

[2026] Optimizing SRU Startup: Dynamic Dependency Relocation ¹

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Abstract

In general success of large-scale oil and gas facility startups pivots on the precise sequencing of construction, pre-commissioning, and operational readiness. Especially in oil and gas projects, Sulfur Recovery Unit (SRU) is a common bottleneck in the process, where refractory dry out process for the fired equipment often dictates the critical path. In conventional setups, this dry out process is performed during the commissioning phase, based on the readiness on permanent burners and fuel gas. This late-stage dependency creates significant risks for the project completion and safety factors, as it ties the startup timeline to the availability of fuel gas, the completion of instrumentation, and final system turnover, potentially causing delays. Recognizing this bottleneck is the first step toward re-engineering the dry out process to decouple it from these late constraints.

This paper presents a strategic schedule optimization initiative undertaken within a major gas development project in Saudi Arabia, focusing on the fired equipment, for example, Reaction Furnace, Thermal Oxidizer, Reducing Gas Generator, etc. By advancing an established electrical dry-out methodology into the construction phase, specifically immediately following refractory installation acceptance, team successfully decoupled the dry out process from long lead fuel gas infrastructure.

While underlying technology remained unchanged, the project achieved significant efficiency gains by re-sequencing the dry out workflow. This approach was governed by a rigorous, structured readiness gate model encompassing five key stages: refractory readiness, electrical readiness, dry out readiness, dry out completion and technical release. The result was a streamlined transition from construction to operation, demonstrating how

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process emphasizing can significantly accelerate project delivery without compromising technical integrity.

This strategy enabled early verification of rectory conditions, allowing deficiencies to be rectified during construction phase and high schedule flexibility. This transferred potential risks away from the high consequences for start-up window, ultimately yielding advancement in the start-up schedule while preserving strict engineering, quality and safety protocols. The paper argues that schedule resilience can be efficiently built through critical path analysis, interface decoupling, and engineering change control, independent of overtime or increased resources. By offering repeatable decision framework, this research provides a valuable tool for identifying and capitalizing on similar construction phase opportunities, ensuring more predictable and efficient project outcomes in future endeavors.

Keywords: *Project Management, Project Control Management, Critical Path method, lean management, Schedule Optimization, Project Framework, Risk Mitigation, Value Engineering, Construction productivity, SRU, Sulfur Recovery Unit, Refractory dry-out, EPC Projects, Saudi Arabia, Oil & Gas.*

Introduction

Large scale oil and gas projects are Characterized by complex interfaces among engineering, procurement, construction, pre-commissioning, commissioning and start-up. As projects near completion, schedule margins narrow while interdependencies intensify. Consequently, the transition from construction to commissioning emerges as one of the most schedule-sensitive phases in the project lifecycle. In this context, activities that may appear insignificant in isolation can become critical path drivers once they are sequentially linked to plant start-up.

Refractory dry out is a critical phase for high-temperature Sulfur Recovery Unit (SRU) equipment, requiring controlled moisture removal prior to exposure to operating temperatures. While conventional practices typically schedule final dry out during commissioning using permanent burners and fuel gas, this paper explores an optimized project-management approach. By strategically advancing the electrical dry out process

into the construction phase, we demonstrate how organizations can reduce critical-path exposure, enable earlier identification of refractory deficiencies, and safeguard startup milestones.

This article provides practitioners with a practical, transferable decision framework rather than proprietary technology. It details the comparison between conventional and optimized sequences, outlines the engineering and project-control disciplines necessary for safe execution, and presents a schedule benefit. Additionally, the paper addresses the limitations inherent in the underlying project data, offering transparency regarding the conditions required for future independent verification.

Literature Review

Conventional literature on construction scheduling consistently positions critical-path analysis as the primary mechanism for identifying activities that driven the project completion. However, research indicates that schedule optimization increases in complexity when resource limitations, material constraints, and inherent uncertainties are introduced during the project life cycle. These findings validate the approach adopted in this case study that optimization must be conducted compared to the integrated system as a whole, rather than through the isolated adjustment of individual activity durations.

Complementing the research into Critical Path Method (CPM) management underscores the limitations of purely deterministic scheduling in complex environments, where inter relationships and project constraints often shift as field conditions develop. Such volatility reinforces the necessity of implementing dynamic interface reviews and readiness-based decisions to maintain schedule integrity. In parallel to these scheduling challenges are the technical imperatives of refractory engineering. Industrial practice emphasizes the necessity of a controlled dry out process, as rapid or non-uniform heating can persuade damaging internal vapor-pressure conditions. Consequently, an electrical dry out strategy is technically feasible only when the heating profile, measurement systems, and ventilation are rigorously engineered and monitored.

Despite these advancements in scheduling and materials engineering, a distinct gap remains in the literature regarding the integration of refractory dry out into construction-phase schedule strategies. This case study does not propose a new refractory chemistry or

heater design, rather, it contributes a repeatable project-engineering framework for the strategic repositioning of commissioning dependencies.

Research Objectives

Key objective is to systematically optimize all activities falling on the project's critical path to enable early completion of the project while sustaining strict adherence to established project constraints. Purpose is to identify opportunities for the activity crushing, fast tracking or re-sequencing in fired equipment fabrication, transportation, installation, testing to reduce the overall project duration without compromising the project integrity. This acceleration should not impact at the expense of the following unavoidable constraints.

1. Technical Requirements: Align engineering deliverables with an accelerated timeline to prevent rework and design gaps.
2. Safety: Implement stringent HSE oversight to ensure schedule compression does not increase site risk or incident rates.
3. Quality: Uphold all QA/QC standards and inspection hold-points to guarantee asset integrity.
4. Project Control: Maintain strict schedule and cost governance to ensure transparency and baseline stability during optimization.

Success of this objective will be measured by the total reduction in the project completion timeline, achieved specifically through the optimization of the dry-out process for all fired equipment within the Sulfur Recovery Unit (SRU). This acceleration will be validated via a formal schedule analysis to ensure that all safety, quality, and engineering thresholds are strictly maintained without compromise.

Key Questions

Research Question: Can construction-phase electrical refractory dry out be safely integrated into a major gas-project execution schedule to reduce commissioning critical-path exposure while maintaining refractory quality, safety, traceability, and readiness?

Secondary questions:

- Which construction and commissioning prerequisites must be separated from the dry out activity?

- What controls are necessary to ensure that schedule acceleration does not create quality or safety risk?
- How should the result be measured and defended in project-control terms?

Hypothesis: If refractory dry out for the SRU Reaction Furnace and Thermal Oxidizer is executed during construction using an engineered electrical-heating system, under an approved dry out curve with continuous temperature monitoring, controlled moisture removal, inspection, and formal technical release, then the commissioning schedule can be decoupled from a portion of the dry out dependency and overall startup critical-path exposure can be reduced without reducing required technical assurance.

Methodology

The strategy was structured by six basic principles: Identify, Decouple, Technology, Control, Verify and Release.

- **Identify:** Map refractory dry out against the integrated Primavera/CPM network and determine whether it is critical or near-critical.
- **Decouple:** Separate dry out from permanent burner, fuel-gas and selected commissioning prerequisites where technically feasible.
- **Technology:** Develop a temporary electrical heating arrangement, temperature measurement plan, power-distribution scheme and ventilation/moisture-removal approach.
- **Control:** Execute only under an approved method statement, risk assessment, inspection/test plan and refractory manufacturer's requirements.
- **Verify:** Confirm temperature history, hold points, refractory condition, moisture removal and punch-list status.
- **Release:** Issue a formal readiness record so commissioning can use the result as a reliable input.

Electrical dry out uses controlled electrical energy to raise refractory temperature progressively and remove residual moisture. In the case study, the technology was positioned as a temporary construction-phase system rather than as a permanent process heating system.

A typical arrangement comprises temporary electrical heaters, distribution equipment, protective devices, temperature sensors, data logging, local control/monitoring, ventilation provisions and calibrated measurement instruments. The engineering design must establish heater capacity, load distribution, protection settings, cable routing, earthing/grounding, enclosure suitability and environmental controls.

Temperature measurement is central to the technology. Multiple measurement points are preferable to a single surface measurement because refractory temperature can vary spatially. The approved dry out curve should define ramp rates, intermediate holds and final conditions in accordance with the refractory system's technical requirements. The project team should not substitute a generic curve for the refractory supplier's approved requirements.

The technology also creates an information advantage: a continuously recorded temperature history provides objective evidence of execution. The record can be attached to the equipment turnover dossier and used to demonstrate compliance with the approved procedure.

Gate Sequence	Minimum Requirement	Decision Making
G1 – Refractory Completeness	Refractory Installation, curing, inspection, and punch-list completion	Proceed or Rework
G2 – Electrical Power readiness	Temporary power, heater inspection	Proceed or Rework
G3– Dry out readiness	Approved heating curve, sensors, ventilation, permits, procedures.	Proceed or Rework
G4– dry out Completion	Trend records and hold points achieved	Inspection
G5– Technical Release	Inspection, records, preservation, and punch-list closure	Earlier inspection and repair window is available

Table 1. Readiness-gate model used to govern the construction-phase optimization.

A key engineering distinction is between heating capability and dry out control. Installing a high-capacity heater does not improve dry out if the heat input is uncontrolled. The system

must be capable of maintaining the required ramp rate and avoiding excessive local temperature gradients.

To optimize the dry-out process for the Sulfur Recovery Unit (SRU) fired equipment, this project employs a Single Case Project Engineering Case Study methodology. This structured approach evaluates the specific complexities of the SRU assets to move from a conventional execution model to an optimized delivery sequence.

The methodology is executed through three integrated analytical lenses:

1. Critical Path Method (CPM) Schedule Review:
2. Construction-Commissioning Interface Analysis:
3. Gap Analysis:

Final output is a validated, accelerated sequence that minimizes the project duration while ensuring that safety margins, technical specifications, and quality hold-points remain intact. This systemic approach transforms the dry-out process from a static constraint into a strategic opportunity for early project completion.

Project Objective & Approach

- Goal: Optimize the dry out process for Sulfur Recovery Unit (SRU) fired equipment
- Methodology: Single Case Project Engineering Case Study methodology – transition from a conventional execution model to an optimized delivery sequence.



STEP 1: Critical Path Method (CPM) Schedule Review:

- Analysis of the baseline schedule is conducted to isolate the dry-out process as a critical path driver.
- By evaluating activity dependencies and float, identifies "bottleneck" durations within the conventional heating and drying cycles during commissioning phase.



STEP 2: Construction-Commissioning Interface Analysis:

- Transition from mechanical completion to commissioning is scrutinized by analyzing the hand-over protocols and resource availability.
- study identifies overlaps where commissioning activities can begin in parallel with the final stages of dry-out, reducing the "dead time" between phases.



STEP 3: Gap Analysis:

- A rigorous comparison is performed between the Conventional Sequence (linear, sequential drying) and the Optimized Sequence (parallel processing, revised ramp-up rates, or integrated testing).
- This analysis quantifies the time-gap and identifies the technical or resource

Figure-01

Project Background

The optimization of the dry-out process for fired equipment within the Sulfur Recovery Unit (SRU) is a critical component of a large-scale gas development within the Jafurah gas field. The facility is characterized by a high degree of complexity, consisting of multiple integrated systems including the SRU, a Tail Gas Treatment Unit (TGTU), and a comprehensive network of supporting utilities. These systems are highly interdependent, forming a sophisticated processing network where the technical readiness and operational performance of each individual unit directly dictate the overall operability and safety of the entire plant.

Conventional dry out Strategy

Conventional approach uses permanent process burners supplied by fuel gas to provide controlled heating of refractory-lined equipment. This is an established and technically valid method, consistent with refractory installation quality-control practice (American Petroleum Institute, n.d.). From a schedule perspective, however, the sequence creates a dependency on commissioning readiness and fuel-gas availability.

The standard execution sequence follows a linear path as illustrate in figure 2. Because the dry out occurs at the end of the project lifecycle, any identified refractory deficiencies—such as cracking or spalling—trigger a costly corrective cycle. This necessitates a controlled cooldown, detailed inspection, structural repair, re-curing, and a repeated dry out and verification process.



Figure-02

When these failures occur immediately preceding the planned startup, the remedial work directly impacts the project's critical path. Inability to decouple the drying process from the fuel gas system means that any technical failure in the refractory lining becomes a primary bottleneck, potentially delaying the entire facility's commissioning and operational handover. Consequently, exploring alternative heating methods may mitigate these schedule vulnerabilities and reduce the risk of late-stage project delays.

Opportunity for Schedule Optimization

During critical-path and commissioning-readiness reviews, meticulously evaluated activities that could be advanced or re-sequenced to compress the schedule. Electrical dry out emerged as a strategic opportunity to decouple the curing process from the availability of permanent fuel gas. By shifting to electrical heating, it could execute dryouts independently, provided that engineering approvals were secured and strict readiness requirements were met. This approach remains contingent upon implementing rigorous safety controls and adhering to the applicable refractory procedures to ensure technical integrity and equipment safety prior to final startup.

Issue Description	Conventional Position	Optimization Opportunity
Sequence	After Construction, during commissioning	Execute during construction once refractory installation/curing readiness is met
Energy Source	Permanent burner using fuel gas	Temporary, controlled electrical heating
Utilities Dependencies	Permanent systems required	Temporary construction power with engineered load control
Schedule Exposure	Later stage of the project lifecycle prior to startup sequence	Re-sequenced earlier stage to create commissioning float
Defect Discovery	Impact the start-up schedule	Earlier inspection and repair window is available

Table 2. Conventional dryout position compared with the identified optimization opportunity.

Decision making to implement electrical dryout was driven by four strategic considerations as critical-path optimization, risk mitigation, the opportunity for early corrective action, and parallel execution. By shifting the dryout process earlier in the project lifecycle, the team significantly reduced the volume of high-risk work remaining immediately before final startup.

This proactive approach allowed potential refractory deficiencies to be identified and rectified sooner, ensuring that construction-phase findings were addressed while schedule flexibility and essential construction resources were still readily available on-site. Furthermore, this strategy enabled the dryout process to be seamlessly integrated with remaining construction activities. By decoupling the heating process from fuel-gas availability, the project avoided consuming valuable commissioning time, thereby mitigating the risk of later-stage bottlenecks and ensuring a more predictable and efficient transition to operational handover.

Technology Selection Criteria

The broader technology stack supporting the strategy consisted of established project-engineering tools rather than a single device.

Technology / tool	Application in the strategy	Value
Electrical heating	Controlled thermal input during construction	Decouples dryout from permanent burner/fuel availability
RTD/thermocouple measurement	Temperature monitoring at defined locations	Controls ramp and identifies non-uniform heating
Data logging	Continuous temperature history	Traceability and objective acceptance evidence
Temporary power distribution	Dedicated controlled supply	Safe and reliable energy delivery
Primavera/CPM logic	Critical-path and float analysis	Identifies schedule value of early dryout
Digital reporting	Daily status and trend review	Rapid management decisions
Inspection technology	Visual/technical refractory checks	Early defect detection

Table 3. Technology criteria.

This approach also supports future digital integration. Temperature logs can be linked to equipment identifiers, inspection records and turnover dossiers. In a mature digital-project environment, such records can become part of a broader construction-to-commissioning digital thread.

- Technical compatibility with the refractory system and equipment geometry.
- Ability to achieve and hold the approved heating curve.
- Adequate measurement coverage and calibration.
- Safe temporary electrical installation and protection.
- Availability within the construction schedule.
- Low interference with other construction activities.
- Traceable data suitable for quality and commissioning handover.

Execution

Execution of electrical dry-out followed a controlled sequence designed to preserve both technical integrity and schedule optimization to avoid rework during commissioning phase.



Figure-3 Electrical Dry-out Process flow

Pre-Heating Readiness and Verification process begins with a comprehensive site walkthrough to verify that all prerequisites are fully met. Once confirms that the refractory installation is complete and properly cured, while ensuring the equipment is clean and accessible. specifically verifying that sensor installations are accurate and ventilation systems are fully operational. In order to secure the work area, temporary power has to be finalized and safe work boundaries are established. It concludes with a pre-requisite review with the approved heating curve and emergency response protocols, ensuring every team member is aligned on how to react to unforeseen events.

Once preparations are complete, initiates a controlled, incremental increase in temperature. Utilizes a proactive monitoring strategy, tracking real-time sensor trends, heater loading, and electrical parameters to observe moisture-release behavior. This allows to treat the heating curve as a live document; any deviation from the projected trends triggers an immediate, controlled intervention. By prioritizing thermal stability over speed, which prevents the risks associated with rapid heating, thereby protecting the integrity of the refractory lining throughout the entire thermal cycle.

Upon completion of the heating cycle, the temperature history is meticulously audited against established acceptance criteria to verify a successful dryout. Final physical inspection is then performed to identify any visible distress or cracking that may require further engineering disposition. To maintain the integrity of the asset, the equipment is preserved to prevent contamination before it ever reaches the commissioning stage. The overall success of this sequence is maintained through daily coordination between

construction, engineering, quality, E&I, and HSE teams, reinforcing the principle that dryout is not a standalone construction task, but a critical interface activity that enables seamless downstream commissioning.

Table 4 outlines the sequence of the electrical refractory dry-out process, demonstrating how resequencing these activities during the construction phase optimizes the overall project schedule.

Processes	Key Inputs	Tools & Technique	Key Outputs
INITIATION & PLANNING	<ul style="list-style-type: none"> Refractory Datasheets Vendor Procedure Project Schedule Lesson Learned 	<ul style="list-style-type: none"> Level-4 project schedule Risk Assessment Lesson Learned database 	<ul style="list-style-type: none"> Comprehensive dry out procedure Execution Plan Risk Assessment Job Safety Analysis
ENGINEERING & DESIGN	<ul style="list-style-type: none"> NMR-601 & 602 drawings Project requirements Heating element data Power availability 	<ul style="list-style-type: none"> Engineering review Temperature curve model analysis Power demand calculation 	<ul style="list-style-type: none"> Electrical dry-out design document Customized Heating curve Check list Site Acceptance Test Criteria
PROCUREMENT & MOBILIZATION	<ul style="list-style-type: none"> Refractory Datasheets Fired Equipment GA and detail drawings Inspection Test Plan Delivery Schedule Refractory completion report 	<ul style="list-style-type: none"> Cost benefit analysis Comparative analysis Bidding process 	<ul style="list-style-type: none"> Electrical element and associated resources Inspection Test Plan Temporary power source Skilled resources
ELECTRICAL DRYOUT EXECUTION	<ul style="list-style-type: none"> IFC drawings Electrical dryout procedure Inspection Test packs Calibration certificates Pre-Qualification approval 	<ul style="list-style-type: none"> Temperature data log Checklist Temperature Trend Analysis Thermocouple calibrator 	<ul style="list-style-type: none"> Temperature logs Daily performance report Verified checklist Dryout completion status
VALIDATION	<ul style="list-style-type: none"> IFC drawings Approved Procedure Dryout completion report 	<ul style="list-style-type: none"> Data Analysis Visual inspection Hammer test 	<ul style="list-style-type: none"> Completion Certificate Lesson Learned Clearance certificate for final Box-up

Table 4. Electrical dry out execution Process

This case study demonstrates that the mega project-engineering organization can create schedule value by challenging the timing of established activities rather than changing the

fundamental technology. Electrical refractory dryout was used as a construction-phase intervention to reduce late commissioning dependency within the Project. For the SRU Reaction Furnace and Thermal Oxidizer, advancing electrical dry out into construction provided an earlier opportunity to verify refractory condition, increased the available window for corrective action, reduced exposure of the startup milestone to refractory-related cracks, damages and removed dry out from the commissioning critical path.

The most important conclusion is that schedule optimization was achieved through interface decoupling. By completing a technically controlled activity earlier, the project created approximately 14 days of startup schedule opportunity while retaining engineering, quality and safety gates.

Key Learning

Critical-path optimization should begin with dependency analysis, not limited to the resource escalation. Construction and commissioning activity electrical dry out using permanent burner could be resequencing into the construction activity. Established technology electrical dry-out can become innovative when this activity repositioning in project lifecycle. Temporary facilities such as power sources, temperature monitoring system can create permanent schedule value when this critical path activity is engineered and controlled properly. Earlier quality verification and identifying the risk findings in the dryout report can reduce late-stage startup risk. Successful acceleration requires cross-functional ownership and clear readiness gates for the interdependency activities.

For future projects, the method can be generalized into a commissioning-readiness workshop held during FEED and detailed construction planning. Each commissioning-critical activity should be screened for early execution opportunities based on technical feasibility, temporary utility availability, risk, quality evidence and critical-path impact.

therefore a framework to resequencing the work earlier when the technical prerequisites are demonstrably satisfied and the resulting completion is accepted as a valid downstream input.

Future studies could compare multiple projects using a common metric set such as days of critical-path exposure removed, cost benefit analysis, temporary-power consumption, defect discovery timing, rework rate and commissioning readiness. Digital integration of

temperature logs, inspection records and schedule milestones are another potential research direction. A broader research model could evaluate several construction-to-commissioning activities—not only refractory dryout—to determine which can be safely relocated earlier and which should remain within the commissioning window.

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