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ANALYSIS OF THE PARAMETERS OF SMART MEASURING DEVICES IN PHOTOVOLTAIC SYSTEMS

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ABSTRACT: *The development of photovoltaic (PV) systems and the need for efficient energy flow management have established smart measuring devices (smart meters and loggers) as key components. They provide bidirectional measurement of energy production and consumption, remote monitoring capabilities and integration with inverters, controllers and cloud platforms. This paper presents a classification of the different device types. Their technical characteristics, communication technologies, accuracy, self-consumption and range of applications are analyzed. The analysis facilitates the selection of suitable solutions tailored to specific needs, ranging from household to industrial applications.*

KEY WORDS: *Photovoltaic systems, Smart meters, Loggers, Energy monitoring.*

1. Introduction

Smart metering systems are the basis of the smart grid concept, which connects renewable energy sources, such as photovoltaic panels, to the traditional energy infrastructure. Smart measuring devices provide detailed data on energy consumption, enabling more accurate forecasting and efficient management of energy flows in households and businesses. In this context, smart meters and loggers have emerged as key components, offering accurate metering and remote monitoring capabilities.

2. Classification of smart meters

2.1. According to the application, smart meters are divided into residential, commercial and industrial. Residential meters are mainly designed for individual PV systems and small power consumers. They provide basic real-time monitoring of energy production and consumption and typically connect to mobile apps or cloud platforms for easy monitoring and management. In small and medium-sized businesses with larger PV systems, commercial devices enable multipoint consumption monitoring and support power cost optimization. In most cases, industrial communication protocols such as Modbus or BACnet are used. Industrial-grade instruments are applied in large PV installations as well as in complex industrial and commercial settings. They provide high measurement accuracy, including AC and DC lines, battery management and power flow optimization, and are often integrated with SCADA systems and standards such as IEC 61850.

2.2 The classification based on communication technology encompasses various approaches tailored to the requirements of the system. Wi-Fi devices provide easy connectivity to home networks and mobile applications, enabling remote monitoring, but they have limited range and higher power consumption. Bluetooth devices are suitable for close range and local monitoring, providing easy synchronization with mobile applications. A disadvantage is their limited coverage. LoRa (Long Range) communication features long range and low power consumption, making it suitable for distributed or remote PV systems, although the data rate is lower. The industry standards Modbus, RS485 and IEC 61850 allow integration of the devices with controllers and SCADA systems and are mainly used in large industrial and commercial installations.

RS485 is a hardware standard that describes exactly how the signal is transmitted over the cable. It works on a differential principle - two twisted wires (A and B) are used over which information is transmitted as a voltage difference. This approach ensures excellent protection against electromagnetic interference while permitting cable runs of up to 1200 meters. In addition, RS485 allows multiple devices to be connected on the same line - up to 32 active participants. It is important to emphasize that RS485 only defines the physical layer, i.e. the transmission method, but not what data is transmitted.

Table 1 Comparison between RS485 and Modbus in PV systems

Category	RS485	Modbus
Type	Physical layer (hardware standard)	Logical layer (communication protocol)
Function	Defines the way of signal transmission	Defines the structure and content of the data
Operating level	Electrical – voltages, cables	Logical – addressing, registers, commands
Application	Can carry various protocols (Modbus, Profibus, BACnet, etc.)	Usually used over RS485, but can also be over TCP/IP (Ethernet)
Use in PV systems	Connection between inverter and peripherals (smart meter, logger)	Exchange of parameters and readings between these devices

Modbus is a communication protocol - a set of rules and structures for data exchange. The most used variant in power and PV systems is Modbus RTU, which is based on the RS485 physical layer. Here, communication is organized in a master-slave model: typically, the inverter or controller acts as master and sends requests, and the smart meter, logger or other device responds as a slave. The information is fed into ordered registers - e.g. voltage, current, energy, power register - which makes integration between different manufacturers possible [3,4].

2.3. In terms of functionality, devices offer a range of options that vary with the complexity of the system. Bidirectional metering allows simultaneous metering of electricity consumed and electricity generated, which is particularly important for PV net metering systems. Monitoring of three-phase systems involves measuring voltage, current, and power across three-phase lines, a capability particularly important for large installations and industrial applications. Battery management optimizes charging and discharging processes, which improves energy storage efficiency and extends battery life. Energy flow management provides real-time monitoring of production and consumption, combined with automatic power flow regulation, to maximize the use of self-generated energy and reduce costs.

The smart meter is positioned at the interface between the inverter, the power grid, and the user's internal installation. This allows it to measure bidirectional energy flows - both the energy produced by the PV system and the energy consumed or fed into the grid. Thus, the device delivers precise information on system balance and enables functions such as "zero export". Standard communication interfaces establish the connection between the inverter, smart meter, and/or logger, enabling synchronization and monitoring of energy flows. The system arrangement is shown in fig. 1.

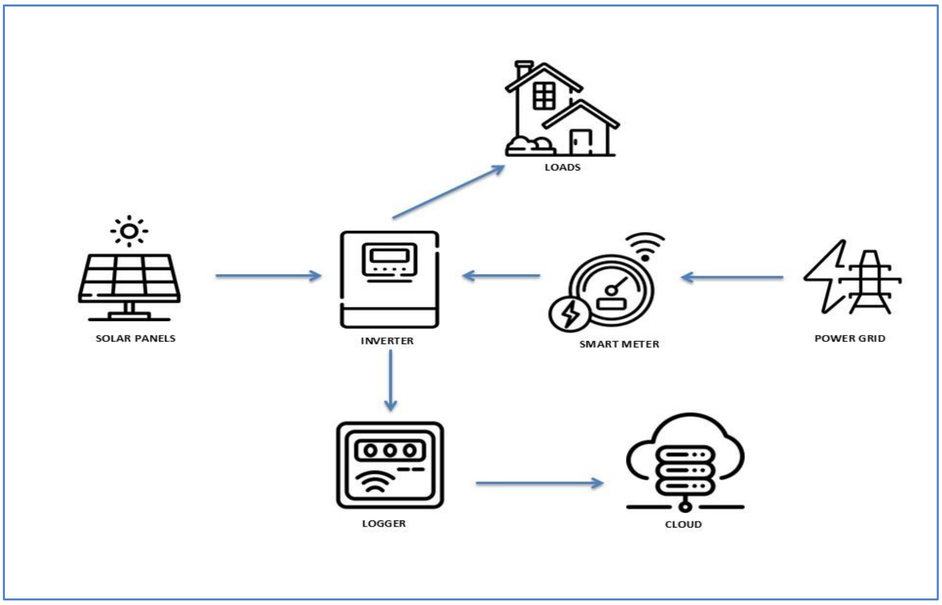

Fig. 1. Network diagram of PV system with smart meter and logger

Unlike the smart meter, the logger is connected to the inverter or smart meter via RS485, Wi-Fi, LAN, or 4G, rather than being installed on the power line. The logger's function is to collect data, store it locally, and transmit it to cloud platforms or monitoring systems (e.g. FusionSolar, SolisCloud, Elekeeper, etc.). As a result, the logger facilitates remote management and detailed analysis of system performance. [1,2].

3. Technical characteristics and analysis

To objectively evaluate the capabilities of the different smart meters, a comparison table is presented that summarizes their main technical parameters. It includes information on maximum current, use of current transformers (CTs), communication interfaces, accuracy, temperature range, self-consumption, and monitoring and configuration capabilities. The table serves to emphasize the differences between the devices and their applicability to PV systems of varying scales, from residential to industrial. Table 2 summarizes the main technical characteristics of the devices.

Table 2 Comparison of smart measuring devices

№	Device	Type	Max Current / CT	Communication	Accuracy	Temperature Range	Self-consumption	Number of Devices in System	Monitoring / Configuration
1	DEYE SDM230 Modbus V1	Smart Meter	100 A (direct)	RS485 (Modbus), pulse outputs	±0.5 %	–25…+55 °C	≤ 1 W / 10 VA	1	DEYE SunSpec / Solarman
2	DEYE DDSU666	Smart Meter	100 A	RS485 (Modbus)	±0.5 %	–25…+55 °C	≤ 1 W	1	DEYE SunSpec / Solarman
3	Huawei DDSU666-H + CT	Smart Meter	100 A (with CT)	RS485	±0.5 %	–25…+60 °C	< 1.5 W	1	Huawei FusionSolar
4	Growatt SPM-E	Smart Meter	up to 100 A (CT)	RS485	±0.5 %	–25…+60 °C	< 1.5 W	1	Growatt ShineServer / ShinePhone
5	SAJ DDSU666 + CT	Smart Meter	up to 100 A (CT)	RS485	±0.5 %	–25…+60 °C	< 1 W	1	SAJ Elekeeper
6	SAJ DTSU666	Smart Meter	80 A (direct) / CT	RS485	±0.5 %	–25…+60 °C	≤ 2 W	1	SAJ Elekeeper
7	SAJ DTSU666 + CT (kit)	Smart Meter	CT up to 250 A	RS485	±0.5 %	–25…+60 °C	≤ 2 W	1	SAJ Elekeeper
8	Growatt	Smart	up to	RS485	±0.5 %	–	≤ 2 W	1	Growatt

	TPM-CT-E (SDM630MCT)	Meter	250 A (CT)			25…+55 °C	/ 10 VA		ShineServer / ShinePhone
9	SAJ 80 A + SEC-C	Smart Meter (kit)	80 A	SEC-C (Wi-Fi / Ethernet / BLE)	±1 %	–25…+60 °C	< 3 W	1	SAJ Elekeeper
10	SAJ 250 A + SEC-C	Smart Meter (kit)	up to 250 A (CT)	SEC-C (Wi-Fi / Ethernet / BLE)	±1 %	–25…+60 °C	< 3 W	1	SAJ Elekeeper
11	Solis S2 Dual LAN & Wi-Fi Stick	Logger	—	LAN + Wi-Fi	—	–30…+65 °C	< 2 W	up to ~10 inverters	SolisCloud
12	SAJ LOGGER – 4G	Logger	—	4G (mobile data)	—	–25…+60 °C	< 5 W	up to 10 inverters	SAJ Elekeeper
13	Huawei SmartLogger3000A01EU	Logger / Controller	—	RS485, Ethernet, PLC	—	–25…+60 °C	≤ 15 W	up to 80 devices	Huawei FusionSolar
14	Huawei SmartLogger3000A03 (MBUS)	Logger / Controller	—	RS485, Ethernet, PLC, MBUS	—	–25…+60 °C	≤ 20 W	up to 80 devices	Huawei FusionSolar

Smart meters are electronic meters that not only record consumed or produced energy but also transmit real-time data to the inverter or logger. Their operation is primarily defined by the maximum current they can measure. For models up to 80 - 100 amperes, the device is connected directly to the circuit. At higher capacities, current transformers are used to reduce the current to a safe level for measurement. In this way, smart meters are applicable to small residential systems as well as to large-scale commercial and industrial installations.

Most smart meters communicate through the RS485 interface, using the Modbus RTU protocol. Through this communication, the inverter obtains real-time measurements of voltage, current, instantaneous power, and stored energy, with the additional benefit of ensuring interoperability between devices from different manufacturers. In newer developments, such as SEC-C kits, connectivity is no longer limited to wired lines but can also be established via Wi-Fi, Ethernet, or Bluetooth, simplifying connections and eliminating the need for additional cabling.

The self-consumption of these devices is minimal, typically below 2–3 W, which ensures high energy efficiency and negligible impact on the overall energy balance. The accuracy of most models is within ±0.5%, providing sufficient precision for reliable monitoring and energy management. Furthermore, their broad operating temperature range (−25 to +60 °C) enables deployment in panels for both outdoor and industrial settings. Practical applications of sensor technologies demonstrate that accuracy and temperature resilience are essential for reliable operation. Intelligent information systems for process management support more efficient data processing and improve the reliability of monitoring.

Loggers are devices that collect data from one or more inverters and smart meters and transmit them to a cloud platform or to a local management system. They provide centralized collection and storage of information, which is particularly useful in installations with more than one inverter. Compact solutions, including small stick-type modules, allow quick and simple installation with LAN or Wi-Fi connectivity. Alternatively, some devices rely on 4G mobile networks to transmit data from remote locations where wired internet is unavailable.

In advanced configurations, professional controllers integrate the functionalities of both a logger and a control system. They support multiple communication protocols - RS485, Ethernet, PLC and in some cases MBUS - and can control dozens of devices simultaneously. In addition to monitoring and data collection, these controllers enable active intervention in system operation, including tuning, energy flow management, and integration with larger SCADA and BMS solutions. As a result, they are considered indispensable in large industrial PV farms.

The parameters of the different devices determine their role in the PV system. The maximum current and the use of CT transformers determine the application scale, while communication options - RS485, Modbus, or wireless interfaces - provide flexibility and compatibility. In addition to technical parameters, the price of the devices is essential, as it directly influences the choice of a suitable solution. Figure 2 presents a comparison of the prices of the smart meters and loggers included in the analysis.

Low-cost smart meters, including the Deye SDM230, Deye DDSU666, Growatt SPM-E, and Huawei DDSU666-H, are suitable for residential and small-scale PV systems up to 10 kW. Smart meters in the mid-range segment - including the SAJ DDSU666, SAJ DTSU666, and Growatt TPM-CT-E - support current transformers (CTs), extend the measurement range, and are designed for small to medium-sized business applications. Communication module kits, such as the SAJ 80 A+ SEC-C and SAJ 250 A+ SEC-C, provide Wi-Fi, Ethernet, and Bluetooth connectivity, making them convenient for remote control.

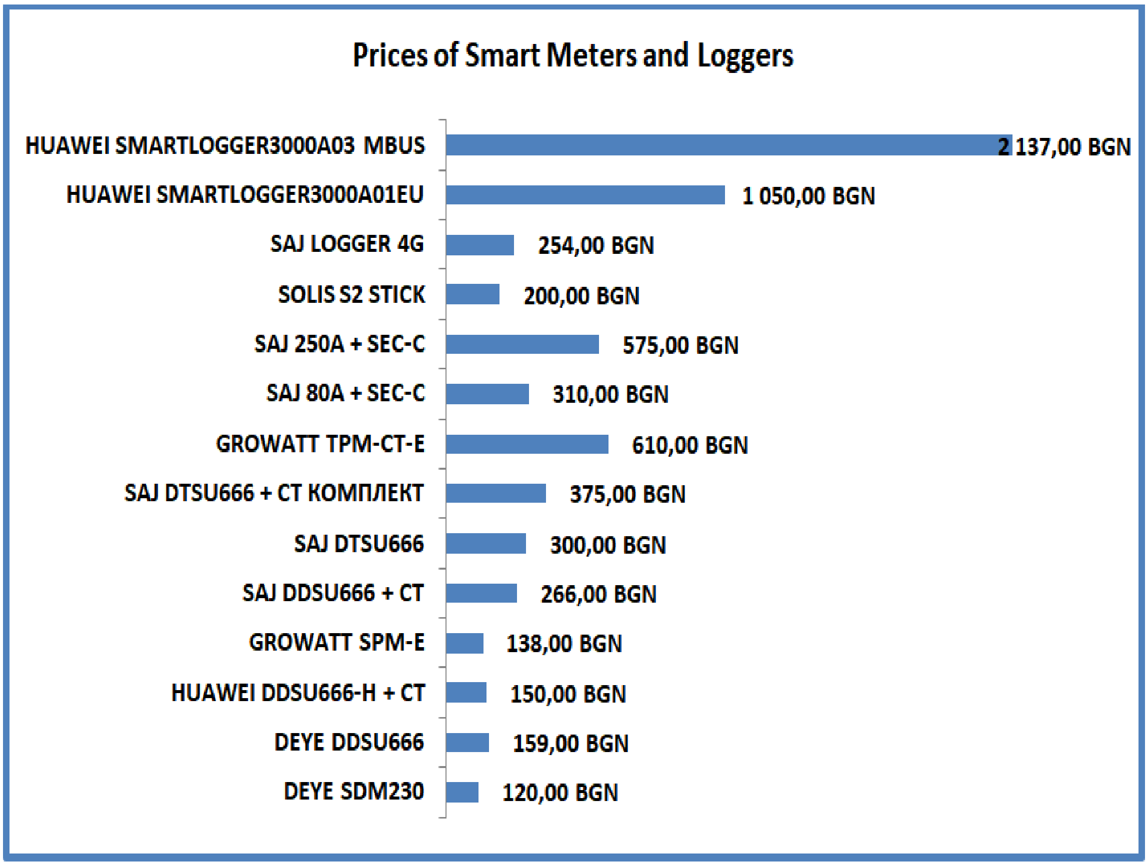

Fig. 2. Price chart

Devices such as the Solis S2 Stick and SAJ Logger 4G serve as loggers capable of connecting multiple inverters (up to 10), while providing straightforward integration and cost-effective solutions. In the professional segment, the Huawei SmartLogger3000 models (A01EU and A03 MBUS) support up to 80 devices and various communication protocols, positioning them as the most suitable solution for industrial-scale PV farms [5,6,7,8,9,10,11].

4. Conclusion

Smart measuring devices are an essential component of efficient PV system management. The analysis shows that the choice of a specific solution depends not only on system scale but also on technical parameters such as maximum current, current transformer support, communication technologies, and self-consumption.

The use of smart meters and loggers enables monitoring and provides a basis for improving the energy efficiency of future smart energy systems. Their implementation supports grid optimization and prepares energy systems for future challenges in renewable energy development and management. This role is particularly significant for Bulgaria, given the growing share of photovoltaic capacity and the need for synchronization with the global energy transition.

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