Floating Solar PV and Storage Integration

A Strategic Framework for India

Renewable Energy Chronicles: The Power Saga Vol. 07 / 2026
ISBN: 978-81-993949-6-4

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Citation

"Floating Solar Photovoltaics (FSPV) and Storage Integration: A Strategic Technical Framework for Scaled Deployment in India". Renewable Energy Chronicles: The Power Saga (ISBN: 978-81-993949-6-4). Renewable Energy Society of India (RESI), Page 1-13, July 2026 | Infor@resiindia.org /resocietyofindia@gmail.com | https://www.resiindia.org/

Floating Solar Photovoltaics (FSPV) and Storage Integration: A Strategic Technical Framework for Scaled Deployment in India

Abstract

As India advances toward its 500 GW non-fossil fuel capacity target by 2030 and net-zero goals by 2070, land acquisition constraints for ground-mounted solar have become increasingly binding. Floating Solar Photovoltaics (FSPV) offer a strategically important, land-neutral alternative that simultaneously delivers higher specific energy yields through evaporative cooling, reduced soiling losses, and measurable water-conservation benefits. The National Institute of Solar Energy (NISE) 2026 geospatial assessment quantifies a realistic national potential of 102.18 GWp under a conservative 20% surface-utilisation constraint [1].

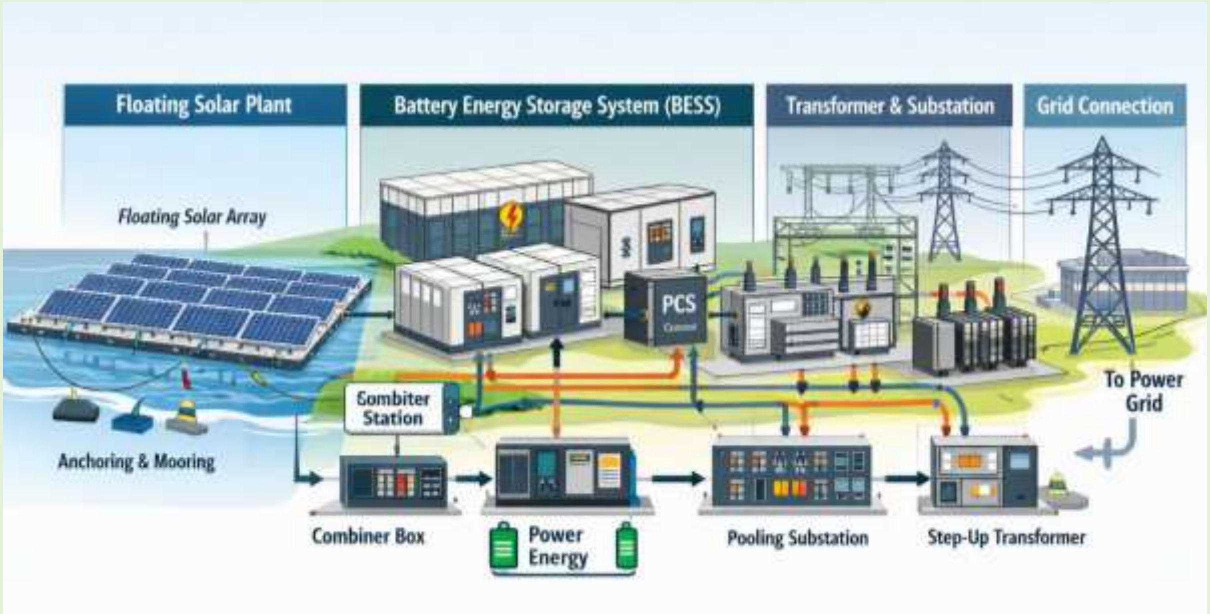

Figure 1 FSPV plus Storage System

This paper presents a comprehensive technical and policy analysis of FSPV in India. It synthesises the latest official potential assessment, detailed project-level deployment data (including the six large floating solar parks aggregating 1,077 MW sanctioned under the Solar Parks scheme), performance characteristics, cost and tariff dynamics, and the system value of co-located energy storage. Drawing on international experience from China, Singapore, the Netherlands and other leading markets, the paper proposes a strategic framework for optimised utilisation of India's water-body resources through prioritised hybrid deployment

with storage. The analysis is intended to serve as a reference document for policymakers, Central Public Sector Undertakings, state agencies, developers and financial institutions.

Keywords: *Floating Solar Photovoltaics (FSPV), Energy Storage Integration, Solar Potential Assessment, Hybrid Hydro-Solar Systems, Renewable Energy Policy, Water-Body Resource Utilisation, India Clean Energy Transition*

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Introduction

India's solar capacity has grown from less than 3 GW in 2014 to over 160 GW by mid-2026 [2]. This rapid expansion has, however, intensified competition for land with agriculture, forestry and urban development. In this context, Floating Solar Photovoltaics (FSPV) on reservoirs, irrigation tanks and industrial water bodies have emerged as a high-potential complement to ground-mounted solar [1, 3].

Figure 2 Floating Solar System

Beyond land neutrality, FSPV systems deliver quantifiable technical advantages: module operating temperatures are lower due to the cooling effect of water, resulting in 5–10% higher energy yields; soiling losses are reduced; and dense arrays can significantly lower evaporative losses from reservoirs [4, 5]. When co-located with energy storage and existing hydropower infrastructure, FSPV can provide higher system value than pure solar by improving dispatchability and transmission utilisation [6].

Global experience from China (multi-hundred MW projects), Singapore (high-density deployment with rigorous monitoring), and the Netherlands and Japan (advanced mooring systems) demonstrates that FSPV can be scaled rapidly when supported by appropriate technical standards, offtake frameworks and targeted financial instruments [3, 7, 8]. India currently stands at an inflection point, with operational projects such as Omkareshwar (278 MW) and a substantial pipeline of large parks providing critical performance and commercial data for future expansion [9, 10].

National Potential and Geospatial Assessment

The NISE 2026 report, *Solar PV Potential of India (Floating Solar)*, constitutes the most authoritative official assessment of FSPV potential in the country [1]. Unlike earlier independent estimates that indicated a range of 78–280 GW under varying coverage assumptions (1–5% moderate coverage versus 5–30% extensive coverage) [11], the NISE study applies rigorous multi-criteria filters to arrive at a realistic, implementable figure.

Key methodological parameters include:

- Minimum water-body area of 10 hectares
- Seasonal water availability of at least 11 months
- Bathymetry (water depth) between 3 and 30 metres
- Global Horizontal Irradiance greater than 4.5 kWh/m²/day
- Proximity to roads and substations within 10 km
- Maximum surface coverage of 20% for natural water bodies [1]

After applying these filters, the feasible water surface area is estimated at 1,946.24 km² (out of a total identified reservoir area of 10,725.99 km²). The corresponding national potential is **102.18 GWp** [1].

State-wise Distribution of Potential (at 20% Utilisation)

Rank	State	Potential (GWp)	Approximate Share
1	Maharashtra	16.28	15.9%
2	Madhya Pradesh	14.89	14.6%
3	Karnataka	13.69	13.4%
4	Odisha	12.81	12.5%
5	Telangana	10.72	10.5%
6	Gujarat	6.32	6.2%
7–10	Rajasthan, Tamil Nadu, Jharkhand, Chhattisgarh	3.3–2.7 each	~12% combined
—	Other States/UTs	~15.2	~14.9%
Total	**India**	**102.18**	**100%**

Source: NISE (2026) [1]

The top five states — Maharashtra, Madhya Pradesh, Karnataka, Odisha and Telangana — together account for approximately 67% of national potential. These states possess large multipurpose irrigation and hydropower reservoirs that already have existing grid connectivity, access infrastructure and institutional arrangements for water-body management. This concentration enables a focused, high-impact deployment strategy that

 | ISBN: 978-81-993949-6-4

prioritises hybridisation with existing hydro assets and minimises the need for new transmission corridors [1, 6].

Current Deployment and Operational Landscape

As of mid-2026, cumulative commissioned FSPV capacity in India is estimated at 500–600 MW [9, 10, 12]. The largest single operational installation is the Omkareshwar Floating Solar Park (278 MW) in Madhya Pradesh. Other significant operational projects include NTPC Ramagundam (100 MW, Telangana), NTPC Kayamkulam (approximately 92 MW, Kerala), NTPC Simhadri (25 MW, Andhra Pradesh), and smaller installations by various CPSUs and state agencies [10, 12].

Large Floating Solar Parks under the Solar Parks Scheme

Under the scheme for “Development of Solar Parks and Ultra-Mega Solar Power Projects,” six floating solar parks aggregating **1,077 MW** have been sanctioned. Central Financial Assistance of ₹20 lakh per MW or 30% of project cost (whichever is lower) is available [13].

Sl. No.	State	Location	Implementing Agency	Capacity (MW)	Status (mid-2026)
1	Jharkhand	Getalsud Dam, Ranchi	SECI	100	Under construction
2	Jharkhand & West Bengal	Tilaiya / Panchet	GVREL (JVC of DVC & NTPC)	310	Part awarded; balance under tendering
3	Jharkhand	Maithon Dam, Dhanbad	DVC	234	Under implementation
4	Kerala	West Kallada, Kollam	NHPC	50	Under construction
5	Madhya Pradesh	Omkareshwar, Khandwa	RUMSL	278	**Completed / Commissioned**
6	Maharashtra	Erai Dam, Chandrapur	MAHAGENCO	105	Implementation stage
Total				**1,077**	

Sources: Project documentation and public status updates [9, 10, 13]

Performance data from operational projects confirm the technical advantages of FSPV. Specific yields are typically 5–10% higher than comparable ground-mounted systems due to the cooling effect [4, 5, 14]. Detailed project reports for parks such as Maithon indicate Performance Ratios in the range of 83–85% under optimised designs [15].

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Technical Characteristics and Performance Advantages

A typical utility-scale FSPV system comprises modular high-density polyethylene (HDPE) floating platforms, bifacial or mono-facial PV modules mounted at low tilt angles (usually 5–15°), mooring and anchoring systems designed for seasonal water-level fluctuations, marine-grade cabling, and inverters (string or central) [3, 5].

Key performance advantages relative to ground-mounted solar include:

- Higher energy yield (5–10%) arising from lower module operating temperatures [4, 5, 14].
- Reduced soiling losses and easier cleaning using available water [5].
- Significant reduction in reservoir evaporation (reported reductions of 20–40% under dense coverage in international studies) [3, 7].
- Potential for hybrid operation with existing hydropower plants, enabling complementary generation profiles [6, 16].

Technical design considerations that influence cost and reliability include hydrodynamic loading, cable fatigue from continuous movement, biofouling, and corrosion in high-moisture environments. Robust bathymetry and hydrodynamic studies are essential prerequisites for durable design, particularly on reservoirs with large seasonal water-level variations [3, 8].

Storage Integration and Hybridisation

The inherent variability of solar generation necessitates energy storage to improve dispatchability and offtake attractiveness.

2-hour Energy Storage Systems currently represent the most bankable configuration for FSPV. They enable effective peak shifting, ramp-rate control and limited firming at moderate incremental capital cost [6, 17]. Co-location of storage with FSPV maximises the benefits of shared grid connectivity and reduces overall system costs compared with standalone storage projects.

Hybridisation with hydropower offers particularly high system value. Daytime solar generation can displace water release from hydro plants, effectively converting the reservoir into a form of "water battery" for evening peak hours [6, 16]. This complementarity improves the utilisation of existing transmission infrastructure and enhances the overall capacity value of the combined portfolio.

As inverter-based resources increase, detailed grid interconnection studies addressing short-circuit ratio, protection coordination and reactive power capability become essential for larger FSPV-plus-storage projects [17].

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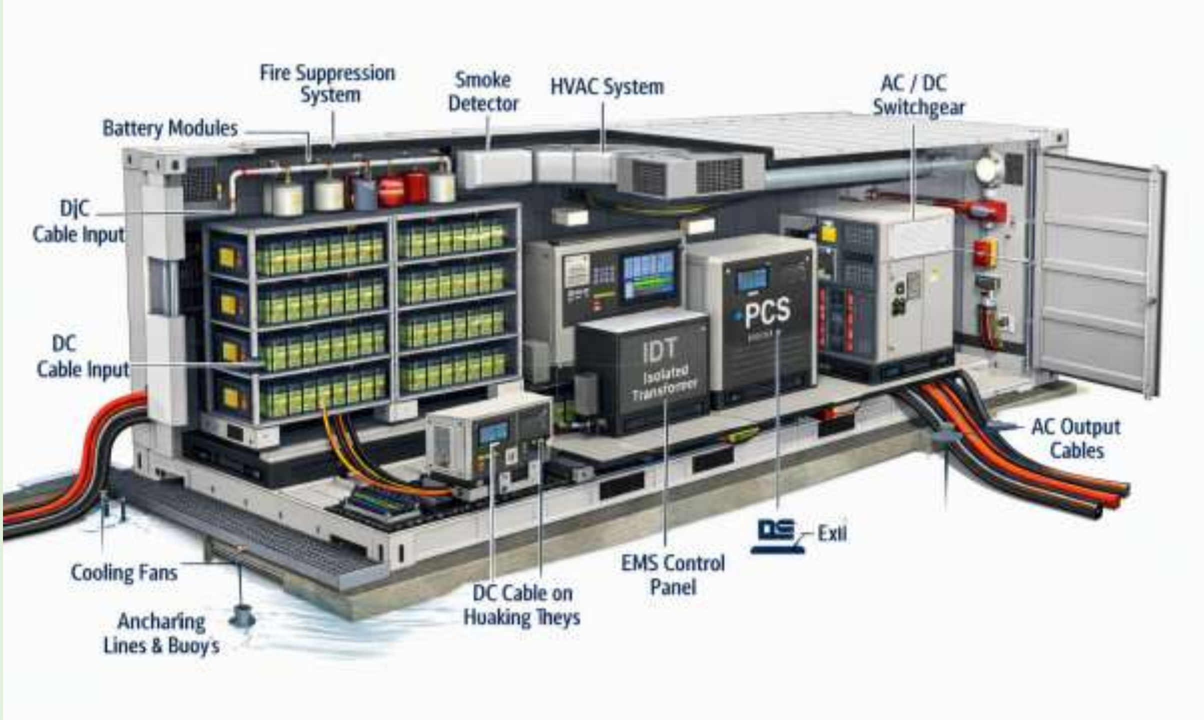

Figure 3 Battery Energy Storage System (BESS)

Cost Structure, Tariff Dynamics and Economic Barriers

Capital costs of FSPV projects are typically ₹1–1.5 crore per MW higher than contemporaneous ground-mounted solar projects [9, 13]. The primary cost drivers are the flotation platforms, specialised mooring systems and marine-grade electrical components.

As a result, discovered tariffs have generally been approximately ₹0.8–1.2 per unit higher than ground-mounted benchmarks (recent FSPV tariffs in the range of ₹3.2–3.8/unit) [9, 10]. In several cases, elevated tariffs have led to offtake reluctance by distribution companies, limiting the commercial momentum of early projects.

Additional cost factors include higher logistics expenses for water-based construction, intensified maintenance requirements (corrosion protection and biofouling management), and elevated perceived risk among lenders, which can increase financing costs [3, 5].

Operational Challenges and Mitigation Pathways

Key residual challenges include:

- Corrosion and biofouling in the aquatic environment [5, 8].
- Design of mooring systems capable of accommodating large water-level fluctuations [3, 8].
- Limited domestic manufacturing capacity for specialised floats [1].
- Higher perceived technology and operational risk among financial institutions [3].

- Need for specialised marine construction and long-term O&M skills [5].

Mitigation approaches include the adoption of international technical standards (IEC and equivalent) for buoyancy, anchoring and electrical safety; progressive localisation of float manufacturing; mandatory pre-bid bathymetry and environmental baseline studies; and the development of model water-lease agreements and single-window clearance mechanisms [3, 7, 8].

International Benchmarking

China has demonstrated the feasibility of multi-hundred-megawatt FSPV projects and has achieved cost reductions through domestic float manufacturing and hybrid hydro-solar models [3, 7]. Singapore's 60 MW Tengeh Reservoir project illustrates high-density deployment accompanied by rigorous long-term environmental monitoring [7]. The Netherlands, Japan and South Korea have advanced mooring technologies and clear technical guidelines that reduce lender risk perception [8].

A consistent international finding is that pure FSPV requires either targeted capital support, strong offtake frameworks, or hybridisation that captures system-level value in order to compete commercially with ground-mounted solar [3, 7]. India's early experience aligns closely with these global patterns.

Proposed Strategic Framework for Scaled Deployment

To convert the 102.18 GWp potential into operational capacity while maximising the productive use of existing water bodies, a focused national approach is recommended. Core elements of such a framework include:

1. Targeted capital support calibrated to close the observed tariff gap, thereby improving offtake viability [9, 13].
2. Dedicated funding for pre-bid bathymetry, hydrography and environmental studies to de-risk projects at the development stage [1, 3].
3. Priority allocation of capacity to high-potential reservoirs that already possess grid connectivity or hydropower infrastructure [1, 6].
4. Primary emphasis on 2-hour co-located storage, with limited provision for longer-duration storage where offtakers explicitly value firming [6, 17].
5. Strict adherence to a 20% maximum surface-coverage guideline for natural water bodies, with higher coverage considered only on industrial or low-ecological-value water bodies after rigorous assessment [1].
6. Progressive domestic content requirements for flotation systems to strengthen local manufacturing and supply-chain resilience [1, 3].

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7. Development of standardised technical guidelines, model water-lease agreements and single-window clearance processes [3, 8].

This architecture would enable efficient utilisation of India's concentrated FSPV resource, deliver higher system value through storage and hybridisation, and conserve both land and water resources.

Socio-Economic and Environmental Considerations

FSPV generates specialised local employment in marine installation, specialised O&M and related services [5]. Water-surface lease arrangements can create new revenue streams for irrigation departments and dam authorities. Reduced pressure on agricultural and forest land lowers the risk of social conflict [1, 3].

The dominant environmental co-benefit is evaporation reduction [3, 7]. Potential impacts on aquatic ecosystems can be managed effectively through the 20% coverage limit, continuous monitoring of key water-quality parameters, and exclusion of high-sensitivity sites (such as Ramsar wetlands) unless full statutory clearance is obtained [1, 8].

Conclusions and Recommendations

India possesses a substantial and geographically concentrated floating solar resource of 102.18 GWp [1]. Current commissioned capacity of approximately 500–600 MW, anchored by the 278 MW Omkareshwar project and supported by a 1,077 MW pipeline of large parks, demonstrates technical viability [9, 10, 13]. Persistent commercial barriers—primarily the residual cost and tariff differential—have constrained the pace of scale-up.

International experience and domestic project data indicate that a well-designed support framework focused on closing the tariff gap, de-risking technical studies, prioritising hybridisation with existing infrastructure, and embedding appropriately sized storage can unlock rapid and efficient deployment [3, 6, 7].

Priority recommendations include:

- Establishing a dedicated national framework for FSPV with storage that prioritises high-potential, grid-connected reservoirs.
- Accelerating the development of technical standards and domestic manufacturing capacity for flotation systems.
- Institutionalising pre-bid bathymetry support and model contractual frameworks.
- Integrating FSPV-plus-storage into peak-power and round-the-clock procurement strategies of distribution companies and Central agencies.
- Strengthening long-term environmental monitoring and skill-development programmes for marine O&M.

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With coordinated action across Central and State governments, CPSUs, transmission utilities and the private sector, floating solar can transition from a promising niche technology to a mainstream contributor to India's clean energy transition while delivering important land, water and grid benefits.

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