WHITE PAPER

INDUSTRIAL CONNECTIVITY SERIES

Stop Terminating.
Start Connecting.

The Real Cost of Traditional Control System Wiring, and What Industrial Machine Builders Can Do About It

FOR

Senior leaders, VPs, engineering directors and controls managers at industrial machine builders

WHAT YOU WILL FIND INSIDE

- Why traditional wiring is your most expensive hidden cost
- The skilled labour gap that's getting worse, not better
- How variability in hand-terminated wiring drives rework and warranty exposure
- The reliability case for IP67 connectorized systems
- A practical framework for calculating your own total cost of ownership

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OVERVIEW

Executive Summary

THE CORE ARGUMENT

If you are an OEM building machines with traditional centralized control panels, a significant portion of your build cost, field service exposure, and warranty risk is sitting inside that cabinet. Most of it never appears as a clean line item. It shows up later as wiring errors, commissioning rework, troubleshooting time, service calls, and intermittent faults that are expensive to diagnose in production.

This white paper makes the business case for decentralized IP67 connectivity architecture as a financial decision, not a technical preference. It shows where traditional centralized wiring costs accumulate across the build, commissioning, field service, and warranty, and explains how moving signal connections from the cabinet to the machine can reduce manual terminations, improve build consistency, simplify troubleshooting, and reduce reliance on scarce skilled labour.

The argument is not that centralized wiring is wrong for every application. Cabinets still have their place. The issue is that many OEMs have never fully calculated what traditional machine wiring costs across the full lifecycle of the machine. Once they do, the conversation changes from component price to total machine cost, reliability, and long-term competitiveness.

The question worth asking is whether anyone on your team has ever run that number, and what they found if they did

~50%

Of total panel build time consumed by wiring alone

Stuttgart / Rittal / Eplan

2 min

Per terminal connection when fully accounted

Cutting, stripping, ferrule, labelling, connecting

54 hrs

Wiring time documented in a single enclosure

Real Rittal case study (Elpex AG)

WHAT IT TAKES TO WIRE A MACHINE WITH 100 I/O DEVICES

100 I/O devices
at 2 minutes each wire

=

16.6 hours
of termination labour

→

$664 to $879
at journeyman rate

Before any testing. Before any commissioning. Before the first engineering change order arrives.

THE CORE FINDING

Wiring labour alone consumes approximately 50 percent of total panel build time. A machine with 100 I/O points carries roughly 16 hours of termination labour before a single test is run. When that work is done by a journeyman electrician at $40 to $53 per hour fully loaded, it is your most expensive build activity, and the one most likely to produce the faults that follow a machine into the field.

01 SECTION

How IP20 Architecture Actually Gets Built

Before making the cost argument, it helps to be precise about what traditional IP20-based machine wiring actually involves. The IP20 rating means a component is protected against solid objects larger than 12.5mm. It offers zero protection against water, moisture, or dust. Which is why every IP20-rated terminal block, relay, and I/O card must live inside a sealed, climate-controlled electrical cabinet.

THE IP20 PANEL BUILD WORKFLOW

01 Engineering produces schematics and a wiring schedule.

02 Enclosure is fabricated. Marked up and taped, holes drilled and punched for cutouts and cable glands, back panel prepared.

03 Internal components are mounted: DIN rail, wire duct, terminal blocks, fuse holders/breakers, PLC, I/O cards, power supply, etc.

04 Wiring begins. Each conductor is cut, stripped, fitted with a ferrule, crimped, labelled, routed through wire duct, and terminated at a terminal block.

05 Every field device runs a dedicated home-run cable back to those terminal strips.

06 On a machine with 100 I/O points, this produces a cabinet with over a hundred metres of internal wiring.

~50%

Of build time spent on wiring alone

Stuttgart / Rittal / Eplan

500

Terminations on a 100 I/O machine

About 20 hours of labour, panel only

A joint study by Rittal, Eplan, and the University of Stuttgart's ISW Institute found wiring alone consumes 49 to 50 percent of total panel production time. They documented enclosures requiring up to 54 hours of wiring. Graham Traill at Murrelektronik puts the time at approximately two minutes per terminal connection when stripping, ferrule crimping, labelling, and screw connection are properly accounted for.

THE HIDDEN COST IN PLAIN SIGHT

Most OEMs budget for the components inside the cabinet. Very few budget for all the time it takes to wire them. Almost none account for what happens when that wiring fails in the field. The enclosure is not incidental to the design. It is a structural requirement, and it costs money at every stage.

02 SECTION

The Skilled Labour Problem Is Structural, Not Cyclical

THE STRUCTURAL SHORTAGE

81,000

Electrician openings projected annually through 2034

BLS Occupational Outlook

$40 to $53

Fully loaded hourly cost for a journeyman

UL 508A panel work, North America

-14%

Projected workforce shrinkage by 2030

Against 25% projected demand growth

Traditional control panel wiring is skilled work. It requires electricians who understand schematics, can read wiring schedules, apply ferrules correctly, observe colour-code and sequencing conventions, and work to UL 508A or equivalent standards. That workforce is shrinking.

The US Bureau of Labor Statistics projects approximately 81,000 electrician job openings annually through 2034. The industry currently loses around 10,000 electricians per year to retirement and gains only 7,000 new entrants. A 2024 Manufacturing Institute and Deloitte study found nearly 30 percent of union electricians at or near retirement age.

Electrical Contractor Magazine projects the electrician workforce will shrink by 14 percent by 2030, while demand will grow by 25 percent. For a packaging OEM, this is a compounding risk. The supply of qualified panel builders is shrinking. The cost of the ones you can find is rising.

WHAT THE DATA SHOWS

- 10,000 electricians lost to retirement annually vs 7,000 new entrants
- 30% of union electricians at or near retirement age
- Field electrician rates $81 to $136 per hour, including travel
- Not just a North American problem. Consistent across Western Europe, Australia, and most developed markets

> *"Qualified and skilled employees are practically unavailable on the labour market."*
> Rittal, Assessment of the Panel-Building Market

THE KEY QUESTION FOR YOUR LEADERSHIP TEAM

If the supply of qualified electricians tightens further over the next five years, which all available data suggests it will, what is the strategic risk to your production capacity and delivery commitments? Is your machine control system architecture dependent on a workforce that is becoming structurally scarce?

03 SECTION

The Tribal Knowledge Problem

WHAT LEAVES WHEN THE EXPERT RETIRES

In most panel shops and machine-building facilities, the ability to wire a complex control panel correctly is not documented in a procedure manual. It lives in the heads of experienced panel builders, who know where the wire duct gets congested on a particular machine, which terminal positions cause problems or rework, and the torque feel for terminal blocks from a specific supplier. They know which routing choices look fine on the drawing but become awkward on the bench, which parts of the panel always take longer than estimated, and where a small shortcut during build will usually become a bigger problem during testing. None of this is written down because, until recently, it did not need to be.

When that person retires, the decision-making framework built from years of trial and error leaves with them. The replacement may be technically competent, but they will make the same slow, expensive mistakes every new panel builder makes: the under-torqued terminal, the transposed label, the cable that is three inches too short. They may follow the drawing exactly and still miss the practical judgement that tells an experienced builder when something will be hard to service, difficult to troubleshoot, or likely to cause problems once the machine is under pressure.

Traditional control panel wiring is a craft skill, and craft skills are passed down through apprenticeship, not training manuals. Reading a wiring schedule and executing a complex panel build correctly under delivery pressure are not the same competency. The gap between them is filled by experience, and that experience takes years to accumulate. In a market where experienced panel builders are leaving faster than new ones are being trained, that gap is widening. The result is not just a labour shortage. It is a knowledge-transfer problem hidden inside the wiring system itself.

<1 hour

To train a new hire on IP67 connectorized wiring

Versus 2 to 4 years for a panel builder apprenticeship

$27 to $30

Hourly cost for a general assembly technician

Versus $40 to $53 for a journeyman electrician

THE IP67 ALTERNATIVE

- No craft skill required
- Align the connector, plug in, verify the green LED
- Trainable in under 1 hour
- Quality is binary, not variable
- Verified at manufacture, not installation

> *"The knowledge required to wire a complex IP20 panel correctly cannot be written down. It can only be transferred person to person, over years, through repetition. That transfer chain is breaking. IP67 connectorized architecture does not require a transfer chain. It requires a label, a connector, and a green LED."*

THE GENERATIONAL DIMENSION

The generation entering industrial manufacturing today has grown up with plug-and-play technology as the baseline expectation. Handing them a wiring schedule, ferrule crimpers, and a DIN rail full of terminal blocks is a skills mismatch. IP67 redirects skilled development toward diagnostics and machine optimization, where human judgment adds value, rather than mechanical execution, where human variability adds risk.

04 SECTION

Variability: The Cost That Hides in Plain Sight

Hand-terminated wiring introduces variability that cannot be fully engineered away. Every connection is made by a human being, under time pressure, potentially late in a build schedule. The problem is not that skilled electricians do bad work. It is that humans are variable, and variability at the connection level produces intermittent, difficult-to-trace faults.

HIGH RISK

Under-torqued screw terminals

A screw terminal torqued below specification produces a connection that tests fine on the bench but loosens under vibration and thermal cycling in service. Research found terminals torqued at 67 percent below specification show temperature increases of 13 to 16 percent. Grace Technologies reports loose connections contribute to over 30 percent of all electrical faults.

HIGH RISK

Ferrule omission and incorrect sizing

Ferrules protect stranded conductors from splaying inside a screw terminal and from being partially cut during tightening. An omitted ferrule, or one that is the wrong gauge, produces a connection that may carry current normally but degrades under vibration or thermal cycling. Detection requires point-to-point testing that cannot be done at speed.

HIDDEN COST

Wire labelling errors

Every conductor must be labelled at both ends to enable tracing. A mislabelled wire does not cause an immediate failure. It causes a diagnostic failure when something else goes wrong. Black Rhino Electric documents a four-hour fault-finding case where a single mislabelled conductor was the root cause.

NOTE

A note on spring cage terminals

Spring cage terminals are mechanically better on vibration resistance. But the issue was never the clamping mechanism. It was workmanship-dependent variability at scale. A machine with 400 spring cage terminations still has 400 hand-made connections. Strip length, conductor preparation, and ferrule choice still matter.

BUILD-TO-BUILD VARIATION

Different panel builders route wires differently. Strip lengths vary. Terminal positions shift. Every machine becomes a unique build, and the schematic no longer matches the physical machine. Diagnostic history from one machine does not predict fault locations on another.

THE 80/20 RULE MOST OEMS DO NOT TALK ABOUT

Industry practitioners often cite field wiring and manual termination points as the source of most electrical faults. Not the PLC, not the HMI, and usually not the software. The machine's weak point is often the wiring between the cabinet and the field devices. That is where variation enters, and that is where reliability quietly gets compromised.

05 SECTION

How Variability Becomes Rework and Warranty Cost

The consequences of wiring variability do not stay on the shop floor. They travel with the machine to the customer site. When they surface, they become your problem. Cost accumulates across three stages, each more expensive than the last.

STAGE 01

Rework at build

An engineering change order mid-wiring requires re-routing cables, re-labelling conductors, sometimes re-fabricating sections of the DIN rail. Since wiring accounts for half of the build time, a mid-build change on a 40-hour panel can easily cost 10 to 15 additional hours of skilled labour without adding any new capability.

STAGE 02

Field commissioning

A machine that arrives at a customer site with an incorrect termination requires a return visit by a qualified electrician. At field rates, a single remedial visit costs $81 to $136 per hour plus travel. For machines shipped internationally, this becomes a serious liability.

STAGE 03

Warranty failures

Most wiring-related warranty failures do not appear as wiring failures. A machine that stops intermittently is a “machine fault.” A sensor that reads incorrectly is an “alignment issue.” The customer calls in service, or sometimes a subcontractor, before anyone finds the loose terminal that was there from the original build.

TABLE 1 — FAILURE MODES BY ARCHITECTURE

Failure mode	IP20 hand-terminated	IP67 connectorized
Wiring error at build	Possible at every termination - strip, ferrule, torque, label all variable	Low - pre-tested factory cordsets
Vibration loosening	Ongoing risk at every screw terminal	Eliminated - Connector locking indents
Intermittent open circuit	Common, fault only present under load	Very low - tested to 20g vibration
Field rework cost	$81 to $136/hr - licensed electrician	Swap cable, one tool, any technician
Warranty diagnostics	Schematic vs physical mismatch	Per-channel LED indicator

$260K/HR - SIEMENS TRUE COST OF DOWNTIME REPORT, 2024

Average cost of unplanned manufacturing downtime across industrial sectors. When a warranty call involves two to four hours of customer downtime, the cost to your customer is real, and the cost to your relationship is harder to recover.

06 SECTION

IP67 Decentralized Architecture

WHAT IT IS AND WHY IT CHANGES THE MATHS

In a decentralized IP67 architecture, machine-mounted I/O modules rated IP67 sit directly on the machine frame, close to the devices they serve. Sensors and actuators connect via M12 or M8 circular connectors on factory-made, pre-tested cordsets. The PLC communicates with these distributed modules over a single industrial Ethernet network cable rather than routing hundreds of individual signal conductors back to a central cabinet.

86 to 89%

Reduction in total machine cable length

Kollmorgen, 8-axis machine study

40 to 80%

Installation time reduction vs traditional

Murrelektronik / Process Industry Forum

30 to 60%

Reduction in wiring hardware and labour costs

Balluff / Healy, Assembly Magazine

THE SKILL LEVEL QUESTION

IP20 - SKILLS REQUIRED

- Read and interpret electrical schematics
- Apply ferrules correctly, correct gauge
- Maintain colour coding and sequencing
- Work to UL 508A or equivalent
- 2 to 4 year apprenticeship to proficiency

JOURNEYMAN ELECTRICIAN

$40 to $53/hr fully loaded

IP67 - SKILLS REQUIRED

- Identify cable by label
- Align connector to port
- Thread or click into place
- Verify LED shows green
- Trainable in under 1 hour

ASSEMBLY TECHNICIAN

$27 to $30/hr fully loaded

THE STRATEGIC CHANGE

The most strategically important change with IP67 architecture is not the connection time. It is the skill level required. Hand-terminated IP20 wiring requires electricians who can read schematics, apply ferrules, maintain colour coding, and work to UL 508A. That workforce is constrained and expensive. IP67 connectorized wiring requires mechanical assembly skills: identify the cable, align the connector, plug it in, confirm LED is green. There is no need for an electrician because there is no cabinet and there are no wires to terminate.

07 SECTION

The Reliability Case for IP67

The business case for IP67 decentralized architecture rests partly on total cost reduction and partly on a fundamentally different reliability profile. The two are connected. The failure modes that drive your highest-cost warranty events are the same ones that IP67 architecture eliminates at the design level.

20g

M12 vibration resistance per EN 60068-2-6

430K hrs

Murrelektronik Emparro67 MTBF, ~49 years

Per-channel

LED fault indication on every IP67 module

IP67

Total dust, water immersion to 1 metre

FAULT DIAGNOSIS: SAME FAULT, TWO DIFFERENT EXPERIENCES

IP20 HAND-TERMINATED

01 Machine stops. Fault code references a sensor input.

02 Electrician opens cabinet. Fault not present at rest.

03 Machine restarted. Fault recurs under vibration.

04 Schematic consulted. Wiring does not match drawing precisely (build variation).

05 Point-to-point continuity test across relevant terminals.

06 Under-torqued terminal found on row 7. Re-terminated.

07 Total elapsed: 3 to 6 hours. Electrician required throughout.

IP67 CONNECTORIZED

01 Machine stops. Fault code references a sensor input.

02 Technician walks to the I/O module. LED on channel 4 is off.

03 M12 cordset on channel 4 inspected. Connector partially unseated.

04 Cordset reseated and locked. LED returns to green.

05 Machine restarted. Production resumes.

06 Total elapsed: 8 to 12 minutes. No electrician required.

66% - SCHNEIDER ELECTRIC / PARKER PRECISION CASE STUDY

A documented case study for a 5,000 HP motor control application showed a 66 percent reduction in panel build time and approximately 30 percent reduction in total cost when moving from traditional wiring to a connectorized architecture. Measured outcomes from a production build, not projections.

08 SECTION

Total Cost of Ownership Framework

Evaluating IP20 versus IP67 architecture on component cost alone produces the wrong answer. The business case rests on total system cost across the full machine lifecycle: build, commissioning, field service, and warranty. The framework below identifies the five cost components that matter most.

01 — Build labour

Electrician time to wire, route, label, and terminate

02 — Rework (ECOs)

Engineering changes mid-build. Re-route, re-label, re-terminate

03 — Commissioning

Time to verify connections, diagnose faults, confirm operation

04 — Field service

Electrician cost, travel, customer downtime

05 — Warranty

Intermittent fault diagnosis and customer downtime exposure

TABLE 2 - TCO COMPARISON SUMMARY

Component	IP20 architecture	IP67 architecture
Build labour	$40 to $53/hr journeyman, ~2 min per termination, 50% of build time	$27 to $30/hr assembly tech, seconds per M12, no ferrule or torque tool
Rework (ECOs)	Re-route, re-label, re-terminate. Skilled labour throughout	Reconfigure cordset routing. Minimal rework, no special skills
Commissioning	Point-to-point verification. Electrician traces every conductor	Per-channel LED. Green = correct. No schematic tracing
Component cost	Lower unit cost on terminal blocks, I/O cards, enclosures	Higher unit cost on IP67 modules and cordsets. Evaluate on system cost
Field service	$81 to $136/hr including travel. Cabinet access required	Swap cable or module. Any technician. Per-channel diagnosis
Warranty exposure	Intermittent vibration faults. Complex diagnosis	Vibration-stable M12 collar. LED indicators. Visible fault location
Floor space / cooling	HVAC, floor footprint, panel shop space ongoing	Machine-mounted modules. No cabinet cooling required

THE HONEST CAVEAT

IP67 hardware typically costs more per unit than IP20 equivalents. Pre-molded cordsets, IP67 I/O blocks, and field-mounted power supplies carry a unit premium. The business case rests on total system cost - components, cables, enclosures, labour, commissioning, and lifetime maintenance - not on component-level line items. OEMs who evaluate IP67 on component cost alone will always reach the wrong answer.

09 SECTION

What the Market Is Telling You

The evidence that decentralized IP67 architecture is becoming the standard, not the exception, for industrial machine design is visible in what every major automation supplier is now building, promoting, and selling. These are not niche products for specialist applications or unusual machine designs. They are mainstream catalogue items from the largest automation vendors in the world, which tells you the market has already moved beyond the question of whether machine-mounted connectivity is viable. The real question now is how quickly OEMs will adapt their machine designs to take advantage of it.

ROCKWELL AUTOMATION

ArmorBlock 5000

Designed for on-machine distributed I/O in harsh environments. CIP Safety option, EtherNet/IP native. Rockwell position it as a primary architecture for new machine designs.

SIEMENS

ET 200eco PN

Block I/O for cabinet-free setup. The phrase "cabinet-free setup" in Siemens' own product language describes the architecture the product is designed to enable.

BECKHOFF

EtherCAT Box

Directly on the machine, without a control cabinet. The EtherCAT Box series has been in continuous production for 25 years. Mature, proven, mainstream.

MURRELEKTRONIK

MVK Fusion CIP & Impact67 Pro

MVK Fusion with CIP Safety, IO-Link, and DIO combined on a single module eliminates the need for a separate safety relay cabinet. Impact67 Pro offers advanced IO-Link with DIO, MQTT and OPC UA for IIoT applications.

PILZ

IP67 Safety I/O

Cabinet-free functional safety architecture. When safety-rated I/O can be mounted directly on the machine, the last argument for a centralized safety cabinet becomes significantly weaker.

These five suppliers represent a large portion of the industrial automation and connectivity market. The fact that all of them have made IP67 decentralized I/O a core part of their product strategy is not a coincidence. It reflects where their customers are going, and where machine design expectations are heading. For an OEM evaluating machine designs for the next five to ten years, the question is not whether the industry is moving toward decentralized IP67 connectivity. The industry has already moved. The real decision is whether your control system designs keep pace with it, or whether hidden wiring costs, complexity, and serviceability issues remain built into all your machines.

THE STRATEGIC QUESTION

The question is whether your control system architecture is aligned with the direction the industry is heading, or whether your machines will arrive at customer sites carrying an out-of-date wiring architecture, a dependence on skilled labour, and a reliability profile from a previous decade.

CONCLUSION

The Cost Is Already in Your Budget. You Just Cannot See It.

The case for IP67 decentralized connectivity is not a technical argument. It is a business argument. It rests on five propositions that the evidence consistently supports. The machines you are designing today will be in production for ten, fifteen, or possibly twenty years. The wiring architecture you choose now is the warranty liability, the service profile, and the dependence on skilled labour you are committing to for that entire period.

THE FIVE PROPOSITIONS

01

Wiring labour is your largest hidden build cost.

It consumes half your panel build time, is performed by your most expensive trade, and produces the most variable output on your production floor.

02

The skilled labour you depend on is becoming structurally scarce.

The projections are not ambiguous. The workforce is shrinking faster than it is being replenished. The skilled labour shortage is not a temporary market condition.

03

Tribal knowledge that cannot be documented or quickly transferred.

It takes years to develop, walks out the door when panel builders retire, and no training manual compensates for its absence. IP67 architecture replaces craft dependency with a process that any new hire can execute correctly within an hour.

04

Hand terminations introduce variability that follows your machine into the field.

The failures it produces are intermittent, hard to diagnose, and expensive to resolve, both in direct service cost and in warranty liability.

05

IP67 connectorized systems eliminate failure modes that drive your highest-cost field events.

IP67 connectorized systems reduce skill requirements, shorten build time, and produce consistent results across every machine you build, regardless of who built it.

STOP TERMINATING. START CONNECTING.

The total cost of IP20 control architecture, across build labour, rework, commissioning, field service, and warranty, is substantially higher than the component cost suggests. The total cost of IP67 connectorized systems, evaluated on the same basis, is much lower than the hardware price implies.

Let's talk about your machines.

If this white paper raised questions about your current wiring practices, or confirmed something you already suspected, I am happy to work through the specifics with you. No sales pitch. Just an honest conversation about what your machines actually cost to build, commission, and support.

FREE 30-MINUTE SESSION

Book a Connectivity Chat

No agenda. No pitch. Just a casual conversation about your current control architecture, your specific machines, and whether there is a better way to build them.

- We talk through your current build process and where the costs are sitting
- I give you specific examples of where IP67 architecture would change the math
- You leave with a clear, prioritized list of opportunities and where to start
- Conducted virtually or on-site. No obligation. No sales pitch.

Schedule your free session at ConnectivityColin.com/chat

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