Standards Compliance according to IEC 61131-3

1. Introduction:

The **IEC 61131** standard is applicable for the programmable logic controllers (PLC).
In accordance with the rules of the European Union, this international standard has been accepted in Germany as DIN EN 61131, in France as NF EN 61131, and in England as BS EN 61131.
The most important parts of the standard are quoted below. Quotes are in italics.

Part 3 of this standard defines the application area in Section 1.1
" *This Part of IEC 61131 specifies syntax and semantics of programming languages for programmable controllers as defined in part 1 of IEC 61131.*
The functions of program entry, testing, monitoring, operating system, etc., are specified in Part 1."

Section 1.4 explains the overview and general requirements:
"This Part of IEC 61131 specifies the syntax and semantics of a unified suite of programming languages for PLCs. These consist of textual languages, IL (Instruction List) and ST (Structured Text), and two graphical languages, LD (Ladder Diagram) and FBD (Function Block Diagram)."
"Sequential Function Chart (SFC) elements are defined for structuring the internal organization of programmable controller programs and function blocks. Also, configuration elements are defined which support the installation of programmable controller programs into programmable controller systems...."
" The programming language elements defined in this part may be used in an interactive programming environment. The specification of such environments is beyond the scope of this standard; however, such an environment shall be capable of producing textual or graphic program documentation in the formats specified in this part."

Section 1.5 of the standards compliance specifies:
"A programmable controller system, as defined in IEC 61131-1, which claims to comply, wholly or partially, with the requirements of this Part of IEC 61131 shall do so only as described below.
A compliance statement shall be included in the documentation accompanying the system, or shall be produced by the system itself. The form of the compliance statement shall be:
"This system complies with the requirements of IEC 61131-3, for the following language features:", followed by a set of compliance tables ..."

The table numbers must correspond to the respective standard properties.

2. Standards Compliance in STEP 7

The programming languages of SIMATIC STEP 7 meet the requirements of IEC 61131-3:

• **Instruction List**	**AWL/STL**	**(corresponds to the IEC 61131-3 language "AWL/IL")**
• **Ladder Logic**	**KOP/LAD**	**(corresponds to the IEC 61131-3 language "KOP/LD")**
• **Function Block Diagram**	**FUP/FBD**	**(corresponds to the IEC 61131-3 language "FUP/FBD")**
• **Structured Control Language**	**SCL**	**(corresponds to the IEC 61131-3 language "ST")**
• **S7-GRAPH**		**(corresponds to the IEC 61131-3 language "AS/SFC")**

in the characteristics described in the following Chapter 4 and in the appendices.

3. Substitutes and Additional Language Elements

In addition, the standard stipulates that a standardized PLC system

a) may not include any substitute or additional language elements to attain a standardized characteristic, except if they are treated as described in e), f).
b) has specified all implementation-dependent parameters according to *Annex D* in a document.
c) reports user errors from *Annex E*. (for a partial program check, reference must be made to incompleteness)
d) reports user errors during converting and/or during start-up, and specifies or introduces appropriate measures.
e) All characteristics not permissible or not present in the standard must be described as "expansions" in a document.
f) treats these expansions in the same way as is specified for errors (as a test that can be used as an option)
g) All implementation-independent characteristics from *Annex D* must be handled as is specified for errors (as a test that can be used as an option)
h) No standardized names with meanings that vary can be used for manufacturer-defined characteristics.
i) The formal syntax of the text languages is described according to *Annex A* in a document.
j) shall be capable of reading and writing files containing any of the language elements defined as alternatives in the production library_element_declaration in B.0, in the syntax defined in requirement i) above, encoded according to the "ISO-646 IRV" given as Table 1 - Row 00 of ISO/IEC 10646 1.

The STEP 7 programming software meets the requirements of the standard in points b), c), d), e), h), i), j). In respect to a), there exist language elements for compatibility reasons with STEP 5, which might be taken for additional elements. The f) and g) requirements are not used for STEP 7.

4. Elements Realized According to the Standard

The standard defines all standardized language elements in tables, the rows of which reference the realized feature by number.
The language elements which are realized in STEP 7 according to the standard are specified below.

(A good knowledge of the norm mentioned is a prerequisite for understanding the following tables.
The German version **DIN IEC 61131-3 : 2003-12 (2nd Edition)** is available at Beuth Verlag GmbH, 10787 Berlin, Fax (030) 2601-1260.)

4.1 Common Elements

Table	No.	Language Elements
1	**Character set features**	
	2	Lower case characters
	3a	Number sign
	3b	Pound sign
	4a	Dollar sign
	4b	Currency sign
	5a	Vertical bar
	5b	Exclamation mark
2	**Identifier features**	
	1	Upper case and numbers
	2	Upper and lower case, numbers, embedded underlines
	3	Upper and lower case, numbers, leading and embedded underlines
3	**Comment features**	
	1	Comment

Note: STL only line comments starting with // and ending with new line

4 **Numeric literals**

1	Integer literals
2	Real literals
3	Real literals with exponents
4	Base 2 literals
5	Base 8 literals (SCL only)
6	Base 16 literals *)
7	Boolean digits 0/1 (SCL only)
8	Boolean FALSE and TRUE

Note *): bit length required: W#16#ADAC, DW#16#ADAC_4711

5 **Character string literals**

1	Single-Byte character string
3	single byte typed string literals

Note: corresponds to data type char#

6 **Two-character combinations in character strings**

2	$$
3	$'
4	$L or $l
5	$N
6	$P or $p
7	$R or $r
8	$T or $t

7 **Duration literals**

1a	without underlines: short prefix
1b	long prefix
2a	with underlines: short prefix
2b	long prefix

8 **Date and time of day literals**

1	Date literals (long prefix)
2	Date literals (short prefix)
3	Time of day literals (long prefix)
4	Time of day literals (short prefix)
5	Date and time literals (long prefix)
6	Date and time literals (short prefix)

10 **Keywords**

1	BOOL
2	SINT
3	INT
4	DINT
6	USINT
7	UINT
8	UDINT
10	REAL
11	LREAL
12	TIME
13	DATE
14	TIME_OF_DAY or TOD
15	DATE_AND_TIME or DT
16	STRING *)
17	BYTE
18	WORD
19	DWORD

*): STRING [n] with length n; otherwise 254 bytes

12 **Data type declaration**

5	Combined data types *)

*): data types have to be declared individually.

14 **Declaration of data type initial value**

5	Initialization of elements from combined data types

15 **Memory location and size prefix features for directly represented variables**

1	I or E	depending on the language setting
2	Q or A	depending on the language setting
3	M	
4	X *)	
5	none	
6	B	
7	W	
8	D	

Note *): for DB only

16 a **Keywords for variable declarations**

VAR, VAR_INPUT, VAR_OUTPUT, VAR_IN_OUT, VAR_TEMP according to IEC 61131-3

17 **Assignment of types to variables**

5	Automatic memory allocation of symbolic variables, *) see note in table 10
6	Array declaration
7	Declaration of retentive array declaration
8	Declaration for structured variable

18 **Assignment of initial values for variables**

5	Initialization of symbolic variables, *) see note in table 10
6	Array initialization
7	Declaration and initialization of retentive array declaration
8	Initialization for structured variable

19 **Graphical negation of Boolean signals**

1	negated Input	(FBD only)
2	negated Output	(FBD only)

19 a **Textual invocation of functions for formal and non-formal argument list**

1	formal

20 **Use of EN input and ENO output**

1	Use of "EN" and "ENO" with LAD/FBD For FBD: see footnote a)

20 a **Function features**

1	Variable declaration (textual)

21 **Typed and overloaded functions**

Overloaded functions (SCL only)

2	Typed functions

22 **Type conversion function features**

1	*_TO_**
2	TRUNC
3	BCD_TO_** (not for SCL)
4	*_TO_BCD (not for SCL)

23 **Standard functions of one numeric variable**

1	ABS	
2	SQRT	
3	LN *)	
4	LOG	(SCL only)
5	EXP	
6	SIN *)	
7	COS *)	
8	TAN *)	
9	ASIN *)	
10	ACOS *)	
11	ATAN *)	

Note *): The implementation of these functions is CPU specific.

24 **Standard arithmetic functions**

12	ADD +
13	MUL *
14	SUB -
15	DIV /
16	MOD
17	EXPT
18	MOVE :=

Note: All functions with FBD/LAD are typed (e.g. integer).

25 **Standard bit shift functions**

1	SHL
2	SHR
3	ROR
4	ROL

Note: All functions are typed (e.g. word).

26 **Standard bitwise Boolean functions**

5	AND
6	OR
7	XOR
8	NOT

27 **Standard selection functions**

1	SEL	Binary selection
2a	MAX	Expandable maximum
2b	MIN	Expandable minimum
3	LIMIT	Limiter
4	MUX	Expandable multiplexer

28 **Standard compare functions**

5	GT	>
6	GE	>=
7	EQ	=
8	LE	<=
9	LT	<
10	NE	<>

Note: All functions with FBD/LAD are typed (e.g. INT).

29 **STRING data type functions**

1	LEN
2	LEFT
3	RIGHT
4	MID
5	CONCAT
6	INSERT
7	DELETE
8	REPLACE
9	FIND

Note: The implementation of these functions is CPU specific.

30 **TIME data type functions**

1a	ADD or + (SCL only)
1b	ADD_TIME
2	ADD_TOD_TIME
3	ADD_DT_T
4	SUB_TIME
6	SUB_TOD_TIME
8	SUB_DT_T
12	CONCAT_D_TOD

Note: The implementation of these functions is CPU specific.

33 **Function block declaration**

1a	RETAIN identifier for internal variables
2a	RETAIN identifier for output variables
2b	RETAIN identifier for input variables
3a	RETAIN identifier for internal function blocks
4a	VAR_IN_OUT declaration (textual)
11	VAR_TEMP declaration

34 **Standard bistable function blocks**

1	SR
2	RS

35 **Standard edge detection function blocks**

1	R_TRIG	Rising edge detector	(P_TRIG)
2	F_TRIG	Falling edge detector	(N_TRIG)

36 **Standard Counter function blocks**

1a	CTU	(Up-counter)
1b	CTU_DINT	(Up-counter)
1d	CTU_UDINT	(Up-counter)
2a	CTD	(Down-counter)
2b	CTD_DINT	(Down-counter)
2d	CTD_UDINT	(Down-counter)
3a	CTUD	(Up/Down-counter)
3b	CTUD_DINT	(Up/Down-counter)
3d	CTUD_UDINT	(Up/Down-counter)

37 **Standard timer function blocks**

1	TP	(Pulse)
2a	TON	(On-delay)
3a	TOF	(Off-delay)

50 1-5 **Tasks**

STEP7 offers tasks as organization blocks (OBs)
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4.2 S7-GRAPH Elements (Sequential Function Chart, SFC)

Table	No.	Language Elements	
40	**Step**		
	1	Graphical:	Step, initial step
	2	Textual: *	Step, initial step
	3a	Step marker - general	
	3b	Step marker - direct connection	
	4	Elapsed step time	

Note *): Textual: *.GR7

41 **Transitions and transition conditions**

2	Condition in LAD
3	Condition in FBD
5	Condition in text form
7d	Name

42 **Declaration of actions**

1	Random Boolean variable

43 **Assignment step/action**

1	Action block
2	Sequential actions
3	Step body in text form

44 **Action block features**

1	"a": Identifier
2	"b": Action name

45 **Identifiers for actions**

2	N
3	R
4	S
5	L
6	D

Note: Detailed information - see S7-Graph.
S7-Graph offers additional identifiers of actions with conditions.

45a **Action control features**

2 Without "last run"

46 **Sequential run**

1	Simple sequence
2a	Branching with sequence selection
3	Combination of sequence selection
4	Simultaneous sequences: branching/combination
5a	Sequence jump
6a	Sequence loop
7	Direction arrows

Note: Sequence loop implemented with language element "Jump", i.e. no graphical representation. Direction arrows not required because processing always takes place from top to bottom and on the same level from left to right.

47 **Compatibility of sequence chain features**
Not relevant, because only a summary of preceding tables

48 **Minimum requirements of standard compliance**
The requirements for standard compliance according to table 48 are met for graphical representation.

4.3 Configuration Elements

50 **Tasks**

1-5 STEP7 offers tasks as organization blocks (OBs)

4.4 Language: Instruction List (IL)

Preliminary remark to no. 52:
The main deviation of IL in STEP7 from the standard is the deviating command syntax (see no. 52). This deviation has been accepted to meet the compatibility requirements for IL with previous software versions.
IL includes many more commands than specified in the basic command list of the standard.

Table	No.	Language Elements
52	**Operators**	
	1-21	Note: different syntax, same functionality
53	**Function block call in IL**	
	1-3	CAL with list of input parameters, with load / save of input parameters, use of input operators
	3	Use of input operators *)

Note: different syntax, same functionality

4.5 Language: SCL (Structured Text ,ST)

Table	No.	Language Elements	
55	**Operators of ST language**		
	1	Parentheses	( )
	2	Function processing	
	3	Exponentiation	**
	4	Negation	-
	5	Complement	NOT
	6	Multiplication	*
	7	Division	/
	8	Modulo	MOD
	9	Addition	+
	10	Subtraction	-
	11	Comparison	<, >, <=, >=
	12	Equality	=
	13	Inequality	<>
	14	Boolean AND	&, AND
	16	Boolean exclusive OR	XOR
	17	Boolean OR	OR
56	**Instructions of ST language**		
	1	Assignment	
	2	Function block call and use of FB output	
	3	RETURN	
	4	IF	
	5	CASE	
	6	FOR	
	7	WHILE	
	8	REPEAT	
	9	EXIT	
	10	Empty instruction	

4.6 Common Graphical Elements

Table	No.	Language Elements
57	**Representation of lines and blocks**	
	Horizontal lines:	
	1	ISO 646 "minus" character
	2	Graphic or semigraphic
	Vertical lines:	
	3	ISO 646 "vertical line" character
	4	Graphic or semigraphic
	Horizontal/vertical connection:	
	5	ISO 646 "plus" character
	6	Graphic or semigraphic
	Blocks with connecting lines:	
	11	ISO 646 characters
	12	Graphic or semigraphic

58	**Graphic execution control elements**	
	2	Unconditional jump LAD
	3	Conditional jump FBD
	4	Conditional jump LAD
	5	Conditional return LAD
	6	Conditional return FBD
	7	Unconditional return
	Note: in LAD represented as coils	

4.7 Language: Ladder Diagram (LD)

Table	No.	Language Elements
59	**Power rail symbols**	
	1	Left power rail
	2	Right power rail
60	**Link element symbols**	
	1	Horizontal link
	2	Vertical link
61	**Contacts**	
	1	Normally open contact
	3	Normally closed contact
	5	Contact for positive edge detection
	7	Contact for negative edge detection
62	**Coils**	
	1	Coil
	2	Negated coil
	3	SET coil (latch)
	4	RESET coil (unlatch)
	8	Coil for positive edge detection
	9	Coil for negative edge detection

ANNEX A - Syntax

see IL and SCL online help.

ANNEX D - Implementation-dependent Parameters

Below you will find the parameters for the language elements defined in the standard and the limits realized in STEP 7.

IEC Reference	Parameters	STEP 7
1 General	Error handling procedures	see Annex E
2 Common elements	National characters used # or "pounds Sterling" sign # or "currency" sign | or !	Yes
	Maximum length of identifiers	128
	Maximum comment length	Network comment max. 64 kB Operand comment > 2000 characters
	Range of values of duration	- 24D_20H_31m_23.648s to + 24D_20H_31m_23.647s
2.3 Data types	Range of values for variables of TIME type	- 24D_20H_31m_23.648s to + 24D_20H_31m_23.647s
	Precision of representation of seconds in TIME_OF_DAY and DATE_AND_TIME	milliseconds
	Maximum number of array subscripts Maximum array size Maximum number of structure elements Maximum structure size Maximum number of variables per declaration	1 Max. 65536 elements dependent on memory limit and data type not available ca. 2000 (estimate)
	Maximum number of enumerated values Default maximum length of STRING variables Maximum permitted length of STRING variables	not available 254 254
2.4 Variables	Maximum number of hierarchical levels Logical or physical mapping	2 physical mapping
	Maximum number of subscripts Maximum range of subscript values Maximum number of structure levels	1 65536 entries 1
	Initialization of system inputs	System: 0 User: definable initial values
	Maximum number of variables per declaration	ca. 2000 (estimate)
2.5 Program organization units	Information to determine execution times of program organization units	not available
	Maximum number of function specifications	dependent on operation and PLC
	Maximum number of inputs for expandable functions	> 32
	Effects of type conversions on accuracy	not available
	Accuracy of functions of one variable Implementation of arithmetic functions	IEEE floating point up to 64 bit

IEC Reference	Parameters	STEP 7
	Maximum number of function block specifications and instantiations	dependent on CPU 128 to 65536
	PVmin, PVmax of counters	dependent on counter data type (up to UDINT)
	Program size limitations	dependent on the PLC memory and used operations per block
2.6 Sequential Function Chart (SFC)	Effects of elements on timing for execution control Transferability Accuracy of elapsed step time	 1 ms
	Maximum number of steps per SFC and per step	250
	Maximum number of transitions per SFC and per step	250
	Control mechanism actions with the exception of "saved and delayed"	All identifiers
	Maximum number of actions per step	100
	Graphical display of step status	Colors selectable
	Transition switch time	< 10 ms
	Maximum width of branching/ combination	8 parallel / alternative branches in 8 sequences (64)
2.7 Configuration Elements	Contents of RESOURCE library	Integrated functions Integrated functions / FB and FC
	Maximum number of tasks Task interval resolution	not available
3.3 Structured Text (ST)	Maximum expression length	No limit
	Partial evaluation of Boolean expressions	No
	Maximum instruction length	No limit
	Maximum number of CASE selectors	No limit
	Value of control variables when ending FOR loop	Final value +1
4 Graphical languages	Graphical/semigraphical display limit Network topology	Graphical
	Evaluation sequence of feedback loops	not available

ANNEX E - Error Conditions

Below you will find the error conditions named in the standard and when these occur in STEP 7.

Error conditions	LAD/FBD	ST (SCL) expansions only
Value of a variable exceeds the specified subrange	at run time	
Length of initialization list does not match number of array entries	at compilation time	
Improper use of directly represented or external variables in functions	at compilation time	
Type conversion errors	at compilation time	
Numerical result exceeds range for data type Division by zero	at run time system flags	At run time: Evaluation ENO bit
Mixed input data types to a selection function Selector (K) out of range for MUX function	at compilation time	
Invalid character position Result exceeds maximum string length	at run time	
Result exceeds range for data type	Request system flag	At run time: Evaluation ENO bit
Data type conflict in VAR_ACCESS	not available	
Task requires too many processor resources Execution deadline not met Other task scheduling conflicts	not available	
Numerical result exceeds range for data type	Request system flag	At run time: Evaluation ENO bit
Division by zero Invalid data type for function	Request system flag	At run time: Evaluation ENO bit
Return from function without value assigned	at compilation time	
Iteration fails to terminate	at run time	
Same identifier used as connector label and element name	Not possible error message during compilation	
Un-initialized feedback variable	not available	
S7-Graph error behavior		
Zero or more as initial step in SFC network,	Zero initial steps> compiler message max.8 initial steps possible	
User program attempts to alter step status or step time	No error message when changing step status or step time	
Simultaneously satisfied, non-prioritized transitions in a selection branch	Prioritized transitions not possible	
Side effects when evaluating transition condition	No, message during compilation	
Action control error	SD missing, therefore no message	
"Unsafe" or "unattainable" SFC	Message during editing/compilation	
Data type conflict in VAR_ACCESS	not available	
Task requires too many processor resources		
Execution deadline not met		
Other task scheduling conflicts		