

SIEMENS



SIPROTEC 5 Application Note

Phasor Measurement Unit in SIPROTEC 5

SIP5-APN-037, Edition 1

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SIPROTEC 5 – Application Notes

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SIP5-APN-037, Edition 1

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1 Phasor Measurement Unit in SIPROTEC 5

1.1 Introduction

Phasor Measurement Units (PMUs) make a valuable contribution to the dynamic monitoring of transient processes in energy supply systems. The advantage over standard RMS values is for one thing that the phasor values of current and voltage are transmitted. Secondly, each measured value includes the exact time stamp and therefore should be assigned within the transmission path in which it originates independent of the time delay. The phasors and analog values are transmitted by the PMU with a configurable repetition rate (reporting rate). Due to the high-precision time synchronization (via GPS), the measured values from different substations that are far removed from each other are compared, and conclusions about the system state and dynamic events, such as power fluctuations, are drawn from the phase angles and dynamic curves. The PMU function transmits its data via an integrated Ethernet module using a standardized protocol IEEE C37.118. The evaluation can be done with a Wide Area Monitoring System e.g. with SIGUARD PDP (Phasor Data Processor).

1.2 Definition

A Phasor Measurement Unit (PMU) measures the phasor values of current and voltage, as well as the values of power frequency and rate of change of frequency (ROCOF). This data will be combined with high precision time stamp.

The measured data are transmitted to a central analysis station (Phasor Data Concentrator, PDC) in accordance to the standardized transmission protocol IEEE C37.118.

A PMU can be a stand-alone physical unit or a functional unit within another physical unit.

Total Vector Error (TVE)

The TVE describes the error between the actual and the measured values of the input signal of the PMU device.

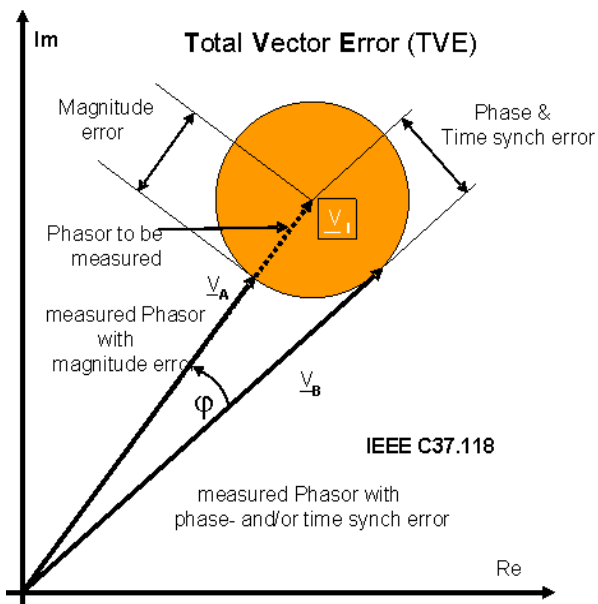


Figure 1: Total Vector Error (TVE)

Both amplitude and phase angle error have to be considered for synchrophasor accuracy.

In the Standard IEE C37.118 the allowed TVE is limited to 1%. The standard IEEE C37.118 defines 2 performance classes, Class P and Class M of the PMU device. We recommend the setting: "P class" to secure at dynamic event a save and exact recording. P class is intended for applications requiring fast response.

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1.3 Structure of the Function Group in SIPROTEC 5

The PMU function group is activated by selecting the protocol IEEE C37.118PMU on an Ethernet module (electrical or optical).

The PMU obtains the measured values from the measuring points and the precise time from time synchronization.

The time-stamped synchrophasors for current and voltage are formed from this and transferred together with additional values via the communication module to a server (PDC, Phasor Data Concentrator).

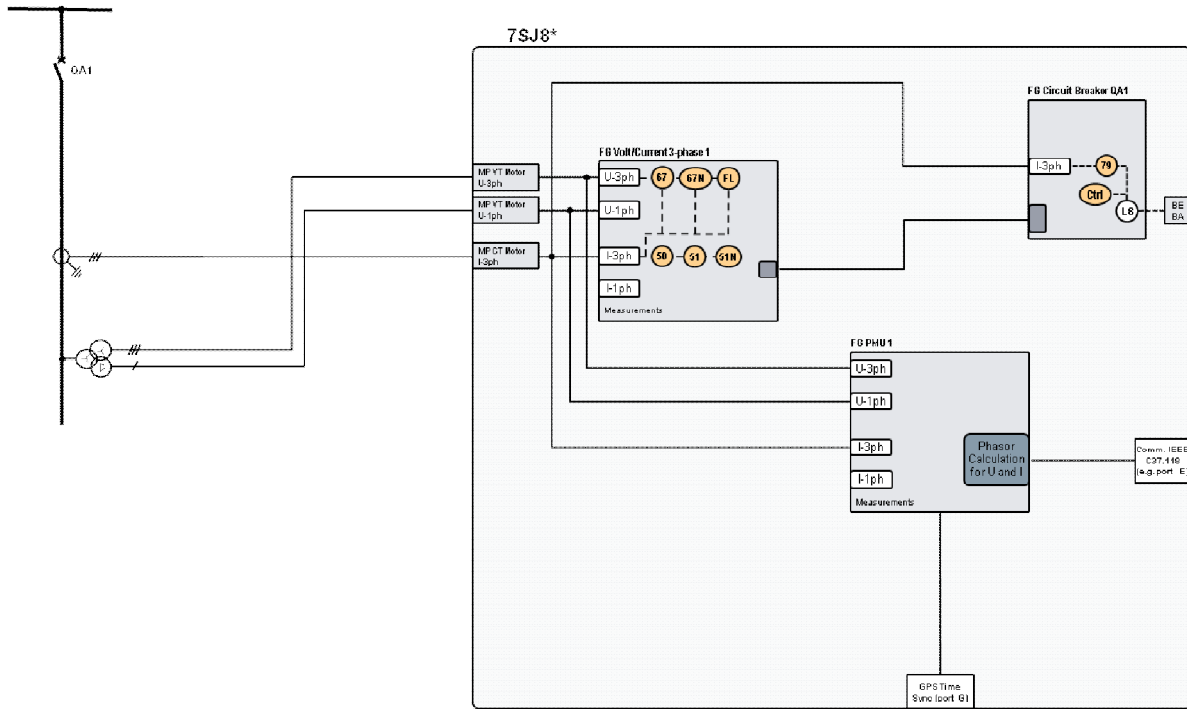


Figure 2: Function Group PMU as Part of SIPROTEC5 (7SJ8* in one feeder application)

The maximum number of measuring points that can be routed to one function group PMU are: 2 x U-3ph, 2 x I-3ph, 2 x U-1ph, 2 x I-1ph

Each Function Group PMU needs a related Communication module to run the C37.118 protocol.

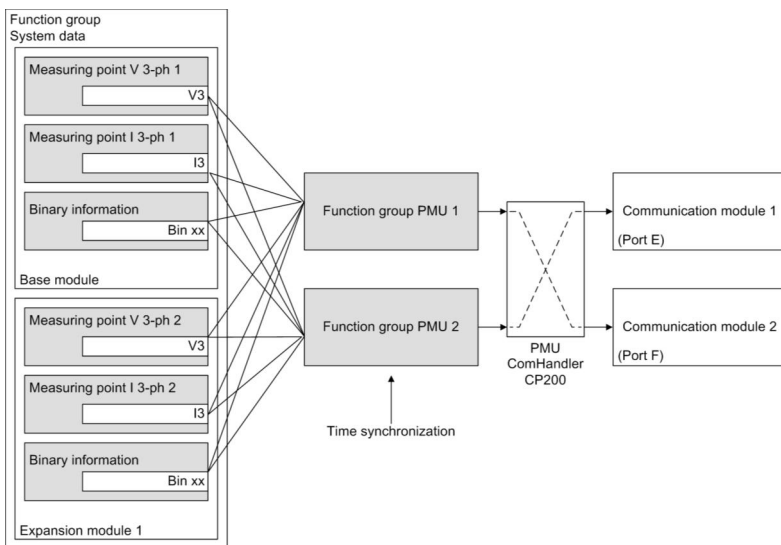


Figure 3: Structure/Embedding of the Function

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Or with other words: one (1) Function Group PMU can serve CT & VT measurement of two (2) feeders.

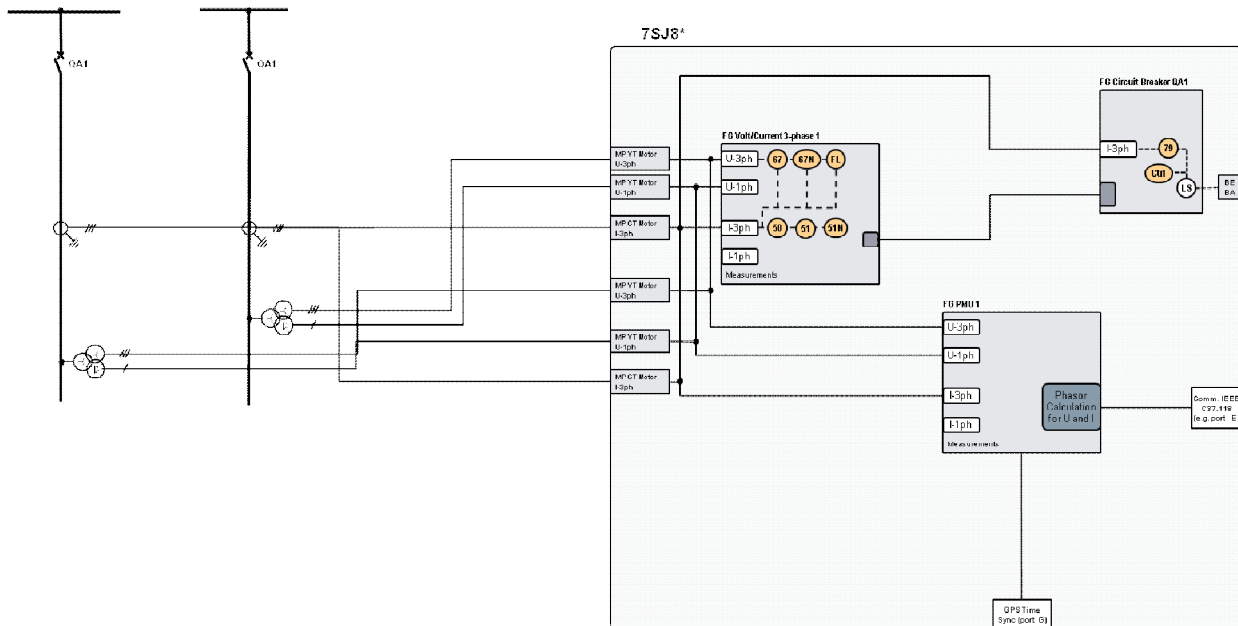


Figure 4: Application; Two (2) feeder on one Function Group PMU in 7SJ8* SIPROTEC5

If you like to measure phasors at more than two feeders in a substation you need to select an expanded version of SIPROTEC 5 device.

In case of three feeders you need an additional expansion module with analog measuring inputs, one additional FG PMU and the related C37.118 communication module (e.g. in port F).

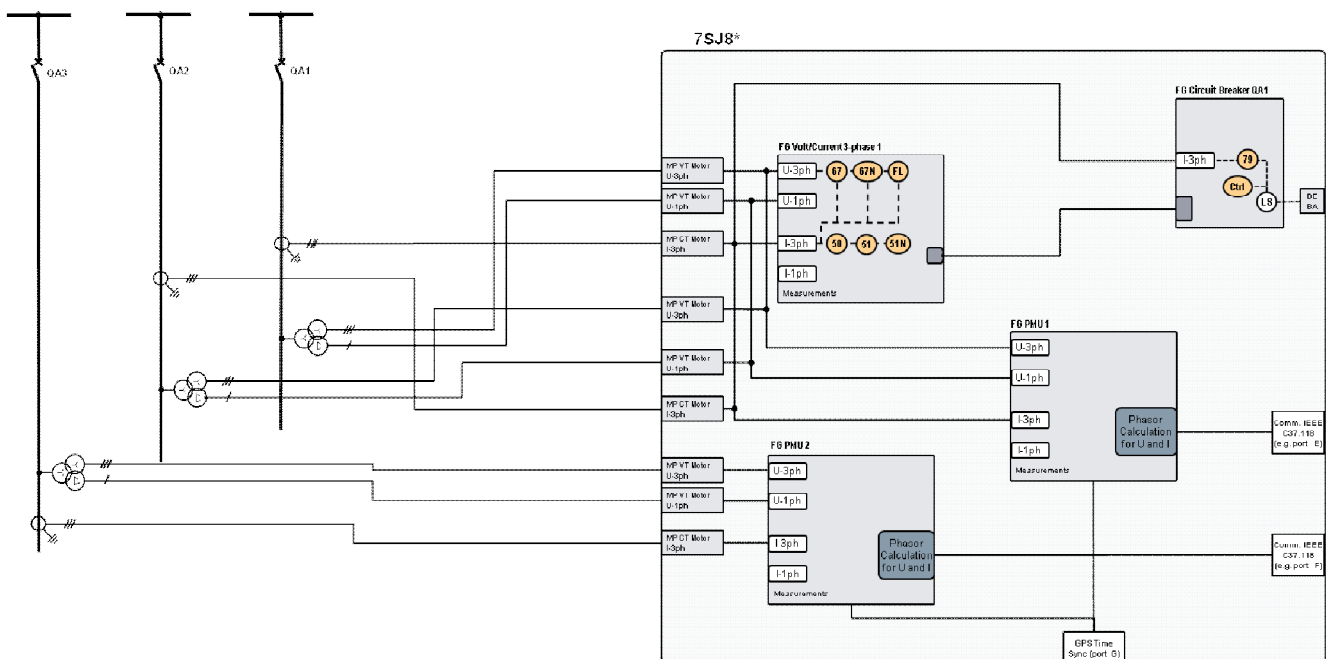


Figure 5: Application; Three (3) feeder on two Function Groups PMU in 7SJ8* SIPROTEC5

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1.4 Selection of SIPROTEC 5 device

The selection of the proper device is done in the online SIPROTEC 5 Configurator tool.

You will find the SIPROTEC 5 Online Configurator on our INTERNET page

<http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/Protection/Pages/overview.aspx>.

Siemens colleagues please have a look to INTRANET page:

https://intranet.for.siemens.com/org/smart-grid/en/about/ea/about/organisation/EA_PRO/Pages/PRO.aspx

1.4.1 Basic

After open the tool please select the preferred Product Group and Device Type.

That can be any SIPROTEC 5 device. For cost optimized version the recommended standard is 6MD85.

In this paper I have used Overcurrent protection 7SJ85, which is an expandable version.

The simplest version is the Standard Variant S1 with 11 binary inputs, 9 binary outputs, 4 CT and 4 VT. That allows phasor measurement on one feeder.

To determine the necessary function point you select an application template, e.g. Non-directional OC (4*I, 4*U), scroll down in the table and choose 1 x PMU.

The FG PMU needs 40 function points.

Click to: *Apply* and *Next* and again *Next*.

As mentioned above each FG-PMU needs a Ethernet communication module with the protocol selection IEEE C37.118-PMU.

You need to select this Plug-in module on position E by click on the relevant pull down menu.

Following communication modules support synchrophasors:

- ETH-BA-2EL (2 x Ethernet electric, RJ45)
- ETH-BB-2FO (2 x Ethernet optical, 2 km, LC duplex).

Please select one of them.

Click to: *Next*.

If you don't look for special housing type please click to: *Show Result*.

The configuration is finished.

Together with selected data a picture of the front plate and the Short as well as the Long Code are displayed.


NOTE:

It is recommended to store this result as pdf File (see Figure 6).

SIEMENS
SIPROTEC 5
Configuration
May 20, 2016 2:10 PM

Device: 7SJ85 Overcurrent Protection

Product code
 Short: P1J198448
 Long: 7SJ85-DAAA-AA0-0AAAA0-AED111-12111B-BAA000-000AC0-CB1BA1



Housing width:	2/6 x 19"
Housing type:	Flush mounting
Binary inputs:	11
Binary outputs:	9 Relays (3 Standard, 6 Fast, 0 High-Speed, 0 Power)
Current transformers:	4 for protection, 0 for measurement and sensitive ground-current detection
Voltage transformers:	4
Measuring-transducer inputs:	0 (20 mA or 10 V, fast)
CPU:	CP300
Modules in 19" row 1:	IO202 , PS201
Modules in 19" row 2:	
Number of LEDs:	16
Operation Panel:	Integrated
Key switch:	Without
Display type:	Small display
Front Design:	Standard
Power Supply:	DC 60 V-250 V, AC 100 V-230 V

Communication/Plug-in modules:

Communications encryption:	Normal
Integrated Ethernet port J:	for DIGSI 5
Plug-in module position E:	ETH-BB-2FO: 2 x optic Ethernet 100 Mbit/s, 1300 nm, LC-Duplex connector, 2 km over 50/125 µm or 62,5/125 µm multimode - fiber
Plug-in module position F:	Port is available but not assembled

Functions:

Function points class:	Base + 40 function points
------------------------	---------------------------

Note on function-points class
 The function-points class results from the sum of the function points of the selected functions. You can apply these functions as selected. The device allows also each other selection of functions as long as the sum of the required

Figure 6: Result of 7SJ85 configuration for phasor measurements on one feeder

1.4.2 Extensions

In case you would like to measure phasors in a second feeder, the following is necessary.

For the 2nd feeder you need to add an expansion module e.g. IO202 with necessary analog inputs (4*I, 4*U) to the selected basic type.

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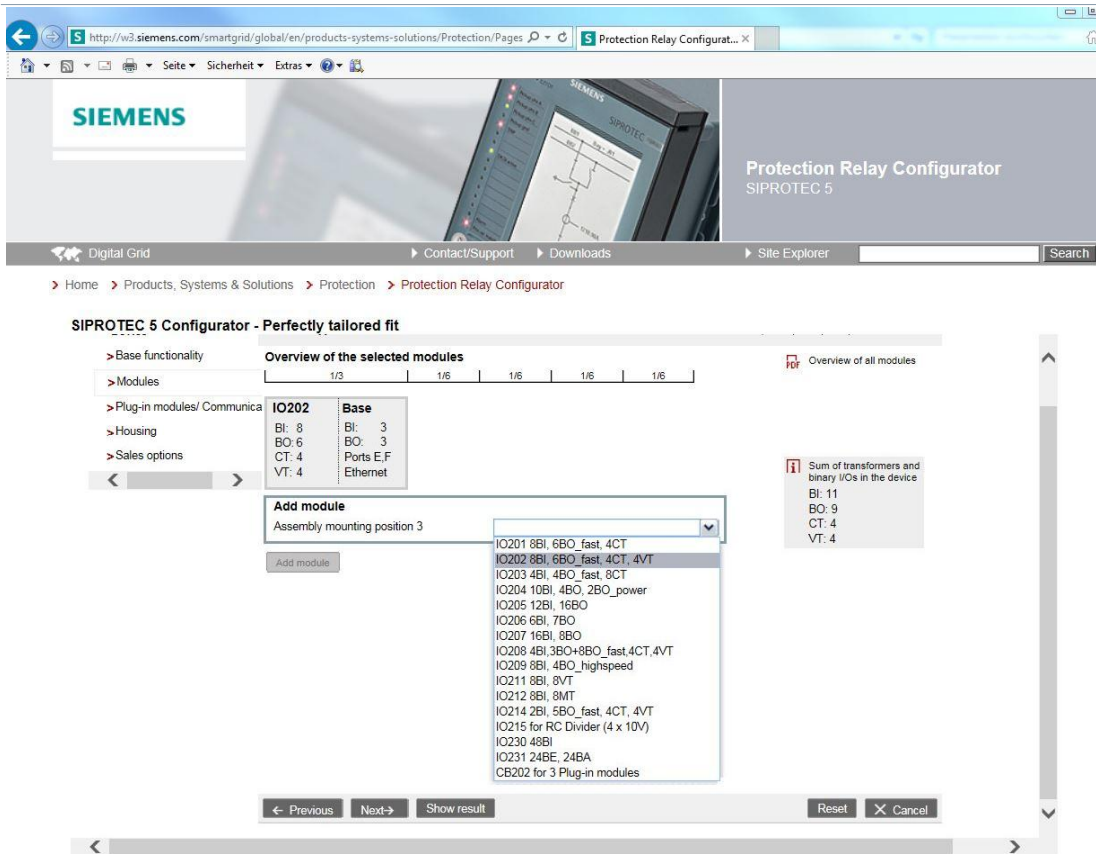


Figure 7: Selection of IO module

The additional measuring inputs will be connected in DIGSI 5 to the existing Function group FG-PMU.

The new devices result is:

SIEMENS
SIPROTEC 5
Configuration
May 20, 2016 2:29 PM

Device: 7SJ85 Overcurrent Protection

Product code
Short: P1J228705
Long: 7SJ85-DAAA-AA0-DAAAA0-AED111-12111B-BAA000-000AC0-CB1BA1-CB1



Housing width:	3/6 x 19"
Housing type:	Flush mounting
Binary inputs:	19
Binary outputs:	15 Relays (3 Standard, 12 Fast, 0 High-Speed, 0 Power)
Current transformers:	8 for protection, 0 for measurement and sensitive ground-current detection
Voltage transformers:	8
Measuring-transducer inputs:	0 (20 mA or 10 V, fast) 0 (20 mA)
CPU:	CP300
Modules in 19" row 1:	IO202 , PS201 , IO202
Modules in 19" row 2:	
Number of LEDs:	18
Operation Panel:	Integrated
Key switch:	Without
Display type:	Small display
Front Design:	Standard
Power Supply:	DC 60 V-250 V, AC 100 V-230 V

Communication/Plug-in modules:

Communications encryption:	Normal
Integrated Ethernet port J:	for DIGSI 5
Plug-in module position E:	ETH-BB-2FO: 2 x optic Ethernet 100 Mbit/s, 1300 nm, LC-Duplex connector, 2 km over 50/125 µm or 62,5/125 µm multimode - fiber
Plug-in module position F:	Port is available but not assembled

Functions:

Function points class:	Base + 40 function points
------------------------	---------------------------

Note on function-points class
The function-points class results from the sum of the function points of the selected functions. You can apply these functions as selected. The device allows also each other selection of functions as long as the sum of the required

Figure 8: Selection of 7SJ85 with PMU function for 2 feeders

1.5 Substations with more than two feeders

If you like to measure; e.g. in three (3) feeders you need to extend the hardware as follows.

Open the SIPROTEC 5 Online Configurator as described above.

Select e.g. Overcurrent Protection 7SJ85 with Standard Variant S1, Application template: Non-directional OC (4*I, 4*U).

Attention!

Now you need to select two (2 x) FG-PMU in the table; which will cost 80 function points. Due to the function class system it is rounded up to 100 function points (20 points spare).

Furthermore you need two (2x) expansion modules (IO202) which provides the necessary current and voltage measurement inputs.

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Related to the second FG-PMU you need to select also one more Ethernet communications modules (e.g. ETH-BB-2FO: 2 x optic Ethernet).

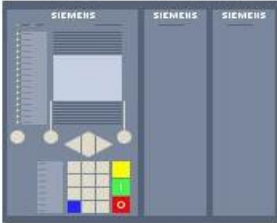
One module is inserted on position E and the other on position F.

The result is as following.

SIEMENS
SIPROTEC 5
Configuration
May 20, 2016 2:50 PM

Device: 7SJ85 Overcurrent Protection

Product code
Short: P1J256867
Long: 7SJ85-DAAA-AA0-0AAAA0-AH0111-12111B-BBB000-000AC0-CB1BA1-CB1CB1



Housing width:	4/8 x 19"
Housing type:	Flush mounting
Binary inputs:	27
Binary outputs:	21 Relays (3 Standard, 18 Fast, 0 High-Speed, 0 Power)
Current transformers:	12 for protection, 0 for measurement and sensitive ground-current detection
Voltage transformers:	12
Measuring-transducer inputs:	0 (20 mA or 10 V, fast) 0 (20 mA)
CPU:	CP300
Modules in 19" row 1:	IO202 , PS201 , IO202 , IO202
Modules in 19" row 2:	
Number of LEDs:	16
Operation Panel:	Integrated
Key switch:	Without
Display type:	Small display
Front Design:	Standard
Power Supply:	DC 60 V-250 V, AC 100 V-230 V

Communication/Plug-in modules:

Communications encryption:	Normal
Integrated Ethernet port J:	for DIGSI 5
Plug-in module position E:	ETH-BB-2FO: 2 x optic Ethernet 100 Mbit/s, 1300 nm, LC-Duplex connector, 2 km over 50/125 µm or 62,5/125 µm multimode - fiber
Plug-in module position F:	ETH-BB-2FO: 2 x optic Ethernet 100 Mbit/s, 1300 nm, LC-Duplex connector, 2 km over 50/125 µm or 62,5/125 µm multimode - fiber

Functions:

Function points class:	Base + 100 function points
------------------------	----------------------------

Note on function-points class

Figure 9: 7SJ85 with PMU for 3 Feeder

1.6 GPS Time Synchronization

To secure high precise time synchronization you need to connect the related signal to terminal G of your device.

This selection corresponds to above mentioned example in Figure 1.

Synchronization accuracy is affected by a GPS timer and the precise correction of the time delay within the GPS receiver module, as well as by the optimal setup of the GPS antenna.

The GPS time synchronization unit 7XV5664-1AA00, together with Sync-Transceiver 7XV5654 and prepared cable with plugs, is a comprehensive solution for time synchronization of SIPROTEC 5 devices with PMU function.

The transmission of the time signals (telegram or impulse) takes place, immune to disturbances and over long distances, via a FO cable to the protection cubicles. A sync-transceiver converts the optical signals into electrical signals (< 200 ns delay).

The 7XV5664-1AA00 supports protocols like IRIG-B which is required to be used for the synchronization of SIPROTEC 5 – PMU devices.



Figure 10: GPS Time Synchronization Receiver (Meinberg)

The GPS-antenna has to be mounted with a free view to the whole sky, on the top of a roof or an outside wall. Within the antenna cable, the lightning protector has to be mounted close to the antenna. The GPS time synchronization unit can be connected to usual AC supply or a station battery.

1.7 Standard Application, Time Synchronization of SIPROTEC 5 / PMU

Using the GPS Time Synchronization Unit 7XV5664-1AA00, the internal time of all connected protection devices can be synchronized.

IRIG-B is the preferred telegram for SIPROTEC 5.

The IRIG-B telegram signal has to be connected to the SIPROTEC5 time sync terminal G.

The transmission of the time telegrams or synchronizing impulses takes place via optical outputs, immune to interference with FO cable to the protection devices, distributed in the substation.

For the conversion of the FO signals to 24 V signals as required by the SIPROTEC time synchronization interfaces, Sync-Transceivers 7XV5654 are implemented (for details please have a look to the Sync-Transceivers 7XV5654 manual).

The connection between SIPROTEC 5 devices and Sync- Transceiver 7XV5654 is made by specially designed bus cable system 7XV5104 (see figure 10).

Note: No bus termination resistance is required here.

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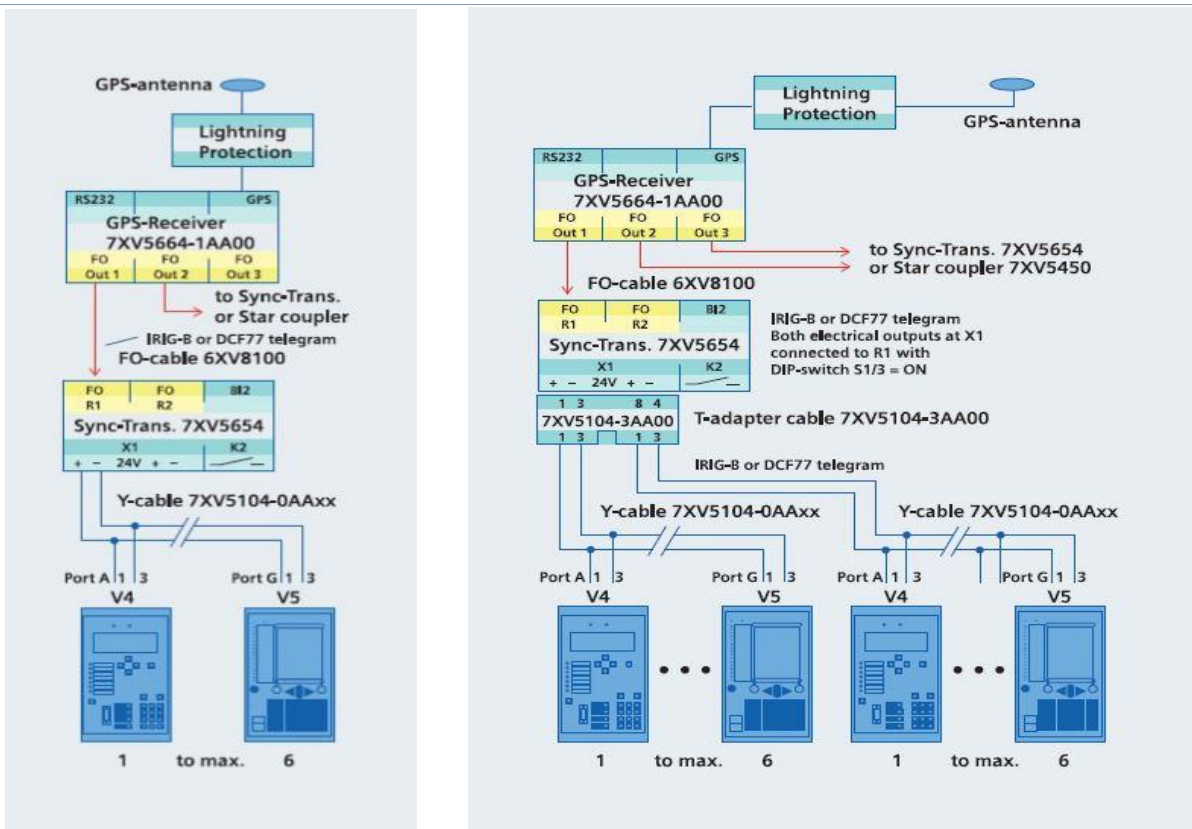


Figure 11: SIPROTEC 4/5 protection devices with IRIG-B or DCF77 time synchronization

Devices of type SIPROTEC 5 (port G) (and SIPROTEC 4 (port A)) are connected via channel R1 of Sync Transceiver 7XV5654 to optical port "Out 1" of the GPS time synchronization unit.

It is possible with a T-plug a bus cable system 7XV5104 to connect up to 6 IEDs.

Due to its highly precise abilities, the GPS Time Synchronization Unit 7XV5664-1 is able to send the IRIG-B C37.118 telegram in an extended high quality, which is amust for the PMU applications.

For detailed information please have a look to SIPROTEC 5 manual e.g. chapter 10.10 of 7SJ85 (C53000-G5040-C017-5).

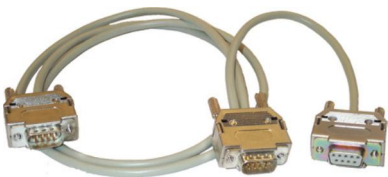


Figure 12: 7XV5104-0AAxx Y-Bus cable (RS485 bus system)

By using Y-Cable 7XV5104-0AAxxx (Fig. 11) the configuration of connected devices can be done in different ways, e.g. by selecting 7XV5104-0AA10 (10m length) in a chain topology you may reach a total distance of up to 60m between PMU device and sync transceiver.

The other possibility is to locate sync transceiver in the middle and connect PMU devices to both sides.

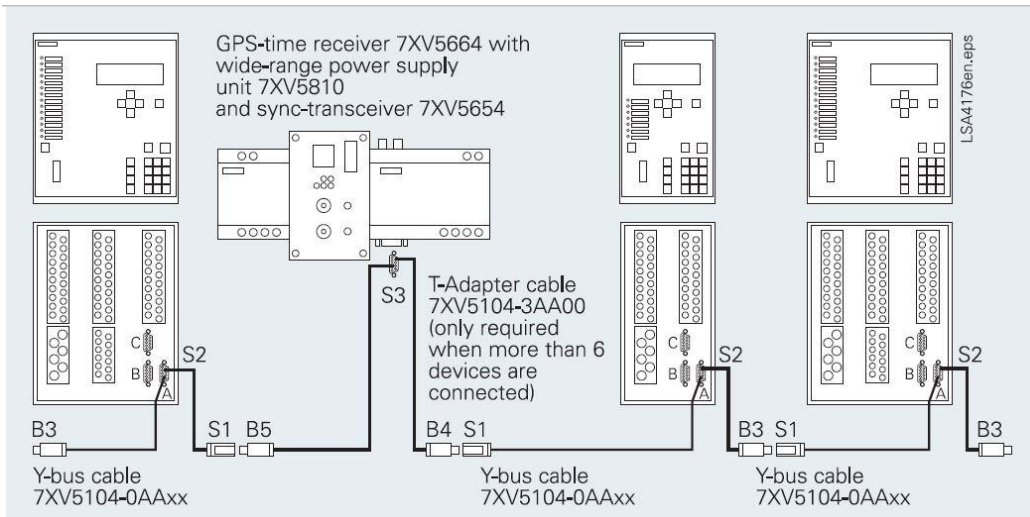


Figure13: Connection of max. twelve SIPROTEC 5 units to the IRIG-B bus

1.8 PMU Communication (IEEE C37.118)

PMU communication according to standard IEEE C37.118 is a client-server application.

Once the PDC has been connected to the device PMU and the PMU configuration data has been queried, the PDC initiates transmission of the synchrophasor data from the PMU.

In addition to the phasors (U-3ph, I-3ph, U-1ph, I-1ph), the channel names of the routed measuring points and the binary information are transferred.

The following ports are used for data transmission:

- TCP: Port 4712
- UDP: Port 4713

The ports must be configured on the PDC.

Up to 3 different PDCs can be connected to one function group PMU at the same time. The IP addresses of the maximum 3 PDCs are set in the PMU function group.

If four (4) function groups PMUs are configured, this enables support for up to 12 PDCs.

Each single phase measurement is counted as channel.

One PMU contains typically 3 + 1 voltage channels, 3 + 1 current channels and 2 - 4 binary signals; in total around 10 channels.

1.9 Ordering number of time synchronization accessories

1.9.1 Sync-Transceiver 7XV5654-0BA00

2 x FO-Input for 62.5/125 μm with ST-plug

2 x electrical outputs, DC 24 V / max. 50 mA per channel

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Fig. 14 GPS Time Synchronization Unit 7XV5664-1AA00 contains of: 1 x Parameterization Cabel (left above), 2 x Communication cable (50m +5m RG58) Antenna -> Lightning protection -> GPS Receiver (left below), Lightning protection (below), Antenna with mounting kit (center), GPS Receiver (right)

1.9.2 Y-Connection cable 7XV5104-0AAxx

Y-Bus cable system for time synchronization (2 core with 9-pole sub-D connector and metallic housing for clock synchronization SIPROTEC 5)

Available length: 1m, 3m, 5m, 10m.

1.9.3 Adapter 7XV5104-3AA00

T- Adapter cable tp symc—transceiver 7XV5654-0BA00.

Splits connector X1 into 2 buses for max. 6 SIPROTEC 5 devices per bus.

Copper cable 2-wire, shielded (length 0.3m)

1.10 Functional description of SIGUARD Phasor Data Processor

The WAMs components of SIGUARD PDP are highlighted in yellow blocks in Fig 15.

The synchrophasors, sent from the PMU in a continuous data stream to a PDC, are provided with time stamps and thus are comparable with the measured values of other PMUs.

The power frequency, the power frequency change rate and optional binary information are also transmitted as time-stamped measured values. Therefore, you receive an overview of the transient processes in a distributed energy transfer system, for example network fluctuations and compensating processes.

This data are archived and can be visualized via one or more User Interfaces, e.g. Phase Angle Differences. Communication from PDC to other PDC or to Control Center is also possible. With different applications it is possible to process the PMU data to do e.g. Power Swing Recognition, Island Detection, Voltage Stability Curve or Automatic Disturbance Recognition.

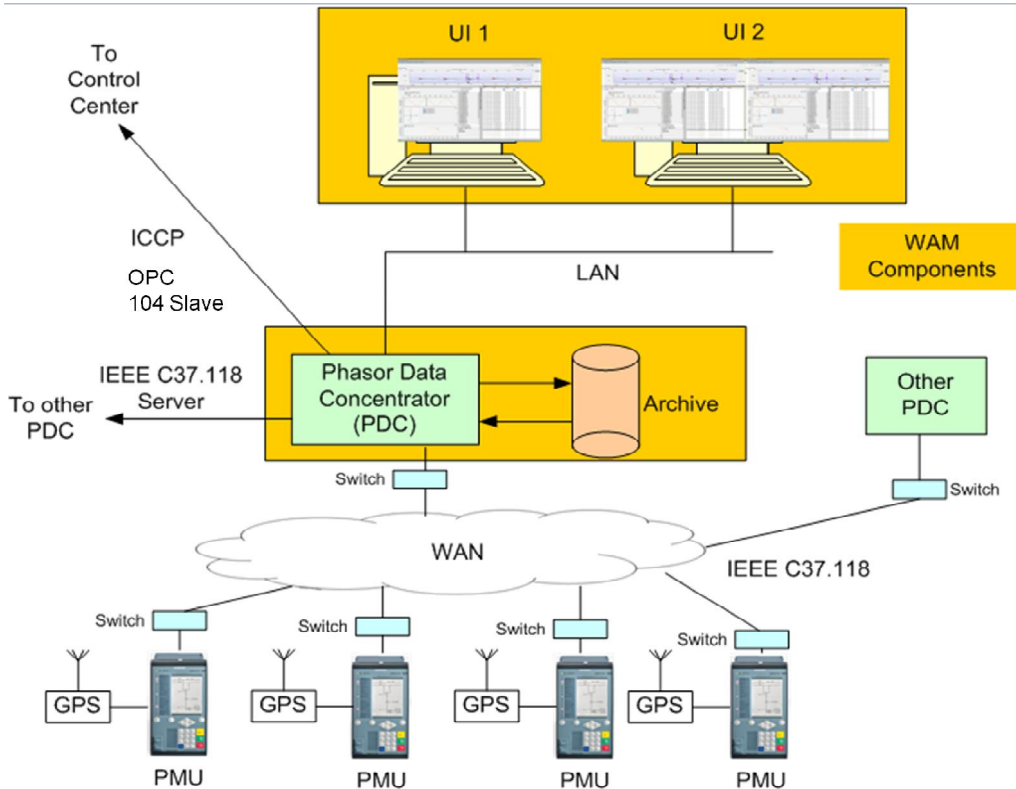


Figure 15: Structure of a Wide-Area Monitoring System with Phasor-Measurement Units

1.11 Summary

All SIPROTEC 5 devices have integrated measuring of synchrophasors (PMU) and can easily and at any time be activated. Therefore by selecting the option "Phasor Measurement Unit" in the SIPROTEC 5 devices current and voltage phasors with highly accurate time stamps can be determined and transmitted for analysis together with other measured values (frequency, speed of frequency change) using IEEE C37.118 communication to SIGUARD PDP in order to automatically detect power swings and trigger alarms.

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(Charges depending on the provider)
Email: support.energy@siemens.com

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