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De-risking E-Drive Retrofits at Aging LNG Plants: *Lessons Learned from Feasibility Studies*

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AGENDA

INTRODUCTION

- LNG MAIN REFRIGERANT COMPRESSOR DRIVERS

CASE STUDY

- SOLUTION COMPARISON
- RISK ASSESSMENT

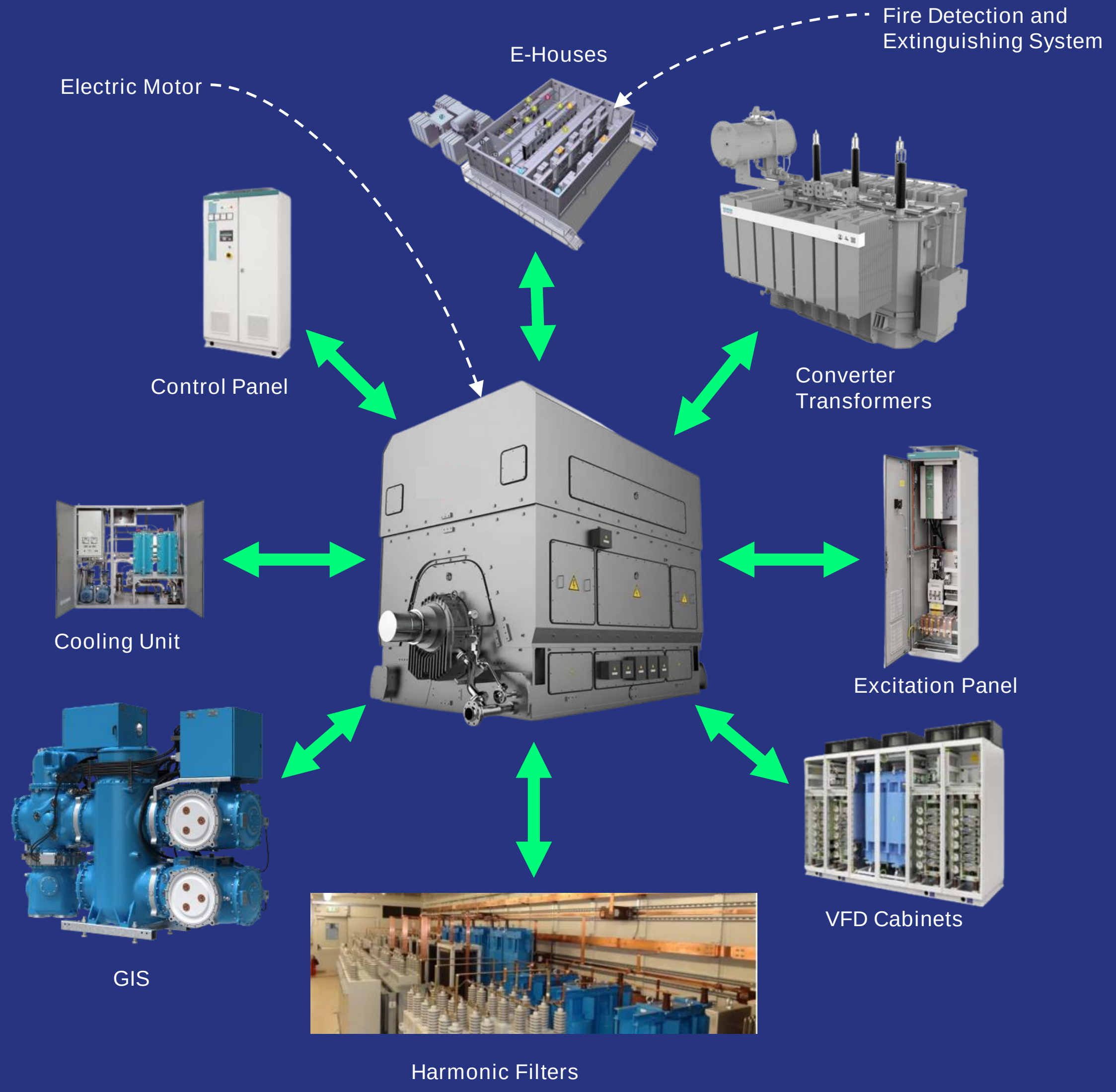
ADDITIONAL PATHWAYS TO RISK REDUCTION

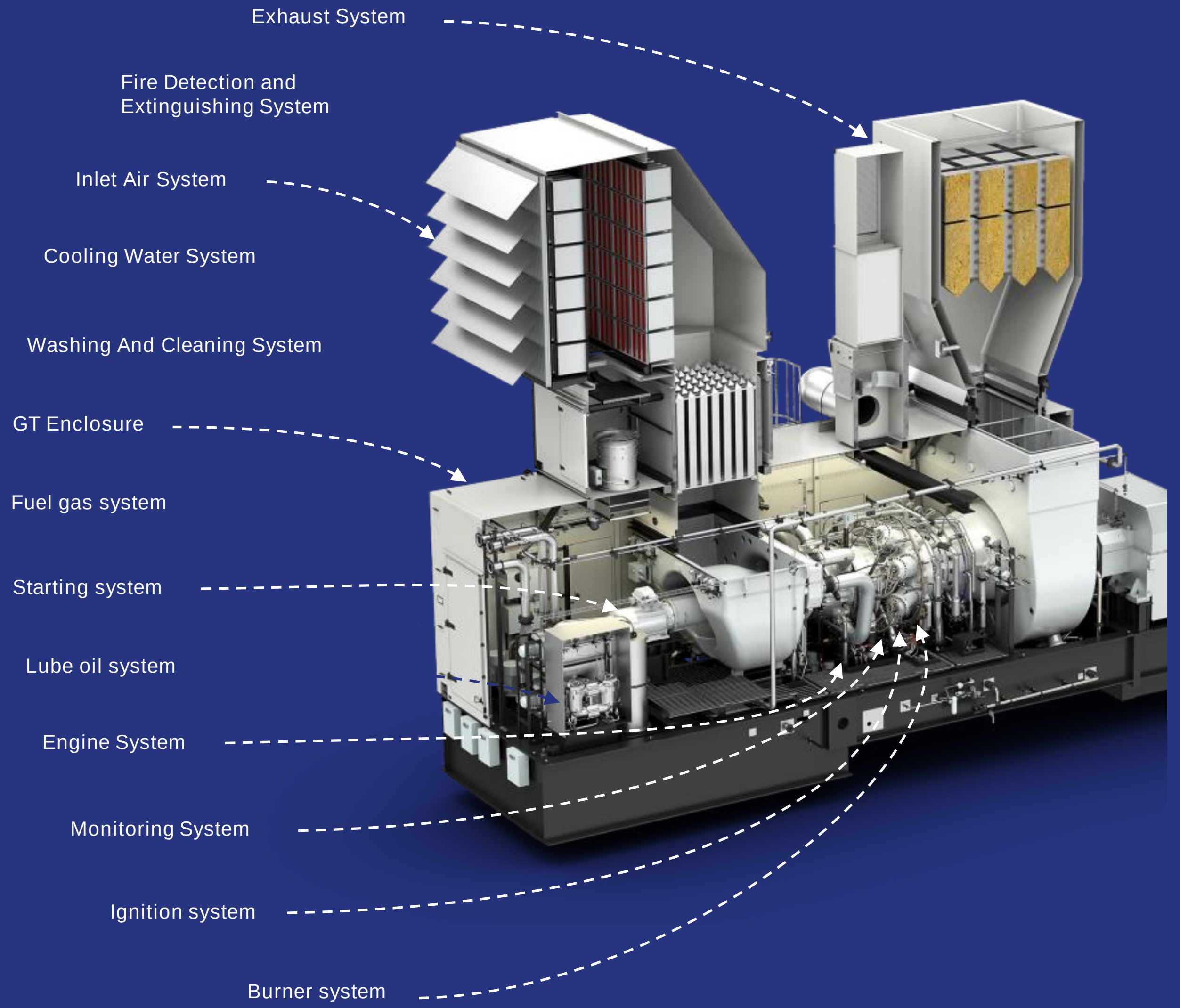
- END-TO-END SOLUTIONS
- GRID ANALYSIS STUDIES

LNG MAIN REFRIGERANT COMPRESSOR DRIVER

Refrigerant Compressor Drive Systems

The Gas Turbine Drive Cognitive Bias





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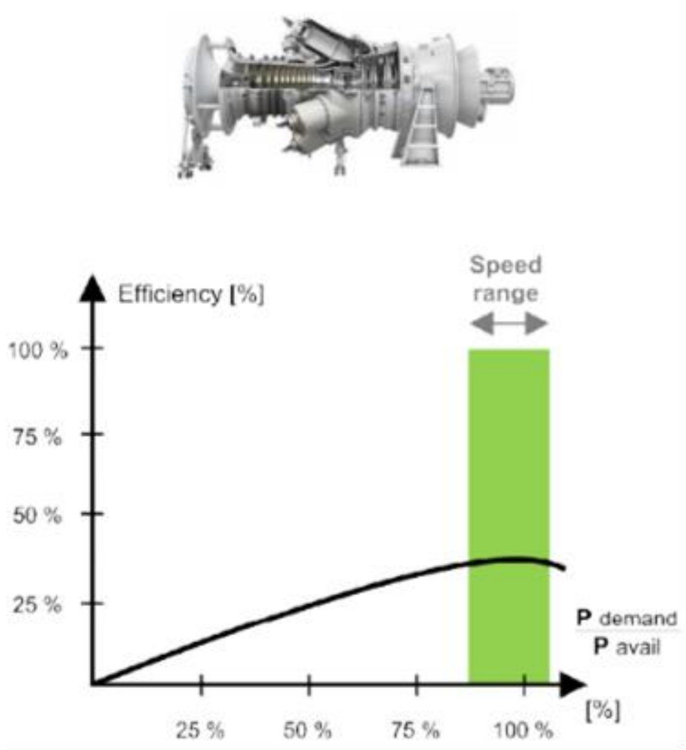
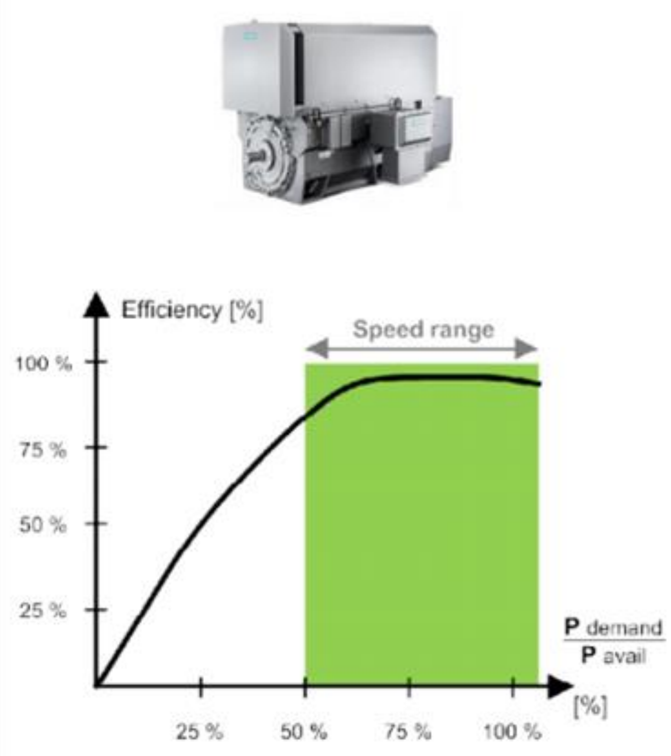
Driver Comparisons: Turbine and Electric Motor

Efficiency of the Drive Train





Drive Train Efficiency Contributor	**Mechanical Drive Design**	**Electrical Drive Design**
Compressor	85%	85%
Gas Turbine	40 – 42%	N/A
Electric Motor	N/A	98%
Transformer	N/A	99%
Variable Frequency Drive	N/A	98%
Transmission	N/A	98%
Drive Train Efficiency (Grid Connection)	34 – 36%	80%
Power Island Electrical Efficiency	N/A	50%
Drive Train Efficiency (Power Island)	34 – 36%	40%

Driver Comparisons: Turbine and Electric Motor

Availability of the Drive Train

Electric motors also provide advantages over gas and steam turbines with respect maintenance and thus availability:

- A typical gas turbine-driven LNG plant design has an availability of approximately 95%. After two years in operation, anywhere from 1-3 weeks is required for scheduled maintenance
- Electric-driven LNG plant, on the other hand, can achieve 97% availability, because it is not uncommon for large motors to go as many as 5-6 years without scheduled maintenance

RETROFIT CASE STUDY OF THE MAIN REFRIGERANT COMPRESSOR DRIVER

Case Study: Main Refrigerant Compressor Driver Retrofit

Brownfield Project Risk Profiling

Problem

Reduce facility's carbon emissions by utilizing expanding municipal electrical grid

Goal

Optimize a design for a Retrofit of existing turbine driven compressors to motor driven

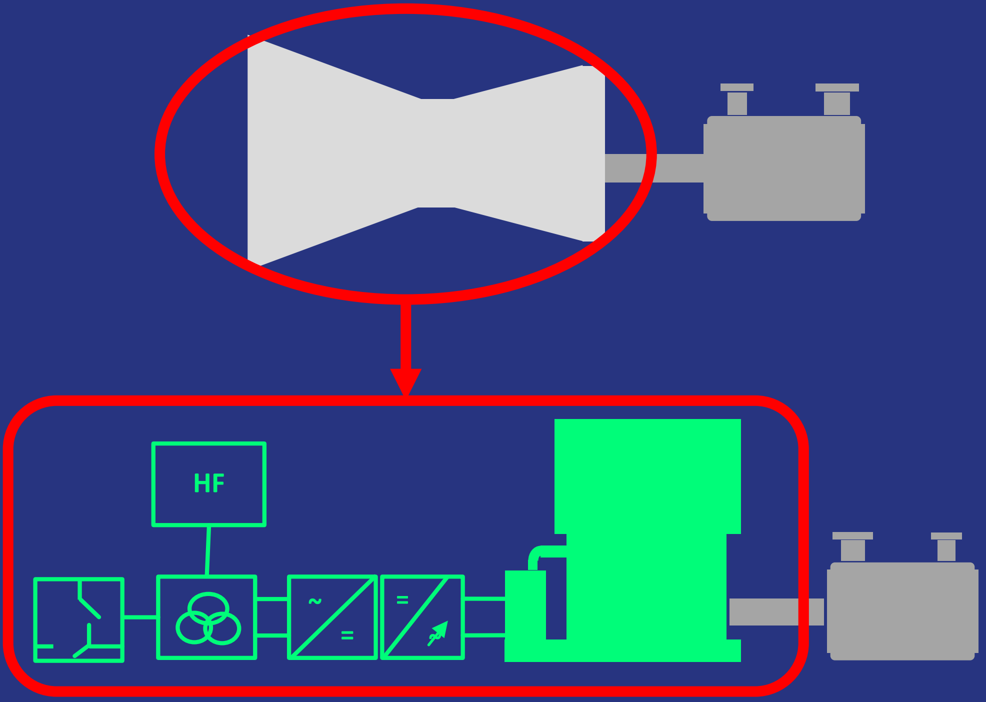
Solutions

1. Direct Driver Swap – Replacement of the existing turbines with high-speed synchronous motors without replacing the compressor casings.
2. Total String Replacement – Replacement of the existing turbine-driven compression strings with new motor-driven compressor configurations.

Solution 1: Direct Driver Swap

Case Study: Main Refrigerant Compressor Driver Retrofit

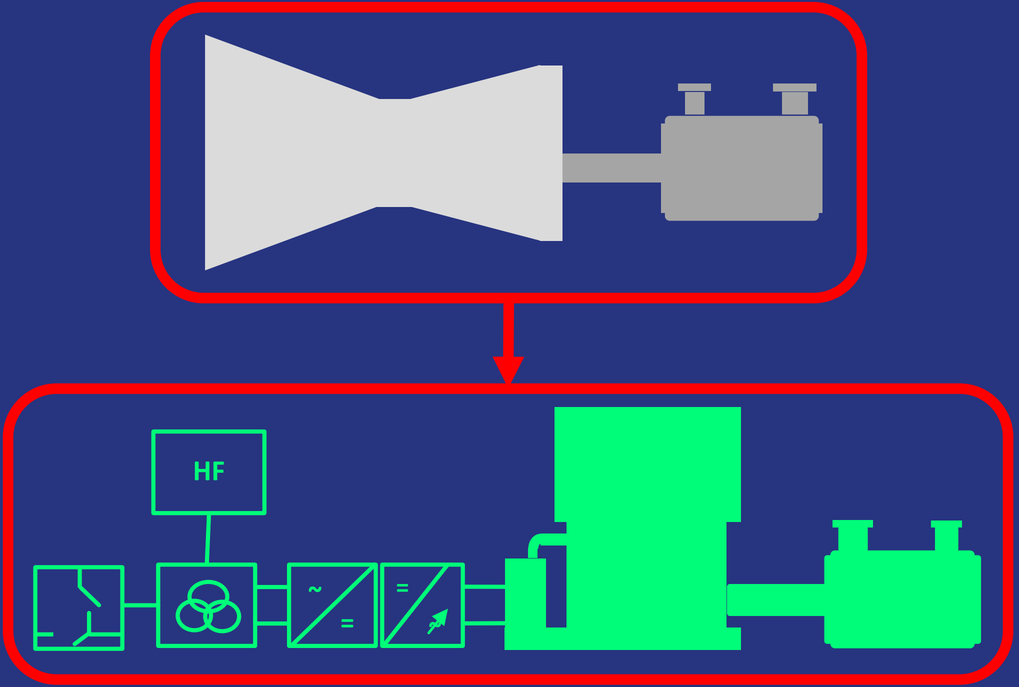
+	The only section of pipe requiring rerouting will be the pipe demolished to facilitate potential reinforcement of the tabletop
-	Major demolition scope is required to accommodate the new electric motors
-	Full Testing Scope must be performed on-site during scheduled downtime
-	Terminate and test all cables from VFD to Motor during shutdown and only then energize the system
-	Will require significant craneage to set the motors
-	Two separate Motors for HP MR and LP MR
-	Full Alignment and leveling of Motor
-	Separate E-House for HP MR and LP MR
-	Demolition of Feed Gas Compressor to accommodate compressor string 1&2 E-Houses
-	Reinforcement of tabletop (Extent Unknown)



Solution 2: Total String Replacement

Case Study: Main Refrigerant Compressor Driver Retrofit

+	Tie-in can be performed during planned shutdown
+	All Compressor Skids will be fully tested prior to shipping
+	Limited equipment foundation installation and can be carried out during facility operations
+	Compressor string 3 area is free and clear
+	Compressor skids can be set using self-propelled modular transporter direct from Material Offloading Facility
+	Potential for Debottlenecking Compressors
+	One large motor for compressor string 3 HP&LP compressor skid
+	Compressor string 3 HP&LP MR Requires one motor and hence one less E-House
+	Fully energize system prior to shutdown
-	Substantial scope of tie-in work required
-	Major reinforcement of the existing racks and associated foundations & Installation of new racks to accommodate new pipe
-	Compressor string 1 & 2 area requires demolition of existing feed gas compressors
-	Alignment and leveling of Train 3 Motor and HP&LP MR Compressor Skid
-	Additional land necessary to accommodate compressor string 1&2 E-Houses
-	More cable length due to distance from E-House to compressor string 1&2 Motors
-	Installed capacity of the motors 10MW greater than Solution 1



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Constructability Considerations

Case Study: Main Refrigerant Compressor Driver Retrofit

Mechanical

Solution 1 requires motor alignment with the compressors on the existing foundation and full testing performed during the shutdown period.

Electrical

Both solutions involve the installation of new E-houses containing VFDs and an additional modular Gas-Insulated Substation.

Piping

The scope of installation of piping for Solution 2 is extensive, however; the majority of this work could be carried out during normal plant operations.

Civil & Structural

The major scopes that differentiate the construction effort are the rerouting of the pipe and resultant reinforcement of the existing racks for Solution 2, versus the demolition of the equipment and potential reinforcement of the tabletop for Solution 1

Financial Considerations

Case Study: Main Refrigerant Compressor Driver Retrofit

Capital Expenditure

The total installed cost of Solution 2 is estimated to be 71% higher than Solution 1.

Operational Expenditure

The initial expectation is that the OPEX of Solution 2 will be lower, potentially by 3-5%.

Scheduled Downtime

The interruption of production is expected to be much higher for Solution 1 compared to Solution 2.

Execution Risk and Mitigation Measures – Solution 1

Case Study: Main Refrigerant Compressor Driver Retrofit

Risk Description	Category	Impact Description	Risk I	Risk P	Risk Score	Mitigation Notes
Torsional instability between existing compressor and new motor	Mechanical	Delays in project implementation/extended shutdown period	5	3	15	Verify the schedule and identify when demolition works will be finished
Extensive demolition scope for compressor shelters will require a congested workforce to perform in the suggested scheduled duration	Safety	Recordable incident	4	3	12	Identifying what can be done prior to shutdown to alleviate congestion. Set limits of personnel within the demolition area
No data available for existing compressors	Mechanical	Delays in project implementation/extended shutdown period	4	3	12	Early engagement with OEM to assist in finding the relevant data. Collect all available reports on testing and performance of the existing compressors

Notes

- Risk is scored based on two factors multiplied together. A higher score for an identified risk indicates a riskier event.
    - Impact (I) - intensity of the impact caused by the risk
    - Probability (P) - probability of the risk occurring
- A higher total score for a solution is a negative outcome in this assessment.

Execution Risk and Mitigation Measures – Solution 2

Case Study: Main Refrigerant Compressor Driver Retrofit

Risk Description	Category	Impact Description	Risk I	Risk P	Risk Score	Mitigation Notes
No possible route through existing infrastructure to deliver new compressors or new E-house from Material Offloading Facility	Logistics	Major delays to site work until route is cleared	4	3	12	Constructability engineer to walk through site after motor definition to map delivery route and list adequate counter measures in case any interference is mapped
Existing pipe racks not able to withstand new piping/cable trays due to overstress/structural damage	Structural	Major reinforcement works needed to strengthen pipe racks.	4	3	12	Site to be 3D laser scanned throughout intended pipe-routes to detect failures. Pipe racks to be checked for new loads prior to any work onsite. Some piping/cables to be routed outside on new racks

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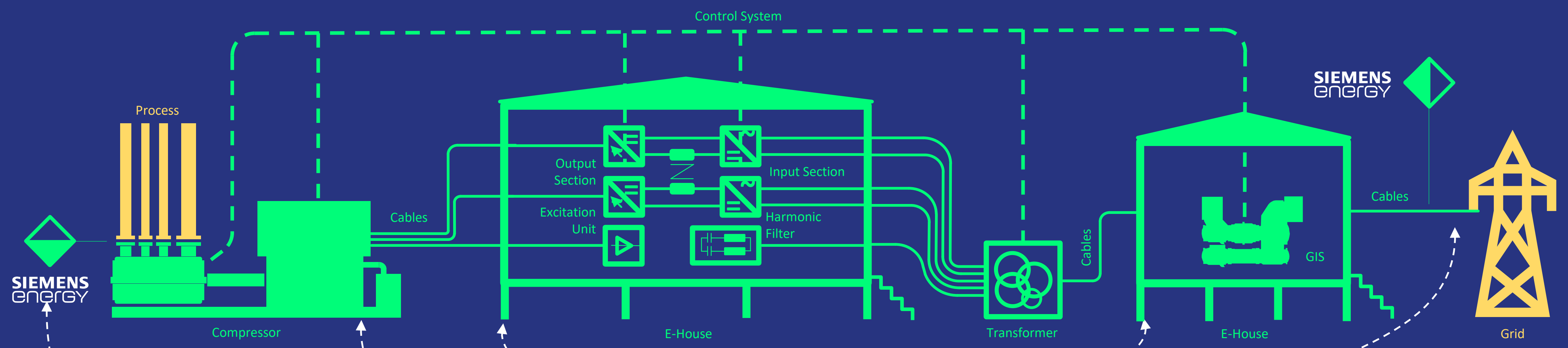
ADDITIONAL METHODS FOR RISK REDUCTION

The Electromechanical Refrigerant Compressor System

Reducing Execution Risk with End-to-End Solutions



1 Process-Machinery Interface Integration

Holistic solutions to the overarching process to achieve maximum plant efficiency.

2 Compression Systems

State of the art compression technology, with in-house electrical expertise.

3 Integrated Electromechanical Systems

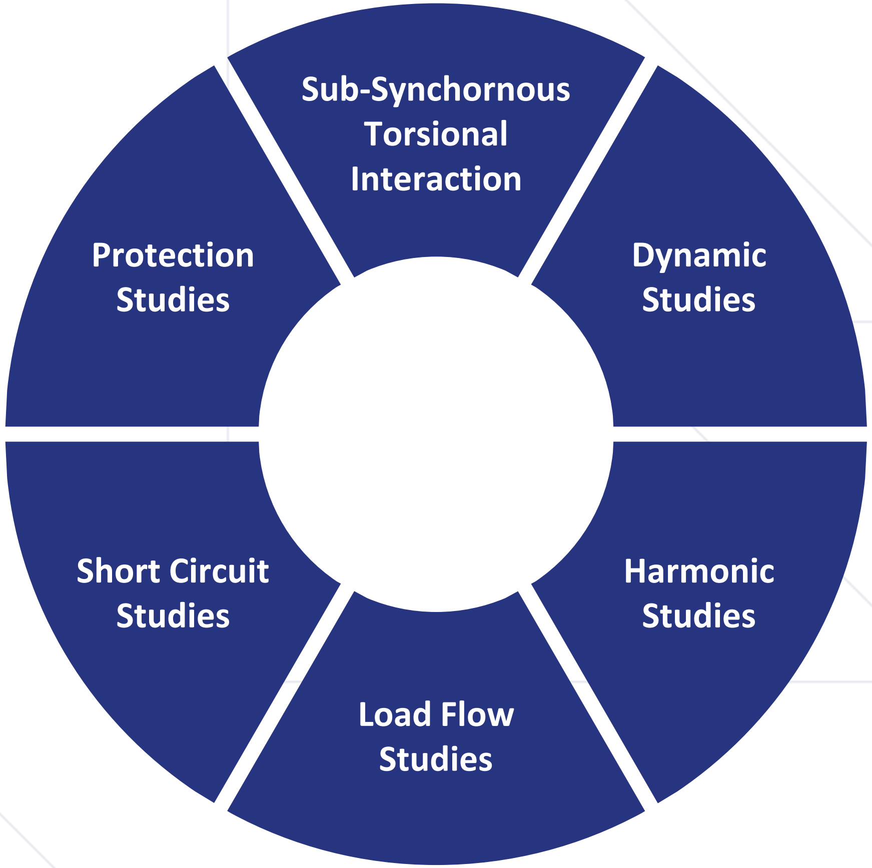
Achieve maximum reliability and operational excellence, lowering down the project risk profile.

4 Grid Connection

Rigorous electromechanical engineering model for stable, reliable, and risk-free integration with the grid.

The Facilities Expanded Electrical Microgrid

Reducing Execution Risk by Conducting Grid Stability Studies



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