HUIJUE GROUP

Off-Grid Telecom Power with Solar, Storage and Generator Control

Design off-grid telecom power with solar, batteries and generator control to reduce fuel use while maintaining reserve, recovery and site availability.

Powered by The Solar Telecom

HYBRID POWER STRATEGY

Off-Grid Telecom Power with Solar, Storage and Generator Control

A staged engineering method for reducing diesel use and generator wear while keeping the telecom load protected through nights, poor-solar periods and equipment faults.

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Hybrid power guide
Approx. 9 minute read

Contents
 An off-grid telecom hybrid works when solar carries as much of the routine energy as the site can use, batteries move that energy across time, and the generator covers extended deficits or faults. The generator should no longer run by habit, but it must remain available when the resilience model calls for it.

This is not simply a matter of adding panels and batteries to an existing diesel site. Load measurement, worst-month solar conditions, battery limits, fuel logistics and control behavior all affect the result. A system can show a high annual renewable fraction and still fail during three cloudy days if the reserve and recovery strategy were poorly defined.

The scale of the issue remains material. The GSMA Mobile Net Zero 2026 report states that mobile operators consumed around 3 billion litres of diesel and gasoline in 2024. That total is not a generator-only figure, but it shows why fuel use, clean energy access and operational resilience remain important to the sector.

Build a reliable diesel baseline

Begin with evidence from the existing site. Record at least the telecom and auxiliary load, generator runtime, starts, delivered fuel, measured electrical output, loading, service history, outage causes and site visits. Where fuel theft or leakage is plausible, treat it as a measured business risk rather than an informal adjustment added after the financial model is complete.

Runtime alone is a weak fuel baseline. A generator operating lightly for many hours can consume a different amount of fuel per delivered kWh than one operating in a more suitable load range. Reconcile three independent records where possible:

- Generator-controller runtime and start history
- Fuel deliveries, tank-level change and documented withdrawals
- Electrical energy measured at the generator output

If the records disagree, investigate meter scaling, undocumented refuelling, idling, leaks, theft, sensor drift and missing data. Do this before forecasting savings. A neat model built on an unreliable fuel baseline only makes the uncertainty harder to see.

Baseline item	Preferred measurement	Common mistake
Site load	Interval DC and AC energy plus peak power	Using rectifier nameplate rating as the live load
Fuel use	Delivered volume reconciled with tank and output energy	Multiplying runtime by a brochure fuel rate
Generator condition	Starts, failed starts, loading and maintenance records	Assuming an old set will perform like a new one
Outage impact	Unserved telecom minutes and event sequence	Counting every generator alarm as a service outage
Delivered fuel cost	Purchase, transport, security, loss and handling	Using the urban pump price for a remote site

Segment the portfolio before standardizing hardware

A tower portfolio rarely has one energy problem. Coastal salt exposure, desert dust, mountain access, utility quality, tenant load and fuel-delivery distance can vary within the same country. Standardization is still valuable, but it should happen inside defensible site classes.

Site class	Typical condition	Likely first action
Off-grid, high delivered-fuel cost	Continuous or long generator runtime	Model solar, storage and generator displacement together
Bad-grid	Frequent or unpredictable outages	Define reserve policy and multi-source control first
Grid site with an ageing generator	Rare backup use but rising maintenance burden	Compare battery backup, generator renewal and hybrid options
High-growth shared tower	Load rises when tenants or radio bands are added	Reserve expansion space in rectifiers, batteries, PV and cooling
Difficult-access site	Seasonal roads, security risk or long service travel	Value autonomy, remote diagnostics and critical spares explicitly

Use measured load profiles rather than one average value. A site with a 3 kW average and a 6 kW evening peak has different converter, battery and generator requirements from a flat 3 kW load. Include planned radio expansion and distinguish the critical telecom load from cooling or other loads that may be controlled during an emergency.

Choose the degree of diesel displacement

Upgrade level	Typical change	Purpose	Main risk to check
Battery-first	Add storage and coordinated charging	Run the generator in fewer, better-planned blocks	Battery throughput without enough fuel reduction
Solar-assisted	Add PV for live load and battery charging	Reduce daytime generator operation and starts	PV curtailment when storage is full
Renewable-led hybrid	Expand PV and storage; retain generator contingency	Increase renewable fraction while preserving recovery	Insufficient recharge after poor-solar weather
Generator removal	Solar and storage only	Eliminate on-site fuel dependence	Loss of the last controllable energy source

There is a point at which adding more PV stops producing equal value. If the battery is full and the live load is low, additional solar is curtailed. There is also a point at which adding battery capacity gives little benefit because the array cannot recharge it during the worst solar period. The two assets must be simulated together.

A quick sizing check, not a final design

Consider an illustrative site with a continuous 3 kW critical load. It uses 72 kWh per day. If the design month provides five equivalent full-sun hours and the combined PV derating factor is 0.78, the first-pass array needed to replace average daily energy is:

PV capacity = 72 kWh / (5 h x 0.78) = approximately 18.5 kWp.

That figure does not yet include recovery after a poor-solar day, abnormal load, module ageing or the selected resilience margin. Adding a provisional 20% recovery allowance would raise the check to roughly 22.2 kWp. Final sizing should use time-series weather and load data rather than one peak-sun-hours value.

For 12 hours of battery autonomy, the load requires 36 kWh delivered. With 85% allowable depth of discharge and 90% discharge-path efficiency:

Initial battery energy = 36 kWh / (0.85 x 0.90) = approximately 47.1 kWh.

A further 20% allowance for ageing, temperature or uncertainty would take the planning check to about 56.5 kWh. These assumptions are illustrative, not product recommendations. The selected chemistry, warranty, end-of-life criterion, current limits and local temperature must replace them in a project calculation.

NREL’s PVWatts V8 can provide a useful first estimate of location-based PV production and weather variability. It is designed for grid-connected PV estimates, so it does not replace off-grid battery-autonomy, generator-dispatch or loss-of-load simulation.

Control strategy creates the savings

Hardware determines what the system can do. Control logic determines what it actually does. The controller needs source priority, battery reserve, generator start and stop conditions, minimum runtime, warm-up and cooldown, charge-current limits and recovery behavior after low-solar weather. Any minimum generator loading rule should follow the selected manufacturer’s requirements rather than a universal percentage copied between projects.

A practical source-priority sequence

1. Use available solar to serve the live telecom and approved auxiliary loads.
2. Send surplus solar to the battery within BMS voltage, current and temperature limits.
3. Discharge storage while protecting the planned resilience reserve.
4. Start the generator when reserve, forecast, load, BMS limits or a source failure requires it.
5. Use the generator to serve the load and restore the planned battery reserve in a controlled block.
6. Stop only after minimum runtime, cooldown, reserve and stability conditions are satisfied.

Condition	Expected local response	Remote notification
Battery communication lost	Limit or stop battery power according to the validated safe state	Major alarm with last valid SoC and timestamp
Generator fails to start	Retry within the approved sequence, protect reserve and shed approved noncritical load	Critical alarm and estimated reserve time
PV sensor or forecast unavailable	Continue on conservative local thresholds	Advisory or major alarm according to consequence
Controller reboots	Return to a deterministic state without interrupting the DC load	Event log with configuration version
Remote connection lost	Keep the validated local state machine running	Backfill buffered events when communications return

Weather-aware control can be useful, but it should refine a safe local state machine, not replace it. Forecast errors, expired data and WAN outages need explicit treatment. ITU-T L.1210 (12/2025) and the technically aligned ETSI ES 203 700 V1.2.1 provide current reference context for sustainable, multi-source power feeding and intelligent management in 5G networks.

Measure the full business case

The business case should compare lifecycle cash flows by site class, not promise one payback period for an entire country. Delivered fuel cost is usually more useful than commodity price because it includes transport, security, handling and losses at the remote site.

- Fuel avoided, delivered fuel cost and fuel-price sensitivity
- Generator service, overhaul and replacement avoided or deferred
- Logistics, security and emergency site visits
- PV, battery, converter, controller and cooling replacement assumptions
- Battery cycling cost and expected residual capacity
- Communications, software support, spares and technician training
- Availability risk and the contractual value of avoided outages
- Civil works, transport, finance, taxes and end-of-life obligations

Test at least the base case, low-solar case, high-load case and high/low fuel-price cases. Move battery replacement forward in a stress case. Extend the poor-solar period. Add a new tenant. Delay a spare generator part. A model that remains acceptable after these tests is more valuable than one optimized around an average year.

Payback is easy to communicate but can hide replacement timing and residual value. Net present value, lifecycle cost and cost per delivered kWh or per available site-hour give a fuller picture. Keep assumptions visible so procurement, finance and operations can challenge the same model.

Verify savings after commissioning

Factory and site acceptance establish function and safety; they do not prove annual fuel savings. During FAT and SAT, test source transitions, generator start failure, sensor loss, BMS communication loss, controller reboot, remote-link loss, alarm routing and restoration. Record firmware and settings as part of the as-built package.

Then establish an agreed verification period, often long enough to include representative load and weather. Compare pre- and post-upgrade fuel per day, litres per generator kWh, generator hours and starts, source energy, PV curtailment, battery throughput, site visits and critical-load outage minutes. Normalize for material load, weather and availability changes.

Recommended acceptance principle: confirm safety, source switching and fault behavior during FAT and SAT, then verify fuel and energy performance over an agreed operating period. A one-day commissioning test cannot demonstrate annual diesel displacement.

A monthly review should reconcile generator output energy, fuel movement, PV yield, battery energy and load. If the reported savings look unusually good, first check meter boundaries, counter resets and missing records. Good measurement protects both the buyer and the supplier.

Huijue can prepare a preliminary hybrid architecture and control schedule from measured load, destination climate, fuel baseline, autonomy target and operator requirements. Final equipment selection and savings commitments should follow the approved simulation, evidence package and acceptance method for the specific site class.

Model a diesel-reduction pathway for your site portfolio.

Start with a representative set of measured sites, not a preferred cabinet size. The first review should establish the baseline, site classes, resilience target, control states and the data needed to verify results.

Request a hybrid power review through your established Huijue sales or engineering contact.

Related engineering guides

Solar & Battery Sizing Fuel and Energy KPIs Hybrid System Architecture

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