DESIGN STUDY

Offshore wind farm OT and IT network: 72 turbines on eight rings to a remote operations center, with the IT–OT boundary drawn once

Complete design on current platforms

CAPABILITY	INDUSTRY	SETTING
Networking	Energy	Offshore wind operator
DOCUMENT	**VERSION**	**DATE**
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Document control

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Sign-off	"An engagement under this design is signed by the practice lead before any build proceeds."		

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CONVENTIONS

Source tags. [S] figure read from the vendor's or standards body's own current page on Sep 25, 2026 · [S*] figure from the vendor's page summary where the page itself could not be opened · [A] design assumption, to be confirmed by the signing engineer · [T] design target: the record's outcome figure and anything derived from it. No figure comes from any engagement, file or asset. A row with more than one tag is counted once: as a published figure if any tag is [S] or [S*], otherwise as an assumption if any tag is [A], otherwise as a design target.

Table 1. Revision history

Date	Version	Change
Sep 27, 2026	1.0	First issue.
Oct 10, 2026	1.1	Approval line now reads: approved by the Founder, issued by Symbeeo. Mark Winston remains the author.

1 · Scope

Who it is for. The head of engineering at the operator of one offshore wind farm who has inherited a network built by the construction contractor — turbine rings, an offshore substation, an onshore substation, a leased line to the control room — and who has been asked two questions it cannot yet answer: which paths join the corporate network to the turbines, and what happens to control of the farm when the main control center loses its links.

Typical buyer [A]. A single-asset offshore wind operator in the North Sea: 72 turbines in eight array strings of nine, one offshore substation (OSS), one onshore substation (ONSS) about 60 km away by export cable, a remote operations center (ROC) at the head office and a standby ROC at the operations and maintenance base in the harbor town. The turbine manufacturer runs its own SCADA network inside each turbine under a service agreement. Corporate IT — email, ERP, the historian's business copy — is at the head office. 140 staff; the ROC is staffed 24 × 7.

What is in. The owner's turbine network (one base switch per turbine), the farm area rings, the OSS and ONSS networks, the export-cable and control-center links, the ROC and standby ROC OT networks, and the boundary between OT and IT: zones, conduits, the OT DMZ, and the firewalls that enforce them. **What is out.** The turbine manufacturer's in-turbine network and SCADA (a zone this design connects to, not one it builds); protection relays and the substation automation system; the grid operator's link; corporate IT; vessel and helicopter communications.

Assumptions. Cisco is the network vendor, following Cisco's validated design for offshore wind [A]. Each array cable carries fiber, and each string's far turbine is linked back to the OSS on a second fiber path so that every string closes into a ring [A]. Two export cables each carry fiber [A]. Two diverse carrier circuits run from the ONSS to the ROC and one to the standby ROC [A].

Related documents, read Sep 25, 2026.

- SRA-NET-001, SDD-NET-001, STP-NET-001 — this capability's reference architecture, design and test plan (Catalyst 9500X figures as read Sep 24, 2026 in SRA-NET-001 R5)
- Cisco, Renewable Energy: Offshore Wind Farm 1.3 Design Guide (Apr 2, 2026) — https://www.cisco.com/c/en/us/td/docs/solutions/Verticals/Utilities/Wind_Farm/Wind-Farm_1-3_Design_Guide.html
- Cisco Catalyst IE3400 Rugged Series data sheet (updated May 13, 2025) — https://www.cisco.com/c/en/us/products/collateral/switches/catalyst-ie3400-rugged-series/cat-ie3400-rugged-series-ds.html
- Cisco Catalyst IE9300 Rugged Series data sheet (updated Jul 8, 2026) — https://www.cisco.com/c/en/us/products/collateral/switches/catalyst-ie9300-rugged-series/catalyst-ie9300-rugged-series-ds.html

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- Cisco Secure Firewall 3100 Series data sheet — https://www.cisco.com/c/en/us/products/collateral/security/firewalls/secure-firewall-3100-series-ds.html
- Cisco, End-of-Sale and End-of-Life Announcement for the Firepower 2100 Series (Nov 26, 2024) — https://www.cisco.com/c/en/us/products/collateral/security/firepower-ngfw/firepower-2100-series-sec-app-5-yr-sub-eol.html
- Cisco Catalyst 9500 Series end-of-life notice listing — https://www.cisco.com/c/en/us/products/switches/catalyst-9500-series-switches/eos-eol-notice-listing.html
- IEC 62443-3-3:2013, System security requirements and security levels (stability date 2027) — https://webstore.iec.ch/en/publication/7033

1c · Public implementations this design follows

Deployment rows are real public deployments, each dated. Where no public deployment matches, the row is Vendor documentation: the vendor's document that this design, Symbeeo's own, is built on.

Table 2. Public implementations this design follows

Implementation	Who published it · date	What it settles for this design	URL
Vendor documentation. Offshore Wind Farm 1.3 Design Guide: turbine area network on IE3400, a farm area network of closed 1G fiber rings of turbine base switches, at most 18 base switches per ring, REP for ring resilience; OSS and ONSS cores; an NGFW at the OSS DMZ facing the turbine manufacturer's network; VRFs for management, video and voice, Wi-Fi, OT and internet; Cyber Vision sensors on the IE switches; control-center traffic behind a firewall pair in HA	Cisco · Apr 2, 2026	R2, R3, R9, §3 and §4.1–4.4: the ring shape, ring limit, the manufacturer-facing DMZ and the VRF split are the vendor's validated design, not this document's invention	https://www.cisco.com/c/en/us/td/docs/solutions/Verticals/Utilities/Wind_Farm/Wind-Farm_1-3_Design_Guide.html

Current parts in place of two validated ones: the design guide validates the OSS core on the C9500-16X, whose end-of-sale was announced Apr 30, 2025 with end of sale on Apr 30, 2026 [S], and the firewall on the Secure Firewall 2140, past end of sale on May 27, 2025 with the 3100 series named as its migration [S]. This document uses the C9500X-60L4D and the Secure Firewall 3110 and 3120 in their places (R5, R6).

2 · Requirements register

Table 3. Requirements register

#	Requirement	Value	Source
R1	Farm	72 turbines, 8 strings of 9, one OSS, one ONSS, ROC and standby ROC	[A]
R2	Ring size	at most 18 base switches per farm area ring; 9 used	[S] Cisco design guide 1.3; [A] 9
R3	Turbine base switch	IE-3400-8P2S: 8 × 1GE PoE/PoE+ copper, 2 × 1GE SFP; 240 W PoE; −40 to +70 °C vented; IEC 61850-3, IEEE 1613, DNV-CG-0339; REP, PRP, HSR, MRP	[S] IE3400 data sheet

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#	Requirement	Value	Source
R4	Ring aggregation, OSS	IE-9320-22S2C4X: 22 × 100/1000 SFP, 2 dual-media, 4 × 1/10G; stack of up to 4; REP, MRP, HSR, PRP; MACsec-256; IEC 61850-3, IEEE 1613; −40 to +75 °C in a blower-equipped cabinet	[S] IE9300 data sheet
R5	OSS and ONSS core	C9500X-60L4D pair in StackWise Virtual: 60 × 10/25/50G + 4 × 40/100/200/400G	[S] via SRA-NET-001 R5
R6	Boundary firewalls	Secure Firewall 3110: 17.0 Gbps FW+AVC+IPS, 2 million sessions; 3120: 21.0 Gbps, 4 million; 8 × 1G RJ45 + 8 × 1/10G SFP; 1 RU; 0–40 °C	[S] 3100 data sheet
R7	Export-cable links	2 × 10G, OSS core to ONSS core, one per export cable	[A]
R8	Control-center links	2 × 1 Gbps diverse carrier circuits ONSS to ROC, 1 × 1 Gbps ONSS to standby ROC; encrypted end to end	[A]
R9	Zones and conduits	zones under IEC 62443-3-2, each with a target security level under IEC 62443-3-3: SL-T 2 for OT zones, SL-T 3 for the control zone	[S] IEC 62443-3-3 levels; [A] targets
R10	IT to OT	no routed path from IT into an OT zone; every IT–OT flow terminates in the OT DMZ	[T]
R11	Turbine manufacturer network	its own zone; one conduit, through the OSS DMZ firewall	[S] Cisco design guide 1.3 pattern
R12	Ring recovery	one fiber cut per ring recovered in under 1 s, measured at commissioning	[T]; the design guide publishes no figure
R13	Standby ROC	takes control of the farm within 15 min of the ROC losing both links	[T]
R14	OT visibility	Cyber Vision sensor on every IE switch	[S] design guide; [A] license tier

Fourteen rows; eight carry a vendor or standards figure, three are design assumptions, three are design targets.

3 · Architecture overview

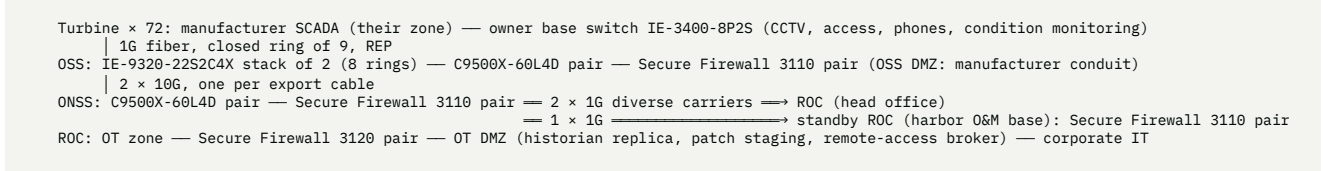


Figure 1. Wind farm OT and IT network

Three places where the design draws a line: at the OSS DMZ, where the manufacturer's network meets the owner's; at the ONSS, where the farm meets the carriers; and at the ROC, where OT meets IT. Everything on the OT side of the

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ROC's OT DMZ is OT; nothing in IT holds a route into it.

Table 4. Architecture overview

Role	Product (exact model)	Qty	Capacity used	Why this unit
Turbine base switch	Cisco IE-3400-8P2S	72 + 8 spares [A]	2 SFP for the ring, 5 of 8 PoE ports [A]	Marine-certified (DNV-CG-0339), substation-rated, −40 °C [S]; the design guide's turbine switch [S]
Ring aggregation (OSS)	Cisco IE-9320-22S2C4X	2 (stack)	16 of 44 SFP ports, 36 % [A]/[S]	Each ring closes on two stack members; IEC 61850-3 in the OSS equipment room [S]
OSS and ONSS core	Cisco C9500X-60L4D	4 (2 pairs)	under 20 of 60 ports per switch [A]/[S]	Chosen over Cisco's named migration for the design guide's C9500-16X, the C9500-24Y4C [S] (end-of-sale notice: `https://www.cisco.com/c/en/us/products/collateral/switches/catalyst-9500-series-switches/c9500-16x-switch-nm-c9500-nm-8x-nm-2q-eol.html`), for a 400G path to a second farm [A]; 10G for the export links
OSS and ONSS boundary	Cisco Secure Firewall 3110	4 (2 pairs)	about 1 Gbps of 17.0 Gbps, 6 % [A]/[S]	3100 series is Cisco's named migration from the 2100 [S]; SFP ports for fiber [S]
Standby ROC boundary	Cisco Secure Firewall 3110	2 (1 pair) [A]	about 1 Gbps of 17.0 Gbps, 6 % [A]/[S]	terminates the third tunnel (§4.4); same model as the substations [A]
ROC IT–OT boundary	Cisco Secure Firewall 3120	2 (1 pair)	about 1 Gbps of 21.0 Gbps, 5 % [A]/[S]	4 million sessions for the historian and remote-access brokers [S]

4 · Design by subsystem

4.1 Turbine network.

The manufacturer's SCADA network inside each turbine is its zone, and it connects to the owner's network only through the OSS DMZ (R11) [S]. The owner's base switch in each tower carries the owner's services — CCTV, access control, phones, condition-monitoring sensors — on separate VLANs mapped to VRFs at the OSS core, as the design guide's VRF list does [S]: management, video and voice, OT, Wi-Fi [A]. The IE-3400-8P2S is DNV-certified for marine use and runs from −40 to +70 °C [S]. Rejected: one switch shared with the manufacturer — it merges two owners' change control into one box.

4.2 Farm area rings.

Eight rings of nine base switches, each closed on two members of the IE-9320 stack at the OSS [A], inside the design guide's limit of 18 [S] (R2). REP on every ring [S]; a cut anywhere in a ring leaves every turbine reachable the other way. R12's under-one-second recovery is a target for commissioning, because the guide publishes no convergence figure [T]. Ring load: two 4 Mbps cameras per turbine [A] puts about 72 Mbps on a 1G ring. Rejected: rings of 18 — allowed [S], but a double cut then isolates up to 18 turbines rather than 9 [A].

4.3 OSS, export links and ONSS.

A C9500X-60L4D pair in StackWise Virtual at each substation [S]: two 10G links, one over each export cable (R7), so losing one cable leaves the farm connected [A]. The OSS firewall pair holds the DMZ facing the manufacturer's network;

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the ONSS pair terminates the carrier circuits [A]. Rejected: the design guide's C9500-16X — end of sale Apr 30, 2026 (announced Apr 30, 2025) [S]. Rejected: an IE-9320 stack as the substation core — it would work at this port count [S], but the 400G-capable core keeps the ONSS ready for a second farm's export link [A].

4.4 Control-center links.

Two diverse carrier circuits from the ONSS to the ROC and one to the standby ROC (R8) [A]. Route-based IPsec between the ONSS firewall pair and the ROC pair over both circuits, and a third tunnel to a Secure Firewall 3110 pair at the standby ROC; BGP over the tunnels picks the path [A]. The tunnels carry only OT zone traffic; CCTV is recorded at the ONSS and viewed on demand, so the links are not sized for continuous video [A]. The standby ROC holds a warm SCADA client set and takes control inside 15 minutes of the ROC losing both links (R13) [T].

4.5 The IT–OT boundary.

At the ROC a Secure Firewall 3120 pair separates the OT zone from an OT DMZ, and the corporate firewall (out of scope) separates the DMZ from IT [A]. The DMZ holds three things: a historian replica that IT reads, a patch and antivirus staging server that OT pulls from, and a remote-access broker for the manufacturer and contractors [A]. No IT host holds a route into an OT zone (R10) [T]; every flow is initiated from the OT side or terminates in the DMZ [A]. Security levels: SL-T 2 for OT zones and SL-T 3 for the control zone (R9) [A], against the IEC 62443-3-3 requirement set [S]. Rejected: a one-way data diode for the historian — stronger, but the operator's remote-access and patching flows are two-way, so the DMZ is needed anyway [A].

4.6 Visibility and management.

Cyber Vision sensors on every IE switch report assets and flows to a Cyber Vision Center at the ROC, as in the design guide [S]. Management traffic rides its own VRF to the ROC and never crosses the OT DMZ into IT [A]. Software baseline: the IOS XE release Cisco recommends on the staging day, recorded per platform [A].

5 · Failure behavior

Table 5. Failure behavior

Failure	Behavior	Source
One fiber cut in a ring	REP opens the blocked port; every turbine stays reachable	[S] REP; [T] < 1 s
One base switch lost	that turbine's owner services dark; the ring stays whole the other way	[A]
One export cable lost	second 10G carries all farm traffic	[A]
One carrier circuit lost	BGP moves the tunnel to the second circuit	[A]
ROC loses both circuits	standby ROC takes control over its own circuit (R13)	[T]
Firewall member fails	its HA peer carries the traffic	[S] HA pair per the design guide; [A]
Manufacturer's network compromised	contained at the OSS DMZ; the owner's zones hold	[S] pattern; [A]

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6 · Limits

- The turbine manufacturer's network is outside the design; its security rests on the service agreement and the single conduit, not on this document.
- Ring recovery under 1 s is a target; the design guide publishes no figure for it.
- Security levels are targets set here, not the result of an IEC 62443-3-2 risk assessment, which the operator runs before the build.
- The C9500X-60L4D is sized for growth, not for this farm; one farm alone would fit a smaller core.
- The standby ROC depends on one carrier circuit; a second is a cost decision left to the operator.

7 · Lessons learned

None yet — this is a design study; populated after the first build against it.

8 · The author

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Figures are as published by their sources on the dates given in this document; figures marked [A] are assumptions.

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