APPLICATION NOTE

Busbar protection 7SS85 having more than one ETH-BD-2FO for connecting 6MU85

SIPROTEC 5

APN-074, Edition 3, ENG; unrestricted

SIEMENS

SIPROTEC 5 - Application

Busbar protection 7SS85 having more than one ETH-BD-2FO for connecting 6MU85

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Content

1 Introduction

The distributed busbar protection 7SS85 receives the bay measurements from Merging Units as Sampled Value streams that are compliant to IEC 61850-9-2 / IEC 61869 standard. It is capable to handle up to 24 measuring points. However, due to the limited bandwidth of the process bus interface card ETH-BD-2FO it might be required to install additional ETH-BD-2FO cards for processing the high data load caused by the SV streams of the Merging Units that provide the measuring point data. This is especially required when the MUs provide the measuring point data with SV streams with high sampling rates or with streams containing many measurement channels among which the four currents that are required for the BBP are included.

The APN introduces an advanced engineering concept that allows to configure such kind of systems, so that the 7SS85 can process the high data loads and the bandwidth limitations are considered. Because the solution presented in this document is fully compliant to IEC 61850-9-2 / IEC 61869 it is generally applicable for any process bus system or can easily be combined with and integrated in existing process bus systems.

Explicitly to be noted here that for BBP systems with more than 20 measuring points the back-up protections, for example overcurrent and breaker failure, should be done in the merging units. Only busbar differential and end-fault protection shall be included in the central unit.

2 Distribution of Streams on several ETH-BD-2FO Interfaces based on Network Load Calculation

Depending on the stream layout – the number of measurement channels contained in a stream and the sampling rate of the steam are configurable - the number of streams that can be subscribed by one ETH-BD-2FO interface with 100 MBit/s bandwidth varies. The table below shows the data load generated by streams with 8 measurement channels.

Stream Type	Sample Rate [Hz]	ASDUs	Data rate [Mbit/s]	Max. no of streams with 60 % load
F4000S14I4U	4000	1	5,440	11
F4000S24I4U	4000	2	4,432	13
F4800S14I4U	4800	1	6,528	9
F4800S24I4U	4800	2	5,318	11
F12800S84I4U	12800	8	11,763	5
F14400S64I4U	14400	6	13,536	4
F15360S84I4U	15360	8	14,116	4

Table 1: Data load contributed by the various stream types containing 8 channels

With the recommendation that max. 60 % of the bandwidth to be used with above table can be calculated how many streams can be processed by one ETH-BD-2FO with 100 MBit/s bandwidth. When the limit of 60 % is exceeded an additional interface card must be used. In a 7SS8 up to three ETH-BD-2FO cards for SV stream processing can be installed.

For managing the high data loads of such kind of systems Virtual LANs (VLANs) must be used. This application note explains the engineering of VLANs and their configuration in the RUGGEDCOM Switches forming the process bus network. Furthermore, the network and VLAN configuration in DIGSI 5 and IEC 61850 System Configurator, when more than one ETH-BD-2FO module is required in the 7SS8 device, are focus of this document.

3 Topology Example

'*Figure 1*' shows a schematic of a maximum configuration of a busbar differential protection for up to 24 measuring points, with having 3 numbers of ETH-BD-2FO modules mounted in the 7SS8 IED. The assignment of the merging units to the 3 ETH-BD-2FO modules shall be well balanced; this means, referring to below figure, that the data load of all three groups shall be as much as possible the same, but not higher than approx. 60 % of 100 MBit/s each.

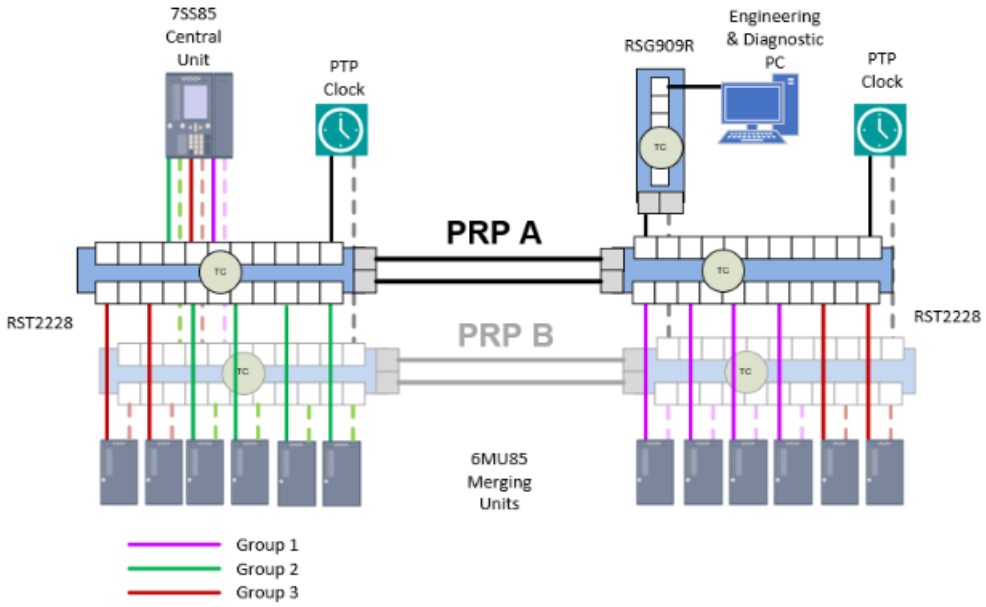

Figure 1: Simplified scheme for a distributed busbar differential protection using three ETH-BD-2FO modules

Note: The configuration described in this, and the following sections is only an example for showing the engineering principles. In real application cases most probably one pair of switches will be mounted in the control room having the 7SS8, PTP clocks and RedBox RSG909R connected. The other switches (one pair or more) will be mounted close to the switchgear having all Merging Units connected.

For the simpler topology without network redundancy connecting the IEDs and other equipment only with one line to the process bus network please refer to section ***'Fehler! Verweisquelle konnte nicht gefunden werden.*** *Fehler! Verweisquelle konnte nicht gefunden werden.*', which explains the difference in configuration.

4 Network and VLAN Engineering

Essential for the VLAN engineering is the network topology, which is defining how the devices are connected to the ports. This mapping is needed for all network components, in example configuration described in this document the mapping table for the RST2228 switches and for the RedBox RSG909R are provided.

Network Topology in Detail

Referring to '*Figure 1*' we assume per PRP network that on each pair of the two switches 12 Merging Units are connected. For the example configuration of this APN a network topology as defined in following tables shall be assumed for the RST2228 switches and the RSG909R.

Swith	Port	Connected Device	Port Type	Description
RST2228 Left side PRP A/B	0/1	RST 2228 (right side)	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	0/2	RST 2228 (right side)	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	0/3			
	0/4	Eng PC **	SFP Transceivers RUGGEDCOM SFP1112-1	RJ45, 10/100/1000 BASE-TX
	1/1	PTP GNSS Clock *	RMM2973-4RJ45	4 x RJ45, 10/100/1000 BASE-TX
	1/2	Diagnosis & Test		
	1/3			
	1/4			
	2/1	7SS85 Port E	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	2/2	7SS85 Port F		
	2/3	7SS85 Port N		
	2/4			
	3/1	MU 1 - Group 1	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	3/2	MU 2 - Group 1		
	3/3	MU 3 - Group 1		
	3/4	MU 4 - Group 1		
	4/1	MU 9 - Group 2	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	4/2	MU 10 - Group 2		
	4/3	MU 11 - Group 2		
	4/4	MU 12 - Group 2		
	5/1	MU 17 - Group 3	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	5/2	MU 18 - Group 3		
	5/3	MU 19 - Group 3		
	5/4	MU 20 - Group 3		
	6/1		RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	6/2			
	6/3			
	6/4			
		* only PTP ** emergency access on switch via default management VLAN 1 (can be removed later)		

Table 2: Connection Table of both RST2228 Switches on the left side

Swith	Port	Connected Device	Port Type	Description
RST2228 Right side PRP A/B	0/1	RST 2228 (left side)	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	0/2	RST 2228 (left side)	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	0/3	RedBox RSG909R	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	0/4	Eng PC **	SFP Transceivers RUGGEDCOM SFP1112-1	RJ45, 10/100/1000 BASE-TX
	1/1	PTP GNSS Clock *	RMM2973-4RJ45	4 x RJ45, 10/100/1000 BASE-TX
	1/2			
	1/3			
	1/4			
	2/1	MU 5 - Group 1	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	2/2	MU 6 - Group 1		
	2/3	MU 7 - Group 1		
	2/4	MU 8 - Group 1		
	3/1	MU 13 - Group 2	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	3/2	MU 14 - Group 2		
	3/3	MU 15 - Group 2		
	3/4	MU 16 - Group 2		
	4/1	MU 21 - Group 3	RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	4/2	MU 22 - Group 3		
	4/3	MU 23 - Group 3		
	4/4	MU 24 - Group 3		
	5/1		RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	5/2			
	5/3			
	5/4			
	6/1		RUGGEDCOM RMM2942-4LC2	100Base-FX, MM, 1310 nm, LC, 2 km
	6/2			
	6/3			
	6/4			
		* only PTP ** emergency access on switch via default management VLAN 1 (can be removed later)		

Table 3: Connection Table of both RST2228 on the right side

Swith	Port	Connected Device	Port Type	Description
RSG909R	RNA A/B	RST 2228 (right side)	SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX	1000Base-SX SFP – MM, 850 nm, LC, 0.5 km
	1	Engineering & Diagnostic PC	---	RJ45, 10/100/1000 BASE-TX
	2		---	RJ45, 10/100/1000 BASE-TX
	3		---	RJ45, 10/100/1000 BASE-TX
	4		---	RJ45, 10/100/1000 BASE-TX
	5		---	RJ45, 10/100/1000 BASE-TX
	6	Eng PC **	---	RJ45, 10/100/1000 BASE-TX
	7		---	Coupler port - empty
		** emergency access on switch via default management VLAN 1 (can be removed later)		

Table 4: RedBox connection details

More details regarding emergency access on switch (see footer in both tables above) will follow in section explaining the RuggedSwitch configuration.

VLAN Engineering

Next figure displays the VLAN engineering scheme to be applied for systems that require more than one interface card in the 7SS8 IED. In configuration described in this document 24 Merging Units will be connected to the busbar protection IED, each Merging Unit publishing the SVs of one measuring point.

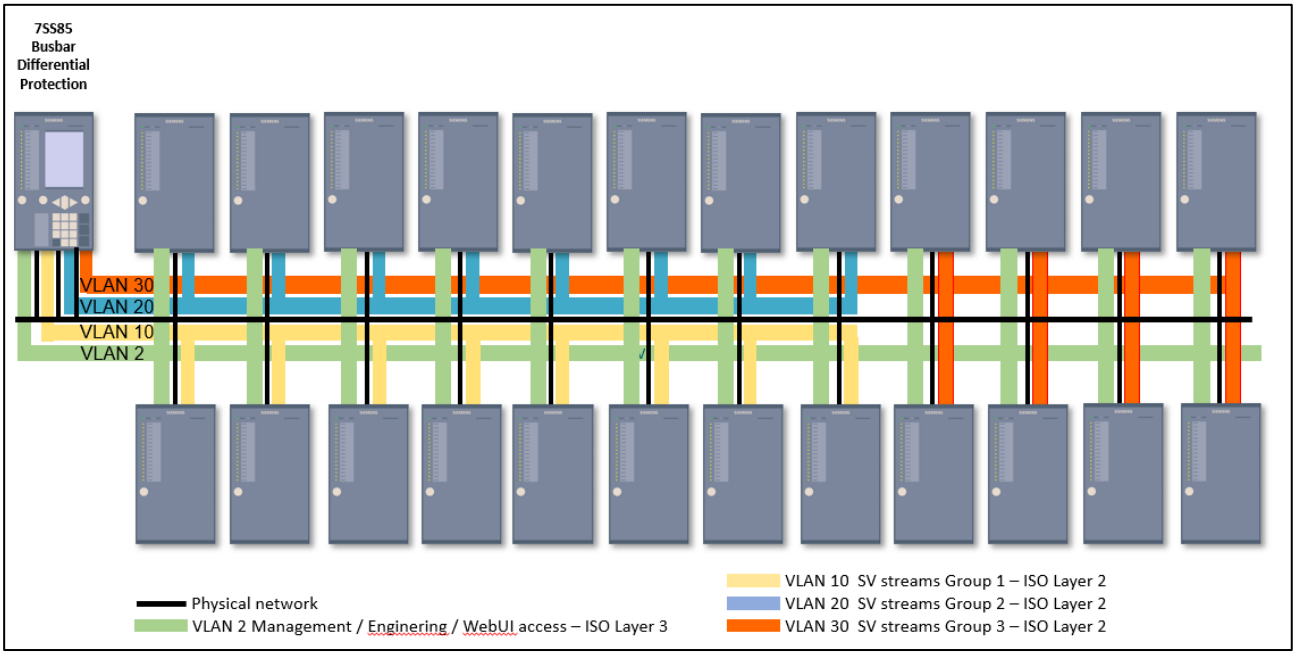

Figure 2: Simplified VLAN distribution for the example in this application note

The VLANs have to manage the traffic as follows:

- VLAN 2 → Port E/F/N of 7SS85 and all MUs
- VLAN 10 → Port E of 7SS85 and all Group 1 MUs
- VLAN 20 → Port F 7SS85 and all Group 2 MUs
- VLAN 30 → Port N 7SS85 and all Group 3 MUs

Each of the three ETH-BD-2FO modules will subscribe the SVs from 8 Merging Units. With VLAN scheme as shown above it will be achieved that each interface only receives the appropriate SV streams. Based on the assumption that each Merging Unit is publishing a stream type F4000S14I4U each card has to process a network load as per '*Table 1*'of approx. 44 MBit/s. The limit of 60 % bandwidth consumption is herewith adhered to. In this calculation the traffic running in VLAN 2 is neglected due to its small data load compared to the loads caused by SV streams.

For the PTP time synchronization a separate VLAN 1 will be configured in the switches, which is not shown in above figure. Explanations will be given in section below, in which the VLAN configuration of the switches is explained in detail (refer to '*Fehler! Verweisquelle konnte nicht gefunden werden. Fehler! Verweisquelle konnte nicht gefunden werden.*').

IP Addressing

According to the current IEC 61850 Standard a device may not be connected through more than one access points to the same network (Edition 3 of IEC 61850 Standard will be released soon and most probably cancel this restriction – please follow release details of SIPROTEC 5 team). However, in our application ports E, F and N of the 7SS85 will be connected to the same physical network. For that, we'll need to implement a workaround during the configuration in IEC 61850 System Configurator, creating three independent subnets. In addition, the IP-traffic must reach all devices. Therefore, the same IP address segment will be used for all of them.

Take the following table as example when assigning the IP addresses for the protection device and merging units:

Subnet 1 (Group 1)			Subnet 2 (Group 2)			Subnet 3 (Group 3)	
MU 1 - Group 1	10.16.60.5		MU 9 - Group 2	10.16.60.45		MU 17 - Group 3	10.16.60.85
MU 2 - Group 1	10.16.60.10		MU 10 - Group 2	10.16.60.50		MU 18 - Group 3	10.16.60.90
MU 3 - Group 1	10.16.60.15		MU 11 - Group 2	10.16.60.55		MU 19 - Group 3	10.16.60.95
MU 4 - Group 1	10.16.60.20		MU 12 - Group 2	10.16.60.60		MU 20 - Group 3	10.16.60.100
MU 5 - Group 1	10.16.60.25		MU 13 - Group 2	10.16.60.65		MU 21 - Group 3	10.16.60.105
MU 6 - Group 1	10.16.60.30		MU 14 - Group 2	10.16.60.70		MU 22 - Group 3	10.16.60.110
MU 7 - Group 1	10.16.60.35		MU 15 - Group 2	10.16.60.75		MU 23 - Group 3	10.16.60.115
MU 8 - Group 1	10.16.60.45		MU 16 - Group 2	10.16.60.80		MU 24 - Group 3	10.16.60.120
7SS85_Port E	10.16.60.1		7SS85_Port F	10.16.60.2		7SS85_Port N	10.16.60.3

Table 5: IP table 7SS8 and Merging Units

The subnet to be used is 255.255.255.0.

Note:
The IP addresses and subnet used here are only indicative and must be adapted to your own network.

5 Configuration of the RUGGEDCOM Switches

The RUGGEDCOM switches and the Redundancy Box must be properly parametrized to allow a controlled flow of data according to the required VLANs.

Get access to the switch by typing on the web browser its IP address (for example https:// 192.168.0.1). Upon connecting to the device, some web browsers may report the web server's certificate cannot be verified against any known certificates. This is expected behavior, and it is safe to instruct the browser to accept the certificate. Once the certificate is accepted, all communications with the Web server through that browser will be secure. Once the connection is established the login box appears. Below the default values.

Username	Password
admin	admin

Keep in mind that if the switch has been previously configured you must know the IP address used as well as the enabled username and password.

For the VLAN configuration and assignment of IP addresses in WebUI it is recommended to have as backup access via the USB-Console interface via putty or teraterm available. Access via USB might become necessary for the case that you lock yourself out from the switch when you change these settings.

Note:

- This application note focuses on PTP (IEEE 1588) and VLAN configuration. Other settings are not scope of this document.
- All screenshots in this chapter showing the configuration in the WebUI of the Ruggedcom Switches are originated from ROS v5.6.0 or later. The WebUI configuration pages of older ROS versions might differ slightly.

Identical Settings in all Switches and RedBox

This section explains the settings which have to be the same for in switches and Redundancy Box. Navigate to the menu “System Time Manager”, select “Configure Time source” and apply configuration as shown next.

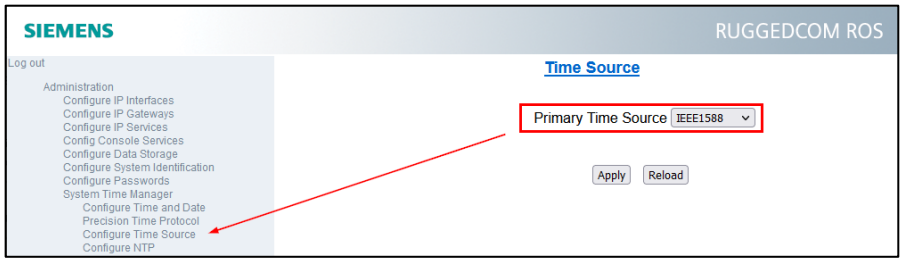

Figure 3: Time Source configuration

Navigate to “Configure Global Parameters” and check if PTP is enabled and if the clock type is selected as P2P Transparent clock. Next figure shows the complete ‘Global Parameter’ configuration.

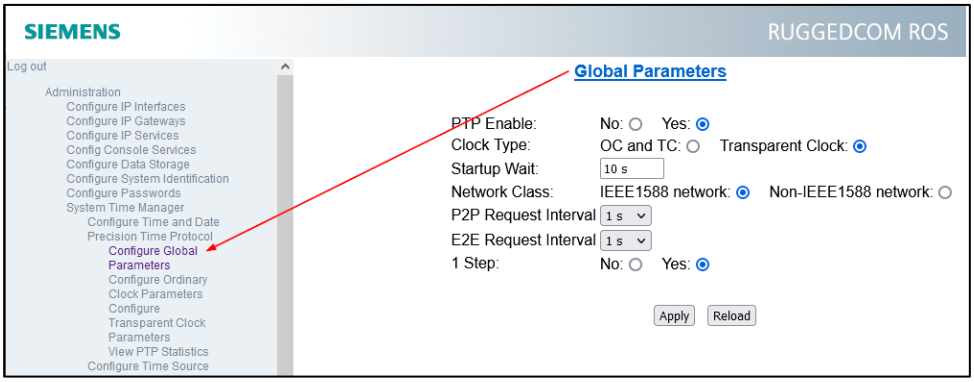

Figure 4: PTP - Global parameters

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Open the “Configure Transparent Clock Parameter” page and apply settings as displayed in below figure. The Utility Profile Level 1, which corresponds to the IEC 61850-9-3, and the transport protocol to “Layer 2 multicast” must be set. The Path Delay Mechanism must be set to Peer-to-Peer.

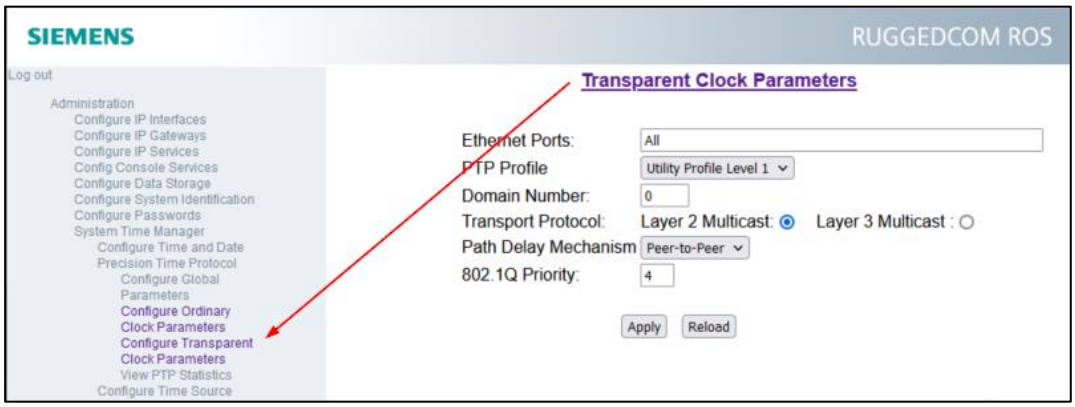


Figure 5: PTP – Transparent Clock Parameters

An essential part of the configuration is the correct parameterization of the virtual LANs.
Start under “Virtual LANs” with the item “Configure Global VLAN Parameters” and check if the VLAN- Awareness is given and the “Ingress Filtering” is disabled.

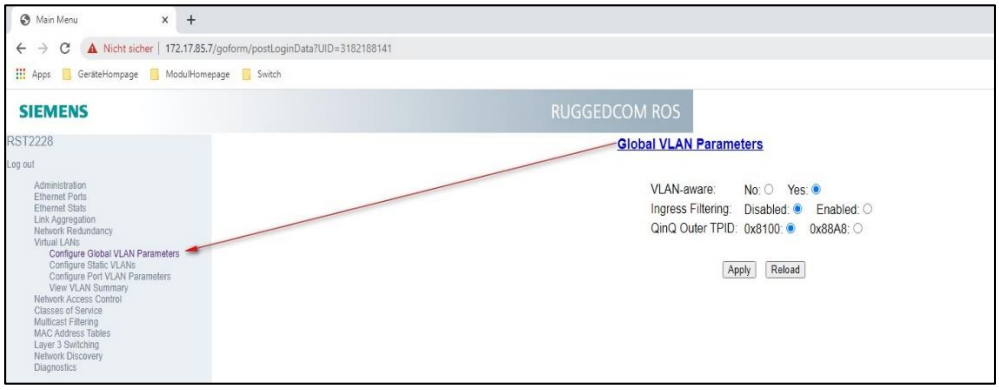


Figure 6: Global VLAN Parameters in Ruggedcom switch

Now the “Configure Port VLAN Parameters” and “Configure Static VLANs” pages to be configured on all switches and theRedundancy Box. Since in both PRP networks the traffic must be managed identical, in PRP A and PRP B the same VLAN configuration must be applied.

Configuring VLANs on both (PRP A/B) RST2228 on the left

"Configure Port VLAN Parameters" as shown below.

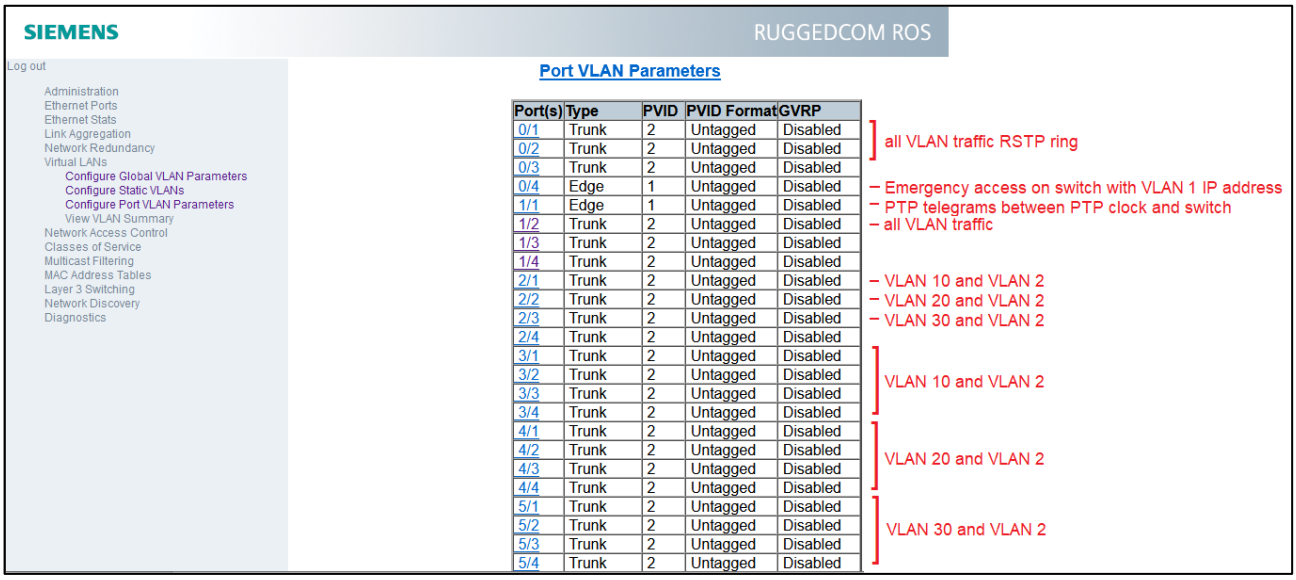


Figure 7: Port VLAN Parameter Configuration of both left hand RST2228 switches

Then configure the 'Static VLANs' as shown in next figure. From the explanation in red font on the right given in previous figure the 'Forbidden Ports' configuration on the 'Static VLANs' page can be derived.

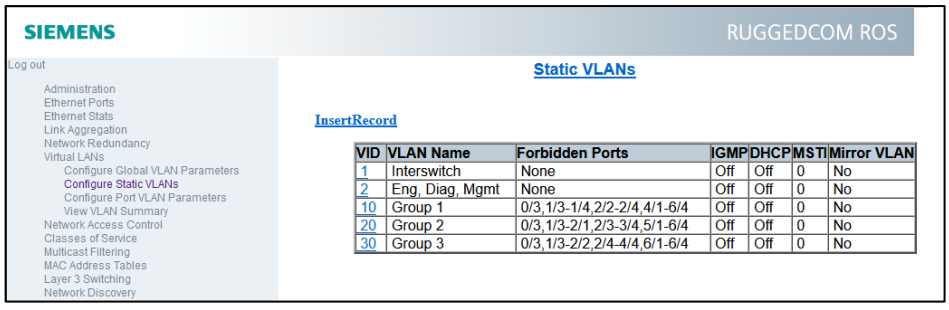


Figure 8: Static VLANs and Forbidden Port settings of both left hand RST2228 switches

Configuring VLANs on both (PRP A/B) RST2228 on the right

"Configure Port VLAN Parameters" as shown below.

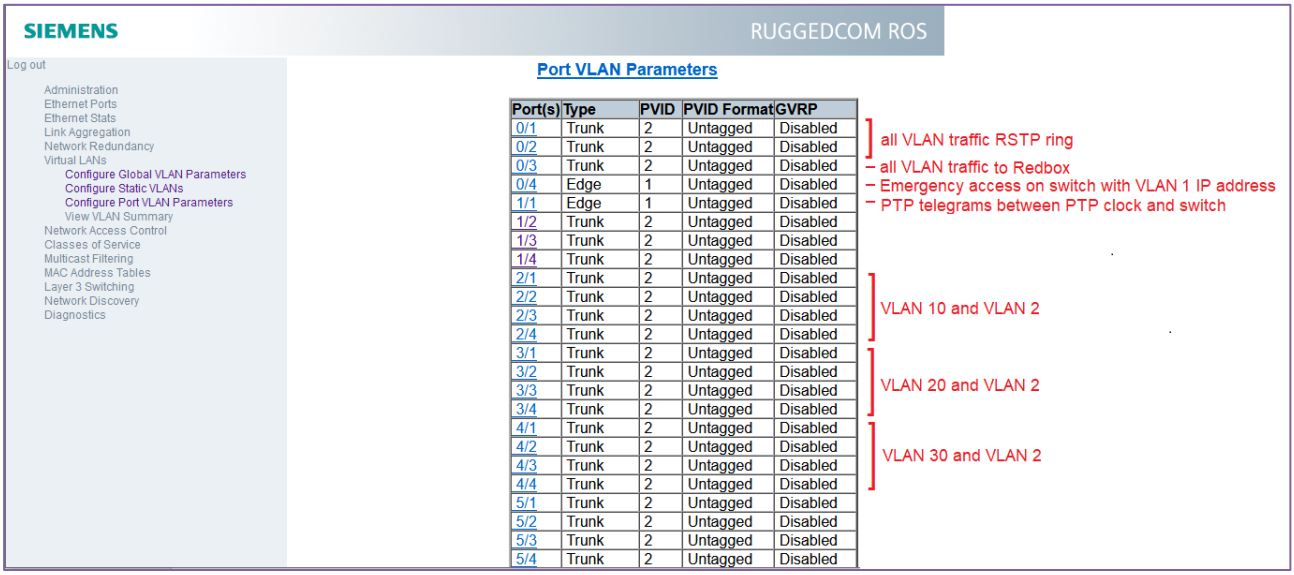


Figure 9: Port VLAN Parameter Configuration of both right hand RST2228 switches

Then configure the 'Static VLANs' as shown in next figure. From the explanation in red font on the right given in previous figure the 'Forbidden Ports' configuration on the 'Static VLANs' page can be derived.

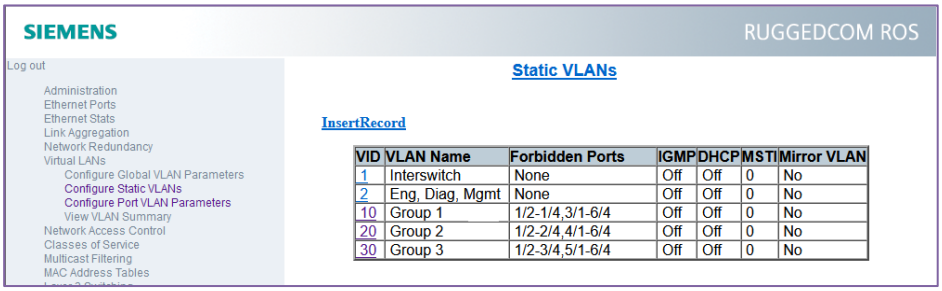


Figure 10: Static VLANs and Forbidden Port settings of both right hand RST2228 switches

Redundancy Box RSG909R

"Configure Port VLAN Parameters" as shown below.

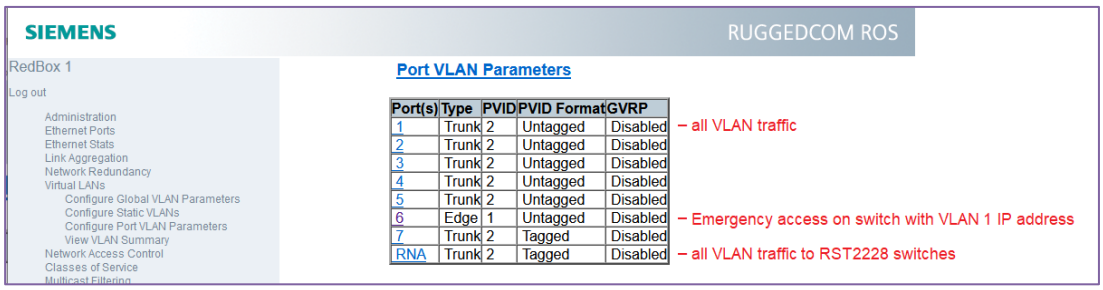
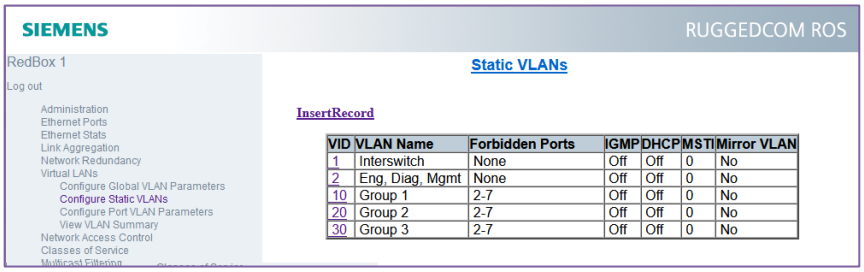


Figure 11: Port VLAN Parameter Configuration of RSG909R



VID	VLAN Name	Forbidden Ports	IGMP	DHCP	MSTI	Mirror VLAN
1	Interswitch	None	Off	Off	0	No
2	Eng, Diag, Mgmt	None	Off	Off	0	No
10	Group 1	2-7	Off	Off	0	No
20	Group 2	2-7	Off	Off	0	No
30	Group 3	2-7	Off	Off	0	No

Figure 12: Static VLANs and Forbidden Port settings of RSG909R

Some Comments and Explanation to above VLAN configuration

- The basic principle of above configuration scheme is, to configure per default all ports as trunk; hence these ports receive per default all telegrams independently from the VLAN tag they have; which telegrams are forwarded through a trunk port is defined in the forbidden port settings using the VLAN tag as criteria.
- From the Engineering PC connected to Port 1 of the RedBox it must be possible to connect on any SIPROTEC 5 device for Engineerung, Diagnostic, Web UI access, etc. Hence this traffic must be directed through all ports, to which SIPROTEC 5 devices are connected.
  For example, a WebUI access telegram is send from Engineering PC, getting tagged with VLAN 2 when entering in Redundancy Box and forwarded untagged from RNA port to PRP RST2228 switch; at entry port 0/3 of RST2228 the telegram is getting tagged again with VLAN 2 and forwarded to all ports, on which SIPROTEC 5 devices are connected. The ports connected with SIPROTEC 5 IEDs are configured as 'Untagged – VLAN 2', hence they forward the telegram without VLAN tag and in the receiving ports of the SIPROTEC 5 IEDs there must be no VLAN tagging configured (see also section below explaining the IEC 61850 System Configurator configuration).
- Exceptional case 'Edge 1' – Reason 1 Emergency Access:
  it might happen that during VLAN configuration the VLAN setting of the port, on which the laptop / PC is connected to, is getting changed; when this happens you cannot connect any more through this port, since the management IP address is assigned to VLAN 1; with connecting engineering PC to the 'Emergency Access' port an access through this back door is still possible; of course alternatively access via USB console will also be possible.
- Exceptional case 'Edge 1' – Reason 2 Time Synchronization:
  The PTP clock connected to the 'Edge 1 Untagged' port exchanges with the RST2228 switch only untagged PTP telegrams; the PTP telegrams are send out untagged from switch through this ports, PTP clock replies with untagged PTP telegrams; the 'Edge 1' setting guarantees that the switch only forwards the PTP telegram traffic on this port, hence the PTP clock network interface has only to process PTP traffic and is not getting overloaded with MBits/s of multicast SV traffic existing in the network;
  Note: on PTP clock VLAN tagging must be disabled

6 Configuration in DIGSI 5

Complete the DIGSI 5 configuration as required for a process bus system. Assign to each device the IP address, which has been defined in the IP address table before. As just explained at the end of previous section the TCP/IP based engineering, troubleshooting and diagnosis traffic is forwarded untagged from the switch port to device, hence the CheckBox 'Use VLAN tag' remains unticked in IED 7SS85, as well as in the Merging Units.

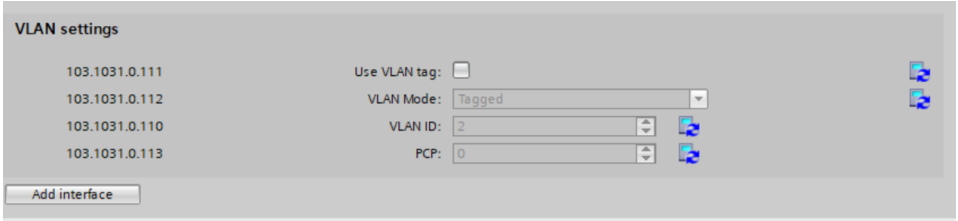


Figure 13:. VLAN Settings disabled in DIGSI 5

Create the IEC 61850 station (Edition 2.1 if strongly recommended) and assign to it the merging units and protection device. Export the changes to the IEC 61850 System Configurator.

7 Configuration in IEC 61850 System Configurator

Per default when opening the IEC 61850 System Configurator the first time in the "Network" view the ports E, F and N of the 7SS85 will be assigned to different default subnets. This happens because, as mentioned before, the IEC 61850 Standard doesn't allow the connection of more than one access point of a device to the same network.

In the next step rearrange the merging units using the drag and drop functionality, in such a way that each 7SS8 process bus interface and its associated MUs are assigned to a separate subnet, as shown in below figure.

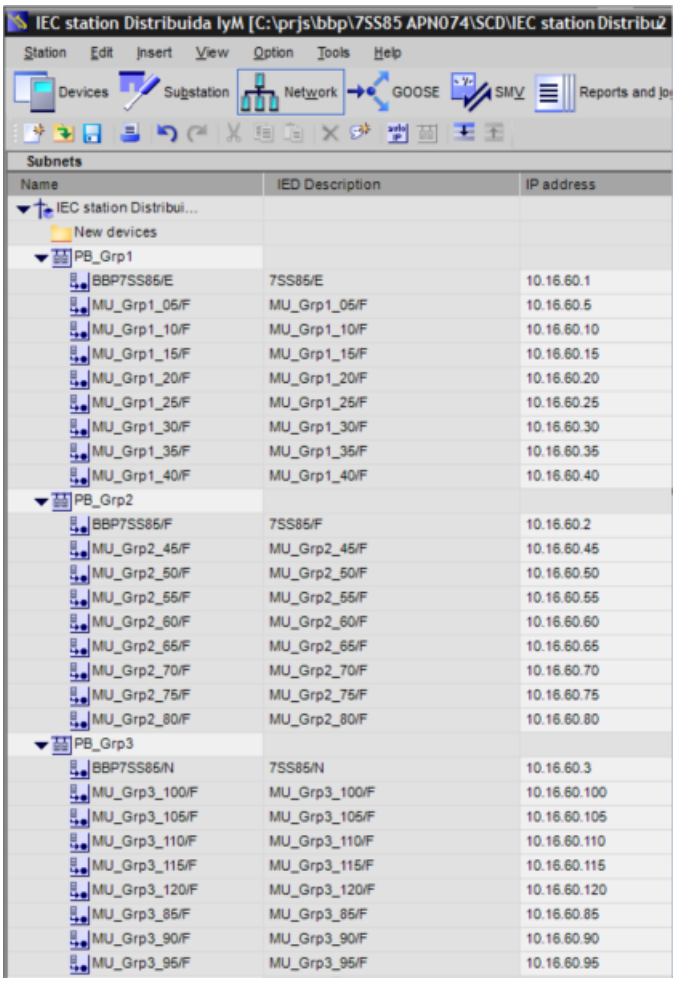


Figure 14: Subnet assignment IEC 61850 System Configurator

With this workaround the IP-addressing of the three subnets maintains the rules of a unique network and can be managed as such when using the same physical infrastructure.

Now, in the GOOSE and SMV editors the signals to be connected, as described in the manuals '*IEC 61850 System Configurator – Manual*' and '*SIPROTEC 5 Process Bus – Manual*', both can be found in the SIOS portal.

As per the VLAN engineering concept, explained in previous section, the related parameters of each SMV control block must be adapted. To do that, go to the dataset and click on the properties of the "SMV Control Block" at the right side of the screen, as shown in '*Figure 15: Assignment of VLAN ID in the SMV Control Block*'. Alternative you can right-click on the dataset and select the option "Configure SMV".

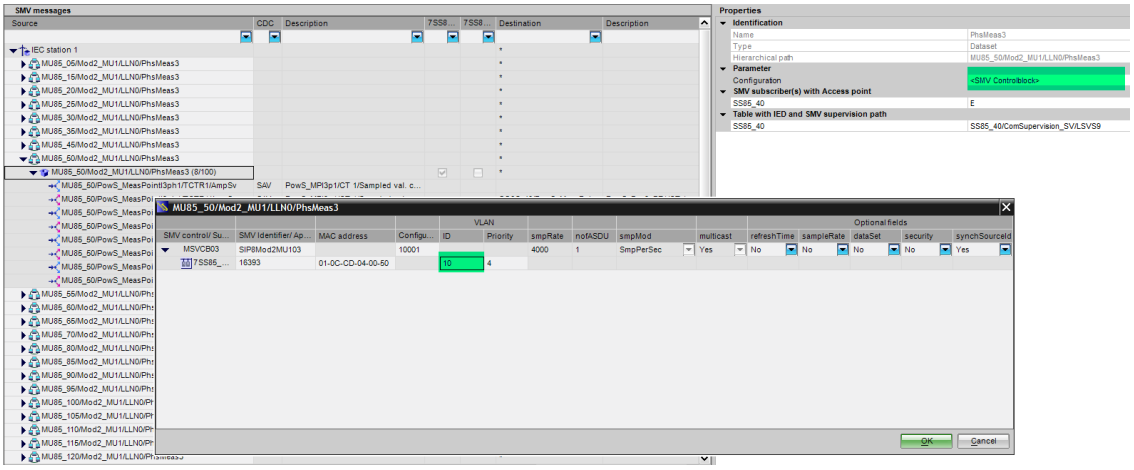


Figure 15: Assignment of VLAN ID in the SMV Control Block

Assign the VLAN ID in control blocks as follows:

- VLAN 10 in Group 1 Control Blocks of MUs subscribed by Port E of 7SS85
- VLAN 20 in Group 2 Control Blocks of MUs subscribed by Port F of 7SS85
- VLAN 30 in Group 3 Control Blocks of MUs subscribed by Port N of 7SS85

In the same way assign the VLAN ID for the control blocks of the GOOSE messages, use the same VLAN as for the SV subscriptions.

Note:
Due to the current valid version of IEC 61850 Standard, which states that a device may not be connected through more than one access points to the same network, GOOSE messages can be only exchanged within the same subnet, which may lead to inconvenient configurations.
As already stated before, it is expected that with new Edition 3 of IEC 61850 Standard this restriction will become obsolete, which accordingly also will be removed in the upcoming release of IEC 61850 Station Configurator.

8 Differences in Configuration for a Non-redundant Network Topology

This section briefly explains the differences in configuration that must be applied for a busbar bar protection network topology without PRP redundancy, a schematic view provides the figure below.

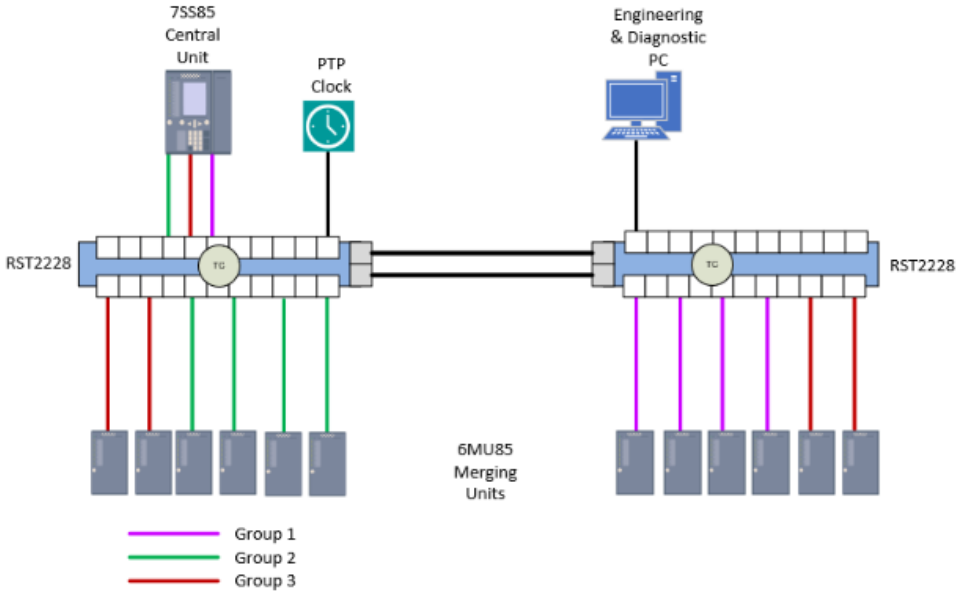


Figure 16: Distributed busbar differential protection without PRP redundancy and one PTP Clock

This example is without PTP clock redundancy, only one PTP clock is used. Further can be seen that a RedBox is not required anymore, the Engineering & Diagnostic PC is connected directly with the switch.

Basically, the configuration of such kind of system is nearly the same as of a system that implements PRP redundancy as explained above. Apart from fact that only two switches are needed and have to be configured, following are the differences to be considered:

- In DIGSI 5 for all devices the Redundancy protocol must be set to 'Line Mode'
- Replace on the right switch the 'SFP/SFP+Transceivers RUGGEDCOM SFP1122-1SX' in Port 0/3 with a 'SFP Transceivers RUGGEDCOM SFP1112-1' and connect the Engineering & Diagnostic PC with this port
- Connect the PTP clock configured as Single Attached Node (SAN) to the switch

Apply for both switches the same settings as described in '***Fehler! Verweisquelle konnte nicht gefunden werden.*** *Fehler! Verweisquelle konnte nicht gefunden werden.*'.

9 Conclusions

For large busbar protection schemes it might be required to use more than one ETH-BD-2FO for connecting 6MU85 devices. This might be necessary due to the module's maximum bandwidth of 100 MBit/s.

When using several modules, the traffic load shall be balanced between them, i.e. subscribing fairly the same amount of measuring points with each module.

Each ETH-BD-2FO of the 7SS85 device and the corresponding bay units (merging units) must belong to the same subnet, which must be different to the subnet used for the other module in the IEC 61850 Station Configurator. To limit the GOOSE and SMV traffic handled by each communication module it is necessary to use VLANs.

When the IP based traffic e.g. Engineering traffic, MMS IEC 61850, etc. shall be separated by VLANs then also for that a dedicated VLAN engineering will be required, which needs to be considered in the interface settings of the DIGSI 5 hardware configuration and in the VLAN configuration of the network switches.

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