From Hardware Redundancy to Diagnostic Visibility

A field-ready digital-twin and predictive-maintenance architecture that turns a dual-drive electrohydraulic actuator into a self-diagnosing pipeline safety valve

CATEGORY · AI & Digital Transformation

About this proposal. Paper proposal prepared for the ADIPEC 2026 Technical Conference (Abu Dhabi, 2–5 November 2026) under the **AI & Digital Transformation** category. It follows the SPE paper-proposal format (Objectives/Scope; Methods, Procedures, Process; Results, Observations, Conclusions; Novel/Additive Information) within the 225–450-word limit, presents original, previously unpublished electrohydraulic-actuator engineering, and observes SPE policy on non-commercial content. Safety-integrity results reflect internal evaluation against the cited standards, with independent functional-safety certification on a defined path.

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Paper Proposal

1. Objectives / Scope (25-75 words)

Conventional SIL 2 hydraulic power units on pipeline Emergency Shutdown Valves run on a single motor with no drive redundancy, and operate as opaque assets whose degradation stays hidden until a proof test or trip reveals it. This paper presents a field-ready dual-drive electrohydraulic actuator whose two independent drive lanes add redundancy beyond the SIL 2 baseline and, through continuous telemetry and a paired digital twin, operate as a self-diagnosing asset for condition-based intervention.

2. Methods, Procedures, Process (75-100 words)

Each independent motor lane streams current-envelope, position and pressure data while the dual-drive pump generates four physically grounded diagnostic signatures: inter-motor current cross-checking, drive-gear and idler-gear phase-lock signatures, correction-table drift trending and partial-stroke torque-differential analysis. A digital-twin engine ingests these streams, solves the site-specific duty and tracks degradation against a baseline. The diagnostic value was qualified through a component-level Failure Modes, Effects and Diagnostic Analysis under IEC 61508 and IEC 61511, comparing detected and undetected dangerous failure rates against a single-motor actuator carrying only indirect diagnostics.

3. Results, Observations, Conclusions (100-200 words)

The digital signatures migrate the three dominant failure modes — stiction, internal leakage and volumetric drift — from dangerous-undetected to dangerous-detected, substantially reducing the undetected-dangerous failure rate on the actuator channel relative to the single-motor baseline. This control-room visibility supports a materially extended proof-test interval at equivalent integrity, alongside a reduced maintenance-dispatch rate, because incipient degradation is trended and flagged before it reaches a dangerous state. Higher integrity and lower operating burden are delivered primarily through information — richer diagnostic coverage and predictive analytics — rather than through additional safety hardware. The actuator operates as a self-diagnosing node within a digitally monitored pipeline-safety network, with the physical dual-drive topology making high diagnostic coverage attainable and the digital twin making it actionable. Engineered for field deployment, the architecture is portable to other hydraulically actuated safety functions on remote, unmanned assets, and meets the target integrity in internal evaluation against the cited standards.

4. Novel / Additive Information (25-75 words)

The contribution is a deployable digitalisation-of-safety architecture in which pump topology enables high diagnostic coverage and a digital twin renders it actionable. It establishes the gear-pair phase-lock signature as a machine-interpretable, credited diagnostic feature and defines the data architecture linking actuator telemetry to a predictive-maintenance layer, giving operators a field-ready path to condition-based integrity management with a defined route to independent certification.

Total ≈ 373 words · within SPE/ADIPEC 225–450-word proposal guideline. Structured per the SPE four-section proposal format. Title and author details are provided in the submission portal fields, not in the proposal body.