

Voltage Regulator backup supervision functions & error reporting

With the A.Eberle REG-D/DA Voltage Regulators there are various supervision/fault detection algorithms available with the different paralleling routines. This document focus's upon the two most common paralleling methods describing the main backup supervision functions, error reporting and controllable behaviour.

Parallel Programme	Regulation basis	Main backup supervision
Master-Follower	Voltage regulator algorithm drives tap decision for Master. Follower is simply driven (at same time) to match the same tap number as the Master.	Icirc (a Parallel Error)
Circulating-Current (delta I sin phi)	Voltage regulation and/or Icirc drives tap decision. All regulators in group are actively monitoring/controlling.	Permissible Difference of Taps (a Parallel Error)

Master-Follower

With regulators operating in Master-Follower mode, it is only the Master that runs the voltage regulation algorithm. The Followers simple follow the command of the Master to which tap they should change to. As the transformers should be matched, and always on the same tap, there should be negligible circulating current. Circulating current is however monitored as a backup check. If there is a circulating current detected (greater than setting value), this is a good indication that at least one transformer is on a different tap, and therefore something is wrong with a transformer tap changer, the tap position indication, the wiring or settings, or perhaps a regulator itself.

Circulating-Current

With regulators operating in Circulating-Current mode, all the regulators are measuring local transformer current, and sharing communications and control functions. Transformer control is based upon the settings, which will determine if regulation is controlling voltage and/or circulating current. The main noticeable feature of circulating current schemes is that transformers may not all be on the same tap. A backup function for circulating current schemes is provided by monitoring the tap position (if available) of all regulators and checking the setting "Permissible Difference of Taps" is not exceeded. If the setting is exceeded, it may be due to something wrong with the regulation settings, or tap change control mechanism etc.

Parallel Error ("ParErr")

As described earlier, the backup supervision functions for Master-Follower and Circulating-Current both generate a Parallel Error signal. Within the Regulators "ParErr" is used to report a detection of a faulty paralleling condition including:

- A transformer tap position is changed directly (for example via direct motor drive control) and is not returned to expected position within an interval being 1.5 times the tap change in operation time setting.
- The "Permissible Difference of Taps" setting is exceeded [Circulating-Current regulation modes only]
- The maximum permissible Icirc value is exceeded [Master-Follower regulation mode]

- The “1st ParErr after n*AL-Time Setting” is exceed [Master-Follower regulation mode]. For regulators joining an existing parallel scheme, n provides a time multiplier to allow additional time for the introduced transformer to tap to the same tap as others before a Parallel Error is signalled.

With default SysCtrl setting (Bit 6 =1, i.e normally SysCtrl=64), a “ParErr” will cause that regulator to drop from Automatic to Manual control:

- With Master-Follower, when the other regulators in the group detect a regulator dropping to Manual, they also drop to Manual. Therefore, if attending site due to a “ParErr” report, it would be expected to find all regulators in the manual mode, with one or more showing a “ParErr”.
- With Circulating-Current, only the affected regulator(s) will drop to Manual. This is as with Circulating-Current regulation each regulator is basically an independent masters, with an Icirc bias and taps apart check.

We recommend that Parallel Error indication is marshalled to front panel LED (#29:ParErr), to SCADA, and to the log via log mask. Note that Parallel Error is not in the System Event list, so needs to be logged via the LED-Event, or by a virtual output – refer HV Powers Technical Note “How to assign a function to a virtual output for logging”

Tap Error (TapErr)

It can be seen above that for Master-Follower schemes the correct reporting of Tap Position is critical for successful operation of the scheme. For Circulating-Current schemes, while Tap Position indication was not required, if available it allowed backup supervision (Permissible Difference of Taps) to occur. We now take a closer look at the relative importance of Tap Error detection.

This error message reports an incorrect/unexpected tap position. Each regulator runs it own Tap Error detection – which **only** considers its **local** tap changer. [Tap Error does **not** consider unexpected differences between two or more tap changers – this is a function of the Parallel Error detection routines].

The Tap Error is generated after a tap change, if the expected tap position is not reported within 1.5 times the tap changer run time setting.

Examples of TapErr:

- Tap changer operates in the wrong direction.
- No tap change (e.g. motor drive defective). Following each (automatic and manual) tap change command via the regulator, the transformer is expected to have completed its tap change within 1.5 x tap-changer-in-operation time setting.
- Illogical tap change (tap position information is not received from next tap after a tap change command or Tap Position reported is outside expected limits.)

With default SysCtrl setting (SysCtrl=64, where Bit 7 = 0), the behaviour of the Regulators is for them to remain in Automatic mode if a Tap Error occurs.

We recommend that Tap Error indication is marshalled to front panel LED (#69:TAPERR), to SCADA, and to the log via log mask (System Event = #26:TapErr)

SysCtrl Setting

The REG-D/DA “SysCtrl” setting and the Parallel Programme selected determine the Regulators reaction to a Parallel Error and a Tap Error. The SysCtrl value in binary determines both Parallel Error (Bit 6) and Tap Error (Bit 7) behaviour.

SysCtrl Value	Bit 6 function	Bit 7 function
xxxxx00x = 0	Bit 6=0 Parallel Error does not cause regulator to drop from Auto to Manual	Bit 7=0 Tap Error does not cause regulator to drop from Auto to Manual
xxxxx10x = 64 Factory Default	Bit 6=1 Parallel Error causes regulator to drop from Auto to Manual	Bit 7=0 Tap Error does not cause regulator to drop from Auto to Manual
xxxxx01x = 128	Bit 6=0 Parallel Error does not cause regulator to drop from Auto to Manual	Bit 7=1 Tap Error causes regulator to drop from Auto to Manual*
xxxxx11x = 134	Bit 6=1 Parallel Error causes regulator to drop from Auto to Manual	Bit 7=1 Tap Error causes regulator to drop from Auto to Manual*

*For Master-Follower parallel programme only (not Circulating-Current)

On an “Error” do one or all the regulators drop from Automatic to Manual?

With Master-Follower parallel programme, if one regulator drops from Automatic to Manual (Hand) due to a Tap Error (if Bit 7 set) or Parallel Error (if Bit 6 set), then all other Regulators in the group will also drop from Automatic to Manual.

With Circulating-Current parallel programme, it is only the Parallel Error (if Bit 6 set), which only causes the affected regulator(s) to drop from Automatic to Manual.

E-LAN Error

With the A.Eberle Voltage Regulators, the “E-LAN” is the (machine to machine) communication link between voltage regulators, which is primarily used by the regulators to share information about their local status for the correct operation of the selected parallel programme.

An E-LAN error is generated if the regulators detect communication problems on the E-LAN communication bus. If an E-LAN error occurs, correct automatic regulation cannot be assured, so actions are taken dependent upon parallel mode settings being used.

The main setting that affects behaviour of the Regulators when an E-LAN failure occurs is the “*Manual Locked at E-LAN error*” setting. Let’s look at the behaviour with the different “*Manual Locked at E-LAN error*” settings for the two most popular parallel programmes, Master-Follower and Circulating-Current (delta I sin phi). In each case we will assume two regulators are operating in parallel in “Automatic” mode when a permanent E-LAN error occurs, and the E-LAN error is routed to an LED.

We recommend that E-LAN Error indication is marshalled to front panel LED (#16:ELAN-Err), to SCADA, and to the log via log mask (System Event = #25:ELanErr)

Master-Follower parallel programme:

“Manual Locked at E-LAN error” = ON

When operating with the Master-Follower parallel programme, an E-LAN error will cause each regulator to change to Master⁽¹⁾, but will also force each from Automatic to Manual (Hand) Voltage Regulation mode, thus stopping automatic tap operations, and stopping the risk of the Transformers being tapped apart by the two “Masters”.

(1) In a healthy Master-Follower scheme, only the Master regulates the voltage, while the Slave follows to the same tap position as the Master. If communication with the Master is lost, (E-LAN error) the Slave no longer has a Master and therefore becomes a Master to regulate the voltage itself.

The E-LAN error status LED on the regulator will be cleared by fixing the fault on the E-LAN. Ten seconds after the error is cleared, the regulators are returned to their prior parallel state, i.e, the original Slave will return back from Master to Slave. However, the regulators will remain (“locked”) in Manual till the Master (the first in the group list) is set back to Automatic. At this time the Slave will also switch from Manual back to Automatic.

The function of “Manual Locked at E-LAN Error” is to lock the regulators in Manual, where they cannot be returned to Automatic till the E-LAN error is cleared and the Master is physically changed (local or remotely) back to Automatic.

Figure 1, shows an example of the displays of both paralleled regulators when an E-LAN failure occurs.

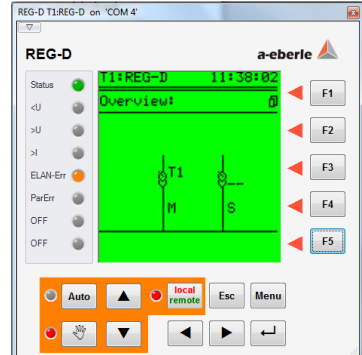
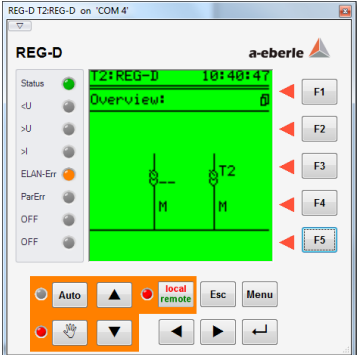
T1 ParaGramer Panel Display:	T2 ParaGramer Panel Display:
	
<ul style="list-style-type: none"> • An E-LAN-Err is indicated by LED • Manual (Hand) mode is indicated by red LED (green Auto light is extinguished) • T1 is shown with the mode being “M” for Master • The transformer representation to the right of T1 has no label, to indicate information cannot be communicated across the faulty E-LAN. However, “S” for Slave is reported, which was the last known state 	<ul style="list-style-type: none"> • An E-LAN-Err is indicated by LED • Manual (Hand) mode is indicated by red LED (green Auto light is extinguished) • The transformer representation to the left of T2 has no label, to indicate information cannot be communicated across the faulty E-LAN. However, “M” for Master is reported, which was the last known state • T2 is shown with the mode being “M” for Master

Figure 1. Example reporting of E-LAN failure with Master-Follower parallel programme and “Manual Locked at E-LAN Error”=ON



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“Manual Locked at E-LAN error” = OFF (not recommended)

If operating with the Master-Follower parallel programme, an E-LAN error will cause each regulator to change to Master. Operation will continue with each regulator remaining in Automatic mode.

This is not a recommended combination, as the regulators are still connected to the same bus and could start working against each other (one tapping up, the other down); therefore causing excessive circulating current to occur. Without the E-LAN working, the Master-Follower backup supervisions of zero taps apart and I_{circ} monitoring cannot function.

Upon return of the E-LAN, the Master-Follower parallel programme will automatically resume again, with the first unit in the group list remaining as Master and the other returning to being a Slave. If the transformers have become too many taps apart when the E-LAN returns, and do not return to the same tap within the “*ParErr after n*TCinOperation*” time setting, then a Parallel Error would occur, resulting in all regulators being switched to Manual.

Circulating-Current (delta I sin phi) parallel programme

“Manual Locked at E-LAN error” = OFF

If operating with Circulating-Current parallel programme, an E-LAN error will cause all regulators to change to dCos(phi) “Emergency Mode”, but will continue to operate in Automatic mode.

The indicated status on ParaGramer will change from “P” (Paralleled) to “I” (Independent).

When the E-LAN fault is cleared, the regulators automatically return back to normal operation.

Figure 2, shows an example of the displays of both paralleled regulators when an E-LAN failure occurs.

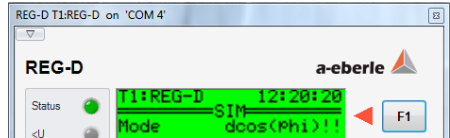
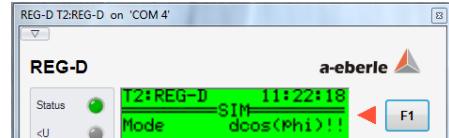
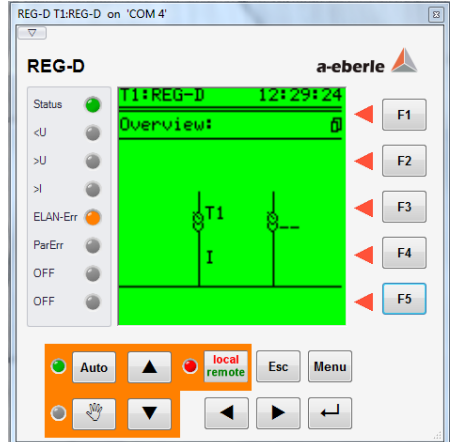
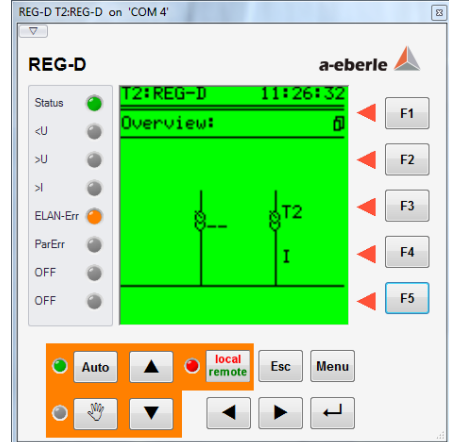
<p>T1 Mode Panel Display:</p>  <p>Note dcos(phi) now indicated</p>	<p>T2 Mode Panel Display:</p>  <p>Note dcos(phi) now indicated</p>
<p>T1 ParaGramer Panel Display:</p> 	<p>T2 ParaGramer Panel Display:</p> 
<ul style="list-style-type: none"> • An E-LAN-Err is indicated by LED • Auto mode is indicated by green LED • T1 is shown with the mode being “I” for Independent • The transformer representation to the right of T1 has no label, to indicate information cannot be communicated across the faulty E-LAN. 	<ul style="list-style-type: none"> • An E-LAN-Err is indicated by LED • Auto mode is indicated by green LED • The transformer representation to the left of T2 has no label, to indicate information cannot be communicated across the faulty E-LAN. • T2 is shown with the mode being “I” for Independent

Figure 2. Example reporting of E-LAN failure with Circulating-Current parallel programme with “Manual Locked at E-LAN error”=OFF

“Manual Locked at E-LAN error” = ON

If operating with Circulating-Current parallel programme, an E-LAN error will cause all regulators to change from “P” (Paralleled) to “I” (Independent), but will also force each from Automatic to Manual (Hand) Voltage Regulation mode, thus stopping automatic tap operations.

The E-LAN error status LED on the regulator will be cleared by fixing the fault on the E-LAN. At this time both will also switch from Independent to Paralleled. However, the regulators will remain (“locked”) in Manual till each is set back to Automatic.

Figure 3, shows an example of the displays of both paralleled regulators when an E-LAN failure occurs.

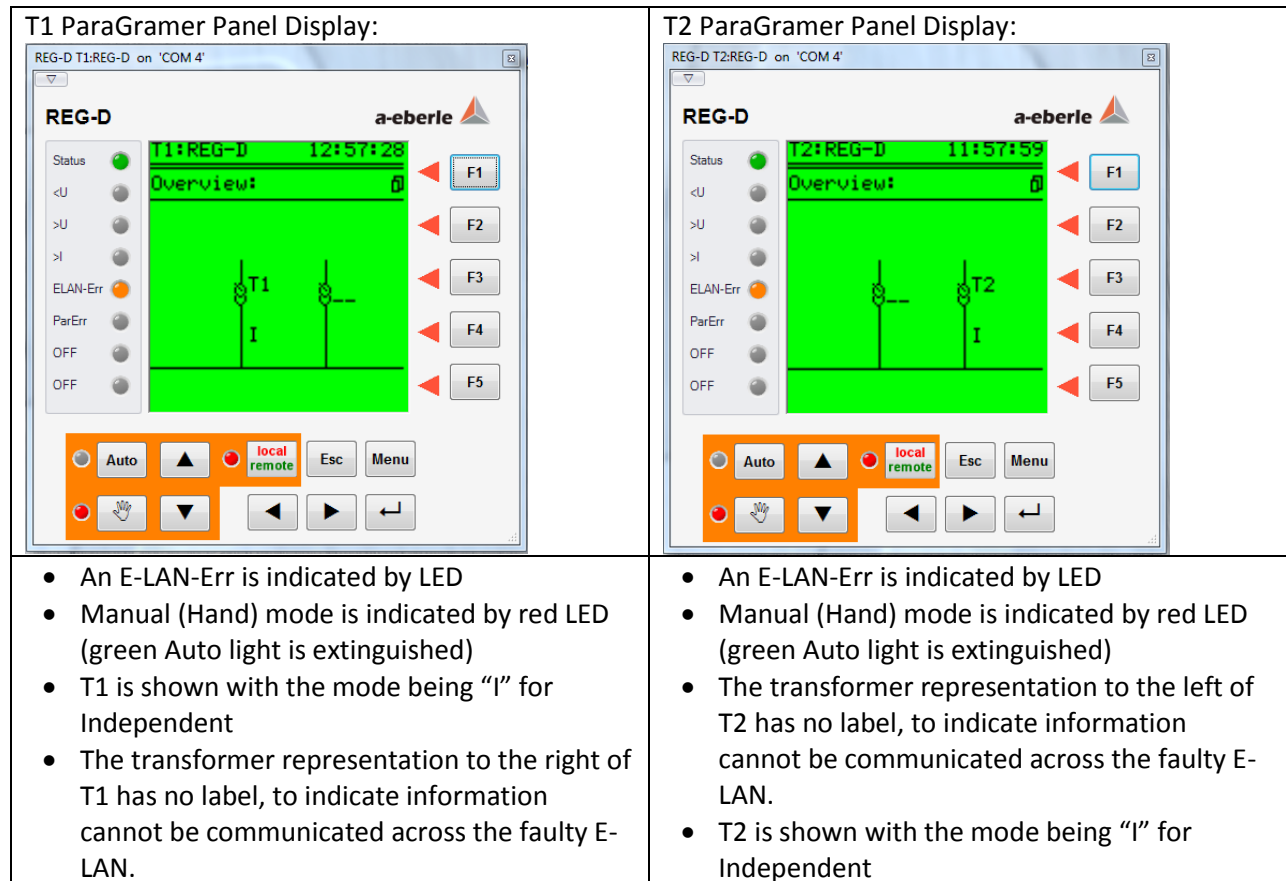


Figure 3. Example reporting of E-LAN failure with Circulating-Current parallel programme with “Manual Locked at E-LAN error”=ON

Review of Relevant Settings:

Master-Follower: 1st ParErr after n*AL-Time Setting:

- This setting allows for the situation where a transformer is brought into a parallel scheme at a different tap setting to the existing transformers. The setting gives time for the introduced transformer to be tapped to match the others. The setting is a time multiplier of the “tap-changer-in-operation” time setting

Maximum permissible I_{circ} value (Perm. I. circ.):

- In Circulating-Current regulation modes, this setting value is used as part of the Circulating-Current regulation algorithm.
- In Master-Follower regulation mode, it is used as a backup measurement and generates a Parallel Error if the setting value is exceeded (as any difference in taps will generate a circulating current).

Permissible difference of taps:

- This setting applies to Circulating-Current regulation mode to provide backup supervision.

“Manual Locked at E-LAN error”:

- This setting will force regulators into Manual, upon an E-LAN error. It is recommended to select this option

SysCtrl value:

- The SysCtrl value permits the designer to implement a different behaviour of the regulator on the occurrence of Tap or Parallel Error. The SysCtrl value is not a WinREG “setting”, but is altered by use of a Terminal Programme. The SysCtrl setting can be viewed in the “Features” list, after downloading a setting file from the relay.

If any of this promotes a question or concern about how your existing regulators are configured, feel free to contact HV Power to discuss. Our Services can be tailored to your needs ranging from advice, to scheme reviews or to the creation of standard designs etc.