PSI*control* Base

System Engineering System Specification

Technical Appendix J

IEC 101/104 Profile

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Creation	1.0	12/07/2007	A. Scheurich
Corrections to current versions of telecontrol gate-ways	1.1	07/17/2008	A. Scheurich
New structure: chapter for IEC101 and IEC104 summarized for the sake of a better overview	1.2	12/08/2008	A. Scheurich

Table of Contents

1 The IEC 870-5-101 Telecontrol Protocol

The PSI Network Control System can connect new telecontrol technology to the serial interface by means of the IEC 870-5-101 telecontrol protocol. The corresponding telecontrol protocol software is included in the scope of delivery.

The Network Control System is multiprotocol-capable. The parallel application of IEC-870-5-101 protocols and other - even proprietary - telecontrol protocols is possible.

1.1 Basis of Implementation

The implementation of the IEC-870-5-101 protocols by PSI is based on the following documents:

- DIN EN 60870-5-101 according to the published standard, status of October 1996 [1],
- IEC 60870-5-101 A1 "Additional Definitions for DIN EN 60870-5-101", dated 1999 (previously IEC 57/351/CDV "Extension of Time Tags", additional definitions for DIN EN 60870-5-101, dated July 1998) [2],
- IEC 60870-5-101 A2 "Additional Definitions for DIN EN 60870-5-101", dated January 2000 (previously E DIN 40952 Revision 9, dated November 1997) [3].

For the implementation of IEC-870-5-101 via dialup modem, also see:

- IEC 57/428/CDV "Influence of modem transmission procedures with scramblers on the data integrity of transmission systems using the Protocol IEC 60870-5", dated October 1999 [4].

1.2 ISO/OSI Layer Model According to IEC-870-5-101

<table>
<tr><td colspan="2">IEC-870-5-101 „Companion Standard for basic telecontrol tasks“
IEC-870-5-5 „Basic application functions“
IEC-870-5-4 „Definition and coding of application informations elements“
IEC-870-5-3 „General structure of application data“</td><td>7</td></tr>
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<tr><td colspan="2">---</td><td>5</td></tr>
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<tr><td colspan="2">---</td><td>3</td></tr>
<tr><td colspan="2">IEC-870-5-2 „Link transmission procedures“</td><td rowspan="3">2</td></tr>
<tr><td>Balanced operation</td><td>Unbalanced operation</td></tr>
<tr><td colspan="2">IEC-870-5-1 „Transmission frame formats“ FT1.2</td></tr>
<tr><td>V.24/V.28</td><td>X.24/X.27 (X.21)</td><td>1</td></tr>
</table>

Figure 1.2-1 ISO/OSI layer model according to IEC-870-5-101

1.3 Boundary Conditions

The use of both standardized bit pattern telegram types and of types from the private sector is possible, but is not included in the scope of delivery.

A specific telecontrol protocol has to be assigned to each RTU.

1.4 Comment on the Transmission Rate under IEC 870-5-101

The IEC 870-5-101 telecontrol protocol is information object-oriented. In contrast to bit-oriented telecontrol protocols, it therefore requires a higher transmission bandwidth, given the same volume of information to be transmitted. This applies in particular to General Interrogations or the transmission of periodical measured values of the RTU.

The transmission rate must be at least 600 bps. When working with low transmission rates, optimum information object blocking of the RTU should be ensured. With IEC-870-5-101, this requirement is linked with the assignment of information object addresses. Optimal blocking (SQ = 1) can only be attained within the same information types if the assignment of information object addresses is sequentially increased by "1".

1.5 Comment on Transmission Protection under IEC 870-5-101

On the ISO/OSI layer 2, the IEC 870-5-101 telecontrol protocol uses the balanced or unbalanced connection protocol according to IEC-870-5-2 with telegram formats according to IEC-870-5-1 FT 1.2.

Telegram formats according to IEC-870-5-1 ensure transmission protection via a hamming distance of d = 4 by means of

- the use of synchronization-persistent start and end byte as telegram framing,
- the acknowledgment of all bytes of a telegram with an even parity bit per data byte and additional framing via start and stop bits,
- the acknowledgment of the data bytes of a complete telegram via additional check bytes per telegram (arithmetical sum modulo 256 over all data bytes)

in control and monitoring direction.

1.6 Comment of the Application of IEC870-5-101 via Dialup Modem (Option)

In the standard, the protocol IEC 870-5-101 is exclusively intended for leased lines. The operation over dialup modems is the responsibility of the supplier and customer according to [2].

In contrast to periods set for leased line connections of 10 seconds, the periodical connection monitoring ("test link") can be changed to a longer period, for instance to several hours. This serves to avoid high connection costs. In the PSI Network Control System, the period can be parameterized channel-specifically

- between 1 and 16383 s (approximately 4 1/2 h) or
- between 1 and 8191 10-second units (approximately 22 1/2 h / once per day).

In addition, periodical connection monitoring can be switched off for dialup connections. For RTU monitoring, a System General Interrogation can be initiated once per day via dialup RTU.

1.7 Time Synchronization of the RTU

RTUs without own time receiver are time-synchronized over the telecontrol interface.

The corresponding procedure according to IEC 870-5-5 Section 6.7 is used in the IEC 870-5-101 protocol. The telegrams for time synchronization are transmitted by the telecontrol protocol software in the telecontrol gateway. The time basis is the Unix system time, which is synchronized via the NTP protocol (see Chapter "LAN Clocks" in the Functional Design "System Engineering").

The NTP protocol is designed for high precision with any network connection types. For leased line connections, a preciseness of +/- 10 ms can be reached, even though the time is distributed within the Network Control System or between the Network Control System and the telecontrol gateway over LAN/WAN connections.

1.8 Time Synchronization of the RTU for Leased Line Connections

The telegrams for time synchronization are transmitted connection-specifically according to the following procedures:

- after each successful IEC101 connection setup,
- subsequently, in parameterizable mode every 1 / 5 / 10 / 60 minutes.

1.9 Time Synchronization of the RTU for Dialup Connections (Option)

The telegrams for time synchronization are transmitted connection-specifically according to the following procedures:

- after each successful IEC101 connection setup,
- within the first minute after the connection setup every 10 seconds.

For time synchronization, an RTU requires a specific number of received time synchronization telegrams with equidistant time intervals to be able to "tune" its integrated fine synchronization algorithm.

If a dialup connection is set up only temporarily, the time synchrony of +/- 10 ms will not be reached and a processing in realtime will not be possible. However, information which includes their own timestamps can be transmitted. These attachments can be used in the Network Control System for logging instead of the receive time without being specified as "realtime processing" in the protocol.

1.10 Parameterization of Telecontrol Addresses in the Network Control System

The IEC 870-5-101 telecontrol address, which may maximally consist of 5 levels, is preset in two steps during the parameterization of the Network Control System:

- During the parameterization of the Remote Terminal Unit, the 2-level station address - consisting of the common ASDU address octet 1/2 - can be assigned to each Remote Terminal Unit. A "physical" telecontrol device can be entered as one or several "virtual" Remote Terminal Units in the parameterization of the Network Control System. This means that several common ASDU addresses can be assigned to this device. As a result, several station query commands with the corresponding ASDU addresses will, for instance, be transmitted by the Network Control System for a station query for this component.
- During the parameterization of the individual operating objects, each operating object is assigned a reference to the Remote Terminal Unit over which it is transmitted by telecontrol technology. By doing so, it implicitly receives its station addressing. In addition, a 3-level information object address - consisting of the 3 octets 3/4/5 - as well as the IEC type identifiers of the telegram used for transmission can be preset for each operating object. For realtime transmission, the type identifier of the realtime telegram will be preset.

The common ASDU address or the information object address can be entered in structured mode. This has no effect for telegram processing in the SCADA system, but it simplifies the entry of the data.

1.11 The Project-Specific IEC 870-5-101 Data Profile

1.11.1 Compatibility Definitions of the Application Layer in IEC-870-5-101

This section gives an overview of the project-specific set of telegram types from the completeness of the ASDUs of the application layer, using the compatibility lists of the IEC-870-5-101 standard. Further details can be found in the corresponding standards.

1.11.2 Compatibility According to IEC

This standard defines parameter sets and alternatives. Specific telecontrol systems are created from subsets of these preset parameters. In this context, specific parameters will exclude each other and only one value of the defined parameter will be permitted per system. Other parameters will permit the definition of the total volume or of subsets, which are appropriate for the application in question.

This section summarizes the parameters described in the above sections to allow an appropriate selection for a specific application. If a system is set up with several system components of different vendors, it will be necessary that all partners agree on the selected parameters.

1.11.3 Additional Features of the PSI Network Control System

The PSI Network Control System offers the option to set the following selectable compatibility parameters in Data Engineering (DE) differently and station-specifically:

- length of the address of the data link layer 0/1/2 octets,
- length of common ASDU address 1/2 octets,
- length of the transmission cause 1/2 octets (without/with origin address),
- the length of the information object address 1/2/3 octets.

Legend for Compatibility List

☐	=	Function or ASDU is not used.
X	=	Function or ASDU is used as standardized (preferred value).
R	=	Function or ASDU is used in reverse mode.
B	=	Function or ASDU is used in control and reverse mode.

1.11.3.1 System or Device (System-Related Parameter)

	System definition
X	Definition for the central station (Network Control System)
	Definition for the substation

1.11.3.2 Network Configuration (Network-Related Parameter)

X	End-to-end configuration [also called point-to-point configuration]	X	Multipoint-party line
X	Multiple point-to-point configuration		Multipoint-star configuration

1.11.3.3 Physical Layer (Network-Related Parameter)

Transmission Rate (Control and Monitoring Direction)

Unbalanced interface V.24/V.28, conventional		Unbalanced interface V.24/V.28, recommended for > 1200 bps		Balanced interface X.24 / X. 27			
X	100 bps	X	2 400 bps		2 400 bps		56 000 bps
X	200 bps	X	4 800 bps		4 800 bps	X	64 000 bps
X	300 bps	X	9 600 bps		9 600 bps		
X	600 bps	X	19 200 bps (PSI)		19 200 bps		
X	1200 bps				38 400 bps		

Transmission rate in monitoring direction = transmission rate in control direction

1.11.3.4 Data Link Layer (Network-Related Parameter)

According to this standard, the telegram format FT 1.2, single character "1", and the fixed time monitoring interval are used exclusively.

Transmission Procedure of the Data Link Layer

- [X] Balanced transmission
- [X] Unbalanced transmission

Address Field of the Data Link Layer

- [X] Not available (only balanced transmission)
- [X] One octet
- [X] Two octets
- [X] Structured
- [X] Unstructured

Telegram Length

249 Maximum length L control direction

249 Maximum length L monitoring direction

[ ] Time period during which repetitions are permissible (Trp) or number of repetitions

During unbalanced transmission, the following ASDUs will be retransmitted as user data with the specified transmission causes with data class 2 (low priority).

- [ ] Standardized assignment of ASDU to data class 2:

Type Identifier	Transmission Cause
9, 11, 13, 21	1

- [ ] Special assignment of ASDU to data class 2:

Type Identifier	Transmission Cause

As a reply to a request for data of data class 2, a substation will be permitted to transmit data of class 1 if no data of class 2 is available.

1.11.3.5 Application Layer

Transmission Type of Application Data

According to this standard, only mode 1 (Last significant octet first) is used according to 4.10 IEC-870-5-4.

Common Address of the ASDU (System-Related Parameter)

X	One octet	X	Two octets

Address of the Information Object (System-Related Parameter)

X	One octet	X	Structured
X	Two octets	X	Unstructured
X	Three octets		

Transmission Cause (System-Related Parameter)

X	One octet	X	Two octets (with origin address) The origin address will be set to "o" if it is not used.

Selection of the Standard ASDU

Process Information in Monitoring Direction (Station-Related Parameters)

B	<1> := M_SP_NA_1 =	Single indication
B	<2> := M_SP_TA_1 =	Single indication with time tag
B	<3> := M_DP_NA_1 =	Double indication
B	<4> := M_DP_TA_1 =	Double indication with time tag
B	<5> := M_ST_NA_1 =	Tap position indication
B	<6> := M_ST_TA_1 =	Tap position indication with time tag
	<7> := M_BO_NA_1 =	Bit pattern 32 bits
	<8> := M_BO_TA_1 =	Bit pattern 32 bits with time tag
B	<9> := M_ME_NA_1 =	Measured value, standardized value
B	<10> := M_ME_TA_1 =	Measured value, standardized value with time tag
B	<11> := M_ME_NB_1 =	Measured value, scaled value
B	<12> := M_ME_TB_1 =	Measured value, scaled value with time tag
B	<13> := M_ME_NC_1 =	Measured value, abbreviated floating comma value
B	<14> := M_ME_TC_1 =	Measured value, abbreviated floating comma value with time tag
B	<15> := M_IT_NA_1 =	Counter value
B	<16> := M_IT_TA_1 =	Counter value with time tag
X	<17> := M_EP_TA_1 =	Protection event with time tag
X	<18> := M_EP_TB_1 =	Block excitation of protection with time tag
X	<19> := M_EP_TC_1 =	Block initiation of protection with time tag
X	<20> := M_PS_NA_1 =	Blocked individual indication with state display
X	<21> := M_ME_ND_1 =	Measured value, standardized value with quality identifier
B	<30> := M_SP_TB_1 =	Single indication with time tag CP56Time2a
B	<31> := M_DP_TB_1 =	Double indication with time tag CP56Time2a
B	<32> := M_ST_TB_1 =	Tap position indication with time tag CP56Time2a
	<33> := M_BO_TB_1 =	Bit pattern 32 bits with time tag CP56Time2a
B	<34> := M_ME_TD_1 =	Measured value, standardized value with time tag CP56Time2a
B	<35> := M_ME_TE_1 =	Measured value, scaled value with time tag CP56Time2a
B	<36> := M_ME_TF_1 =	Measured value, abbreviated floating comma value with time tag CP56Time2a
B	<37> := M_IT_TB_1 =	Counter value with time tag CP56Time2a

X	<38> := M_EP_TD_1 =	Protection event with time tag CP56Time2a
X	<39> := M_EP_TE_1 =	Blocked excitation of protection with time tag CP56Time2a
X	<40> := M_EP_TF_1 =	Blocked initiation of protection with time tag CP56Time2a

Either the ASDU set 2, 4, 6, 8, 10, 12, 14, 16, 17, 18, 19 (short time format) or set 30 ... 40 (formats with time CP56Time2a) are used.

Process Information in Control Direction (Station-Related Parameters)

X	<45> := C_SC_NA_1 =	Single command
X	<46> := C_DC_NA_1 =	Double command
X	<47> := C_RC_NA_1 =	Tap position command
X	<48> := C_SE_NA_1 =	Setpoint command, standardized value
X	<49> := C_SE_NB_1 =	Setpoint command, scaled value
X	<50> := C_SE_NC_1 =	Setpoint command, abbreviated floating comma number
	<51> := C_BO_NA_1 =	Bit pattern 32 bits

System Information in Monitoring Direction (Station-Related Parameters)

X	<70> := M_EI_NA_1 =	Initialization end

System Information in Control Direction (Station-Related Parameters)

B	<100> := C_IC_NA_1 =	Station query command
X	<101> := C_CI_NA_1 =	Counter query command
	<102> := C_RD_NA_1 =	Single object query command
X	<103> := C_CS_NA_1 =	Time synchronization command
X	<104> := C_TS_NA_1 =	Check command
X	<105> := C_RP_NA_1 =	Process reset command
X	<106> := C_CD_NA_1 =	Command for telegram delay logging

Parameters in Control Direction (Station-Related Parameters)

	<110> := P_ME_NA_1 =	Parameter measured values, standardized value
	<111> := P_ME_NB_1 =	Parameter measured values, scaled value
	<112> := P_ME_NA_1 =	Parameter measured values, abbreviated floating comma number
	<113> := P_AC_NA_1 =	Parameter for activation

File Transmission (Station-Related Parameters)

<120> := F_FR_NA_1 =	File ready
<121> := F_SR_NA_1 =	Section ready
<122> := F_SC_NA_1 =	Query file directory, file selection, file query, section query
<123> := F_LS_NA_1 =	Last section, last segment
<124> := F_AF_NA_1 =	File confirmation, section confirmation
<125> := F_SG_NA_1 =	Segment
<126> := F_DR_TA_1 =	File directory (empty or X, only regularly available in monitoring direction)

Assignment of Transmission Causes to Type Identifiers

Type Identifier		Transmission Cause																		
		1: Cyclical	2: Background query	3: Spontaneous	4: Initialized	5: Queried	6: Activation	7: Activation acknowledgment	8: Deactivation	9: Deactivation acknowledgment	10: Activation end	11: Response telecontrol command	12: Response on-site command	13: File transfer	20 ... 36: Queried (via TK-100)	37 ... 41: Queried (via TK-101)	44: Unknown type identifier	45: Unknown transmission cause	46: Unknown ASDU address	47: Unknown information object address
1	M_SP_NA_1		B	B		X						X	X		B					
2	M_SP_TA_1			B		X						X	X							
3	M_DP_NA_1		B	B		X						X	X		B					
4	M_DP_TA_1			B		X						X	X							
5	M_ST_NA_1		B	B		X						X	X		B					
6	M_ST_TA_1			B		X						X	X							
7	M_BO_NA_1																			
8	M_BO_TA_1																			
9	M_ME_NA_1	B	B	B		X									B					
10	M_ME_TA_1			B		X														
11	M_ME_NB_1	B	B	B		X									B					
12	M_ME_TB_1			B		X														
13	M_ME_NC_1	B	B	B		X									B					
14	M_ME_TC_1			B		X														
15	M_IT_NA_1			B																
16	M_IT_TA_1			B																
17	M_EP_TA_1			X																
18	M_EP_TB_1			X																
19	M_EP_TC_1			X																
20	M_PS_NA_1		X	X		X									X					
21	M_ME_ND_1	X	X	X		X									X					
30	M_SP_TB_1			B		X						X	X							
31	M_DP_TB_1			B		X						X	X							
32	M_ST_TB_1			B		X						X	X							

33	M_BO_TB_1																			
34	M_ME_TD_1			B		X														
35	M_ME_TE_1			B		X														
36	M_ME_TF_1			B		X														
37	M_IT_TB_1			B																
38	M_EP_TD_1			X																
39	M_EP_TE_1			X																
40	M_EP_TF_1			X																
45	C_SC_NA_1						X	X			X						X	X	X	X
46	C_DC_NA_1						X	X			X						X	X	X	X
47	C_RC_NA_1						X	X			X						X	X	X	X
48	C_SE_NA_1						X	X			X						X	X	X	X
49	C_SE_NB_1						X	X			X						X	X	X	X
50	C_SE_NC_1						X	X			X						X	X	X	X
51	C_BO_NA_1																			
70	M_EI_NA_1				X															
100	C_IC_NA_1						B	B			B						X	X	X	X
101	C_CI_NA_1						X	X			X						X	X	X	X
102	C_RD_NA_1																			
103	C_CS_NA_1			X			X	X									X	X	X	X
104	C_TS_NA_1						X	X									X	X	X	X
105	C_RP_NA_1						X	X									X	X	X	X
106	C_CD_NA_1			X			X	X									X	X	X	X
110	P_ME_NA_1																			
111	P_ME_NB_1																			
112	P_ME_NC_1																			
113	P_AC_NA_1																			
120	F_FR_NA_1																			
121	F_SR_NA_1																			
122	F_SC_NA_1																			
123	F_LS_NA_1																			
124	F_AF_NA_1																			

125	F_SG_NA_1																			
126	F_DR_TA_1																			

1.11.3.6 Basic Application Functions

Station Initialization (Station-Related Parameter)

X	Remote initialization

Cyclical Data Transmission (Station-Related Parameter)

B	Cyclical data transmission

Polling Procedure (Station-Related Parameter)

	Polling procedure (single object query)

Spontaneous Transmission (Station-Related Parameter)

B	Spontaneous transmission

Double Transmission of Information Objects with Transmission Cause "Spontaneous" (Station-Related Parameters)

The following type identifiers may be transmitted as a result of a single state change of an information object. The individual information object addresses, for which double transmission is activated, are parameterized in project-specific mode.

X	Single indications M_SP_NA_1, M_SP_TA_1, M_SP_TB_1, and M_PS_NA_1
X	Double indications M_DP_NA_1, M_DP_TA_1, and M_DP_TB_1
	Tap indications M_ST_NA_1, M_ST_TA_1, and M_ST_TB_1
	Bit pattern indications M_BO_NA_1, M_BO_TA_1, and M_BO_TB_1 (if used in the project)
	Measured values standardized, M_ME_NA_1, M_ME_TA_1, and M_ME_TD_1
	Measured value scaled, M_ME_NB_1, M_ME_TB_1, and M_ME_TE_1
	Measured value floating value, M_ME_NC_1, M_ME_TC_1, and M_ME_TF_1

Station Query (Station-Related Parameter)

B	Global				
	Group 1		Group 7		Group 13
	Group 2		Group 8		Group 14
	Group 3		Group 9		Group 15
	Group 4		Group 10		Group 16
	Group 5		Group 11		
	Group 6		Group 12		

The assignment of the addresses of the information objects per group has to be defined in a separate table.

Time Synchronization (Station-Related Parameters)

X	Time synchronization
X	Weekday is used.
X	RES1 or GEN (time tag set / not set) is used.
X	SU bit (DST = "daylight saving time") is used.

Command Transmission (Object-Related Parameter)

X	Direct command transmission
X	Direct setpoint command transmission
	Command "Selection and Execution"
	Setpoint command "Selection and Execution"
	C_SE ACTTERM used
X	No additional definition
X	Short command execution time period (execution time period defined via a system parameter in the RTU)
X	Long command execution time period (execution time period defined via a system parameter in the RTU)
	Persistent command
	Monitoring of the maximum delay in control direction of switching and setpoint commands
	Maximum delay of switching and setpoint commands

Transmission of Counter Values (Station- or Object-Related Parameter)

- [X] Mode A: local copy with spontaneous transmission
- [X] Mode B: local copy with counter query command
- [X] Mode C: copy and transmit via counter query command
- [X] Mode D: copy via counter query command, spontaneous transmission of the restored values

- [X] Counter query
- [X] Counter copy without reset
- [X] Counter copy with reset
- [X] Counter reset

- [X] General counter query
- [ ] Counter query group 1
- [ ] Counter query group 2
- [ ] Counter query group 3
- [ ] Counter query group 4

Addresses have to be defined per group.

Loading Parameters (Object-Related Parameter)

- [ ] Threshold value
- [ ] Smoothing factor
- [ ] Lower limit value for measured value transmission
- [ ] Upper limit value for measured value transmission

Parameters for Activation (Object-Related Parameter)

- [ ] Activation / deactivation of cyclical or periodical transmission of the addressed object

Test Procedure (Station-Related Parameter)

- [x] Test procedure

File Transmission (Station-Related Parameter)

File Transmission in Monitoring Direction

- [ ] Transmission of transparent data
- [ ] Transmission of fault data from protection equipment
- [ ] Transmission of event sequences
- [ ] Transmission of sequences of logged analog values

File Transmission in Control Direction

- [ ] Transmission of transparent data

Background Query (Station-Related Parameter)

- [x] Background query

Telegram Delay Logging (Station-Related Parameter)

- [x] Telegram delay logging

1.12 Serial Process Interface Variants with IEC-870-5-101

Remote Terminal Units can be connected with IEC-870-5-101 over telecontrol gateways to the Interface Computer Systems and, thus, to the Network Control System.

The telecontrol technology is serially connected to the Network Control System over the telecontrol gateways. A serial interface of a telecontrol gateway, which serves to connect a telecontrol link, is designated as telecontrol channel.

In the PSI Network Control System, serial RTUs can be connected redundantly in single or double mode. For this purpose, a redundant, channel-specific switchover is made at the telecontrol gateways. There are three different options (also see Figure 1.12-1).

Default Variant: One Leased Line Connection and Y Switching Sequence

A redundant connection of an RTU with a serial interface over a leased line connection and a logical telecontrol link to a telecontrol gateway redundant pair with serial Y switching sequence.

Variant A: Two Leased Line Connections

A redundant connection of an RTU with two serial interfaces over two leased line connections and two logical telecontrol links to a telecontrol gateway redundant pair.

Variant B (Option)

A redundant connection of an RTU with two serial interfaces over a leased line connection and a dialup connection and two logical telecontrol links to a telecontrol gateway redundant pair.

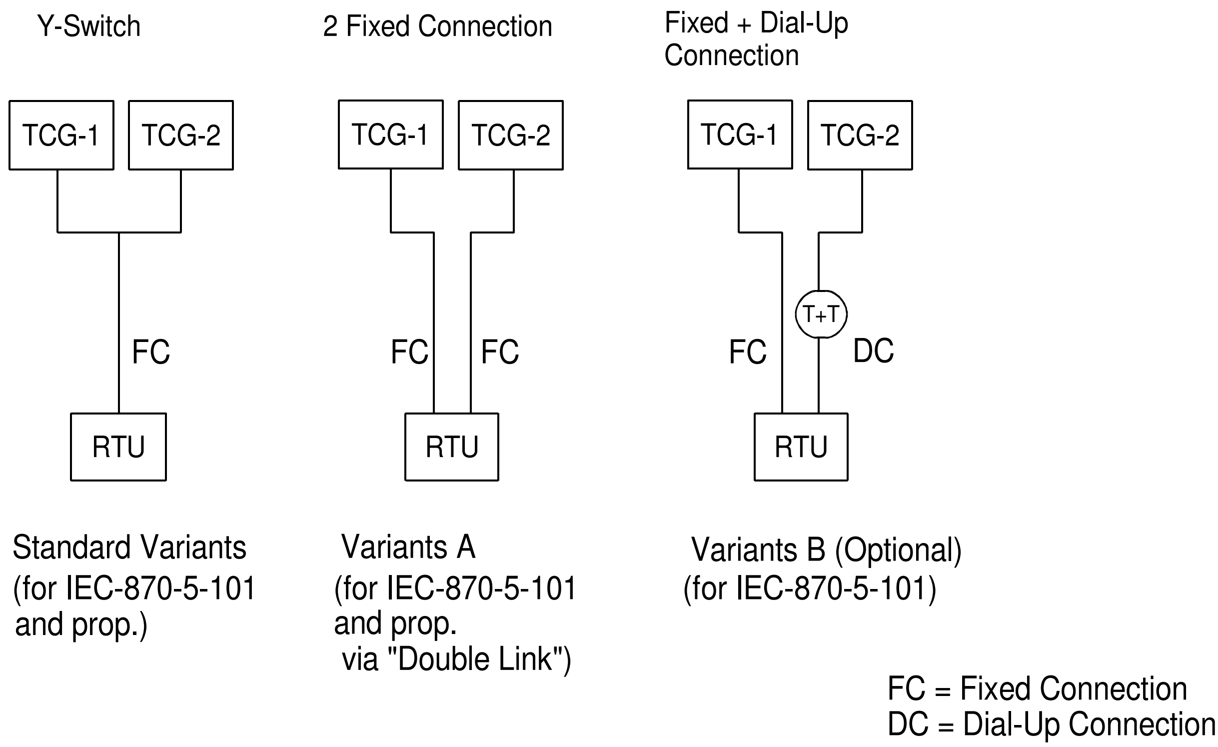

Figure 1.12-1 Connection variants

For all variants, a telecontrol channel of a telecontrol gateway redundant pair is operated in operating mode "actively in control and monitoring direction" ("active" channel). The Network Control System can send and receive telecontrol telegrams over this active channel.

According to the variant selected, the redundant telecontrol channel is operated in operating mode "in passive mode in control and monitoring direction" or "in active mode in control and monitoring direction".

Variants A and B with redundant 2-way connection of an RTU can be used for IEC-870-5-101 RTUs.

Variant A with redundant 2-way connection of an RTU can be used for RTUs with proprietary protocol and double link if this supported by the protocol.

All variants refer to the connection of RTUs via IEC-870-5-101. They will be described in the following in terms of their information flows.

For the connection of proprietary telecontrol technology, both the default variant and variant A can be used if the RTUs are extended accordingly.

The connection over an IEC-870-5-101 dialup connection without redundant path will be described in a proper section.

1.12.1 Default Variant of Telecontrol Connection (Y Switching Sequence)

Figure 1.12-2 shows the default variant of telecontrol transmission with a leased line connection.

Information Flows during Fault-Free Normal Operation

Figure 1.12-3 shows the information flows during fault-free normal operation.

Information Flows in Fault Situations

The following table shows selected fault situations, for which the options of fault compensation are explained with the help of specific diagrams of the information flow.

Figure 1.12-4 and 5 show the information flows for selected fault situations.

For the fault situations, the following assumptions are made:

- The corresponding channel at the telecontrol gateway is active in control and monitoring direction.
- The redundant channel at the telecontrol gateway 2 is passive in control and monitoring direction. The channel only detects cycle faults.

Single Failure

Fault	Description	Figure	Compensation
F1	Outage of transmission technology	1.12-3	no
F2	Outage of the active channel or of the telecontrol gateway with the active channel	1.12-4	yes

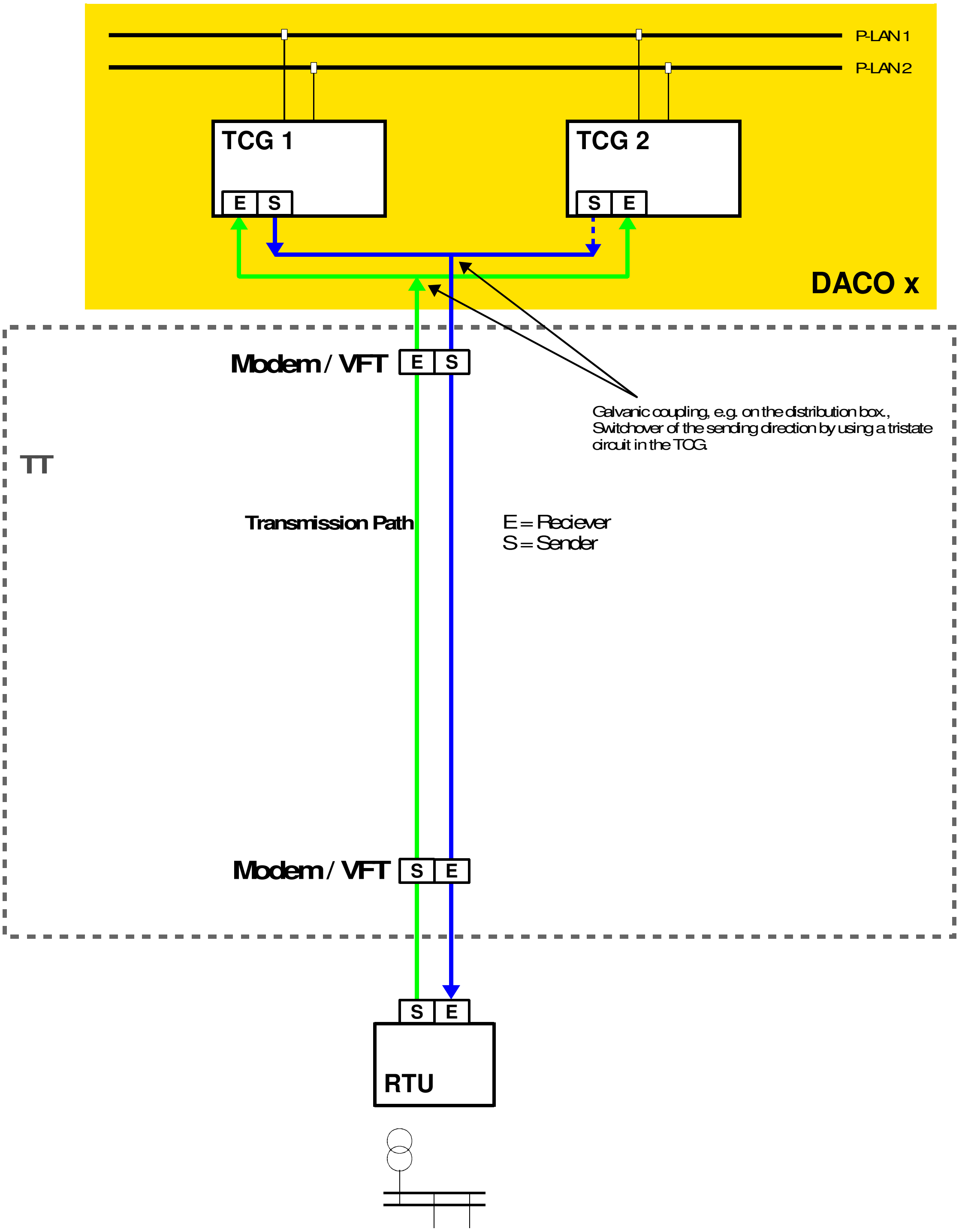

Figure 1.12-2 Default variant of redundant connection of a substation

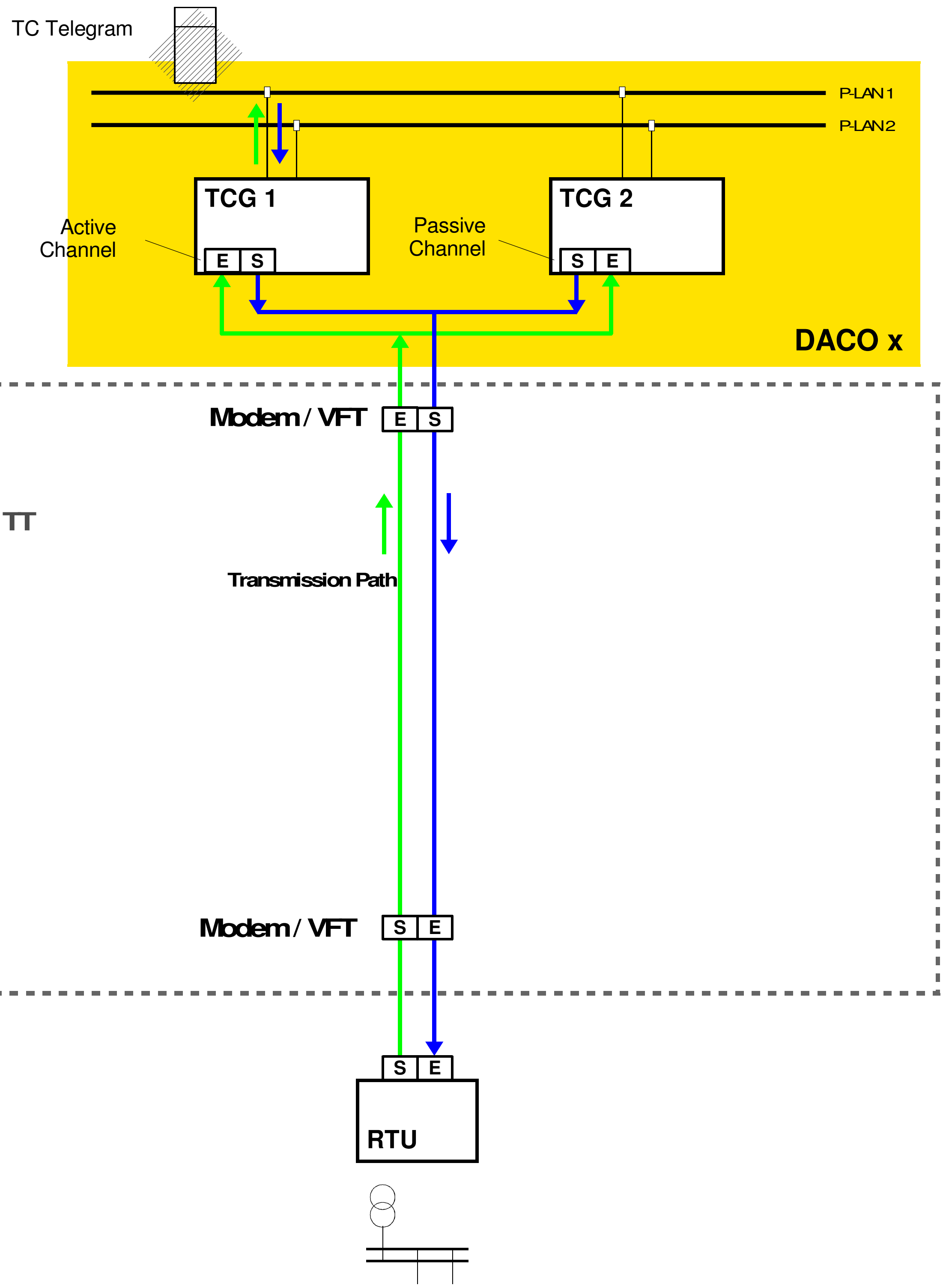

Figure 1.12-3 Information flow during fault-free operation

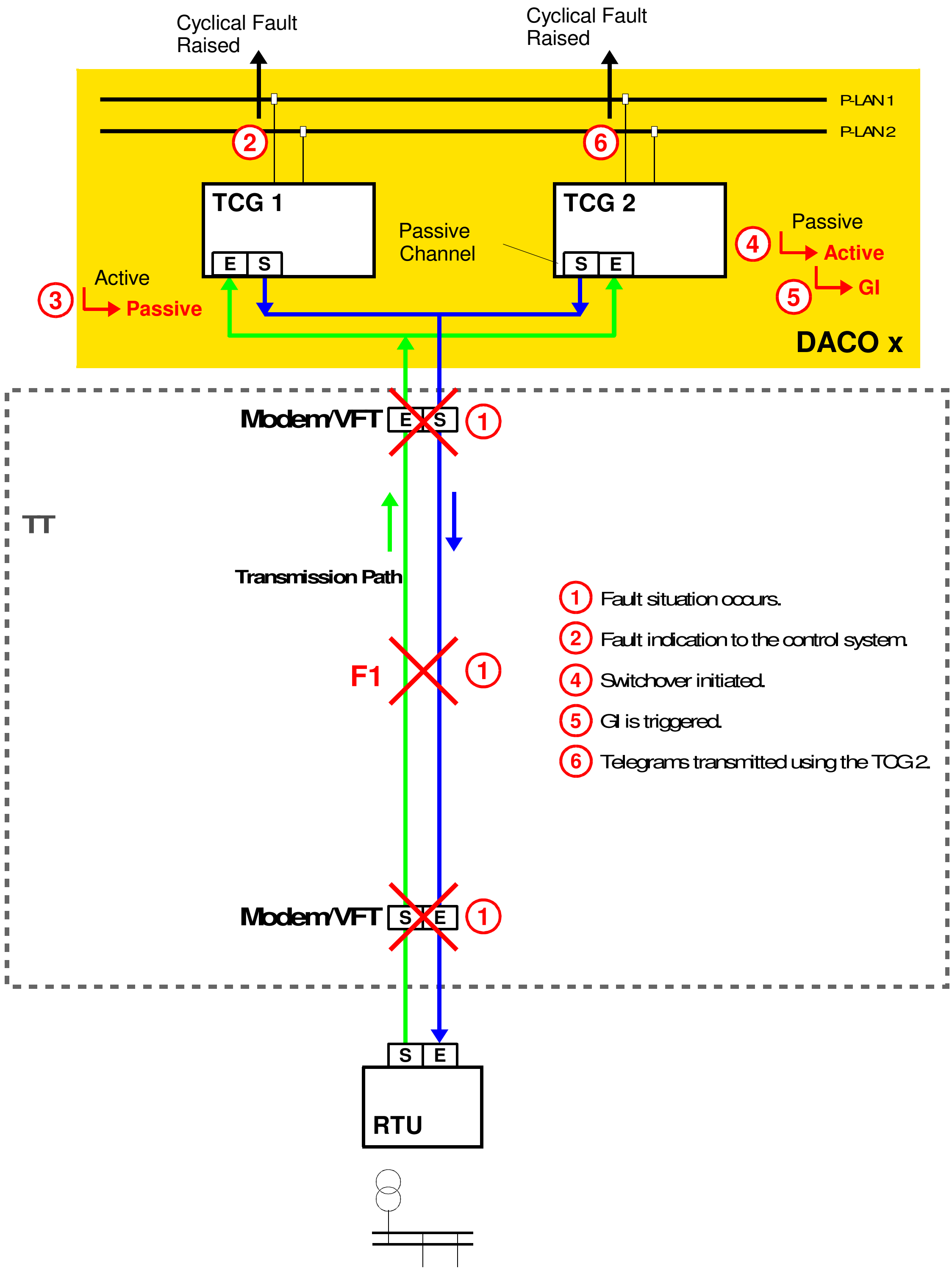

Figure 1.12-4 Information flow with disturbed transmission technology

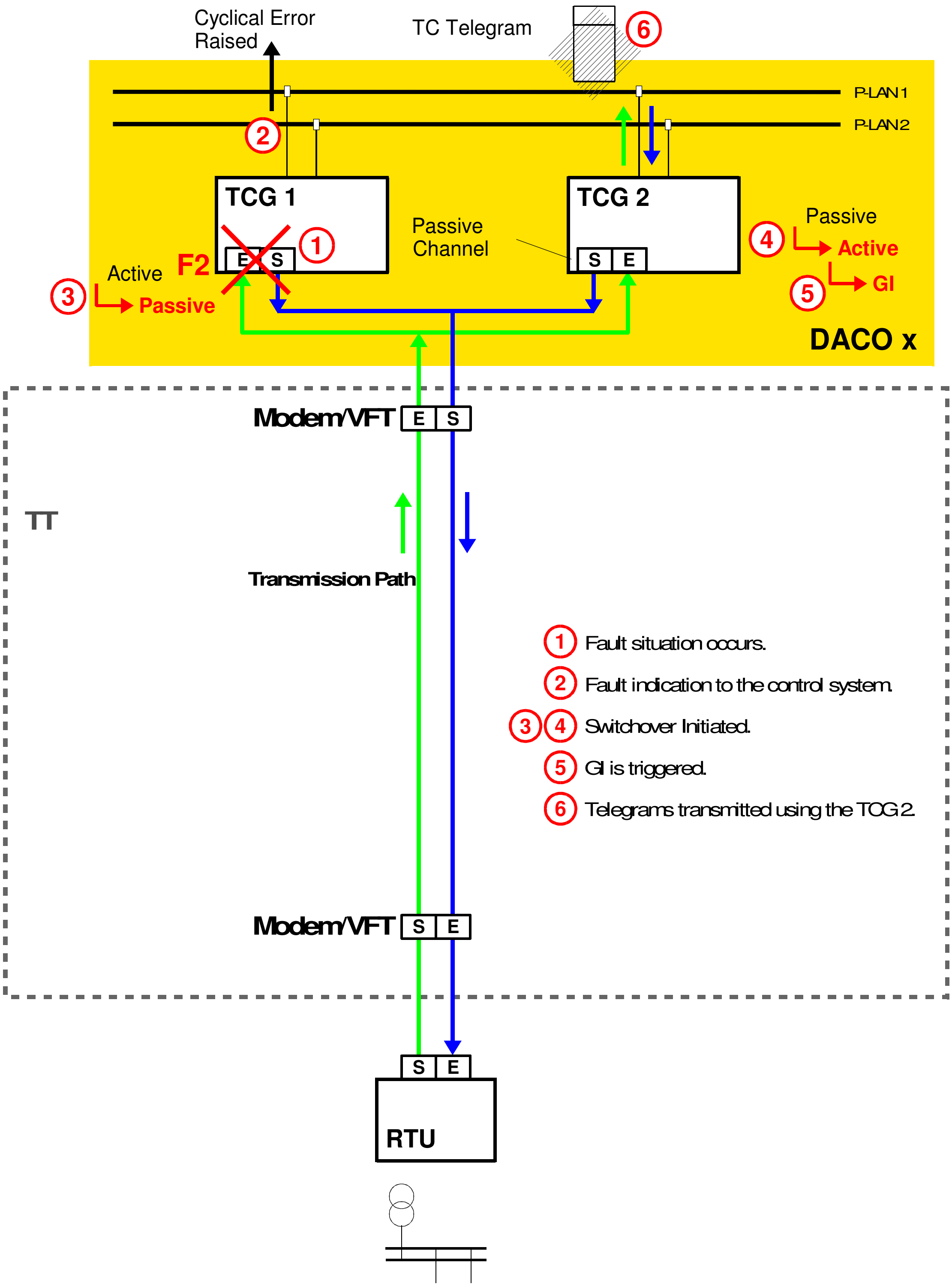

Figure 1.12-5 Information flow during outage of the active telecontrol channel

1.12.2 Variant A of Telecontrol Connection (2 Leased Line Connections)

Figure 1.12-5 shows variant A of the telecontrol transmission with two leased line connections.

Information Flows during Fault-Free Normal Operation

Figure 1.12-6 shows the information flows during fault-free normal operation. The operating mode of the two redundant IEC101 connections is described in Chapter 1.12.4.

Information Flows in Fault Situations

The following table shows selected fault situations, for which the options of fault compensation are explained with the help of specific diagrams of the information flow.

Figure 1.12-7 shows the information flows for selected fault situations.

For the fault situations, the following assumptions are made:
- The corresponding channel at the telecontrol gateway is active in control and monitoring direction.
- The redundant channel at the telecontrol gateway 2 is passive in control and monitoring direction. The channel only detects cycle or channel faults.

Single Failure

Fault	Description	Figure	Compensation
F1	Outage of transmission technology	1.12-7	yes
F2	Outage of the active channel or of the telecontrol gateway with the active channel Procedure corresponds to the one for fault F1.	1.12-7	yes

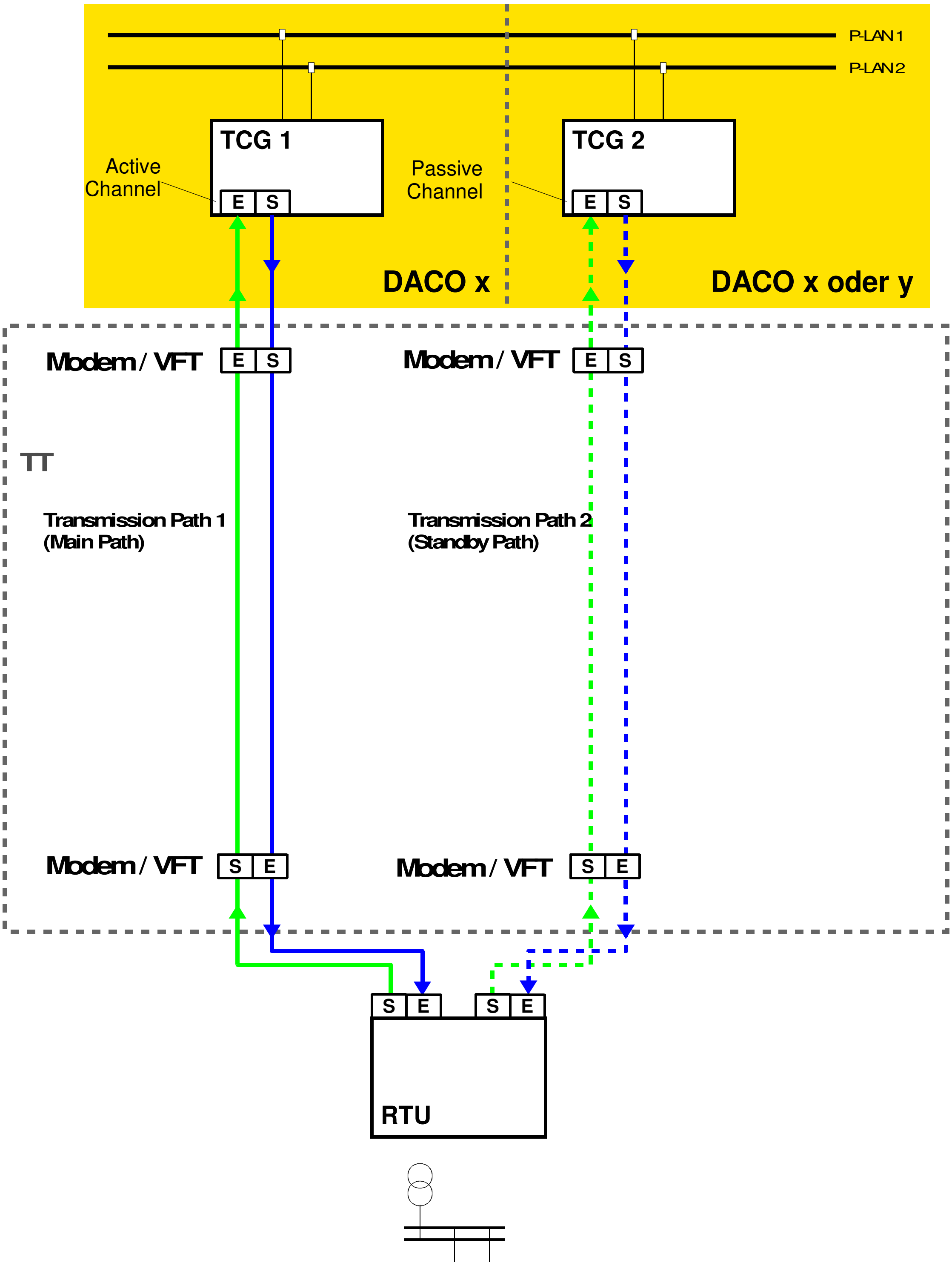

Figure 1.12-6 Variant A of redundant connection of a substation

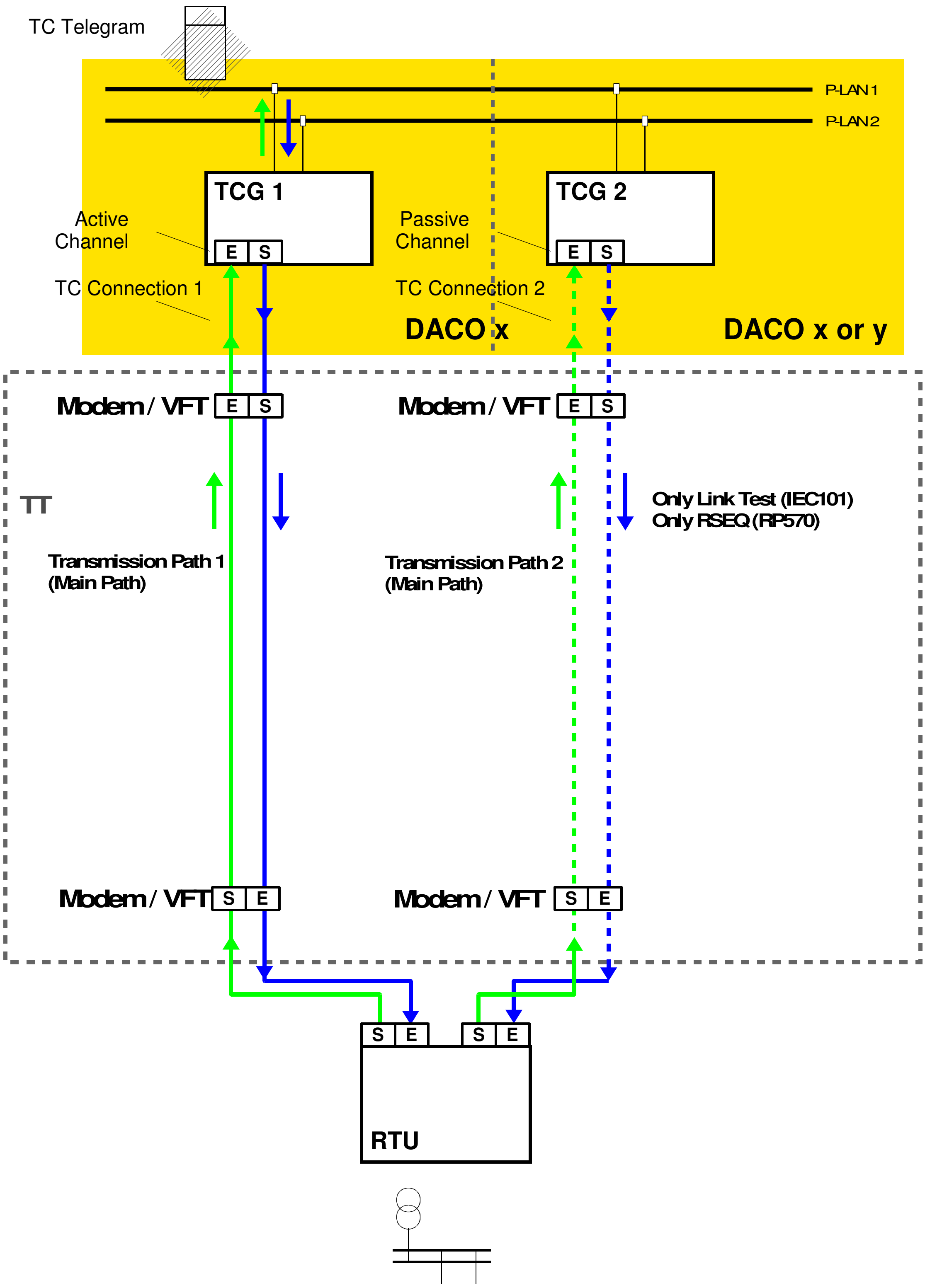

Figure 1.12-7 Information flow during fault-free operation for variant A

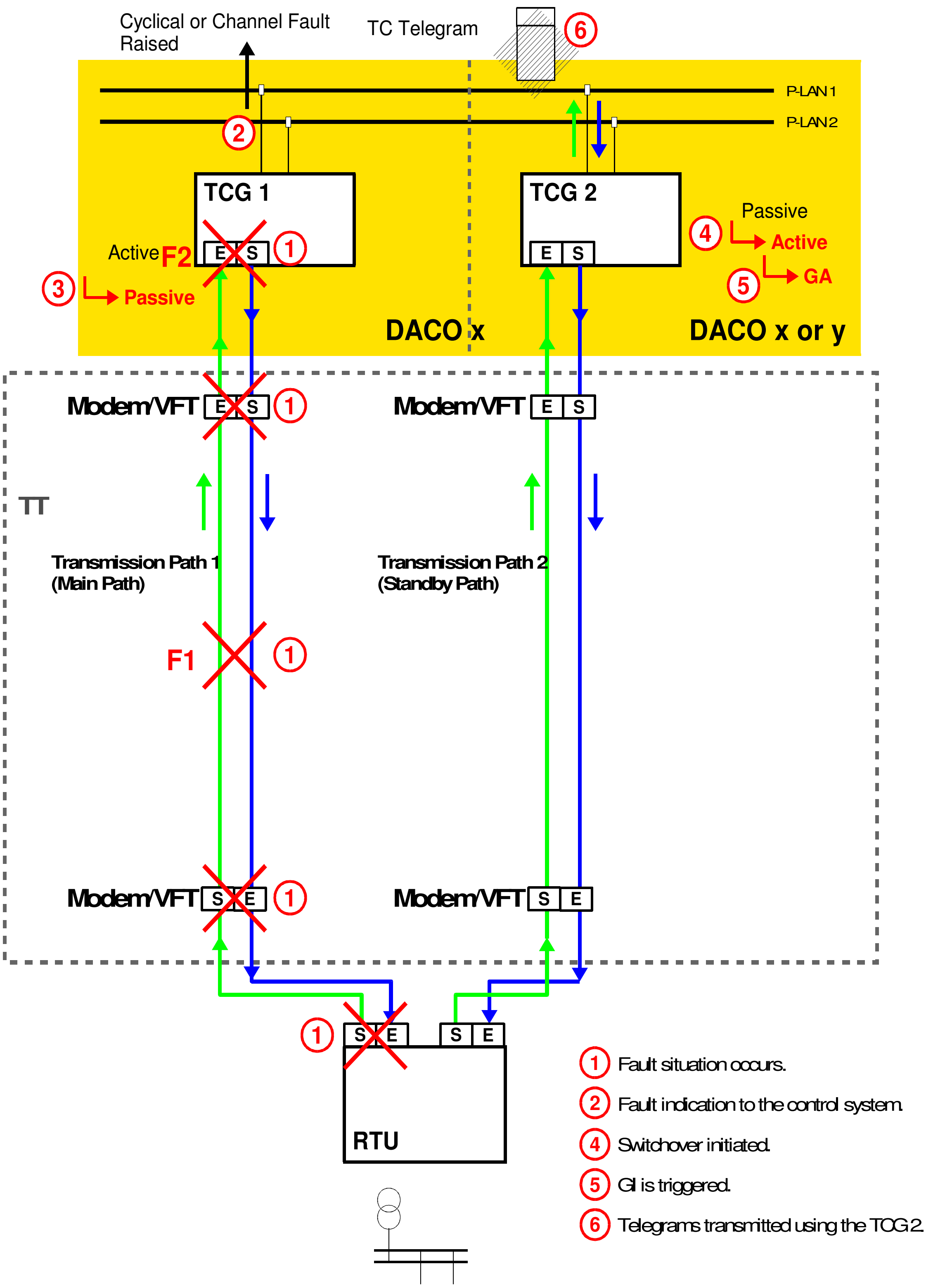

Figure 1.12-8 Information flow with disturbed transmission technology for variant A

1.12.3 Variant B of Telecontrol Connection (Leased Line and Dialup Connection) (Option)

Figure 1.12-8 shows variant B of the telecontrol transmission with one leased line and one dialup connection.

As with leased line connections, for the dialup connections designed as backup connections each telecontrol channel with dialup modem is assigned precisely one RTU.

Information Flows during Fault-Free Normal Operation

Figure 1.12-9 shows the information flows during fault-free normal operation. The operating mode of the two redundant IEC101 connections is described in Chapter 1.12.4.

Variant B can only be used for IEC101 RTUs.

Information Flows in Fault Situations

The following table shows selected fault situations, for which the options of fault compensation are explained with the help of specific diagrams of the information flow.

Figure 1.12-10 shows the information flows for selected fault situations.

For the fault situations, the following assumptions are made:

- The corresponding channel at the telecontrol gateway is active in control and monitoring direction.
- The redundant channel at the telecontrol gateway 2 is passive in control and monitoring direction. The channel only detects cycle or channel faults.

Single Failure:

Fault	Description	Figure	Compensation
F1	Outage of transmission technology	1.12-10	yes
F2	Outage of the active channel or of the telecontrol gateway with the active channel Procedure corresponds to the one for fault F1.	1.12-10	yes

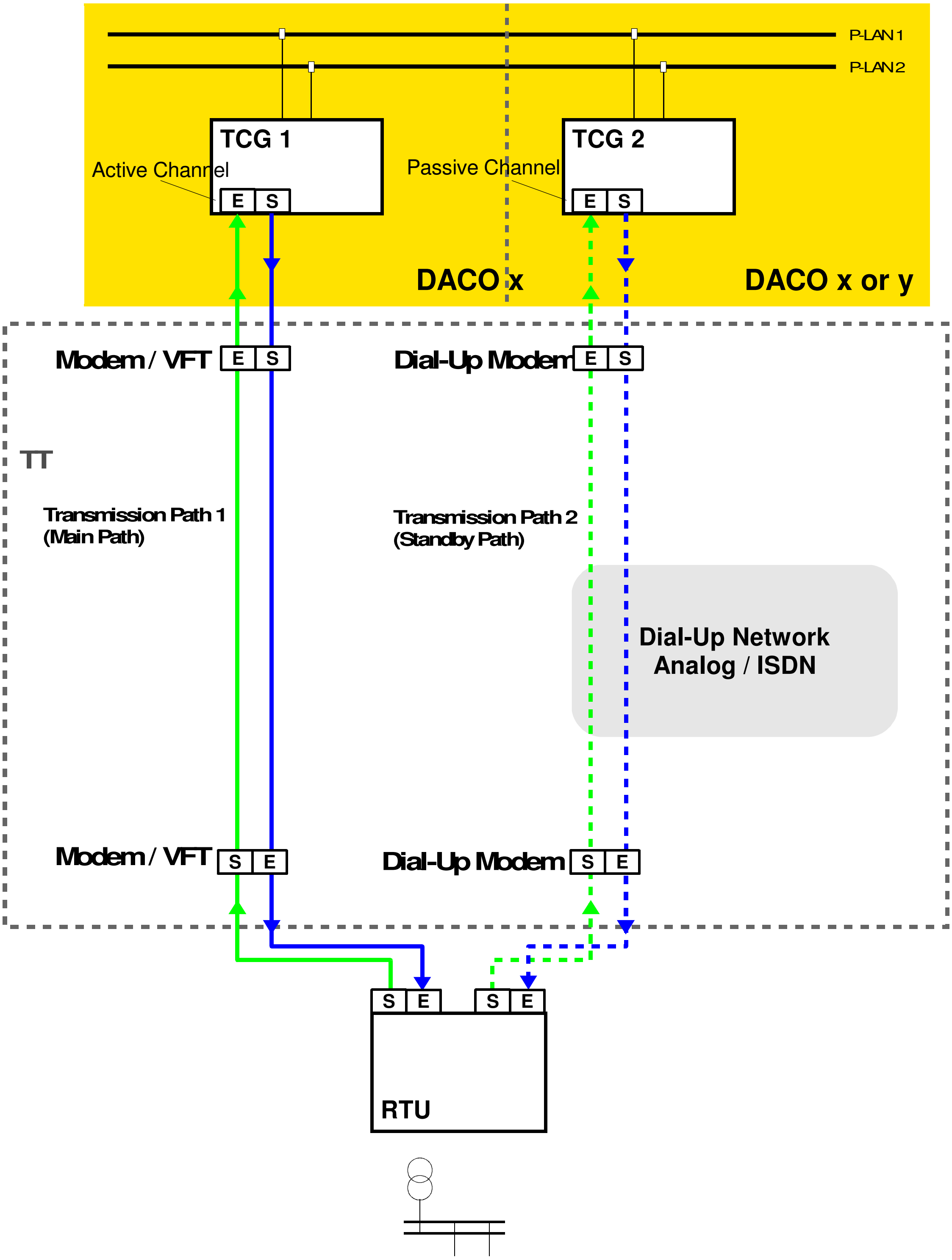

Figure 1.12-9 Variant B of redundant connection of a substation

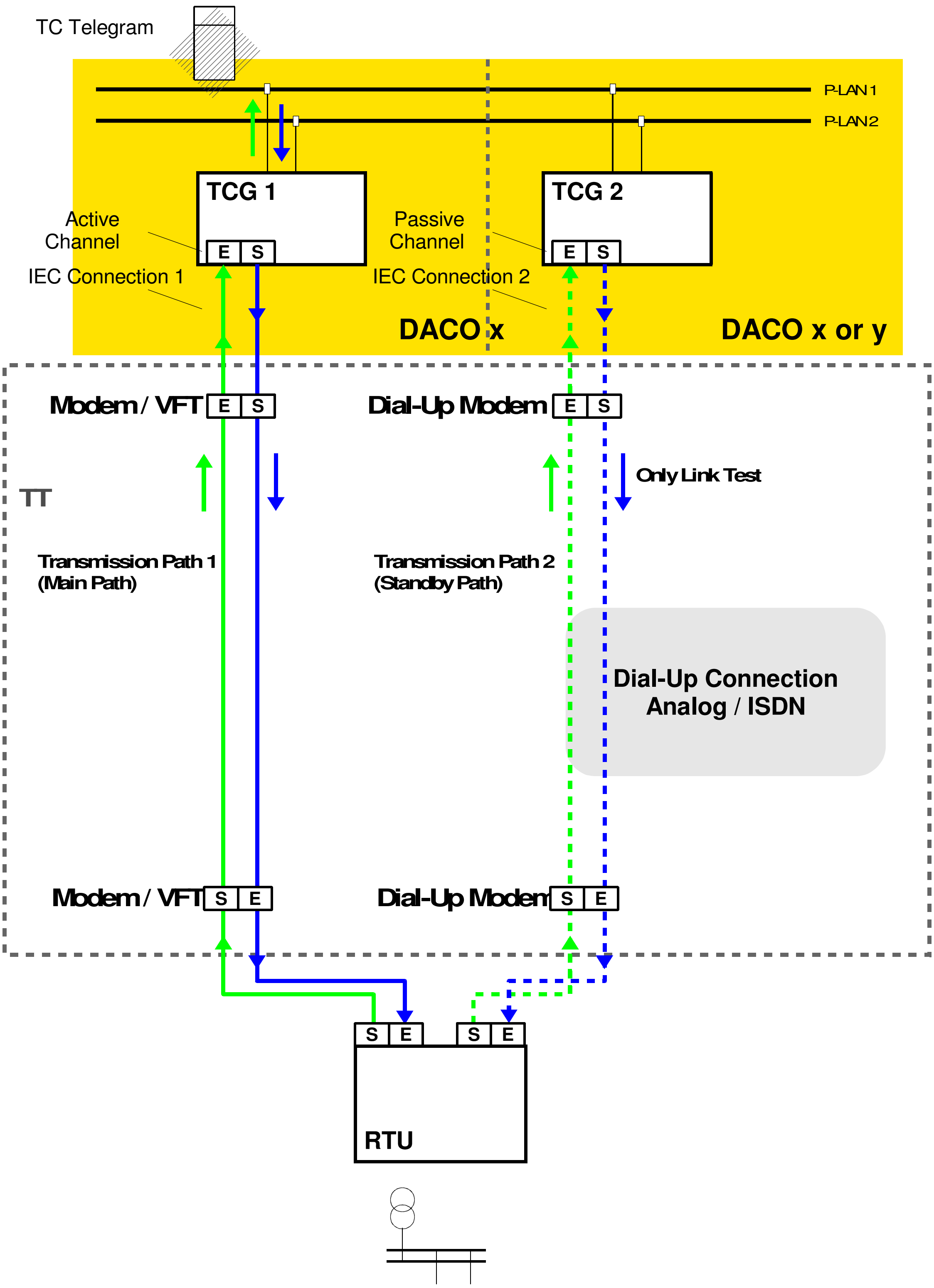

Figure 1.12-10 Information flow during fault-free operation for variant B

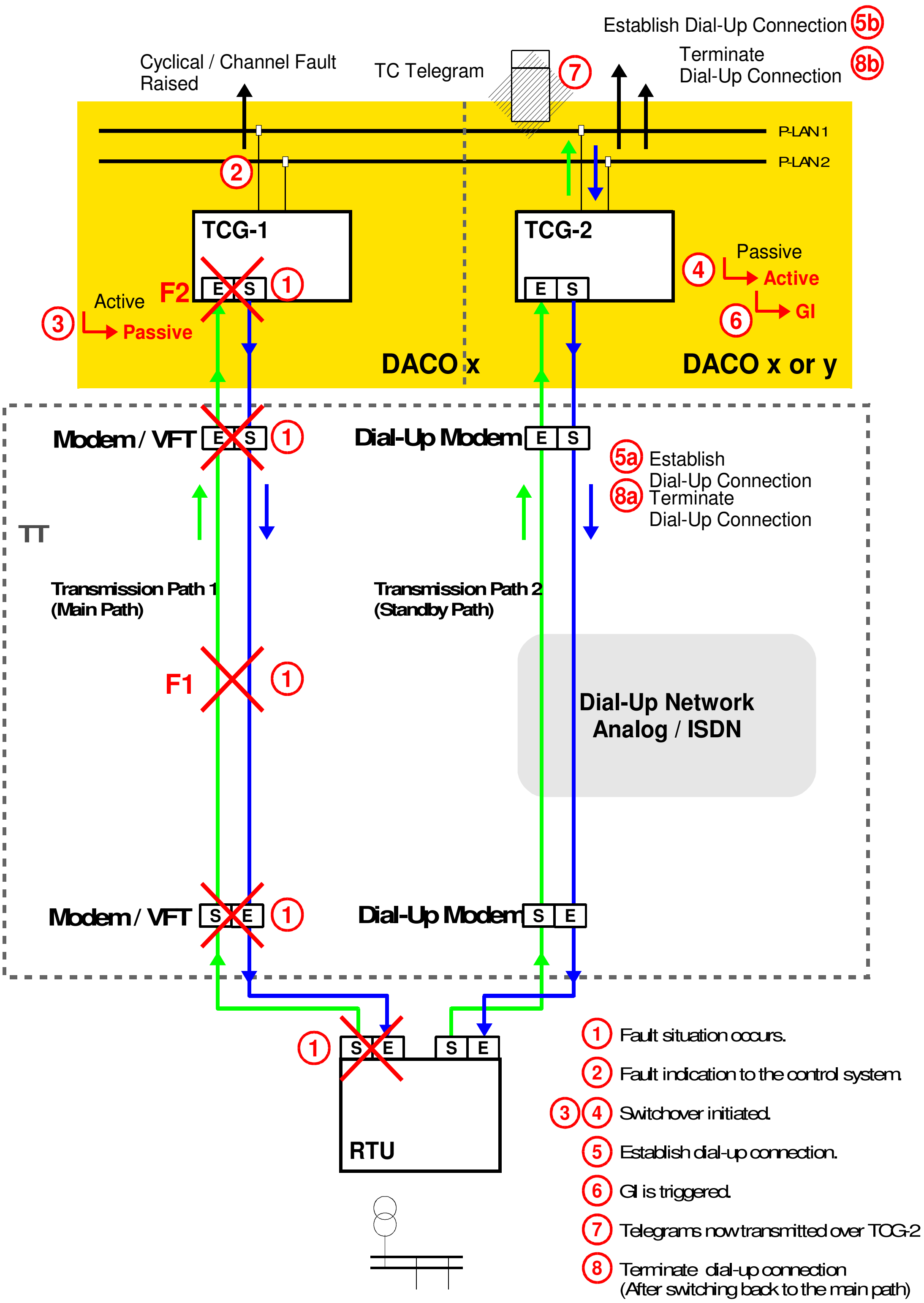

Figure 1.12-11 Information flow with disturbed transmission technology for variant B

1.12.4 2-Way Connection of RTUs over IEC-870-5-101

For variants A and B, two redundant paths and, thus, two redundant connections are used between the Network Control System and an RTU.

IEC 870-5-101 does not contain any information on the connection of IEC-870-5-101 RTUs over redundant connections. Information on the redundant connection is given in Chapter 7.2 of the document "Norwegian IEC 870-5-101 User Conventions (NUC)", Revision 1.4, dated December 1, 1998. The procedure described here is supported by some telecontrol technology suppliers. This procedure is the basis for the implementation by PSI.

A balanced operating mode of the IEC connection according to IEC 870-5-2 is used.

For a redundant connection, two serial communication interfaces with IEC protocol are required at the RTU. At these interfaces, the two "logical" IEC connections are operated. One connection is operated as the main connection, the other one as the backup connection. The two connections can also be operated over different paths with different transmission rates.

Information on dialup lines as substitute paths are supplemented.

- Between the RTU and the Network Control System, independent IEC connections with the same link address are set up over both paths. The Control System is referred to as "controlling station" (IEC-870-5-2 direction flag = 1), the RTU as "controlled station" (IEC-870-5-2 direction flag = 0). The IEC connection which is used to exchange data telegrams (APDUs) is referred to as active connection. The redundant (= passive) connection is only used for tests ("link test"). If two functioning connections are provided, the dialup connection will automatically be used as the passive connection.

- The "controlling station" automatically selects the active connection anew after each setup / outage of the two IEC connections to an RTU. During the connection initialization, the General Interrogation command TK-100 with the transmission cause "Activation" or another valid ASDU, such as the user test command TK-104, will only be sent over the active connection.

- For the "controlled station", both connections are passive after the restart. By receiving one of the defined, valid APDUs, the connection concerned will be marked as active. The "controlled station" transmits the ASDU "Initialization End" TK-70 only over the active connection. This can be used in the "controlling station" to additionally control the active / passive state.
- Both connections are periodically tested in control direction by the "controlling station" (link test). The connections can additionally be tested by the "controlled station". For dialup connections, a long time period will be set for the test to reduce the

number of dialup connections and, thus, the telephone costs. On the active connection, the test will be answered with "ACK", on the passive connection with "NACK". If a response permanently fails to arrive after n transmission repetitions, this connection will be terminated, be marked as disturbed, will be reported as such, and - if required - the redundant connection will be initialized as active connection by the Network Control System with the defined ASDU (General Interrogation, TK-104, ... etc.). For connection monitoring, the response monitoring time and an n-time transmission repetition can be parameterized connection-specifically in the Network Control System.

- After the switchover, the "physical" dialup connection will be set up after the first transmission by the Network Control System or by the RTU via AT modem commands. The dialup connection will be maintained until a switch-back to the functioning main connection is possible again. Then, it will be terminated via an AT modem command. Even after terminating the dialup connection, the "logical" IEC connection is "formally" maintained. Even if the dialup connection is terminated, no channel fault will be signaled in the Network Control System. The "logical" IEC connection is disturbed if a transmission is not acknowledged (data or link test) and if the response monitoring time expires. The setup and termination of the physical dialup connection is logged independently again in the Network Control System in addition to the logging of the state of the "logical" IEC connection.

- If the main connection is disturbed, it will be attempted to set up a "logical" IEC connection in this way (periodical "Request Link State"). If the connection can be set up, it will be switched over as the active connection in this way and the dialup connection will be terminated via AT modem commands.

1.13 Serial Process Interfaces with IEC-870-5-101 over a Dialup Connection (Option)

In the PSI Network Control System, it is possible to connect RTUs exclusively or as backup connections via dialup connections.

Additionally, a dialup modem pool can be configured to connect many RTUs over one or a few modems (see Figure Figure 1.13-1). The principle of a connection over two telecontrol gateways corresponds to connecting substations. In this case, however, several RTUs have to be reached over one telecontrol channel and, thus, over a dialup modem. This is not a point-to-point connection, but a multiple point-to-point connection as a telecontrol network structure.

In the PSI Network Control System, up to 16 RTUs can be connected to a telecontrol channel for this purpose. If point-to-point traffic according to IEC-870-5-101 (balanced operation according to IEC-870-5-2) is used for this purpose, the RTUs can set up the dialup connection and the IEC connection on their own when receiving information with priority from the process. If multipoint traffic according to IEC-870-5-101 (unbalanced operation according to IEC-870-5-2) is used, only the Network Control System will be able to poll the RTUs periodically. A fast transmission of events with priority would be possible in multipoint traffic by means of polling in short periods and would involve high dialup connection costs.

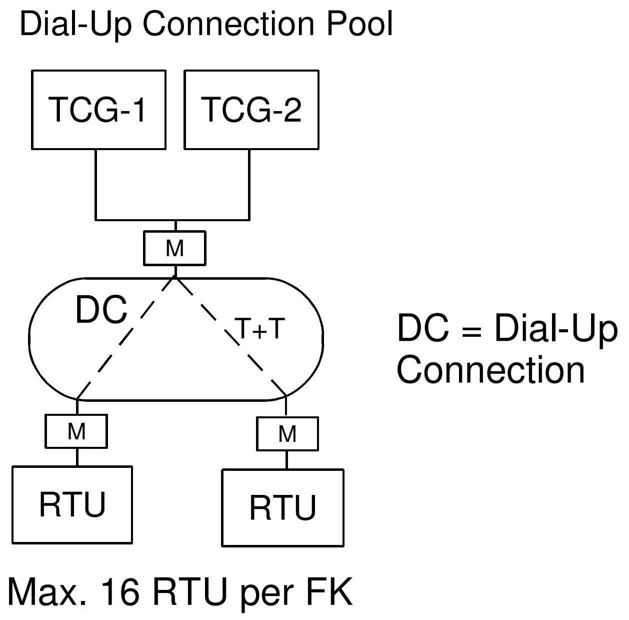

Figure 1.13-1: Connection of stations with dialup modem connections

Information Flows during Fault-Free Normal Operation

Figure 1.13-2 shows the information flows during fault-free normal operation.

Information Flows in Fault Situations

The following table shows selected fault situations, for which the options of fault compensation are explained with the help of specific diagrams of the information flow.

Figure 1.13-3 shows the information flows for selected fault situations.

For the fault situations, the following assumptions are made:

- The corresponding channel at the telecontrol gateway is active in control and monitoring direction.
- The redundant channel at the telecontrol gateway 2 is passive in control and monitoring direction. The channel only detects cycle or channel faults.

Single Failure

Fault	Description	Figure	Compensation
F1	Outage of transmission technology	1.13-3	no
F2	Outage of the active channel or of the telecontrol gateway with the active channel	1.13-4	yes

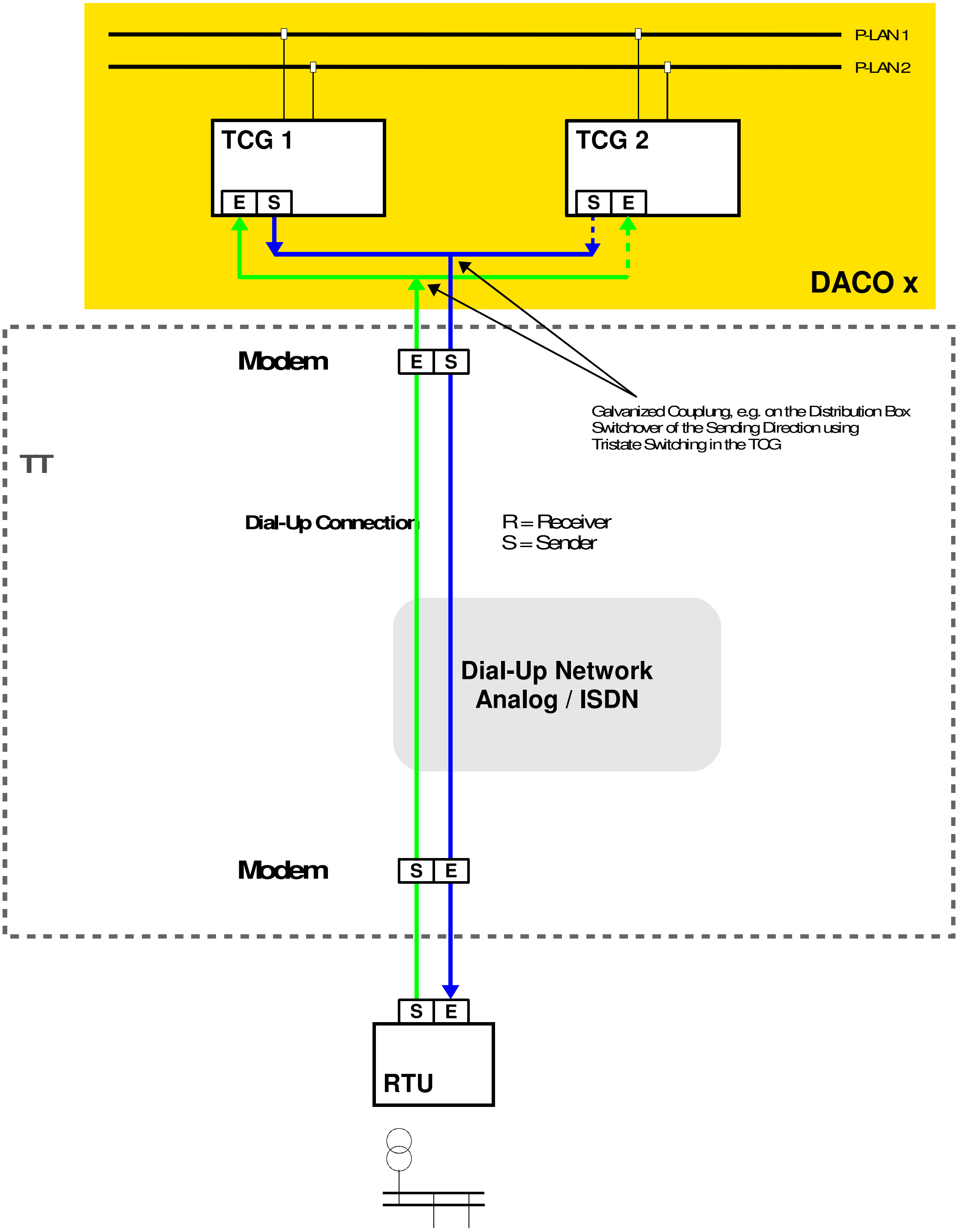

Figure 1.13-2 Connection of an IEC101 RTU over a dialup connection

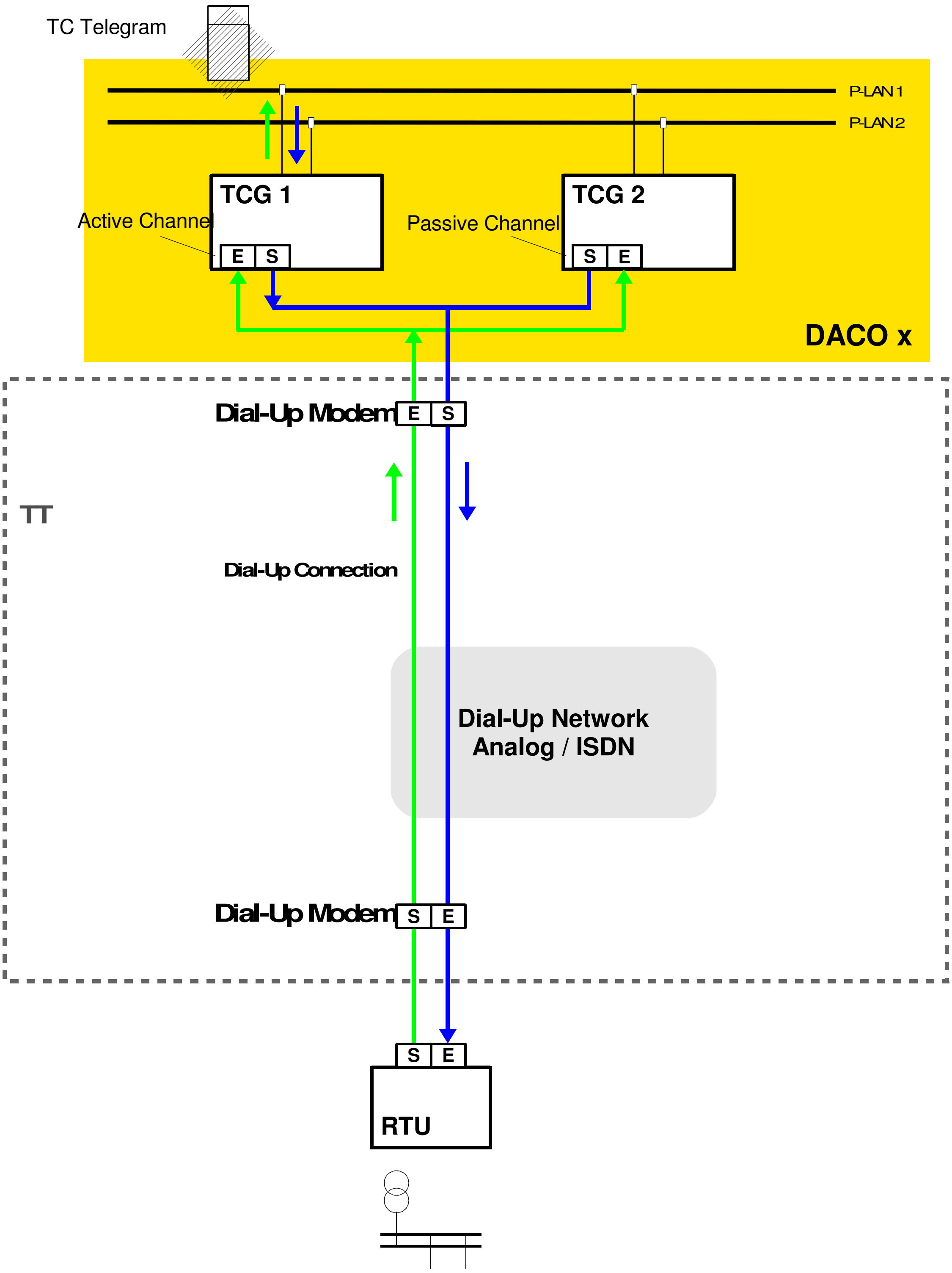

Figure 1.13-3: Information flow during fault-free operation with dialup connection

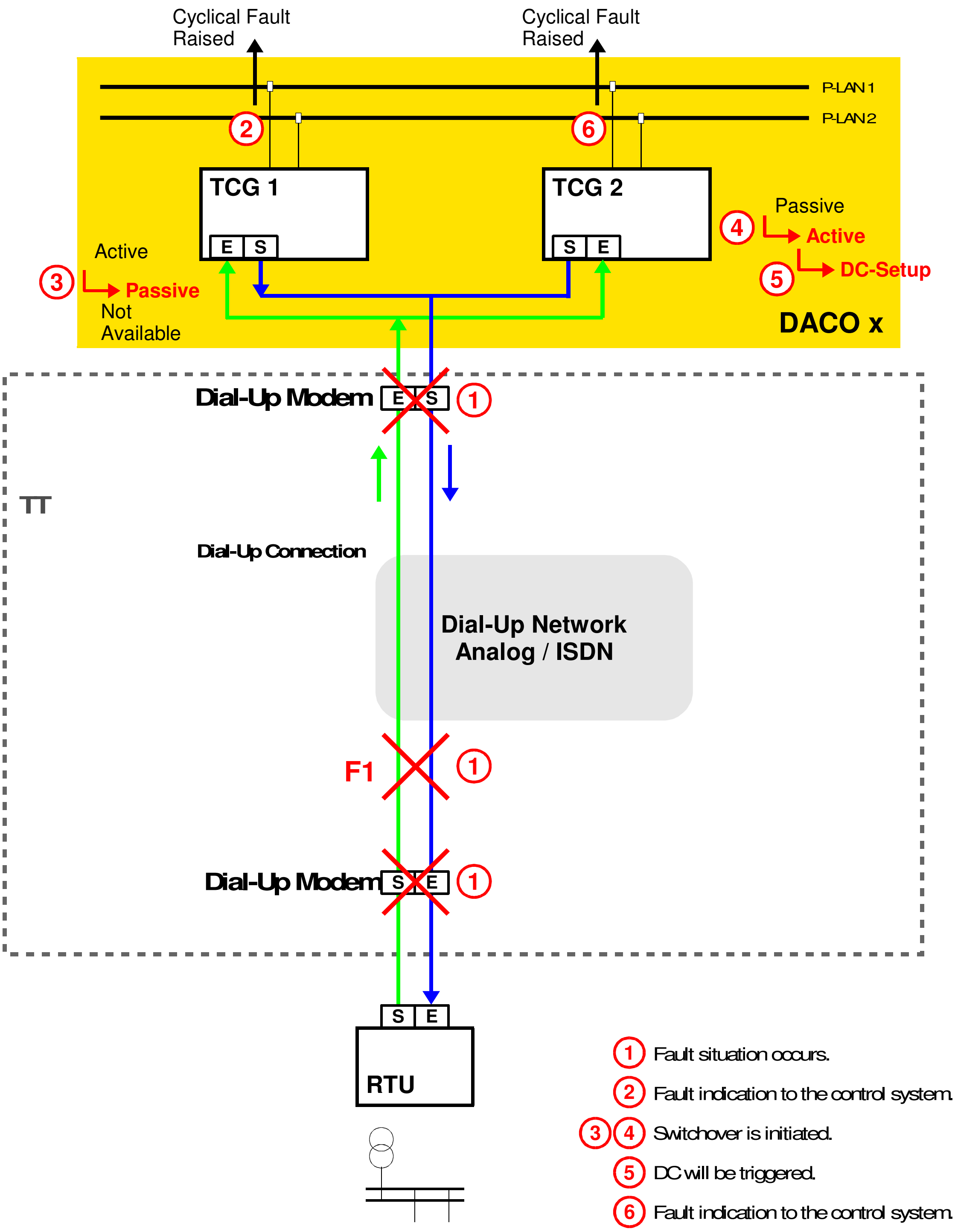

Figure 1.13-4: Information flow with disturbed transmission technology with dialup connection

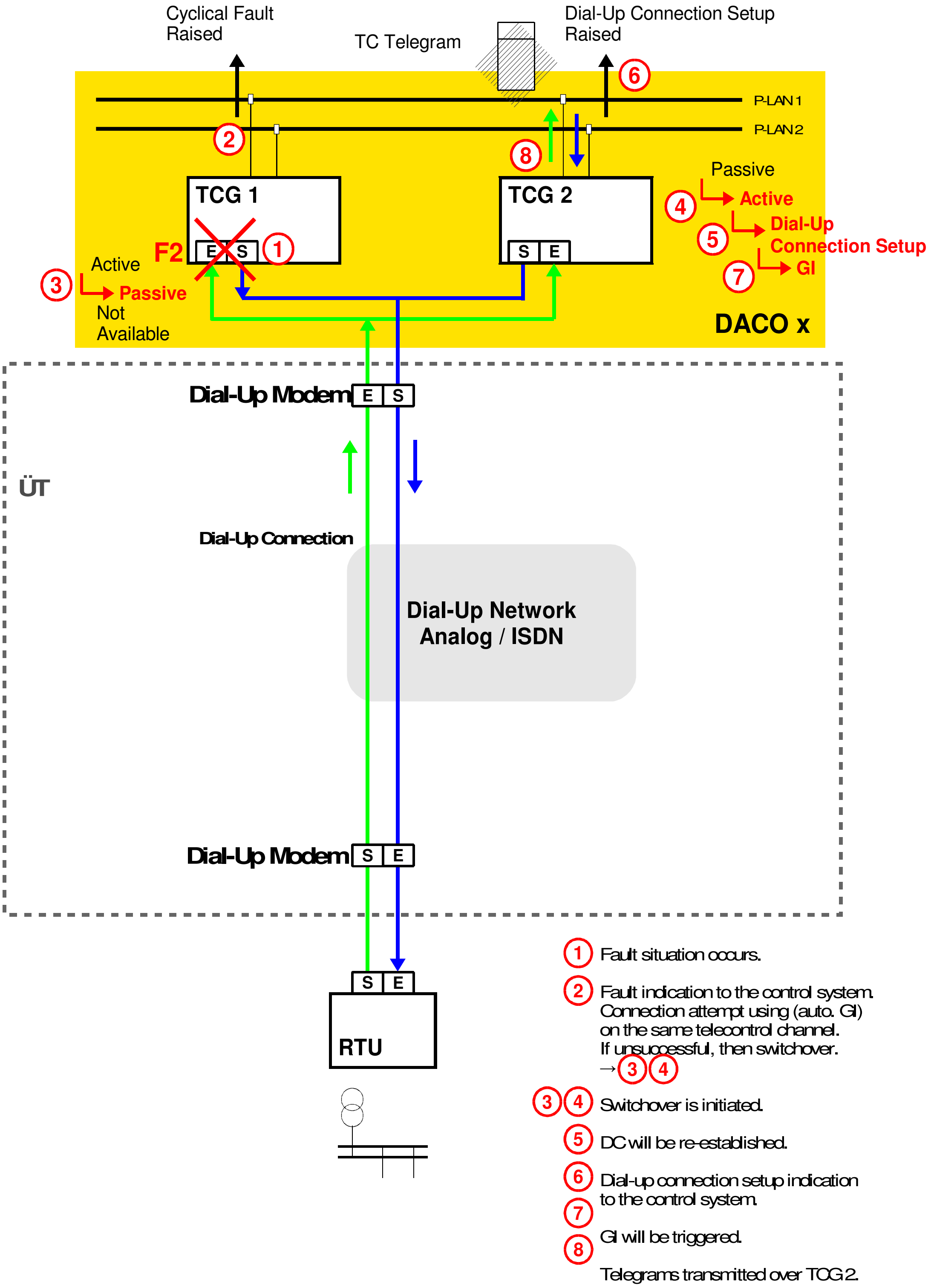

Figure 1.13-5: Information flow during outage of the telecontrol channel / gateway with dialup connection

1.13.1.1 Criteria for the Setup and Termination of a Dialup Connection (Option)

The criteria for the setup and termination of a dialup connection are required for

- cost controlling of the telephone charges and
- for the time synchronization of the RTUs over the telecontrol connection from the Network Control System.

1.13.1.2 General Criteria

The following applies to dialup connections between the Network Control System and the RTUs.

- The end which has set up the connection has to terminate it again.

Additionally, the following is valid in the Network Control System:

- Expiration of a configurable time interval in seconds within which no payload telegram (ASDU) has been received under consideration of a minimum connection period after entry of a command.
- Expiration of a time interval (which has to be configured as a longer interval in any case) which limits the maximum duration of a connection. This time interval will always be valid in the Network Control System, even if the dialup connection is activated by the RTU.

Additionally, the following applies in the RTU:

- Expiration of a configurable time interval in seconds within which no payload telegram (ASDU) has been received.
- Expiration of a configurable time interval which determines the maximum connection duration.

1.13.1.3 Dialup Connection as Backup Connection

For important substations, a dialup connection is used as a backup connection to the leased line connection. There is a 1:1 assignment of leased line and dialup connections, which means that for each RTU a proper backup telecontrol channel with its own dialup modem will be used.

The dialup connection is set up as soon as an IEC connection can no longer be operated over the leased line connection. The dialup connection will be maintained until an IEC connection can be set up again over the leased line connection. Subsequently, the dialup connection will be terminated. For this purpose, the telecontrol channels for the leased line and dialup connections will be configured in the same way with regard to the IEC connection parameters (connection monitoring, ...).

1.13.1.4 Dialup Connection to Stations

For selected stations, dialup connections are used as the only path to the RTUs of these stations. In this case, up to 16 RTUs have to be reached via one telecontrol channel and one dialup modem.

These dialup connections are not permanently set up, but only when data has to be transmitted from the Network Control System to the RTU or vice versa. After the transmission, the connection is terminated again. After the setup of the dialup connection, the IEC connection will be set up anew and will be terminated after termination of the dialup connection.

Additionally, the dialup connections to each RTU will be set up and terminated once after longer periods of time (after several hours or once per day) to check the operability of the connections between the Network Control System and the RTUs.

1.13.1.5 Time Synchronization over Dialup Connections

The telegrams for time synchronization are transmitted connection-specifically according to the following procedures:

- after each successful IEC101 connection setup,
- within the first minute after the connection setup every 10 seconds.

For time synchronization, an RTU requires a specific number of received time synchronization telegrams with equidistant time intervals to be able to "tune" its integrated fine synchronization algorithm.

If a dialup connection is set up only temporarily, the time synchrony of +/- 10 ms will not be reached and a processing in realtime will not be possible. However, information which includes its own timestamps can be transmitted. These attachments can be used in the Network Control System for logging instead of the receive time without being specified as "realtime processing" in the protocol.

2 The IEC -870-5-104 Telecontrol Protocol

The PSI Network Control System can connect new telecontrol technology to the Ethernet interface by means of the IEC 870-5-104 telecontrol protocol. The corresponding telecontrol protocol software is included in the scope of delivery.

The Network Control System is multiprotocol-capable. The parallel application of IEC-870-5-104 protocols and other - even proprietary - telecontrol protocols is possible.

2.1 Basis of Implementation

The implementation of the IEC-870-5-104 protocols by PSI is based on the following documents:

- DIN EN 60870-5-101 according to the published standard, status of October 1996
- Additional Definitions A2 for DIN EN 60870-5-101 E DIN 40952 Revision 9, dated January 2000
- DIN EN 60870-5-104, German Standard, dated January 2002
- 57/658/CD Amendment 1 to IEC 60870-5-104 Ed.1, dated August 2003 and September 2004

2.2 ISO/OSI Layer Model According to IEC 870-5-104

<table>
<tr><td colspan="2">Selection of application functions
from IEC 60870-5-5
according to IEC 60870-5-101</td><td>Initialization</td><td>User Process</td></tr>
<tr><td colspan="3">Selection of "Application Service Data Units" (ASDUs)
from IEC 60870-5-101 and -104</td><td rowspan="2">7 (Application)</td></tr>
<tr><td colspan="3">APCI "Application Protocol Control Information" Transport Interface
(User to TCP Interface)</td></tr>
<tr><td colspan="3">Not Used</td><td>6 (Presentation)</td></tr>
<tr><td colspan="3">Not Used</td><td>5 (Session)</td></tr>
<tr><td colspan="3">RFC-793 (TCP)</td><td>4 (Transport)</td></tr>
<tr><td colspan="3">RFC-791 (IP)</td><td>3 (Network)</td></tr>
<tr><td rowspan="3">RFC-894
(Transmission of IP Datagrams over Ethernet Network)</td><td rowspan="4"></td><td>RFC-1661
(PPP)</td><td rowspan="2">2 (Data Link)</td></tr>
<tr><td rowspan="2">RFC-1662
(PPP in HDLC Framing)</td></tr>
<tr><td rowspan="2">1 (Physical)</td></tr>
<tr><td>IEEE 802.3
Ethernet LAN</td><td>X.21</td></tr>
</table>

Ethernet serial line for connection over router (10/100BaseT, RJ45) (D-SUB-15)

Figure 2.2-1: IEC-870-5-104 protocol structure in the PSI system

2.3 Boundary Conditions

The use of both standardized bit pattern telegram types and of types from the private sector is possible, but is not included in the scope of delivery.

A specific telecontrol protocol has to be assigned to each RTU.

2.4 Time Synchronization of the RTU

RTUs without own time receiver are time-synchronized over the telecontrol interface.

The corresponding procedure according to IEC 870-5-5 Section 6.7 is used in the IEC 870-5-104 protocol. The telegrams for time synchronization are transmitted by the telecontrol protocol software in the telecontrol gateway, TCP/IP gateway, or in the Interface Computer System. The time basis is the Unix system time, which is synchronized via the NTP protocol (see Chapter "LAN Clocks" in the Functional Design "System Engineering").

Due to the features of the TCP protocol and of the IP network, this procedure is not appropriate for IEC 870-5-104 for precisions below 1 second.

As an alternative, the NTP protocol can be used for the time synchronization of the RTU. The PSI computers are equipped with an activated NTP server software and can be used by the RTUs as NTP servers.

2.5 Parameterization of Telecontrol Addresses in the Network Control System

Using all selectable address octets from IEC 870-5–101 and IEC 870-5–104, five octets are available for the addressing pattern:

- 2 octets common address of the ASDU and
- 3 octets for the address of the information object.

These 5 octets are structured in various address segments. The address pattern of the individual segments can be freely defined.

Since the ASDU address ("common address of the ASDU") only exists once per ASDU and since the address of the information object may exist several times in an ASDU (per information object), the bit value for the two addresses has to be considered separately:

- ASDU address = 2 octets = $2°$ to 2^{15}
- Object address = 3 octets = $2°$ to 2^{23}

Common ASDU Address

In the identification field of the data unit, two octets are defined as the common address of the ASDU. "Common" means that this address is the same for all information objects within the ASDU. If several information objects exist in an ASDU, they will differ in the addressing only with regard to the address of the information object.

The 5-level IEC 870-5-104 telecontrol address is preset in two steps during the parameterization of the Network Control System:

- During the parameterization of the Remote Terminal Unit, the 2-level station address - consisting of the common ASDU address octet 1/2 - can be assigned to each Remote Terminal Unit. A "physical" telecontrol device can be entered as one or several "virtual" Remote Terminal Units in the parameterization of the Network Control System. This means that several common ASDU addresses can be assigned to this device. As a result, several station query commands with the corresponding ASDU addresses will, for instance, be transmitted by the Network Control System for a station query for this component.

- During the parameterization of the individual operating objects, each operating object is assigned a reference to the Remote Terminal Unit over which it is transmitted by telecontrol technology. By doing so, it implicitly receives its station addressing. In addition, a 3-level information object address - consisting of the 3 octets 3/4/5 - as well as the IEC type identifiers of the telegram used for transmission can be preset for each operating object. For realtime transmission, the type identifier of the realtime telegram will be preset.

The common ASDU address or the information object address can be entered in structured mode. This has no effect for telegram processing in the SCADA system, but it simplifies the entry of the data.

2.6 The Project-Specific IEC 870-5-104 Data Profile

Legend for Compatibility List

☐	=	Function or ASDU is not used.
X	=	Function or ASDU is used as standardized (preferred value).
R	=	Function or ASDU is used in reverse mode.
B	=	Function or ASDU is used in control and reverse mode.
■	=	Function or ASDU is not available in this standard profile.

2.6.1 System or Device (System-Related Parameter)

☐	System definition
X	Definition for the central station (Network Control System)
☐	Definition for the substation

2.6.2 Network Configuration (Network-Related Parameter)

■	End-to-end configuration [also called point-to-point configuration]	■	Multipoint-party line configuration
■	Multiple point-to-point configuration	■	Multipoint-star configuration

2.6.3 Physical Layer (Network-Related Parameter)

Transmission Rate (Control and Monitoring Direction)

Unbalanced interface V.24/V.28, conventional		Unbalanced interface V.24/V.28, recommended for > 1200 bps		Balanced interface X.24 / X. 27			
■	100 bps	■	2 400 bps	■	2 400 bps	■	56 000 bps
■	200 bps	■	4 800 bps	■	4 800 bps	■	64 000 bps
■	300 bps	■	9 600 bps	■	9 600 bps	■	
■	600 bps			■	19 200 bps		
■	1200 bps			■	38 400 bps		

Transmission rate in monitoring direction = transmission rate in control direction

2.6.4 Data Link Layer (Network-Related Parameter)

According to this standard, the telegram format FT 1.2, single character "1", and the fixed time monitoring interval are used exclusively.

Transmission Procedure of the Data Link Layer

[redacted] Balanced transmission

[redacted] Unbalanced transmission

[redacted]

Telegram length

[redacted] Maximum length L Control Direction

[redacted] Maximum length L Monitoring Direction

Address Field of the Data Link Layer

[redacted] Not available
(only balanced transmission)

[redacted] One octet

[redacted] Two octets

[redacted] Structured

[redacted] Unstructured

[redacted] Time period during which repetitions are permissible (Trp) or number of repetitions

During unbalanced transmission, the following ASDUs will be retransmitted as user data with the specified transmission causes with data class 2 (low priority).

☐ Standardized assignment of ASDU to data class 2:

Type Identifier	Transmission Cause
9, 11, 13, 21	1

☐ Special assignment of ASDU to data class 2:

Type Identifier	Transmission Cause

As a reply to a request for data of data class 2, a substation will be permitted to transmit data of class 1 if no data of class 2 is available.

2.6.5 Application Layer

Transmission Type of Application Data

According to this standard, only mode 1 (Last significant octet first) is used according to 4.10 IEC-870-5-4.

Common Address of the ASDU (System-Related Parameter)

X	One octet	X	Two octets

Address of the Information Object (System-Related Parameter)

X	One octet	X	Structured
X	Two octets	X	Unstructured
X	Three octets		

Transmission Cause (System-Related Parameter)

X	One octet	X	Two octets (with origin address) The origin address will be set to "o" if it is not used.

Length of the APDU (System-Related Parameter)

The maximum length "L" of the APDU is 253 (default). It can be decreased per system.

253	Maximum length of the APDU

Selection of the Standard ASDU

Process Information in Monitoring Direction (Station-Related Parameters)

B	<1> := M_SP_NA_1 =	Single indication
■	<2> := M_SP_TA_1 =	Single indication with time tag
B	<3> := M_DP_NA_1 =	Double indication
■	<4> := M_DP_TA_1 =	Double indication with time tag
B	<5> := M_ST_NA_1 =	Tap position indication
■	<6> := M_ST_TA_1 =	Tap position indication with time tag
	<7> := M_BO_NA_1 =	Bit pattern 32 bits
■	<8> := M_BO_TA_1 =	Bit pattern 32 bits with time tag
B	<9> := M_ME_NA_1 =	Measured value, standardized value
■	<10> := M_ME_TA_1 =	Measured value, standardized value with time tag
B	<11> := M_ME_NB_1 =	Measured value, scaled value
■	<12> := M_ME_TB_1 =	Measured value, scaled value with time tag
B	<13> := M_ME_NC_1 =	Measured value, abbreviated floating comma value
■	<14> := M_ME_TC_1 =	Measured value, abbreviated floating comma value with time tag
B	<15> := M_IT_NA_1 =	Counter value
■	<16> := M_IT_TA_1 =	Counter value with time tag
■	<17> := M_EP_TA_1 =	Protection event with time tag
■	<18> := M_EP_TB_1 =	Block excitation of protection with time tag
■	<19> := M_EP_TC_1 =	Block initiation of protection with time tag
X	<20> := M_PS_NA_1 =	Blocked single indication with state display
X	<21> := M_ME_ND_1 =	Measured value, standardized value with quality identifier
B	<30> := M_SP_TB_1 =	Single indication with time tag CP56Time2a
B	<31> := M_DP_TB_1 =	Double indication with time tag CP56Time2a
B	<32> := M_ST_TB_1 =	Tap position indication with time tag CP56Time2a
	<33> := M_BO_TB_1 =	Bit pattern 32 bits with time tag CP56Time2a
B	<34> := M_ME_TD_1 =	Measured value, standardized value with time tag CP56Time2a
B	<35> := M_ME_TE_1 =	Measured value, scaled value with time tag CP56Time2a
B	<36> := M_ME_TF_1 =	Measured value, abbreviated floating comma value with time tag CP56Time2a
B	<37> := M_IT_TB_1 =	Counter value with time tag CP56Time2a

X	<38> := M_EP_TD_1 =	Protection event with time tag CP56Time2a
X	<39> := M_EP_TE_1 =	Blocked excitation of protection with time tag CP56Time2a
X	<40> := M_EP_TF_1 =	Blocked initiation of protection with time tag CP56Time2a

Either the ASDU set 2, 4, 6, 8, 10, 12, 14, 16, 17, 18, 19 (short time format) or set 30 ... 40 (formats with time CP56Time2a) are used.

Process Information in Control Direction (Station-Related Parameters)

X	<45> := C_SC_NA_1 =	Single command
X	<46> := C_DC_NA_1 =	Double command
X	<47> := C_RC_NA_1 =	Tap position command
X	<48> := C_SE_NA_1 =	Setpoint command, standardized value
X	<49> := C_SE_NB_1 =	Setpoint command, scaled value
X	<50> := C_SE_NC_1 =	Setpoint command, abbreviated floating comma number
	<51> := C_BO_NA_1 =	Bit pattern 32 bits
X	<58> := C_SC_TA_1 =	Single command with time tag C56Time2a
X	<59> := C_DC_TA_1 =	Double command with time tag CP56Time2a
X	<60> := C_RC_TA_1 =	Tap position command with time tag CP56Time2a
X	<61> := C_SE_TA_1 =	Setpoint command, standardized value with time tag CP56Time2a
X	<62> := C_SE_TB_1 =	Setpoint command, scaled value with time tag CP56Time2a
X	<63> := C_SE_TC_1 =	Setpoint command, abbreviated floating comma number with time tag CP56Time2a
	<64> := C_BO_TA_1 =	Bit pattern 32 bits with time tag CP56Time2a

Either ASDU set 45 ... 51 (formats without time) or set 58 ... 64 (formats with time CP56Time2a) is used.

System Information in Monitoring Direction (Station-Related Parameters)

X	<70> := M_EI_NA_1 =	Initialization end

System Information in Control Direction (Station-Related Parameters)

B	<100> := C_IC_NA_1 =	Station query command
X	<101> := C_CI_NA_1 =	Counter query command
	<102> := C_RD_NA_1 =	Single object query command
X	<103> := C_CS_NA_1 =	Time synchronization command
■	<104> := C_TS_NA_1 =	Check command
X	<105> := C_RP_NA_1 =	Process Reset Command
■	<106> := C_CD_NA_1 =	Command for telegram delay logging
X	<107> := C_TS_TA_1 =	Check command with time tag CP56Time2a

Parameters in Control Direction (Station-Related Parameters)

☐	<110> := P_ME_NA_1 =	Parameter measured values, standardized value
☐	<111> := P_ME_NB_1 =	Parameter measured values, scaled value
☐	<112> := P_ME_NA_1 =	Parameter measured values, abbreviated floating comma number
☐	<113> := P_AC_NA_1 =	Parameter for activation

File Transmission (Station-Related Parameters)

☐	<120> := F_FR_NA_1 =	File ready
☐	<121> := F_SR_NA_1 =	Section ready
☐	<122> := F_SC_NA_1 =	Query file directory, file selection, file query, section query
☐	<123> := F_LS_NA_1 =	Last section, last segment
☐	<124> := F_AF_NA_1 =	File confirmation, section confirmation
☐	<125> := F_SG_NA_1 =	Segment
☐	<126> := F_DR_TA_1 =	File directory (empty or X, only regularly available in monitoring direction)

Assignment of Transmission Causes to Type Identifiers

Type Identifier		Transmission Cause																		
		1: Cyclical	2: Background query	3: Spontaneous	4: Initialized	5: Queried	6: Activation	7: Activation acknowledgment	8: Deactivation	9: Deactivation acknowledgment	10: Activation end	11: Response telecontrol command	12: Response on-site command	13: File transfer	20 - 36: Queried (via TK-100)	37 - 41: Queried (via TK-101)	44: Unknown type identifier	45: Unknown transmission cause	46: Unknown ASDU address	47: Unknown information object address
1	M_SP_NA_1		B	B		X						X	X		B					
2	M_SP_TA_1																			
3	M_DP_NA_1		B	B		X						X	X		B					
4	M_DP_TA_1																			
5	M_ST_NA_1		B	B		X						X	X		B					
6	M_ST_TA_1																			
7	M_BO_NA_1																			
8	M_BO_TA_1																			
9	M_ME_NA_1	B	B	B		X									B					
10	M_ME_TA_1																			
11	M_ME_NB_1	B	B	B		X									B					
12	M_ME_TB_1																			
13	M_ME_NC_1	B	B	B		X									B					
14	M_ME_TC_1																			
15	M_IT_NA_1			B												X				
16	M_IT_TA_1																			
17	M_EP_TA_1																			
18	M_EP_TB_1																			
19	M_EP_TC_1																			
20	M_PS_NA_1		X	X		X									X					
21	M_ME_ND_1	X	X	X		X									X					
30	M_SP_TB_1			B		X						X	X							
31	M_DP_TB_1			B		X						X	X							
32	M_ST_TB_1			B		X						X	X							

33	M_BO_TB_1																			
34	M_ME_TD_1			B		X														
35	M_ME_TE_1			B		X														
36	M_ME_TF_1			B		X														
37	M_IT_TB_1			B																
38	M_EP_TD_1			X																
39	M_EP_TE_1			X																
40	M_EP_TF_1			X																
45	C_SC_NA_1						X	X			X						X	X	X	X
46	C_DC_NA_1						X	X			X						X	X	X	X
47	C_RC_NA_1						X	X			X						X	X	X	X
48	C_SE_NA_1						X	X			X						X	X	X	X
49	C_SE_NB_1						X	X			X						X	X	X	X
50	C_SE_NC_1						X	X			X						X	X	X	X
51	C_BO_NA_1																			
58	C_SC_TA_1						X	X			X						X	X	X	X
59	C_DC_TA_1						X	X			X						X	X	X	X
60	C_RC_TA_1						X	X			X						X	X	X	X
61	C_SE_TA_1						X	X			X						X	X	X	X
62	C_SE_TB_1						X	X			X						X	X	X	X
63	C_SE_TC_1						X	X			X						X	X	X	X
64	C_BO_TA_1																			
70	M_EI_NA_1				X															
100	C_IC_NA_1						B	B			B						X	X	X	X
101	C_CI_NA_1						X	X			X						X	X	X	X
102	C_RD_NA_1																			
103	C_CS_NA_1			X			X	X									X	X	X	X
104	C_TS_NA_1																			
105	C_RP_NA_1						X	X									X	X	X	X
106	C_CD_NA_1																			
107	C_TS_NA_1						X	X									X	X	X	X
110	P_ME_NA_1																			
111	P_ME_NB_1																			

112	P_ME_NC_1																			
113	P_AC_NA_1																			
120	F_FR_NA_1																			
121	F_SR_NA_1																			
122	F_SC_NA_1																			
123	F_LS_NA_1																			
124	F_AF_NA_1																			
125	F_SG_NA_1																			
126	F_DR_TA_1																			

2.6.6 Basic Application Functions

Station Initialization (Station-Related Parameter)

| X | Remote initialization |

Cyclical Data Transmission (Station-Related Parameter)

| B | Cyclical data transmission |

Polling Procedure (Station-Related Parameter)

| | Polling procedure (single object query) |

Spontaneous Transmission (Station-Related Parameter)

| B | Spontaneous transmission |

Double Transmission of Information Objects with Transmission Cause "Spontaneous" (Station-Related Parameters)

The following type identifiers may be transmitted as a result of a single state change of an information object. The individual information object addresses, for which double transmission is activated, are parameterized in project-specific mode.

X	Single indications M_SP_NA_1, M_SP_TA_1, M_SP_TB_1, and M_PS_NA_1
X	Double indications M_DP_NA_1, M_DP_TA_1, and M_DP_TB_1
	Tap indications M_ST_NA_1, M_ST_TA_1, and M_ST_TB_1
	Bit pattern indications M_BO_NA_1, M_BO_TA_1, and M_BO_TB_1 (if used in the project)
	Measured values standardized, M_ME_NA_1, M_ME_TA_1, and M_ME_TD_1
	Measured value scaled, M_ME_NB_1, M_ME_TB_1, and M_ME_TE_1
	Measured value floating value, M_ME_NC_1, M_ME_TC_1, and M_ME_TF_1

Station Query (Station-Related Parameter)

[B] Global

[ ] Group 1	[ ] Group 7	[ ] Group 13
[ ] Group 2	[ ] Group 8	[ ] Group 14
[ ] Group 3	[ ] Group 9	[ ] Group 15
[ ] Group 4	[ ] Group 10	[ ] Group 16
[ ] Group 5	[ ] Group 11	
[ ] Group 6	[ ] Group 12	The assignment of the addresses of the information objects per group has to be defined in a separate table.

Time Synchronization (Station-Related Parameters)

[X] Time synchronization (selectable)

[X] Weekday is used.

[X] RES1 or GEN (time tag set / not set) is used.

[X] SU bit (DST = "daylight saving time") is used.

Command Transmission (Object-Related Parameter)

[X] Direct command transmission

[X] Direct setpoint command transmission

[ ] Command "Selection and Execution"

[ ] Setpoint command "Selection and Execution"

[ ] C_SE ACTTERM used

[X] No additional definition

[X] Short command execution time period (execution time period defined via a system parameter in the RTU)

[X] Long command execution time period (execution time period defined via a system parameter in the RTU)

[ ] Persistent command

[ ] Monitoring of the maximum delay in control direction of switching and setpoint commands

[ ] Maximum delay of switching and setpoint commands

Transmission of Counter Values (Station- or Object-Related Parameter)

- [x] Mode A: local copy with spontaneous transmission
- [x] Mode B: local copy with counter query command
- [x] Mode C: copy and transmission via counter query command
- [x] Mode D: copy via counter query command, spontaneous transmission of the restored values

- [x] Counter query
- [x] Counter copy without reset
- [x] Counter copy with reset
- [x] Counter reset

- [x] General counter query
- [ ] Counter query group 1
- [ ] Counter query group 2
- [ ] Counter query group 3
- [ ] Counter query group 4

Addresses have to be defined per group.

Loading Parameters (Object-Related Parameter)

- [ ] Threshold value
- [ ] Smoothing factor
- [ ] Lower limit value for measured value transmission
- [ ] Upper limit value for measured value transmission

Parameters for Activation (Object-Related Parameter)

- [ ] Activation / deactivation of cyclical or periodical transmission of the addressed object

Test Procedure (Station-Related Parameter)

- [X] Test procedure

File Transmission (Station-Related Parameter)

File Transmission in Monitoring Direction

- [ ] Transmission of transparent data
- [ ] Transmission of fault data from protection equipment
- [ ] Transmission of event sequences
- [ ] Transmission of sequences of logged analog values

File Transmission in Control Direction

- [ ] Transmission of transparent data

Background Query (Station-Related Parameter)

- [X] Background query

Telegram Delay Logging (Station-Related Parameter)

■ Telegram delay logging

Definitions for Time Monitoring

Parameter	Default Value	Comment	Selected Value
t_0	30 s	Timeout for connection setup	30 s
t_1	15 s	Timeout for transmitted data or test APDU	15 s
t_2	10 s	Timeout for acknowledgment if no data APDUs are transmitted for t2 < t1	10 s
t_3	20 s	Timeout for transmitted test APDU in the case of longer idle states for t3 < t1	20 s

Maximum value range for time monitoring t_0 ... t_2:
1 s ... 255 s, precision 1 s
Maximum value range for time monitoring t_3:
0 s ... 48 h, precision 1 s

Window Sizes

Parameter	Default Value	Comment	Selected Value
k	12 APDUs	Maximum difference between the number of receive sequences and the number of transmit sequences	12
	8 APDUs	Latest acknowledgment after receipt of w APDU in the I frame format	8

Maximum range of k:
1 ... 32767, precision 1 APDU
Maximum range of w:
1 ... 32767, precision 1 APDU
w should not be larger than 2/3 k.

PSI only supports the range 1 ... 255 for k and w.

TCP Port Number

Parameter	Value	Comment
Port Number	2404	in all cases

Redundant Connections

1	Number of n redundancy groups used.

RFC-2200 Collection

X	Ethernet 802.3
	Serial X.21 interface (for connection over IP router)
	Other excerpts from RFC 2200

List of permissible documents from RFC 2200:

1. ....

2. ....

2.7 Process Interface Operated with IEC-870-5-104 over TCP/IP Gateway

Remote Terminal Units and telecontrol gateways can be connected with IEC-870-5-104 over TCP/IP gateways to the Interface Computer Systems and, thus, to the Network Control System.

2.7.1 Remote Terminal Units in Comparison with Telecontrol Gateways

The telecontrol gateways can be connected in two ways over IEC-870-5-104:

- as "front end" with the PSI KETEL protocol in IEC104 "container operation",
- as "telecontrol head" with IEC104 implementation in the IEC104 default mode (in "information nodes" or as "station head") (option).

Connection as "Front End"

PSI telecontrol gateways are connected over IEC-870-5-104 "as front ends" in a different mode than Remote Terminal Units with regard to the used IEC-870-5-104-ASDUs. Remote Terminal Units only use IEC-870-5-104 standard telegrams, as a rule. In "container operation", PSI telecontrol gateways transmit their serially received telecontrol telegrams with PSI KETELs and use IEC-870-5-104 only as transport protocol. For this purpose, KETEL messages are "encapsulated" in IEC104 container ASDUs. The container ASDUs use two private IEC104 type identifiers (TK-254 and TK-255). The telecontrol gateways themselves do not keep Realtime Databases or telecontrol most recent value buffers. The serial telegrams are not implemented on IEC104 standard ASDUs.

The following descriptions of IEC-870-5-104 and TCP/IP gateways are valid both for Remote Terminal Units and (to a large extent) for telecontrol gateways.

2.7.2 Functions of TCP/IP Gateways

The information, which is sent by the substations directly connected to the telecontrol transmission network for IEC 60870-5-104, is captured and preprocessed by the "TCP/IP gateways" and is forwarded to the network Control System. In this context, the following tasks are carried out:

- Termination of the IEC-870-5-104 connections as "control center", decapsulation of the payload data, encapsulation into the KETEL-UDP protocol, and distribution of the process information to the Interface Computer Systems. The telecontrol gateways and IEC104 Remote Terminal Units transmit the process information with the help of IEC 870-5-104 telegrams to the TCP/IP gateway with the active telecontrol channel. The TCP/IP gateway takes over and stores the data blocks in a receive buffer and forwards the information via KETEL-UDP to the P-LAN at the Interface Computer Systems. If the TCP/IP gateway which has the master role breaks down, the other TCP/IP gateway will be able to take over the operation. For this purpose, it will send a STARTDT telegram to activate the transmission of payload data.
- Disconnection of the Process LAN (P-LAN), which is close to the Network Control System, and of the Site LAN (S-LAN).
- Processing of blocked telegrams.
- Transmission-technical checks (station numbers).
- Management / adaptation of different network address spaces to be open for further extensions.

The process information is not technologically processed. For this reason, no technological data models are kept.

2.7.3 Network Connection Principle of TCP/IP Gateways

IEC-870-5-104 stations (RTUs) can be connected in three ways to the PSI Network Control System:

- via a Site LAN (S-LAN) to redundant TCP/IP gateways of the Network Control System, which are in turn connected to the Process LAN (P-LAN) of the system (variant 1),
- over a Site LAN (S-LAN) to redundant telecontrol gateways (this variant (2) corresponds to the TCP/IP gateway variant 1 to a large extent), or
- over the Process LANs (P-LAN) directly to the Interface Computer System of the Network Control System (variant 3, is not taken into consideration here).

In the PSI Network Control System, the IEC-870-5-104 RTUs are connected over redundant TCP/IP gateways or over redundant telecontrol gateways. The advantages of variants 1 and 2 are:

- the Site LAN does not have to be connected between the TCP/IP gateways,
- double redundancy (2 TCP/IP gateways) or 2 x 2-fold redundancy (4 TCP/IP gateways) instead of n-time redundancy (n Interface Computer Systems) of the IEC104 connections for the RTU (there are RTUs which only work with double redundancy). The TCP/IP gateway redundancy variants 2-fold and 2x2-fold can also be applied in mixed mode. For variant 2 with telecontrol gateways instead of TCP/IP gateways, only double redundancy is possible.
- The telecontrol channel concept known from PSI telecontrol gateways can be applied here 1:1. There is no master / standby role for the complete TCP/IP gateway, but only for single logical telecontrol channels (= IEC104 connections) and, thus, no complete switchover between the two TCP/IP gateways.
- In the direction of the Control System, the PSI-KETEL protocol is used on the basis of UDP with the option of UDP broadcast transmissions. This improves the information flow management (1 source - n destinations) and saves bandwidth.

In redundant Network Control System sites, the TCP/IP gateways can be redundantly designed 2x2-fold (double redundancy at the Network Control System sites A and B) and can be connected to the Process LAN at the sites. The following explanations always refer to a twofold redundant TCP/IP gateway pair.

From the viewpoint of the Network Control System, the TCP/IP gateways are a proper class of front end systems, which behave like telecontrol gateways with regard to the Network Control System. Instead of a serial telecontrol interface, an IEC104 connection is designated as logical telecontrol channel in the TCP/IP gateway and is modeled accordingly via Data Engineering.

2.7.3.1 Connection without Ethernet Channel Bundling ("Bond") at the TCP/IP Gateway

At the TCP/IP gateway, two Ethernet interfaces in two different IP networks are used as Site LAN-1 and Site LAN-2 interface. The following two figures show this variant with double redundancy and 2x2-fold redundancy of the TCP/IP gateways. Both redundancy variants can also be used in mixed operation.

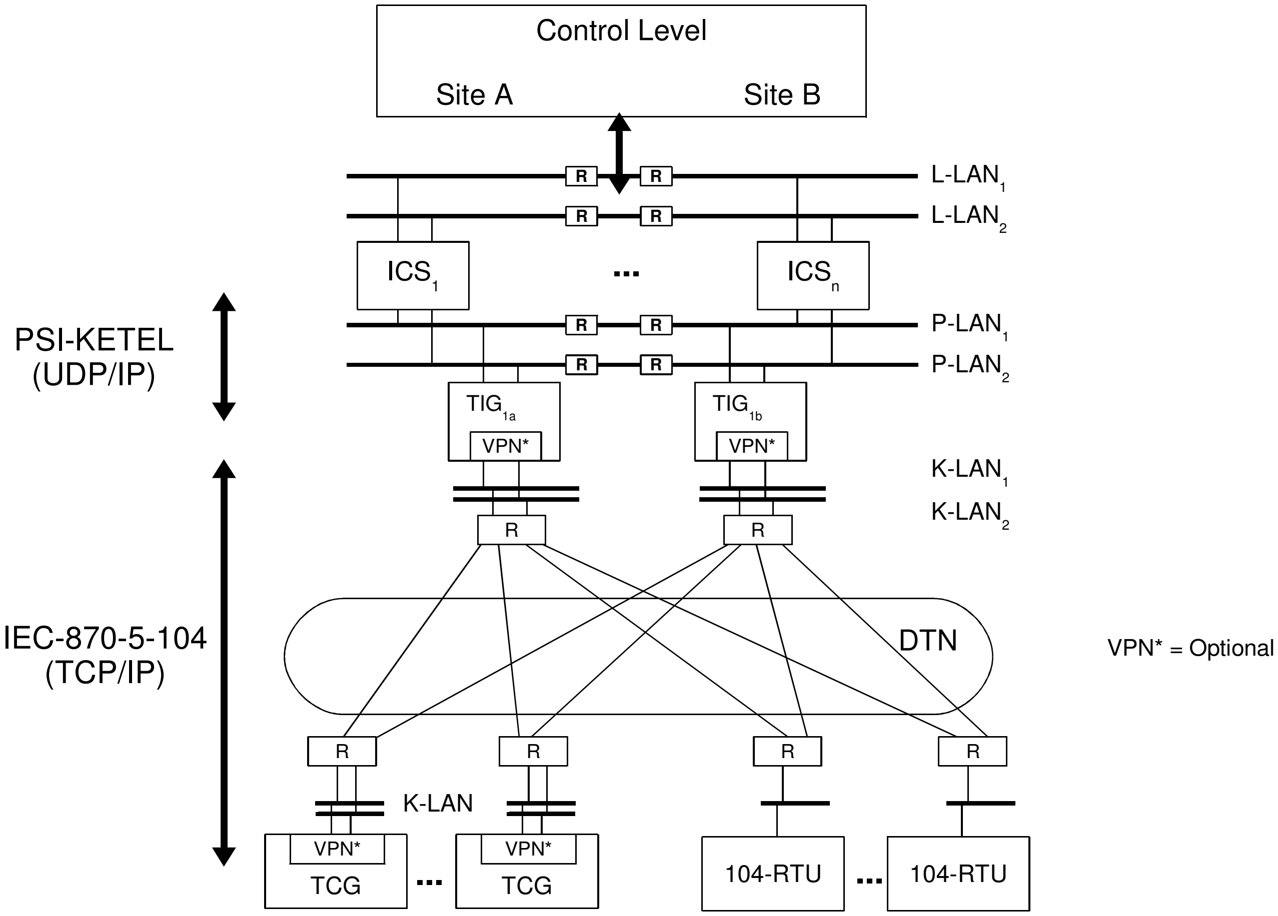

Figure 2.7-1: IEC-870-5-104 connection over TCP/IP gateways twofold redundant

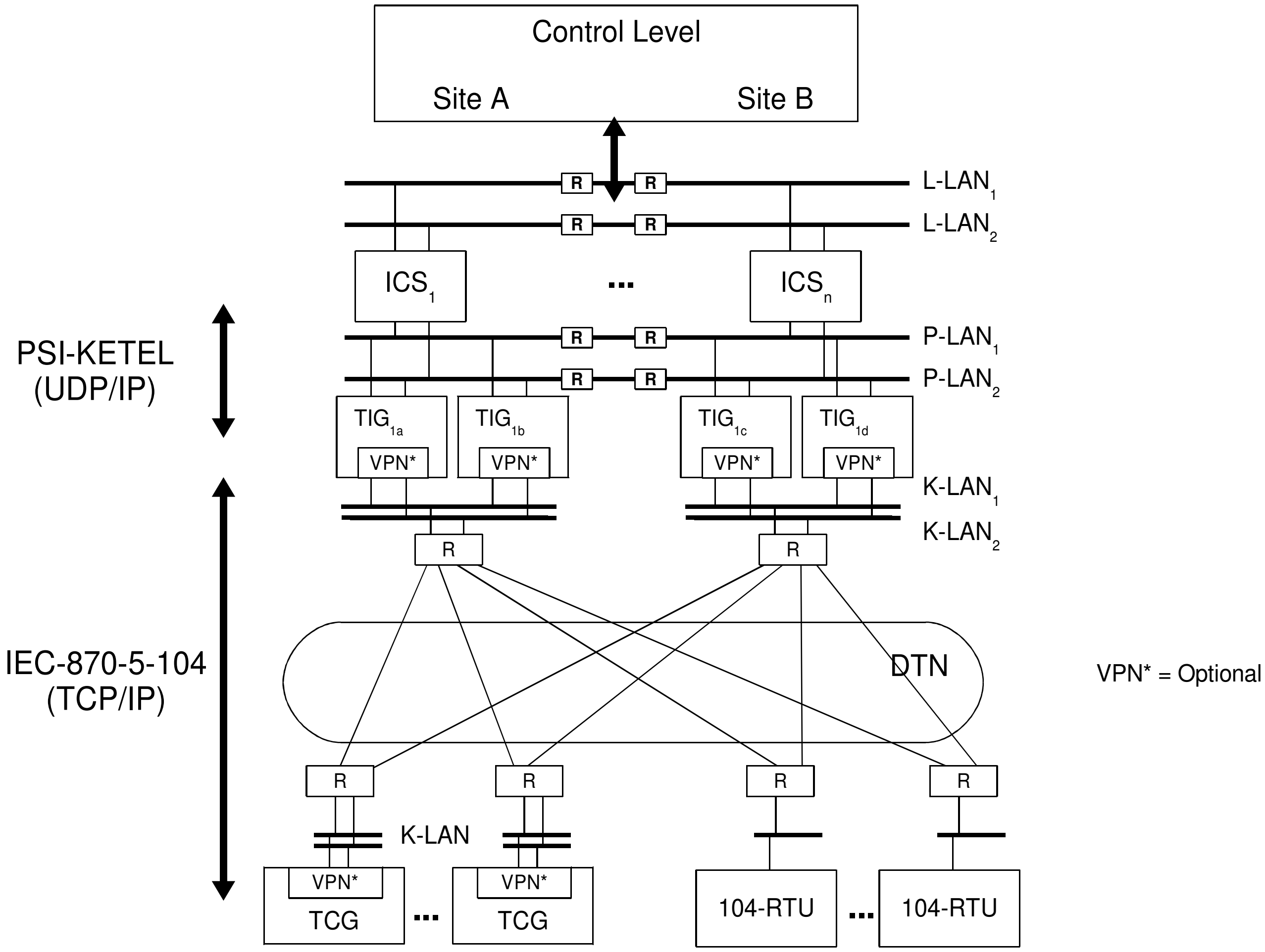

Figure 2.7-2 IEC-870-5-104 connection over TCP/IP gateways 2x2-fold redundant

2.7.3.2 Connection with Ethernet Channel Bundling ("Bond") at the TCP/IP Gateway

At the TCP/IP gateway, two Ethernet interfaces are used as Site LAN-1 and Site LAN-2 interfaces. The interfaces are configured in an IP network with different host numbers. If corresponding redundant Site LAN switches are used, the two Site LAN interfaces of the TCP/IP gateway can be accessed as "bond", i.e. as a logical LAN interface summarized under a further IP address. This increases the device redundancy of the Site LAN switches and of the LAN interfaces at the TCP/IP gateways. The following two figures show this variant with double redundancy and 2x2-fold redundancy of the TCP/IP gateways. Both redundancy variants can also be used in mixed operation.

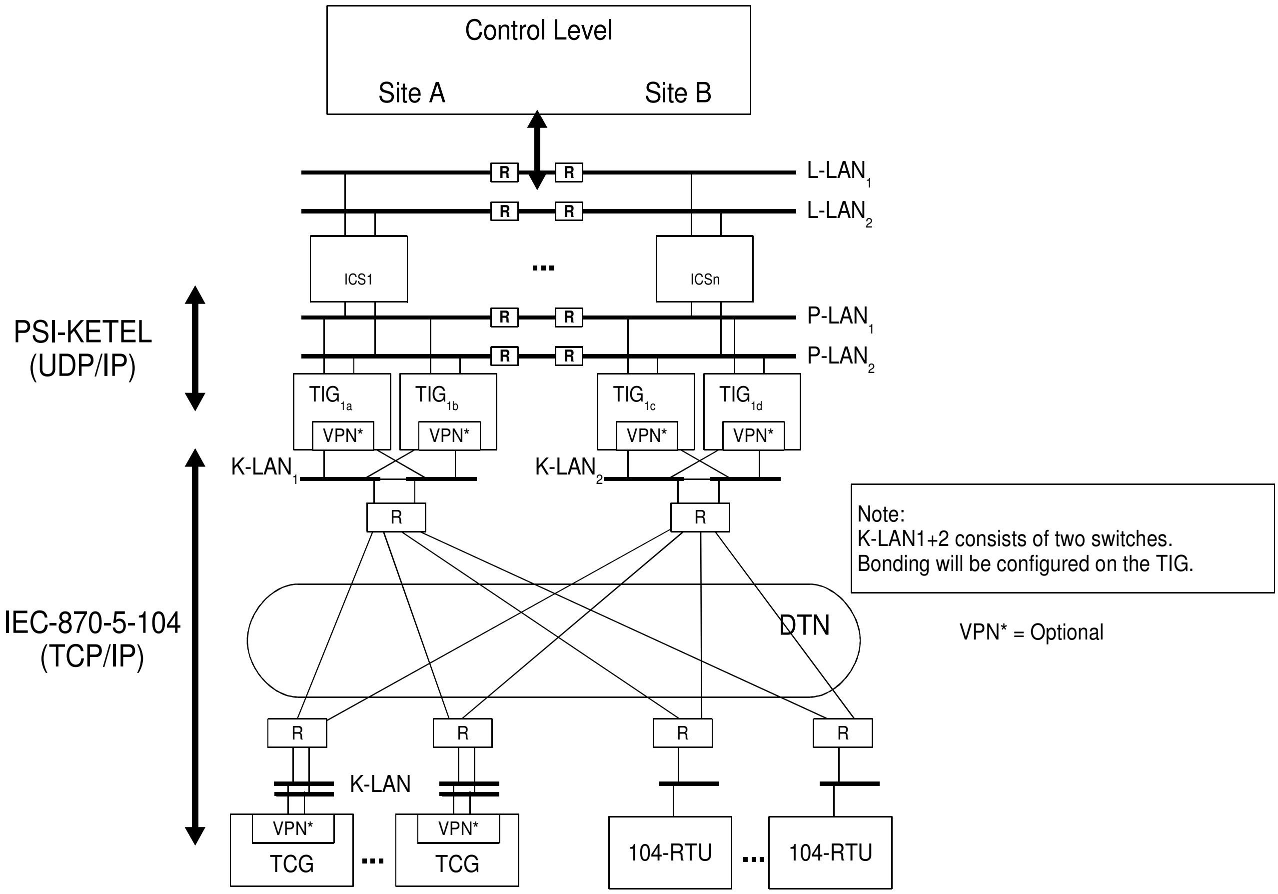

Figure 2.7-3: IEC-870-5-104 connection over TCP/IP gateways twofold redundant via "bond"

2.7.4 Demands Made on New IEC-870-5-104 Remote Terminal Units

If an IEC-870-5-104 substation is connected to the Network Control System, the substation

- must fulfill the IEC-870-5-104 requirements for the Network Control System described in this Functional Design.
- must have at least one LAN interface per connected Network Control System. The path redundancy is achieved with the IP networking per router.
- must be able to be time-synchronized via the NTP protocol.

The substation will be redundantly connected to the two TCP/IP gateways of the Network Control System with the help of an IEC104 redundant group in the RTU, which contains an IEC-870-5-104 connection to one TCP/IP gateway each. One connection of the redundant group is technologically active (payload telegrams are transmitted), the second is being tested.

2.7.5 Requirements for Router Configuration for IEC-870-5-104

The digital data transmission network (DTN) of the customer is used to transfer the process data over IEC-870-5-104. The Ethernet ports at the Site LAN switches are the interfaces between the TCP/IP gateways of the PSI Network Control System and the customer network.

If a path redundancy is required between the stations and the TCP/IP gateways for reasons of availability, it will be implemented with the IP routers in the DTN.

Further specifications for the router network are, as follows:

- In the TCP/IP gateways, a proper IP subnetwork is used for each of the two Site LANs (for configuration without channel bundling).

- In the TCP/IP gateways, precisely one static network route or one default router will be configured for each IP subnetwork to be addressed. No dynamic routing protocol is required in the TCP/IP gateways.

- If possible, private Class C IP networks will be used with the netmask 255.255.255.0 according to the pattern applied by the customer (e.g. 192.168.1.0 / 24 or 10.n.n.0 / 24)192.168.1.0 / 24 or 10.n.n.0 / 24).

- In the Network Control System and in the TCP/IP gateways, no special procedures or functions for secure transmission (encryption, authentication, protection against eavesdropping) are contained in the scope of delivery (no packet filters, no firewall functions, no IPSec, ...). These functions are provided by the customer.

- To avoid IEC104 connection outages and information losses, the IP router must not require more than 10 seconds for path switchovers in fault situations.

For the transmission of process data over IP router networks, the networks have to fulfill the following prerequisites (also see Figure 2.7-4):

- The router network must be able to transport a payload telegram with approximately 100 bytes (corresponding to an IEC104 telegram with approximately 50 bytes and TCP/IP overhead with approximately 50 bytes)
  - within 25 ms (roundtrip time) with 2 Mbps connection bandwidth
  - within 80 ms (roundtrip time) with 64 kbps connection bandwidth

  through the router network from LAN-A to LAN-B.
- As the daily average, the packet losses must be below 1%.
- Jitters must be below 5 ms for 95% of the transmitted IP packets.
- Process data (which can be identified via the standardized TCP port for IEC104) have to be transported with priority to other IP services by the routers, if required.

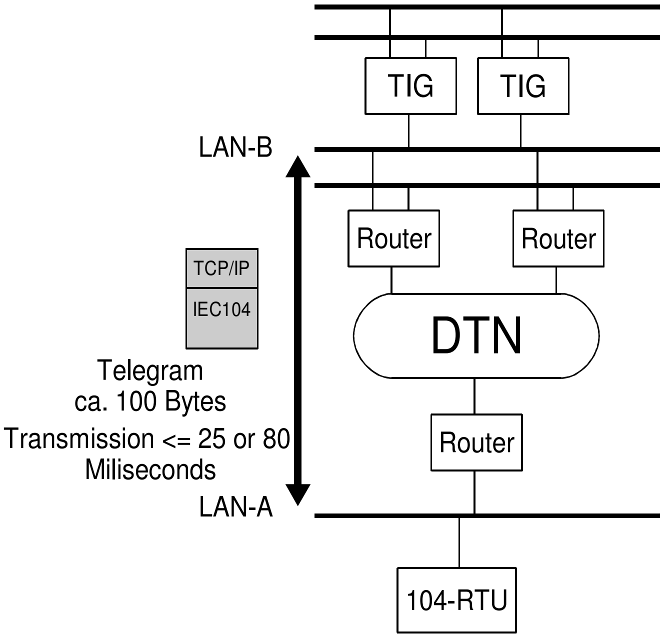

Figure 2.7-4 Requirements made on router connections

2.7.6 Telecontrol Channel and Remote Terminal Unit Volume in the TCP/IP Gateway

An IEC104 connection between an RTU and a TCP/IP gateway is modeled in Data Engineering (DE) as a telecontrol channel analogous to the serial channels of the telecontrol gateways.

Context between Ethernet Interface and IEC104 Telecontrol Channel

There is no direct context between an IEC104 and a TCP/IP gateway telecontrol channel. Ethernet is a bus system. All IEC104 telecontrol channels can, for instance, be led over an Ethernet interface. The Ethernet interface is assigned to the IEC104 telecontrol channel with the IP address and route configuration in the TCP/IP gateway.

Volume

Depending on the device variant, a maximum of
- 64 IEC104 connections (correspond to telecontrol channels in DE) per TCP/IP gateway for FG-3G-TIG,
- 128 IEC104 connections (correspond to telecontrol channels in DE) per TCP/IP gateway for FG-XS- and SUN-TIG

is possible in a TCP/IP gateway.

Maximally 1024 directly connected RTUs (in the sense of logical IEC104 stations, each with an unambiguous ASDU address, which corresponds to an RTU in DE) can be connected over an TCP/IP gateway.

Example

3000 small stations are directly connected to central TCP/IP gateways.
3000 / 128 = 24 central TCP/IP gateways are required.

Example

3000 small stations are directly connected to the decentralized FG-3G, which in turn is connected via central TCP/IP gateways.
3000 / 128 = 24 decentralized FG-3G and one central TCP/IP gateway are required.

2.7.7 Information Flows IEC-870-5-104 over TCP/IP Gateways

Figure 2.7-5 to Figure 2.7-7 show the principle of connecting an IEC-870-5-104 Remote Terminal Unit (RTU) to the Network Control System.

The PSI Network Control System is designed with device redundancy, both in terms of the computers themselves and in terms of the design of the Network Control System-internal local networks. Within the system, IEC104 RTUs are connected over the redundantly designed TCP/IP gateways.

For the TCP/IP gateways, a channel-specific redundancy concept is applied. A logical telecontrol channel at the TCP/IP gateway describes an IEC104 connection of this TCP/IP gateway to an IEC104 RTU. Each IEC104 RTU is connected over a logical telecontrol channel to both TCP/IP gateways of a redundant pair. A TCP/IP gateway is a "Master of Operations (M)" for this telecontrol channel. The other TCP/IP gateway of the redundant pair is "Standby (S)" for this channel. This corresponds to the active/passive concept for the telecontrol channels for the serial connection of telecontrol stations. Only the TCP/IP gateway with the active channel processes process information in monitoring direction and transmits process commands (commands, queries) in control direction.

For the TCP/IP gateways, the following rules are valid with regard to IEC-870-5-104 (will be explained in the following sections):

- Each TCP/IP gateway pair sets up an IEC-870-5-104 connection to each RTU in fault-free operation. The connection is periodically monitored for operability with the IEC-870-5-104 control procedure "Connection Test". The exchange of payload data in monitoring and control direction is activated for the connection with the IEC-870-5-104 control procedure "Start / Stop Payload Data Transfers". This connection is designated as main path or as active connection. The Master Interface Computer System in the Network Control System decides which of the two TCP/IP gateways of a redundant pair will set up the active connection by setting the operating state "ACTIVE in Control and Monitoring Direction" at one of the two telecontrol channels to this RTU.
- Moreover, each TCP/IP gateway pair sets up an IEC-870-5-104 connection to each RTU in fault-free operation in dependence on the used redundancy variant. The connection is periodically monitored for operability with the IEC-870-5-104 control procedure "Connection Test". The exchange of payload data in monitoring and control direction is not activated for the connection with the IEC-870-5-104 control procedure "Start / Stop Payload Data Transfers". This connection is designated as substitute path or as passive connection. The Master Interface Computer System in the Network Control System decides which of the two TCP/IP gateways of a redundant pair will set up the passive connection by setting the operating state "ACTIVE in Control Direction, PASSIVE in Monitoring Direction" at one of the two telecontrol channels to this RTU. If a redundant LAN connection of the RTU to both TCP/IP gateways is configured, a passive connection will additionally be set up by both TCP/IP gateways via the redundant LAN. In this case, there will be one active and three passive connections.
- In control direction, command telegrams and General Interrogation telegrams are only sent over the active connection to the RTU.
- In monitoring direction, all active connections are provided with information (see Chapter 2.7.8)

As of August 2003, a first amendment to IEC-870-5-104: 2000 exists with the title "IEC 60870-5-104 Amendment 1 Edition 1, Revision 1.0 (57 / 658 / CD)" as a standard draft, which also describes the rules for redundant IEC-870-5-104 connections in Chapter 10: "Redundant Connections". This description is used as the basis for the functions and operation of redundant IEC-870-5-104 connections in the PSI Network Control System. The latest version of this standard draft was published in September 2004.

2.7.8 Redundant Connections According to IEC 60870-5-104 Amendment 1

IEC 60870-5-104 Amendment 1 defines the following requirements made on redundant IEC-870-5-104 connections (see Chapter 10.2):

- R1: Central station (= control entity station) and substation (= controlled station) must be able to operate several (n) logical connections.
- R2: The n logical connections represent a redundant group.
- R3: Only the logical connection between the (central and substation) is activated at a specific point of time (= started via StartDT) to transmit / receive payload data (I frames).
- R4: The central station decides which of the n connections is to be activated.
- R5: All logical connections of a redundant group are monitored via test frames, as described in IEC 60870-5-104.
- R6: A redundant group is supplied from a Realtime Database (data basis / event buffer).
- R7: If more than one central station is to access the same substation simultaneously, each central station must form its own redundant group and, thus, has to be supplied from a proper Realtime Database of the substation.

The application of these general rules to the configuration of the PSI Network Control System means:

- Each TCP/IP gateway pair (in the case of 2x2 redundancy, both pairs together) forms a redundant group and is supplied from a proper Realtime Database of the RTU (see R6).
- Each TCP/IP gateway in the PSI Network Control system maximally operates two IEC104 connections to one RTU, one per connected and configured Interface Computer System LAN network interface at the TCP/IP gateway.
- Each IEC104 connection possesses its own connection layer and, thus, an individual IEC104 sequence number.
- If one RTU possesses several redundant groups, the distribution of information of the RTU initiated by the PSI Network Control System via command or query procedures (the ASDU types of Chapter 7.2.1 "Type Identifiers" of EN 60870-5-101:2003 marked with "CON") will depend on the origin address used. In terms of the origin

address in the command and query procedures, the following applies according to IEC 60870-5-101 (also see Chapter 7.2.3 "Transmission Cause" of EN 60870-5-101:2003):

If the origin address = 0 is used for the activation of the command or query procedures according to IEC-870-5-5 (which is the standard in the PSI Network Control System), the complete process information initiated in this way will be transmitted to all active IEC104 of the RTU. The acknowledgments of the command procedure (with transmission cause "ACTION", "ACTTERM", ...) will be transmitted according to the parameterization of the RTU either to the activated connections of all redundant groups or only to those of the "initiating" redundant group. In the PSI Network Control System, this is the TCP/IP Network Control System which operates the active connection. The acknowledgments of the query procedures (with transmission cause "ACTION", "ACTTERM", ...) will be transmitted to the activated connections of all activated IEC104 connections of all redundant groups, which are configured in the RTU with origin address = 0. This can depend on the implementation or parameterization of the RTU.

If the origin address = 0 is used for the activation of command or query procedures according to IEC-870-5-5, the command or query acknowledgments (with the transmission cause "ACTION", "ACTTERM", ...) will only be transmitted to the activated IEC104 connection of the initiating redundant group. For the query procedures, the queried process information will also only be transmitted to the activated IEC104 connection of the initiating redundant group. For the command procedure, however, the process information (response) initiated by the command will be transmitted to the activated connection of all redundant groups.

2.7.9 Connection of an RTU with a Network Interface over a Single IEC104 Connection

Figure 2.7-6 shows the connection of an IEC-870-5-104 Remote Terminal Unit (RTU) to the Network Control System over a network interface with a single IEC104 connection and an appropriate router configuration.

The RTU only has one network interface and, thus, only one IP address. In this variant, only one IEC104 connection will be set up at a time between a TCP/IP gateway and an RTU. The main path and the substitute path can only be switched as potential routes over the IP router and cannot be controlled or influenced by the IEC104 software in the TCP/IP gateway. If a switchover between main and substitute path is made by the routers, the IEC104 connection between the TCP/IP gateway and the RTU will possibly be terminated and set up again anew. This depends on the switchover of the routes. If the switchover is longer than t_1 of the IEC104 profile, the connection will be terminated, because the acknowledgment monitoring time of IEC104 has been exceeded. If the switchover does not take so much time, the route switchover will be transparent and will have no influence on the IEC104 connection set up.

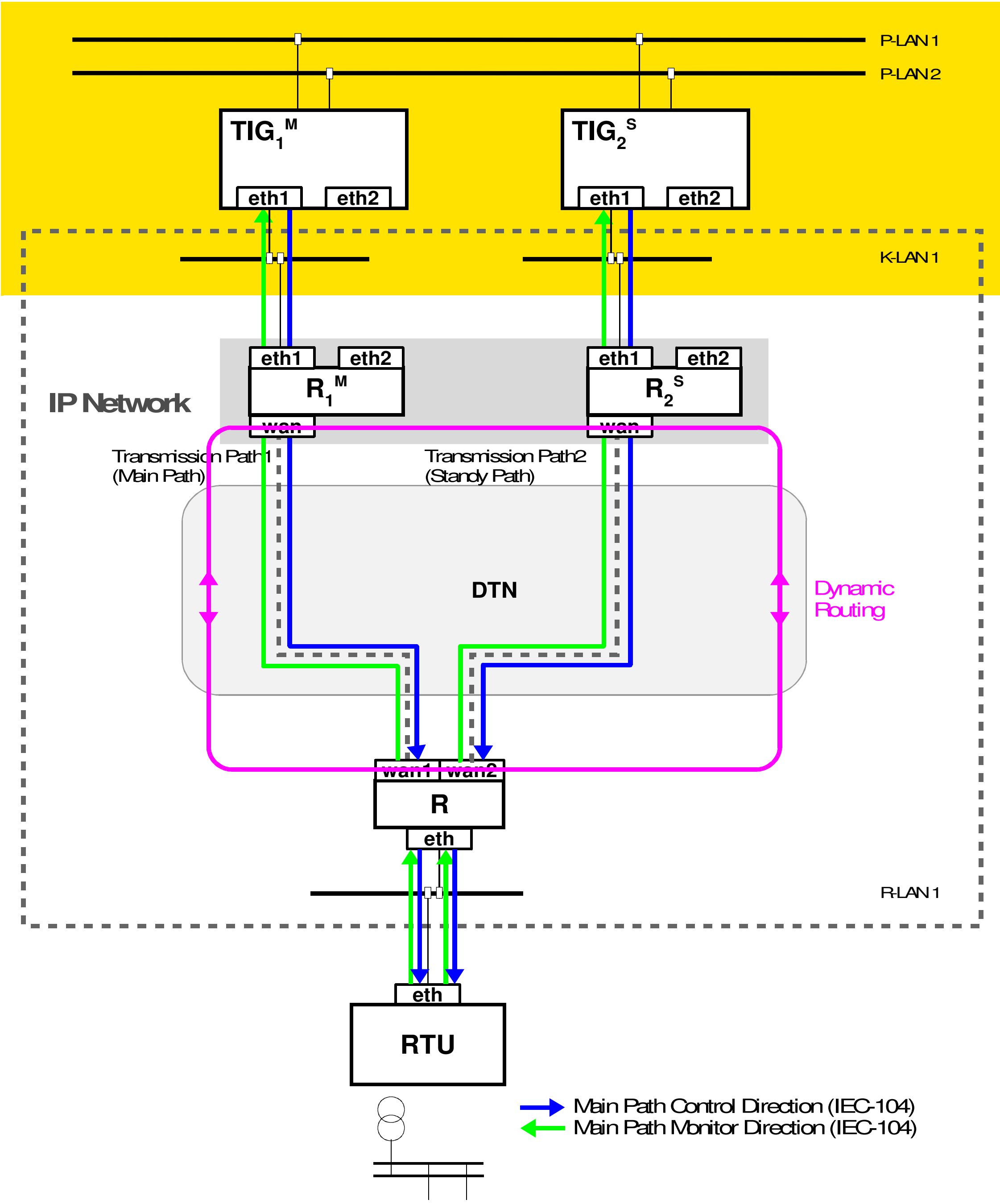

Figure 2.7-5: Normal operation of an RTU connection when connected over a LAN and over a single IEC104 connection

2.7.9.1 Network and Router Configuration

For this configuration at the RTU router, the second WAN interface is required for the substitute path (alternatively, a second router for the substitute path).

The Network Control System and the RTU routers have to synchronize themselves in the described default configuration - not via dynamic routing - on the selected path.

The real information flows for the normal operation and after outages depend on the routing configuration in the routers of the Network Control System.

Figure 2.7-7 shows a possible situation after the outage of a path (connection). Here, an IEC104 connection outage to the TCP/IP gateway 1 cannot be avoided, since the Site LAN between the TCP/IP gateways is not connected end-to-end via a single cable.

The router configuration must
- be able to cope with many fault situations (also in combination) and
- include a deterministic behavior in fault situations, i.e. a specific fault must always trigger the same reaction.

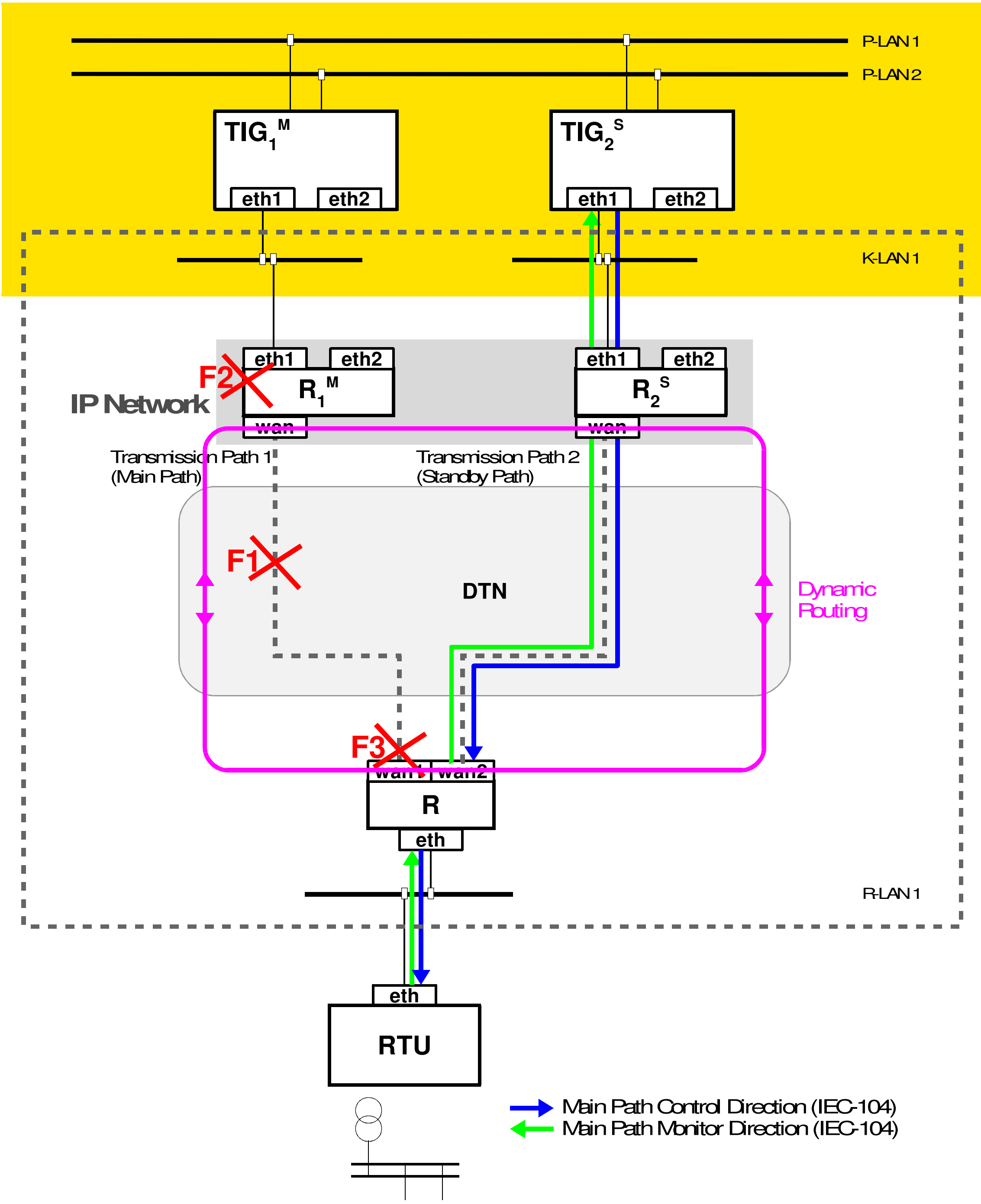

Figure 2.7-6: Outage of the main path of an RTU when connected over a LAN

2.7.9.2 Initialization of the IEC 104 Connection

Only one IEC104 connection will be set up at a time between a TCP/IP gateway and an RTU with a network interface.

The following example is based on routing over the Site LAN-A. The TCP/IP gateway and the RTU are connected over the WAN of the customer. The Site LANs are part of the customer WAN.

RTU => S-LAN => WAN => S-LAN-A => TCP/IP Gateway => P-LAN-A + P-LAN-B

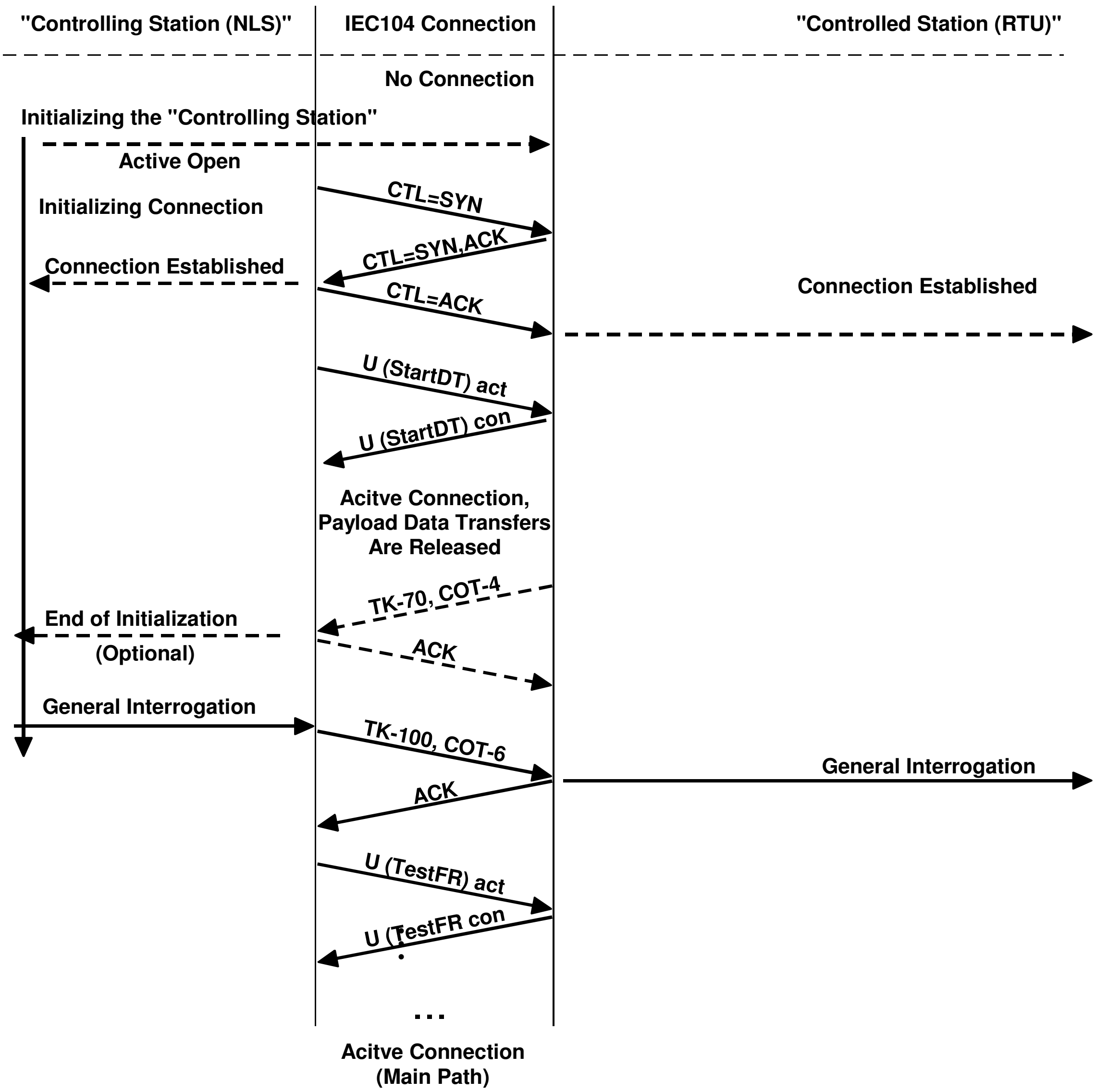

Figure 2.7-7 Initialization of a possible path

2.7.10 Operational Mode of the 2x2-fold Redundancy of the TCP/IP Gateways

The 2x2-fold redundancy works like the serial channel redundancy at a telecontrol gateway pair or at a TCP/IP gateway pair.

The following parameters have to be parameterized in Data Engineering (example: a 3G8 telecontrol gateway which is connected over the 2x2 TCP/IP gateways):

- The two TCP/IP gateway pairs (= 4 TCP/IP gateways) (4 Front End Systems and 4 Pseudo Remote Terminal Units, 2 Front End Systems have redundancy references to each other at a time, which makes up 2x2 pairs).
- The four telecontrol channels (one channel per TCP/IP gateway) for the TCP/IP gateway-specific IEC104 connection to the telecontrol gateway 3G8. For each channel, it is specified whether it is to be the main or backup connection.
- The 3G8 telecontrol gateway (Front End System and Pseudo Remote Terminal Unit; here, the Pseudo Remote Terminal Unit receives a reference to a telecontrol channel with the main connection).
- The system indications SYM and the channel fault indication to signal outages.

The assignment of main and backup connections is modeled over the telecontrol channels.

The Front End System software for redundancy control of the telecontrol channels by default automatically switches one telecontrol channel at each of the two TCP/IP gateway pairs as technologically active path (main connection) and one channel as system-technically active path (backup connection). Each IEC104 telegram, which is transmitted by this telecontrol gateway to the Network Control System, sends this information over the two technically active telecontrol channels to the two TCP/IP gateways in the two Network Control Systems A and B. The other two TCP/IP gateways also set up an IEC104 connection to this telecontrol gateway a, but test this connection only periodically (the telecontrol channel is system-technically active). In the default case, there will, thus, be four IEC104 connections from one 3G8 telecontrol gateway, one to each of the four TCP/IP gateways. At one Network Control System site, one IEC104 connection is the active connection, the other one is the backup connection.

The following outage scenarios and reactions of the Front End System telecontrol channel software are possible (IEC104 connection = telecontrol channel):

- Outage of the IEC104 connection in the Network Control System B

  Only the fault is signaled. The TCP/IP gateway concerned periodically attempts to put the broken down connection into operation again.

- Outage of the main EC104 connection in the Network Control System B

  The backup IEC104 connection in the Network Control System B is switched as the active IEC104 connection. The concerned TCP/IP gateway periodically attempts to put the broken down connection into operation again.

- Outage of both IEC104 connections in the Network Control System B

  Only the error is signaled, since one active IEC104 connection still exists in the Network Control System A. The TCP/IP gateway concerned periodically attempts to put the broken down connection into operation again.

- Outage of both IEC104 connections in the Network Control System B and of the backup IEC104 connection in the Network Control System A

  Only the error is signaled, since one active IEC104 connection still exists in the Network Control System A. The two TCP/IP gateways in the Network Control System B and the TCP/IP gateway in the Network Control System A periodically attempt to put the broken down connections into operation again.

- Outage of both IEC104 connections in the Network Control System B and of the active IEC104 connection in the Network Control System A

  The backup connection IEC104 in the Network Control System A is switched as active IEC104 connection. General Interrogations are initiated. The two TCP/IP gateways in the Network Control System B and the TCP/IP gateway in the Network Control System A periodically attempt to put the broken down connections into operation again.

It is attempted always to have an active IEC104 connection per Network Control System site. Only after the outage of the last active connection and the switchover to the backup connection will General Interrogations be initiated.

Each IEC104 communication failure is shown in the control center by a SYM error message for the respective telecontrol channel.

2.7.11 Connection of Multiple IEC104 Small Stations via DSL / GPRS / UMTS (Option)

The Network Control System can connect IEC104 small stations with telecontrol technology connections over IEC104.

2.7.11.1 Direct Connection of IEC104 Small Stations to Central TCP/IP Gateways

If the small stations are directly connected to the TCP/IP gateways, the maximum number of IEC104 connections per TCP/IP gateway has to be considered. For the used gateways, the maximum number ranges - according to the device variant - from 64 to 128.

Exemplary calculation of the number of TCP/IP gateways:

For 3000 IEC104 stations and telecontrol gateway XS TCP/IP gateways,
- 24 TCP/IP gateways,
- for redundant connection, 24 TCP/IP gateway pairs, and
- for 2x2-fold redundant connection to two Network Control Systems, 48 TCP/IP gateway pairs

are required.

2.7.11.2 Connection of IEC104 Small Stations to Decentralized Telecontrol Gateways

The small stations can also be connected via IEC104 to the telecontrol gateways. Via the internal telecontrol gateway data model, 64 channels can be configured at each telecontrol channel. The channels may correspond either to serial interfaces or to IEC104 connections. The advantage of this solution consists in the better scalability in combination with the decentralized connection of the small stations at concentrator sites, which permit the setup of more favorable connections between the telecontrol channel and the small stations in terms of the distance to be bridged. For this purpose, a double redundancy of the telecontrol gateways suffices instead of the 2x2-fold redundancy of the TCP/IP gateways. Moreover, the connection of the small stations to the telecontrol gateways allows the small stations also to use the VPN tunnels of the telecontrol gateways to the Network Control System sites. The IT security of the Network Control System can, thus, be ensured more easily than with a direct connection of the small stations to the TCP/IP gateways.

Table of Figures

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