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App note 0037

Phasor Measure Unit

Document revision	Release date	For version		
		Hardware	Firmware	Software ENVIS
1.0	15.11.2024	ARTIQ, SMY G3, SMP G3	$\geq$ 4.17	$\geq$ 2.2

Contents

1 Phasor measure unit

Phasor measure unit (PMU) is device or function for monitoring and protecting the transmission grid and its stability. PMU measures instantaneous values of voltage and currents, from which it calculates phasors – complex numbers representing the value and phase shift of a given quantity. This measurement occurs at several locations within the transmission system at synchronized moments. By subsequently comparing these phasors from multiple points in the system, it is possible to protect the network from instability, which, in extreme cases, could lead to a complete network failure – blackout.

For synchronized measurement, it is necessary to synchronize the measuring devices using precise synchronization methods – PTP (Precision Time Protocol) or GPS (PPS – Pulse Per Second). These synchronization methods can achieve accuracy in the microseconds range.

Thanks to several samples from the network at precisely synchronized times, differences in phase shifts at these locations can be detected, allowing for monitoring of grid stability and load distribution, detection of faults, and analysis of oscillations. This enables the observation of overload issues or the risk of network collapse. Power in the network can be optimally distributed, ensuring a balance between generation and consumption. Faults can be more easily localized, facilitating quicker responses.

2 PMU at KMB devices

For using PMU at KMB devices, it is necessary to have compatible device with FW version new enough (4.17 or newer) and activated FW extension module PMU.

- Compatible devices are:
  - ARTIQ
  - SMC RTU7M G3
  - SML G3 / SMY G3 / SMP G3
    - AA, AT, DT
    - V, VT, RV, W
    - OI, OIT

The synchronization of measurements occurs automatically via the PPS signal on the first digital input (DI1 / DIO1) of the device. Synchronization using PTP is not supported.

With each second pulse, an accurate timestamp is recorded with a precision of 1ns, and the time of the synchronization pulse is stored with a precision of 1s. After the arrival of the pulse, the effective values of voltage and current, as well as the phase shift of these quantities, frequency, and rate of change of frequency (RoCoF), are measured. These values are available in modbus registers at the addresses described below until the next pulse.

2.1 Modbus registers of values

Mapped data	Base address		Size, type	Unit
	DEC	HEX		
GMT time of pulse	19840	0x4D80	64b, KMB time	*KMB time*
timestamp of pulse	19844	0x4D84	64b	ns
frequency	19848	0x4D88	32b, float	Hz
U_1	19850	0x4D8A	32b, float	V
U_2	19852	0x4D8C	32b, float	V
U_3	19854	0x4D8E	32b, float	V
U_4	19856	0x4D90	32b, float	V
phi_{U1}	19858	0x4D92	32b, float	rad
phi_{U2}	19860	0x4D94	32b, float	rad
phi_{U3}	19862	0x4D96	32b, float	rad
phi_{U4}	19864	0x4D98	32b, float	rad
I_1	19866	0x4D9A	32b, float	A
I_2	19868	0x4D9C	32b, float	A
I_3	19870	0x4D9E	32b, float	A
I_4	19872	0x4DA0	32b, float	A
phi_{I1}	19874	0x4DA2	32b, float	rad
phi_{I2}	19876	0x4DA4	32b, float	rad
phi_{I3}	19878	0x4DA6	32b, float	rad
phi_{I4}	19880	0x4DA8	32b, float	rad
RoCoF	19882	0x4DAA	32b, float	Hz/s

Table 1: Modbus registers of values captured by PMU

In the table above, there are Modbus register addresses for the values measured by the PMU.

GMT pulse time is the pulse time rounded to whole seconds in KMB time format.

timestamp of pulse is the value in nanoseconds when the synchronization pulse initiating the measurement arrived. This value or the GMT pulse time can serve as an identifier for the measured values.

frequency is the network frequency measured over 10 cycles (200 ms) from the arrival of the pulse.

U_n / I_n is the effective value of voltage / current of the first harmonic of the given phase, measured over one cycle (20 ms) from the arrival of the pulse. Measurement of U_4 / I_4 may not be supported on all devices.

fi_{Un} / fi_{In} is the phase shift of the voltage / current of the given phase relative to the synchronization pulse.

RoCoF (Rate of Change of Frequency) is a measure of frequency change [Hz/s] that can signal an imbalance between production and consumption, detect outages and faults, and protect sensitive equipment. Ideally, the RoCoF value should be as close to zero as possible.

The update of all registers occurs simultaneously after the last measured quantity is recorded. The pulse to which the values belong can be determined using the GMT pulse time or the pulse timestamp.

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