pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

INSTALLATION AND MONITORING OF A 10 kW OFF-GRID SOLAR PHOTOVOLTAIC SYSTEM FOR RESIDENTIAL APPLICATIONS

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ABSTRACT. This paper presents an integrated approach to the installation and monitoring of a 10 kW off-grid PV system suitable for the climatic conditions of Uzbekistan, where annual solar irradiation reaches 1,800–2,200 kWh/m² and there are more than 300 sunny days per year. The system architecture comprises seventeen 615 W monocrystalline panels, a 10 kW pure-sine-wave hybrid inverter, lithium iron phosphate ($LiFePO_4$) battery storage of 20–30 kWh at 48 V, and an integrated MPPT charge controller. Three commercial inverter platforms (Deye, Growatt, Jingsun) are compared based on their functional and economic characteristics. Installation procedures, including site assessment, structural mounting, electrical interconnection, and commissioning, are described.

KEYWORDS: off-grid solar PV system; 10 kW residential system; $LiFePO_4$ battery; MPPT charge controller; hybrid inverter; cloud monitoring; energy autonomy; Uzbekistan.

1. Introduction

The growing demand for reliable and sustainable electricity in residential and small-business sectors has led to increasing interest in off-grid solar photovoltaic (PV) systems. Unlike grid-tied systems, off-grid configurations operate independently of the utility network, providing complete energy autonomy through battery storage [1]. Such systems are particularly relevant for remote rural areas, regions with unstable grid supply, and consumers seeking energy independence.

The Republic of Uzbekistan possesses one of the highest solar potentials in Central Asia, receiving 1,800–2,200 kWh/m² of solar irradiation annually with more than 300 sunny days per year [2]. National policy, expressed in Presidential Decree PF-158 "On accelerating the transition to a green economy" (2022), has established the strategic goal of expanding solar generation capacity to 8 GW by 2030. In this context, residential-scale off-grid systems play an important role by reducing pressure on the central grid and supporting decentralized energy supply.

A 10 kW system represents an optimal scale for medium-sized households or small commercial premises, capable of generating 35–55 kWh of electricity per day depending on seasonal conditions. The objective of the present paper is to provide a concise technical description of the installation, monitoring, and maintenance of a 10 kW off-grid PV system, with practical considerations adapted to the conditions of Uzbekistan.

2. System Architecture and Components

The proposed 10 kW off-grid PV system consists of six principal subsystems whose specifications are summarized in Table 1. Each subsystem must be selected to ensure functional compatibility, mechanical reliability, and electrical safety throughout the design lifetime of 20–25 years.

Table 1. Specifications of the principal components of a 10 kW off-grid PV system

Component	Specification	Function
Solar panels	17 × 615 W monocrystalline modules	Conversion of solar radiation to DC electricity
Hybrid inverter	10 kW pure-sine-wave (Deye / Growatt / Jingsun)	DC–AC conversion, system orchestration
Battery bank	$LiFePO_4$, 48 V, 20–30 kWh capacity	Energy storage and reserve supply
MPPT controller	Integrated within inverter	Maximum power point tracking
Mounting structure	Anti-corrosion aluminium or galvanized steel	Mechanical support, wind resistance
Combiner box	DC/AC breakers, fuses, surge protection (SPD)	Electrical safety and isolation

Three leading commercial inverter platforms are commonly applied in 10 kW off-grid configurations, each offering distinct technical and economic advantages (Figure 1). Deye inverters are recognized for their robust enclosure, integrated AC and DC connectivity, and capability to integrate diesel generators, making them suitable for complex hybrid applications. Growatt offers a cost-effective alternative with simplified installation and intuitive operation modes (SUB and SBU), and ranks among the world's best-selling inverter brands. Jingsun provides OEM-based hybrid solar inverters frequently supplied as part of complete utility-scale solar power plant packages [3].

Figure 1 - Three commercial 10 kW off-grid hybrid inverter platforms: (a) Deye, (b) Growatt, (c) Jingsun

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

The selection of protective AC circuit breakers is determined by the rated current. For a 220 V single-phase configuration:

$$I = P / (U \cdot \cos \varphi) = 10\,000 / (220 \cdot 0.9) = 50.51\ A \quad (1)$$

Applying a 1.25 reserve coefficient: I = 50.51 × 1.25 = 63.14 A, which corresponds to a standard 63 A breaker. For a 380 V three-phase configuration:

$$I = P / (U \cdot \sqrt{3} \cdot \cos \varphi) = 10\,000 / (380 \cdot 1.732 \cdot 0.9) = 16.88\ A \quad (2)$$

With the same reserve factor: I = 16.88 × 1.25 = 21.10 A, corresponding to a standard 25 A breaker. Surge protection devices (SPDs) of Type II rating must be installed on both DC and AC sides to safeguard the system from atmospheric overvoltages.

3. Installation Procedure

System installation comprises six sequential stages. Site assessment establishes that solar panels must be oriented southward in a shade-free area, requiring approximately 50–60 m² of available surface for a 10 kW array. Tilt angle should be set close to the local latitude (≈40° for Andijan) for optimal year-round performance.

Mounting structures (aluminium rails or treated steel frames) are anchored to the roof or ground to withstand local wind loads, with engineering calculations confirming structural integrity for wind speeds up to 35 m/s. Solar panels are interconnected in series-parallel configurations using double-insulated PV cables of 4 mm² or 6 mm² cross-section terminated with MC4 connectors. The double insulation reduces electrical losses and improves long-term durability under UV exposure.

The inverter is installed indoors in a humidity-protected environment, with the $LiFePO_4$ battery bank connected at 48 V DC in series-parallel topology to achieve the required 20–30 kWh capacity. DC and AC combiner boxes are integrated with appropriate breakers, fuses, and SPDs. During commissioning, system parameters - including battery type, charging current limits, and operating mode - are configured through the inverter menu following manufacturer specifications [4].

4. Monitoring and Maintenance

Modern off-grid systems integrate cloud-based monitoring frameworks that enable real-time tracking of system performance and remote diagnostics. The principal monitoring technologies include: (i) Wi-Fi/GPRS modules connected to the inverter that transmit operational data to a cloud server; (ii) dedicated mobile applications such as ShinePhone (Growatt) and Deye Cloud, displaying solar generation, instantaneous load consumption, battery state of charge (SoC), and overall system status; (iii) battery management system (BMS) monitoring for cell temperature, voltage, and balancing; and (iv) on-board LCD displays for local diagnostics [5].

Periodic maintenance is essential for sustained performance. Panel cleaning to remove dust accumulation can improve generation efficiency by 20–30%, especially relevant for arid climates such as the Fergana Valley. Annual inspection of cable connections, torque verification of mechanical fixings, and BMS-based monitoring of $LiFePO_4$ cell capacity are recommended [6]. With proper maintenance, modern off-grid PV systems can deliver more than 80% of nominal capacity after 25 years of operation.

5. Results and Discussion

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

Based on the average solar irradiation in Andijan region (1,950 kWh/m² annually), the 10 kW system is expected to produce 35–55 kWh per day, corresponding to an annual energy yield of approximately 14,500–17,800 kWh. This output significantly exceeds the average household consumption in Uzbekistan (3,500–5,000 kWh/year), enabling full energy autonomy with surplus capacity available for additional appliances or electric vehicle charging.

Economic analysis indicates that the total installation cost of a 10 kW off-grid system in Uzbekistan ranges from 8,500 to 12,000 USD, depending on inverter brand and battery configuration. With current electricity tariffs and the absence of grid extension costs in remote areas, the simple payback period is estimated at 6–9 years. The 25-year design life offers a return on investment exceeding 200%, while substantially reducing the carbon footprint of household energy consumption.

The proposed system is fully suitable for the climatic conditions of Uzbekistan, where high solar irradiation, low humidity, and stable insolation patterns favor PV generation. Integration with cloud-based monitoring further supports remote management and predictive maintenance, lowering operational costs and extending system lifetime.

6. Conclusion

This paper presented a concise technical description of a 10 kW off-grid solar PV system suitable for residential and small-business applications in Uzbekistan. The system, comprising seventeen 615 W monocrystalline panels, a 10 kW pure-sine-wave hybrid inverter, and a 20–30 kWh $LiFePO_4$ battery bank at 48 V, is capable of providing 35–55 kWh per day - sufficient for full energy autonomy of a typical household. Three leading inverter platforms (Deye, Growatt, Jingsun) were compared, each suitable for different application scopes. Cloud-based monitoring through Wi-Fi/GPRS modules and dedicated mobile applications enables real-time supervision and predictive maintenance. With an estimated payback period of 6–9 years and a 25-year design life, off-grid PV systems represent a technically and economically justified solution for advancing the green-economy strategy of Uzbekistan.

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