Relay : Pos 89.7 ABB BVW 2800/110V

B) Inputs to control system:

Binary input of 89.7 to QD11 HBB1

C) Limit-value monitoring, protective action:

binary signal 0 : normal operation

binary signal 1 / 3 min : diagnostic data set (DDS) 'earth fault battery circuit'

(HBB1: PA09\_P0902MEFRContTon / 1G = 0.2s)

D) Implementation:

- The earth fault current is monitored by HBB1.
- The limit values shall be implemented as constants.

## 5.16 Earth fault Hotel Load Supply

Monitoring and protective actions:

- Monitoring of the earth fault current of the hotel load supply
- Switch-off VCB and contactor hotel-load supply (Pos. 32) if earth fault detected

A) Available sensors and transformers:

Current Relay : Pos 38.1 ABB BVW 2800/110V

B) Inputs to control system:

Binary input of 38.1 to QD9 HBB1

C) Limit-value monitoring, protective action:

binary signal 0 : normal operation

binary signal 1 / 1 sec : VCB off, contactor hotel load supply (Pos. 32) off

(HBB1: PA09\_P0902MEFRHoteTon / 1G = 0.2s)

D) Implementation:

- The earth fault current is monitored by HBB1 as soon as the contactor hotel load supply (Pos. 32) is closed. The contactor hotel load is controlled by STB1, the VCB is controlled by HBB1.
- The limit values shall be implemented as constants.

## 5.17 Earth fault Auxiliary Circuit

Monitoring and protective actions:

- Monitoring of the earth fault current of the auxiliary circuit

A) Available sensors and transformers:

Earth fault Relay : Pos 89.2 ABB BVW 2800/110V

B) Inputs to control system:

Binary input of 89.2 to LA12 STB2

C) Limit-value monitoring, protective action:

binary signal 0 : normal operation

binary signal 1 / 3 min : diagnostic data set (DDS) 'earth fault auxiliary circuit'

(STB2: PA09\_P0902-EFFilter / 1G = 0.1s)

D) Implementation:

- The earth fault current is monitored by STB2.
- The limit values shall be implemented as constants.

## 5.18 Earth fault 415V/110V Circuit

Monitoring and protective actions:

- Monitoring of the earth fault current of the 415V/110V circuit

A) Available sensors and transformers:

Current Relay : Pos 89.5 ABB BVW 2800/110V

B) Inputs to control system:

Binary input of 89.5 to QD1 HBB1

C) Limit-value monitoring, protective action:

binary signal 0 : normal operation

binary signal 1 / 3 min : diagnostic data set (DDS) 'earth fault 415V/110V circuit'

(HBB1: PA09\_P0902MEFR415Ton / 1G = 0.2s)

D) Implementation:

- The earth fault current is monitored by HBB1.
- The limit values shall be implemented as constants.

## 5.19 Earth fault Filter Circuit

Monitoring and protective actions:

- Monitoring of the earth fault current of the filter circuit

A) Available sensors and transformers:

Current Relay : Pos 89.6 ABB BVW 2800/110V

B) Inputs to control system:

Binary input of 89.6 to QD3 HBB1

C) Limit-value monitoring, protective action:

binary signal 0 : normal operation

binary signal 1 / 3 min : diagnostic data set (DDS) 'earth fault filter circuit'

(HBB1: PA09\_P0902MEFRFiltTon / 1G = 0.2s)

D) Implementation:

- The earth fault current is monitored by HBB1.
- The limit values shall be implemented as constants.

## APPENDIX A: LIST OF CHANGES

Release C	Paragraph:	modification:
	5.1.1 A	minimum voltage relay
	5.1.2 A	primary voltage: cancelled
	5.2.1 C	0..1 sec replace by "within 1 sec"
	5.2.2 C	0..5 sec replace by "within 5 sec"
	5.3 C	0..1 sec replace by "within 1 sec"
	5.6 C	WAG-9: b) 108 km/h replace by 110km/h c) $v > 110 \text{ km/h}$ replace by $v > 112 \text{ km/h}$
	5.7 D	inhibition
	5.7 C	1) $T < 80^\circ\text{C}$ 2) $T < 190^\circ\text{C}$
	5.7 F	ventilation level 1..... cancelled
	5.8	new: transformer oil pressure measurement (difference pressure in/output of oil cooler)
	5.6 + 5.9	according replace by corresponding
	5.11 C	1) $T < 40^\circ\text{C}$ 2) $T < 60^\circ\text{C}$
	5.12 C	$U_{dc} < 400 \text{ V}$ , 1 sec --> check from DC-link and contactor precharging
	5.13 C	$0.35 < U_e/U_{dc} < 0.65$ / 20 sec --> in case of an earth fault in AC-part of traction circuit $U_e = U_{dc}/2$ --> normal operation $U_e = U_{dc} \cdot R_1 / (R_1 + R_2)$ , $R_1 \neq R_2$
	5.14 C	completion: There's no selfprotection from over pressure through the pressure switch, only a indication available
	5.16 C	3 min replace by 1 sec
	5.10 C	missing of pressure oil circuit new 20 sec
	5.14 D) 5.19 D)	... The limit values shall be implemented as constants.
Release D	5.6 A)	
	5.7 C)	
	5.7 D)	SLG1, SLG2
	5.7 E)	
	5.7 F)	deleted
	5.8 A)	0-4 bar (250mbar =1mA)
	5.8 C)	1) reduction to 70% per bogie, 2) or signal $> 14 \text{ mA}$ for more then 10 sec
	5.8 D)	SLG1, SLG2
	5.9 C)	
	5.9 D)	SLG1/2
	5.9 E)	deleted
	5.10 C)	GTO-pulsing inhibited deleted

	5.11 C)	
	5.11 E)	deleted
	5.12	DC-link status (discharged, charged), switch off VCB .....
	5.12 C)	Udc > 3200 V .....
Release E	4.	Precise explaining of description of limits and triggered actions (time for VCB off, contactor off and sample time)
	5.1.1 C)	Detailed limit values of primary voltage (cooling mode)
	5.2.1 C)	Detailed limit values of primary overcurrent
	All	Detailed definition of current or voltage (RMS, peak value)
	5.6	gear ratio, speed if $n > 3705 / 2948$ BoBo/CoCo
	5.7, 5.9, 5.11	Definition of failure if in both sensors an open or a short circuit is detected
	5.10	Pressure changed from 2 bar to 1.5 bar
	5.7.C).1)	Definition of TE/BE > 70% in case of level 2 or level 3 ventilation
	5.1.1 A)	Elin-PSPW 10/25/S replaced by MWB-VGF 36
	5.1.2. A)	Elin-PSPW 10/25/S replaced by MWB-VGF 36
Release F	5.7.C).2)	$T \geq 230^{\circ}\text{C}$ <b>longer than 10 sec</b>
	5.3.C).2)	Harmonic filter current: $I \geq 410\text{A}_{(\text{RMS})}$ / $t_{\text{filt}} = 500\text{ms}$
	5.5.C).1)	Auxiliary current: $I \geq 400\text{A}_{(\text{RMS})}$
Release G	All	Parameter names for all limitations: ( <i>Processorname</i> , <i>Parametername</i> , <i>Scaling</i> )
	5.1.2	2) Minimum-voltage monitoring: $U \leq 17 \text{ kV}_{(\text{RMS})}$ / $t_{\text{filt}} = 2\text{s}$ : VCB off
	5.10	<b>a) Converter oil temperature &lt; 50°C</b> pressure < <b>1.3 bar</b> / 20 sec: VCB off <b>b) Converter oil temperature &gt; 50°C</b> pressure < 1.5 bar / 20 sec: VCB off
	5.12	C) Udc < <b>150V</b>
Release H	4.	All values defined correspond to the software release 1.20 for WAP5/WAG9 as delivered in December 99
	4.	An exception exists for the primary current. Switching off a high primary current should be done very fast. To reduce the sample time, the input signal is differenced to get a faster rise time. The resulting filter time and sampling time is approx. 50 ms (see SLG segment 0104)
	5.1.2	PA09_P0903-GWZeiUMin / 1G = 0,1s PA09_P0903-GWZeiUMax / 1G = 0,1s
	5.2.2	Maximum-current monitoring within <b>1,25</b> sec after switch-on of VCB..... (old value: 5 sec)
	5.2.2	$t_{\text{filt}}$ <b>approx. 50 ms</b> (old value: = 200 ms)
	5.3	$t_{\text{filt}} = 0$ ms (old value : 100, 500 ms)
	5.4	$t_{\text{filt}} = 0$ ms (old value : 300 ms)
	5.5	$t_{\text{filt}} = 0$ ms (old value : 200 ms)
	5.6	a.) and b.) for shunting mode: 15 km/h (FLG: PA53_P5302-VmaxShBoBo / 100% = 100 km/h)

- 5.6 a.) and b.) for shunting mode: 15 km/h (FLG: PA53\_P5302-VmaxShCoCo / 100% = 100 km/h)
- 5.7 Level 2  $\uparrow T = 80^{\circ}\text{C}$   $\downarrow T = 75^{\circ}\text{C}$  (Hyst.  $5^{\circ}\text{C}$ ) (SLG: PA09\_P0902-GWTmpMotL2 /  $100^{\circ}\text{C} = 100\%$ )  
or  $[TE/BE > 50\%^* \text{ and } v < \uparrow 30\text{km/h}, \downarrow 25\text{km/h}$  (Hyst.  $TE/BE = 10\%$ ,  $v = 5\text{km/h}$ )] (30 sec ventilation afterwards if  $TE/BE$  was  $> 50\%$ ). Rules only valid for speed  $> 30 \text{ km/h}$ ; for speed  $< 30 \text{ km/h}$  level 1.
- Level 3  $\uparrow T = 100^{\circ}\text{C}$   $\downarrow T = 95^{\circ}\text{C}$  (Hyst.  $5^{\circ}\text{C}$ ) (SLG: PA09\_P0902-GWTmpMotL3 /  $100^{\circ}\text{C} = 100\%$ )  
or  $[TE/BE > 50\%^* \text{ and } v > \uparrow 30\text{km/h}, \downarrow 25\text{km/h}$  (Hyst.  $TE/BE = 10\%$ ,  $v = 5\text{km/h}$ )]  
or level 2 longer than 20 sec because of  $TE/BE > 50\%$   
(30 sec ventilation afterwards if  $TE/BE$  was  $> 50\%$ ) Rules only valid for speed  $> 30 \text{ km/h}$ ; for speed  $< 30 \text{ km/h}$  level 2
- 5.8 C1) ..... power reduction to 70% per bogie + ventilation level 3, **hotel load off**
- 5.8 C2) .....for more than 10 5 seconds .....power reduction to 70% per bogie + ventilation level 3, **hotel load off**
- 5.9 Level 1:  $T = 50/47^{\circ}\text{C}$  (old values: 60/55)  
Level 2:  $T = 55/52^{\circ}\text{C}$  (old values: 68/63)  
Level 1:  $T = 60/57^{\circ}\text{C}$  (old values: 76/71)  
all levels: hysteresis = 3 K (old value: 5)
- 5.11 C)  $TE/BE$  reduction from 100% to 0%  $64^{\circ}\text{C} < T < 66^{\circ}\text{C}$  (old values: 62/65)  
D) – Monitoring starts 5 sec after switch-on VCB (old value: 40)  
- real temperature = measured temperature – 3.5 K  
(to get the same temperature as measured with a calibration equipment)
- Release I 4. Updates for release I are requested by Bombardier Transportation India due to reviewing the documents.
- 1.1 [1] Vehicle Control System Software Specification (Revision F) 3EHP 541 681
- 5.7 **Remark: Due to redistribution of BUR loads, traction motor blowers are always running in level 3 (fixed frequency). But software managing ventilation levels remains untouched.**
- 5.7 Ventilation off  $T < 60 \text{ } 55^{\circ}\text{C}$  and ..
- 5.9 Ventilation off  $T < 55 \text{ } 47^{\circ}\text{C}$

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# Vehicle Control System Software - Specification

INDIAN RAILWAYS WAP-5/WAG-9



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## **1. Introduction**

### **1.1 General**

Anything not specified in this specification will not be implemented by software function. All optional software functions which are not specified in this document shall be ordered by change request.

This specification describes all the control system functions of consequence for the operation of the WAP-5 and WAG-9 locomotives for the Indian Railways project. It is intended for use by the customer and the development engineer. The specification also serves the development engineer as a basis for designing the software.

### **1.2 Scope**

Generally vehicle control systems can be divided into three levels:

1. The train control level coordinates and controls the functions of the entire train (e.g. coordination of several locomotives under multiple control). The train control level transforms the control signals issued by the driver into commands for the individual vehicles and transfers them to the vehicle control level.
2. The vehicle control level performs all the functions associated with a particular vehicle. It carries out the actions according to the commands received from the driver or train control level and transmits confirmation signals and other data back to the driver. In order to relieve the load on the driver, the vehicle control level responds as far as possibly independently to events which occur.
3. The drive control level receives the tractive effort set-point from the vehicle control level and controls the converter such that the motors deliver the required torque.

### 1.3 Instructions for reading

Instruments, controls and other apparatus are defined in the following text by their function names followed by their main circuit diagram page number and position number {Page, Pos.}.

Example: Pan switch {05A,129}

If necessary, on the third position the position number of the pneumatic apparatus (ref pneumatic diagram D&M SCH B 1685) is given.

Example: Pressure switch emergency brake {06A,269.1,Pn69}

The number preceding a statement refers to the section and location in the section, the digits in front of the point being the Section and the digits after the point a consecutive number within the Section.

The lower case letter preceding a statement number indicates the relevance of the statement according to the particular operation:

n: normal case  
v: multiple control  
r: redundancy  
s: disturbance

The lower case letter succeeding a statement indicates its significance:

i: Information, not an essential requirement  
d: Definition, definition of a term  
f: Requirement, must be fulfilled

### 1.4 Abbreviations

MCE:	MICAS-S2 Control electronics
CEL:	Central electronics
DDS:	Diagnostic data set (including environment datas)
GUSP	Gate unit power supply
MUB	Overvoltage protection unit (DC-link main converter)
MVB	Multi functional vehicle bus
Pan	Pantograph
TE/BE	Tractive / braking effort
VCB	Main circuit breaker (V = Vacuum)
MCB	Miniature circuit breaker

## Processor names:

ALG	Drive inverter & Line converter control (includes ASC and NSC)
ASC	Drive inverter control
NSC	Line- or four quadrant converter control
SLG	Converter control
FLG	Vehicle control
BUR	Auxiliary converter control
HBB	Auxiliary cubicle control
STB	Low voltage cubicle control
DIA	Diagnostic processor
DDA	Display controller
FBV	Vehicle bus administrator
ZBV	Train bus administrator

**1.5 Reference documents**

Changes to Software Specification (for version C) .....	3EHP 542 511
Vehicle schematics .....	3EHP 281 117
Engineering specification; Vehicle control software .....	3EHP 510 223
Driver's cab equipment .....	3EHW 420 047
Diagnosis: Functionality .....	3EHP 510 190
Diagnosis: Screen structure and operation .....	3EHP 541 783
Central electronics: List of signals .....	3EHP 510 060
Specification of ABB protection functions .....	3EHP 541 526
Engineering specification auxiliary converter .....	3EHW 500 458
Engineering specification nickel-cadmium-accumulator .....	3EHW 510 061
Software description of auxiliary converter .....	3EHE 620 298
Tractive effort diagram (WAP-5) .....	3EHP 510 115
Tractive effort diagram (WAG-9) .....	3EHP 510 116
Braking effort diagram (WAP-5) .....	HBTB 490 730
Braking effort diagram (WAG-9) .....	HBTB 490 731
ALG engineering specification .....	3EHL 420 622

## 2. Functional requirements

### 2.1 Control Electronics

#### 2.1.1 Sequential control in general

- n 211.01 i A sequential control checks the operating status and determines the order in which operations are carried out. It includes nodes (states) which are connected by transitions. The state of a system or sub-system can thus be simply and logically controlled. The sequential control can only be in one defined state at any one time
- n 211.02 i The **master sequential control** defines the current state of the locomotive with the aid of a node number. The node number is the central reference for all the system processors and is therefore decisive for maintaining the proper locomotive operating procedures. The MSC also performs various protection functions, e.g. the main circuit-breaker can only be closed after the MSC has reached the corresponding node or state.
- n 211.03 i A **sub-sequential control** defines the current state of a processor with the aid of a node number. It is generally controlled by the MSC.
- n 211.04 i Special case SLG: Because of the complexity of the converter control unit function, these processors are controlled by a sub-sequential control module which operates in close co-operation with the MSC to control the different operating states of a drive (e.g. clock enable, traction, braking etc.).

#### 2.1.2 Redundancy (reliability)

- n 212.01 i The most important functions are duplicated to enable the locomotive to remain in operation in spite of the failure of a sub-system --> 2.11 Redundancy

#### 2.1.3 Manual turn on / off

- n 213.01 i Position "drive" of cab activation key switch {08A,125} means, the vehicle control electronics (MCE) is under power and the corresponding cab is activated. Exception: The temperature of vehicle control electronics is too high; --> 2.1.4 Cooling mode.
- n 213.02 f Turn On conditions for MCE:  
 - Temp. CEL < 70°C ;{08B,211} is switched on  
 - Key switch in Position "drive"  
 - Uprim < 17.5kV {08B,86} (monitored by hardware)
- n 213.03 f Position "off" will turn off the MCE 10 min. delayed. The 10 min. delay must be setable during commissioning.  
**Note:** The time must be minimal to ensure driver checks that loco is shut down.



2.1.4 Cooling mode

- n 214.01 i In case of over temperature ( $>70^{\circ}\text{C}$ ) inside the cubicle CEL Rack, provision is made to avoid to turn on the MCE. The indication lamp for control electronics {08B,166} will indicate that the temperature is too high.
- n 214.02 i The driver shall select the position "cooling" with the cab activation key switch, raise the pan and switch on the main circuit breaker (control electronic is still off, the protection is done by hardware).
- n 214.03 i In this position the machine room blowers and the internal fans of the CEL racks are working. If the temperature in the CEL rack is below  $70^{\circ}\text{C}$  the indication lamp {08B,166} is extinguished.
- n 214.04 i The driver opens the VCB and lowers the Pan and selects the position "off" on the cab activation key switch.

2.1.5 Automatic MCE turn off

- n 215.01 f Conditions for autom. CEL turn off:
1. Key switch {08A,125} is longer than 10 min. in position "0".
  2. Key switch is. in position "D" and the pan is lowered longer than 10 min. (inhibited in simulation mode)
  3. Battery discharge protection --> 2125.01

Note: Over temperature ( $>70^{\circ}\text{C}$ ) inside cubicle CEL rack is monitored by {08B, 411.LA 1} and a respective DDS & message to the driver produced. --> n 21266.01 f

## 2.2 Cab control equipment of main circuit

### 2.2.1 Definition of set-up and shut down

- n 221.01 d **Set-up:** Pan up, VCB on, Auxiliary system active, Main converter DC-Link charged, loco ready for drive.
- n 221.02 d **Shut-down:** VCB off, Auxiliary system inactive, Pan down, Main converter DC-Link deenergised
- n 221.03 d The table explains the following position of the key switch, in case of a single loco.

	CEL on	Cab active	Loco set-up
Key switch Pos. "0"	-	-	-
Key switch Pos. "D"	x	x	-
Key switch Pos. "D" Pan up, VCB on	x	x	x

- n 221.04 d Single loco set-up means: One cab on the Loco is active (occupied) and the Loco is ready for drive.
- v 221.05 d Multiple unit set-up means: One cab of both Locos is active and both Locos are ready for drive.

### 2.2.2 Switch on MCE, activation of cab

- n 222.01 i The key switch {08A,125} has 3 positions:  
Pos. "0": = off  
Pos. "C": = Cooling mode -> 2.1.4.  
Pos. "D": = Drive  
Ref. to Driver's cab equipment 3EHW 420 047  
To remove the key, the key switch shall be in Pos. "0"
- n 222.02 f Both cab activated means, on two cab's the key switch is not in Pos. "0". If one key is in Pos. "D" in a cab and a second key will be tried to set in Pos. "D" on the second cab this won't be accepted by hardware. --> 2.8 Multiple operation
- n 222.03 f If the key switch is in Pos. "D" the corresponding cab control equipment is activated. The self test starts and continues for approximately 2 min.
- n 222.04 f The lamp test is active during 10 sec after self test. This is the sign that the loco now is ready for the driver. The pan up command will interrupt the lamp test sequence. --> 2.7.5 Test of indication lamps
- n 222.05 i As soon as the key switch is in Pos. "D" the MCE makes self-hold by energising contactor {08A,126} and contactor {08B,218}.

2.2.2.1 Drivers cab equipment in an active cab

- n 2221.01 f In an active cab (key switch in Pos."D") all control equipment for the driver are active.

2.2.3 Cab deactivation, switch off of MCE

- n 223.01 f If the driver moves the key switch from Pos."D" to Pos."0" an automatic shut-down will happen.
- n 223.02 f After deactivation of the cab, the MCE must stay operating for 10 minutes, to control the shut-down of the loco and to enable the initialisation of multiple operation. In addition, an info picture will inform the driver.
- n 223.03 f During shut down of loco prevention must be made from setting-up the cooling mode. Therefor the contactor {05A,130.1} and {05B,136.4} must be disabled by the MCE (= energising of MCE outputs 'Pantograph disable' and 'Main circuit breaker disable'), to avoid set-up in cooling mode. After shut down (DC-link deenergised) changing in cooling mode must be possible with key switch in Pos. "C" without waiting 10 minutes.
- n 223.04 f 10 min. after the pan is lowered, the self-hold mode is released (contactor {126} and {218} deenergised) and the MCE will switch off. See also --> Protection battery 2125.01

2.2.3.1 Drivers cab equipment in an inactive cab

- n 2231.01 f In each inactive cab (key switch in Pos."0"), only the following control equipment's are active:
- Speedometer recorder & indicator {94.2 & 94.3}
  - Catenary voltage meter {12A,74}
  - cock for assistant driver's emergency brake {Pn 113}
  - cab, desk lighting and handlamp {324, 324.21, 324.22, 337}
  - windscreen wiper
  - cab venting and heating {03A,65.6}
  - diagnostic terminal {435}
  - marker lights red and white switches {316.11, 316.12}
  - crew fans {69.7}

2.2.4 Pantograph2.2.4.1 Pantograph selection

- n 2241.01 f The rotary switch for pantograph selection {05A, 129.1} has the following 3 positions:
- Pos. "I": Pan above cab 1 is selected
- Pos. "AUTO": Pan above the inactive cab will be selected automatically
- Pos. "II": Pan above cab 2 is selected

n 2241.02 i The rotary switch is located in the machine room. The selection is hardwired and without MCE control. Only if the pantograph selector is in Pos."AUTO", then the MCE selects the pantograph, otherwise the selected pan (rotary switch Pos"I" or Pos"II") will raise independently of the selection by the MCE.

Multiple unit --> 284.01 f

#### 2.2.4.2 Raise and lower pantograph

- n 2242.01 f To handle the pan there is a spring loaded switch {129} with 3 positions .  
Pos. "UP": Raise Pan (spring loaded)  
Pos. "0": Neutral  
Pos. "DN" Lower Pan (spring loaded)
- n 2242.02 i Both EP valves {05A,130} to raise the pan are controlled either by the MCE (key switch in Pos."D") or by hardware (cooling mode).
- n 2242.03 f The driver gives the command to raise the pan with a short push to Pos. "UP" of the spring loaded switch {129}.  
He gives the command to lower the pan with a short push to Pos. "DN" of the switch.
- n 2242.04 f The pulse generated in the "UP" position energises the auxiliary contactor pantograph {05A, 130.1}, the pulse generated in the "DN" position deenergises it. The contactor {130.1} has different effects depending on mode of the locomotive.
- Cooling mode:  
contactor {130.1} raise the pantograph above the unoccupied cab
- Driving mode:  
contactor {130.1} transmit the command of the driver to the CEL
- n 2242.05 i The auxiliary compressor secures enough air pressure to raise the pantograph --> 2.5.4 Auxiliary compressor.
- n 2242.06 f The pan should be able to be lowered by the driver in each situation without any risk of damages to the loco.
- n 2242.07 f It shall be possible to raise the pan at any speed --> 277.02 Neutral section
- n 2242.08 f The MCE shall lower the pan and overwrite the driver's command "pan up" with "pan down" by deenergising the auxiliary contactor pantograph {05A,130.1} in the following cases:  
- Key switch in Pos. "0"  
- Emergency stop push button {06B, 244}  
- Fatal mode of MCE (loco dead)
- n 2242.09 f The pan is not lowered automatically in case of the catenary voltage exceeding the upper limit voltage.

- n 2242.10 f Each pan is monitored by a pressure switch {05A, 130.4}.  
VCB open: After the driver's wish to raise the pan, the driver will be informed by a message on the diagnosis display, that the pan is raising. As long as the air pressure of the pan is not ok, the VCB will be disabled. If the pantograph air pressure will not be ok after 35s, a fault message will be displayed.  
VCB closed: In case of low pressure with 2 sec delay at raised pan, VCB will be opened and a priority 1 fault message is displayed. The time delay shall be setable during commissioning
- n 2242.11 f If HBB2 isolated, the pan 1 is not available and the pressure switch of pan 2 is not monitored.

### 2.2.5 Main circuit breaker (VCB)

- n 225.01 f To handle the VCB there is a spring loaded switch {05B,134} with 3 positions .  
Pos. "On": Close VCB (spring loaded)  
Pos. "0": Neutral  
Pos. "Off" Open VCB (spring loaded)
- n 225.02 f The driver gives the command to close the VCB with a short push to Pos. "On" of the spring loaded switch {134}.  
He gives the command to open the VCB with a short push to Pos. "Off" of the switch.
- n 225.03 i The pulse generated in the "On" position energises the auxiliary contactor VCB {05B, 136.4}, the pulse generated in the "Off" position deenergises the auxiliary contactor. The contactor {136.4} has different effects depending of the mode of the locomotive.

#### Cooling mode:

The contactor {136.4} closes the VCB if:

- the auxiliary contactor pantograph {05A,130.1} is closed
- the catenary voltage within limits --> 3EHP 541 526, 5.1.1

#### Driving mode:

The contactor {136.4} transmits the command of the driver to the CEL if:

- the auxiliary contactor pantograph {05A,130.1} is closed

- n 225.04 f To close the VCB in driving mode, the HOLD coil of VCB {05B,5} shall be energised and the ON coil will get a turn-on pulse by 1 second. In cooling mode the ON pulse is generated by a time relay. The CEL closes the VCB under the following conditions:
- command received from auxiliary contactor VCB {136.4}
  - catenary voltage is ok --> 3EHP 541 526, 5.1
  - no disturbance with VCB off is active: see n2122.03

- n 225.05 f The driver must be able to open the VCB in any situation without any risk of damages to the loco. In case of a controlled VCB off, the VCB will open 60ms delayed to the VCB off command of the main converter control (time for ramp down tractive/braking effort). There is no explicit delay by software, the delay is the result of task switching and delivering data by the MVB.
- n 225.06 f The CEL shall switch-off the VCB (together with a corresponding disturbance message) by interruption of the VCB HOLD line and overwrite the driver's command "VCB on" with "VCB off" by deenergising the auxiliary contactor VCB {05B,136.4} in the following cases:
- Catenary voltage is out of range --> 3EHP 541 526
  - Cause of VCB tripping due to disturbance--> n 2122.03 f
  - Emergency stop push button {06B,244} pressed (hardware function)
  - Primary overcurrent indication/isolation provided by auxiliary contact {05B, 78}
- n 225.07 i The lamp VCB {05C,137.3} indicates the status of the VCB (hardware function). Not lighted means VCB on, lighted means VCB off.
- s 225.08 f The CEL monitors the VCB on stuck on and stuck off position (Definition stuck on/off --> 21263.03). The following measures are taken:
- If VCB is stuck in the off position:
- priority 1 fault message is generated.
  - the control of the VCB is changed to the redundant processor
- If VCB is stuck in the on position:
- switch-off converter contactors{01B,12.3 & 12.4}
  - switch-off hotel load contactors{05D,32}
  - lower pan
  - priority 1 fault message, will be displayed: Loco dead
- s 225.09 i A list of all disturbances with VCB off is in --> 2.12.2 Protection concept
- v 225.10 i Special functions of multiple unit are explained in --> 2.8 Multiple operation

#### 2.2.6 Interaction: Key switch - Pan - VCB

- n 226.01 f The driver shall be able to press the switch Pan "UP" and VCB "On" in a short sequence to set-up the loco.
- n 226.02 f The command VCB "On" before the pan is raised will be ignored.
- n 226.03 f If the VCB is closed and the driver gives the command pan "DN" the normal shut-down sequence will start. The command VCB on must be reset by deenergising auxiliary contactor {136.4}.

- n 226.04 f      If the VCB is closed and the driver turns the cab activating key switch from Pos. "D" to "0" , the normal shut-down sequence will start. The command VCB on and Pan up shall be reset by deenergising the auxiliary contactors {136.4} & {130.1}.

### 2.2.7 Cab change on a single loco

- n 227.01 f      The driver shall turn the key switch {08A,125} to Pos."0" and remove the key. Then he will change the cab and activate the other (key switch to Pos."D").
- n 227.02 i      Note: After the deactivation of a cab, the MCE will remain on for 10 min. If MCE shall start-up again, it takes more time to set-up the loco because of periphery test sequence after each start-up of MCE, if MCE was off.

### 2.2.8 Cab change in multiple operation

- v 228.01 f      The driver shall turn the key switch {125} to Pos."0" and remove the key on Loco 1. Then he will change the Loco to activate the other front cab (key switch to Pos."D"). That action has to be done within 10 minutes. The train-bus configuration thereafter is performed --> 2.8 Multiple operation.

## 2.3 Set-up, Shut-down

### 2.3.1 Set-up

n 231.01 f In case of indication lamp temperature of CEL {166} is lighting, the cooling mode ( --> 2.1.4 ) shall be activated first.

n 231.02 f The usual set-up sequence is:

1. Operate key switch {08A,125} from Pos."0" to "D" (MCE is on power)
2. Push the pan switch {05A,129} to Pos. "UP" (Raise pan)  
The pan will raise, the voltmeter {74} will indicate the line voltage (range 0..30kV)
3. Push the VCB switch {05B,134} to Pos. "On" (VCB will close)
4. The driver has to wait until the main compressor has filled up the main reservoir
5. Operate the reverser {08C,140} from position neutral to forward or reverse. If the main reservoir is not filled up, a fault message 'Low main reservoir pressure' will be displayed.
6. Loco status: DC-Link energised, ready for drive.

Information about the reverser --> 2.4.1.1 Direction selection

Information about converter contactor sequence --> 2.3.3.1 - 2.3.3.4

### 2.3.2 Shut-down

n 232.01 f The usual shut-down sequence is:

1. The driver operates the reverser {08C, 140} back to pos. "neutral"
2. Push the VCB switch {05B,134} to Pos. "Off" (VCB will open)
3. Push the pan switch {05A,129} to Pos. "DN" (Lower pan)
4. Operate the key switch {08A,125} to Pos. "0"
5. Loco Status: VCB off, pan down, DC-Link discharged

n 232.02 f To shut-down the loco, step 1, 2, and 3 are optional. If necessary, the shut-down sequence can start with step 4 only.

n 232.03 f By pressing emergency stop push button {06B,244}, a shut-down is performed which includes step 2 and 3.

### 2.3.3 Sequences main circuit / converter

n 233.01 f Both traction converter circuits from bogie 1 & 2 will set-up (charging of intermediate circuit) at the same time.

n 233.02 f The two gate unit supplies are switched on with a a time shift of 3 seconds in order to minimise the switch on current drawn from battery system.



2.3.3.1 First start up

- n 2331.01 f
1. Status:  
Driver's cab activating by key switch {08A,125} in position "drive"
    - Pantograph raised (by driver)
    - Main circuit breaker closed (by driver)
    - Filter contactor on/off {01A/05H, 8.1} opens
    - Contactor filter discharging closed (by MCE)
  2. The driver selects the travel direction by moving {08C,140} to Pos. "F" or "R"
  3. Contactors gate unit power supply {16B,218.2 /\*} closes.
  4. Converter precharging contactors {01B/05E,12.3 /\*} will close.  
The intermediate circuit will be charged
  5. Converter contactors {01B/05E,12.4 /\*} will close, if the DC-link voltage is high enough. The level is about 80% of secondary transformer voltage (rectified peak).
  6. Converter precharging contactors {01B/05E,12.3 /\*} opens
  7. Testing of MUB (DC-link over voltage protection circuit)
  8. The driver sets the TE/BE-demand by the throttle {150}
  9. Filter discharging {01A/05H,8.41} opens
  10. - Filter contactor on/off {01A/05H, 8.1} closes
    - Contactor filter adaptation in correct position --> 2334.04
  11. Line- and drive-converter start pulsing
  12. Loco makes tractive effort.
- n 2331.02 f
- The line-converter and drive-inverter stops pulsing with 10 seconds delay under following condition:
- TE/BE-demand set to zero and the loco is stationary
- n 2331.03 i
- Whenever the converters stop pulsing,
- the converter contactors {01B/05E,12.3} stay closed
  - the intermediate DC-link stay charged over the rectifier effect.

2.3.3.2 VCB off - VCB on

- n 2332.01 f
1. Vacuum circuit breaker is switched off, therefore the intermediate DC-link of the converter is not charged anymore. Since cab activating switch remains still in D position the intermediate circuit will not discharge through MUB but will start discharging slowly through the snubber circuits of GTOs.
  2. If the intermediate circuit voltage drops below its minimum value (voltage is too low for converter triggering), then the precharge contactor {05E,12.3} will be closed and the converter contactor {05E,12.4} will be opened .

3. To restart the loco the following sequence shall be performed:
  1. The driver closes the VCB
  2. If converter contactors {12.4 /\*} were opened and the precharge contactor was closed, the DC-link will be charged. After DC-link gets charged up, converter contactor {12.4} will be closed and precharging contactor {12.3} will be opened.
  3. The driver sets the TE/BE-demand by the throttle {150}
  4. Filter contactor {8.1} is switched on --> 2333.01, 9. & 10.
  5. Line-converter and drive-inverter start pulsing

#### 2.3.3.3 Shut down

- n 2333.01 f
1. Main circuit breaker off (by driver)
  2. Pantograph down (by driver)
  3. Cab activating key switch {08A,125} in position "off" (by driver)
  4. Discharging of intermediate circuit through MUB
  5. Converter contactors opens {01B/05E,12.4 /\*},
  6. Filter contactor opens {01A/05H,8.1}
  7. Filter discharging contactor closes {01A/05H,8.41} to discharge the filter capacitor {8.4}.
  8. Contactors gate unit power supplies opens {218.2}

#### 2.3.3.4 Harmonic filter

- n 2334.01 i      The contactor filter on/off {8.1} and the contactor filter discharging {8.41} are interlocked by auxiliary contacts.

- n 2334.02 f      To prevent the discharging resistor {01A,8.42} from overload, its thermal characteristic shall be modelled in the MCE. The discharging resistor is designed for the following duty cycle:

After the first discharging, the next discharging shall not take place within the next 10 seconds. After the fifteenth discharge with 10s delay the discharge resistor will have the max. temperature achieved (Max. cycles: 15 discharges over 147.5 seconds). To protect the resistor, the VCB is inhibited within the next 15 minutes (Time to cool down the resistor beginning from the max. temperature) . Thereafter the overall duty cycle may be repeated.

- n 2334.03 f      **Contactor Filter On/Off {8.1}**  
 The contactor shall be closed ...  
 - before the main converter starts pulsing  
 The contactor shall be opened ...  
 - 20 seconds after the converter stopped pulsing or  
 - if the VCB is switched off

- n 2334.04 f      **Contactor Filter Adaption {8.2}**  
The contactor shall be closed ...  
- after passing the self test of the MCE in normal two bogie operation  
  
The contactor shall be opened ...  
- if one bogie is isolated
- n 2334.05 f      Switching of contactor filter adaption {8.2} will be prevented, if  
contactor filter on/off {8.1} is closed.
- n 2334.06 f      **Contactor Filter Discharging {8.41}**  
The contactor shall be closed ...  
- after passing the self test MCE  
- after opening of filter contactor {8.1}  
  
The contactor shall be opened ...  
- before filter contactor {8.1} will be closed
- n 2334.07 f      Start up is prevented for 500ms (time delay due to discharge filter  
capacitor) after contactor {8.41} has been closed.
- s 2334.08 i      Protective actions i.e. in case of overcurrent --> 3EHP 541 526

### 2.3.3.5 Monitoring of Converter and Filter Contactors

- s 2335.01 i      The following contactors of the converters and the harmonic filter are  
equipped with auxiliary contacts and are monitored on stuck-on and  
stuck-off positions by the CEL:
- contactor filter on/off {05H, 8.1}
  - contactor filter adaptation {05H, 8.2}
  - contactor for discharging resistor {05H, 8.41}
  - contactor converter pre-charging {05E, 12.3}
  - contactor converter {05E, 12.4}
- s 2335.02 f      The following actions are taken on stuck-off or stuck-on of the  
contactors:
- contactor filter on/off {8.1}**  
stuck off:
- VCB off with disturbance
  - priority 1 fault message
  - > Isolation of harmonic filter 295.01
- stuck on:
- priority 1 fault message
  - contactor for filter discharging {8.41} must stay off
  - the filter capacitor {01A, 8.4} remains charged
  - if the VCB opens, it's not allowed to close the VCB again
- contactor filter adaptation {8.2}**  
stuck off:

- VCB off with disturbance
- priority 1 fault message, in normal 2 bogie operation
- > Isolation of harmonic filter 295.01

stuck on:

- VCB off with disturbance
- priority 1 fault message, if isolation of one bogie is required
- > Isolation of harmonic filter 295.01

#### **contactor filter discharging {8.41}**

stuck off:

- priority 1 fault message
- the filter capacitor {01A, 8.4} remains charged
- > Isolation of harmonic filter 295.01

stuck on:

- VCB off with disturbance
- priority 1 fault message
- contactor filter on/off {8.1} must stay off
- > Isolation of harmonic filter 295.01

#### **contactor converter pre-charging {12.3}**

stuck off:

- priority 1 fault message
- protective shut-down
- one renewed switch-on attempt
- isolation of defective converter

stuck on:

- VCB off, shut-down, priority 1 fault message,
- Isolation of subsystem main power

#### **contactor converter {12.4}**

stuck off:

- priority 1 fault message
- protective shut-down of converter
- one renewed switch-on attempt
- isolation of defective converter

stuck on:

- priority 1 fault message
- trip VCB, shut-down (to ensure no risk of overheating the MUB-resistor
- isolation of the subsystem main power (closing of VCB is impossible)

## 2.4 Driving

### 2.4.1 Motoring

#### 2.4.1.1 Direction selection

- n 2411.01 f The reverser {08C,140} is a part of the master controller {08C/D,150}. The reverser has 3 positions:  
 Pos."F": Forward  
 Pos."0": Neutral  
 Pos."R": Reverse
- r 2411.02 f The binary inputs of the reverser are redundant.
- n 2411.03 f During set-up when the direction is selected for the first time, the main converter DC-Link is charged. The corresponding starting sequence is described in --> 2.3.3 Starting sequence main circuit /converter.
- n 2411.04 i There is a mechanical interlocking between reverser and TE/BE throttle which prevents any operation of reverser unless the TE/BE throttle is in Pos."0".
- n 2411.05 f Changing of travel direction is possible only if speed is below 2 km/h, and TE/BE is '0'. If driving direction and reverser position are not equal a start/running interlock is generated.

#### 2.4.1.2 Tractive / braking effort demand

- n 2412.01 f The tractive effort/regenerative brake throttle (short: TE/BE throttle) {08C/D,150} includes an angle transmitter and auxiliary contacts for tractive effort and brake demand. The TE/BE throttle has following positions:  
 Pos."TE max": max. tractive effort (100%)  
 Pos."0": no tractive/regenerative braking effort (0%)  
 Pos."BE max": max. regenerative braking effort (100%)
- r 2412.02 f The auxiliary contacts of TE/BE throttle are in the following positions serviceable:
- |           |        |   |      |
|-----------|--------|---|------|
| Motoring: | TEmax  | = | 100% |
|           | 2/3 TE | = | 67%  |
|           | 1/3 TE | = | 33%  |
| Neutral:  |        | = | 0%   |
| Braking:  | 1/3 BE | = | 33%  |
|           | 2/3 BE | = | 67%  |
|           | BE max | = | 100% |

Driving operation with auxiliary contacts is described in  
 --> 2.10 Failure mode operation

- n 2412.03 f As soon as the loco is ready for drive (direction selected), the driver can select the TE-Demand to accelerate the loco or train, or BE demand to brake the loco or train. Pneumatic brakes can be applied up to 10km/h to allow for hill start conditions.

#### 2.4.1.3 Maximum tractive effort limitation (only WAG-9)

- n 2413.01 f The tractive effort limitation is only available on the freight loco WAG-9. On WAP-5 TE limitation is set to 100%.  
The switch max. tractive effort limitation {08E,151.1} has 2 positions:  
Pos."On" : limitation on ( = 300kN)  
Pos."Off" : limitation off
- n 2413.02 f The braking effort is not limited in Pos."On".
- n 2413.03 f The tractive effort limitation switch can be switched on only when the throttle tractive/brake effort {08C/D,150} is in Pos."0".  
To switch off the limitation, the TE/BE throttle shall be in Pos."0".
- s 2413.04 f If one bogie is isolated, the tractive effort limitation is not active.
- v 2413.05 f Limitations in multiple operations are explained in --> 2.8 Multiple operation

#### 2.4.1.4 TE/BE demand ramp

- n 2414.01 f Increase and decrease of TE/BE demand will be limited to a default value. This value shall be setable during commissioning. (Note: A new ramp will have an influence to the speed and acceleration control). The ramps are different for BoBo and CoCo and implemented using parameters.
- n 2414.02 i Parameters for above ramps are implemented in FLG, Cluster 53

#### 2.4.1.5 Constant speed control

- n 2415.01 f The constant speed control push button {08E,151.4} is illuminated when the speed control is active. In order to activate the constant speed control the driver may push the button {08E,151.4} at the desired speed.
- n 2415.02 f To activate speed control, the loco-speed shall be more than 5 km/h and TE/BE demand from throttle must be greater than zero.
- n 2415.03 f The speed control will have access to 100% of the available tractive- & regenerative brake effort. That means, TE/BE throttle position doesn't limit the TE/BE demand in constant speed control.
- n 2415.04 i To minimise speed oscillations, the driver may set the speed control during a slow acceleration.

n 2415.05 f

The following actions will disable the constant speed control:

- Movement of the TE/BE throttle {08C/D,150}
- Press the constant speed control push button {08E,151.4}, while the speed control is active
- Pressure of the automatic air pipe is < initial application according to UIC (train brake pressure < 4.75 kg/cm<sup>2</sup> {06E,260A}).
- Pressure switch brake cylinder {06A, 269.6} is closed

v 2415.06 i

Limitations in multiple unit --&gt; v 286.02 f

2.4.1.6 Limitation of acceleration / deceleration

- n 2416.01 f The max. acceleration is limited to (example):  
WAP-5: 0.5m/s<sup>2</sup>; 0.25 m/s<sup>2</sup> (normal mode ; shunting mode)  
WAG-9: 0.25m/s<sup>2</sup>; 0.125 m/s<sup>2</sup>;(normal mode ; shunting mode)
- n 2416.02 f The max. deceleration is limited to (example):  
WAP-5: 1m/s<sup>2</sup>  
WAG-9: 1m/s<sup>2</sup>
- n 2416.03 f For an adjustment during commissioning the values shall be settable.
- n 2416.04 i The driver shall be able to break the train pneumatically in addition to the regenerative brake.
- v 2416.05 f In multiple operation the master loco will control the acceleration for the train.
- v 2416.06 i Parameters for above values are implemented in FLG, Cluster 53. Actual values can be different to above examples.

2.4.1.7 Power and TE/BE demand limitations

- s 2417.01 f Power reduction and TE/BE demand limitations in case of over temperatures main converter, main transformer ,traction motors or line voltage limitations are explained in --> 2.12 Protection concept

2.4.1.8 Display for tractive/braking effort

- n 2418.01 f For the actual tractive/braking effort indication, there is a TE/BE meter for each bogie {08E,79.1/2} on each cab. The indication is +/- 100%.
- v 2418.02 f Master loco in trailing mode --> v 2813.03 f
- v 2418.03 f In multiple operation the tractive/braking effort from the bogies 1 respectively the bogies 2 of Master-Loco and Slave-Loco will be added and displayed on the TE/BE meter for each bogie.

2.4.1.9 Weight transfer compensation

- n 2419.01 i The trailing traction bogie shall supply more tractive effort than the leading bogie. Applicable only up to power curve rating, therefore not required in braking.
- n 2419.02 f The tractive effort of 100% is distributed to the bogies as follows:

<b>Leading bogie:</b>	
WAP-5: - 3.5%	WAG-9: - 3.5%
<b>Trailing bogie:</b>	
WAP-5: + 3.5%	WAG-9: + 3.5%



## 2.4.2 Braking

- n 242.01 i WAP-5/WAG-9 locomotives are equipped with the following brake systems:
- regenerative brake (electric brake)
  - direct loco brake
  - automatic train brake
  - parking brake (charged spring brake)
- In reference to the pneumatic scheme D&M SCH B 1685 the pneumatic positions are indicated as {Pn Pos.Nr.}.
- s 242.02 f If the control electronics of the brake equipment is not working, then a priority 1 fault message is displayed and a traction interlock is provided. (Brake control failed means: MCE input 'Brake electronic o.k.' = 0).
- s 242.03 i If the brake control electronics fails with the cab activated, the emergency brake will apply automatically.
- n 242.04 f If the speed of the loco is above 10 km/h and the pneumatic loco brake is applied, a start/running interlock is provided. The brake application is detected by pressure switch brake cylinder bogie 1 or 2 {06A, 269.6}.
- n 242.05 f The isolation cock brake pipe control system {06A, 293.2} shall be in open position on the leading loco of a train. The closed cock on a leading loco causes a start/running interlock.
- n 242.06 f To avoid feeding of the brake pipe from a banking loco, the isolation cock brake pipe control system shall be in closed position on a loco operating in banking mode. The open cock on a banking loco causes a start/running interlock.

### 2.4.2.1 Regenerative brake

- n 2421.01 f The driver has to operate the regenerative brake with the TE/BE throttle, --> 2.4.1.2 Tractive/Braking effort demand
- n 2421.02 f If the regenerative brake is more than 10 kN, the automatic loco brake {06H,270.1,Pn 52} shall be cut out (=> MCE output 'Loco brake cut out' = 1 and the pneumatic brake effort MCE output 'Pneumatic brake effort demand' {Pn 55} shall be 0 V).
- s 2421.03 f If the regenerative brake is not available or fails when braking, equivalent pneumatic loco brake will be applied by increasing the signal at MCE output pneumatic brake effort demand from 0V (=no braking effort) to required value between 0V and 10V (=max braking effort) corresponding to the BE demand. The restart of regenerative brake is possible again, after TE/BE throttle is brought to '0'.
- s 2421.04 i Even if the electric brake and the pneumatic loco brake are applied simultaneously due to a fault, overbraking of the loco is prevented since the slip/slide control reduces the electric brake effort.

- n 2421.05 f The electric brake effort will be reduced from full braking effort at 10km/h down to 0kN at zero speed. The ramp shall be setable during commissioning.

#### 2.4.2.2 Pneumatic direct loco brake

- n 2422.01 i The direct loco brake is only able to brake the loco. The brake handle {294,Pn112} is only active in an active cab.
- n 2422.02 i Monitoring for a direct loco brake application, is the pressure switch {06A,269.2, Pn 59} 0.2/0.65 kg/cm<sup>2</sup>

#### 2.4.2.3 Pneumatic automatic train brake

- n 2423.01 i The automatic train brake is able to brake the train and the loco. On each cab is a brake handle for the automatic train brake {293,Pn111}.
- n 2423.02 i If the driver activates the automatic brake by the automatic train brake handle {293,Pn111}, the pneumatic brakes are applied on the locomotive and the train.
- n 2423.03 f There is a spring loaded foot switch {06D,262} on each cab to release the automatic loco brake {271,Pn 49}.
- n 2423.04 f In case of
- automatic brake pressure {06H,269} < 4.75 kg/cm<sup>2</sup> and
  - demanded tractive effort > 0 and
  - speed > 10 km/h
- a start/running interlock is generated.

#### 2.4.2.4 Parking brake

- n 2424.01 f An illuminated push button is on each cab to apply and release the parking brake {06B,268}. An applied parking brake will be indicated through the illuminated push button {06B,268} on the active cab.
- n 2424.02 f It will not be possible to move the loco (start/running interlock), if the parking brake is applied. The parking brake is monitored by a pressure switch {06B,269.3}. --> n 2122.05 f
- n 2424.03 f Parking brakes shall be applied by MCE, if the cab activation key switch is turned to Pos."0".
- n 2424.04 f The application of parking brake is disabled above a speed of 5 km/h.
- v 2424.05 i Control of parking brake in multiple operation --> 2.8. Multiple operation