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IEC 60870-5-101

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AMENDMENT 2
2001-10

Amendment 2

Telecontrol equipment and systems –

Part 5-101:
Transmission protocols –
Companion standard for basic telecontrol tasks

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FOREWORD

This amendment has been prepared by IEC technical committee 57: Power system control and associated communications.

The text of this amendment is based on the following documents:

FDIS	Report on voting
57/535/FDIS	57/551/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until 2003. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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1 Scope and object

Add, after the third paragraph, the following new text:

Although this companion standard defines the most important user functions, other than the actual communication functions, it cannot guarantee complete compatibility and interoperability between equipment of different vendors. An additional mutual agreement is normally required between concerned parties regarding the methods of use of the defined communication functions, taking into account the operation of the entire telecontrol equipment.

2 Normative references

Insert, in the list, the titles of the following standards:

IEC 60870-5-103:1997, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*

ISO/IEC 8824-1:2000, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

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5 Physical layer

5.1 Selections from ISO and ITU-T standards

Add, on page 19, after 5.1.3, the following new subclause:

5.1.4 Other compatible interfaces

Physical interfaces other than those which are recommended in the IEC 60870-5 series may be used, according to agreement between user and vendor. However, if other interfaces are used, it is the responsibility of the user and the vendor to prove their functionality and interoperability.

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6 Link layer

6.1 Selections from IEC 60870-5-1: Transmission frame formats

Add, after the notes, the following new text:

Transmission rule R3 states that no idle line intervals are admitted between characters. This may not be possible to achieve in some practical implementations, particularly with high bit rate transmission, because of unavoidable hardware or software delays.

However, annex B demonstrates that a line idle interval between characters that has a duration not longer than one transmitted bit time does not reduce the frame integrity. Therefore, transmission rule R3 may be relaxed to allow line idle intervals of up to one transmitted bit time duration between characters. The line idle intervals between characters extend the transmission time of time critical information (for example, clock synchronization) which may reduce the accuracy of clocks in controlled stations.

There is no requirement for the receiver to measure line idle intervals between characters. For example, the receiver may be implemented using an industry standard UART circuit alone, without any special hardware or software concerned with the duration of gaps between characters in a received frame.

6.2 Selections from IEC 60870-5-2: Link transmission procedures

Add, after the third paragraph, the following new subclause:

6.2.1 State transition diagrams

This subclause adds more detail to the base definitions of link transmission procedures given in IEC 60870-5-2. State transition diagrams are used to define the procedures more exactly so that link layers implemented by different manufacturers can be made fully interoperable. State transition diagrams represent the states (in this case of the link layer defined in IEC 60870-5-2) and the transitions from one state into another. The actions (send Tx and receive Rx) are included. In addition to the states, important internal processes are described.

The state transition diagrams are presented in the format defined by Grady Booch/Harel. The explanation of the particular elements is shown in figure 75.

Figure 75 – State transition diagram by Grady Booch/Harel

The word "in" describes an action which is triggered when a transition into a new state occurs. The transition to the next state may be triggered by the termination of the current state, in the case where there is no defined event to cause the transition.

The notation used in the following state transition diagrams is:

FC0 to FC15 = function code number 0 to 15, see tables 1 to 4 of IEC 60870-5-2

FCB = frame count bit

FCV = frame count bit valid

DFC = data flow control

ACD = access demand

PRM = primary message

SC = single character

Replace the heading "UNBALANCED TRANSMISSION" *by:*

6.2.1.1 Unbalanced transmission procedures

Add, after the fourth paragraph of 6.2.1.1, the following new text:

The SEND/NO REPLY service is used when issuing a user data message to all stations (broadcast address).

Add, after the second sentence of the sixth paragraph, the following new text:

The assignment of the causes of transmission to the two classes is defined in 7.4.2.

Add, after the sixth paragraph, the following new text:

Table 10 shows the permissible combinations of the unbalanced link layer procedures.

Table 10 – Permissible combinations of unbalanced link layer services

Function codes and services in the primary direction	Permitted function codes and services in the secondary direction
<0> Reset of remote link	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<1> Reset of user process	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<3> SEND/CONF user data	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<4> SEND/NO REPLY user data	No reply
<8> REQUEST for access demand	<11> RESPOND: status of link
<9> REQUEST/RESP request status of link	<11> RESPOND: status of link
<10> REQUEST/RESP request user data class 1	<8> RESPOND: user data or <9> RESPOND: requested data not available
<11> REQUEST/RESP request user data class 2	<8> RESPOND: user data or <9> RESPOND: requested data not available

Responses <14> Link service not functioning or <15> Link service not implemented are also permitted. The single control character E5 may be used instead of a fixed length CONFIRM ACK (secondary function code <0>) or fixed length RESPOND NACK (secondary function code <9>) except when there is an access demand for class 1 data (ACD = 1) or further messages may cause an overflow (DFC = 1). This is shown in figures 77 and 78. The single character A2 must not be used.

For unbalanced transmission procedures: The primary station contains only a primary link layer and the secondary station contains only a secondary link layer (see figure 76). More than one secondary station may be connected to one primary station. Compatible communication between the primary station and a particular secondary station relies on these two stations alone. The polling procedure for requesting data from multiple secondary stations is a local internal function of the primary station and need not be shown in figures 76 to 78. Consequently, these diagrams only show the primary station and a single secondary station. In the case of more than one secondary station, the primary station has to remember the current state of each secondary station.

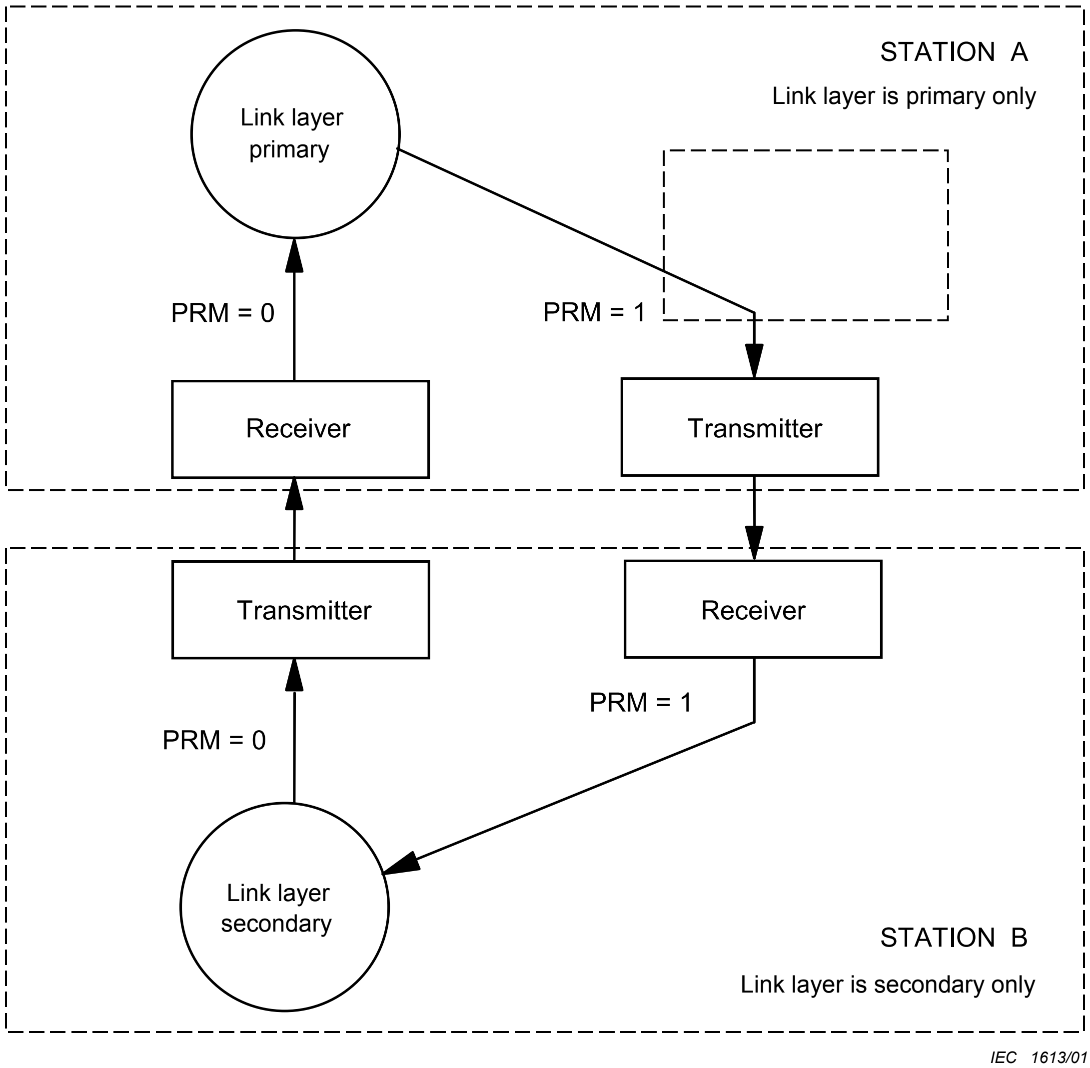

Figure 76 – Unbalanced transmission procedures, primary and secondary stations

Figure 77 shows the state transition diagram of the primary station, figure 78 that of the secondary station.

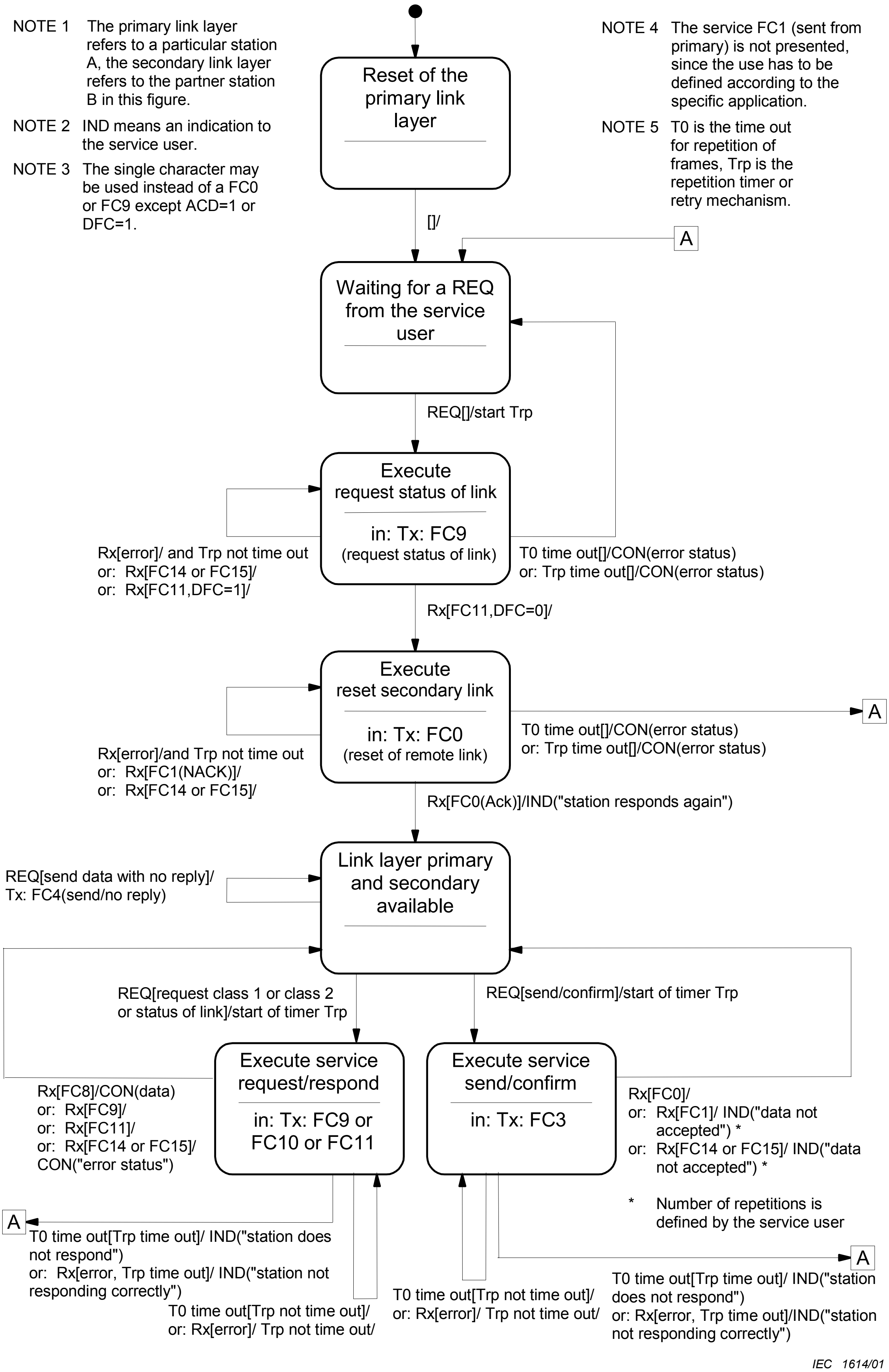

Figure 77 – State transition diagram for unbalanced transmission primary to secondary

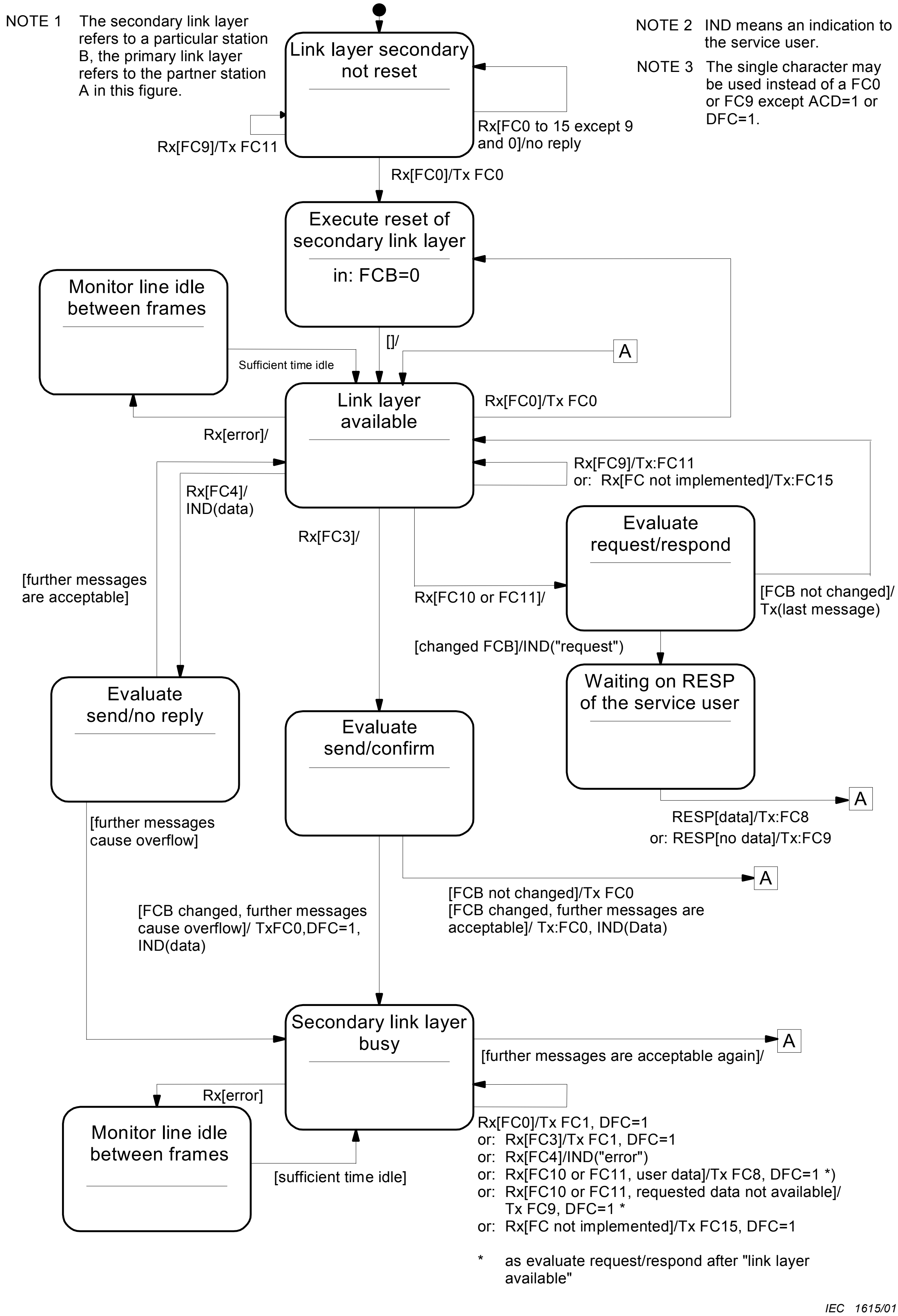

Figure 78 – State transition diagram for unbalanced transmission secondary to primary

Replace the heading "BALANCED TRANSMISSION" *by:*

6.2.1.2 Balanced transmission procedures

Add, after the first paragraph of 6.2.1.2, the following:

The following table shows the permissible combinations of the balanced link layer procedures

Table 11 – Permissible combinations of balanced link layer services

Function codes and services in the primary direction	Permitted function codes and services in the secondary direction
<0> Reset of remote link	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<1> Reset of user process	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<2>SEND/CONF test function for link	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<3> SEND/CONF user data	<0> CONFIRM: ACK or <1> CONFIRM: NACK
<4> SEND/NO REPLY user data	No reply
<9> REQUEST/RESP request status of link	<11> RESPOND: status of link

Responses <14> link service not functioning or <15> link service not implemented are also permitted. The single control character E5 may be used instead of a fixed length CONFIRM ACK (secondary function code <0>) except when further messages may cause an overflow (DFC = 1).

Add, after the second paragraph, the following new text:

The link layers for balanced transmission procedures consist of two decoupled logical processes, one logical process represents station A as the primary station and station B as the secondary station and the other logical process represents station B as the primary station and station A as the secondary station (each station is a combined station). Thus, two independent processes exist in each station to control the link layer in the logical primary and in the secondary direction. Figure 79 shows the typical arrangement of the link layer using balanced transmission procedures.

NOTE The physical transmission direction is fixed defined by the bit DIR. The logical processes primary or secondary may change from station A to B and vice versa. The primary message is defined by the bit PRM = 1, the secondary message by the bit PRM = 0 (see 6.1.2 of IEC 60870-5-2).

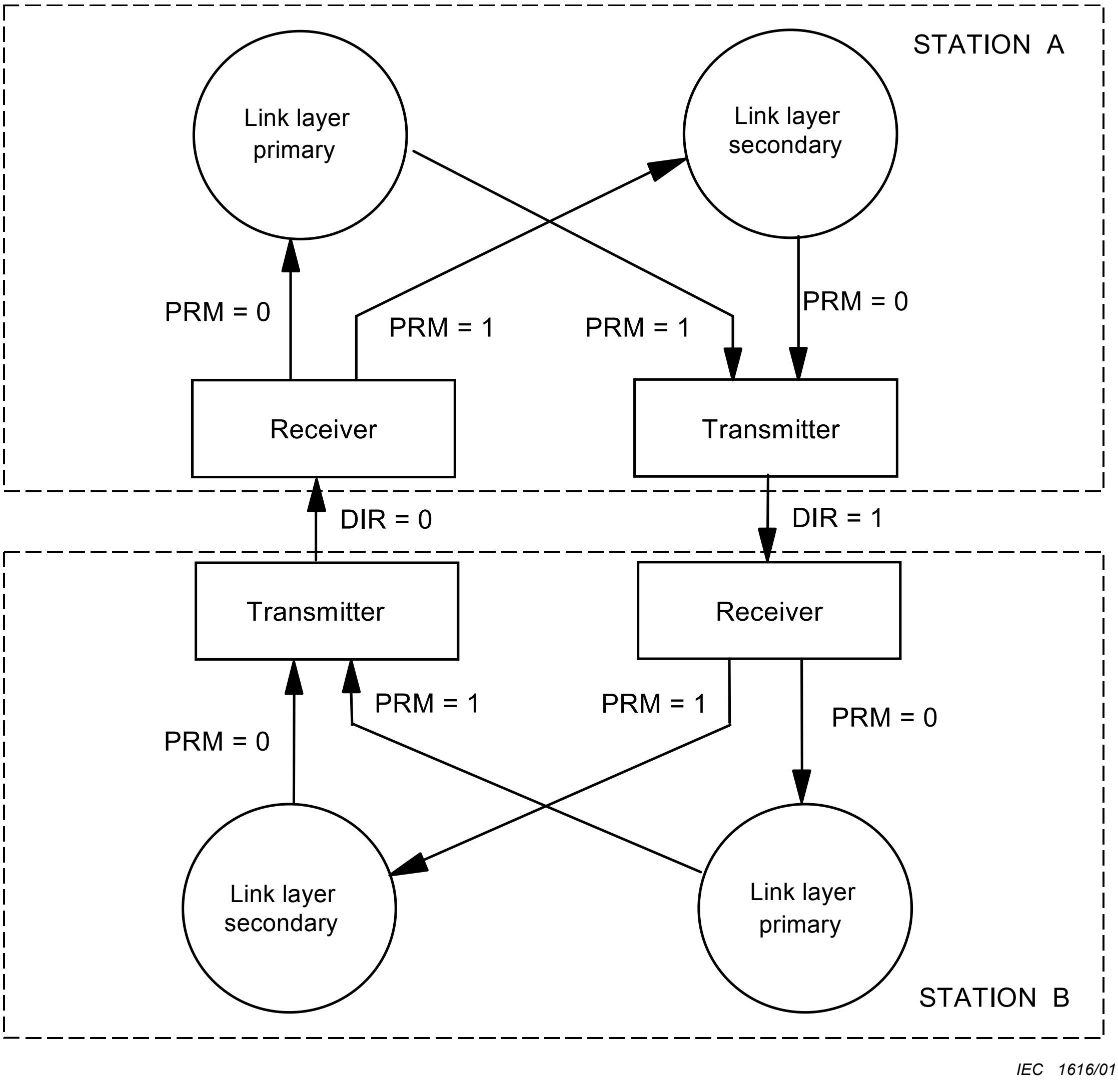

Figure 79 – Balanced transmission procedures, primary and secondary link layers

Figures 80 and 81 do not show the reactions of the link layer in the case of receiving corrupted frames. These frames are already rejected by a process which is not shown in the following. This process is also responsible for the control of the time out interval. Figure 80 shows the state transition diagram of the primary link layer using balanced transmission procedures. Figure 81 shows the secondary link layer.

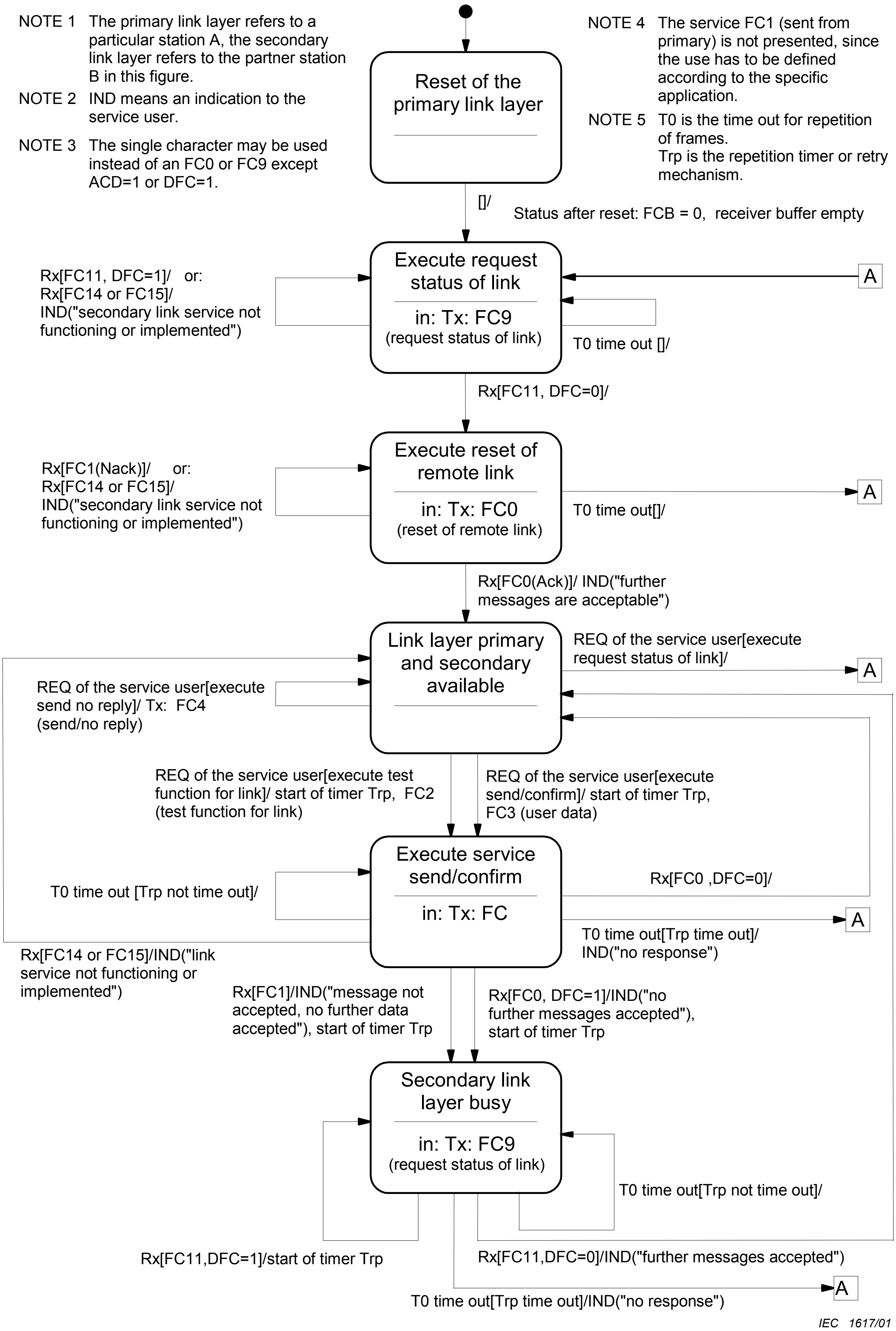

Figure 80 – State transition diagram for balanced transmission primary to secondary

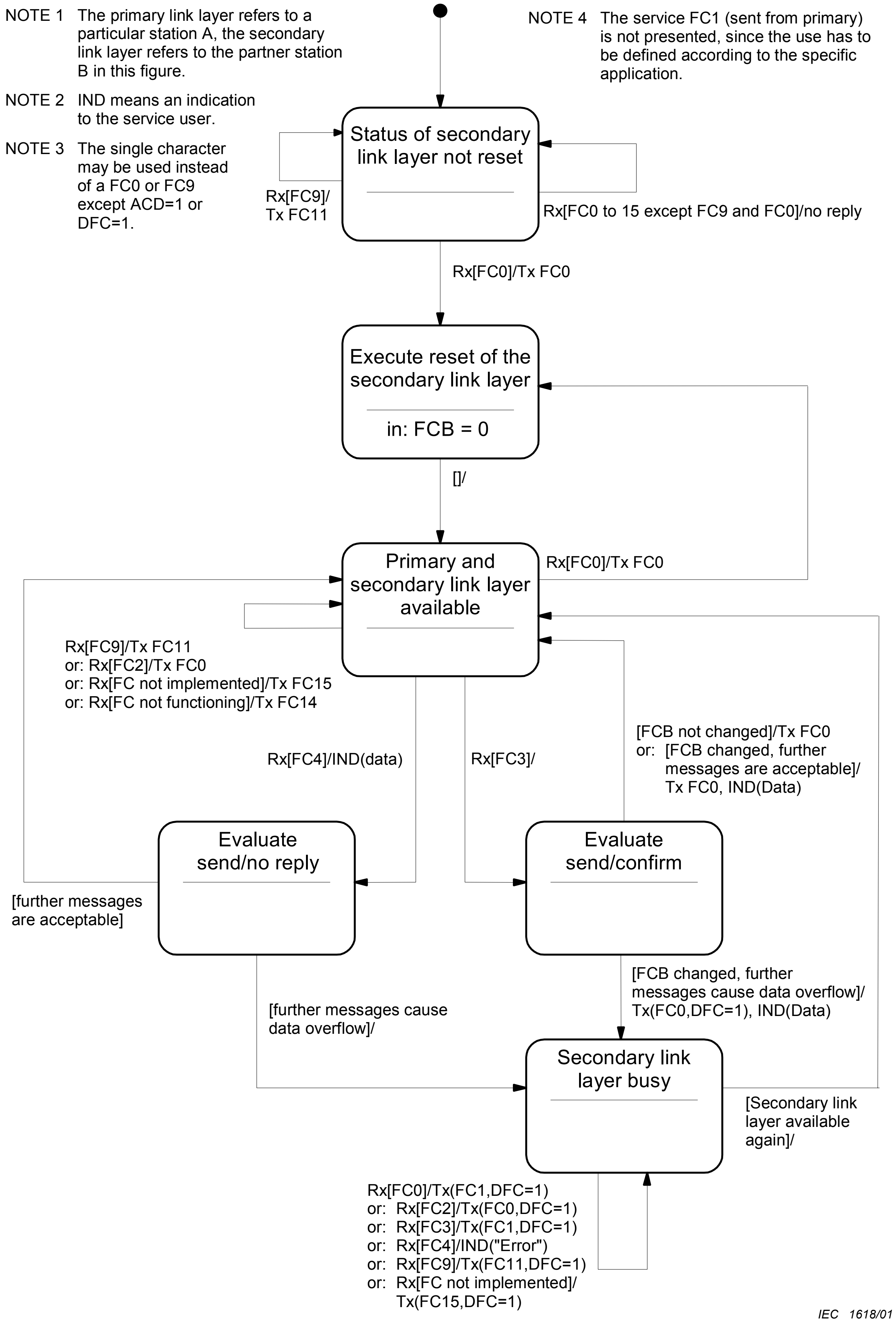

Figure 81 – State transition diagram for balanced transmission secondary to primary

Add, at the end of the last paragraph, the following new text:

DIR defines the physical transmission direction (see 6.1.2 of IEC 60870-5-2):

1 = station A (controlling station) to station B (controlled station)

0 = station B (controlled station) to station A (controlling station)

All messages sent by the controlling station will have the data link control field DIR bit set to 1. All messages sent by the controlled station will have the data link control field DIR bit set to 0.

In the case of two equivalent stations (for example, two control centres) the DIR is defined by agreement.

If defined, the balanced mode address field will contain the destination address for both primary and secondary messages.

Replace the heading "TIME OUT INTERVAL FOR REPEATED FRAME TRANSMISSION" *by*:

6.2.2 Definitions of time out interval for repeated frame transmission

Add, at the beginning of the first paragraph, the following new text:

Formulae are given in annex A of IEC 60870-5-2 for calculating the time out interval for repeated transmissions, assuming two cases and a variety of project-specific parameters.

Add, after the first paragraph, the following new text:

This present subclause clarifies the use of the formulae by calculating two tables which give examples of time out intervals for a number of typical conditions for both balanced and unbalanced transmission.

Reference: IEC 60870-5-2, annex A – figure A.2, case 1 (unbalanced transmission procedures);
IEC 60870-5-2, annex A – figure A.4, case 1 (balanced transmission procedures).

Abbreviations not defined in IEC 60870-5-2:

BAB transmission speed from station A to station B

BBA transmission speed from station B to station A

LBAmax number of octets of the longest frame from B to A

LADDR length of the link address field

BAB, BBA, LBAmax, LADDR, t_R and t_{RB} are project-specific parameters.

6.2.2.1 Unbalanced transmission

The following condition is valid for the time out interval T_O:

$$T_O > t_{LD} + T_{LBA}$$

where t_{LD} $= t_{DAB} + t_R + t_{DBA}$

and t_R is the reaction time of station B (specific per equipment)

t_{DAB} = 0,5/BAB (see note below)

t_{DBA} = 0,5/BBA (see note below)

T_{LBA} = $11 \times$ LBAmax/BBA

Examples for the specification of the time out interval

Definitions: station B = controlled station,

equal transmission speed in both directions,

reaction time of station B t_R = 50 ms.

NOTE The signal delays t_{DAB} and t_{DBA} (see IEC 60870-5-2, annex A) are assumed to be half the transmission time of a data bit.

Table 12 – Time out intervals (T_O) depending on frame length, transmission speed and project specific parameters (examples)

LBAmax	Transmission speed bit/s	t_{LD} ms	T_{LBA} ms	T_O ms
20	100	60,0	2 200,0	2 260,0
	600	51,7	366,7	418,4
	1 200	50,8	183,3	234,1
	9 600	50,1	22,9	73,0
	19 200	50,0	11,4	61,4
	64 000	50,0	3,4	53,4
240	100	60,0	26 400,0	26 460,0
	600	51,7	4 400,0	4 451,7
	1 200	50,8	2 200,0	2 250,8
	9 600	50,1	275,0	325,1
	19 200	50,0	137,5	187,5
	64 000	50,0	41,3	91,3

6.2.2.2 Balanced transmission

The following condition is valid for the time out interval T_O:

$$T_O > t_{LDA} + T_{LSPBA} + t_{GB} + T_{LPSBA}$$

where $t_{LDA} = t_{DAB} + t_{RB} + t_{DBA}$

and t_{RB} is the reaction time of station B (specific per equipment)

t_{DAB} = 0,5/BAB (see note below)

t_{DBA} = 0,5/BBA (see note below)

t_{GB} = 33/BBA [1)]

$T_{LPSBA} = 11 \times$ LBAmax/BBA

T_{LSPBA} = 11(LADDR + 4)/BBA

NOTE The signal delays t_{DAB} and t_{DBA} (see IEC 60870-5-2, annex A) are assumed to be half the transmission time of a data bit.

[1)] t_{GB} = 33 bit is the critical case for the definition of T_O.
t_{GB} is a system specific parameter which may be significantly less than 33 bit (for example, 0,5 bit).

Examples for the specification of the time out interval

Definitions: station B = controlled station,
equal transmission speed in both directions,
reaction time of station B t_R = 50 ms
length of address field LADDR = 1

Table 13 – Time out intervals (T_O) depending on frame length, transmission speed and project specific parameters (examples)

LBAmax	Transmission speed bit/s	t_{LDA} ms	t_{GB} ms	T_{LSPBA} ms	T_{LPSBA} ms	T_O ms
20	100	60,0	330,0	550,0	2 200,0	3 140,0
	600	51,7	55,0	91,7	366,7	565,1
	1 200	50,8	27,5	45,8	183,3	307,4
	9 600	50,1	3,4	5,7	22,9	82,1
	19 200	50,0	1,7	2,9	11,4	66,0
	64 000	50,0	0,5	0,9	3,4	54,8
240	100	60,0	330,0	550,0	26 400,0	27 340,0
	600	51,7	55,0	91,7	4 400,0	4 598,4
	1200	50,8	27,5	45,8	2 200,0	2 324,1
	9 600	50,1	3,4	5,7	275,0	334,2
	19 200	50,0	1,7	2,9	137,5	192,1
	64 000	50,0	0,5	0,9	41,3	92,7

6.2.3 The use of the different resets

IEC 60870-5-2 defines the services FC0 reset of remote link and FC1 reset of user process. Additionally, IEC 60870-5-5 and this standard define the remote initialization procedure which uses the reset process command C_RP_NA_1 type identification number <105>.

The use of the different resets is specified in table 14.

Table 14 – Effects of the different resets

Controlling station layer 7 and user	Primary link	Secondary link	Controlled station layer 7 and user
	Reset of remote link (FC0)	Secondary link reset	–
	Reset of user process (FC1)	Reset	Reset
Reset process command	–	–	Reset

Reset of remote link is used when the secondary link is reset independently from the layers above the link. In this case, the frame count bit of the control field is always set to zero. A pending secondary link layer message is deleted.

Reset of user process as a link function is used if the link layer is still working but the process functions of the controlled station are not available. In this case, a reset of the user process via a link service might put the user process into operation. This service can only be used if the link layer is able to reset the user process via a separate signal.

The use of the **reset process command** is defined in detail in 6.1.4 and 6.1.7 of IEC 60870-5-5.

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7 Application layer and user process

Replace, on page 27, "j" *in the formula for the* INFORMATION OBJECT *by* "d".

Replace, on page 27, "Variable parameter j" *by:* "Variable parameter d".

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7.2.1 Type identification

Replace the existing text of the last paragraph by the following new text:

ASDUs with undefined values of TYPE IDENTIFICATION are discarded by controlling stations.

7.2.1.1 Definition of the semantics of the values of the type identification field

Add, to the second paragraph, the following new text:

In standard operations, there is a vertical flow of information between stations in a network. Commands are sent down from the central controlling station to one of several controlled stations and events/measurements are sent up from a controlled station to the central controlling station.

In some installations, there may be an additional need for information to flow laterally between stations of equal rank. This may be done using a dual-mode option so that both commands and event/measurements may be sent in both directions. A common link layer may support both standard direction operation and reverse direction operation. Individual application functions and ASDUs may be chosen for standard direction use, reverse direction use or for both uses as required.

A dual-mode station may be run on top of either a balanced or an unbalanced link layer. When an unbalanced link is used to connect to a dual-mode station, the role of the primary link layer must be established during system design and does not change during communications. In the case of an unbalanced link, the command ASDUs in reverse direction are requested by the unbalanced link layer request/respond service.

A dual-mode station must set the Common Address of ASDU in each transmitted message corresponding to the station currently acting as a controlled station. The receiving station may use the Common Address of ASDU to determine if the message should be interpreted as a request or a response.

Type identification 7, 8, 33 and 51 (bitstring of 32 bits in monitor and command direction) shall only be used when no other appropriate data types are defined. These types must not include data that appear in single- or double-point information (whether packed or unpacked).

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Replace, at the end of table 3, "<22..44>" *by* "<22..29>".

Add the following:

<30>	:= single-point information with time tag CP56Time2a	M_SP_TB_1
<31>	:= double-point information with time tag CP56Time2a	M_DP_TB_1
<32>	:= step position information with time tag CP56Time2a	M_ST_TB_1
<33>	:= bitstring of 32 bits with time tag CP56Time2a	M_BO_TB_1
<34>	:= measured value, normalized value with time tag CP56Time2a	M_ME_TD_1
<35>	:= measured value, scaled value with time tag CP56Time2a	M_ME_TE_1
<36>	:= measured value, short floating point number with time tag CP56Time2a	M_ME_TF_1
<37>	:= integrated totals with time tag CP56Time2a	M_IT_TB_1
<38>	:= event of protection equipment with time tag CP56Time2a	M_EP_TD_1
<39>	:= packed start events of protection equipment with time tag CP56Time2a	M_EP_TE_1
<40>	:= packed output circuit information of protection equipment with time tag CP56Time2a	M_EP_TF_1
<41..44>	:= reserved for further compatible definitions	

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Table 6 – Semantics of TYPE IDENTIFICATION

Insert "**CON**" *in front of* "<102>"

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7.2.2 Variable structure qualifier

7.2.2.1 Definition of the semantics of the values of the VARIABLE STRUCTURE QUALIFIER field

Replace "SQ<0> and N<0..127> = number of INFORMATION OBJECTs" *by*

"SQ<0> and N<0..127> = number of INFORMATION OBJECTs i"

and

"SQ<1> and N<0..127> = number of INFORMATION ELEMENTS of a single object per ASDU" *by*

"SQ<1> and N<0..127> = number of INFORMATION ELEMENTS j of a single object per ASDU".

Add, after 7.2.2.1, the following new subclause:

7.2.2.2 Requirements for the transmission of information objects in chronological order

For information objects to be correctly transmitted in chronological order while preserving priority classes specified by the controlled station's priority control manager, the following specifications are valid.

Monitored information objects may be transmitted with the following causes of transmission:

- cyclic/periodic,
- background scan,
- spontaneous,
- requested,
- return information caused by a remote command,
- return information caused by a local command,
- interrogated by station and group interrogation,
- interrogated by general and counter request

Each ASDU always contains a single type identification and a single cause of transmission.

Transmission of values from a single information object must always be in the chronological order in which those values were measured.

NOTE To ensure that the transmission of values from a single information object is always in the correct chronological order, it may be necessary to ensure that all values from that information object use a single priority buffer, or that there is coordination between values of the object that may be placed in different priority buffers.

For the transmission of objects buffered in priority buffers, the conditions shown in figure 82 are valid.

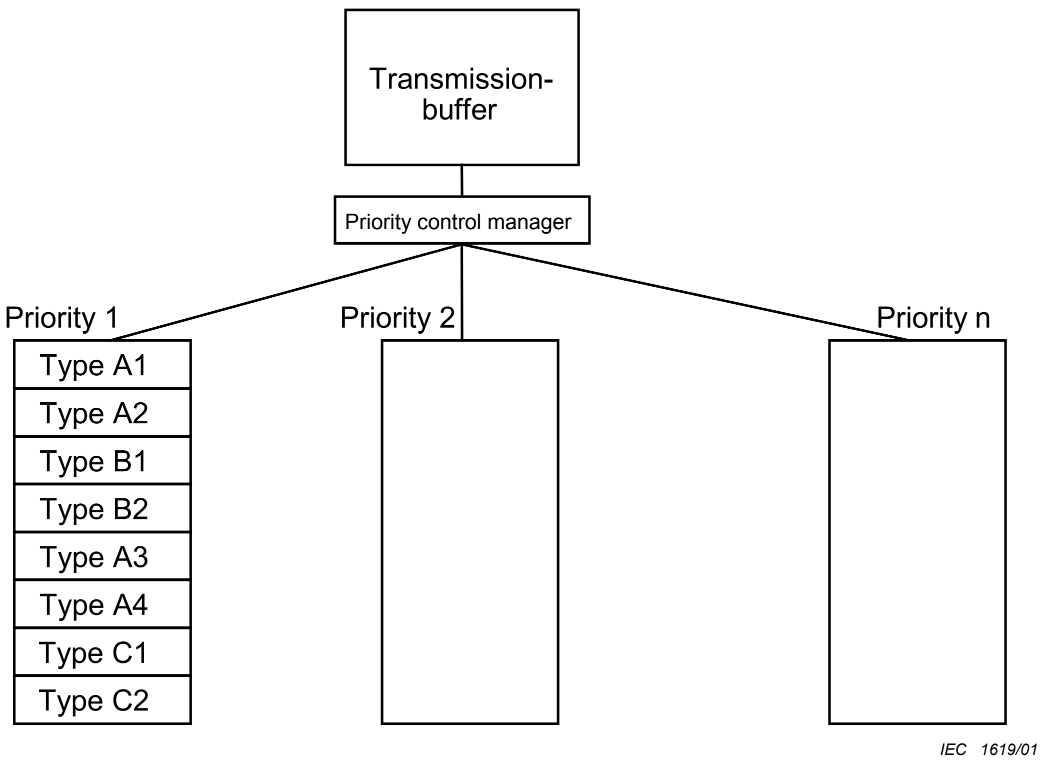

Figure 82 – Presentation of types of ASDUs in priority buffers

To transmit correct chronological sets of information objects from a priority buffer, the following procedure should be implemented. In the example in figure 82, the information objects having type identifications A, B and C are shown in a randomly buffered order in the priority buffer 1. For the transmission of the information objects from this buffer, the first two objects of type identification A, namely A1 and A2, are packed in one ASDU. The objects B1 and B2 are packed in a second ASDU, then the objects A3 and A4 follow in a third ASDU, etc. In general, the priority buffer is examined closely for objects having a single type identification and cause of transmission that are buffered in chronologically correct order without any intermediate objects having a different identification. Only these homogeneous groups of objects are transmitted together in one ASDU. When an object having a different type identification is encountered in the buffer, that object is transmitted in the next following ASDU, which may consist again of packed objects with a single type identification. The packed objects transmitted in one ASDU always have the same transmission priority class.

The maximum length of the transmission frame is a fixed parameter. Since the lengths of objects of different type identification are not all the same, the maximum number of objects of a given type that may be sent in an ASDU may vary. The ASDUs are automatically filled with the objects up to the maximum length specified, if there is a sufficient number of sequential buffered objects with the same type identification and cause of transmission available in one priority buffer.

It is not permissible to delay the transmission of an ASDU while waiting for further buffered objects which could be used to fill that ASDU to the maximum possible length.

Best efficiency can be achieved by defining objects with only a single type identification in each priority buffer. This is normally performed by configuration parameters.

This subclause refers to the spontaneous transmission of events and does not specify the construction of sequences of information elements which are used in ASDUs with unstructured information object addresses, such as responses to a station interrogation. However, the requirement that all values reported for a single information object are in correct chronological order must be observed.

When implementing the priority buffers and priority control manager defined in this subclause, it is necessary to ensure that an information object without a time tag is not transmitted to the controlling station before all versions of the same object, generated before the present version, have been transmitted.

Care must be taken for a number of reasons including

a) the time taken to generate an object for different causes of transmission (for example, as a sample for background scan or an event for spontaneous transmission) may not be exactly the same. Thus, two versions of the same object may not be entered into the priority buffers in the correct chronological order, when their times of generation are very close together;

b) the streams of objects in different priority buffers are unlikely to progress through the buffers at the same speed. This means that objects entered into the buffers in the correct chronological order may not be presented to the priority control manager still in that correct order;

c) objects within ASDUs waiting in the transmission buffer may not be transmitted in the same order as they were entered, when unbalanced mode link procedures are being used. This is because the controlled station has no control over the order in which requests for class 1 and requests for class 2 data are received.

The method used to maintain the correct chronological order in any implementation is a local matter (internal to the particular controlled station) and is not defined in this standard.

NOTE When using structured information object addresses, the ASDUs that are defined for sequences of information elements in a single information object might not be completed to optimal lengths due to possible gaps in the address numbering. Typically this reduces the packing efficiency for station interrogation procedures.

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7.2.3 Cause of transmission

7.2.3.1 Definition of the semantics of the values of the CAUSE OF TRANSMISSION field

Add, after "<1..255> := number of originator address"*, the following new text:*

ASDUs with undefined values of CAUSE OF TRANSMISSION are discarded by controlling stations.

Add, after the last paragraph and before table 9, the following new text:

If the originator address is used, the following definitions are valid.

<0> = default

<0> is used to define process information as return information, events, etc. that are stored in network images and which have to be transmitted to all parts of a distributed system.

<1..255>

This range may be used to address the specific part of the system to which the corresponding information in the monitor direction is returned.

Within a system, parts of the system can be information sources which may initiate station interrogations, requests for integrated totals, commands, etc. The returned information is only of importance for the source which initiated the request or the command. In these systems, the information source should set the originator address of the ASDUs in the command direction, and the controlled station should echo this originator address in the response in the monitor direction.

EXAMPLE 1

The station interrogation initiated by a specific source (controlling station A in figure 83) returns interrogated information in monitor direction which are exclusively directed to the particular source and not to other parts of the system (for example, controlling station B in figure 83). The ASDUs which are used for this station interrogation are marked with a specific originator address (of range <1..255>) which is used to route the interrogated information in monitor direction (for example, via a concentrator station in figure 83) to the initiating source.

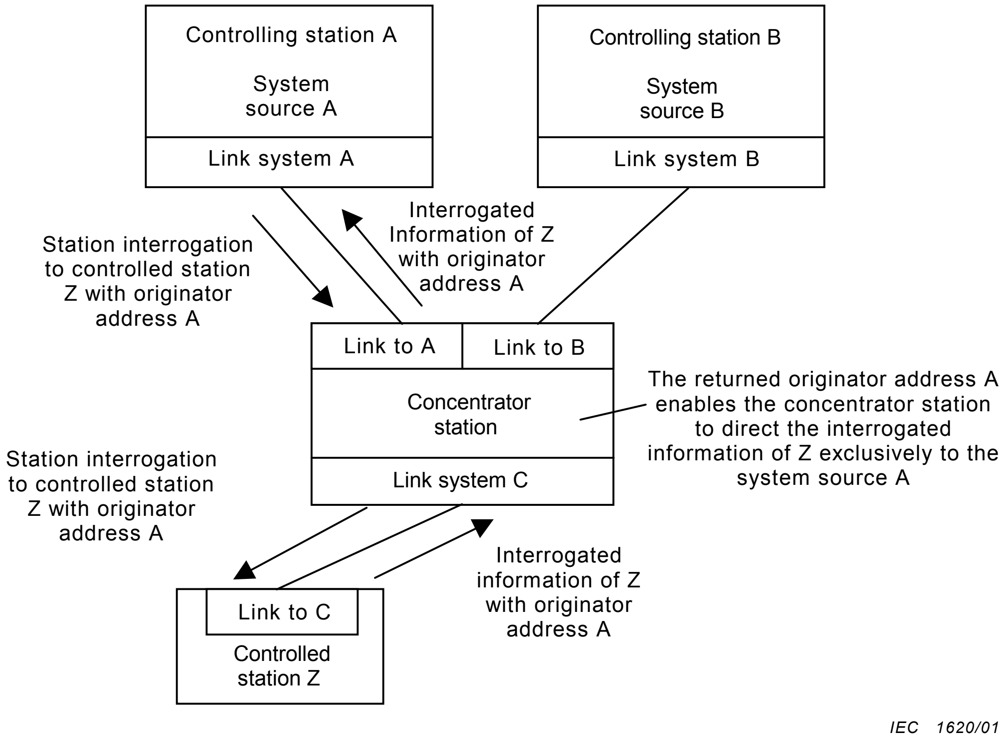

Figure 83 – Station interrogation via a concentrator station using the originator address

EXAMPLE 2

The command initiated by a specific source (cause of transmission = act, controlling station A in figure 84) returns acknowledges (cause of transmission = actcon, actterm) that are only of importance for the source which initiated the command. Therefore, the actcon and actterm should be routed (for example, via a concentrator station in figure 84) via the originator address to this specific point only. However, the corresponding return information (cause of transmission 11 or 12) represents process information which is memorized and controlled in different network images of the whole system (controlling stations A and B in figure 84) and which has to carry the originator address = 0 to be distributed to all parts of the equipment where it is needed.

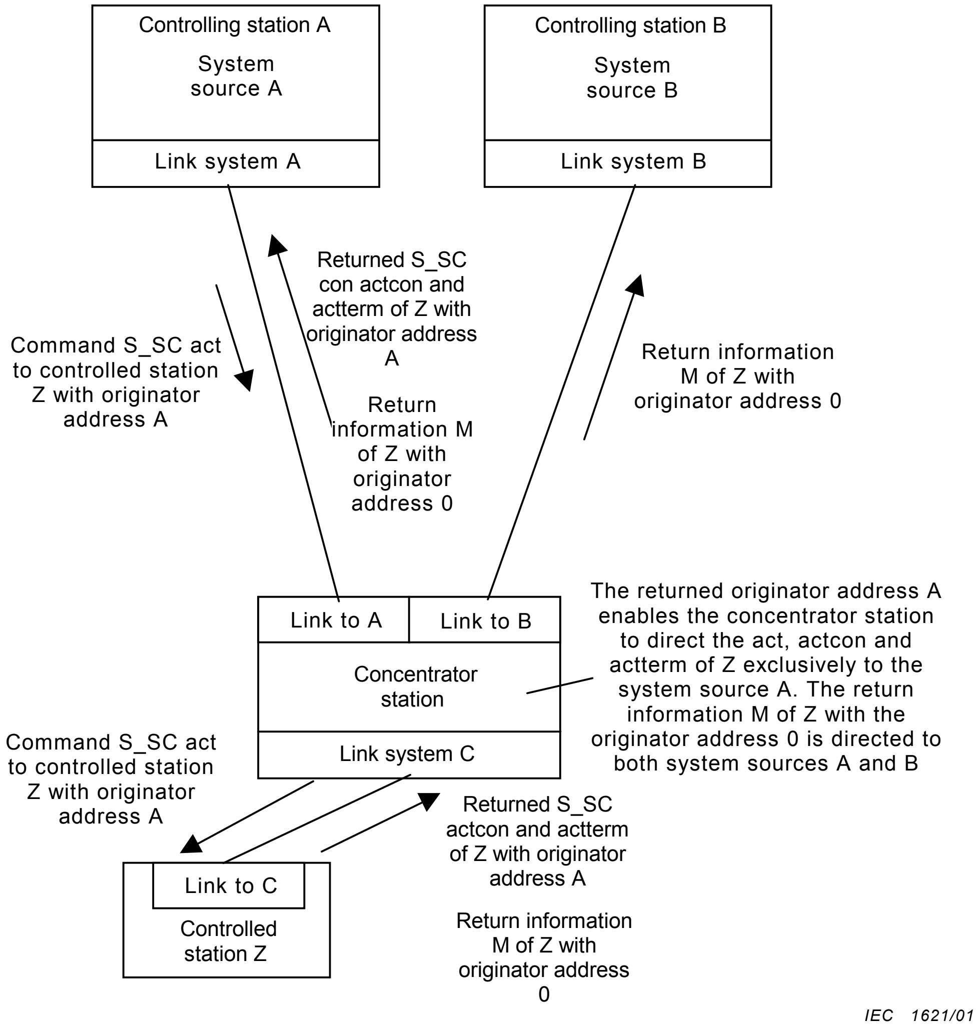

Figure 84 – Command transmission via a concentrator station using the originator address

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Table 9 – Semantics of CAUSE OF TRANSMISSION

Replace the term "general interrogation" *by* "station interrogation"*.*

Replace "<42..47> := reserved for further compatible definitions" *by* "<42..43> := reserved for further compatible definitions".

Add to table 9:

<44> := unknown type identification

<45> := unknown cause of transmission

<46> := unknown common address of ASDU

<47> := unknown information object address

Add, after table 9, the following new text:

ASDUs in control direction with undefined values in the data unit identifier (except the variable structure qualifier) and the information object address are mirrored by the controlled station with bit "P/N := <1> negative confirm" and the following causes of transmission:

Unknown	Cause of transmission
type identification	44
cause of transmission	45
common address of ASDU	46
information object address	47

A controlling station may monitor for and maintain a communications error log reporting each time that the following ASDUs are received:

- ASDUs in the monitor direction with undefined values in the data unit identifier (except the variable structure qualifier);
- ASDUs in the monitor direction with undefined values of information object address;
- mirrored ASDUs due to unknown numbers in control direction (type identifiers 45 to 51).

Receipt of one of these ASDUs does not affect the processing of subsequent messages.

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7.2.4 COMMON ADDRESS OF ASDUs

Add, after "<65535> := global address", *the following new text:*

ASDUs with undefined values of COMMON ADDRESS are discarded by controlling stations.

Add, at the end of 7.2.4, the following new text:

When using the common address FF or FFFF (broadcast address, request of all), ACTCON, ACTTERM and the interrogated information objects (if any) are returned with the specific common addresses of the controlled stations as they would be when caused by commands to specific controlled stations.

The use of the common address FF or FFFF is restricted to the following ASDUs in the control direction:

type Identification <100> :=	interrogation command	C_IC_NA_1
type Identification <101> :=	counter interrogation command	C_CI_NA_1
type Identification <103> :=	clock synchronization command	C_CS_NA_1
type Identification <105> :=	reset process command	C_RP_NA_1

The common address FF or FFFF may be used when the same application function in all stations of a specific system have to be initiated at the same time, for example, to synchronize the local clocks by a clock synchronization command or to freeze the integrated totals by a counter interrogation command.

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7.2.5 INFORMATION OBJECT ADDRESS

Add, after "<1..16777215> := INFORMATION OBJECT ADDRESS", *the following new text*:

ASDUs with undefined values of INFORMATION OBJECT ADDRESS are discarded by controlling stations.

Add, at the end of this subclause, the following new text:

An information object is a well-defined piece of information which requires a name (information object address) in order to identify its use in an instance of communication (see 3.31 of ISO/IEC 8824-1 and 3.3 of IEC 60870-5-3). As defined, the information objects carry information elements that identify single information points which are unambiguously addressed by the information object addresses. Example: An information object which transmits return information must have a different information object address to the information object which transmits the belonging command.

The read command C_RD_NA_1 is a general exception since its information object address serves to address available information objects which are returned in the monitor direction.

The information object address may be specified independently from the ASDU (type identification) which transmits the particular information object. Information objects may be transmitted with the same information object addresses using different ASDUs, for example, as a single-point information with or without time tag.

Table 15 – ASDUs in the monitor direction which may transmit objects with equal information object addresses

Type identification	Type identification with time tag	Alternative format type identification
1	2 or 30	20
3	4 or 31	17 or 38
5	6 or 32	
7	8 or 33	
9	10 or 34	21
11	12 or 35	
13	14 or 36	
15	16 or 37	

There are no other combinations of ASDUs of specific common addresses which may carry the same information object addresses in monitor or (and) control direction. Specifically, commands (ASDU types 45 to 69) and parameters (ASDU types 110 to 119) cannot use the same information object address values as monitored data (ASDU types 1 to 44).

In the case of a single status change of an information point, the same information object with the same information object address may be transmitted twice, with and without time tag. The information object without time tag is normally transmitted with high priority to be available in the controlling station for process control purposes as soon as possible. The information object with time tag may be transmitted with low priority to be used, for example for later verifications of series of events. All information objects which may be transmitted with cause of transmission 3 (spontaneous) are allowed to be transmitted twice. This mode is called "double transmission" and has to be defined by a fixed station-specific parameter.

For all ASDU types not indicated as supporting double transmission, a single status change will only cause the transmission of a single information object.

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7.2.6.3 Quality descriptor (separate octet)

Add, at the end of this subclause, the following new text:

The quality descriptor consists of five defined quality bits which may be set independently from each other. The quality descriptor provides the controlling station with additional information on the quality of an information object.

The quality descriptors of information objects are passed transparently through all levels of a substation system (from the data acquisition through to the communication interface) without being modified by the intermediate devices.

EXAMPLE 1

Suppose that the monitored status of a circuit-breaker is blocked because the field interface is in test mode. In this case, the quality descriptor (BL = 1 "blocked") will be transferred unchanged through all system levels from the field interface to the controlling station.

EXAMPLE 2

A substituted value may be assigned automatically or manually to a measured value, for example when the data acquisition is disturbed. This substituted measured value is transmitted to the controlling station with the quality bit SB = 1 substituted.

If the value of an information object is automatically marked with a new quality descriptor due to specific conditions, the quality descriptor may be reset manually or automatically when the conditions change.

Every change of the quality descriptor initiates a spontaneous transmission of the affected information object. Information objects with time tag are transmitted with the point of time at which the change of the quality descriptor occurred.

The station interrogation procedure interrogates all information objects which are defined for the specific interrogation group independently of the content of the quality descriptor. In this case the quality descriptor contains the most recent state when the information object is interrogated. This guarantees that a completeness check may be performed in the controlling station.

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7.2.6.18 Seven octet binary time

Add, at the end of this subclause, the following new text:

Summer-time is not used in this companion standard and set to 0.

For systems that span time-zone boundaries, the adoption of UTC for all time tags is recommended.

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7.2.6.23 Qualifier of counter interrogation command

Replace, under "RQT", "<0> := no counter requested" *by* "<0> := no counter requested (not used)".

Replace, under "FRZ", *the existing text by the following new text:*

<0> := read (no freeze or reset)
<1> := counter freeze without reset (value frozen represents integrated total)
<2> := counter freeze with reset (value frozen represents incremental information)
<3> := counter reset

Add, at the end of this subclause, the following new sentence:

The action specified by the FRZ code is applied only to the group specified by the RQT code.

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7.2.6.30 Select and call qualifier

Replace, under "SCQ", "<0> := not used" *by* "<0> := default".

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7.2.6.33 Name of file

Replace, under "NOF", "<0> := not used" *by* "<0> := default".

7.2.6.34 Name of section

Replace, under "NOS", "<0> := not used" *by* "<0> := default".

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Replace, throughout subclause 7.3, the term "general interrogation" *by* "station interrogation."

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Delete, in 7.3.1.2, 7.3.1.4, 7.3.1.6, 7.3.1.8, 7.3.1.10, 7.3.1.12, 7.3.1.14, 7.3.1.22, 7.3.1.23, 7.3.1.24, 7.3.1.25, 7.3.1.26, 7.3.1.27, 7.3.1.28 and 7.3.6.7, "<2> := background scan" *and* "<20> up to <36>" *from the* CAUSE OF TRANSMISSION.

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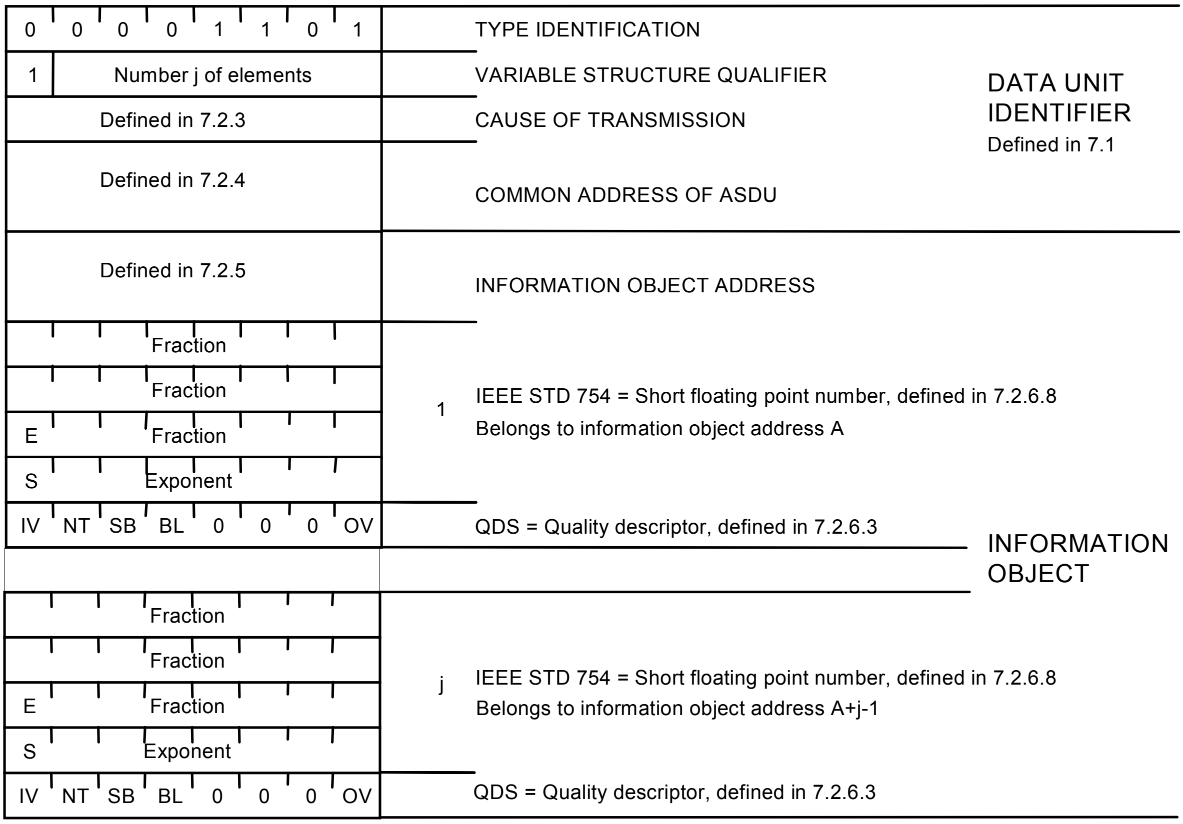
7.3.1.13 TYPE IDENT 13: M_ME_NC_1

Measured value, short floating point number

Add the following at the end of this subclause:

Sequence of information elements in a single information object (SQ = 1)



IEC 1622/01

Figure 85 – ASDU: M_ME_NC_1 Sequence of measured values, short floating point number

M_ME_NC_1 := CP{Data unit identifier,Information object address,j(IEEE STD 754,QDS)}
j := number of elements defined in the variable structure qualifier

CAUSES OF TRANSMISSION used with
TYPE IDENT 13 := M_ME_NC_1

CAUSE OF TRANSMISSION

<1>	:=	periodic/cyclic
<2>	:=	background scan
<3>	:=	spontaneous
<5>	:=	requested
<20>	:=	interrogated by station interrogation
<21>	:=	interrogated by group 1 interrogation
<22>	:=	interrogated by group 2 interrogation
	up to	
<36>	:=	interrogated by group 16 interrogation

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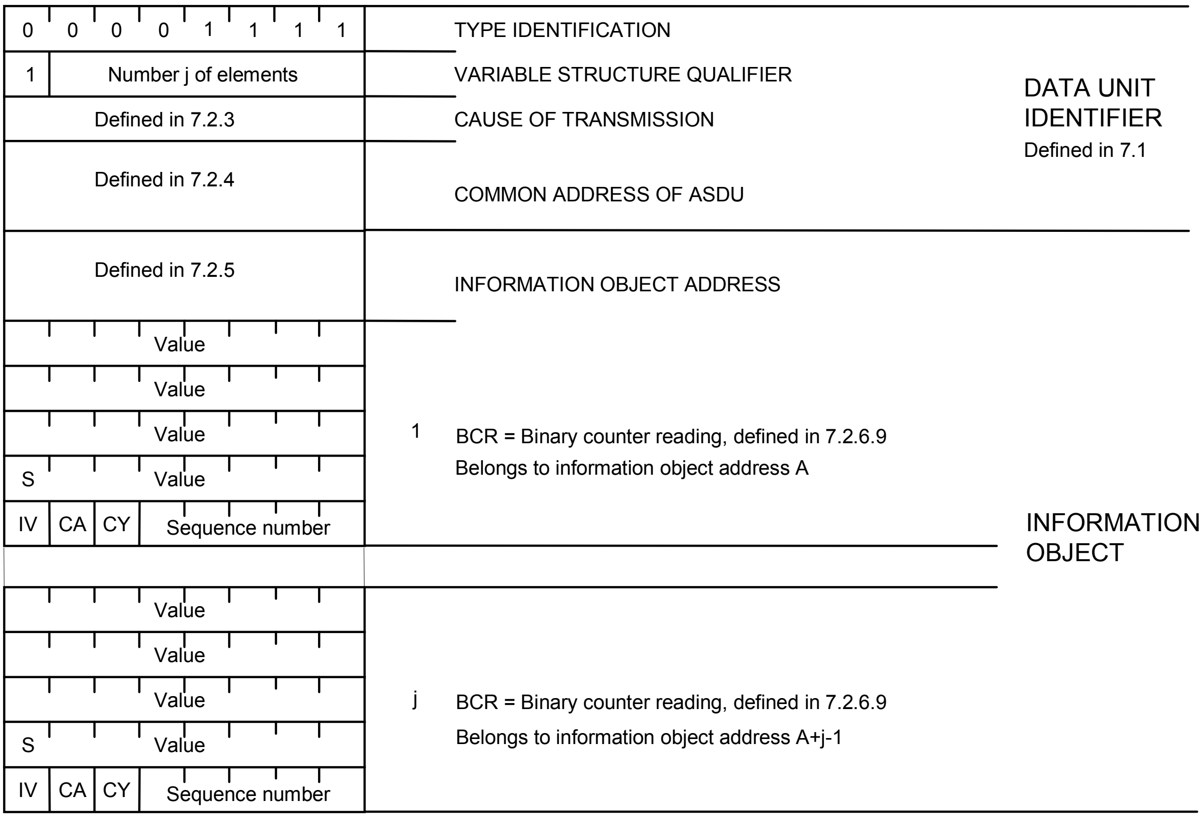
7.3.1.15 TYPE IDENT 15: M_IT_NA_1 Integrated totals

Add, at the end of this subclause, the following new text:

Sequence of information elements in a single information object (SQ = 1)



IEC 1623/01

Figure 86 – ASDU: M_IT_NA_1 Sequence of integrated totals

M_ME_NC_1 := CP{Data unit identifier,Information object address,j(BCR)}
j := number of elements defined in the variable structure qualifier

CAUSES OF TRANSMISSION used with
TYPE IDENT 15 := M_IT_NA_1

CAUSES OF TRANSMISSION
<3> := spontaneous
<37> := requested by general counter request
<38> := requested by group 1 counter request
<39> := requested by group 2 counter request
<40> := requested by group 3 counter request
<41> := requested by group 4 counter request

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Insert, under "CAUSE OF TRANSMISSION",

"<11> := return information caused by a remote command

<12> := return information caused by a local command".

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Add, at the end of "CAUSE OF TRANSMISSION",

"<44> := unknown type identification
<45> := unknown cause of transmission
<46> := unknown common address of ASDU
<47> := unknown information object address"

in 7.3.2.1, 7.3.2.2, 7.3.2.3, 7.3.2.4, 7.3.2.5, 7.3.2.6, 7.3.2.7, 7.3.4.1, 7.3.4.2, 7.3.4.3, 7.3.4.4, 7.3.4.5, 7.3.4.6, 7.3.4.7, 7.3.5.1, 7.3.5.2, 7.3.5.3, 7.3.5.4, 7.3.6.1, 7.3.6.2, 7.3.6.3, 7.3.6.4, 7.3.6.5, 7.3.6.6.

Insert, under "CAUSE OF TRANSMISSION in monitor direction",

<20> := interrogated by station interrogation"

in 7.3.5.1, 7.3.5.2, 7.3.5.3.

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7.3.4.4 TYPE IDENT 103: C_CS_NA_1
Clock synchronization command

Add, in figure 49, after "INFORMATION OBJECT ADDRESS", "= 0"

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7.4 Selections from IEC 60870-5-5: Basic application functions

Add the following new paragraphs:

After successful station initialization, all application functions must be available to run simultaneously.

If a controlled station has data for more than one of the following ASDU types ready for transmission at the same time, they must be sent in the following order regardless of which data was generated first. Table 16 does not define the order in which the controlling station must request the data or require that the controlled station not transmit data until another type of data becomes available. ASDU type identifications within the same row may be sent in any order.

Table 16 – Respond priorities of the controlled station

Request ASDU	Description	Comment
70	End of initialization	In monitor direction
45 to 69	Command transmission	
1 to 44 103 106	Event reporting Clock synchronization Acquisition of transmission delay	In monitor direction with COT = 3
102, 104, 105, 110 to 113	Read command, test procedure, reset process, parameter loading,	
100, 101	Station interrogation, transmission of integrated totals	
9, 11, 13 120 to 127	Cyclic data transmission (in monitor direction with COT = 1), file transfer	

7.4.1 Selections from station initialization

Add the following new text:

IEC 60870-5-101 defines the addressing of a whole station or just particular station sectors by the common address of the ASDU. Station sectors may exist as separate physical pieces of equipment (for example, RTU1 to 4 identical with LRU1 to 4 in figure 87) or as logical units within one physical unit (for example, LRU5 to 5+n within RTU5 in figure 87). In the following, both are defined as logical remote units LRU (see figure 87).

ENDINIT is transmitted separately by each LRU after initialization when this LRU's data becomes available (see 6.1 of IEC 60870-5-5). This is also required when a common initialization procedure for several LRUs is implemented in one item of physical equipment (hardware). In both cases, each LRU has to transmit an ENDINIT containing its specific common address of ASDU.

7.4.2 Selections from data acquisition by polling

Add the following new text:

The polling procedure is supported by the link layer which requests user data of classes 1 and 2. In general, ASDUs containing the causes of transmission periodic/cyclic are assigned to be transmitted with the link layer data class 2 and all time tagged or spontaneously transmitted ASDUs are assigned to be transmitted with the link layer data class 1. Other ASDUs with other causes of transmission of low priority such as background scan may also be assigned to data class 2 and must be listed in the interoperability document.

In this case, it has to be considered that the link request of class 1 occurs at a different point of time (to or from) the link request of class 2 which may influence the correct sequence of the ASDUs delivered to the application layer of the controlling station.

In response to a class 2 poll, a controlled station may respond with class 1 data when there is no class 2 data available.

When using the read command, specific information objects may be requested by interrogating their respective information object addresses. The requested information objects are returned with the cause of transmission <5> requested. Normally, these requested objects do not include the time tag.

7.4.5 Selections from general interrogation, outstation interrogation

Replace the existing title by the following new title:

Selections from station interrogation, outstation interrogation

Add, after the last paragraph, the following new text:

A station interrogation command requests the controlled stations to transmit the actual state of their normally spontaneously transmitted information (cause of transmission := <3>) to the controlling station with the causes of transmission <20> up to <36>. The station interrogation is used to synchronize the process information of the controlling station (network image NIM) and the controlled stations. It is also used for updating the controlling station after an initialization procedure or when the controlling station detects the loss of a link (unsuccessful repetitions of the link layer) and the link layer is available again. Periodic or cyclic transmitted information is not returned by a controlled station in response to a station interrogation. The controlled station does not need to send information which is not retained in the controlling station (see 6.6 of IEC 60870-5-5). This may be achieved by configuring the information to be sent from the controlled station in response to a station interrogation request, but this is not required behaviour for a controlled station.

Table 17 shows the ASDUs that may be transmitted in response to the station interrogation procedure including the type identifications, causes of transmission and the qualifiers of interrogation of the station interrogation command.

Table 17 – ASDUs involved in the station interrogation procedure

Direction C=control M=monitor	Type identification	Cause of transmission	Qualifier of interrogation
C	<100> C_IC_NA_1	<6> act	<20> to <36>
M	<100> C_IC_NA_1	<7> actcon	<20> to <36>
M	<1> M_SP_NA_1 <3> M_DP_NA_1 <5> M_ST_NA_1 <7> M_BO_NA_1 <9> M_ME_NA_1 <11> M_ME_NB_1 <13> M_ME_NC_1 <20> M_PS_NA_1 <21> M_ME_ND_1	<20> inrogen <21> to <36> inro 1 to inro 16	
M	<100> C_IC_NA_1	<10> actterm	<20> to <36>

A remote telecontrol unit RTU may consist of several (logical) sectors (LRUs = logical remote units). Each LRU is defined by a system-specific common address. An outstation containing only one LRU returns the station interrogation (or counter interrogation) which is directed to that LRU with ASDUs which contain the specific common address defined for this LRU. If the outstation consists of several RTUs, all LRUs (in this example LRU 1 to LRU 4) may be interrogated simultaneously via a station interrogation command (or counter interrogation command) with the common address of ASDU FF or FFFF (see figure 88 for this procedure). In the example shown in figure 87, LRU 1 is responsible for the initiation of the station interrogation procedure to the LRUs (LRU 2 to LRU 4) to which it is connected.

If an LRU (LRU 5+n+m+1 in figure 87) is distributed to more than one physical controlled station (RTU 7 and 8 in figure 87), each connected via a separate link layer, the station interrogation (or counter interrogation command) must be sent to each physical controlled station (RTU 7 and 8), this could be done using the broadcast data link address.

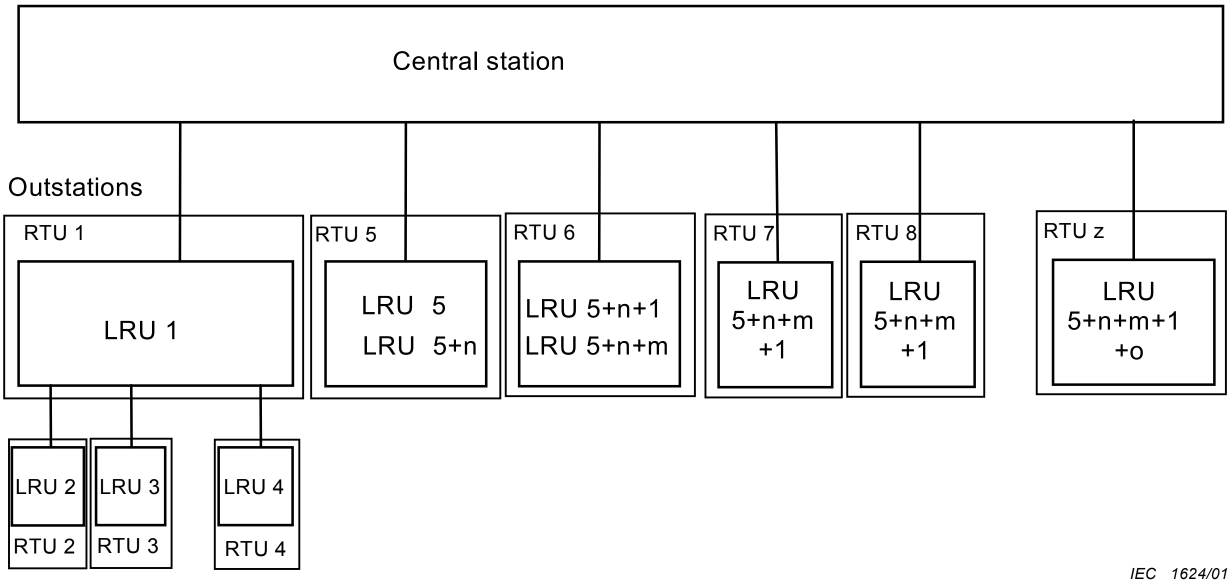


Figure 87 – Hierarchical presentation of the allocation of common addresses of ASDUs to LRUs (example)

A station interrogation request is issued to the controlled station

– if an ENDINIT is received from the controlled station, or

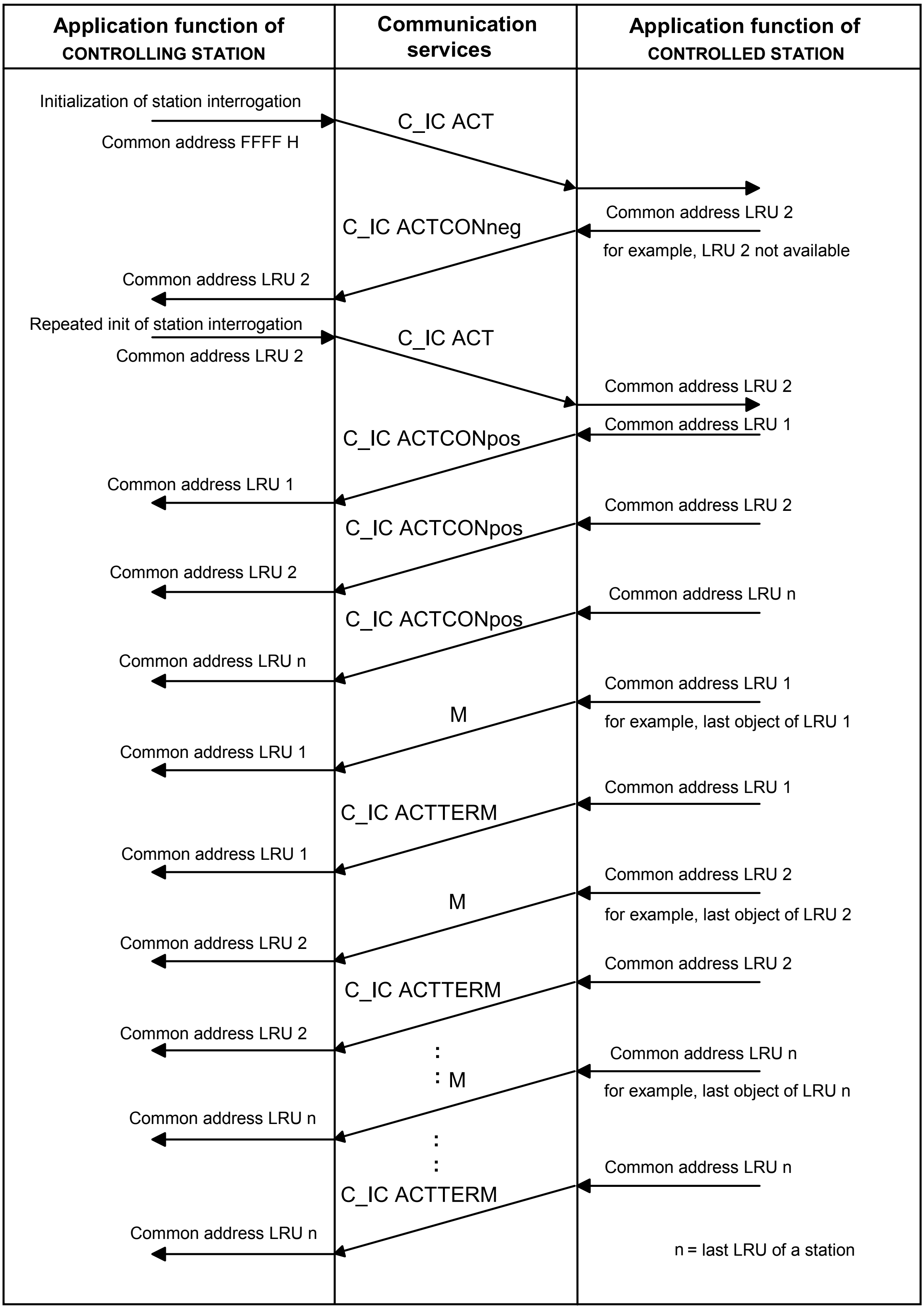
– if the central station observes the loss of a link (unsuccessful repetitions of the link layer) and the link layer is available again. The station interrogation command C_IC ACT is negatively acknowledged by a C_IC ACTCON when the controlled station is not ready to return the interrogated information. In this case, the station interrogation command may be repeated.

Additionally, a station interrogation may be issued to a controlled station in response to other (configurable) criteria, for example, when initiated manually.

When issuing a station interrogation command to a controlled station using the common address FF or FFFF (request of all), ACTCON, ACTTERM and the interrogated information objects are returned with the specific common addresses of the LRUs in exactly the same manner as if they were initiated by a station interrogation command issued to the specific LRU.

The LRU specific interrogation commands to the controlled stations may be transmitted in parallel, for example the response sequence ACTCON through to ACTTERM of a previously transmitted interrogation command need not to be completed prior to issuing an interrogation command to another LRU. The controlled station may respond with a negative activation confirmation to simultaneous requests of the same type to multiple addresses.

ASDUs with cause of transmission 20 to 36 are transmitted without time tags.



IEC 1625/01

Figure 88 – Sequential procedure of station interrogation to all LRUs of a specific controlled station (example)

The sequence shown in figure 88 is an example. The responses from one LRU may be transmitted in a close formation (C_IC ACT, C_IC ACTCONpos, M, M...C_IC ACTTERM) or may be interspersed with those of other LRUs.

7.4.6 Selections from clock synchronization

Add the following new text:

Time information is corrected exclusively by the controlled station.

The reference for the clock synchronization command is a system dependent parameter. The reference may be local time, or if a system spans over several time zones, UTC or a central time reference may be used. The summer-time bit is ignored in both controlling and controlled stations, and should be set to zero.

The invalid bit IV belongs to the information element CP56Time2a and therefore it refers to the accuracy of the transmitted time. Bit IV is set to 1 if the clock is not synchronized for a specific period of time.

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7.4.7 Selections from command transmission

Replace the last line of this subclause by the following new text:

RETURN_INF for control operation complete is used (if available).

Add the following new text:

S/E of the qualifier of command QOC is irrelevant in ASDUs with causes of transmission DEACT and DEACTCON.

NOTE A single command (type identification 45) is used to control an object that is monitored as a single-point (type identification 1, 2 and 30), a double command (type identification 46) is used to control objects that are monitored as double-point (type identification 3, 4 and 31).

7.4.8 Selections from transmission of integrated totals

Add, after the last paragraph, the following new text:

The general counter model is shown in the following figure. Integrated totals are values that are integrated over a specific period of time (see 6.9 of IEC 60870-5-5).

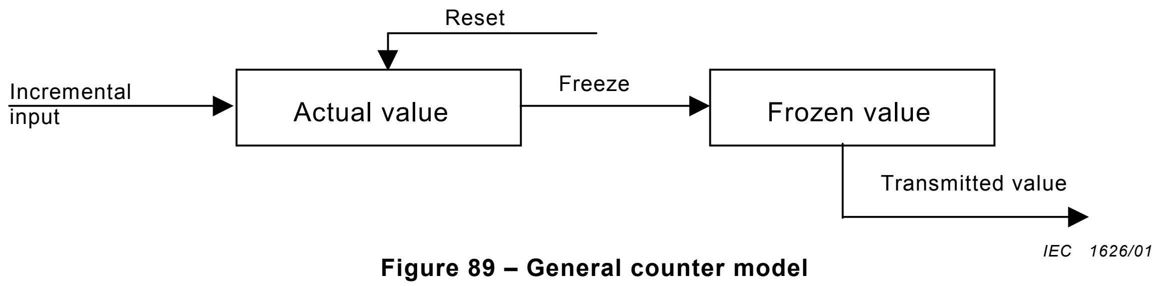

Figure 89 – General counter model

The actual values are normally integrated by counters. The actual values may be memorized (copied) periodically to frozen values by a freeze command received from a controlling station or initiated locally within the device. After freezing, the actual value is either reset to zero (acquisition of incremental information) or continues its operation without being reset (acquisition of integrated totals).

Information object addresses of integrated totals may be defined in groups. These groups may be frozen, reset or transmitted selectively. The counter interrogation command includes a qualifier field (QCC) which defines the action to be performed (FRZ), and the counter group (RQT) upon which the action shall be performed (see 7.2.6.23)

There are four modes of acquisition of integrated totals or incremental information.

Mode A: local freeze with spontaneous transmission.

Local clocks in the controlled station initiate the freeze or freeze with reset operations. The integrated totals (frozen values) are transmitted spontaneously in M_IT ASDUs after the freeze or freeze with reset operation has been performed. The controlling station does not issue counter interrogation commands (C_CI).

If the ASDU integrated totals with time tag (M_IT_TA_1) is used, a frozen counter history may be produced by this mode even when communications have failed for a period and are subsequently restored.

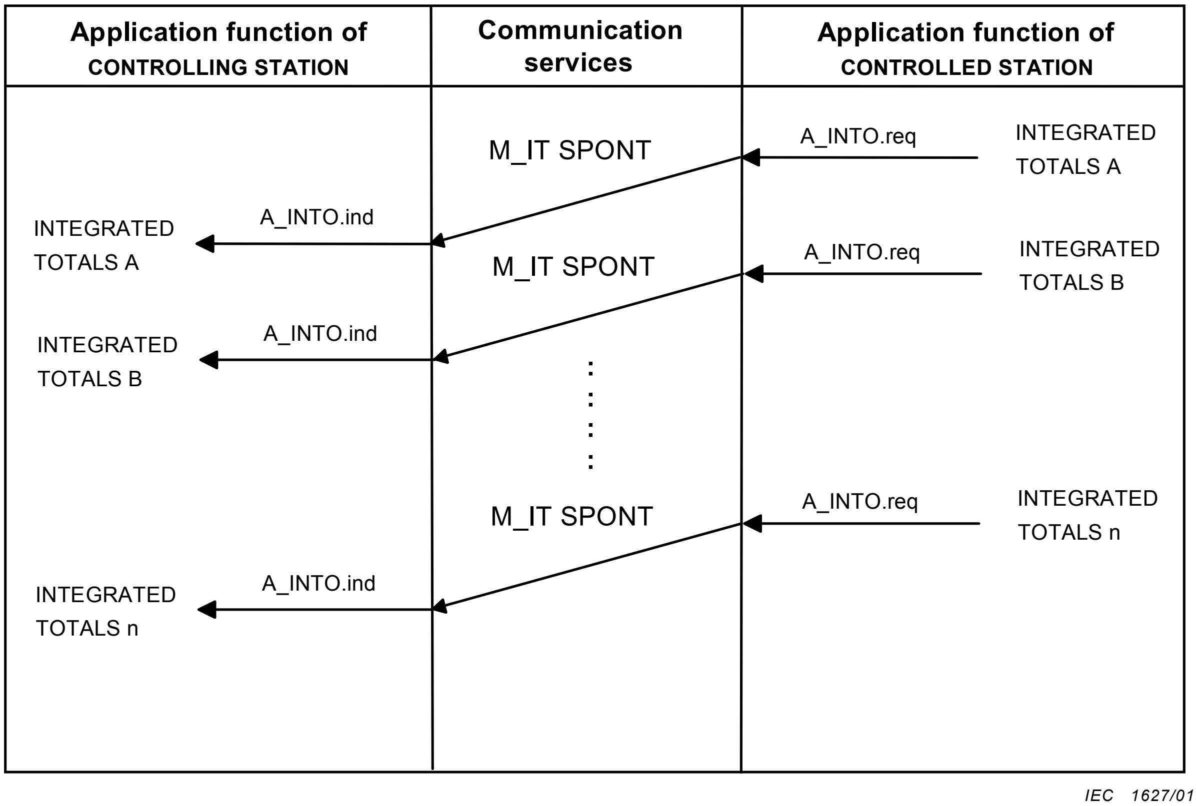

Figure 90 – Sequential procedure of spontaneously transmitted integrated totals (mode A)

Mode B: local freeze with counter interrogation

Local clocks in the controlled station initiate the freeze or freeze with reset operations. The integrated totals (frozen values) are requested by counter interrogation commands (C_CI). In this case, the freeze or freeze with reset functionality must not be used in the counter interrogation command (i.e. the command qualifier must contain FRZ = 0). Integrated totals may be requested in general or in groups 1 to 4. The assignments of the information object addresses of the integrated totals to the specific groups have to be specified in the controlled station. Requested integrated totals are transmitted with cause of transmission 37 to 41.

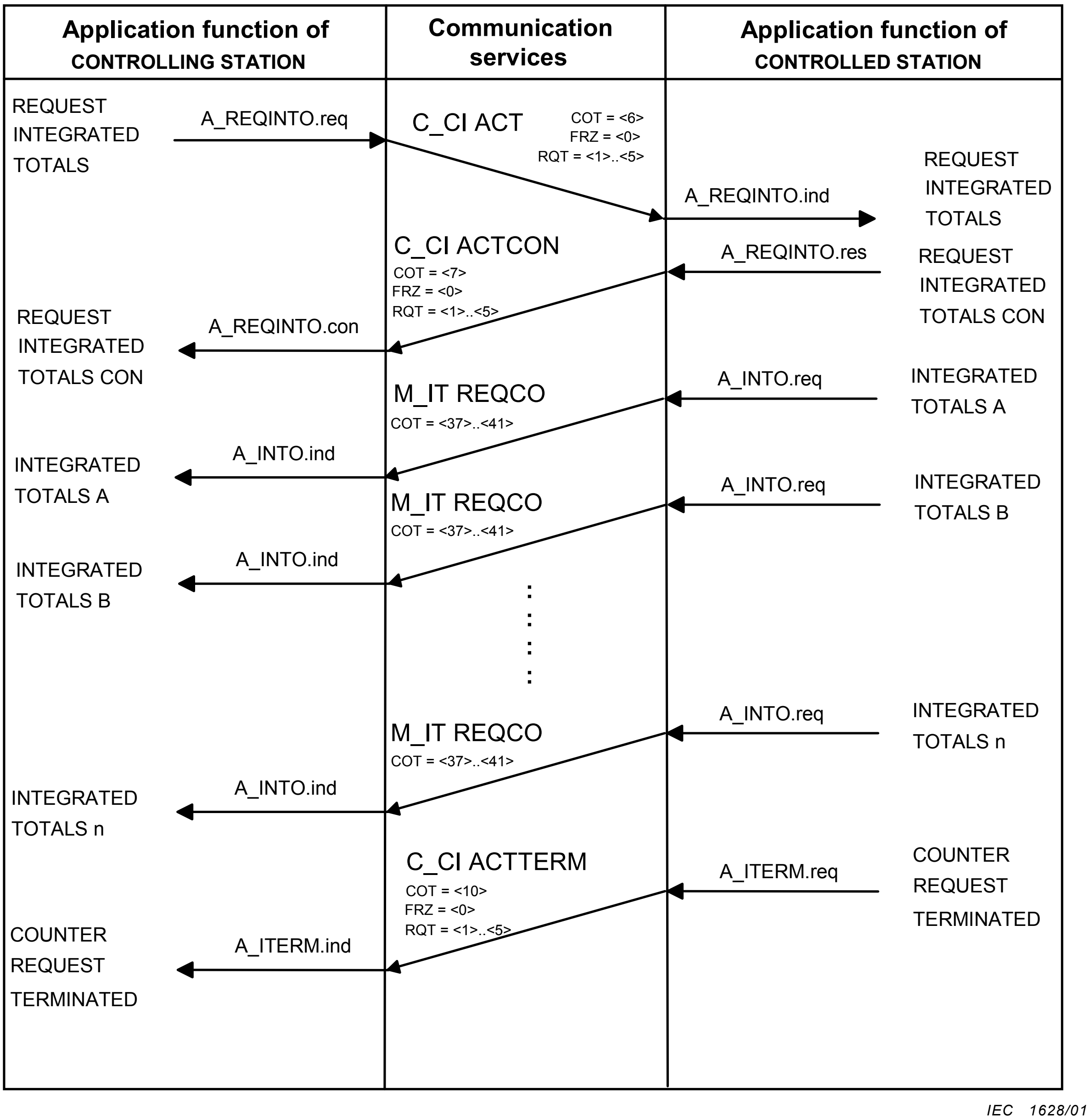

Figure 91 – Sequential procedure of interrogation of integrated totals (mode B)

Mode C: counter interrogation commands from the controlling station initiate the freeze, freeze with reset or reset commands. A subsequent counter interrogation command is issued by the controlling station to collect the frozen values from the controlled station.

A counter interrogation command is issued periodically by the controlling station to control freeze and/or reset.

The counter interrogation command to freeze and/or reset the values may specify all counters (general counter request, RQT = <5>) or specific counter groups (RQT = <1>..<4>). The "no counters" (RQT = <0>) option is not used. The command also specifies the operation to be performed: freeze (FRZ = <1>, see figure 92), freeze with reset (FRZ = <2>, see figure 93) or reset (FRZ = <3>). The operation specified by FRZ is only applied to the counters specified by RQT. All other counters are unaffected. This command does not cause the counter values to be transmitted.

After this transaction is complete, a counter interrogation command to collect the frozen values is issued by the controlling station. The format of this is as described for the collection of the integrated total data in mode B.

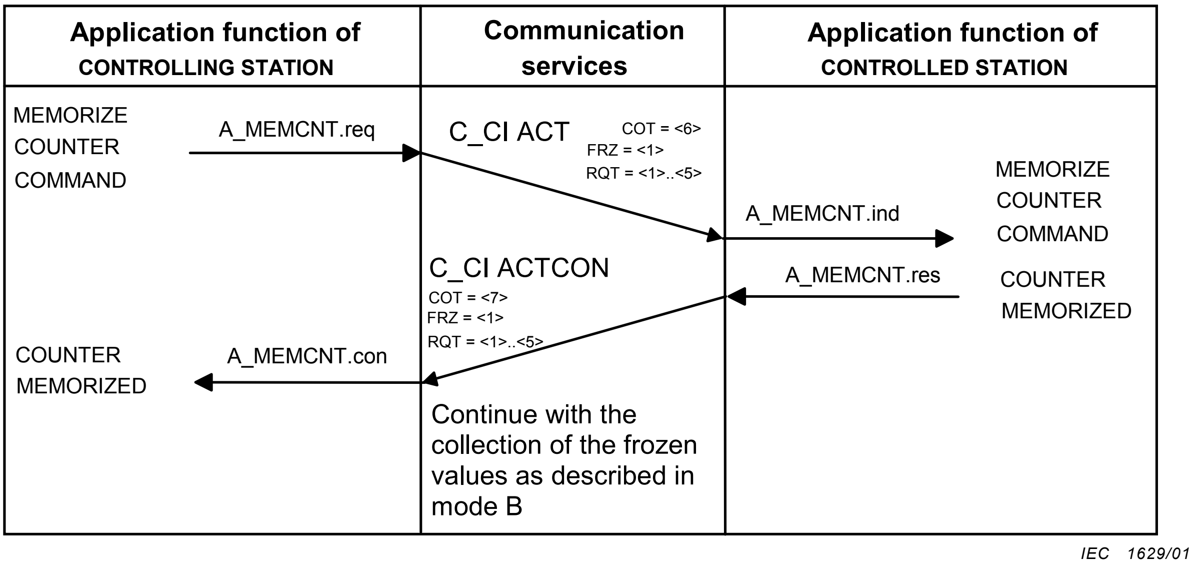

Figure 92 – Sequential procedure of memorizing of integrated totals without reset (mode C)

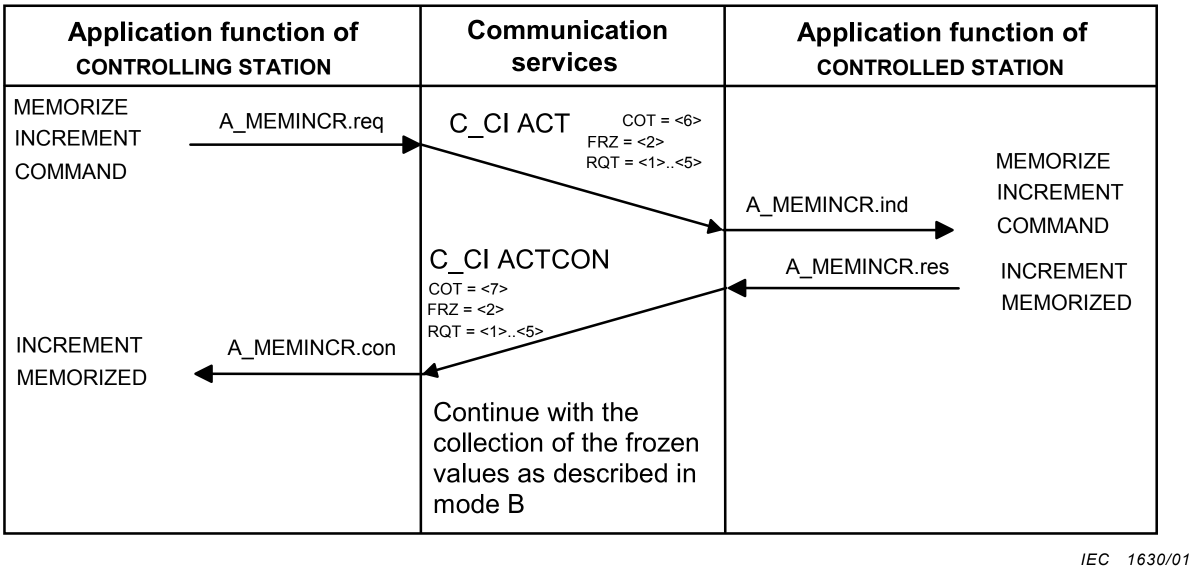

Figure 93 – Sequential procedure of memorizing of integrated totals with reset (mode C)

Mode D: counter interrogation commands from the controlling station initiate the freeze operation, and the frozen values are reported spontaneously.

This mode is a combination of the counter command from the controlling station as specified in mode C, with spontaneous reporting of the integrated totals, as described in mode A.

7.4.11 Selections from file transfer

Add, after the last sentence, the following new subclauses:

7.4.11.1 General addressing structure for file transfer

7.4.11.1.1 Introduction

In general, files are established, controlled and buffered at the part of the system where they are generated, for example, protection files are established in protection equipment, files (records) for sequences of events are established in substation automation systems, files for configuration data are established in the controlling station, etc. Files may be selected and requested by the accompanying communication partner. To avoid implementing extensive data file management functionality twice, for example in the controlling and in the controlled stations, a directory may be requested by the controlling station, which specifies the files that are available in the controlled stations. Each file is unambiguously defined by the combination of the common address of the ASDU, the address of the information object and the name of the file. According to this standard, a file is considered as an information object. The directory either directly specifies the information object address of the file or it references a subdirectory which then defines the real information object addresses and names of files. The information element SOF = status of file of the directory defines the distinction with FOR = 0, name defines file or FOR = 1 name defines subdirectory. Figure 94 shows an example of a possible directory. Protection files defined in IEC 60870-5-103 need to be addressed with name of file in addition to the information object address.

The time tag in a directory with FOR = 1 defines the point of time of the most recent change of the subdirectory.

The following names of files are defined:

Name of file:

<1>	:=	transparent file
<2>	:=	disturbance data of protection equipment
<3>	:=	sequences of events
<4>	:=	sequences of recorded analogue values
<5..127>	:=	reserved for further compatible definitions
<128..255>	:=	reserved for special use (private range)

The second octet of the name of the file is reserved for further compatible definitions.

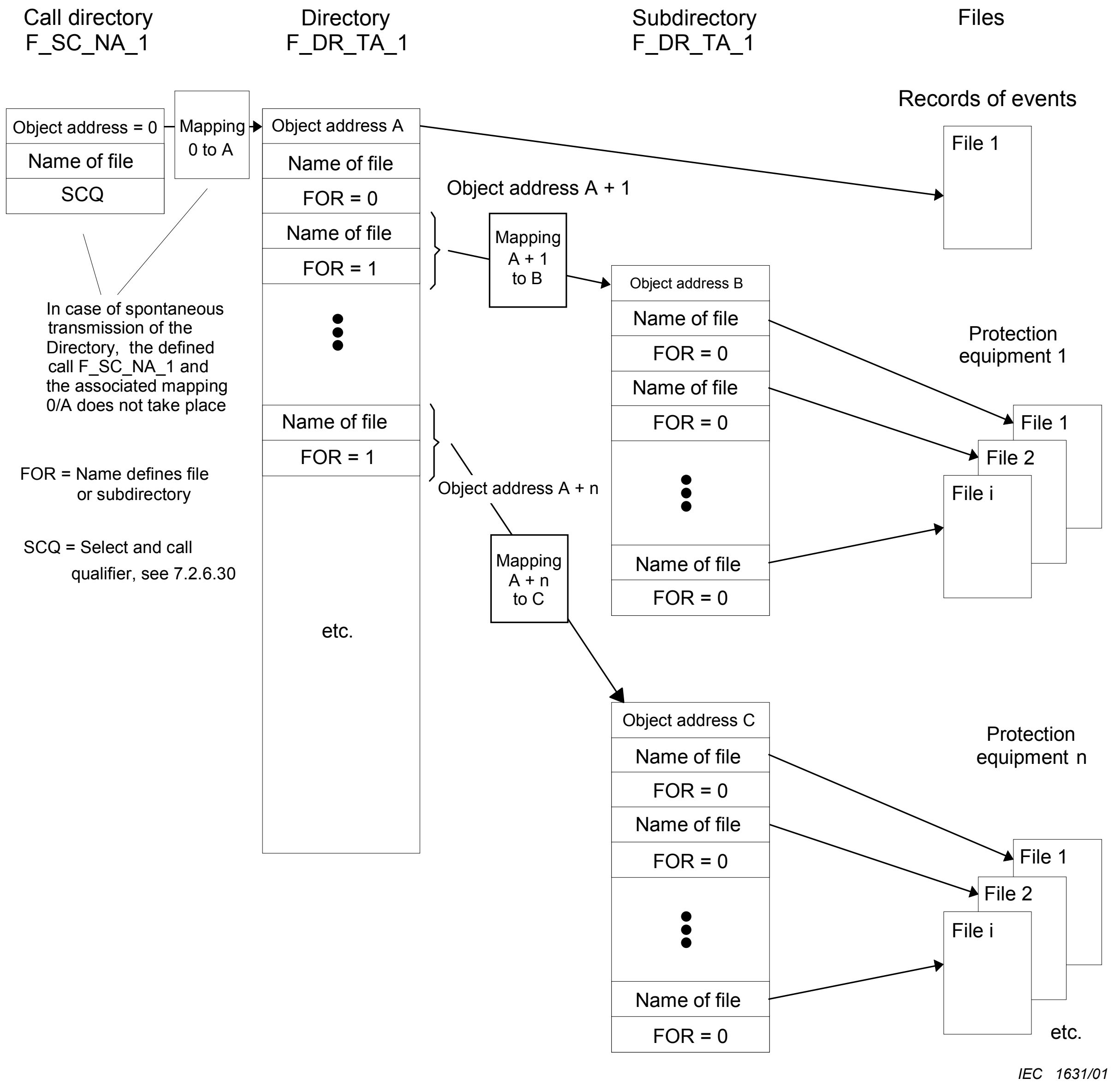

Figure 94 – Addressing of files (example)

7.4.11.1.2 Specification of directories and subdirectories

Directories and subdirectories are ordered in substation automation systems (including RTUs). Both may be requested by the controlling station or transmitted spontaneously in case of changes.

There is no requirement for multiple files to be available simultaneously in the substation automation system. They may be stored in the protection equipment and obtained upon request. However, the substation automation system must reserve the memory for at least one complete file. Deleting of files in substation automation systems is an application specific function and not defined in this standard.

7.4.11.2 Transmission of disturbance data

This subclause defines how disturbance data obtained from protection equipment within a substation shall be mapped onto the file transfer mechanism of this standard, when onward transmission to the controlling station is required. The format of the disturbance files used is as defined for IEC 60870-5-103 companion standard for the informative interface of protection equipment.

The differences in data units and procedures between IEC 60870-5-103 and this standard require additional definitions to permit disturbance data acquired and buffered in substation automation systems to be transmitted to the controlling system. For these definitions, see 7.4.11.2.1 to 7.4.11.2.7.

7.4.11.2.1 Definitions to the request from protection equipment

The following definitions may either be applied for the transmission of disturbance data directly from the protection equipment or from other parts of substation automation systems. In both cases, the splitting of the disturbance data files into specific sections is needed, as defined in figure 97. From the point of view of the controlling station, both cases may be controlled in the same manner except for different time out conditions.

7.4.11.2.2 Request for files by the central station from protection equipment

When the selected file is buffered in the protection equipment at the point of time when it is selected by the controlling station, then the procedure for the transmission of disturbance data defined in IEC 60870-5-103 is initiated with the ASDU 24 (order for disturbance data transmission) which is triggered by the ASDU F_SC_NA_1 SCQ := <1> (select file) of the controlling station (see figure 95, step 1). After that, the transmission of the selected file from the protection equipment to the substation automation system is performed (see figure 95, step 2). After the successful termination of this procedure of the protection equipment (ASDU 31 End of transmission, TOO := <32> End of disturbance data transmission without abortion) the ASDU F_FR_NA_1 with FRQ BS1[8] := <0> (positive confirm of select) is transmitted to the controlling station. In all other cases, F_FR_NA_1 with FRQ BS1[8] := <1> (negative confirm of select) is transmitted to the controlling station. Then the request of the disturbance data file from the substation automation system followed by the transmission of the file to the controlling station may follow (see figure 95, step 3).

The transfer time of the selected file from the protection equipment to the substation automation system has to be allowed for (for example, there must be no premature time out of the central file processing manager of the controlling station).

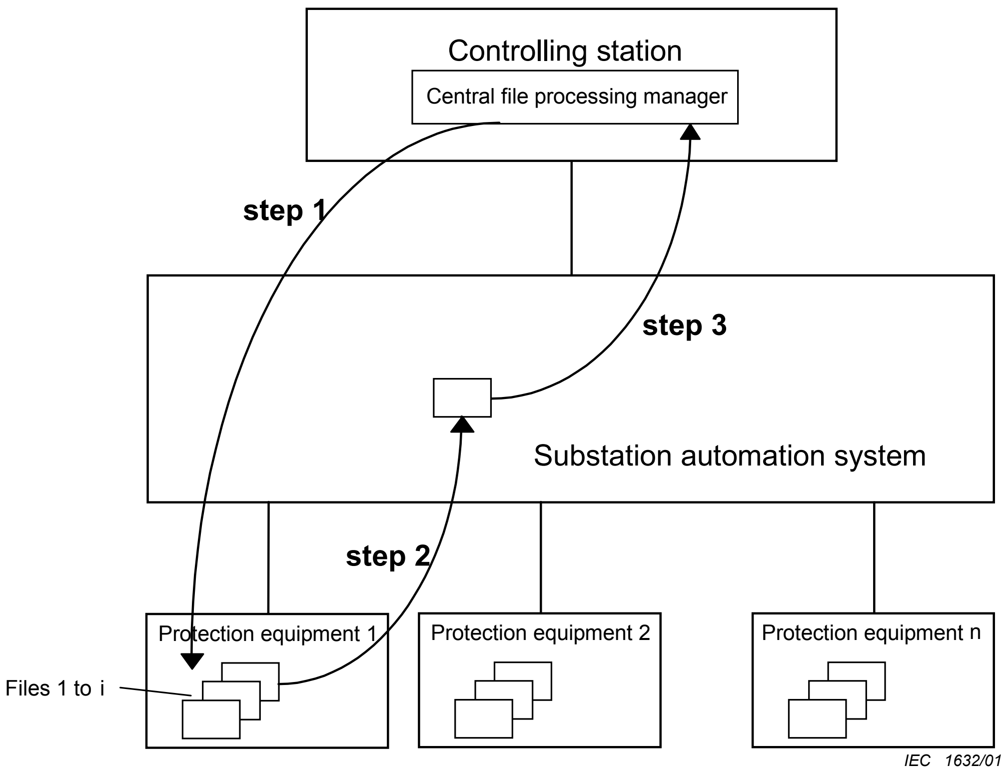

Figure 95 – Request from protection equipment

7.4.11.2.3 Request for files by the controlling station from substation automation systems

In the case where the files are available in the substation automation system, the file is selected with the ASDU F_SC_NA_1 SCQ := <1> (select file) which is confirmed positively directly with F_FR_NA_1 FRQ BS1[8] := <0> (positive confirm of select, see figure 96, step 1). In all other cases, F_FR_NA_1 with FRQ BS1[8] := <1> (negative confirm of select) is transmitted to the controlling station. The request and transmission of the file containing disturbance data from the substation automation system to the controlling system follows (see figure 96, step 2). The transmission to the central file processing manager of the controlling station is performed directly from the substation automation system without any files being requested from the protection equipment. In this case, the transmissions are decoupled in time and there are no direct assignments of the procedural services of IEC 60870-5-101 to those of IEC 60870-5-103.

The number of files 1 to k buffered in the substation automation system for each protection equipment may exceed the number of files 1 to i buffered in the protection equipment itself.

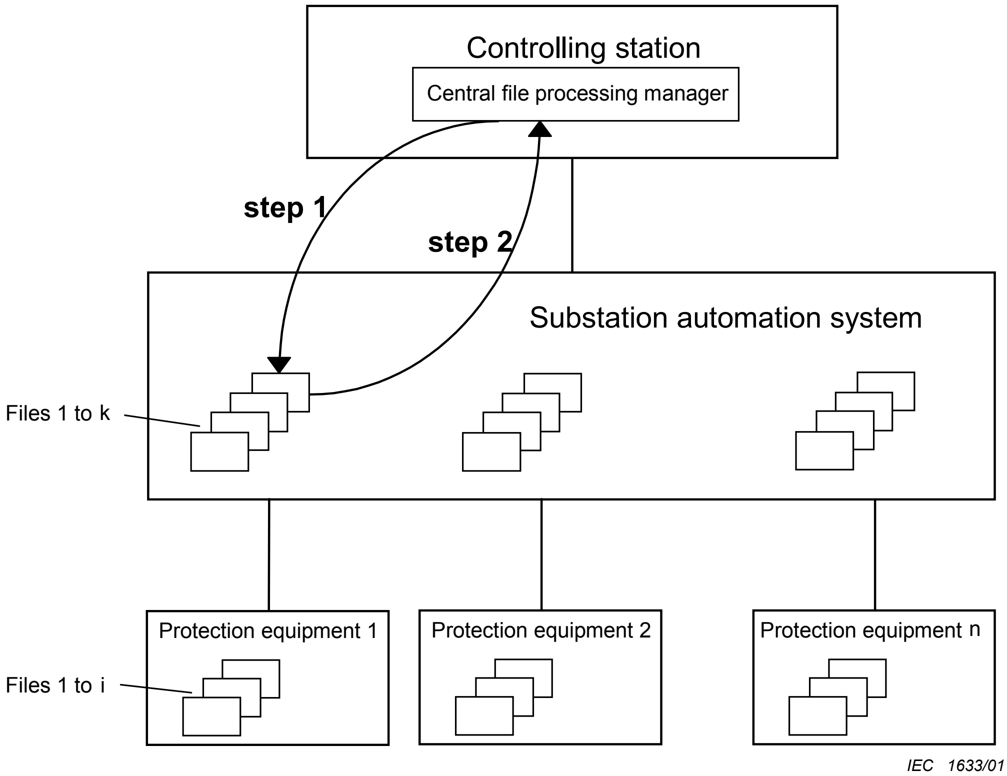

Figure 96 – Request from substation automation system

7.4.11.2.4 Structure of disturbance data files

The ASDUs and procedures as defined in IEC 60870-5-103 are structured according to disturbance, time tags and disturbance data channels. The file transfer according to this standard maintains this structure when disturbance data are transmitted. The disturbance data, generated by the protection equipment, are buffered in disturbance data files. In addition, each protection equipment establishes a list of recorded disturbances (directory). This list of recorded disturbances is mapped in a subdirectory F_DR_TA_1 (see 7.4.11.2.5).

The transmission to the controlling station is performed separately for each file.

Figure 97 shows the structure of the list of recorded disturbances of a protection equipment. Each buffered disturbance file is split into the sections 1 to n, which correspond to the sections defined in IEC 60870-5-5. Parameters, time tags and disturbance data from IEC 60870-5-103 are allocated to these sections as follows:

Section 1 parameter of disturbances 1 to k

Section 2 tags of disturbances 1 to k

Section 3 parameter of disturbance 1 to k for channel 1

Section 4 disturbance data of disturbance 1 to k channel 1

Section 5 parameter of disturbance 1 to k for channel 2

Section 6 disturbance data of disturbance 1 to k channel 2,

etc.

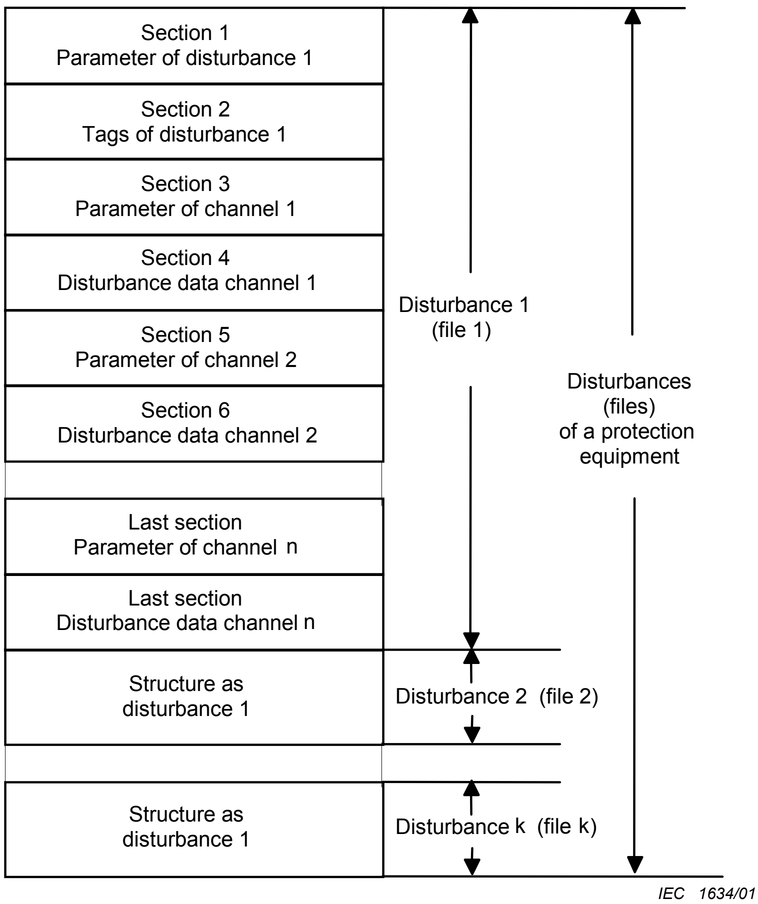

Figure 97 – Structure of disturbance data of a protection equipment

Parameters for a disturbance, time tags for a disturbance, parameters for a channel and disturbance data for a channel as defined in IEC 60870-5-103 (see figure 98). These parameters and data are originally attached to the sections of a subdirectory of a protection equipment and transmitted in the octets 1 to n of the segment of the ASDUs F_SG_NA_1.

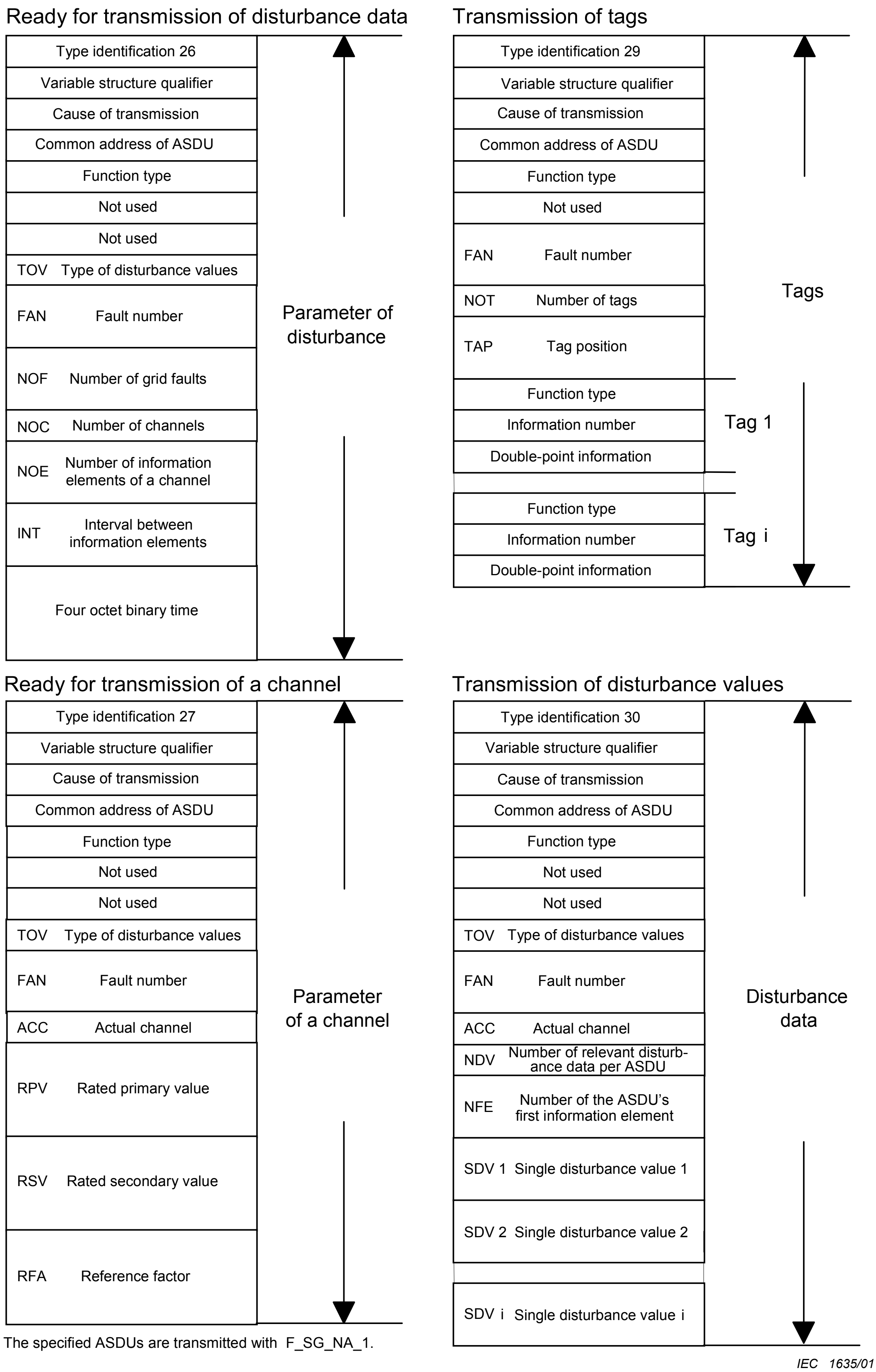

Figure 98 – Allocation of data types (ASDUs) of IEC 60870-5-103 to the sections of disturbance data files

7.4.11.2.5 Mapping of the list of recorded disturbances to the directory

The list of recorded disturbances defined in IEC 60870-5-103 is mapped on the subdirectory F_DR_TA_1 defined in this standard. Figure 99 shows the mapping of the ASDUs. The information fields type identification, information object address and status of file are not only copied from type 126 of this standard to type 23 of IEC 60870-5-103 and vice versa but mapped via mapping lists (see table 18). The information fields' name of file to fault number and binary time tags are identically mutually copied (see figure 99).

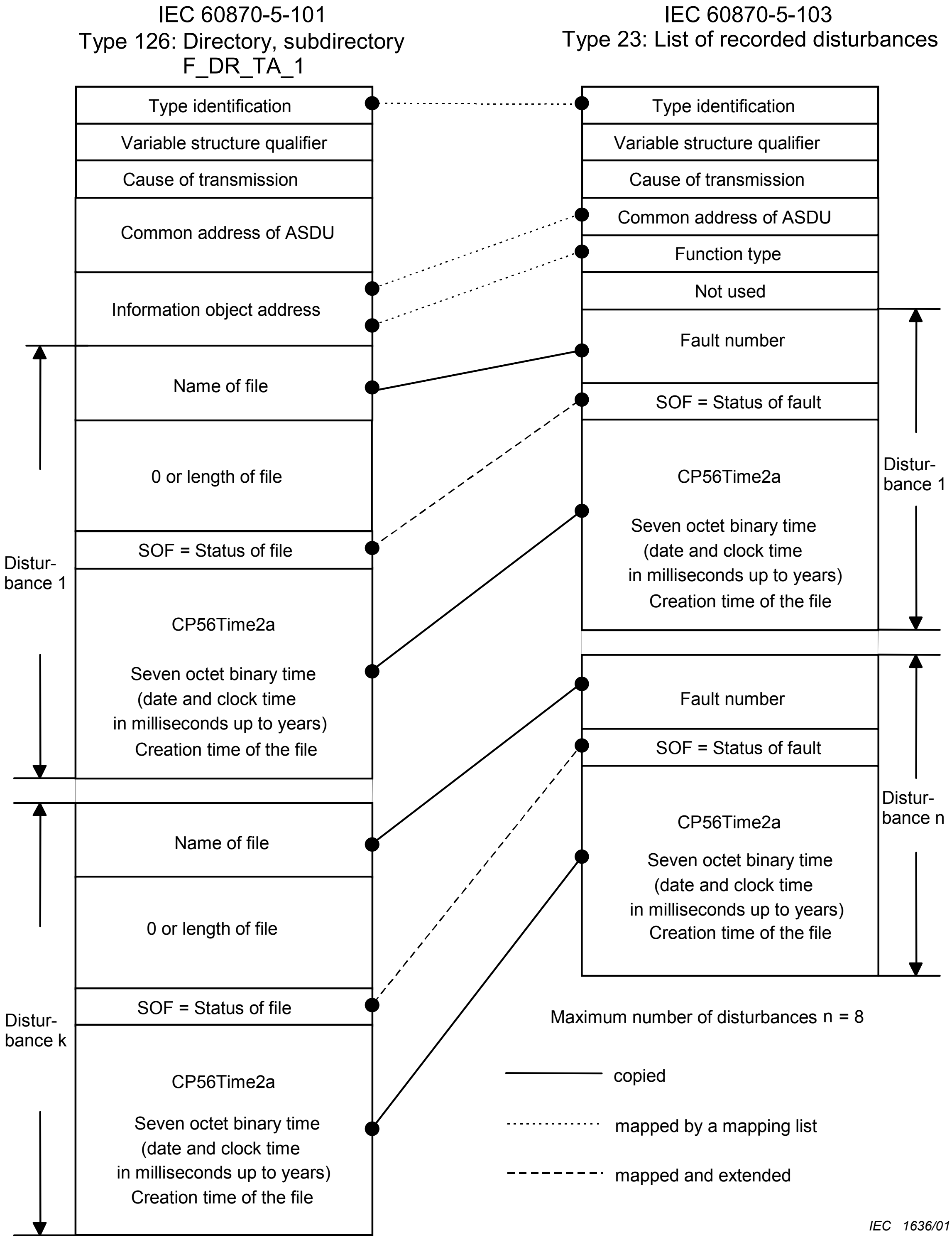

Figure 99 – Allocation of the data unit type 23 to the directory F_DR_TA_1

Table 18 – Allocation of type identification to type identification (IEC 60870-5-101 and IEC 60870-5-103)

IEC 60870-5-101	IEC 60870-5-103
Type identification	Type identification
<126>	<23>

Variable structure qualifier and cause of transmission are used independently from each other.

The common address of F_DR_TA_1 is used according to the definitions of this standard.

The information object address of F_DR_TA_1 of the interface of the controlling station to the controlled station is specified independently from the common address/function type of the interface to the protection equipment and allocated to the common address/function type of the type identification 23 via a table of the substation automation system. The sequence of the fault numbers (names) may be interrupted by gaps due to the deletion of disturbances and restarts of the protection equipment. As a consequence a name may even occur several times. Thus, disturbance data files have to be unambiguously addressed with the information object address B and the name = fault number (see table 19). Whereas, the information object addresses are defined in a fixed way, the names (fault numbers) may change, for example, when they are generated or deleted. In this case, the topical directories are transmitted spontaneously to the controlling station.

The directories or the recently transmitted files must not be updated in the substation automation system whilst a transfer of files to the controlling station is being performed. In the case of a coincidence of a change of the directory of the substation control system with a request (call) of the controlling station before the topical directory has been transmitted to the controlling station, the object address and the name of the file may be changed and be incorrect. In this case, the request (call) is rejected negatively and has to be repeated.

Table 19 – Example for the definition of information object addresses (directory or subdirectory)

Object address A	Object address A+1	Object address A+2	Object address A+n
1000	1001	1002	1000 + n
FOR = 0	FOR = 1	FOR = 0	FOR = 0
NAME = 1	NAME = 2	NAME = 1	NAME = 1

allocation of A + 1 = 1001 to B = 2000

Object address B	Object address B+1	Object address B+2	Object address B+n
2000	2001	2002	2000 + n
FOR = 0	FOR = 0	FOR = 0	FOR = 0
NAME = fault number = 10000	NAME = fault number = 10001	NAME = fault number = x	NAME = fault number = y

When the file is requested by the controlling station from the protection equipment, the length of the file is not known in the substation automation system at the time that the directory or subdirectory is transmitted. In this case, the field length of file is defined as <0>.

Allocation of the name of file to fault number in the case of FOR = 0:

The name of the file is the same as the fault number in the case of FOR = 0.

Table 20 – Allocation of SOF status of file to SOF status of fault (IEC 60870-5-101 and IEC 60870-5-103)

IEC 60870-5-101	IEC 60870-5-103
UI5[1..5]<0..31>	
<0> = not defined	
<1>	TP:=BS1[1]:=<0>; TEST:=BS1[3]:=<0>; OTEV:=BS1[4]:=<0>
<2>	TP:=BS1[1]:=<1>; TEST:=BS1[3]:=<0>; OTEV:=BS1[4]:=<0>
<3>	TP:=BS1[1]:=<0>; TEST:=BS1[3]:=<1>; OTEV:=BS1[4]:=<0>
<4>	TP:=BS1[1]:=<1>; TEST:=BS1[3]:=<1>; OTEV:=BS1[4]:=<0>
<5>	TP:=BS1[1]:=<0>; TEST:=BS1[3]:=<0>; OTEV:=BS1[4]:=<1>
<6>	TP:=BS1[1]:=<1>; TEST:=BS1[3]:=<0>; OTEV:=BS1[4]:=<1>
<7>	TP:=BS1[1]:=<0>; TEST:=BS1[3]:=<1>; OTEV:=BS1[4]:=<1>
<8>	TP:=BS1[1]:=<1>; TEST:=BS1[3]:=<1>; OTEV:=BS1[4]:=<1>
<9..15> = reserved for further compatible definitions	
<16..31> = for special use (private range)	
RES1 := LFD := BS1[6]<0..1>	Not available
<0> := Additional file follows	
<1> := Last file of the directory	
FOR := BS1[7]<0..1>	Not available
<0> := Name defines file	
<1> := Name defines subdirectory	
FA := BS1[8]<0..1>	Not available (TM not relevant for 101)
<0> := file waits for transfer	
<1> := Transfer of this file is active	

The clock time CP56Time2a is added at the point of time when the disturbance data file is generated in the protection equipment. This time is copied in the ASDU F_DR_TA_1.

7.4.11.2.6 Procedures

For procedures regarding transmission of directory and transmission of disturbance data with the ASDUs defined in 7.4.11.2.4 and 7.4.11.2.5, see figures 100 and 101. The definitions correspond to the procedures defined in 6.12 of IEC 60870-5-5. In order to transmit voluminous directories with more than a single ASDU, the RES1 bit of the octet status of file of F_DR_TA_1 is defined as follows:

RES1 := LFD = last file of directory =

- <0> := additional file of the directory follows;
- <1> := last file of the directory.

The directory may also be transmitted spontaneously following any change (see figure 100). If the list of recorded disturbances of a protection equipment changes, for example due to a reset, the topical list of recorded disturbances is transmitted after re-initialization to the substation automation system, following any station interrogation. This leads to changes of the directories and to spontaneous transmissions of the topical directories from the substation automation system to the controlling station. If the link to the controlling station is disrupted, the directory has to be requested again after the restoration of the link.

Controlling station	**Communication services**	**Controlled station**	**Action**
A_CALL_DIRECTORY.req	F_SC_NA_1 req	A_CALL_DIRECTORY.ind	Request of directory
A_DIRECTORY.ind	F_DR_TA_1 req	A_DIRECTORY.req	Requested directory 1, additional directory follows
A_DIRECTORY.ind	F_DR_TA_1 req	A_DIRECTORY.req	Requested directory 2, additional directory follows
⋮	⋮	⋮	
A_DIRECTORY.ind	F_DR_TA_1 req	A_DIRECTORY.req	Requested directory n, directory contains last file
⋮	⋮	⋮	
A_DIRECTORY.req	F_DR_TA_1 spont	A_DIRECTORY.req	Spontaneous transmission of a directory (possibly several ASDUs for each change)

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Figure 100 – Sequential procedure, transmission of the directory

Controlling station	Communication services	Controlled station	Action
A_SELECT_FILE.req	**F_SC_NA_1 file**	A_SELECT_FILE.ind	Selection of disturbance to be transmitted (automatically or by operator)
A_FILE_READY.ind	**F_FR_NA_1 file**	A_FILE_READY.req	Selected disturbance is ready to be transmitted (pos/neg)
A_CALL_FILE.req	**F_SC_NA_1 file**	A_CALL_FILE.ind	Request of disturbance to be transmitted (automatically or by operator)
A_SECTION1_READY.ind	**F_SR_NA_1 file**	A_SECTION1_READY.req	Section 1 (parameter of a disturbance) is ready to be transmitted (pos/neg)
A_CALL_SECTION1.req	**F_SC_NA_1 file**	A_CALL_SECTION1.ind	Request of section 1
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 1 (parameter of a disturbance) is being transmitted
A_LAST_SEGMENT1.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT1.ind	Last segment section 1 (parameter of a disturbance) is transmitted (pos/neg)
A_ACK_SECTION1.req	**F_AF_NA_1 file**	A_ACK_SECTION1.ind	Acknowledge of transmission of section 1 (pos/neg)
A_SECTION2_READY.ind	**F_SR_NA_1 file**	A_SECTION2_READY.ind	Section 2 (tags of a disturbance) is ready to be transmitted (pos/neg)
A_CALL_SECTION2.req	**F_SC_NA_1 file**	A_CALL_SECTION2.ind	Request of section 2

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Figure 101 – Sequential procedure, transmission of disturbance data files

Controlling station	Communication services	Controlled station	Action
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 2 (tags of disturbance) is being transmitted
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 2 (tags of disturbance) is being transmitted
A_LAST_SEGMENT1.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT1.ind	Last segment section 2 (tags of a disturbance) is transmitted (pos/neg)
A_ACK_SECTION2.req	**F_AF_NA_1 file**	A_ACK_SECTION2.ind	Acknowledge of transmission of section 2 (pos/neg)
A_SECTION3_READY.ind	**F_SR_NA_1 file**	A_SECTION3_READY.ind	Section 3 (parameter of channel 1) is ready to be transmitted (pos/neg)
A_CALL_SECTION3.req	**F_SC_NA_1 file**	A_CALL_SECTION3.ind	Request of section 3
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 3 (parameter of channel 1) is being transmitted
A_LAST_SEGMENT.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT.ind	Last segment section 3 (parameter of channel 1) is transmitted (pos/neg)
A_ACK_SECTION3.req	**F_AF_NA_1 file**	A_ACK_SECTION3.ind	Acknowledge of transmission of section 3 (pos/neg)
A_SECTION4_READY.ind	**F_SR_NA_1 file**	A_SECTION4_READY.ind	Section 4 (disturbance data of channel 1) is ready to be transmitted (pos/neg)
A_CALL_SECTION4.req	**F_SC_NA_1 file**	A_CALL_SECTION4.ind	Request of section 4
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 4 (disturbance data of channel 1) is being transmitted
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section 4 (disturbance data of channel 1) is being transmitted
A_LAST_SEGMENT.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT.ind	Last segment section 4 (disturbance data of channel 1) is transmitted (pos/neg)
A_ACK_SECTION4.req	**F_AF_NA_1 file**	A_ACK_SECTION4.ind	Acknowledge of transmission of section 4 (pos/neg)
A_SECTIONm_READY.ind	**F_SR_NA_1 file**	A_SECTIONm_READY.ind	Section m (parameter of channel n) is ready to be transmitted (pos/neg)
A_CALL_SECTIONm.req	**F_SC_NA_1 file**	A_CALL_SECTION m.ind	Request of section m

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Figure 101 – Sequential procedure, transmission of disturbance data files *(continued)*

Controlling station	Communication services	Controlled station	Action
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section m (parameter of channel n) is being transmitted
A_LAST_SEGMENT.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT.ind	Last segment section m (parameter of channel n) is transmitted (pos/neg)
A_ACK_SECTION m.req	**F_AF_NA_1 file**	A_ACK_SECTION m.ind	Acknowledge of transmission of section m (pos/neg)
A_SECTION m+1_READY.ind	**F_SR_NA_1 file**	A_SECTION m+1_READY.req	Section m +1 (disturbance data of channel n) is ready to be transmitted (pos/neg)
A_CALL_SECTION m+1.req	**F_SC_NA_1 file**	A_CALL_SECTION m+1.ind	Request of section m+1
A_SEGMENT1.ind	**F_SG_NA_1 file**	A_SEGMENT1.req	Section m+1 (disturbance data of channel n) is being transmitted
A_SEGMENT2.ind	**F_SG_NA_1 file**	A_SEGMENT2.req	Section m +1 (disturbance data of channel n) is being transmitted
	⋮		
A_LAST_SEGMENT.ind	**F_LS_NA_1 file**	A_LAST_SEGMENT.req	Last segment section m +1 (disturbance data of channel n) is transmitted (pos/neg)
LAST_ACK_SECTION m+1.req	**F_AF_NA_1 file**	LAST_ACK_SECTION m+1.ind	Acknowledge of transmission of section m +1 (pos/neg)
A_LAST_SECTION.ind	**F_LS_NA_1 file**	A_LAST_SECTION.ind	Last section is transmitted (pos/neg)
A_ACK_FILE.req	**F_AF_NA_1 file**	A_ACK_FILE.ind	Acknowledge of transmission of disturbance (pos/neg)
A_DIRECTORY.ind	**F_DR_TA_1 spont**	A_DIRECTORY.req	List of disturbances (topical) may be transmitted in order to update the directory

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Figure 101 – *(continued)*

7.4.11.2.7 Conditions in case of interruptions of the transmission of disturbance data

Subclauses 7.2.6 and 7.3.6 specify provisions for the correct transfer of files which include the test of the completeness and consistency of data files. In the case of recognition of irregular conditions by the controlling station, it may repeat the request for the transmission of a section or a complete file.

The effectiveness of these test routines supposes the correct data transmission of the ASDUs with the type identifications

– 120 file ready
– 121 section ready
– 122 call directory, select file, call file, call section

– 123 last section, last segment
– 124 ACK file, ACK section

which are used to control the file transfer.

In case of incorrectness or loss of one of the above ASDUs, the file transfer is disrupted and cannot be continued without repetitions. The station which detects such incorrectness has to interrupt the transmission of the file transfer eventually after a defined time out. After the recognition of the defect by the controlling station, it transmits F_SC_NA_1 with SCQ = 3 (deactivate file). If the defect is detected by the controlled station it transmits F_LS_NA_1 with LSQ = 2 (file transfer with deactivation).

In case of the complete loss of the communication services of the link layer, the file transfer is deactivated without a specific error indication. The file transfer has to be re-initialized when the link layer functionality is available again.

7.4.11.3 Transmission of sequences of events (spontaneous digital information)

This subclause defines the transmission of sequences of events (spontaneous digital information) which are acquired and recorded as information objects in the substation. The information objects are mapped onto the file transfer mechanism defined in this standard, when onward transmission to the controlling station is required.

7.4.11.3.1 Structure of the record of sequences of events in a section of a file

Figure 102 shows the structure of the record of sequences of events (spontaneous digital information). Each event is transmitted as an ASDU defined in 7.3. The file with the recorded spontaneous digital information consists of exactly one section, which corresponds to a section defined in IEC 60870-5-5.

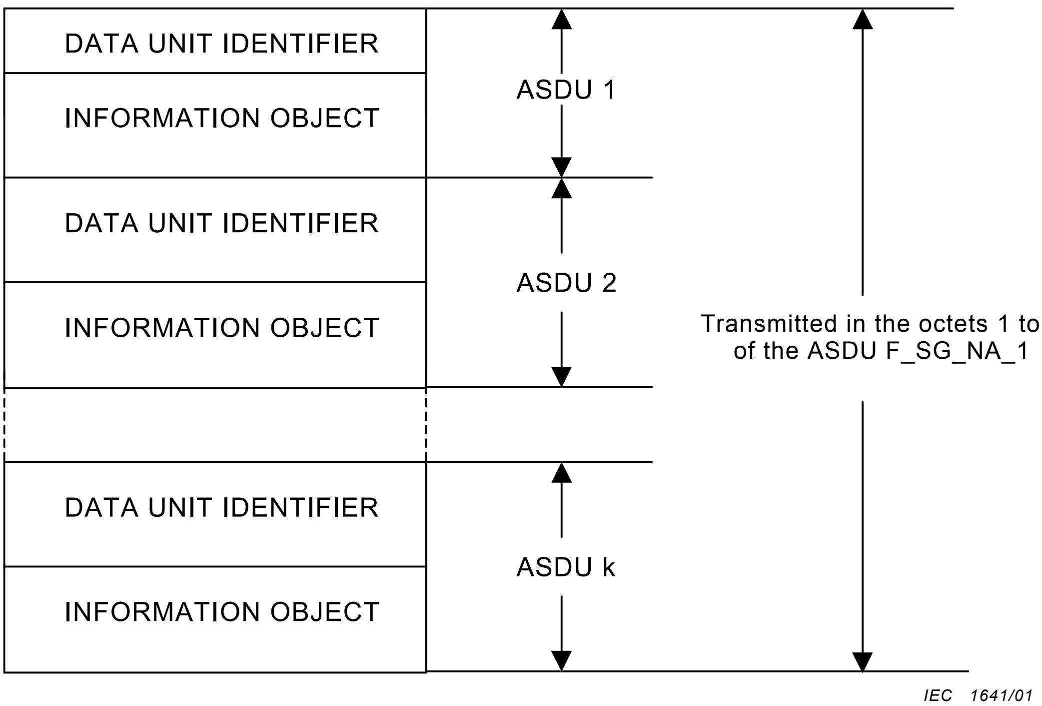

Figure 102 – Record of sequences of events in the section of a data file

ASDUs with the following type identifications may be transmitted as spontaneous digital information:

<30> :=	Single-point information with time tag CP56Time2a	M_SP_TB_1
<31> :=	Double-point information with time tag CP56Time2a	M_DP_TB_1
<32> :=	Step position information with time tag CP56Time2a	M_ST_TB_1
<33> :=	Bitstring of 32 bit with time tag CP56Time2a	M_BO_TB_1
<34> :=	Measured value, normalized value with time tag CP56Time2a	M_ME_TD_1
<35> :=	Measured value, scaled value with time tag CP56Time2a	M_ME_TE_1
<36> :=	Measured value, short floating point value with time tag CP56Time2a	M_ME_TF_1
<37> :=	Integrated totals with time tag CP56Time2a	M_IT_TB_1
<38> :=	Event of protection equipment with time tag CP56Time2a	M_EP_TD_1
<39> :=	Packed start events of protection equipment with time tag CP56Time2a	M_EP_TE_1
<40> :=	Packed output circuit information of protection equipment with time tag CP56Time2a	M_EP_TF_1

The variable structure qualifier is set to 1, i.e. only one information object is transmitted per ASDU.

7.4.11.3.2 Procedures

The procedures for the transmission of the directory are defined in figure 100. The procedures of transmission of sequences of events specified in 7.4.11.3.1 are defined in figure 103. The definitions correspond to the procedures defined in 6.12 of IEC 60870-5-5.

ASDUs <30> – <40>, which are transmitted to the controlling station via file transfer, are buffered in the controlled station including the point of time at which they are acquired. If a predefined number (parameter) of buffered ASDUs is exceeded (complete file to be transmitted), the controlled station transmits spontaneously the directory F_DR_TA_1 to the controlling station. The transmission of a sequence of event file which is ready to be transmitted may be activated by sending an ASDU F_SC_NA_1 Name of file = 3 and FOR = 0:

- by an operator in the controlling station;
- automatically by the controlling station after receiving the spontaneously transmitted directory;
- automatically once per day when files are available to be transmitted indicated by the directory;
- after the restart of the controlling or controlled station when files are available to be transmitted indicated by the directory;
- when the link layer is available again after an interruption.

Controlling station	Communication services	Controlled station	Action
A_SELECT_FILE.req →	F_SC_NA_1 file →	A_SELECT_FILE.ind →	Selection of event data to be transmitted (automatically or by operator)
A_FILE_READY.ind ←	F_FR_NA_1 file ←	A_FILE_READY.req ←	Selected event data is ready to be transmitted (pos/neg)
A_CALL_FILE.req →	F_SC_NA_1 file →	A_CALL_FILE.ind →	Request of event data to be transmitted (automatically or by operator)
A_SECTION_READY.ind ←	F_SR_NA_1 file ←	A_SECTION_READY.req ←	Section (data) is ready to be transmitted (pos/neg)
A_CALL_SECTION.req →	F_SC_NA_1 file →	A_CALL_SECTION_.ind →	Request of section
A_SEGMENT.ind ←	F_SG_NA_1 file ←	A_SEGMENT.req ←	Section (data) is being transmitted
. . .	. . .	. . .	
A_SEGMENT.ind ←	F_SG_NA_1 file ←	A_SEGMENT.req ←	Section (data) is being transmitted
A_LAST_SEGMENT.ind ←	F_LS_NA_1 file ←	A_LAST_SEGMENT.req ←	Last segment of section (data) is transmitted
A_ACK_SECTION.req →	F_AF_NA_1 file →	A_ACK_SECTION.ind →	ACK (pos/neg) of transmission of section 1
A_LAST_SECTION.ind ←	F_LS_NA_1 file ←	A_LAST_SECTION.req ←	Last section is transmitted (pos/neg)
A_ACK_FILE.req →	F_AF_NA_1 file →	A_ACK_FILE.ind →	Acknowledge (pos/neg) of transmission of data

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Figure 103 – Sequential procedure, transmission of sequences of events

Maximum length of a segment: 240 octets

Maximum length of the section: 64 000 octets

7.4.11.3.3 Conditions in case of interruptions of the transmission of sequences of events

(See 7.4.11.2.7.)

7.4.11.4 Transmission of sequences of recorded analogue values

This subclause defines the transmission of sequences of recorded analogue values (for example, measured values, integrated totals) acquired in a controlled station. The recorded analogue values are transmitted via the file transfer defined in IEC 60870-5-5 and this standard when onward transmission to the controlling station is required. Compressed records are not defined in this standard but may be transmitted as transparent data files.

7.4.11.4.1 Structure of data files containing sequences of recorded analogue values

Each file consists of one or more than one section, which correspond to a section defined in IEC 60870-5-5. The structure of the sections is identical. Each section contains the information elements of a specific sequence of recorded analogue values (binary counter readings or measured values) which is defined by the record identifier.

Section 1 sequence of recorded analogue values of section 1

Section 2 sequence of recorded analogue values of section 2

Section 3 sequence of recorded analogue values of section 3

etc.

Figure 104 shows the structure of sequences of recorded analogue values which are transmitted in the octets 1 to n of the ASDU F_SG_NA_1.

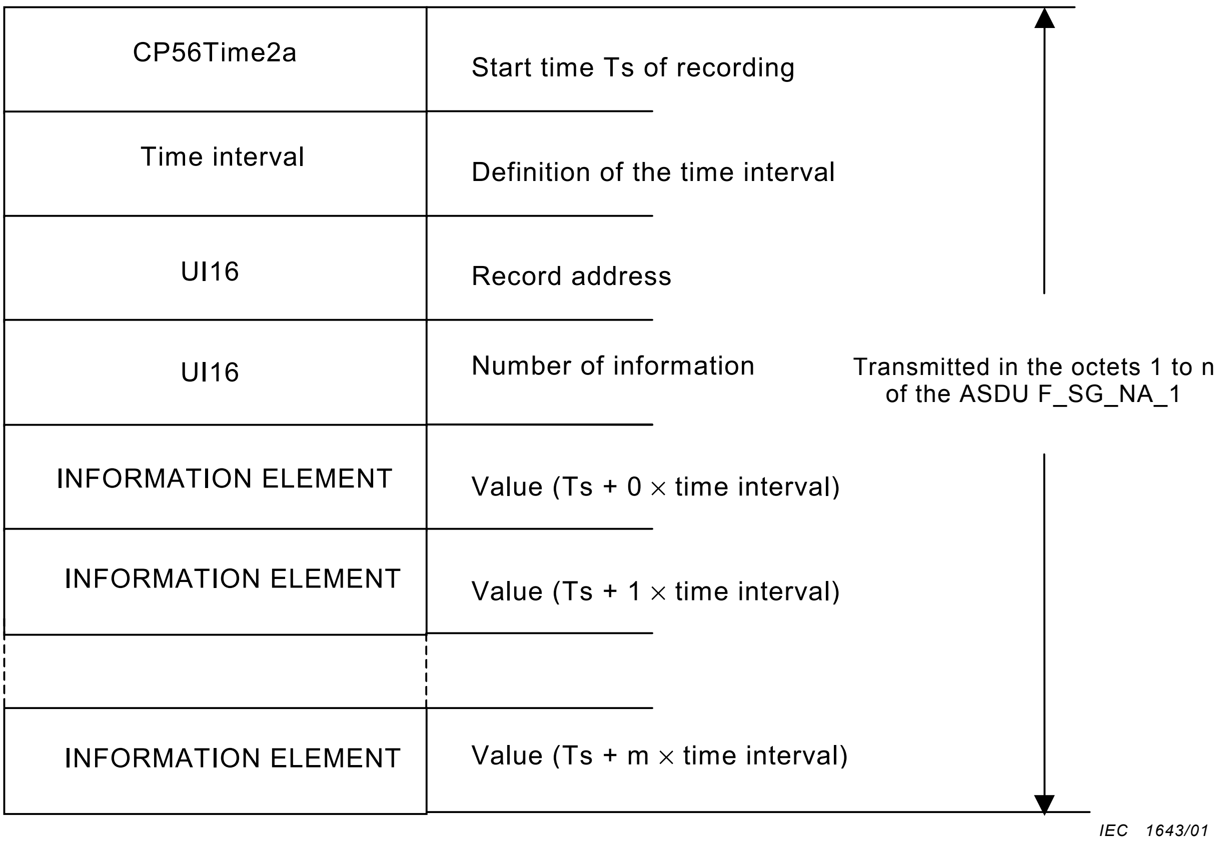

Figure 104 – Section of a data file containing sequences of recorded analogue values

The following information elements may be transmitted as sequences of recorded analogue values:

- binary counter reading according to 7.2.6.9;
- normalized value according to 7.2.6.6;
- normalized value according to 7.2.6.6 with quality descriptor QDS according to 7.2.6.3.

The time interval (interval between information elements) is the product of the time base and the factor.

Definition of the time interval:

Time interval		:=	CP16{ Factor, Time base}
Factor		:=	UI8[1..8]<0..255>
	<0>	:=	Not used
	<1..255>	:=	Factor
Time base		:=	UI8[9..15]<0..255>
	<0>	:=	Not used
	<1>	:=	1 ms
	<2>	:=	10 ms
	<3>	:=	100 ms
	<4>	:=	1000 ms
	<5>	:=	1 min
	<6>	:=	1 h
	<7..15>	:=	Reserved for standard definitions of this companion standard (compatible range)
	<16..255>	:=	Reserved for special use (private range)

Definition of the record identifier:

Record identifier		:=	CP16{Record address, Record qualifier}
Record address		:=	UI14[1..14]<0..16383>
Record qualifier		:=	UI2[15..16]<0..3>
	<0>	:=	Not used
	<1>	:=	Sequences of recorded normalized values according to 7.2.6.6
	<2>	:=	Sequences of recorded binary counter readings according to 7.2.6.9
	<3>	:=	Reserved for special use (private range)

The record identifier defines the set of information elements (normalized values or counter readings) and the address of the complete sequence of recorded analogue values. The record address does not relate to a specific address of an information element.

7.4.11.4.2 Procedures

The procedures for the transmission of the directory are defined in figure 100. The procedures of transmission of recorded analogue values specified in 7.4.11.4.1 are defined in figure 105. The definitions correspond to the procedures defined in 6.12 of IEC 60870-5-5. The transmission of a file sequence of recorded analogue values which is ready to be transmitted may be activated by sending an ASDU F_SC_NA_1 Name of file = 4 and FOR = 0:

- by an operator in the controlling station;
- automatically by the controlling station after receiving the spontaneously transmitted directory;
- automatically once per day when files are available to be transmitted indicated by the directory;
- after the restart of the controlling or controlled station when files are available to be transmitted indicated by the directory;
- when the link layer is available again after an interruption.

Controlling station	Communication services	Controlled station	Action
A_SELECT_FILE.req	F_SC_NA_1 file	A_SELECT_FILE.ind	Selection of file containing analogue values to be transmitted (automatically or by operator)
A_FILE_READY.ind	F_FR_NA_1 file	A_FILE_READY.req	Selected file containing analogue values is ready to be transmitted (pos/neg)
A_CALL_FILE.req	F_SC_NA_1 file	A_CALL_FILE.ind	Request of file containing analogue values to be transmitted (automatically or by operator)
A_SECTION1_READY.ind	F_SR_NA_1 file	A_SECTION_READY1.req	Section 1 (data) is ready to be transmitted (pos/neg)
A_CALL_SECTION1.req	F_SC_NA_1 file	A_CALL_SECTION1_.ind	Request of section 1
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section 1 (data) is being transmitted
.	.	.	.
.	.	.	.
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section 1 (data) is being transmitted
A_LAST_SEGMENT.ind	F_LS_NA_1 file	A_LAST_SEGMENT.req	Last segment of section 1 (data) is transmitted
A_ACK_SECTION1.req	F_AF_NA_1 file	A_ACK_SECTION1.ind	Acknowledge of transmission of section 1 (pos/neg)
A_SECTION2_READY.ind	F_SR_NA_1 file	A_SECTION_READY2.req	Section 2 (data) is ready to be transmitted (pos/neg)
A_CALL_SECTION2.req	F_SC_NA_1 file	A_CALL_SECTION2_.ind	Request of section 2
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section 2 (data) is being transmitted
.	.	.	.
.	.	.	.
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section 2 (data) is being transmitted
A_LAST_SEGMENT.ind	F_LS_NA_1 file	A_LAST_SEGMENT.req	Last segment of section 2 (data) is transmitted
A_ACK_SECTION2.req	F_AF_NA_1 file	A_ACK_SECTION2.ind	Acknowledge of transmission of section 2 (pos/neg)
.	.	.	.
.	.	.	.
A_SECTIONn_READY.ind	F_SR_NA_1 file	A_SECTIONn_READY.req	Section n (data) is ready to be transmitted (pos/neg)
A_CALL_SECTIONn.req	F_SC_NA_1 file	A_CALL_SECTIONn_.ind	Request of section n
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section n (data) is being transmitted
.	.	.	.
.	.	.	.
A_SEGMENT.ind	F_SG_NA_1 file	A_SEGMENT.req	Section n (data) is being transmitted
A_LAST_SEGMENT.ind	F_LS_NA_1 file	A_LAST_SEGMENT.req	Last segment of section n (data) is transmitted
A_ACK_SECTIONn.req	F_AF_NA_1 file	A_ACK_SECTIONn.ind	Acknowledge of transmission of section n (pos/neg)
A_LAST_SECTION.ind	F_LS_NA_1 file	A_LAST_SECTION.req	Last section is transmitted (pos/neg)
A_ACK_FILE.req	F_AF_NA_1 file	A_ACK_FILE.ind	Acknowledge of transmission of data

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Figure 105 – Sequential procedure, transmission of sequences of recorded analogue values

7.4.11.4.3 Conditions in case of interruptions of the transmission of sequences of recorded analogue values

(See 7.4.11.2.7.)

7.4.12 Selections from acquisition of transmission delay

Add, after the last paragraph, the following new text:

When a clock synchronization command is received, the time information must be corrected by the controlled station with the value received in the load delay command.

NOTE A_SDT.ind freezes the time at the instant when the first bit of a C_CD frame is received by the controlled station and A_SDT + tR.ind freezes the time at the instant when the first bit of a C_CD ACTCON frame is received by the controlling station (see figure 23 of IEC 60870-5-5).

7.4.13 Background scan

The background scan is used to update process information from the controlled station to the controlling station as an additional safeguard to the station interrogation and spontaneous transmission procedures. ASDUs with the same type identification numbers as defined for the station interrogation procedure may be transmitted with cause of transmission <2> background scan on a low-priority continuous basis. The background scan is initiated by the controlled station and therefore independent from station interrogation commands. The transmission cycle is configured by fixed parameters in the controlled station. Measured values reported by periodic or cyclic transmission (COT = 1) should not be reported as background scan (COT = 2), spontaneous (COT = 3) or station interrogation (COT = 20 to 36).

Table 21 – Type identifications for background scan

Direction C=command M=monitor	Type identification	Cause of transmission	
M	<1> M_SP_NA_1 <3> M_DP_NA_1 <5> M_ST_NA_1 <7> M_BO_NA_1 <9> M_ME_NA_1 <11> M_ME_NB_1 <13> M_ME_NC_1 <20> M_PS_NA_1 <21> M_ME_ND_1	<2> background scan	

7.4.14 Read procedure

Controlling station	Communication services	Controlled station	Action
A_RD_DATA.req →	C_RD_NA_1 <5> REQ →	A_RD_DATA.ind →	Read information object which is specified by the information object address
← A_M_DATA.ind	← M_ <5> REQ	← A_M_DATA.req	Respond information object which has been read

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Figure 106 – Sequential procedure, read procedure

The application process in the controlling station sends the read command as an A_RD_DATA.req to the communication services, the communication services transmit a C_RD_NA_1 REQ PDU containing the information object address which specifies the requested information object.

The application process in the controlled station returns the requested information object as an A_M_DATA.req to the communication services. The communication services in the controlled station attach the requested information object to the assigned ASDU in monitor direction and transmit it as an M_PDU with the cause of transmission <5> REQ.

The following ASDUs M_REQ may be returned in the monitor direction:

<1> M_SP_NA_1 REQ
<2> M_SP_TA_1 REQ or <30> M_SP_TB_1 REQ
<3> M_DP_NA_1 REQ
<4> M_DP_TA_1 REQ or <31> M_DP_TB_1 REQ
<5> M_ST_NA_1 REQ
<6> M_ST_TA_1 REQ or <32> M_ST_TB_1 REQ
<7> M_BO_NA_1 REQ
<8> M_BO_TA_1 REQ or <33> M_BO_TB_1 REQ
<9> M_ME_NA_1 REQ
<10> M_ME_TA_1 REQ or <34> M_ME_TD_1 REQ
<11> M_ME_NB_1 REQ
<12> M_ME_TB_1 REQ or <35> M_ME_TE_1 REQ
<13> M_ME_NC_1 REQ
<14> M_ME_TC_1 REQ or <36> M_ME_TF_1 REQ
<20> M_PS_NA_1 REQ
<21> M_ME_ND_1 REQ
<126> F_DR_TA_1 REQ

If the values in the data unit identifier (except the variable structure qualifier) and the information object address of the read command are unknown (not defined) in the controlled station, the mirrored C_RD_NA_1 with the cause of transmission <44 – 47> is returned (see 7.2.3.1).

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8 Interoperability

Replace, after the first paragraph, the existing text by the following new text:

The selected parameters should be marked in the white boxes as follows:

☐ Function or ASDU is not used

X Function or ASDU is used as standardized (default)

R Function or ASDU is used in reverse mode

B Function or ASDU is used in standard and reverse mode

The possible selection (blank, X, R, or B) is specified for each specific clause or parameter.

NOTE In addition, the full specification of a system may require individual selection of certain parameters for certain parts of the system, such as the individual selection of scaling factors for individually addressable measured values.

Replace the existing subclauses 8.1 to 8.5 by the following new subclauses 8.1. to 8.6.

8.1 System or device

(system-specific parameter, indicate the definition of a system or a device by marking one of the following with "**X**")

☐ System definition

☐ Controlling station definition (Master)

☐ Controlled station definition (Slave)

8.2 Network configuration

(network-specific parameter, all configurations that are used are to be marked "**X**")

☐ Point-to-point ☐ Multipoint-partyline

☐ Multiple point-to-point ☐ Multipoint-star

8.3 Physical layer

(network-specific parameter, all interfaces and data rates that are used are to be marked "**X**")

Transmission speed (control direction)

Unbalanced interchange Circuit V.24/V.28 Standard	Unbalanced interchange Circuit V.24/V.28 Recommended if >1 200 bit/s	Balanced interchange Circuit X.24/X.27	
☐ 100 bit/s	☐ 2 400 bit/s	☐ 2 400 bit/s	☐ 56 000 bit/s
☐ 200 bit/s	☐ 4 800 bit/s	☐ 4 800 bit/s	☐ 64 000 bit/s
☐ 300 bit/s	☐ 9 600 bit/s	☐ 9 600 bit/s	
☐ 600 bit/s		☐ 19 200 bit/s	
☐ 1 200 bit/s		☐ 38 400 bit/s	

Transmission speed (monitor direction)

Unbalanced interchange Circuit V.24/V.28 Standard	Unbalanced interchange Circuit V.24/V.28 Recommended if >1 200 bit/s	Balanced interchange Circuit X.24/X.27	
☐ 100 bit/s	☐ 2 400 bit/s	☐ 2 400 bit/s	☐ 56 000 bit/s
☐ 200 bit/s	☐ 4 800 bit/s	☐ 4 800 bit/s	☐ 64 000 bit/s
☐ 300 bit/s	☐ 9 600 bit/s	☐ 9 600 bit/s	
☐ 600 bit/s		☐ 19 200 bit/s	
☐ 1 200 bit/s		☐ 38 400 bit/s	

8.4 Link layer

(network-specific parameter, all options that are used are to be marked "**X**". Specify the maximum frame length. If a non-standard assignment of class 2 messages is implemented for unbalanced transmission, indicate the type ID and COT of all messages assigned to class 2.)

Frame format FT 1.2, single character 1 and the fixed time out interval are used exclusively in this companion standard.

Link transmission procedure

☐ Balanced transmission

☐ Unbalanced transmission

Frame length

☐ Maximum length L

Address field of the link

☐ Not present (balanced transmission only)

☐ One octet

☐ Two octets

☐ Structured

☐ Unstructured

When using an unbalanced link layer, the following ASDU types are returned in class 2 messages (low priority) with the indicated causes of transmission:

☐ The standard assignment of ASDUs to class 2 messages is used as follows:

Type identification	**Cause of transmission**
9, 11, 13, 21	<1>

☐ A special assignment of ASDUs to class 2 messages is used as follows:

Type identification	**Cause of transmission**

NOTE In response to a class 2 poll, a controlled station may respond with class 1 data when there is no class 2 data available.

8.5 Application layer

Transmission mode for application data
Mode 1 (least significant octet first), as defined in 4.10 of IEC 60870-5-4, is used exclusively in this companion standard.

Common address of ASDU
(system-specific parameter, all configurations that are used are to be marked "**X**")

☐ One octet ☐ Two octets

Information object address
(system-specific parameter, all configurations that are used are to be marked "**X**")

☐ One octet
☐ Two octets
☐ Three octets

☐ Structured
☐ Unstructured

Cause of transmission
(system-specific parameter, all configurations that are used are to be marked "**X**")

☐ One octet

☐ Two octets (with originator address)
Set to zero in case of no originator address

Selection of standard ASDUs

Process information in monitor direction
(station-specific parameter, mark each type ID "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<1> :=	Single-point information	M_SP_NA_1
☐	<2> :=	Single-point information with time tag	M_SP_TA_1
☐	<3> :=	Double-point information	M_DP_NA_1
☐	<4> :=	Double-point information with time tag	M_DP_TA_1
☐	<5> :=	Step position information	M_ST_NA_1
☐	<6> :=	Step position information with time tag	M_ST_TA_1
☐	<7> :=	Bitstring of 32 bit	M_BO_NA_1
☐	<8> :=	Bitstring of 32 bit with time tag	M_BO_TA_1
☐	<9> :=	Measured value, normalized value	M_ME_NA_1
☐	<10> :=	Measured value, normalized value with time tag	M_ME_TA_1
☐	<11> :=	Measured value, scaled value	M_ME_NB_1
☐	<12> :=	Measured value, scaled value with time tag	M_ME_TB_1
☐	<13> :=	Measured value, short floating point value	M_ME_NC_1
☐	<14> :=	Measured value, short floating point value with time tag	M_ME_TC_1
☐	<15> :=	Integrated totals	M_IT_NA_1
☐	<16> :=	Integrated totals with time tag	M_IT_TA_1
☐	<17> :=	Event of protection equipment with time tag	M_EP_TA_1
☐	<18> :=	Packed start events of protection equipment with time tag	M_EP_TB_1
☐	<19> :=	Packed output circuit information of protection equipment with time tag	M_EP_TC_1
☐	<20> :=	Packed single-point information with status change detection	M_PS_NA_1
☐	<21> :=	Measured value, normalized value without quality descriptor	M_ME_ND_1
☐	<30> :=	Single-point information with time tag CP56Time2a	M_SP_TB_1
☐	<31> :=	Double-point information with time tag CP56Time2a	M_DP_TB_1
☐	<32> :=	Step position information with time tag CP56Time2a	M_ST_TB_1
☐	<33> :=	Bitstring of 32 bit with time tag CP56Time2a	M_BO_TB_1
☐	<34> :=	Measured value, normalized value with time tag CP56Time2a	M_ME_TD_1
☐	<35> :=	Measured value, scaled value with time tag CP56Time2a	M_ME_TE_1
☐	<36> :=	Measured value, short floating point value with time tag CP56Time2a	M_ME_TF_1
☐	<37> :=	Integrated totals with time tag CP56Time2a	M_IT_TB_1
☐	<38> :=	Event of protection equipment with time tag CP56Time2a	M_EP_TD_1
☐	<39> :=	Packed start events of protection equipment with time tag CP56Time2a	M_EP_TE_1
☐	<40> :=	Packed output circuit information of protection equipment with time tag CP56Time2a	M_EP_TF_1

Either ASDUs of the set <2>, <4>, <6>, <8>, <10>, <12>, <14>, <16>, <17>, <18>, <19> or of the set <30 –40> are used.

Process information in control direction
(station-specific parameter, mark each type ID "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<45> := Single command	C_SC_NA_1
☐	<46> := Double command	C_DC_NA_1
☐	<47> := Regulating step command	C_RC_NA_1
☐	<48> := Set point command, normalized value	C_SE_NA_1
☐	<49> := Set point command, scaled value	C_SE_NB_1
☐	<50> := Set point command, short floating point value	C_SE_NC_1
☐	<51> := Bitstring of 32 bit	C_BO_NA_1

System information in monitor direction
(station-specific parameter, mark "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<70> := End of initialization	M_EI_NA_1

System information in control direction
(station-specific parameter, mark each type ID "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<100>:= Interrogation command	C_IC_NA_1
☐	<101>:= Counter interrogation command	C_CI_NA_1
☐	<102>:= Read command	C_RD_NA_1
☐	<103>:= Clock synchronization command	C_CS_NA_1
☐	<104>:= Test command	C_TS_NA_1
☐	<105>:= Reset process command	C_RP_NA_1
☐	<106>:= Delay acquisition command	C_CD_NA_1

Parameter in control direction
(station-specific parameter, mark each type ID "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<110>:= Parameter of measured value, normalized value	P_ME_NA_1
☐	<111>:= Parameter of measured value, scaled value	P_ME_NB_1
☐	<112>:= Parameter of measured value, short floating point value	P_ME_NC_1
☐	<113>:= Parameter activation	P_AC_NA_1

File transfer
(station-specific parameter, mark each type ID "**X**" if it is only used in the standard direction, "**R**" if only used in the reverse direction, and "**B**" if used in both directions)

☐	<120>:= File ready	F_FR_NA_1
☐	<121>:= Section ready	F_SR_NA_1
☐	<122>:= Call directory, select file, call file, call section	F_SC_NA_1
☐	<123>:= Last section, last segment	F_LS_NA_1
☐	<124>:= Ack file, ack section	F_AF_NA_1
☐	<125>:= Segment	F_SG_NA_1
☐	<126>:= Directory {blank or X, only available in monitor (standard) direction}	F_DR_TA_1

Type identifier and cause of transmission assignments
(station-specific parameters)

Shaded boxes are not required.
Blank = function or ASDU is not used.
Mark type identification/cause of transmission combinations:
"**X**" if used only in the standard direction
"**R**" if used only in the reverse direction
"**B**" if used in both directions

Type identification		Cause of transmission																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<1>	M_SP_NA_1																			
<2>	M_SP_TA_1																			
<3>	M_DP_NA_1																			
<4>	M_DP_TA_1																			
<5>	M_ST_NA_1																			
<6>	M_ST_TA_1																			
<7>	M_BO_NA_1																			
<8>	M_BO_TA_1																			
<9>	M_ME_NA_1																			
<10>	M_ME_TA_1																			
<11>	M_ME_NB_1																			
<12>	M_ME_TB_1																			
<13>	M_ME_NC_1																			
<14>	M_ME_TC_1																			
<15>	M_IT_NA_1																			
<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																			
<21>	M_ME_ND_1																			
<30>	M_SP_TB_1																			
<31>	M_DP_TB_1																			
<32>	M_ST_TB_1																			
<33>	M_BO_TB_1																			
<34>	M_ME_TD_1																			
<35>	M_ME_TE_1																			
<36>	M_ME_TF_1																			
<37>	M_IT_TB_1																			
<38>	M_EP_TD_1																			
<39>	M_EP_TE_1																			
<40>	M_EP_TF_1																			
<45>	C_SC_NA_1																			
<46>	C_DC_NA_1																			
<47>	C_RC_NA_1																			
<48>	C_SE_NA_1																			
<49>	C_SE_NB_1																			

Type identification		**Cause of transmission**																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<50>	C_SE_NC_1																			
<51>	C_BO_NA_1																			
<70>	M_EI_NA_1																			
<100>	C_IC_NA_1																			
<101>	C_CI_NA_1																			
<102>	C_RD_NA_1																			
<103>	C_CS_NA_1																			
<104>	C_TS_NA_1																			
<105>	C_RP_NA_1																			
<106>	C_CD_NA_1																			
<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*																			

** Blank or X only.*

8.6 Basic application functions

Station initialization
(station-specific parameter, mark "**X**" if function is used)

☐ Remote initialization

Cyclic data transmission
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Cyclic data transmission

Read procedure
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Read procedure

Spontaneous transmission
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Spontaneous transmission

Double transmission of information objects with cause of transmission spontaneous
(station-specific parameter, mark each information type "**X**" where both a type ID without time and corresponding type ID with time are issued in response to a single spontaneous change of a monitored object)

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

- ☐ Single-point information M_SP_NA_1, M_SP_TA_1, M_SP_TB_1 and M_PS_NA_1
- ☐ Double-point information M_DP_NA_1, M_DP_TA_1 and M_DP_TB_1
- ☐ Step position information M_ST_NA_1, M_ST_TA_1 and M_ST_TB_1
- ☐ Bitstring of 32 bit M_BO_NA_1, M_BO_TA_1 and M_BO_TB_1 (if defined for a specific project, see 7.2.1.1)
- ☐ Measured value, normalized value M_ME_NA_1, M_ME_TA_1, M_ME_ND_1 and M_ME_TD_1
- ☐ Measured value, scaled value M_ME_NB_1, M_ME_TB_1 and M_ME_TE_1
- ☐ Measured value, short floating point number M_ME_NC_1, M_ME_TC_1 and M_ME_TF_1

Station interrogation
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

- ☐ 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	

Information object addresses assigned to each group must be shown in a separate table

Clock synchronization
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

- ☐ Clock synchronization

Command transmission
(object-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

- ☐ Direct command transmission
- ☐ Direct set-point command transmission
- ☐ Select and execute command
- ☐ Select and execute set-point command
- ☐ C_SE ACTTERM used

- ☐ No additional definition
- ☐ Short-pulse duration (duration determined by a system parameter in the controlled station)
- ☐ Long-pulse duration (duration determined by a system parameter in the controlled station)
- ☐ Persistent output

Transmission of integrated totals
(station- or object-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Mode A: local freeze with spontaneous
☐ Mode B: local freeze with counter
☐ Mode C: freeze and transmit by counter interrogation
☐ Mode D: freeze by counter interrogation command, frozen values reported spontaneously

☐ Counter read
☐ Counter freeze without reset
☐ Counter freeze with reset
☐ Counter reset

☐ General request counter
☐ Request counter group 1
☐ Request counter group 2
☐ Request counter group 3
☐ Request counter group 4

Parameter loading
(object-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Threshold value
☐ Smoothing factor
☐ Low limit for transmission of measured value
☐ High limit for transmission of measured value

Parameter activation
(object-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Act/deact of persistent cyclic or periodic transmission of the addressed object

Test procedure
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Test procedure

File transfer
(station-specific parameter, mark "**X**" if function is used)

File transfer in monitor direction

☐ Transparent file
☐ Transmission of disturbance data of protection equipment
☐ Transmission of sequences of events
☐ Transmission of sequences of recorded analogue values

File transfer in control direction

☐ Transparent file

Background scan
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Background scan

Acquisition of transmission delay
(station-specific parameter, mark "**X**" if function is used only in the standard direction, "**R**" if used only in the reverse direction, and "**B**" if used in both directions)

☐ Acquisition of transmission delay

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Add the following annexes:

Annex A
(informative)

Proof of the synchronization stability of frame format class FT 1.2

A.1 Introduction

This abstract proves that the frame format FT 1.2 defined in IEC 60870-5-1 fulfils the required data integrity requirements of data integrity class 2 which requires that less than 4 bit errors must not cause undetectable message errors.

The abstract includes the proof of the detection of three bit inversions at any position of the transmitted frames including the line idles. Synchronization slips caused by bit inversions are demonstrably detected. Bit inversions which may occur within shifted frames are detected by the rules defined in IEC 60870-5-2 (parity and arithmetical check sum).

The proof is provided by the following steps:

a) proof of the shift insusceptibility of the defined characters;
b) proof that the characters are mutually not susceptible to shift, i.e. a character for a fixed block length must not be converted into a character for variable block length by less than 4 bit errors and vice versa;
c) proof of the shift insusceptibility of frames with variable block length.

All rules for format class FT 1.2 specified in IEC 60870-5-1 have also to be taken into consideration.

A.1.1 UART definition

	START	LSB						MSB	EVEN PARITY	STOP
	0	D1	D2	D3	D4	D5	D6	D7	D8	P	1
Bit sequence on the line	1	2	3	4	5	6	7	8	9	10	11

A.1.2 Frame format definitions FT 1.2

The following START, END and CONTROL characters are defined and can be used even in a mixed configuration.

Frame format with variable block length:

1	2 3 4 5 6 7 8 9	10	11
0	START 68H	P	1
0	L	P	1
0	L	P	1
0	START 68H	P	1
1 ↓ *n*	USER DATA		
0	CHECKSUM	P	1
0	END 16H	P	1

START 68H = 0 / 0 0 0 1 0 1 1 0 / 1 / 1

P = even parity

END 16H = 0 / 0 1 1 0 1 0 0 0 / 1 / 1

Frame format with fixed block length:

1	2 3 4 5 6 7 8 9	10	11
0	START 10H	P	1
1 ↓ *n*	USER DATA		
0	CHECKSUM	P	1
0	END 16H	P	1

START 10H = 0 / 0 0 0 0 1 0 0 0 / 1 / 1

P = even parity

END 16H = 0 / 0 1 1 0 1 0 0 0 / 1 / 1

Single characters:

1	2 3 4 5 6 7 8 9	10	11
0	SINGLE CHARACTER E5H	P	1

SINGLE CHARACTER E5H = 0 / 1 0 1 0 0 1 1 1 / 1 / 1

P = even parity

1	2 3 4 5 6 7 8 9	10	11
0	SINGLE CHARACTER A2H *)	P	1

SINGLE CHARACTER A2H = 0 / 0 1 0 0 0 1 0 1 / 1 / 1

* The single character A2 is not used in IEC 60870-5 standards (see IEC 60870-5-2).

The defined numbers specified in hexadecimal code are directly delivered from the processor to the UART, i.e. the reversed sequence of bits of the octets per line is considered.

All four specified octets have at least 4 zero bits (including START bit), so that extinction can only occur by 4 bit errors (0 in 1).

The defined characters shall also comply with the following conditions:

a) shifts as the result of incorrect synchronization in idle condition or in the information field, caused by ≤ 4 bit errors, must not produce undetectable frame errors;

b) in case of a shift produced by incorrect synchronization, caused by ≤ 4 bit errors, START 68H must not be transformed into START 10H or vice versa;

c) in case of a shift produced by incorrect synchronization, caused by ≤ 4 bit errors, START 68H must not be transformed into single characters E5H or A2H or vice versa;

d) in case of a shift produced by incorrect synchronization, caused by ≤ 4 bit errors, START 10H must not be transformed into single characters E5H or A2H or vice versa.

A.1.3 Explanatory information on the proofs according to A.2 and A.3

The upper line comprises the original bit configuration embedded in the idle state. X defines a position at which 1 or 0 bits may occur arbitrarily. An "!" identifies a bit error. The following lines specify the incorrectly synchronized bit configurations and the number of necessary bit errors required to fulfil them.

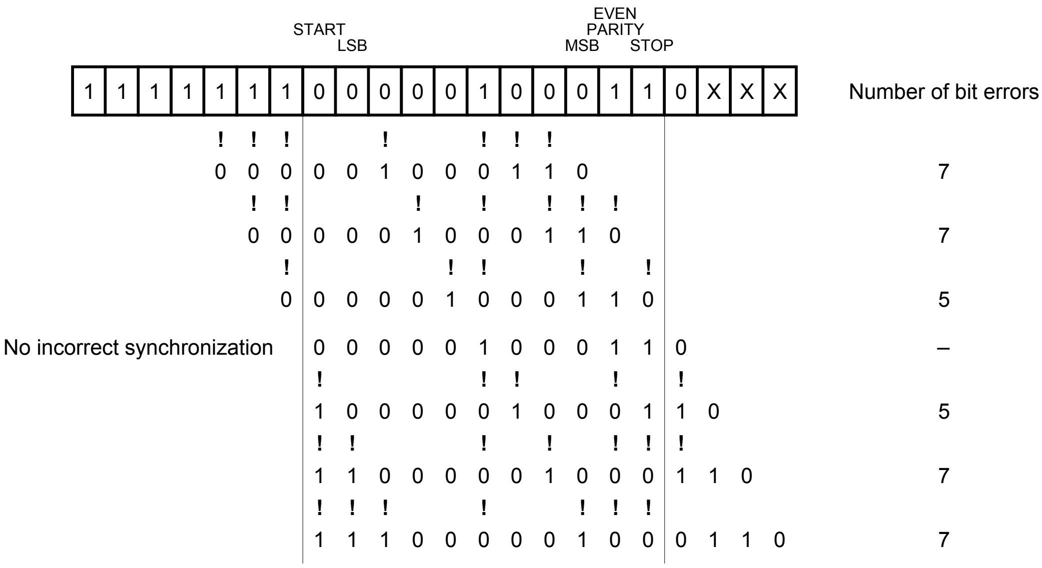
A.2 Proof of the shift insusceptibility of the specified characters

A.2.1 Shift insusceptibility of START 68H

								START	LSB							MSB	EVEN PARITY	STOP					
	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0	X	X	X	Number of bit errors
					!	!	!		!		!												
					0	0	0	0	1	0	1	1	0	1	1	0							5
						!	!			!			!	!		!	!						
						0	0	0	0	1	0	1	1	0	1	1	0						7
							!				!	!	!		!	!		!					
							0	0	0	0	1	0	1	1	0	1	1	0					7
No incorrect synchronization								0	0	0	0	1	0	1	1	0	1	1					–
								!				!	!	!		!	!		!				
								1	0	0	0	0	1	0	1	1	0	1	1	0			7
								!	!			!			!	!		!	!				
								1	1	0	0	0	0	1	0	1	1	0	1	1	0		7
								!	!	!		!		!									
								1	1	1	0	0	0	0	1	0	1	1	0	1	1	0	5

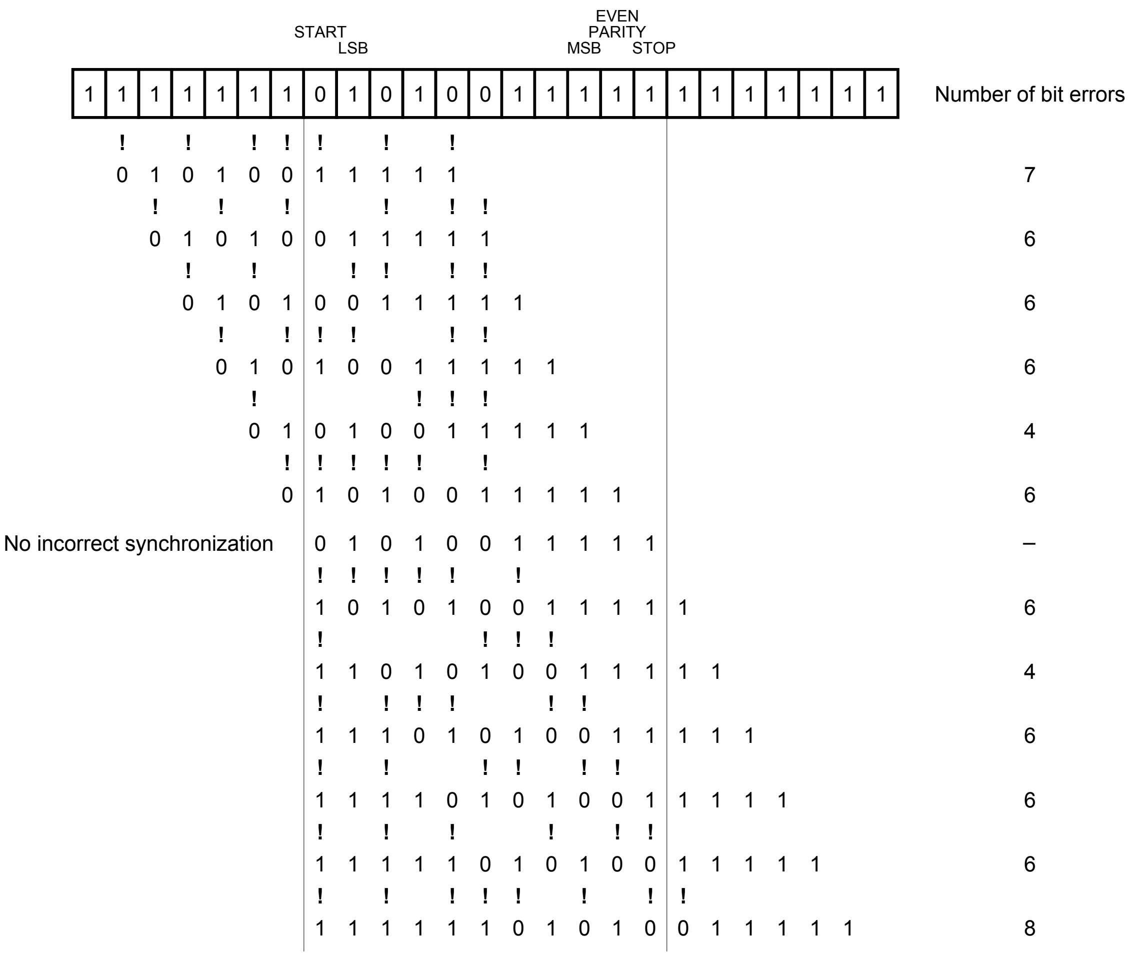
All further shifts are produced by at least 4 bit errors.

A.2.2 Shift insusceptibility of START 10H



All further shifts are produced by at least 4 bit errors.

A.2.3 Shift insusceptibility of SINGLE CHARACTER E5H



All further shifts are produced by at least 4 bit errors.

A.2.4 Shift insusceptibility of SINGLE CHARACTER A2H

								START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	Number of bit errors
		!	!		!	!	!	!			!	!														
		0	0	1	0	0	0	1	0	1	1	1														8
			!	!		!	!		!	!	!	!	!													
			0	0	1	0	0	0	1	0	1	1	1													9
				!	!		!					!	!													
				0	0	1	0	0	0	1	0	1	1	1												5
					!	!				!	!		!		!											
					0	0	1	0	0	0	1	0	1	1	1											6
						!	!	!		!		!			!											
						0	0	1	0	0	0	1	0	1	1	1										6
							!		!	!			!	!	!											
							0	0	1	0	0	0	1	0	1	1	1									6
No incorrect synchronization								0	0	1	0	0	0	1	0	1	1	1								–
								!		!	!			!	!	!										
								1	0	0	1	0	0	0	1	0	1	1	1							6
								!	!	!		!		!			!									
								1	1	0	0	1	0	0	0	1	0	1	1	1						6
								!	!				!	!		!		!								
								1	1	1	0	0	1	0	0	0	1	0	1	1	1					6
								!	!		!					!	!		!							
								1	1	1	1	0	0	1	0	0	0	1	0	1	1	1				6
								!	!		!	!		!		!	!	!		!						
								1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1			9
								!	!		!	!	!	!		!	!	!	!		!					
								1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1		11

All further shifts are produced by at least 4 bit errors.

A.2.5 Shift insusceptibility of END 16H

```
                                                              EVEN
                                            START            PARITY
                                                LSB           MSB STOP
                              X X X X X X 1 | 0 0 1 1 0 1 0 0 0 1 1 | 1 1 1 1 1 1 1       Number of bit errors
                                            | !     !   ! ! ! !     |
                                    1 0 0 1 | 1 0 1 0 0 0 1 1 1 1 1 | 1 1 1                        6
                                          ! | ! ! !     !   ! !     |
                                      1 0 0 | 1 1 0 1 0 0 0 1 1 1 1 | 1 1 1 1   1                  7
                                          ! |   !   ! ! !     !     |
                                        1 0 | 0 1 1 0 1 0 0 0 1 1 1 | 1 1 1 1 1 1 1                6
                                            |                       |
No incorrect synchronization              1 | 0 0 1 1 0 1 0 0 0 1 1 | 1 1 1 1 1 1                  –
                                            | !   !   ! ! !     !   |
                                            | 1 0 0 1 1 0 1 0 0 0 1 | 1 1 1 1 1 1 1                6
                                            |   ! ! ! !     !   ! ! |
                                            |   1 0 0 1 1 0 1 0 0 0 | 1 1 1 1 1 1 1                7
                                            |       !     !   ! ! ! | !
                                            |     1 0 0 1 1 0 1 0 0 | 0 1 1 1 1 1 1                6
                                            |           ! ! !     ! | ! !
                                            |       1 0 0 1 1 0 1 0 | 0 0 1 1 1 1 1 1              6
                                            |         ! !   ! ! !   | ! ! !
                                            |         1 0 0 1 1 0 1 | 0 0 0 1 1 1 1 1 1            8
```

All further shifts are produced by at least 4 bit errors.

A.3 Proof of the mutual shift insusceptibility of the characters

A.3.1 Shift insusceptibility of START 68H against START 10H

```
                                                            EVEN
                                          START            PARITY
                                              LSB         MSB STOP
                              1 1 1 1 1 | 0 0 0 0 1 0 1 1 0 1 1 | 0 X X X X X X       Number of bit errors
                                  ! ! ! |     !   !             |
                                  0 0 0 | 0 0 1 0 0 0 1 1 0     |                            5
                                    ! ! |       ! !   !   ! !   |
                                    0 0 | 0 0 0 1 0 0 0 1 1 0   |                            7
                                      ! |             ! ! !   ! |
                                      0 | 0 0 0 0 1 0 0 0 1 1 0 |                            5
                                        |         ! ! ! !       |
Invalidation without shift              | 0 0 0 0 0 1 0 0 0 1 1 | 0                          4
                                        | !       !     !   !   | !
                                        | 1 0 0 0 0 0 1 0 0 0 1 | 1 0                        5
                                        | ! !     !   !     ! ! | !
                                        | 1 1 0 0 0 0 0 1 0 0 0 | 1 1 0                      7
                                        | ! ! !   !   ! ! ! ! ! |
                                        | 1 1 1 0 0 0 0 0 1 0 0 | 0 1 1 0                    9
```

All further shifts are produced by at least 4 bit errors.

A.3.2 Shift insusceptibility of START 10H against START 68H

						START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	X	X	X	X	X	X	Number of bit errors
			!	!	!		!		!	!	!	!	!											
			0	0	0	0	1	0	1	1	0	1	1	0										9
				!	!			!		!			!	!	!									
				0	0	0	0	1	0	1	1	0	1	1	0									7
					!				!			!		!		!								
					0	0	0	0	1	0	1	1	0	1	1	0								5
										!	!	!	!											
Invalidation without shift						0	0	0	0	1	0	1	1	0	1	1	0							4
						!							!	!	!		!							
						1	0	0	0	0	1	0	1	1	0	1	1	0						5
						!	!				!	!		!		!	!							
						1	1	0	0	0	0	1	0	1	1	0	1	1	0					7
						!	!	!			!		!											
						1	1	1	0	0	0	0	1	0	1	1	0	1	1	0				5

All further shifts are produced by at least 4 bit errors.

A.3.3 Shift insusceptibility of SINGLE CHARACTER E5H against START 68H

						START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	Number of bit errors
			!	!	!					!				!										
			0	0	0	0	1	0	1	1	0	1	1	0										5
				!	!		!	!	!	!	!	!			!									
				0	0	0	0	1	0	1	1	0	1	1	0									9
					!		!				!		!			!								
					0	0	0	0	1	0	1	1	0	1	1	0								5
							!		!	!				!			!							
Invalidation without shift						0	0	0	0	1	0	1	1	0	1	1	0							5
						!	!		!		!	!			!			!						
						1	0	0	0	0	1	0	1	1	0	1	1	0						7
						!			!				!			!			!					
						1	1	0	0	0	0	1	0	1	1	0	1	1	0					5
						!		!	!			!		!						!				
						1	1	1	0	0	0	0	1	0	1	1	0	1	1	0				6
						!		!				!	!		!						!			
						1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0			6
						!		!		!		!	!	!		!						!		
						1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0		8

All further shifts are produced by at least 4 bit errors.

A.3.4 Shift insusceptibility of START 68H against SINGLE CHARACTER E5H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0	X	X	X	X	X	X	Number of bit errors
	!		!		!	!	!	!	!	!															
	0	1	0	1	0	0	1	1	1	1	1														8
		!		!		!		!	!	!		!													
		0	1	0	1	0	0	1	1	1	1	1													7
			!		!				!	!		!													
			0	1	0	1	0	0	1	1	1	1	1												5
				!		!	!			!		!													
				0	1	0	1	0	0	1	1	1	1	1											5
					!			!				!			!										
					0	1	0	1	0	0	1	1	1	1	1										4
						!	!		!		!	!			!										
						0	1	0	1	0	0	1	1	1	1	1									6
								!		!	!				!										
Invalidation without shift							0	1	0	1	0	0	1	1	1	1	1								4
							!		!				!		!			!							
							1	0	1	0	1	0	0	1	1	1	1	1							5
							!	!		!	!	!	!	!	!			!							
							1	1	0	1	0	1	0	0	1	1	1	1	1						9
							!	!	!					!				!							
							1	1	1	0	1	0	1	0	0	1	1	1	1	1					5

All further shifts are produced by at least 4 bit errors.

A.3.5 Shift insusceptibility of SINGLE CHARACTER E5H against START 10H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	Number of bit errors
				!	!	!		!	!	!					!										
				0	0	0	0	0	1	0	0	0	1	1	0										7
					!	!		!						!		!									
					0	0	0	0	0	1	0	0	0	1	1	0									5
						!		!		!	!		!	!			!								
						0	0	0	0	0	1	0	0	0	1	1	0								7
								!		!		!	!	!	!			!							
Invalidation without shift							0	0	0	0	0	1	0	0	0	1	1	0							7
							!	!		!				!	!	!			!						
							1	0	0	0	0	0	1	0	0	0	1	1	0						7
							!			!			!		!	!	!			!					
							1	1	0	0	0	0	0	1	0	0	0	1	1	0					7
							!		!	!			!	!		!	!	!			!				
							1	1	1	0	0	0	0	0	1	0	0	0	1	1	0				9
							!		!				!	!	!		!	!	!			!			
							1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0			9
							!		!		!		!	!	!	!		!	!	!			!		
							1	1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0		11

All further shifts are produced by at least 4 bit errors.

A.3.6 Shift insusceptibility of START 10H against SINGLE CHARACTER E5H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	X	X	X	X	X	X	Number of bit errors
	!		!		!	!	!	!	!	!	!														
	0	1	0	1	0	0	1	1	1	1	1														9
		!		!		!		!	!	!	!														
		0	1	0	1	0	0	1	1	1	1	1													7
			!		!				!	!	!		!												
			0	1	0	1	0	0	1	1	1	1	1												6
				!		!	!			!	!		!	!											
				0	1	0	1	0	0	1	1	1	1	1											7
					!			!			!		!	!	!										
					0	1	0	1	0	0	1	1	1	1	1										6
						!	!		!				!	!	!										
						0	1	0	1	0	0	1	1	1	1	1									6
								!		!		!	!	!	!										
Invalidation without shift							0	1	0	1	0	0	1	1	1	1	1								6
							!		!		!	!		!	!			!							
							1	0	1	0	1	0	0	1	1	1	1	1							7
							!	!		!					!			!							
							1	1	0	1	0	1	0	0	1	1	1	1	1						5
							!	!	!		!	!	!					!							
							1	1	1	0	1	0	1	0	0	1	1	1	1	1					7

All further shifts are produced by at least 4 bit errors.

A.3.7 Shift insusceptibility of SINGLE CHARACTER A2H against START 68H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	Number of bit errors
				!	!	!		!	!	!	!			!	!										
				0	0	0	0	1	0	1	1	0	1	1	0										9
					!	!					!	!	!	!		!									
					0	0	0	0	1	0	1	1	0	1	1	0									7
						!			!	!		!					!								
						0	0	0	0	1	0	1	1	0	1	1	0								5
									!		!			!	!			!							
Invalidation without shift							0	0	0	0	1	0	1	1	0	1	1	0							5
							!		!			!	!	!		!			!						
							1	0	0	0	0	1	0	1	1	0	1	1	0						7
							!	!	!								!			!					
							1	1	0	0	0	0	1	0	1	1	0	1	1	0					5
							!	!					!	!	!			!			!				
							1	1	1	0	0	0	0	1	0	1	1	0	1	1	0				7
							!	!		!			!			!			!			!			
							1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0			7

All further shifts are produced by at least 4 bit errors.

A.3.8 Shift insusceptibility of START 68H against SINGLE CHARACTER A2H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	0	X	X	X	X	X	X	Number of bit errors
			!	!		!			!			!													
			0	0	1	0	0	0	1	0	1	1	1												5
				!	!					!	!	!													
				0	0	1	0	0	0	1	0	1	1	1											5
					!	!	!								!										
					0	0	1	0	0	0	1	0	1	1	1										4
						!		!			!	!	!		!										
						0	0	1	0	0	0	1	0	1	1	1									6
									!		!			!	!										
Invalidation without shift							0	0	1	0	0	0	1	0	1	1	1								4
							!			!	!		!					!							
							1	0	0	1	0	0	0	1	0	1	1	1							5
							!	!					!	!	!	!		!							
							1	1	0	0	1	0	0	0	1	0	1	1	1						7
							!	!	!		!	!	!	!			!	!							
							1	1	1	0	0	1	0	0	0	1	0	1	1	1					9

All further shifts are produced by at least 4 bit errors.

A.3.9 Shift insusceptibility of SINGLE CHARACTER A2H against START 10H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	Number of bit errors
				!	!	!								!	!										
				0	0	0	0	0	1	0	0	0	1	1	0										5
					!	!			!	!			!	!		!									
					0	0	0	0	0	1	0	0	0	1	1	0									7
						!			!		!		!				!								
						0	0	0	0	0	1	0	0	0	1	1	0								5
									!			!	!		!			!							
Invalidation without shift							0	0	0	0	0	1	0	0	0	1	1	0							5
							!		!						!	!			!						
							1	0	0	0	0	0	1	0	0	0	1	1	0						5
							!	!	!				!	!	!	!	!			!					
							1	1	0	0	0	0	0	1	0	0	0	1	1	0					9
							!	!					!			!	!	!			!				
							1	1	1	0	0	0	0	0	1	0	0	0	1	1	0				7
							!	!		!			!		!		!	!	!			!			
							1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0			9

All further shifts are produced by at least 4 bit errors.

A.3.10 Shift insusceptibility of START 10H against SINGLE CHARACTER A2H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	X	X	X	X	X	X	Number of bit errors
			!	!		!			!		!		!												
			0	0	1	0	0	0	1	0	1	1	1												6
				!	!					!			!	!											
				0	0	1	0	0	0	1	0	1	1	1											5
					!	!	!				!	!	!	!	!										
					0	0	1	0	0	0	1	0	1	1	1										8
						!		!						!	!										
						0	0	1	0	0	0	1	0	1	1	1									4
									!			!	!		!										
Invalidation without shift							0	0	1	0	0	0	1	0	1	1	1								4
							!			!		!		!				!							
							1	0	0	1	0	0	0	1	0	1	1	1							5
							!	!			!	!			!	!		!							
							1	1	0	0	1	0	0	0	1	0	1	1	1						7
							!	!	!								!	!							
							1	1	1	0	0	1	0	0	0	1	0	1	1	1					5

All further shifts are produced by at least 4 bit errors.

A.3.11 Shift insusceptibility of SINGLE CHARACTER A2H against SINGLE CHARACTER E5H

							START	LSB							MSB	EVEN PARITY	STOP								
	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	Number of bit errors
		!		!		!		!		!	!	!													
		0	1	0	1	0	0	1	1	1	1	1													7
			!		!					!	!	!													
			0	1	0	1	0	0	1	1	1	1	1												5
				!		!	!		!	!	!	!		!											
				0	1	0	1	0	0	1	1	1	1	1											8
					!			!	!		!	!		!											
					0	1	0	1	0	0	1	1	1	1	1										6
						!	!					!		!											
						0	1	0	1	0	0	1	1	1	1	1									4
								!	!	!				!											
Invalidation without shift							0	1	0	1	0	0	1	1	1	1	1								4
							!				!		!	!											
							1	0	1	0	1	0	0	1	1	1	1	1							4
							!	!	!	!		!	!												
							1	1	0	1	0	1	0	0	1	1	1	1	1						6
							!	!			!				!										
							1	1	1	0	1	0	1	0	0	1	1	1	1	1					4
							!	!		!		!	!	!	!	!									
							1	1	1	1	0	1	0	1	0	0	1	1	1	1	1				8

All further shifts are produced by at least 4 bit errors.

A.3.12 Shift insusceptibility of SINGLE CHARACTER E5H against SINGLE CHARACTER A2H

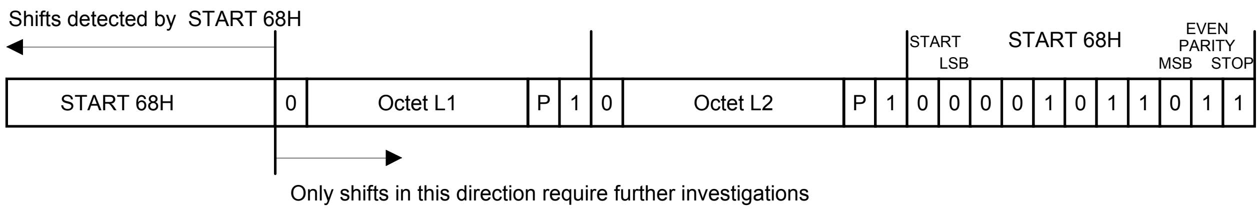
```
                                                          EVEN
                                      START              PARITY
                                          LSB           MSB STOP
                            1 1 1 1 1 1 0 1 0 1 0 0 1 1 1 1 1 X X X X X X   Number of bit errors
                                ! !   !   ! ! ! ! !
                                0 0 1 0 0 0 1 0 1 1 1                       8
                                  ! !     !       !
                                  0 0 1 0 0 0 1 0 1 1 1                     4
                                    ! ! ! !   ! !
                                    0 0 1 0 0 0 1 0 1 1 1                   6
                                      !       !   ! !
                                      0 0 1 0 0 0 1 0 1 1 1                 4
                                          ! ! !       !
Invalidation without shift              0 0 1 0 0 0 1 0 1 1 1               4
                                        ! !         !   !
                                        1 0 0 1 0 0 0 1 0 1 1 1             4
                                        !     ! !   ! !   !
                                        1 1 0 0 1 0 0 0 1 0 1 1 1           6
                                        !   ! !   ! ! ! !   !
                                        1 1 1 0 0 1 0 0 0 1 0 1 1 1         8
                                        !   !         ! ! !
                                        1 1 1 1 0 0 1 0 0 0 1 0 1 1 1       5
                                        !   !   !   !   ! ! !
                                        1 1 1 1 1 0 0 1 0 0 0 1 0 1 1 1     7
```

All further shifts are produced by at least 4 bit errors.

A.4 Shift insusceptibility for frames with variable block length

For structure of the frame see A.1.2.

Only the character START 68H is used for frames with variable length. The proof of the shift insusceptibility of this character guarantees that all synchronization slips caused by less than 4 bit errors are detected (see A.2). Thus shifts can only occur caused by invalidation of startbits from 0 to 1 beginning with the first length octet L1.

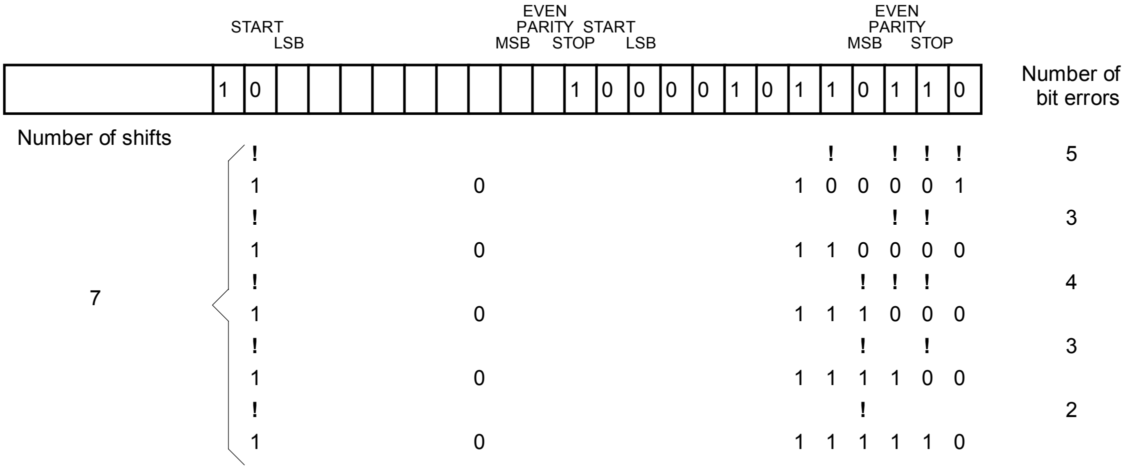


The rules in IEC 60870-5-1 state that octet L1 must always have the same information content as octet L2 when it is sent. The proof that this frame length specification cannot be invalidated undetected by less than 4 bit errors must be provided.

The second START 68 character could be detected as the first length character as the result of extinction of the characters L1 and L2. However, the extinction of these two characters requires at least 4 bit errors, because every character contains at least 2 zero bits: 1 zero bit is the start bit of the character and at least 1 zero bit occurs in the data field due to the even parity bit prescription.

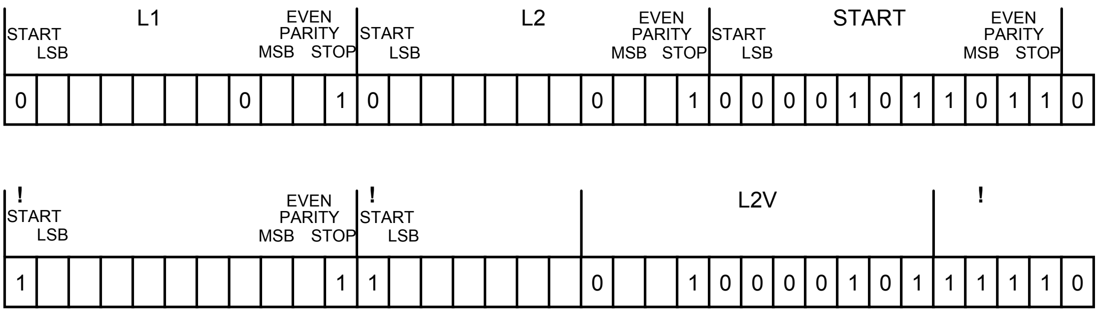
If only one length character (L1 or L2) is extinguished completely, the second START 68H character is evaluated as the length character L2. The number of zero bits in the START 68 character (6 bits), however, is so great that this condition cannot be achieved with less than 4 bit errors since the information content L1 must always be equal to L2. Consequently, we must investigate what happens if the length characters are shifted partially into the second START 68H character as the result of synchronization errors. This corresponds to a shift of the second START 68H character relative to its original position. Below, we shall establish how many synchronization slip positions the length character need to be shifted into the second START 68H character and how many bit errors are needed to cause this in each case.

		START	LSB							MSB	EVEN PARITY	STOP	START	LSB							MSB	EVEN PARITY	STOP		
	1	0										1	0	0	0	0	1	0	1	1	0	1	1	0	Number of bit errors
Number of shifts		!											!				!	!	!		!	!		!	
1		1	0										1	0	0	0	0	1	0	1	1	0	1	1	8
		!											!	!			!			!	!		!	!	
		1	0										1	1	0	0	0	0	1	0	1	1	0	1	8
		!											!	!	!		!		!						
		1	0										1	1	1	0	0	0	0	1	0	1	1	0	6 Further shifts of START 68H require more than 4 bit errors
		!												!			!			!	!		!	!	
2		1		0										1	0	0	0	0	1	0	1	1	0	1	7
		!												!	!		!		!						
		1		0										1	1	0	0	0	0	1	0	1	1	0	5
		!												!	!	!	!		!	!	!	!		!	
		1		0										1	1	1	0	0	0	0	1	0	1	1	10
		!												!	!	!			!	!			!	!	
		1		0										1	1	1	1	0	0	0	0	1	0	1	8 Further shifts of START 68H require more than 4 bit errors
		!													!		!		!						
3		1			0										1	0	0	0	0	1	0	1	1	0	4
		!													!	!	!		!	!	!	!		!	
		1			0										1	1	0	0	0	0	1	0	1	1	9
		!													!	!			!	!			!	!	
		1			0										1	1	1	0	0	0	0	1	0	1	7 Further shifts of START 68H require more than 4 bit errors
		!														!	!		!	!	!	!		!	
4		1				0										1	0	0	0	0	1	0	1	1	8
		!														!			!	!			!	!	
		1				0										1	1	0	0	0	0	1	0	1	6
		!														!		!	!	!		!			
		1				0										1	1	1	0	0	0	0	1	0	6
		!														!		!		!		!	!	!	
		1				0										1	1	1	1	0	0	0	0	1	7
		!														!		!				!	!		
		1				0										1	1	1	1	1	0	0	0	0	5
		!																!	!			!	!		
5		1					0										1	0	0	0	0	1	0	1	5 Further shifts of START 68H require more than 4 bit errors
		!															!	!	!		!				
		1					0										1	1	0	0	0	0	1	0	5
		!															!		!		!	!	!		
		1					0										1	1	1	0	0	0	0	1	6
		!															!				!	!			
		1					0										1	1	1	1	0	0	0	0	4
		!															!			!	!	!			
		1					0										1	1	1	1	1	0	0	0	5 Further shifts of START 68H require more than 4 bit errors
		!																!	!	!		!			
6		1						0										1	0	0	0	0	1	0	5
		!																!		!		!	!	!	
		1						0										1	1	0	0	0	0	1	6
		!																!				!	!		
		1						0										1	1	1	0	0	0	0	4
		!																!			!	!	!		
		1						0										1	1	1	1	0	0	0	5 Further shifts of START 68H require more than 4 bit errors



This demonstrates that shifts of at least seven positions are necessary for a shifted second START 68H character to be found as a result of less than 4 bit errors.

Two bit errors can thus produce the following configuration L2V:



However, this condition can only be achieved if bits 2 to 7 in the characters L1 and L2 (both must have been originally identical) are one bit.

Under these conditions, the erroneous character L2V must be equal to the erroneous L1V which has to be generated by less than 4 bit errors. The combinations which occur in this case are shown in the diagram below with the number of necessary bit errors. The bits X and Y in character L1 must be equal to those in character L2. If they differ in the shifted characters, additional bit errors must have occurred.

L1V: START … STOP   L2V: START … STOP

Bits	Number of bit errors
0 1 1 1 1 1 1 0 X Y 1 0 1 1 1 1 1 1 0 X Y 1 0 0 0 0 1 0 1 1 1 1 1 0	
0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	6
1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	8
1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	6
1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	8
1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	8
1 1 1 1 1 0 1 0 1 0 0 0 0 1 0 1 1 1 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0	6
1 1 1 1 1 1 0 0 X Y 1 0 0 0 0 0 1 1 0 X Y 1 0 0 0 0 1 0 1 1 1 1 1 0	7
1 1 1 1 1 1 1 0 X Y 1 0 0 0 0 1 0 1 0 X Y 1 0 0 0 0 1 0 1 1 1 1 1 0	6

Thus, in the case of shifts to the START 68H character, far more bit errors are necessary to produce undetected, incorrect length specifications than in the case shown above, produced by extinction of complete length characters.

These results were checked by a computer programme. During the test the following criteria, a) to d), were checked for frame lengths 0 to 255 in each case with all possible shifts of L1, L2 and START 68H:

a) identity check for L1 and L2;
b) parity check;
c) start bit of character = 0;
d) bit configuration of the character START 68H.

The cases shown above were confirmed.

Annex B
(informative)

Admittance of line idle intervals between characters of frame format class FT 1.2

Rule 3 of the format class FT 1.2 (see 6.2.4.2.1 of IEC 60870-5-1) requires that no line idle interval between characters of a coherent frame are admitted. The reason for this rule is to avoid undetectable sync slip errors within the frame that may occur, when the line idle bits (line idle is binary 1) are inverted into zero bits which would be interpreted as start bits. Figure B.1 shows a single line idle bit which is wrongly inserted by the transmitter after the first character.

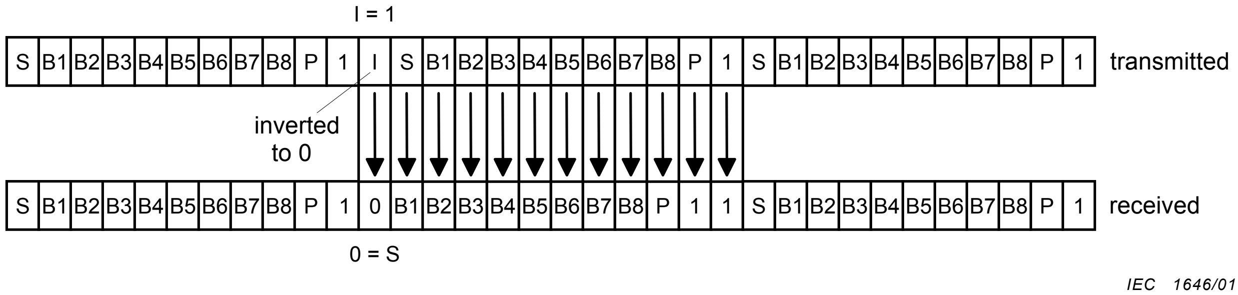


Figure B.1 – Shift of a character caused by an inverted additional line idle bit

The additional line idle bit is normally interpreted by the receiver as an additional stop bit. In this case, the receiver synchronizes correctly on the next following start bit. If that line idle bit were to be inverted into a zero bit, then the receiver would start one bit earlier which would cause a shift of one bit of the following character as shown in line two of figure B.1. In this case, the transmitted start bit shifts to bit one (B1) of the following character, which is then always zero. Bit 8 (B8) is shifted to the parity position and the parity to the stop position. The next following stop bit would be interpreted as a line idle and the next (third) character would be started correctly without any shifting.

In the following, it is required to prove whether the above-described scenario, that means a line idle extension of a single bit, does not reduce the data integrity and the hamming distance d = 4. If this is true, line idles of only one bit length could be admitted.

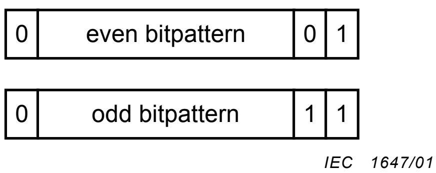


Figure B.2 – Relation of even and odd bit pattern to the parity bit

The number of ones of a character may be even or odd and the parity bit, that completes to an even number of ones, is either zero (even bit pattern) or one (odd bit pattern, see figure B.2).

If the parity bit is zero and the character is shifted, caused by an inverted line idle bit as shown in figure B.1, then the zero parity would be shifted into the stop bit position which causes a stop bit error in any case.

If the parity bit is one then the stop bit would remain as a one bit without any error detection. In this case, bit 8 of the transmitted frame is shifted to the parity bit position. If bit 8 is zero, the parity changes from one to zero (odd or even!), but the character remains odd.

NOTE Bit position one of the shifted character is always zero (see figure B.1).

If bit 8 is one, the parity does not change (it remains one) but the character changes from odd to even. In both cases, the error is detected.

Conclusion

In any case, a second bit inversion besides the first one (change of line idle into a start bit) is necessary to receive an undetectable wrong character. This fulfils hamming distance d = 2.

Further conclusion

If an additional line idle inversion occurs between two other characters of the same frame, then at least 4 bit errors would be necessary to receive an undetectable wrong frame. This fulfils hamming distance d = 4.

The following is proof of the hamming distance in the case of transmitting only one instance of an additional single line idle bit between characters of a frame and of the influence of the checksum-test (arithmetical sum at the end of the frame).

S	B1	B2	B3	B4	B5	B6	B7	B8	P	1	
0	0	1	1	1	1	1	1	1	1	1	transmitted
0	0	0	1	1	1	1	1	1	1	1	received

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Figure B.3 – Shifted bit pattern

Figure B.3 shows the worst case of a shifted bit pattern, where the difference of the transmitted and the received shifted character is one bit only. An additional bit inversion of bit position B2 would change the character into even and therefore the parity would be correct. But in this case, the original transmitted character would be restored and there is no reason to reject it.

In all other cases, at least two additional bit inversions (making a total of four or more) are needed to receive an undetectable wrong frame, because the checksum (arithmetical sum) would fail.

EXAMPLE (based on figure B.3):

If bit 3 of the second character changes, then the parity bit fulfils the even condition. The difference of the shifted character to the original one is at least two bits which is detected by the checksum in any case.

Summarized conclusion

Even when line idle intervals of a length of one transmitted bit occur between characters of a FT 1.2-frame the hamming distance d = 4 is fulfilled. More than one bit line idle is strictly prohibited.

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