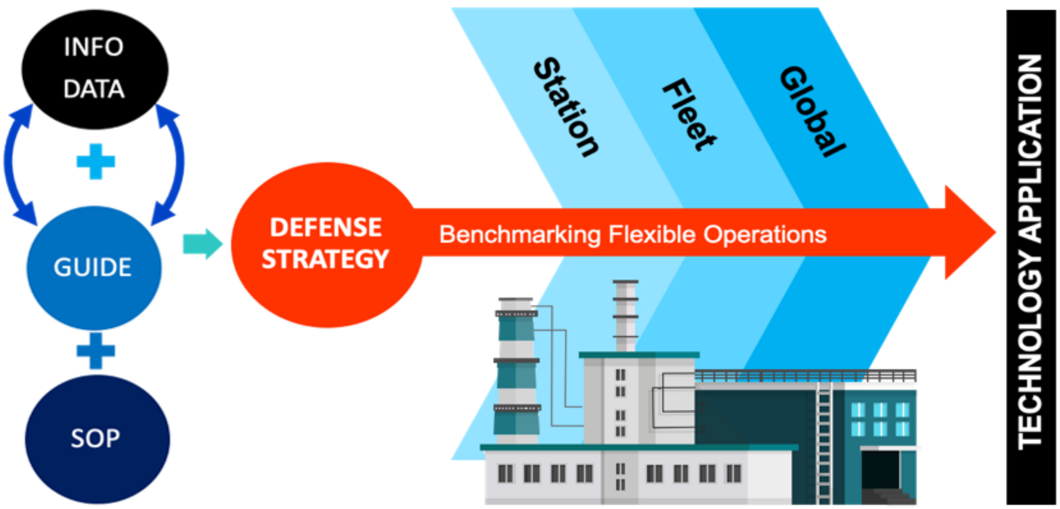
High-Level Flexibility Assessment and Benchmarking Tool

Conventional Steam Generators



Prepared for the U.S. Department of Energy's National Energy Technology Laboratory by:

KEYLOGIC

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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October 2020

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This project was executed through U.S. Department of Energy’s National Energy Technology Laboratory (USDOE/NETL) as a key deliverable under the Power and Energy Efficiency Pillar of the U.S -India Strategic Energy Partnership (SEP), which is co-chaired by USDOE’s Office of Fossil Energy (USDOE/FE) and India’s Ministry of Power (MoP).

USDOE/FE and NETL would like to express their sincere appreciation to the Electric Power Research Institute (EPRI) and NTPC Ltd. for their partnership and collaboration in developing and validating this coal power plant flexibility tool.

PREFACE

Under the U.S.-India Strategic Energy Partnership (SEP), which was launched in April 2018, to expand and elevate our longstanding bilateral energy relationship, cooperation is organized along four technical pillars. The Power & Energy Efficiency Pillar works to strengthen and modernize the power infrastructure for efficient, reliable and affordable generation, transmission and distribution; maximize the efficient use of all forms of energy; collaborate for improved efficiency, flexibility, and emissions reduction of coal-fired power plants; promote energy efficiency and conservation; and support market transformation in the power sector by improving the finance and investment climate.

The Pillar is co-chaired by USDOE's Assistant Secretary for Fossil Energy Steve Winberg and the Indian Ministry of Power's Joint Secretary for International Cooperation and Thermal Vivek K. Dewangan. The Pillar includes strong interagency participation on both sides to plan and execute a wide range of collaborative projects.

To guide the work of the Pillar, the two sides agreed to six high-level priorities:

1. Modernize power system infrastructure through smart grids, grid integration, and energy storage to promote reliable, secure, and efficient transmission and distribution systems.
2. Strengthening electricity systems and markets, including through distributed energy resources, flexible resources, and ancillary services.
3. Highly efficient, cleaner, and more flexible coal-fired power generation.
4. Energy efficiency and conservation in buildings, appliances, and the industrial sector.
5. Market transformation through improved investment climate, procurement practices, ease of doing business, business models, regulatory oversight, and private sector engagement.
6. Strengthening the distribution sector through improved business models, technology, innovation, reforms, and public and private investments.

The Flexibility Assessment and Benchmarking Tool developed under this project complements coal power plant flexibility work under the 'Greening the Grid – Renewable Integration and Sustainable Energy Initiative' supported by the U.S. Agency International Development (USAID) in India. The initial version of this tool for conventional coal-fired steam generators was developed in support of Pillar Priority #3 by EPRI working with NTPC Ltd. with funding from USDOE's Office of International Affairs. Six of NTPC's coal power stations participated in this effort. Their involvement was critically important to development and validation of this public-domain tool, which draws on decades of related work by EPRI and its members.

This tool will assist not only Indian and U.S coal plant operators, but also other plant operators around the world, in improving the flexibility of their existing units – one of most critical issues that they face as power grids evolve with increasing intermittent renewable power sources and energy storage. The ability of coal-fired power plants to operate more flexibly in response to variable power demand will reduce both plant operating and maintenance costs while reducing failure risks, which can be costly in terms of repairs and lost generation.

ELECTRIC POWER RESEARCH INSTITUTE

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Conventional Steam Generators

2020 TECHNICAL REPORT

High-Level Flexibility Assessment and Benchmarking Tool

Conventional Steam Generators

3002019900

Final Report, October 2020

EPRI Project Manager
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The Electric Power Research Institute (EPRI)

U.S. Department of Energy (USDOE)

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- NTPC Limited (NTPC), Corporate Operations Services Team
- NTPC, Centre for Power Efficiency & Environmental Protection (CenPEEP)
- NTPC Stations:
  - NTPC Simhadri (4x500-MW subcritical units)
  - NTPC Bongaigon (3x250-MW subcritical units)
  - NTPC Farakka (3x200-MW subcrtical units and 3x500MW subcritical units)
  - NTPC Gadawara (2x800-MW supercritical units)
  - NTPC Solapur (2x660-MW supercritical units)
  - NTPC Unchahar (5x210-MW subcritical units and 1x500-MW subcritical unit)

Michael Caravaggio, Major Component Reliability (MCR) and EPRI generator sector, is acknowledged for support of the project.

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Since the majority of power in India is comes from coal, conventional steam generators play a key role in helping to balance the grid with flexible operations. From January 2020 until project completion, NTPC supported EPRI with the application of relevant research to develop a user-friendly—yet comprehensive—assessment and benchmarking tool for conventional steam generation operators. The tool is essentially a guide for conducting assessments to reveal gaps and identify areas needing improvement.

The templates provide relevant guidance to address a global challenge facing conventional steam generators. As these units continue to age, reliability is being threatened by thermal transients, vibration, corrosion, and many other damage mechanisms imposed by cyclic conditions. These conditions require periodic assessment and asset management practices to help mitigate potentially costly equipment damage and to promote safe, efficient and event-free operations. This was the inspiration behind developing a tool with integrated templates that provide a high-level assessment process for identifying gaps in flexibility performance. The end goal was to create awareness, leverage past research, and help drive projects to overcome flexibility roadblocks.

NTPC not only supported the project development process, but also demonstrated the effectiveness of the tool by leveraging a project team from six (6) stations that conducted multiple assessments to identify challenges and roadblocks, as well as identifying a fast-paced approach to improvement of their fleet optimization strategy on approximately 8GW of critical generating assets across the NTPC fleet. The quantifiable benefits helped to identify high-level gaps in performance. The results obtained are being used to drive improvement in flexibility by addressing the identified issues. The onset of lower-carbon energy resources on the grid continues to transform the mission for coal-fired generating stations in India.

ABSTRACT

Flexible conventional steam generators play a key role in ensuring grid stability. The objective of this project is to develop user-friendly tools in the form of flexibility templates to help guide operators of these units on how to conduct complex assessment that reveal unit design and operating gaps, as well as identify areas needing improvement. The templates are applicable to both subcritical and supercritical steam generators >100MWs. As units continue to age, reliability is jeopardized by thermal transients associated with cyclic conditions. These conditions may need further assessment and monitoring processes to help mitigate potential costly equipment damage and to promote safe, efficient, and event-free operations without depleting the plant's operating and maintenance budgets.

The assessment templates in this document are high-level and are intended to help identify and address areas of vulnerability that require prioritized focus and attention to flexible operations. Because unit conditions and performance will vary, the templates are intended to be used to evaluate an individual unit. However, while organizing the assessment, multiple units at a given plant can be evaluated simultaneously. Flexible operations can encompass a wide range of plant operating modes and can be applied to all conventional steam generators that are not operating under baseload conditions. Operating modes are typically driven by production costs and the demand from the energy market. Varying modes of operation can have a negative impact on reliability and demands optimization of people, process, and technologies. To operate successfully with cyclic operations, plants will likely need to adopt new strategies that include change in operating procedures, condition-based maintenance, equipment preservation, and process control—which will depend on regional energy markets, seasonal conditions, and/or geographic locations. The onset of lower carbon energy resources on the grid continues to transform the mission for generating stations around the world. Many of the dispatchable thermal plants being used to balance the grid are conventional steam plants. Since cycling can have a major impact on plant reliability, grid stability can be negatively affected if the assets are improperly managed.

Keywords

Assessments
Benchmarking
Operational flexibility
Subcritical
Supercritical

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PRIMARY AUDIENCE: Conventional Steam Generator – Flexible Operations Management Team

SECONDARY AUDIENCE: Conventional Steam Generator Operations and Maintenance Teams

KEY RESEARCH QUESTION

The objective for this project is to provide an overview and set of templates that helps the user identify and assess key areas of focus for managing conventional steam generators operating under flexible operations.

RESEARCH OVERVIEW

The report provides a comprehensive and cross-sector guideline for key areas and serves as a tool that can be used to conduct a self-assessment against standards of performance.

KEY FINDINGS

The findings within this report are an accumulation of information organized from past generation sector research that aligned various programs and working groups to address changes in operating mission profiles.

WHY THIS MATTERS

Due to changes in power generation, thermal power generating plants are increasingly seeking improvements in operational flexibility while minimizing the negative implications on the plant and equipment.

This report provides guidance on how to assess various systems and equipment to help achieve operating goals. The effort was a collaborative project that addressed relevant global issues and it is intended to accelerate elevating industry knowledge.

HOW TO APPLY RESULTS

The information presented in this report is intended to assist management and technical personnel at thermal power plants to better understand the complexity of flexible operations and identify areas that need improvement. Guidance is provided for owners and operators of thermal power plants to assess flexible operations.

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INTRODUCTION AND GUIDANCE

The demand for coal-power plant flexible operations is largely driven by the onset of variable renewable energy on the grid and relative production costs. Conventional steam generating units that are more efficient and have lower electricity production cost typically operate at a higher capacity factor. Externalities—such as regulatory requirements and fuel pricing—can also significantly impact a unit's operational load demand.

Two common operating strategies used to address flexibility are: a reduction in minimum operating load and/or fuel changes to remain competitive with the energy markets. However, the need to apply these strategies is contingent on the power market in which the unit is dispatched. For example, a unit is unlikely to remain economically viable if required to be in extended shutdown (economic reserve) for long periods of time. However, that same unit could remain economically viable if it operates in a capacity market where the plant is compensated for being available to generate power.

Until recently, there had been very little demand for energy storage because variable renewable energy sources have provided a small percentage of electricity. However, with the recent and significant increases in renewable power generation, the demand for energy storage has shifted. Without energy storage, there is a greater demand for conventional and "dispatchable" generation to operate more aggressively with decreasing minimum loads and higher peak ramp rates. Figure 1-1 illustrates the changing trend in global electricity production.

The onset of lower carbon energy resources on the grid continues to transform the mission of generating stations around the world. High penetration of renewables power changes the electricity market demand for flexible operations and often forces thermal assets to change their mode of operation. This is especially true if a generator is bidding into day-ahead or real-time energy markets. However, it is important to understand that dispatchable thermal plants being used to balance the grid are conventional steam plants. Because cycling can have a major impact on plant reliability, this can negatively impact grid stability if these assets are improperly managed.

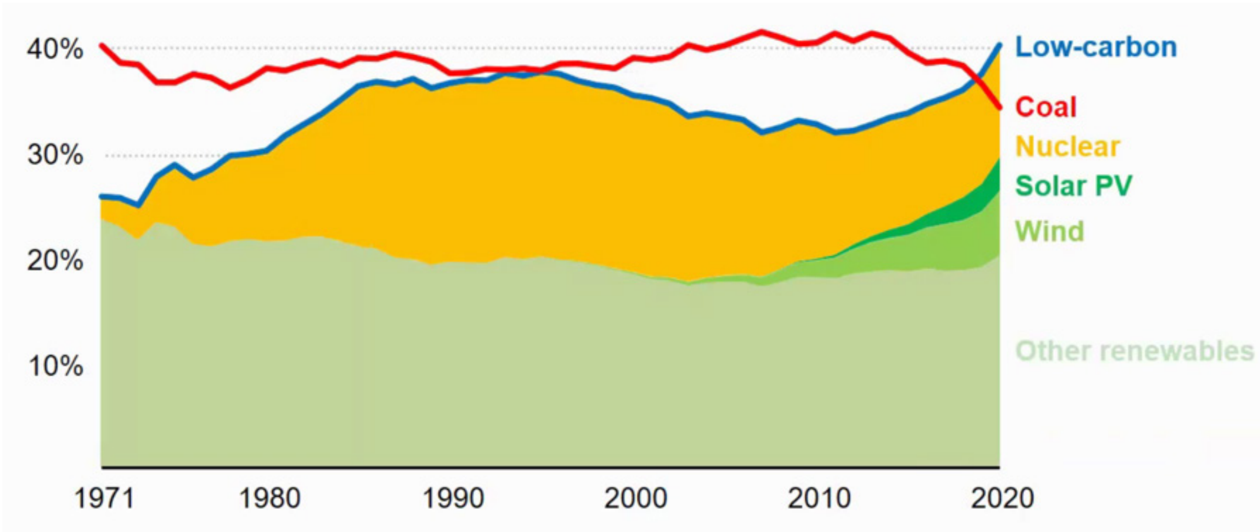

Figure 1-1
Global electricity generation 1971–2019, Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020)

For a non-flexible plant, startup, and load following can result in significant damage in a short amount of time if process controls, safety interlocks, and protection systems are not optimized for the various modes of operation. Considering this, flexible operations demand a systematic approach, continuous improvement, and a focus on proactive damage mitigation in various plant systems.

Modes of Operations

Table 1-1 provides a high-level description of some of the different modes of operation for conventional steam generators.

Table 1-1
Description of operating modes

Base Loaded Units	High net capacity factor; minimal starts (<10 annually)
Reserve Shutdown	Extended: >1,000 hours or limited: <1,000 hours (annually)
Load Following	Service factor >70%, minimal starts (<10 annually), frequent load changes
Minimum Load	Operations at minimum design load and/or a reduced minimum load
Two Shifting	Average run time: < 24hours; typically: >50 Starts per year

Flexible Operations

Many conventional steam generators were designed and built for baseload operations but are now required to operate in varying operating modes. At a high level, one may evaluate (or benchmark) flexibility performance as the ability to meet a wide-load range and/or do it in timely manner. However, the long-term availability, efficiency, production cost and the impact on emissions from unit cycling are likely to have on unit dispatchability and sustainability in the energy market should also be considered. Figure 1-2 describes the basic aspects of operational flexibility.

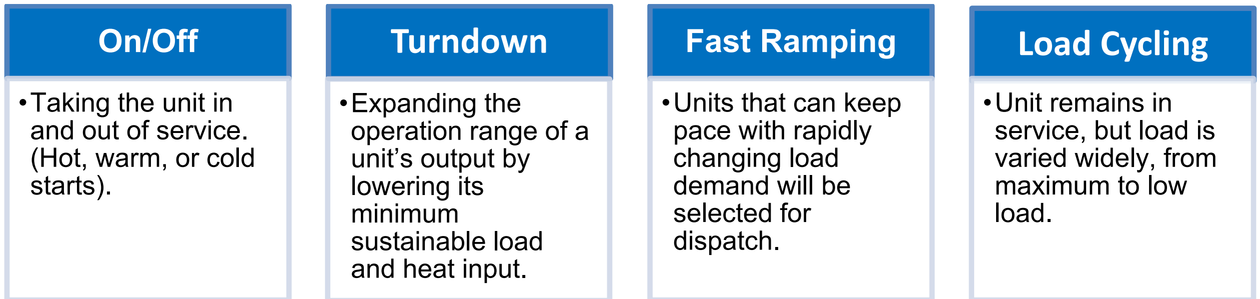

Figure 1-2
Basic operational flexibility descriptions

To manage a generation flexibility program, it is first imperative to understand the electricity market, load profiles and demand on the dispatchable generation assets. Establishing flexibility goals should be based on both current and future forecasted demands. Then, align teams and resources to achieve those goals. After that, it is all about applying a systematic approach toward achieving the flexibility goals. Flexible operations demand can vary significantly from region to region. In some cases, cycling may be minimal. While in other cases, a plant may need to reside in a short- or long-term reserve shut-down regime.

If units are not properly managed both online and offline, such conditions can be damaging to a variety of system components. Cyclic operations demand attention to detail in managing operational models and protecting assets from common damage mechanisms that occur from thermal transients, corrosion and/or issues with process controls or managing the required water and steam chemistry conditions. Depending on plant configuration and design characteristics, the duration required from startup to full load will vary. Furthermore, the type of start (cold, warm, hot) will vary the start-up timing and requirements for returning to normal operations from a reserve shut down. Table 1-2 provides common criteria for start types.

Table 1-2
Common "off-load" criterial for conventional steam generators

Starts	"Off-Load" Criteria	Pre-Start HP Steam Turbine Casing Temperature
Hot Start	<8 hours off-load	700F – 750F (371C – 400C)
Warm Start	8 to 48 hours off-load	320F – 750F (160C – 400C)
Cold Start	>48 hours off-load	250F – 320F (120C – 160C)
Cold Ambient	>48 hours off-load	70F (21C)

As power generating stations continue to shift their mission from baseload to cyclic operations, it's imperative that start-up and shutdowns be managed as best as possible to minimize the negative impact on reliability.

One can compare the design starting and loading curves in to order to determine discrepancies from the design curves. However, feedback to the operators is usually delayed. Automated reports could help operations management with post start-up critiques with the operations team and/or identify control loops that need improvements due to lack of maintenance or tuning. Furthermore, and more importantly, improvements can be made to the start-up process to improve consistency in returning to service for the dispatcher or the independent system operator (ISO) needs. This is especially important with cold starts, which are often the most damaging. Figure 1-3 illustrates load following operation and the types of starts.

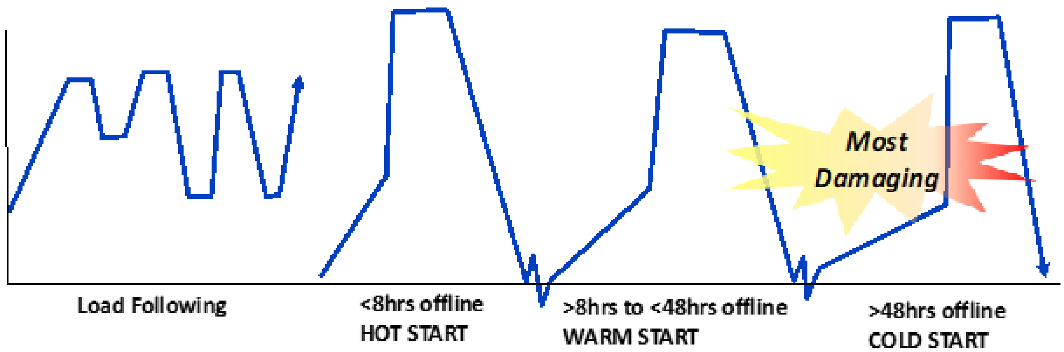

Figure 1-3
Illustration of load following: cold, warm, and hot starts

Referencing 40 years of data from the United States and Canada, there is clearly a correlation between equivalent forced outage ratings (EFORs), the number of starts, and the age of the unit. The younger units operating with increased flexibility seem to recover better than the older units perhaps because operators learn to manage the equipment better with more frequent annual starts. However, with older units, shifts to flexibility without the proper actions and upgrades can lead to a rapid rise in the unit's equivalent forced outage rate. Figure 1-4 is North American Electric Reliability Corporation Generating Availability Data System data for coal units, grouped by age and annual starts versus their average annual EFOR.

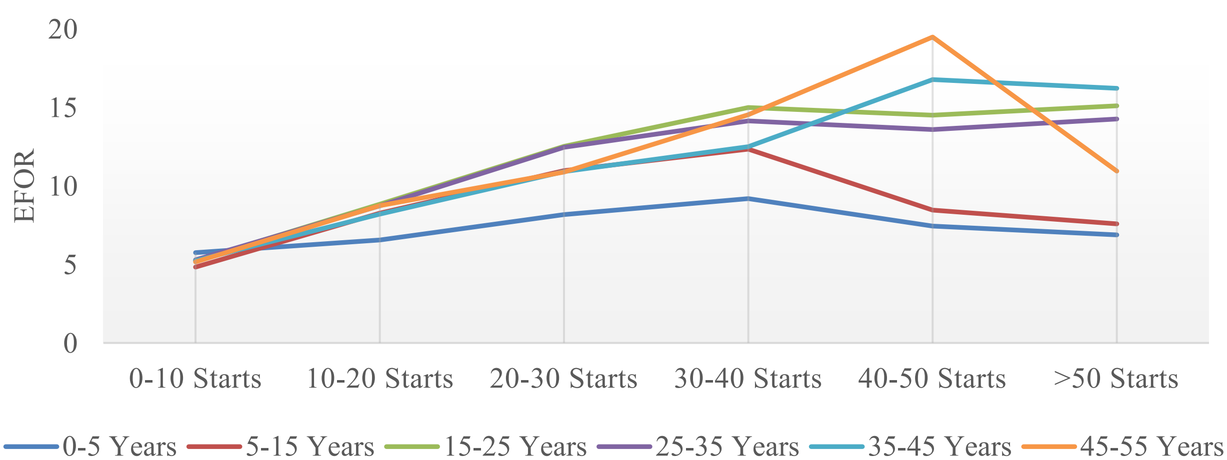

Figure 1-4
GADs data: EFOR coal units >100MW vs. annual start range

Figure 1-5 references the same 40-year data set from the United States breaking it down by operating mission. In most cases, as the number of starts and age increase, so does the EFOR. Baseload, Load Following and Limited Shutdown operating modes have the lowest EFORs.

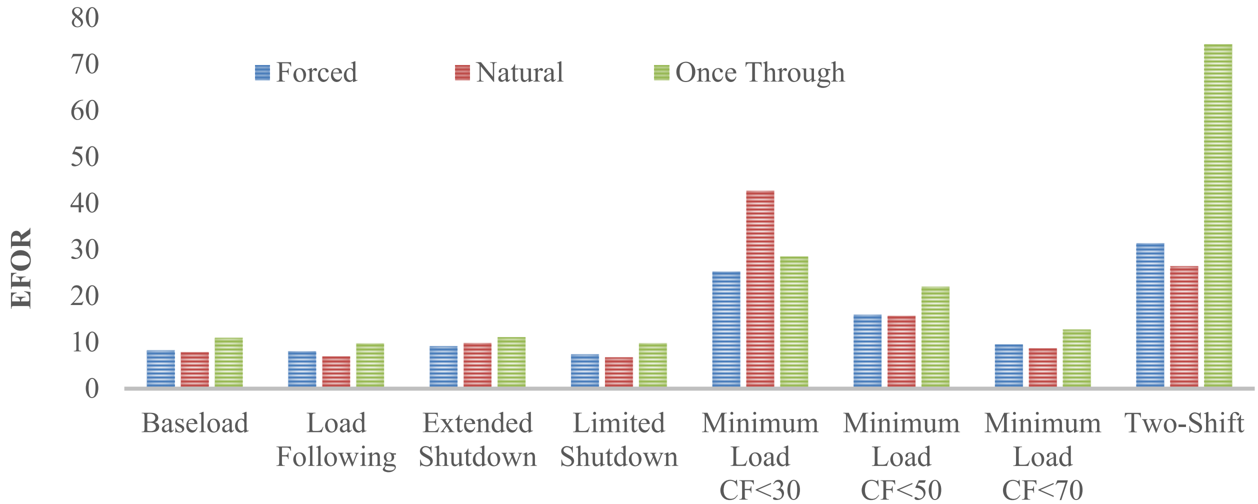

Figure 1-5
GADs data: varying operating modes vs. boiler circulation type (CF = capacity factor)

As illustrated in the previous figure, two-shifting once-through supercritical units (see Figure 1-6 for a typical layout) have traditionally resulted in the highest EFOR, which makes a case to two-shift subcritical units when necessary.

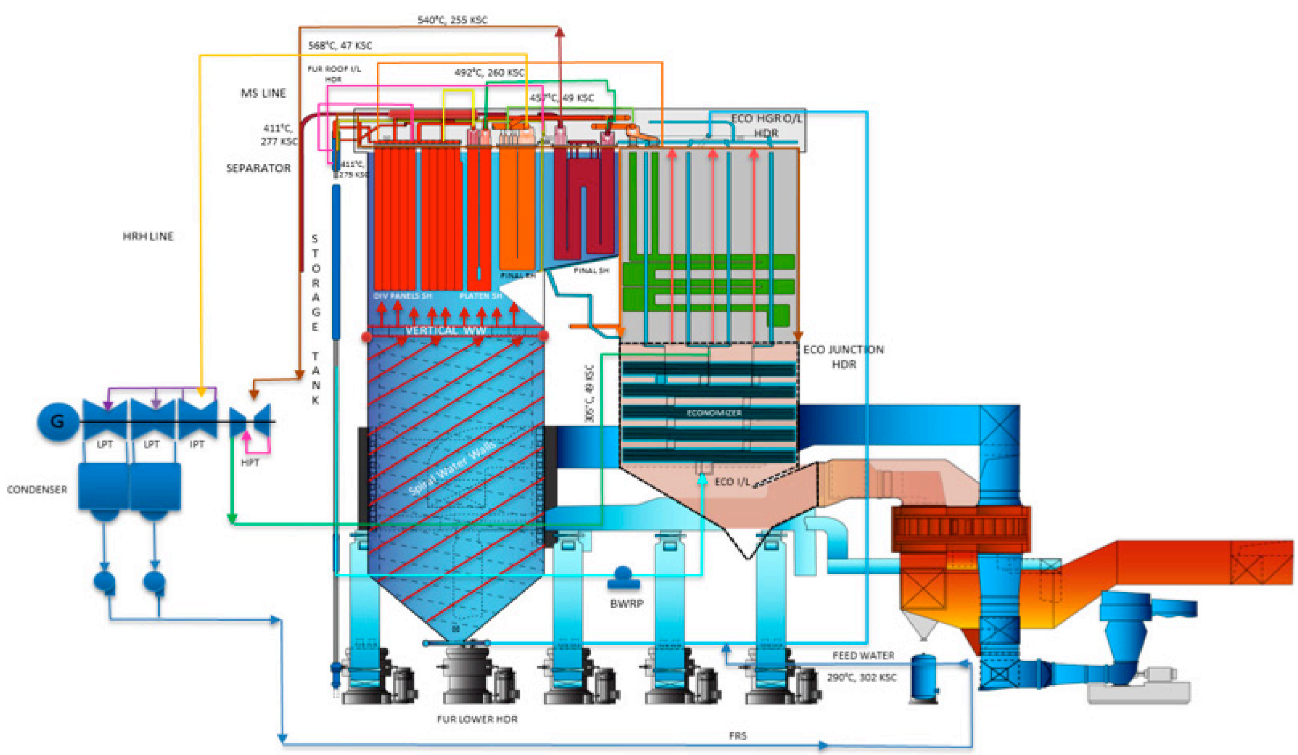

Figure 1-6
Once-through supercritical steam generator

Operations with a flexible future can be more complicated with more stringent air pollution control regulations or operating loads that yield lower thermal efficiencies. Other variables may include challenges from firing lower-quality fuels or operating with constrained budgets due to higher-fixed costs with the lower generating demand and output. Flexibility scenarios that reduce capacity factor, increase cycles or leave assets in reserve shutdowns while awaiting economical dispatch create challenges for both the system operator and generators. The system operator must deal with variability, uncertainty, load frequency control, scheduling reserves, managing the transmission network, ancillary services and cost.

Generators have to not only manage operations with lower capacity factors, but also be available to meet dispatch demands to synchronize with the grid and meet ramp rates in a safe and efficient manner that not only balances the grid, but also operating budgets, maintenance overhauls and the generation asset fuel strategy. Figure 1-7 illustrates the general relationship between efficiency and reliability with turndown and increased annual starts.

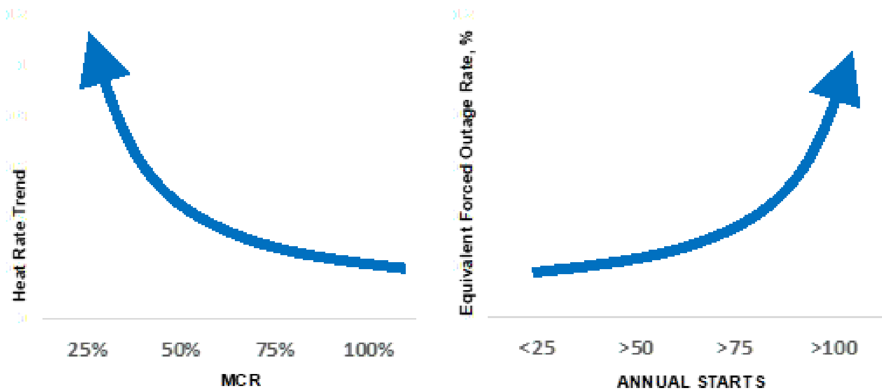

Figure 1-7
Challenging flexible operations trends with heat rate and EFOR (MCR = maximum continuous rating)

The degree to which the overall heat rate is affected by part-load operation depends on the part-load efficiencies of the individual system components as well as the type of fuel selected for use. Plant heat rate can vary significantly between full and low load. Thus, to interpret a plant's thermal efficiency and evaluate the heat losses, one must have an accurate measurement of both turbine cycle heat rate and boiler efficiency to understand where the losses originate and to validate the potential for improvement when implemented. For the impact on EFOR, many locations throughout the cycle can become a challenge as illustrated in Figure 1-8.

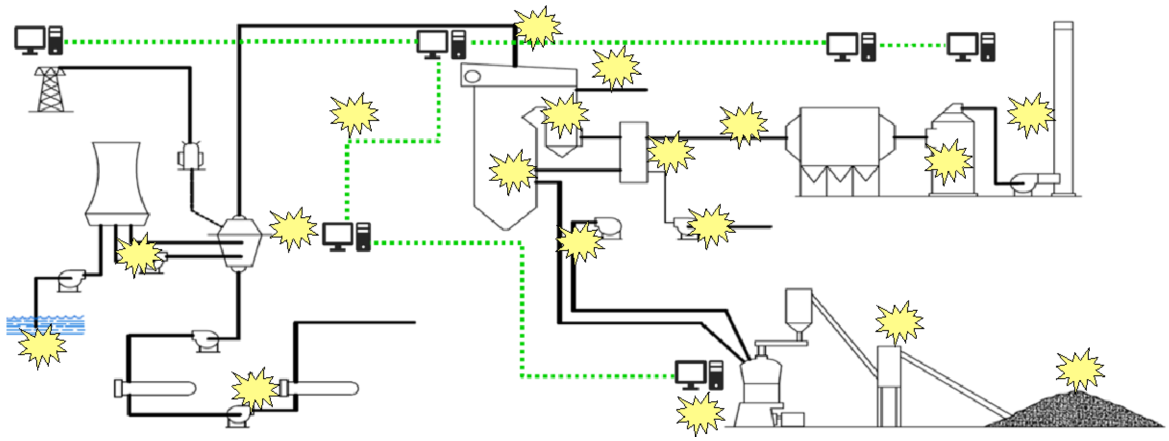

Figure 1-8
Common locations for flexibility challenges on a coal fired steam generator

This may encompass challenges with the water and fuel entering a unit (e.g., managing dissolved O_2, fuel quality and consistency, impacting flame stabilization at low loads) or even air emissions leaving the stack. Because of this, seemingly simple processes, such as fuel management, milling strategies and fuel consistency, can be a challenge for management of system inputs. To overcome flexibility challenges, a systematic approach to optimization is required to address variables, such as mill blue-printing on pulverized coal (PC)-fired units, combustion optimization for managing heat transfer, boiler circulation, temperature control and protection systems for the air, water and gas management systems. Furthermore, thermal expansion, thermal fatigue and corrosion can also be factors impacting major components, piping, casing or structural components within the boiler turbine or balance of plant. Considering all this, it is important to understand that the negative impacts of flexible operations must be offset with flexibility management strategies. Otherwise, the damage imposed by non-optimal performance can create more significant challenges with the inability to balance a preexisting and constrained operations and maintenance budget.

Historically, most staffing levels were set based on steady-state operation, a crew smaller than what may be required when operating more flexibly. Thus, operations strategy is likely required to address the support required to ensure reliable and safe plant startups. Site strategy may require staff resource sharing and training to ensure the staff are confident in managing a flexible operations program. If not already completed, operational procedures will also need to be updated to reflect lessons learned and best practices.

The program must ensure the control system has the proper procedures, training, simulators and/or automation for ensuring properly sequenced startup and shutdowns. Depending on commercial viability of a plant or other factors, there may be a requirement to manage a plant in a non-operational state, which may require plant preservation measures for the boiler, turbine cycle, environmental controls and ancillary equipment. Layups should be classified as either short term or long term. The benefit of a short-term lay-up is that the plant remains available for generation, with little increase in its notice period to be ready for synchronization. As the plant enters an operational state not previously experienced, the unit will be more vulnerable to damage and performance degradation. Performance monitoring, diagnostics and data assessments, can be used to evaluate unit's performance and strategy as a platform which supports the overall systematic approach being applied to achieve flexibility goals. It is imperative to understand that all units vary. Thus, conducting individualized and independent unit assessments is critical to understand flexibility impacts as well as site specific details. Some of those details are described below:

- Age and sizing (MW capacity)
- Maintenance-related activities
- Equipment design variables and manufacturer
- Vintage of technologies installed
- Fuel type, quality, and deviation from design fuel specifications
- Environmental equipment (including retrofits)
- History and timing of past and future overhauls (boiler/turbine/BOP)
- Plant configuration, size, economies of scale, and scope
- Process controls and instrumentation
- Retrofit of equipment, especially for greater flexibility in moving among duty cycles
- Modes of flexible operation over time, measured with variables such as number of hot starts, warm starts, cold starts, and load-following requirements (e.g., two-shifting, double two-shifting, weekend shutdowns, load-following, load-cycling, and/or sporadic operations)

It is also important to understand that reliability and flexibility of conventional steam generators is interrelated with performance of various subsets of equipment, operational and maintenance actions that are driven by people, process and the application of technologies that assist with performance sustainability and market availability.

The mission profile changes for conventional steam generators demands integration of cost-effective defense processes and technologies that help adapt, work smarter and protect assets under challenging conditions. As we evolve with advancements in power generation technologies, conventional steam generators need to build on the fundamentals and lessons learned from the past. This includes both quantitative and qualitative actions that cost-effectively drive awareness, support best practice application and encourages benchmarking and defense strategies to protect assets.

With any successful programs, it is important to first identify the gaps needing improvement, create awareness and then prioritize improvement actions. It is important to understand that the negative impacts of flexible operations must be offset. Otherwise, the damage caused can create more significant challenges including inability to balance the budget. Achieving operational flexibility goals is a complex process that must have senior management’s full commitment.

This recognizes that most thermal plants can operate flexibly in the short-term. However, to sustain reliability and acceptable performance, it is important to conduct flexibility assessments to identify top areas needing improvement. This should take into consideration impacts from multiple areas of the station, including: 1) boiler, 2) turbine generator, 3) balance of plant, and 4) environmental controls.

The templates included address multiple areas for comprehensive evaluation, including the ten areas for evaluation given in Figure 1-9.

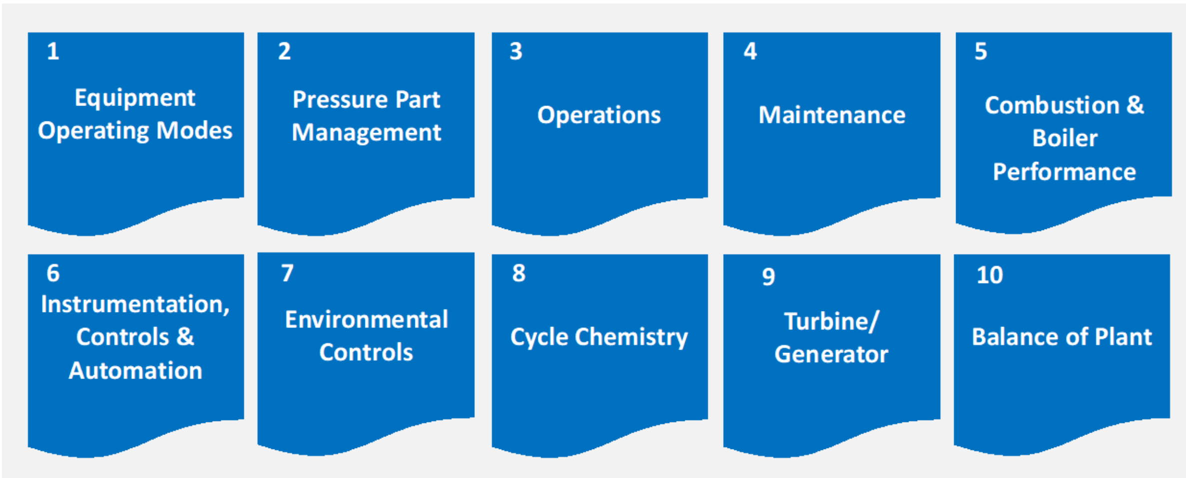

Figure 1-9
Ten templates for comprehensive flexibility assessment

Comprehensive Assessments

As plant teams develop an understanding for flexibility, they must also understand the impacts of flexibility on availability, efficiency and environmental controls. This was the inspiration for developing the templates to help drive awareness with comprehensive flexibility assessments and to provide a path for benchmarking against a high-level standard of performance. Figure 1-10 illustrates the project approach for a complete assessment applying the flexibility templates.

SOP: Standards Of Performance

Figure 1-10
Project approach for the assessment tool application

Conducting High-Level Assessments

A comprehensive assessment should address a multitude of items and suggest needs for improvements. Considering this can be overwhelming, the reason for developing the assessments into ten templates with performance standards, is to allow small groups of competent people working under the direction of the flexibility team leader to accomplish a review in a productive manner.

It should also be mentioned that this activity should be sponsored by senior management, showing "top-down" support for the collaborative initiative. The designated team leader organizing the assessment should have comprehensive knowledge of all areas being evaluated and be able to provide the following leadership:

1. Provide overall direction.
2. The assessment lead would ideally manage a station or fleet flexibility program.
3. Demonstrated ability to plan, communicate, and obtain buy-in for implementation of action items required.
4. Perform or facilitate the assessments aligning the team members from each area.
5. Communicate and incorporate plant improvement projects that help resolve deficiencies that have been identified.
6. Coordinate the annual update for site self-assessment evaluations and audits of controllable variables and mitigation efforts to offset for negative impacts.
7. Provide specialized technical support when required.
8. Arrange and conduct training as requested or needed to address gaps.
9. Maintain annual communications with corporate, regional and/or station management.
10. Provide fleet technical support and develop action plan recommendations for performance improvements needed and overcome roadblocks by first describing the challenges, identifying system owners, resources and prioritizing actions.

High-Level Assessments

All areas of the assessments are not equally weighted regarding importance. Thus, a place has been provided for input of a weighting (WT) factor for the variable being assessed. A weighting factor of (1) represents a "low-impact" variable. A weighting factor of (2) represents a "medium impact" variable. A weighting factor of (3) represents a "high-impact" (important) variable. Weighting factors are subjective and will vary from unit to unit. Thus, the current inputs can be adjusted when evaluating the impact. Furthermore, within the template, the green section references the ideal (best achievable) score of three points, while the needs improvement (yellow) section is two points and the "at risk" (red) zone is a score of one.

After the weighting and assessment score have been evaluated, the weighted assessment score is a simple calculation of the weighted value times the assessment score. This weighted score can then be benchmarked against the "*best-achievable"* score with notations, action items and resources to be evaluated following the high-level assessment.

Template		Wt.	3	2	1	Assessment	Weighted Assessment Score	Best Achievable
1	*Variable*	2	*Details*	*Details*	*Details*	2	4	6
2	*Variable*	2	*Details*	*Details*	*Details*	3	6	6
3	*Variable*	2	*Details*	*Details*	*Details*	3	6	6
4	*Variable*	2	*Details*	*Details*	*Details*	1	2	6
5	*Variable*	2	*Details*	*Details*	*Details*	3	6	6
6	*Variable*	2	*Details*	*Details*	*Details*	2	4	6
7	*Variable*	2	*Details*	*Details*	*Details*	3	6	6
8	*Variable*	2	*Details*	*Details*	*Details*	3	6	6
9	*Variable*	2	*etails*	*Details*	*Details*	2	4	6
10	*Variable*	2	[illegible]	*Details*	*Details*	1	2	6

Totals	46	60
Assessment	76.67	

Assessment Score:
Reference the Green, Yellow and Red Classification that matches the unit being assessed

Weighted Assessment Score
= Weighted Value x Assessment Score

Best Achievable Score
= Weighted Value x 3 (green)

Assessment %
= Weighted Assessment Score / Best Achievable Score

***Suggested or Site Specific Assessment Weight*:**
(1) Low impact
(2) Medium impact
(3) High Impact

Figure 1-11
Assessment and benchmarking score overview

Conducting a comprehensive flexibility assessment with the intent of understanding challenges and improving an aging asset's integrity over time can be complex. This is especially true with personnel changes or an aging workplace where responsibilities shift. Therefore, having a program with a benchmarking guide to manage flexibility information and standards of performance, can be considered part of a defense strategy to manage flexible operations at a station, across a fleet and/or even globally.

Comprehensive and integrated benchmarking templates provide a foundation for identifying gaps where technologies have been developed to address common issues intended to help with the preparation and management of flexible operations needed for conventional steam generators when adapting to a new mission. Although low carbon resources are being integrated to replace some aging assets, fossil fuels and conventional steam generators will remain a vital part of energy security to most countries around the world for many years to come. Thus, these stations must adapt to flexible operations as the grid demands more cyclic operation.

Staff must understand potential damage mechanisms and considerations must be given to the impacts of plant cycling on damage rates. Critical risks related to increased production costs, high probability of equipment failure and reduced-life expectancy demands effective management actions. In addition, staff should make safety and safe plant operations a top priority as the various modes of operations are assessed. The flexibility assessment tool can help in a number of critical areas that are core to program management. Flexibility assessment and benchmarking helps identify gaps and opportunities for improvement, drive awareness and prioritization. Furthermore, it will support development projects or laying the groundwork for more in-depth flex studies that may be required.

	Flexibility Benchmarking Metric	Best Achievable	Goal (>75%)	Site Benchmark
1	Equipment Operating Modes	100.00	75.00	79.45
2	Pressure Part Management	100.00	75.00	47.31
3	Operations	100.00	75.00	62.62
4	Maintenance	100.00	75.00	66.67
5	Combustion and Performance	100.00	75.00	47.22
6	Instrumentation, Controls & Automation	100.00	75.00	70.23
7	Environmental Controls	100.00	75.00	66.67
8	Cycle Chemistry	100.00	75.00	66.67
9	Turbine/Generator	100.00	75.00	79.68
10	Balance of Plant	100.00	75.00	66.67
	Overall Score	100.00	75.00	**65.32**

Scoring Classification	
<70	
>70 or <75	
>75	

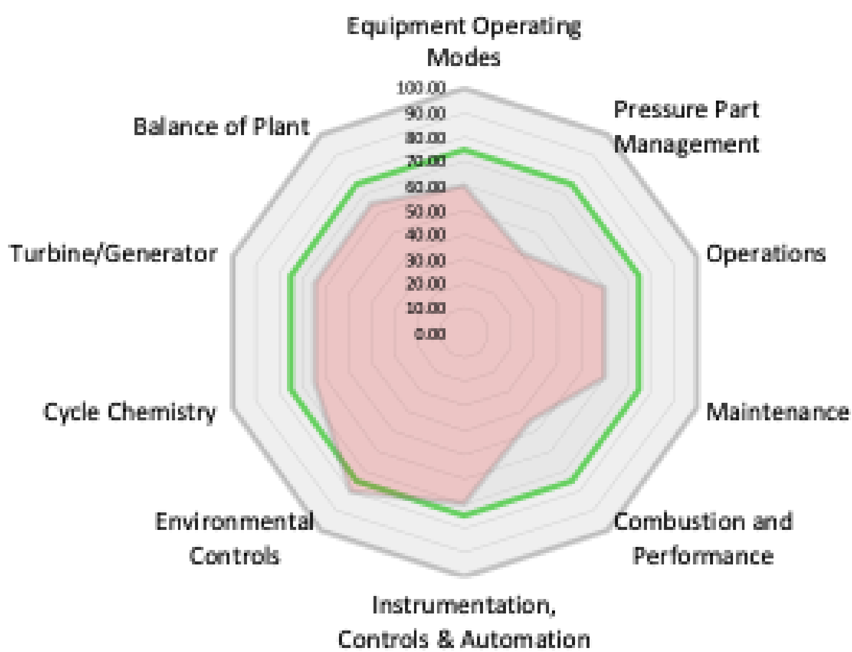

Figure 1-12
Assessment summary table and scoring metric

2
TEMPLATES

High-Level Flexibility Assessment Templates:

1. Equipment operating modes
2. Pressure parts and life availability
3. Operations
4. Maintenance
5. Combustion and boiler performance
6. Instrumentation and controls
7. Environmental controls
8. Steam cycle chemistry
9. Turbine/generator
10. Balance of plant

High-Level Flexibility Assessment Template 1 Equipment Operating Modes

Equipment Operating Modes

		WT	3	2	1
1	Ramp Rate, % /minute	2	6	4	2
2	Minimum Load Turndown Capability	2	<30	>30	>40
3	Ramp-Up time for Hot Start Synchronization to full load	2	1 Hour	2 Hours	>3 Hours
4	Ramp Up time for cold start Synchronization to full load	2	2 Hour	4 Hours	>7 hours

Fuel considerations should be taken into consideration with the above.

Fuel Type	Check Applicable	Comments on Fuel Challenges (if any) – on Unit Flexibility
Low GCV coal		
Medium GCV Coal		
High GCV Coal		
Fuel Oil		
Dual Firing Capability – Coal/Gas		
Dual Firing Capability – Coal/Oil		
Dual Firing Capability – Coal/Biomass		
Other		

GCV = Gross Calorific Value

Equipment Operating Modes

		WT	3	2	1
5	What is the most typical operating mode?	3	Baseload	Expanded the operation range of a unit's output by lowering the unit's minimum load; Unit remains in service, but load is varied widely, running from maximum load to low load; Units expected to rapidly change load demand	Cycling on/off Taking the unit in and out of service. (Inducing hot, warm, or cold starts)
6	Number of Starts per year (Hot)	3	<15	>15 <30	> 30
7	Number of Starts per year (Warm)	3	<15	>15 <30	> 30
8	Number of Starts per year (Cold)	3	<15	>15 <30	> 30
9	Reason for starts per year inquiry	2	Re-starts are planned and/or driven by market demands	Starts are sometimes related to reliability issues and/or water/fuel constraints	Starts are most often related to reliability issues and not market, fuel or water constraint driven
10	Extended or reserve shut down The Unit is Cold Ambient Temperature, 70F (21C)	2	<1,000 hours	>1,000 hours <2,000 hours	>2000 hours
11	Capacity Factor	2	>70%	<70% >50%	<50%
12	Start-up temperature (first stage metal)	2	Most startups are Hot <8 hours off-load 700F-750F (371C – 400C)	Most start-ups are Warm >8 and <48 hours off-load 320F – 750F (160C – 400C)	Most startups are Cold >48 hours off-load 250F-320F (120C – 160C)

Equipment Operating Modes

		WT	3	2	1
13	Net Heat Rate - best achievable across the load range	2	Near Design	< 2% from design	>2% from design
14	Has a reduced minimum load goal been established?	2	Yes	Partial	No
15	Has the reduced minimum load goal been evaluated and reviewed with OEMs to discuss the impact of the temperature and pressure changes on major equipment?	2	Yes	Partial	No
16	Has a reduced minimum load performance review been conducted and understood?	2	Yes	Partial	No
17	Have potential roadblocks been identified?	2	Yes	Partial	No
18	Have minimum load reduction operation trials and studies been conducted?	2	Yes	Partial	No
19	Have minimum load Implementation of upgrades been implemented?	2	Yes	Partial	No
20	If upgrades have been implemented for reducing minimum load, have re-test/evaluations been conducted?	2	Yes	Partial	No
21	Ramp Rate demands and/or Automatic Generation Control (AGC) is understood and optimized	2	Yes	Partial	No
22	Start-up Time is understood and optimal for all units and the fleet	2	Yes	Partial	No
23	Ramp rate speed is understood and optimal for all units and the fleet	2	Yes	Partial	No
24	Cycling scenarios are understood and managed accordingly	2	Yes	Partial	No
25	Dispatch Optimization (Efficiency, availability, emissions impact) all taken into consideration	2	Yes	Partial	No
26	Cold, warm and hot start provisions are understood and optimal	2	Yes	Partial	No
27	Lay-up and/or reserve shut-down requirements are understood and optimized for flexible operations (Boiler, Turbine, BOP equipment)	2	Yes	Partial	No

Equipment Operating Modes: Energy Market Assessment

		WT	3	2	1
28	Baseload demand understood	1	Yes	Partial	No
29	Peak ramping rate understood	1	Yes	Partial	No
30	Peak demand understood	1	Yes	Partial	No
31	Typical/seasonal energy demands for a system understood	1	Yes	Partial	No
32	Peak to base demands understood	1	Yes	Partial	No
33	Minimum load demands are understood	1	Yes	Partial	No
34	On/off timing is understood		Yes	Partial	No
35	Automatic Generation Control (AGC) is operational	1	Yes	Needs Improvement	No
36	Restricted governor mode operation (RGMO) or free governor mode of operation (FGMO) for primary frequency control	1	No issues with primary frequency control	Some issues with primary frequency control	Issues with primary frequency control
37	Reserves regulation ancillary services (RRAS) to restore the frequency level at desired level and to relieve the congestion in the transmission network	1	No issues with restoring frequency control	Issues with restoring frequency control sometimes exist	Constant issue

Template	Item	Comment	Process Variable/PI Tag Details
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High-Level Flexibility Assessment Template 2 Pressure Part Life Assessment

Pressure Parts and Life Assessment

		WT	3	2	1
1	Equivalent availability loss (%)	2	<.5	>.5 or <1.5	>1.5
2	Ranking System (priority) in place for BTF Mechanisms in Plant/System	2	Yes		No
3	Do you have any cycle chemistry related BTF Mechanisms	2	No		Yes
4	What percentage of superheater and reheater circuits in your system/plant do you know the remaining life (using oxide scale technique)	**2**	All	>50%	<50%
5	Do you have a BTF forced outage plan other than "fix it quick" (Must be in writing)?	2	Yes		No
6	Do you have Action Plans (in writing) for repeat BTF that addresses damaged tubing and mitigating actions? See Appendix for Examples	2	Yes		No
7	Do you normally continue running with known tube leaks (written procedure) - except in a system emergency	2	No		Yes
8	Do you normally use pad welding - written procedure (except in a system emergency)	1	No		Yes
9	Do you have a set of BTF goals/objectives?	1	Yes		No
10	Does your organization have a formal life assessment program in place?	3	Corp. Directed and/or Multi-Disciplined Team	Individual coordinator	No formal Program
11	Do you force cool the boiler? Do your operators have access to written, plant-specific procedures for responding to out-of-normal temperature pressure/conditions?	2	Yes		No
12	Have you experienced any operational issues such as over-temperature/over-pressure in the past 5-years?	2	No		Yes
13	Do you monitor steam chemistry (MS or RH) limits?	2	Yes		No
14	Do you have written procedures for reducing load if indications are identified?	2	Yes		No

BTF = Boiler Tube Failure MS = Main Steam RH = Reheat

Pressure Part Life Assessment

		WT	3	2	1
15	Do you have established inspection intervals for all major equipment	2	Yes		No
16	Do you inspect 100% of seam-welded pipes?	2	Yes		No
17	Do you perform remaining life analysis/calculations to establish inspection locations and intervals?	2	Yes		No
18	Do you (or your inspection organization) have calibration blocks for every size pipe in your system?	2	Yes		No
19	Do you utilize advanced inspection methods (TOFD, Focused Array, Acoustic emission, etc.)	2	Yes		No
20	Are NDE inspectors fully qualified via an accredited program?	2	Yes		No
21	Do you have multi-discipline involvement in your failure analysis	3	Yes		No
22	Are failure analysis, root cause analysis, and plan of elimination performed on every indication/failure?	3	Yes		No
23	Do you record and chart all failures or indications?	3	Yes		No
24	Do you involve a staff metallurgist (or have equivalent access) in all failures?	3	Yes		No
25	Do you have qualified welding procedures for every component in your unit? (Including all materials)	2	Yes		No
26	Do you have sample removal and re-installation/repair procedures	2	Yes		No
27	Is permanent repair expressed in every application?	2	Yes		No
28	Do you utilize qualified temper bead welding procedures?	2	Yes		No
29	Life assessment program for all high energy piping (including clam shell elbows)?	**1**	Yes		No
30	Do you monitor temperature for MS & RH piping?	1	Yes		No
31	Do you predict life for every pipe weld or weld joint on High Energy Piping (HEP)	1	Yes		No
32	Do you check all HEP components for long seam welds even if drawings indicate the component is seamless?	1	Yes		No

TOFD = time of flight diffraction NDE = nondestructive examination

Pressure Part Life Assessment

		WT	3	2	1
33	Formal documentation of HEP inspection & analysis results	1	Yes		No
34	Are follow up actions (based on inspection/analysis results) part of your High Energy Piping life assessment program?	1	Yes		No
35	Life assessment program in place for all high temperature headers?	2	>80%	60-80%	<60
36	What percentage of headers have been inspected for ligament damage or borehole cracking?	2	>80%	60-80%	<60
37	Do you monitor temperature for every header at multiple locations along its length?	2	Yes		No
38	Formal documentation of inspection & analysis results?	2	Yes		No
39	Are follow up actions (based on inspection/analysis results) part of your header life assessment program?	2	Yes		No
40	Life assessment program for all drums?	1	Yes		No
41	Do you predict life for all economizer components?	1	Yes		No
42	Do you monitor through-wall temperature gradients for economizers?	1	Yes		No
43	Do you utilize low flow control valves on feedwater lines?	1	Yes		No
44	Formal documentation of inspection & analysis results?	1	Yes		No
45	Are follow up actions (based on inspection/analysis results) part of your low temp header, drum, economizer life assessment program?	1	Yes		No
46	Do you have procedures in place to keep from topping off a hot drum/economizer?	1	Yes		No
47	Formal FAC program in place?	2	Yes	Partial	No
48	Formal documentation of inspection & analysis results?	2	Yes		No
49	Are follow up actions (based on inspection/analysis results) part of your feedwater system life assessment program?	2	Yes		No

FAC = Flow-accelerated corrosion

Pressure Part Life Assessment

		WT	3	2	1
50	Does your organization have a hanger life assessment program? Does it include the following?	2	Yes		No
51	Do you take photos of hangers in hot/cold positions?	2	Yes		No
52	Do you test actual load supported by hangers?	2	Yes		No
53	Have you inspected hanger clamps, blocks, welds, attachments to piping?	2	Yes		No
54	Do you chart hanger hot/cold locations?	2	Yes		No
55	Do you perform a piping analysis which calculates loads, displacements and elastic as well as creep stresses?	2	Yes		No
56	Do you compare hanger observation results to design?	2	Yes		No
57	Formal documentation of inspection and analysis results?	2	Yes		No
58	Are follow up actions (based on inspection/analysis results) part of your hanger program?	2	Yes		No
59	Monitors parameter-based limits (actionable guidance) being given to protect station equipment (e.g., thick-walled components, drum, start-up vessel, headers, etc.)	1	Yes		No
60	Understand and Identify pressure part vulnerabilities and have Implemented defense strategies to mitigate failures (e.g., see cyclic/temperature protection system inquiry in Appendix)	1	Yes		No

Temperature Representation - Pressure Part Assessment

	SUB	SUP		WT	3	2	1
61	X	X	Furnace exit gas temperature (FEGT)	2	Representative	Needs Improvement	Inadequate or N/A
62		X	Water wall outlet header steam temperature rate of change	2	Representative	Needs Improvement	Inadequate or N/A
63		X	Water Wall Outlet Header Metal Temperature	2	Representative	Needs Improvement	Inadequate or N/A
64	X	X	Superheat outlet header temperature	2	Representative	Needs Improvement	Inadequate or N/A
65	X	X	SH inlet/outlet attemperator temps to detect valve leak-by	2	Representative	Needs Improvement	Inadequate or N/A
66	X	X	RH inlet/outlet attemperator temps to detect valve leak-by	2	Representative	Needs Improvement	Inadequate or N/A
67	X	X	Reheat outlet header temperature	2	Representative	Needs Improvement	Inadequate or N/A
68	X		Drum temperature differentials (top-to-bottom) High stress w/ elevated differentials can lead to drum humping	2	Representative	Needs Improvement	Inadequate or N/A
69	X	X	Superheater tube metal temperatures High differential temps from the header to tube can result in cracking	2	Representative	Needs Improvement	Inadequate or N/A
70	X	X	Reheater Tube Metal Temperatures	2	Representative	Needs Improvement	Inadequate or N/A
71	X	X	Economizer Inlet Temperatures	2	Representative	Needs Improvement	Inadequate or N/A
72	X	X	Economizer Outlet Temperatures	2	Representative	Needs Improvement	Inadequate or N/A
73	X	X	Furnace Exit Gas Temperature (FEGT)	2	< 50°F (10°C) Deviation from design	< 75°F (24°C) Deviation from design	>75°F (>24°C) Deviation from design

SUB = Applicable to subcritical unit SUP = Applicable to supercritical unit

Temperature Representation: Pressure Part Assessment

	SUB	SUP		WT	3	2	1
74		X	Water Wall Outlet Header Steam Temperature Rate of Change	2	< 75°F/HR (<24°C/HR)	>75°F/HR (>24°C/HR)	>100°F/HR (>38°C)
75		X	Water Wall Outlet Header Metal Temperature	2	<25°F (<-4°C) from max. metal temp. limit	< 15°F (<-9°C) from max. metal temp. limit	< 10°F (<-12°C) from max. metal temp. limit
76	X	X	Superheat Outlet Header Temp.	2	< 25°F(<-4°C) of max limit	< 15°F(<-9°C) of max limit	< 10°F(<-12°C) of max limit
77	X	X	SH inlet/outlet attemperator temps to detect valve leak-by	2	Yes	Needs Improvement	No
78	X	X	RH inlet/outlet attemperator temps to detect valve leak-by	2	Yes	Needs Improvement	No
79	X	X	Reheat Outlet Header Temperature	2	< 25°F (<-4°C) of max limit	< 15°F (<-9°C) of max limit	< 10°F(<-12°C) of max limit
80	X		Drum Temperature	2	25-50°F (-4°C - 10°C) (top to bottom)	50 -75°F (10°C - 24°C) (top to bottom)	>75-100°F (24°C - 38°C) (top to bottom)
81	X	X	Superheater Tube Metal Temps	2	< 25°F(<-4°C) of max limit	< 15°F (<-9°C) of max limit	< 10°F(<-12°C) of max limit
82	X	X	Reheater Tube Metal Temperatures	2	< 25°F(<-4°C) of max limit	< 15°F (<-9°C) of max limit	< 10°F(<-12°C) of max limit
83	X	X	Economizer Inlet Temperatures	2	< 25°F(<-4°C) of max limit	< 15°F (<-9°C) of max limit	< 10°F(<-12°C) of max limit
84	X	X	Economizer Outlet Temperatures	2	< 25°F(<-4°C) of max limit	< 15°F (<-9°C) of max limit	< 10°F(<-12°C) of max limit

SUB = Applicable to subcritical unit SUP = Applicable to supercritical unit

Template	Item	Comment	Process Variable/PI Tag Details
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Template	Item	Comment	Process Variable/PI Tag Details
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Template	Item	Comment	Process Variable/PI Tag Details
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Template	Item	Comment	Process Variable/PI Tag Details
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High-Level Flexibility Assessment Template 3 Operations

Operations Assessment

		WT	3	2	1
1	Shift Turnovers	2	Guided by a checklist & include a thorough review of appropriate documents describing the important aspects of the facility status. Complemented by a discussion among oncoming and off going operators assuring good communications.	Turn-over checklists and discussions need improvement	Not guided by checklist and/or turn-over discussions are inadequate
2	Flexibility Training	2	Provides adequate flexible operations training on basic principles, plant design, system, cycle, fundamentals, safety, and environmental requirements.	Training is infrequent and needs improvement	Minimal training on flexible operations is conducted
3	Simulators	2	Use of simulator and drills for flexible operations training	Some training scenarios are used on simulators, but infrequently	No simulator training for flexible operations scenarios
4	Bottling up heat	2	Operations procedures include a process for keeping the boiler's metal components as hot as possible during short/overnight shutdown periods.	This is an area that that is understood by some, but not all staff; Needs improvement	No actions are taken to retain system heat
5	Corrosion mitigation (Boiler, Turbine, BOP components)	2	To mitigate corrosion, operations maintains boiler tube temperatures as high as possible during overnight or short cycling periods. Close dampers on the air gas side to help hold in heat and decrease boiler tube metal cool down rates; For longer shutdown periods (one week), drain boiler and purge tubes with nitrogen or dehumidified air.	The stations corrosion mitigation actions need improvement; minimal efforts are done to address system corrosion	No actions are taken to mitigate corrosion

BOP = balance of plant

Operations Assessment

		WT	3	2	1
6	Offline temperature management	2	Use of a boiler circulating water pump during shutdown periods to keep uniform temperatures across water-wall tubes	Needs improvement	No
7	Representative temperature management of SH and RH temperatures	2	Adequate thermocouples are available to monitor and control temperatures in areas subject to overheating boiler tubes.	There are available thermocouples, but representation needs improvement.	Inadequate thermocouples and/or alarming for boiler tube metal monitoring and/or actions
8	Operator guidance on tube metal excursions	2	Clear operator direction has been provided to operations on how to respond to high temperatures scenarios	Operator direction needs improvement	
9	OEM start-up curves	2	Station follows OEM start-up and operating procedures	Operations does not always follow OEM start-up and operating procedures	No
10	Thermography to evaluate boiler casing and insulation	2	Station performs thermography tests on the boiler casing during operation to identify missing or damaged insulation; write work orders to replace/upgrade insulation as needed during outages	Has been done in the past, but not within past year. Some areas need improvement	Not completed or addressed in over two years
11	Startup procedures	2	Startup procedures are used to optimize startup time without violating OEM temperature restrictions for specific components.	Procedures need improvement; OEM temperature restrictions are sometimes exceeded to meet start-up time demands.	Procedures need to be updated. Operations regularly exceeds OEM temperature restrictions

Operations Assessment

		WT	3	2	1
12	Light off process and equipment	2	Light off process and equipment optimized for firing configurations and flame stability at low and reduced operating loads	Light off process needs improvement	Light off process and equipment is not optimized; Flame stability is an issue
13	Boiler cleaning effectiveness	2	Boiler cleaning effectiveness evaluated after switching to flexible operations; Adjusts cleaning cycles according to needs	Boiler cleaning effectiveness needs improvement	Boiler cleaning effectiveness is not acceptable. Slagging and/or fouling is a major concern
14	Training/familiarity with infrequently used procedures.	2	Provide additional training/familiarity with infrequently used procedures. Procedures have been reviewed for safety, economics, repeatability, minimization of plant damage, and environmental performance	Training needs improvement	Training is inadequate and needs attention to detail to improve safety and overall performance
15	New Procedures	2	Station develops new procedures based on modifications, upgrades, control changes, equipment changes; emergency action plans with reduced staffing	Procedures need improvement;	Procedures have not been evaluated or updated following a change in operational mission and/or an equipment upgrade
16	Mitigating Air Heater Cold-end corrosion	2	Station closely monitors exit gas temperatures to stay above the acid dew point and thermocouples are representative	Cold end corrosion of the air heaters needs improvement	This is a significant issue that needs to be addressed.

Operations Assessment: Air/Gas Systems

		WT	3	2	1
17	APH ΔP Management to avoid gas mal-distribution and/or plugging	2	Low DP (or design)	Moderate DP	High DP
18	APH Cleaning System	2	Good Performance	Needs Improvement	Unacceptable
19	APH, Cold-End Temperature Control	2	Above Dewpoint	Near Dewpoint	Below Dewpoint
20	Impact on Furnace Exit Gas Temperature (FEGT)	2	Managed for Overheat Mitigation	Unrepresentative Some control	Not Managed Uncontrolled
21	Minimum Airflow	2	Representative and accurate Measurement	Some control	Not Managed Uncontrolled
22	Boiler O_2 Controlled Minimum to Maximum O_2 Set-Points	2	Controlled to Curve	Needs Improvement	Uncontrolled
23	Burner Air Register & Sleeve controls	2	Good Condition Good Control	Needs Improvement	Poor Condition Poor Control
24	Combustion Air – Fan Performance (PA, FD)	2	Dampers controllable; Acceptable capacity across load range	Needs improvement	Poor control; insufficient capacity control
25	Mill Minimum temperature control	2	Good control	Periodic issues (e.g., wet coal)	Poor control
26	SCR temperature measurement (via representative grid)	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
27	SCR minimum inlet gas temperature	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
28	Exit Gas Temperature	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
29	Water Wall Temps – FW Control	2	Good Control	Needs Improvement	Poor Control

APH = Air preheater
FW = Feedwater
FD = Forced draft
PA = Primary Air
SCR = Selective Catalytic Reduction

Operations Assessment: Fuel Systems

		WT	3	2	1
30	Hot air temperature control to mills	2	Adequate	Needs Improvement	Poor
31	Flame Quality Scanner Performance	2	Acceptable	Needs Improvement	Unacceptable
32	Coal Quality Impacts	2	Managed; No issues	Needs Improvement	Unacceptable
33	Fuel and Ash Management	2	Managed; No issues	Needs Improvement	Non-Optimal
34	Mill Capacity	2	Acceptable	Needs Improvement	Unacceptable
35	No. of Mills in-service at varying loads	2	Acceptable	Needs Improvement	Unacceptable
36	Mill Performance; Air/Fuel Distribution	2	Acceptable	Needs Improvement	Unacceptable
37	Optimal Igniter Performance (Fuel Oil, Gas)	2	Acceptable	Needs Improvement	Unacceptable
38	Flame Scanners	2	Acceptable	Needs Improvement	Unacceptable
39	Burner components, mechanical condition and control (including tilts on a T-fired unit)	2	Acceptable	Needs Improvement	Unacceptable
40	Air Registers	2	Acceptable	Needs Improvement	Unacceptable
41	Mill and Fire Suppression System	2	Acceptable or Not an issue (or N/A)	Needs Improvement	Unacceptable
42	Coal Treatment Systems	2	Not Required Or No Issues	Undetermined	Non-Optimal Issues

Operations Assessment: Water Systems

		WT	3	2	1
43	DCS Controls at minimum loads	2	Good Control	Needs Improvement	Poor Control
44	Minimum & Maximum Drum Level	2	Good Control	Needs Improvement	Poor Control
45	Minimum & Maximum Deaerator Level	2	Good Control	Needs Improvement	Poor Control
46	BFP Controls (on/off operations)	2	Good Control	Needs Improvement	Poor Control
47	FW Heater Level Controls	2	Good Control	Needs Improvement	Poor Control
48	Ensure Condenser Vacuum and Air In-Leakage monitoring systems are in good working order	2	Minimum	Needs Improvement	High
49	Absolute Back Pressure	2	Good	Needs Improvement	Poor
50	Water chemistry controls and monitoring systems: Condensate, Deaerator Inlet and Feedwater/Polisher outlet are working properly	2	Good Control	Needs Improvement	Poor Control
51	Water chemistry controls and monitoring systems working properly for Boiler Drum, Water and Steam are working properly.	2	Good Control	Needs Improvement	Poor Control
52	FWH performance and final FW inlet temperature monitoring for FAC control	2	Good	Needs Improvement	Poor
53	Other: Valves, Start-up Systems, Recirculation valve and controls, Acoustic leak detection systems	2	Good; No issues	Needs Improvement	Poor
54	Filming Products Optimized (if in use)	2	Yes	Need Improvement Or Undetermined	No

BFP = Boiler Feed Pump FWH = Feedwater Heater

Operations Assessment: Steam Control

		WT	3	2	1
55	Main Steam Temperature, Minimum & Maximum (with/without sliding press.)	2	Good control	Needs Improvement	Poor Control
56	RH Steam Temperature Maximum, Minimum	2	Good control	Needs Improvement	Poor Control
57	SH/RH, Temperature Differential	2	Good control	Needs Improvement	Poor Control
58	Boiler Pressure Control, Minimum & Maximum	2	Good control	Needs Improvement	Poor Control
59	Maximum SH/RH de-superheating spray flow rates	2	Good control	Needs Improvement	Poor Control
60	Boiler Expansion (joints, pipe hangers, etc.)	2	Good control	Needs Improvement	Poor Control
61	Boiler Tube and Header Metal Temperatures	2	Good control	Needs Improvement	Poor Control
62	Reduced Minimum Load Steam Temperature Control	2	Good control	Needs Improvement	Poor Control
63	Start-up system valves and controls	2	Good control	Needs Improvement	Poor Control
64	Main Steam and Reheat Attemperators	2	Good control	Needs Improvement	Poor Control
65	Steam Temperature Controls Tuning	2	Good control	Needs Improvement	Poor Control
66	Boiler Metal Temperatures (SH, RH)	2	Good control	Needs Improvement	Poor Control
67	Inspect Boiler Expansion, Movements: boiler, ducts, piping – all hangars and interferences (if any)	2	Good control	Needs Improvement	Poor Control
68	Power Piping Inspection	2	Good control	Needs Improvement	Poor Control
69	Turbine steam Philosophy – first stage admission	2	Good control	Needs Improvement	Poor Control

Operations Assessment: Turbine/Generator Assessment

		WT	3	2	1
70	Turbine Controls – Stop Valves	2	Good control	Needs Improvement	Poor Control
71	Turbine Controls – Control valves & governor valves	2	Good control	Needs Improvement	Poor Control
72	Turbine/Generator supervisory instrumentation (Vibration, Differential, Expansion, Metal Temps, Casing Expansion)	2	Good control	Needs Improvement	Poor Control
73	Turbine/Generator Bearing Oil System Controls	2	Good control	Needs Improvement	Poor Control
74	HP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
75	HP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
76	HP Stator Slot Temperatures – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
77	HP & LP Hydrogen Gas Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
78	LP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
79	LP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist

		WT	3	2	1
80	LP Stator Slot Temperatures – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
81	Generator Protective Systems (Power Factor)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
82	Generator Hydrogen	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
83	Generator Cooling Systems (Stator cooling)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
84	Generator Automatic Voltage Regulator Tuning	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist

Operations Assessment: Turbine

		WT	3	2	1
85	Turbine steam Philosophy – first stage admission	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
86	Turbine Controls – Stop Valves	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
87	Turbine Controls – Control valves & governor valves	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
88	Turbine/Generator supervisory instrumentation (Vibration, Differential, Expansion, Metal Temps, Casing Expansion)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
89	Turbine/Generator Bearing Oil System Controls	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
90	HP & IP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
91	HP & IP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
92	HP & IP Thrust Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
93	HP & IP Thrust Bearing Position (Wear)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
94	HP& IP Differential Expansion - Rotor Long	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
94	HP & IP Differential Expansion – Rotor Short	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
96	LP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
97	LP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist

Operations Assessment: Auxiliary/Environmental Systems

		WT	3	2	1
98	Crossover or Bypass Dampers Controls	2	No issues	Needs Improvement	Issues exist
99	Stack Plume at Low Load	2	No issues	Needs Improvement	Issues exist
100	Precipitators	2	No issues	Needs Improvement	Issues exist
101	Baghouse – Bag Condition	2	No issues	Needs Improvement	Issues exist
102	Ensure Operating Permit Allows Low Load Operation	2	No issues	Needs Improvement	Issues exist

Operations Assessment: Boiler Performance

Boiler Performance		WT	3	2	1
103	Boiler Cleaning System (soot blowers, on/offline cleaning process)	2	Good performance	Needs Improvement	Poor Performance
104	Burner Optimization Controls (air-fuel distribution, tilts on T-fired units; air-fuel mgmt.)	2	Good performance	Needs Improvement	Poor Performance
105	Boiler Stoichiometry control; Air In-Leakage Management	2	Good performance	Needs Improvement	Poor Performance
106	Boiler controls form mitigating thermal transients	2	Good performance	Needs Improvement	Poor Performance
107	Soot Blower (SB) Thermal Drains; SB header temp./pressure monitoring	2	Good performance	Needs Improvement	Poor Performance
108	Steam Coils (for cold-end temperature control)	2	Good performance	Needs Improvement	Poor Performance
109	Dew point & corrosion control	2	Good performance	Needs Improvement	Poor Performance
110	O_2 & CO monitoring	2	Good performance	Needs Improvement	Poor Performance
111	Flame Stability and Mill Configuration Planning	2	Good Performance	Needs Improvement	Poor Performance

Operations Assessment: Emissions Control

		WT	3	2	1
112	NO_X Limits	2	No issues	Needs Improvement	Issues
113	SO_{2} - SO_3 Limits	2	No issues	Needs Improvement	Issues
114	NH_3 Slip Limits	2	No issues	Needs Improvement	Issues
115	Opacity Limits	2	No issues	Needs Improvement	Issues
116	Minimum Temps at SCR inlet limits	2	No issues	Needs Improvement	Issues
117	ID Fan Capacity (May impact availability of Boiler O_2)	2	No issues	Needs Improvement	Issues
118	Controls Optimization (capability to safely and efficiently meet the missions required)	2	No issues	Needs Improvement	Issues

Operations Assessment: Alarms/Graphics

		WT	3	2	1
119	Alarm Rates	2	Average and the peak alarm rates are under control for foreseeable plant operating scenarios; Dynamic and state-based techniques are used to improve the real time performance.	Occasional alarm flooding	Alarm flooding is common
120	Graphics	2	**Effective graphics:** Gray backgrounds to minimize glare; No animation; Black process lines, with major lines shown slightly thicker; Limited use of color. Embedded trends of important process parameters; A layout wherein the process flow is from left to right whenever possible. A layout that is generally consistent with the operator's mental model of the process; Logical and consistent navigation methods; Display access with a maximum of three mouse clicks or keystrokes; Techniques used to minimize the possibility of operator mistakes and provide validation and security measures; Proper layout to avoid unnecessarily crossing lines; Measurement units shown in low contrast lettering, if used at all. (The operators know the units of measurement.)	Needs Improvement Graphics are somewhere in between the Green and Red "effective vs. ineffective" attributes	**Attributes of Ineffective graphics** Bright; flashing graphics. Brightly colors; 3D animations with spinning components; color coding; bright text; No trends; An exact representation of the P&ID with minor connections and manual valves; Lines that cross. Inconsistent process flow direction; Alarm colors used for non-alarm-related functionality; Haphazard, inconsistent navigation from screen to screen; Inconsistent color coding of various elements and overuse of color.

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High-Level Flexibility Assessment Template 4 Maintenance

Maintenance Assessment

		WT	3	2	1
1	Thermal fatigue mitigation strategy	2	Carefully monitors operating parameters to mitigate thermal fatigue. Overheating occurs, the station will perform an engineering review of the systems and equipment materials affected	The existing thermal fatigue mitigation strategy needs improvement.	There is no thermal fatigue mitigation strategy; Or, minimal monitoring/actions are taken to mitigate future temperature excursions.
2	Inspection strategy	2	Parameters and procedures are periodically evaluated and adhered to for improved plant operations and forward planning for replacement of critical components; Frequency of inspections is optimized and aligned with engineering	An inspection strategy exists but needs improvement; Frequency and quality of major component inspections in not aligned with engineering.	No Inspection Strategy exists; Inspection parameters, procedures and teams need guidance and direction
3	Risk ranking	2	Risk ranking utilized to prioritize projects	Sometimes risk ranking is utilized; Needs improvement	Not applicable
4	Superheater and reheater header program	2	Station monitors temperatures follow operating procedures, and periodically inspects all headers; Ensures that all thermocouples are installed and in good working order.	The inspection and monitoring program need improvement	Monitoring is not representative, and the inspection program is inadequate and/or doesn't exist.
5	Feedwater heaters	2	Inspection frequency adequate; Monitor bolt and seal conditions. Replace bolts, as necessary.	FW heater inspection program needs improvement	FW inspection program does not exist and/or is inadequate
6	Shorter maintenance intervals optimized	2	Routinely reviews existing staffing levels and scheduling options; Investigates the feasibility of augmenting the maintenance staff with contract support as needed; Arrange contractor relationships ahead of time. Closely monitors inventory levels.	Previews staffing levels periodically; Periodically investigates contract and contractor relationships. Inventory is managed, but not closely monitored	Short maintenance intervals are not optimized

Maintenance Assessment

		WT	3	2	1
7	Outage/overhaul intervals	2	Wear patterns are monitored, and outages adjusted to required intervals needed for flexible operations. Overhaul intervals and economic outages are optimized.	Outage/overhaul intervals are not optimized for flexible operations; Needs Improvement	Outage/Overhaul intervals are not optimized
8	Large motor integrity program	2	PM frequency is adjusted as needed; Station has verified that all motors are rated for the expected number of starts and the frequency.	Some PMs adjusted and/or investigated; Program needs improvement	Motor integrity is unknown.
9	Keeping the Maintenance Program Current	2	Preventive maintenance is reviewed for critical components and considers new stressors related to flexible operations.	Maintenance program has had some changes, but not all stressors related to flexible operations have been assessed	Maintenance program PMs have not been updated for flexible operations
10	Pumps and auxiliaries	2	A more proactive maintenance regime has been evaluated with the anticipation of wear and tear with flexible operations	Maintenance regime acknowledges the risk, but has not implemented actions	Maintenance regime for pumps and auxiliaries has not changed for flexible operations
11	Staffing versus automation optimized	2	To ensure timely and efficient operations for flexibility, additional staff needed have been evaluated to cut in, align, and isolate systems; Furthermore, the alternative option of automating some equipment, such as valves, dampers, and drain lines has been addressed.	Some staffing and automation have been evaluated. But, needs improvement	Staffing vs. Automation is not optimized.

Maintenance Assessment

		WT	3	2	1
12	PM frequency and spare parts levels	2	Adjusted and optimized for flexible operations demands; Site maintenance strategy moved from time-based to condition-based maintenance to address operating costs, viability to reduce the risk of over-maintaining or under-maintaining the plant.	Identified PMs and spare parts for adjustment, but not optimized	Not Addressed
13	Corrective work vs. planned maintenance work balance	2	Planning and scheduling activities adjusted to complete maintenance activities in a shorter time frame; Proper inventory is available	Planning and scheduling activity adjustment needs identified, but not optimal; Needs improvement	Corrective work vs. planned work is not balanced
14	Resource Sharing and Planning	2	Rescheduling of personnel and overtime optimized; Planning and scheduling activities are closely coordinated with operations; Equipment maintenance changes/needs and operators' skills deterioration is taken into consideration	Resource sharing and planning is utilized but planning and scheduling activities needs improvement to ensure a proper balance of skill sets.	Resource sharing and planning is non-optimal or not applicable
15	Protective circuits managed	2	Optimized PM programs and frequencies	PM Programs and frequencies need improvement	PM program and frequencies have not been addressed
16	Electrical switchgear maintenance	2	Schedules ensure that the number of cycles of operation is included in setting the inspection frequency and maintenance is optimized	Electrical switchgear maintenance program needs improvement for flex-ops	Issues exist and no adjustments have been made for flexible operations
17	Refractory	2	Increase of refractory repairs needed with flexible operations has been addressed; Upgraded to a more durable refractory product	Refractory repairs are being addressed; However, mitigation and management strategy is needed	Issues with refractory exist; PMs and material are non-optimal

Maintenance Assessment

		WT	3	2	1
18	Undersized boiler drains and vents optimized for various modes of operation	2	Survey/study of boiler drains and vents for proper flows have been addressed (ensure proper sizing, slope, etc.); Silencers added as needed.	Boiler drains and vents have been identified as an area that needs improvement	Boiler drains and vents have not been addressed and/or are not optimized
19	Increased wear on high-pressure and cold reheat piping with flexible operations	2	The need to inspect seamed welds and fitting welds more frequently due to the potential for creep damage has been evaluated and addressed; Also, the need for additional drain pots and traps.	Inspection process exists, but has not been adjusted for flexible operations	Potential for increased wear has not been considered.
20	Keep the Generator maintenance program current	2	Critical components have been reviewed and adjusted for new stressors; PMs and maintenance program modified	Critical components are inspected, but maintenance program has not been updated; Needs to be addressed	Generation program has not been updated or addressed for flexible operations
21	Insulation	2	Program to repair/replace/increase insulation to help retain heat as needed has been implemented; Thermography used to survey during operation to help identify problem areas.	General inspections are completed but are not documented and/or planned of outages.	Insulation program needs to be implemented for flexible operations
22	Wear on valve components:	2	Addressed the need for harder valve materials (valve seats and disks), to shorten maintenance intervals; Also, the type of valve actuator/operator to best manage flexible operations has been considered.	Valve materials and types have been addressed but not formally managed; Needs improvement	Valves wear and management is an issue

Maintenance Assessment

		WT	3	2	1
23	Valve leak-through	2	Monitored for proper operation; PM frequency addressed and increased as needed to address	PM frequency has been adjusted to address but is not adequately monitored	Valve leak through is an issue that needs to be addressed
24	FD fan worn components	2	Performs more frequent internal inspections of fan casings to address worn or corroded components; PMs updated	Inspections completed and issues addressed but not PMs not updated for flexible operations	FD fan Issues exist
25	Particulate control systems (electrostatic precipitator/baghouse)	2	Gas duct PMs adjusted to clean more frequently to prevent excessive ash buildup; Additional blowers added in stagnant areas to stir up ash buildup (where needed); Baghouse maintenance and monitoring addressed. Bag materials evaluated and/or upgraded as needed.	Impacts of flexible operations have been assessed and are understood, but program needs improvement	Issues exist and are non-optimal
26	Spare parts usage pattern with flexible operations	2	Update the maintenance basis, taking into flexible operations stressors, PM frequencies and spare parts. Cyclic operation will increase the failure of components (e.g., gaskets, switches, actuators, motors, valves, door seals, valve packing, thermocouples, control system cards, valve limit switches)	Spare part usage pattern changes have been identified, but inventory is not optimized	Issues exist with managing spare parts under flexible operations
27	Operation of the turning gear will increase	2	Spare turning-gears and/or required parts on hand to rebuild a unit, if needed; PMs have been updated to address drive motor cleaning and inspections.	Turning gear operations and/or rebuilds are planned and PMs adjusted, but all spare parts are not on hand to rebuild if needed.	No spare parts on hand and PMs have not been updated for flexible operations

Maintenance Assessment

		WT	3	2	1
28	Increased Starts	2	Increased starts (and rated capacity) of large motors, BFP, and ID and FD fans have been assessed; Frequency of the inspection intervals and PMs have been adjusted; Spare motors, or repair components added to inventory as needed.	Motors have been assessed, but PMs, inspection intervals and spare parts inventory needs improvement	Not addressed for flexible operations
29	Safety and relief valves	2	Inventory of spare safety and relief valves on hand has been assessed and managed accordingly	Safety and relief valve issues have been addressed but need improvement	Not addressed for flexible operations
30	Maintenance and operations coordination	2	Operations and Maintenance personnel aligned with actions and responsibilities through training and interaction regarding challenges with cyclic operations		
31	Establish a formal reliability, availability and maintainability (RAM) program	2	Does predictive maintenance accounting for cycling damage to minimize cycling related forced outage	Some accounting and predictive maintenance is completed; Needs improvement and expansion	No formal reliability, availability and maintainability program exists
32	Works with major equipment owners/engineers to install thermocouples on strategic locations	2	Examples: SH, RH tube metal thermocouples; Drains to monitor condensate accumulation	This needs improvement. Not all components are protected	Not addressed or prioritized

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High-Level Flexibility Assessment Template 5 Combustion and Boiler Performance

Combustion and Boiler Performance Assessment

		WT	3	2	1
1	Measured Furnace Exit O_2 at full load (Low, High, Average); Basis for standard is typical bituminous coal; Lower O_2 operations may be feasible with varying fuel types and system optimization.	2	>3% and/or <3.5%	Low-end >2% and/or high end <4%	Low-end <2% and/or high end >4%
2	Measured Boiler Outlet O_2 actual (Low, High, Average);	2	>3% and/or <3.5%	Low-end >2% and/or high end <4%	Low-end <2% and/or high end >4%
3	Indicated Boiler Outlet Excess O_2 (Low, High, Average)	2	On Curve	Within 10% of operating curve set-point	>10% from curve set-point (across the curve)
4	Deviation between actual boiler exit and actual furnace exit values	2	0 - .5%	>.5% - <1%	>1%
5	Deviation between actual vs. indicated boiler exit values (also stratification from side-to-side)	2	0 - .5%	>.5% - <1%	>1%
6	Clean Airflow Imbalance (Average)	1	±2%	±5%	>5%
7	Dirty Airflow Imbalance (Average)	1	±5%	±8%	>8%
8	Fuel Flow Imbalance (Average)	1	±10%	<15%	>15%
9	Coal Fineness, % through 200m; Use Weighted Average values; For flexible operations, “capacity vs. fineness” must be evaluated to address ramp rate demand vs. storage capacity; depending on fuel type this standard may need to be adjusted based on capacity and performance variables.	2	≥75% thru 200m	>70% thru 200m	<70% thru 200m
10	Mechanical mill blueprint established for achieving optimal mill performance across the load range?	2	Yes	Partial	No
11	Fuel loading curves established for the mills. Operators clearly understand optimal mill configurations; account primary airflow, minimum coal feeder % and A/F ratio management	1	Yes	Partial	No

Combustion and Boiler Performance Assessment

		WT	3	2	1
12	Coal Fineness Average, % through 50m Use Weighted average values (all mills)	2	+99.5% thru 50m	>99% thru 50m	<99% thru 50m
13	Primary Air-Fuel Ratio: Optimized for mill type, piping size, etc.	2	Optimized	Needs Improvement	Non-Optimal; Low Velocities and/or Burner Fires
14	Combustion air to the burners measured, managed and validated to ensure optimal distribution and windbox pressures across the load range.		Validated flow measurement and across the load range	Need improvement	Non- Optimal
15	Mill outlet temperature control is contingent on having enough hot air supplied by the air heater	2	No issues meeting mill outlet Temperature Demands	Needs improvement	Cannot meet mill outlet temperature demands
16	Mechanical Burner Condition (including all combustion airflow damper and/or tilt controls.	2	No blanked burners; +/- ¼ - 1/2” tolerances at burner front	No blanked burners; +/- 1” tolerances at burner front	Blanked burners and/or tolerances greater than 1”
17	Burner ignition optimized for optimal start-ups; Alternative fuels/ igniters may need to be considered	2	No Issues Fast response and no malfunctions	Needs improvement	Frequent malfunctions
18	Flame Stability under Flexible Operations; Integration of upgraded scanners and/or advanced sensors may be required for decreasing flame intensity	2	Good	Needs Improvement	Poor

Combustion and Boiler Performance Assessment

		WT	3	2	1
19	Heat Input Management: Achieving stability typically requires reproducibility of heat input and demands coal quality management in the coal yard w/ blending and proper coal quality management required for flame stability when operating at low loads	2	Good	Needs Improvement	Poor
20	Furnace Exit Gas Temperature (FEGT) & O_2, CO	2	Match design value with uniform temperatures within 25°F ideally less than 2,150°F	No point less than 2% oxygen; Temp. balanced within 50-75°F proximity of design FEGT	Any point <2% oxygen; Temp. stratifications +75-100°F of design FEGT
21	Steam Temperatures Optimized	2	No issues maintaining steam temperatures across the load range	Needs Improvement	Poor control of steam temperature
22	Average SH Spray Flow Rates	2	Achieve Design Basis (or <3 % of FW flow rate on average)	>3%	>4%
23	Average RH Spray Flow Rates (% of FW flow)	2	0	>1%	>2%
24	APH Efficiency	2	≥65%	≥60%	<60%
25	APH X Ratio (This is ratio of heat capacity of air passing thru the APH to heat capacity of flue gas passing through it; Lower than design X-ratio leads to a higher than design gas outlet temperature and is an indicator of excessive tempering air to the mills and/or boiler setting air infiltration.	2	>0.9	<0.8	<0.7

Combustion and Boiler Performance Assessment

		WT	3	2	1
26	Average APH Leakage; Too much leakage can cool the cold end below the dewpoint and induce corrosion and/or plugging issues	2	<10%	<15%	>15%
27	Air Heater Cold End Temperature Control (ACET)l is contingent on adequate hot gas to combat dew point plugging and/or corrosion.	2	ACET is always under control and managed properly with steam coil or economizer bypass system	ACET needs improvement	ACET is not controlled
28	Average Air and Gas APH Outlet Temperatures (Corrected)	2	<15 Deg. F (-9.4C) from design	>15 Deg. F (-9.4C) from design	>25 Deg. F (-3.9C) from design
29	Soot blower Availability-IK (long retracts)	1	>85%	>80%	<80%
30	Soot blower Availability-IR (wall blowers)	1	>85%	>80%	<80%
31	Average Boiler Efficiency (depends on fuel)	1	Meets Boiler Design	1-1.5% below design	>2% below design
32	Losses due to Unburned Carbon in Ash	2	<3% bituminous coal (low - medium ash) <0.7% high volatile sub-bituminous coal	<5% bituminous coal (low - medium ash) <1.2% high volatile sub-bituminous coal	>5% bituminous coal (low - medium ash) >1.2 % high volatile sub-bituminous coal
33	Boiler Exit/SCR NO_X	1	Meeting Design SCR Inlet Temp. and NO_X removal target	Below SCR Inlet temperature and/or NOx removal target required for compliance	Below SCR Inlet temperature with Compounding issues (e.g., NH_3 slip, ABS plugging, etc.)
34	Boiler Exit CO (PPM)	2	<100PPM	<250PPM	>250PPM
35	Average Fly ash Particle Sizing through 200 mesh	1	>90%	<90%	<85%

IK = Insertable Kinetic IR = Insertable Rotating

Combustion and Boiler Performance Assessment

		WT	3	2	1
36	Coal treatment System	1	Optimized for fuel	Periodically Tuned	Not Optimized
37	FD Fan Dampers, % at Full Load (summer months with highest ambient temperature)	1	<75%	>75%	>85%
38	ID Fan Dampers, % at Full Load (summer months with highest ambient temperature)	1	<75%	>75%	>85%
39	Total System Air In-leakage (Furnace to ID discharge)	2	<12%	<15%	>15%
40	Top Size of Raw Coal (Gauging screen/crusher performance)	2	<1"	<2"	>2"
41	Site collects representative Coal Samples for Analysis (coal sampler and/or representative samples)	2	Yes (online sampler)	Daily Grab Sample	Not Daily
42	Ash Deposition and Corrosion Issues	*3*	No issues	Some issues but can be managed	Site specific issues exist that lead to reliability concerns

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High-Level Flexibility Assessment Template 6 Instrumentation, Controls and Automation

Instrumentation and controls have a crucial role with enabling flexible operations. Furthermore, the availability and optimization of operating performance regarding both flexibility and efficiency, is contingent upon quality data assessments and implementation of advanced process controls that cross over much of the generation sector.

This assessment (integrated with the other assessments) is intended to evaluate current status and/or needs for improvement of instrumentation, controls and automation. The outcome of this assessment will classify the Instrumentation, Controls and Automation as follows:

3	2	1
Advanced/Good Flexibility • Fully automated start-up and shutdown • Advanced controls • Advanced protection systems • Diagnostics • Energy management functions • Integrated condition monitoring • Artificial Intelligence • Digital Interconnection to Internet of Things (IoT) • Predictive maintenance	**Flexibility Needs Improvement** • Essentials to operate the plant under flexible conditions • Monitoring of critical components • Critical Protection Systems in place	**Poor Flexibility** • Antiquated controls need to be upgraded • Software and/or hardware issues exist • Control loops are not optimized

Instrumentation, Automation and Controls Assessment

		WT	3	2	1
1	**Controls system Capable of meet desired operating modes and load control?** Controlling unit load to an electrical power output (MW) setpoint during load changes is influenced by fuel control, transport and things such as grinding, combustion, flame stability, heat absorption and boiler metal temperatures on a PC fired unit	2	Yes	Partial	No
2	**Pneumatic or antiquated control hardware installed?**	2	No	Partial	Yes
3	**Microprocessor-based distributed control system on the boilers master, fuel, air and feedwater loops**	2	Yes	Partial	No
4	**Optimal Steam Temperature Control:** To prevent damage to boiler and turbine components and maintain turbine plant efficiency, steam temperature controls must operate effectively under steady-state and dynamic process conditions. At low loads, steam temperature control can become challenging with variation of heat in the boiler. Thus, to maintain temperature control and turbine efficiency, steam temperature controls must operate effectively under both steady state and dynamic process conditions. This may require improvements that implement cascade controls with model-based SH and RH temperature control, Linearization through adaption of control parameters and/or feedforward model designs to improve disturbance rejection (e.g., soot-blowing) and changes in firing combinations.	2	Yes	Partial	No
5	**Spray water control optimized for flexible operations** (including start-up, minimum load and/or ramp rates)	2	Yes	Partial	No
6	**Feedwater control optimized for flexible operations** (including start-up, minimum load and/or ramp rates)	2	Yes	Partial	No
7	**Enthalpy control optimized for flexible operations** (including start-up, minimum load and/or ramp rates)	2	Yes	Partial	No

Instrumentation, Automation and Controls Assessment

		WT	3	2	1
8	**Drum level control optimized for flexible operations** (including start-up, minimum load and/or ramp rates) **At low loads, drum level control in subcritical recirculation boilers can deteriorate due to various reasons, including:** - Changeover of steam supply to the turbine driven feedwater pump - Changes in water circulation (nature circulation boilers) due to fluctuation in furnace wall heat absorption that result from variations in gas flows in the furnace and mill combinations and loads. - Change in process response at low steam flows and with changes in steam pressure (e.g., sliding pressure operation) - Change in feedwater temperature - Reduced accuracy of differential pressure sensors that measure feedwater flow and steam flow that result from square root nonlinearities at low flows. - Relatively large fuel flow changes when starting and stopping mills at lower loads because of smaller number of mills in service.	2	Yes	Partial	No
9	**Primary air pressure Control optimal for the load range** - Hot primary air (PA) duct pressure influences in-service mill airflow controls and the position of the hot air control dampers. Mill airflow controls can affect boiler airflow and unit load control. Setpoint modifications can be beneficial when ramping performance around minimum (or reduced minimum) load.	2	Yes	Partial	No
10	**Air- Fuel (and furnace pressure) control must be optimal for the load range** - Burner flame stability at low loads demands proper mill configuration to avoid too high or low of feed rates that can result in a negative impact. Furthermore, fuel surging can also have a negative impact on boiler pressure control. Developing a process control strategy around taking mills in/out of service through operator management or automation is necessary.		Yes	Partial	No

Instrumentation, Automation and Controls Assessment

		WT	3	2	1
11	**O_2, air controls optimized for flexible operations** (including start-up, minimum load and/or ramp rates)	2	Yes	Partial	No
12	**Circulation control optimized for flexible operations** (including start-up, minimum load and/or ramp rates)	2	Yes	Partial	No
13	**Start-up automation:** Firing Rate; HP Bypass; Start-up fuel control; flow control valves	2	Yes	Partial	No
14	**Advanced unit controls evaluated** (e.g., feed-forward model-based approaches proven to improve dynamic behavior; simulation utilization for minimization of online optimization time and requirements)	2	Yes	Partial	No
15	**Review of unit instrumentation and critical KPIs across Operating Range:** conducted to ensure that coverage of operating ranges is adequate to remain reliable and accurate throughout the new operating range.	2	Yes	Partial	No
16	**Control system tuning:** Determine the expected operating modes and ranges. Tune them for stable, reliable operation across the ranges. For increased I&E calibrations, additional PMs should be expected. Consider additional instrumentation and duel ranges.	2	Yes	Partial	No
17	**Modulating control loop tuning for the load range** - Control systems for utility generating units typically contain 50-100 modulating control loops, each with tunable feedback-controller parameters and in some cases, tunable feedforward and gain-scheduling functions. Tunable parameters are typically optimized for mid-high loads consistent with the design range for normal unit operation and in many cases tuning settings may not be complete for low loads or appropriate across the load range.	2	Yes	Partial	No
18	**Start-up Automation:** Sliding pressure offers advantages over throttle control (constant pressure) during startup by establishing a flow to the turbine earlier. It also retains higher temperatures on shutdown; Automate as much as possible, develop startup procedures, track times taken for each step during each startup, and update procedures with best practices.	2	Yes	Partial	No
19	**Accurate temperature protection systems for thick-walled components are key for start-up and shut down**	2	Yes	Partial	No

Instrumentation, Automation and Controls Assessment

		WT	3	2	1
20	**Valve automation:** Determine if operating modes and startup times support the economics of installing large valve motor operators. May need to consider changing the type of valve and/or actuator/operator to better handle changes in revised operational requirements.	2	No Issues	Some Issues	Issues
21	**Staffing versus automation:** To ensure timely and efficient operations, additional staff may be needed to cut in, align, and isolate systems. An alternative would be to automate some equipment, such as valves, dampers, and drain lines.	2	No Issues	Some Issues	Issues
22	**Sliding Pressure**: Consider modifying the control system and operating procedures to allow the units to be normally operated as sliding-pressure units. Pure sliding-pressure or hybrid sliding-pressure/constant-pressure operating schemes can be considered. Although there are many benefits to variable-pressure operation, it will likely slow the unit loading rates. Sliding pressure operation has benefits that can include heat rate improvement, reduction of thermal stress on turbines components due to rate of change of inlet steam temperature caused by throttling, and/or reduction of solid particle erosion of the control valves by minimizing velocities from throttling. Process control, design considerations must consider plant specific challenges, including variables such as steam attemperator capacity and saturation limits to accommodate under/over firing required to change pressure during load changes; load ramp rates limited by the additional over/under-firing required to change pressure during load changes; Water saturation temperature at the economizer outlet at lower feedwater pressures (such as economizer steaming).	2	Addressed Or Implemented	Some Issues Exist	Issues Exist

Instrumentation, Automation and Controls Assessment

		WT	3	2	1
23	**Alarm Rates**	2	Average and the peak alarm rates are under control for foreseeable plant operating scenarios; Dynamic and state-based techniques are used to improve the real time performance.	Occasional alarm flooding	Alarm flooding is common
24	**Graphics**	2	Effective graphics typically have gray backgrounds to minimize glare; No animation; Black process lines, with major lines shown slightly thicker; Limited use of color Embedded trends of important process parameters; A layout wherein the process flow is from left to right whenever possible. A layout that is generally consistent with the operator's mental model of the process; Logical and consistent navigation methods; Display access with a maximum of three mouse clicks or keystrokes; Techniques used to minimize the possibility of operator mistakes and provide validation and security measures; Proper layout to avoid unnecessarily crossing lines; Measurement units shown in low contrast lettering, if used at all. (the operators know the units of measurement.)	Needs Improvement Graphics are somewhere in between the Green and Red "effective vs. ineffective" attributes	Attributes of Ineffective graphics Bright; flashing graphics. Brightly colors; 3D animations with spinning components; color coding; bright text; No trends; An exact representation of the P&ID with minor connections and manual valves; Lines that cross Inconsistent process flow direction; Alarm colors used for non-alarm-related functionality; Haphazard, inconsistent navigation from screen to screen; Inconsistent color coding of various elements and overuse of color.
25	**Design Philosophy**	2	Established at the Fleet Level	Established at plant Level (not consistent with fleet)	Not Established; No Design Philosophy

Instrumentation, Automation and Controls Assessment: Common Challenges with Process Controls

		WT	3	2	1
26	**SCR Inlet Gas Temperature:** - SCRs are commonly required to maintain flue gas NO_X emissions. The SCR is usually located in the flue gas path between the economizer outlet and the air-heater gas inlet because of the requirement for high flue gas inlet temperatures (typically greater than 550℉ - 600℉ (288℃ - 316℃) to ensure the catalysts can properly function for its design life. Considering this, sometimes by flue gas bypass systems (or other options) are installed for controlling temperature by adjusting variables as inlet temperatures or surface area adjustments. Any change in flue gas temperature control must first consider the feedwater temperature in the economizer and risk of steaming damage due to overheating.	2	No Issues	Some Issues	Issues
27	**Automation** - Implemented sequences are needed to operate the controlled plant and auxiliaries from the defined start point until the defined end point without requiring operations or engineering intervention to overcome software application errors; Sequences must not leave the plant in an unsafe condition; Plant interlocks and protections are independent of the sequences and implemented outside of sequences; The sequence design must account for field actuation and measurement; Sequences must be synchronized with plant status by bypassing any steps already completed. - Automation can help support economic dispatch, fuel cost minimization, wider ranges of operation, minimization of damage and maintenance costs resulting from flexible operations as well as knowledge capture with an aging workforce. - Automation is often required to help minimize time to start-up and shut down	2	No Issues	Some Issues	Issues
28	**Alarms** - At low loads, the plant is operating closer to its design limits with less tolerance to abnormal process conditions and contingency events such as auxiliary plant faults and trips. Thus, to ensure operator is able to act in a timely manner, alarms must be appropriate and complete for low load and/or reduced load operations. Alarm priorities must appropriately reflect the risk of the plant or process for operator response. The existing and peak alarm frequencies must be appropriate for low-load operation.	2	No Issues	Some Issues	Issues

Instrumentation, Automation and Controls Assessment: Key Control Loop Parameters

Tuning (PID) Values, Functions, Feedforwards/Kickers, Interactions, Controller Types, Etc.

KEY CONTROL LOOPS PARAMETERS: *Tuning (PID) Values, Functions, Feedforwards/Kickers, Interactions, Controller types, etc.*		WT	3	2	1
29	**Unit Demand Management** - System Load Demand - Unit Runback and Rundown; High and Low Load Limit - Ramp Rate	2	No Issues	Some Issues	Issues
30	**Furnace Draft Control** - ID Fans and Dampers; Booster Fans and Dampers - Flue Gas Recirculation Fans/Dampers	2	No Issues	Some Issues	Issues
31	**Steam Temperature Control** - SH Attemperator Valves, RH Attemperator Valves - Burner Tilts (if T-fired); Back-pass Dampers	2	No Issues	Some Issues	Issues
32	**Firing Rate Control** - Feeders - Mills - Igniters - FD Fans and Dampers	2	No Issues	Some Issues	Issues
33	**Feedwater Control** - Feed water Pumps - Recirculation Valve - Drum Level - Deaerator Level	2	No Issues	Some Issues	Issues
34	**Steam Turbine Management** - Main steam throttle valves - Intercept valves - Turbine supervisory system	2	No Issues	Some Issues	Issues

Instrumentation, Automation and Controls Assessment
Prior to conducting a Ramp Rate Assessment

		WT	3	2	1
35	**System dispatch trends understood**	2	No Issues	Some Issues	Issues
36	**Magnitude of load changes during the day understood**	2	No Issues	Some Issues	Issues
36	**Future ramping expectations are known**	2	No Issues	Some Issues	Issues
38	**Operating procedure restrictions on ramp rate are understood** - **Temperature limits and alarms** - **Vibration limits and alarms**	2	No Issues	Some Issues	Issues
39	**Operating stability during Ramping to be evaluated:** - Steam flow and temperatures - Flue gas flow and temperatures - Combustion	2	No Issues	Some Issues	Issues
40	**All steps required to start equipment during ramping** - Mills - Burners and igniters - Boiler feedwater pumps - SCR ammonia injection or flue gas sorbent injection	2	No Issues	Some Issues	Issues
41	**Equipment-imposed limits on ramp rate (may be design or condition related)** - Valve operators - Damper operators	2	No Issues	Some Issues	Issues
42	**Equipment condition that may limit ramp rate (review with maintenance)** - Mills - Burners and igniters - Boiler feedwater pumps - Boiler tube conditions - Steam turbine condition	2	No Issues	Some Issues	Issues

Instrumentation, Automation and Controls Assessment
Prior to conducting a Ramp Rate Assessment

		WT	3	2	1
43	**Review Vendor (OEM) recommended load change limits and technical basis with Engineering Team:**	2	No Issues	Some Issues	Issues
44	**Boiler**	2	No Issues	Some Issues	Issues
45	**Steam Turbine**	2	No Issues	Some Issues	Issues
46	**Environmental Controls Equipment** - SCR - ESP - FGD - Other	2	No Issues	Some Issues	Issues
47	**Review logic limits on ramp rate** - Operating curve values - Feedback limits	2	No Issues	Some Issues	Issues

Instrumentation, Automation and Controls Assessment

Ramp Rate Methodology and Minimum Load Reduction

		WT	3	2	1
48	**Ramp Rate Goals:** Current ramp rate goals have been defined and are achievable; Future ramp rate goals have been modeled and forecasted	2	Addressed All Good	Partially Defined	Not Defined
49	**Key parameters are understood:** Use of control system data historian capabilities to facilitate a review of control logic for specific parameters; Control curves evaluated at load range extremes to understand ramp rate impacts; Understand bases of specific alarm limits on unit operation	2	Understood Well	Partially Understood	Not Understood
50	**Potential areas for ramp rate improvement have been identified**; Consider all potential sources of unit ramp rate limits; Identify specific control loop responsible for limiting behavior in operating parameters; Use operating personnel input to understand challenges and previous experience	2	Addressed Potential Areas for Improvement	Partially Addressed	Not Addressed
51	**Ramp Rate diagnosis conducted**; Review potential operational challenges within control room operator prior to test and solicit operator input; Verify operator response to any limit encountered prior to implementing change; Document control actions, both automatic and manual, and cause/effect of each action implemented during unit load ramp; Discuss operator reaction to unit operation during load ramp once steady state has been achieved; Document conclusions from each unit load ramp observed immediately following ramp run.	2	Completed	Partially Completed	Not Completed

Instrumentation, Automation and Controls Assessment
Ramp Rate Methodology and Minimum Load Reduction

		WT	3	2	1
52	**Implementation planning conducted**; Implement one change at a time to avoid unintended consequences and have attributable outcome; Make use of control system simulations to demonstrate control logic changes before live demonstration; Follow good engineering practices for documentation and validation of each planned outage.	2	Completed	Partially Completed	Not Completed
53	**Implement Improvements**; Use existing work control processes to ensure that changes are safely implemented; Implement changes individually on each unit to account for differences; Observe a unit load ramp to verify implemented change advanced unit ramp rate as expected	2	Completed	Partially Completed	Not Completed
54	**Evaluate Improvements**; Use overall goals to determine benefits of pursuing additional changes - Share conclusions with unit operations and maintenance personnel and solicit comments	2	Completed	Partially Completed	Not Completed

Instrumentation, Automation and Controls Assessment
Instrumentation Review

		WT	3	2	1
55	**Instrument Condition (Availability, Accuracy and Calibration)** - Flue Gas Thermocouples - Flame Scanners - Boiler O_2 monitors - Feeder Speed Indication - Feedwater Flow Measurement - Feed Water Valve Position Operators/Indicators - Steam Valve Position Operators/Indicators - Fan Damper Position Operators/Indicators	2	No Issues	Some Issues	Issues
56	**Instrument Loop Response (Time from signal to feedback)** - Steam Valve Position - Fan Damper Position - Feed Water Valve Position	2	No Issues	Some Issues	Issues
57	**Maintenance I&C Backlog** - Trend - System/Instrument Priority	2	No Issues	Some Issues	Issues
58	**Abandoned Instrumentation (Location, Duration OOS, and Reason)** - Recent (2 Years) Decisions - Long-Term Decisions	2	No Issues	Some Issues	Issues

Instrumentation, Automation and Controls System Overview

Air-Gas Systems

		WT	3	2	1
59	APH ΔP Management to avoid gas mal-distribution and/or plugging	2	Low DP (or design)	Moderate DP	High DP
60	APH Cleaning System	2	Good Performance	Needs Improvement	Unacceptable
61	APH, Cold-End Temperature Control, °F	2	Above Dewpoint	Near Dewpoint	Below Dewpoint
62	Impact on Furnace Exit Gas Temperature (FEGT)	2	Managed for Overheat Mitigation	Unrepresentative Some control	Not Managed Uncontrolled
63	Minimum Airflow	2	Representative and accurate Measurement	Some control	Not Managed Uncontrolled
64	Boiler O_2 Controlled Minimum to Maximum O_2 set points	2	Controlled to Curve	Needs Improvement	Uncontrolled
65	Burner Air Register & Sleeve controls	2	Good Condition Good Control	Needs Improvement	Poor Condition Poor Control
66	Combustion Air – Fan Performance (PA, FD)	2	Dampers controllable; Acceptable capacity across load range	Needs improvement	Poor control; insufficient capacity control
67	Mill Minimum temperature control	2	Good control	Periodic issues (e.g., wet coal)	Poor control
68	SCR temperature measurement (via representative grid)	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
69	SCR minimum inlet gas temperature	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
70	Exit Gas Temperature	2	Good control (no issues)	Periodic issues (e.g., seasonal)	Poor control
71	Water Wall Temps – FW Control	2	Good Control	Needs Improvement	Poor control

Instrumentation, Automation and Controls System Overview

Fuel Systems Assessment

		WT	3	2	1
72	Hot air temperature control to mills, °F	2	Adequate	Needs Improvement	Poor
73	Flame Quality Scanner Performance	2	Acceptable	Needs Improvement	Unacceptable
74	Coal Quality Impacts	2	Managed; No issues	Needs Improvement	Unacceptable
75	Fuel and Ash Management	2	Managed; No issues	Needs Improvement	Non-Optimal
76	Mill Capacity	2	Acceptable	Needs Improvement	Unacceptable
77	No. of Mills in-service at varying loads	2	Acceptable	Needs Improvement	Unacceptable
78	Mill Performance; Air/Fuel Distribution	2	Acceptable	Needs Improvement	Unacceptable
79	Optimal Igniter Performance (Fuel Oil, Gas)	2	Acceptable	Needs Improvement	Unacceptable
80	Flame Scanners	2	Acceptable	Needs Improvement	Unacceptable
81	Burner components, mechanical condition and control (including tilts on a T-fired unit)	2	Acceptable	Needs Improvement	Unacceptable
82	Air Registers	2	Acceptable	Needs Improvement	Unacceptable
83	Mill and Fire Suppression System	2	Acceptable or Not an issue (or N/A)	Needs Improvement	Unacceptable
84	Coal Treatment Systems	2	Not Required Or No Issues	Undetermined	Non-Optimal Issues

Instrumentation, Automation and Controls System Overview

Water Systems

Water Systems Assessment		WT	3	2	1
85	DCS Controls at minimum loads	2	Good Control	Needs Improvement	Poor Control
86	Minimum & Maximum Drum Level	2	Good Control	Needs Improvement	Poor Control
87	Minimum & Maximum Deaerator Level	2	Good Control	Needs Improvement	Poor Control
88	BFP Controls (on/off operations)	2	Good Control	Needs Improvement	Poor Control
89	FW Heater Level Controls	2	Good Control	Needs Improvement	Poor Control
90	Ensure Condenser Vacuum and Air In-Leakage monitoring systems are in good working order	2	Minimum	Needs Improvement	High
91	Absolute Back Pressure	2	Good	Needs Improvement	Poor
92	Water chemistry controls and monitoring systems: Condensate, Deaerator Inlet and Feedwater/Polisher outlet are working properly	2	Good Control	Needs Improvement	Poor Control
93	Water chemistry controls and monitoring systems working properly for Boiler Drum, Water and Steam are working properly.	2	Good Control	Needs Improvement	Poor Control
94	FWH performance and final FW inlet temperature monitoring for FAC control	2	Good	Needs Improvement	Poor
95	Other: Valves, Start-up Systems, Recirculation valve and controls, Acoustic leak detection systems	2	Good; No issues	Needs Improvement	Poor
96	Filming Products Optimized (if in use)	2	Yes	Need Improvement Or Undetermined	No

Instrumentation, Automation and Controls System Overview
Steam Control Assessment

		WT	3	2	1
97	Main Steam Temperature, Minimum & Maximum (with/without sliding press.)	2	Good control	Needs Improvement	Poor Control
98	RH Steam Temperature Maximum, Minimum	2	Good control	Needs Improvement	Poor Control
99	SH/RH, Temperature Differential	2	Good control	Needs Improvement	Poor Control
100	Boiler Pressure Control, Minimum & Maximum	2	Good control	Needs Improvement	Poor Control
101	Maximum SH/RH de-superheating spray flow rates	2	Good control	Needs Improvement	Poor Control
102	Boiler Expansion (joints, pipe hangers, etc.)	2	Good control	Needs Improvement	Poor Control
103	Boiler Tube and Header Metal Temperatures	2	Good control	Needs Improvement	Poor Control
104	Reduced Minimum Load Steam Temperature Control	2	Good control	Needs Improvement	Poor Control
105	Start-up system valves and controls	2	Good control	Needs Improvement	Poor Control
106	Main Steam and Reheat Attemperators	2	Good control	Needs Improvement	Poor Control
107	Steam Temperature Controls Tuning	2	Good control	Needs Improvement	Poor Control
108	Boiler Metal Temperatures (SH, RH)	2	Good control	Needs Improvement	Poor Control
109	Inspect Boiler Expansion, Movements: boiler, ducts, piping – all hangars and interferences (if any)	2	Good control	Needs Improvement	Poor Control
110	Power Piping Inspection	2	Good control	Needs Improvement	Poor Control

Instrumentation, Automation and Controls System Overview

Turbine/Generator

		WT	3	2	1
111	Turbine steam Philosophy – first stage admission	2	Good control	Needs Improvement	Poor Control
112	Turbine Controls – Stop Valves	2	Good control	Needs Improvement	Poor Control
113	Turbine Controls – Control valves & governor valves	2	Good control	Needs Improvement	Poor Control
114	Turbine/Generator supervisory instrumentation (Vibration, Differential, Expansion, Metal Temps, Casing Expansion)	2	Good control	Needs Improvement	Poor Control
115	Turbine/Generator Bearing Oil System Controls	2	Good control	Needs Improvement	Poor Control
116	HP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
117	HP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
118	HP Stator Slot Temperatures – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
119	HP & LP Hydrogen Gas Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
120	LP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
121	LP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
122	LP Stator Slot Temperatures – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
123	Generator Protective Systems (Power Factor)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
124	Generator Hydrogen	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
125	Generator Cooling Systems (Stator cooling)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
126	Generator Automatic Voltage Regulator Tuning	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist

Instrumentation, Automation and Controls System Overview

Steam Turbine

		WT	3	2	1
127	Turbine steam Philosophy – first stage admission	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
128	Turbine Controls – Stop Valves	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
129	Turbine Controls – Control valves & governor valves	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
130	Turbine/Generator supervisory instrumentation (Vibration, Differential, Expansion, Metal Temps, Casing Expansion)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
131	Turbine/Generator Bearing Oil System Controls	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
132	HP & IP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
133	HP & IP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
134	HP & IP Thrust Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
135	HP & IP Thrust Bearing Position (Wear)	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
136	HP& IP Differential Expansion - Rotor Long	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
137	HP & IP Differential Expansion – Rotor Short	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
138	LP Bearing Vibration – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist
139	LP Bearing Temperature – Maximum	2	Sensors operable; No issues	Needs Improvement	No sensor or Issues exist

Instrumentation, Automation and Controls Assessment

Auxiliary, Environmental, Boiler

		WT	3	2	1
140	Crossover or Bypass Dampers controls	2	No issues	Needs Improvement	Issues exist
141	Stack Plume at Low Load	2	No issues	Needs Improvement	Issues exist
142	Precipitators	2	No issues	Needs Improvement	Issues exist
143	Baghouse – Bag Condition	2	No issues	Needs Improvement	Issues exist
144	Ensure Operating Permit Allows Low Load Operation	2	No issues	Needs Improvement	Issues exist

	Boiler Performance	WT	3	2	1
145	Boiler Cleaning System (soot blowers, on/offline cleaning process)	2	Good performance	Needs Improvement	Poor Performance
146	Burner Optimization Controls (air-fuel distribution, tilts on T-fired units; air-fuel mgmt.)	2	Good performance	Needs Improvement	Poor Performance
147	Boiler Stoichiometry control; Air In-Leakage Management	2	Good performance	Needs Improvement	Poor Performance
148	Boiler controls form mitigating thermal transients	2	Good performance	Needs Improvement	Poor Performance
149	Soot Blower Thermal Drains; SB header temp./pressure monitoring	2	Good performance	Needs Improvement	Poor Performance
150	Steam Coils (for cold-end temperature control)	2	Good performance	Needs Improvement	Poor Performance
151	Dew point & corrosion control	2	Good performance	Needs Improvement	Poor Performance
152	O_2 & CO monitoring	2	Good performance	Needs Improvement	Poor Performance
153	Flame Stability and Mill Configuration Planning	2	Good Performance	Needs Improvement	Poor Performance

Instrumentation, Automation and Controls Assessment

Emissions Control

		WT	3	2	1
154	NO_X Limits	2	No issues	Needs Improvement	Issues
155	SO_2 - SO_3 Limits	2	No issues	Needs Improvement	Issues
156	NH_3 Slip Limits	2	No issues	Needs Improvement	Issues
157	Opacity Limits	2	No issues	Needs Improvement	Issues
158	Minimum Temps at SCR inlet Limits	2	No issues	Needs Improvement	Issues
159	ID Fan Capacity (May impact availability of Boiler O_2)	2	No issues	Needs Improvement	Issues
160	Controls Optimization (capability to safely and efficiently meet the missions required)	2	No issues	Needs Improvement	Issues

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High-Level Flexibility Assessment Template 7 Environmental Controls

Environmental Controls Assessment

		WT	3	2	1
1	Assess the impact of flexible operations on permit limits?	2	No issues	Some (periodic) issues with achieving environmental limits	Issues Exist with environmental limits
2	Heat rate vs. load impacts on air emissions is understood	2	Yes	Partial	No
3	If installed, have SCR strategies for low load operation been assessed?	2	Yes strategies have been Implemented	Some (periodic) Issues exist	Issues Exist (NH_3 slip, Fouling, corrosion or Ammonia Bisulfate (ABS) formation)
4	Evaluate SO_2 - SO_3 controls if/when firing high sulfur fuels	2	No issues SO_3 is controlled	Some (periodic) Issues exist	Issues Exist
5	Assess need for Sorbent injection at lower loads; SCR minimum operating temperature and/or ammonia bi-sulfate formation	2	No issues	Some issues with ABS at low loads have occurred in the past but is not a common or current issue.	Condensation of Ammonium Bisulfate (ABS) on catalyst pores at low loads can occur at minimum loads.

Environmental Controls Assessment

		WT	3	2	1
6	Flue Gas De-Sulfurization Chemistry Control under flexible operations.	2	No issues FGD Chemistry is under control with cyclic operations	Some issues have existed with FGD chemistry in the past, but this is not a current issue of concern.	Issues Exist Low Load: Oxidation Reduction Potential (ORP) – Mercury re-emissions; Oxidation air turn-down, corrosion, Water balance, Gypsum quality, selenate formation, etc. Load Following: Limited R&D On/off load cycling, extended layup: Foaming, pH control, mercury emission, WWT issues, Solids dewatering.
7	FGD Water Balance vs. Load Control:	2	No issues; FGD efficiency and water balance management is acceptable (e.g., proper mass transfer, proper absorbent flow (liquid-gas ratio); pump operation scheme		Issues with FGD Water Balance exist.
8	Flue Gas Desulfurization Unit Layup	2	Site specific plan developed for all wet FGD equipped units that operating with extended shutdown periods; includes strategy and technical details for treating and/or draining systems	Some planning exists. But, not a written, consistent and/or enforced guidance.	No plan for extended shut-down periods.

Environmental Controls Assessment

		WT	3	2	1
9	Dew Point Controls Strategy Developed for mitigating corrosion	2	No issues; Strategy developed with fuel, alkali sorbent injection upstream of air heater and/or using cold-end temperature controls/operating strategy (e.g., bypass, cold end temp systems, and/or corrosion resistant materials)	Some Issues exist	Issues Exist
10	SO_3 control with higher sulfur fuels	2	No SO_3 issues	Some issues	Poor control of SO_3
11	Identify issues with ESP and/or Bag House performance at low loads	2	No issues	Some Issues	Issues Exist Particulate compliance is challenged <u>Low Load</u>: Impacts of flow distribution; Low gas temperature effects on corrosion, transition from low to high temp and Hg desorption <u>Load Following</u>: Ash re-entrainment from hoppers; Baghouse performance <u>On/off load cycling</u>: ESP Startup issues with oil; Layup Issues <u>Fuel Quality</u>: Numerous issues exist

Environmental Controls Assessment

		WT	3	2	1
12	Fuel Oil Carry-Over Impact on ESP Performance	2	No issues with fuel oil carryover	Some issues in the past; Not common	Issues with dirty start-ups and oil carry-over impact ESP performance
13	Fuel Quality Impacts on baghouse filters	2	No issues	Some degradation to Filter Bags due to corrosion	Reduced bag house filter bag life due to SO_3 condensation
14	System Air In-Leakage from increased cycling (all loads)	2	Minimal Air In-Leakage, validated by system leakage testing	Some issues. But, minimal impact with the current air in-leakage levels.	Negatively impacts heat rate, comb. controls, ESP, SCR and FGD operation; SO_3 formation, dew point, etc.
15	Cycling impacts on fan	2	No issues	Some Issues	Fan reliability is an issue to cycling and/or condensation issues.
16	CO Control	2	No issues	Periodic issues with CO	Issues with managing and controlling CO
17	Fly ash build-up and cleanout	2	No issues	Some/Periodic Issues	Low velocities and fly ash drop out is a common issue that needs to be addressed.

Environmental Controls Assessment

		WT	3	2	1
18	Ash Quality	2	No issues. All ash is marketable	Some ash is marketable, but it is not consistent	Ash is not marketable and/or landfill ash is excessive due to fuel quality
19	Cycling	2	No issues	Sometimes ash re-entrainment at the ESP hoppers is an issue	Ash re-entrainment from ESP hoppers during load swings is an issue
20	May need increased CEMs calibrations and testing at multiple loads. Expect additional PMs.	2	Understood; No issues	Partially Understood	Issues exist that need to be addressed
21	NO_x Maximum Limit	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist
22	SO_2 Max Limit	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist
23	NO_x Limits (hourly, daily, monthly)	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist
24	SCR Ammonia Slip	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist
25	Opacity – Maximum %	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist
26	Particulates Rate	2	No issues; Plenty of Margin	Sometimes an Issue	Issues Exist

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High-Level Flexibility Assessment Template 8 Cycle Chemistry

Cycle Chemistry Program Assessment

		WT	3	2	1
1	Chemically influenced BTF - % of total BTF that is cycle chemistry influenced	2	<5%	>5%	>10%
2	Internal boiler tube corrosion program is managed Station periodically reviews water chemistry procedures and program with plant staff	2	Yes		No
3	Chemically influenced turbine problems	2	No LP blade /disk cracking or pitting		LP blade/disk cracking or pitting Or unknown
4	Chemically influenced turbine problems	2	No Deposition Issues		Excessive deposits (Cu on HP, other on IP/LP) Or unknown
5	Cycle chemistry instrumentation and control % of EPRI core parameters	2	90-100%	>75% - 90%	<75%
6	Are key cycle chemistry control parameters alarmed in the control room	2	Yes	Yes, Some	No
7	Boiler acid cleaning program is managed: Physically inspect the deposition rate increase due to cycling. Adjusts the boiler acid cleaning frequency accordingly.	2	Yes		No
8	Chemistry Deposit Weight Density (conventional units) For more detailed information on chemical cleaning see *Chemical Cleaning Guidelines for Fossil-Fuel-Fired Power Plants.* EPRI, Palo Alto, CA: 2015. 3002000996	2	<10g/ft^2 or <10.8mg/cm^2	>20g/ft^2 or >21.5mg/cm^2	>30g/ft^2 or >32.3mg/cm^2
9	Frequency of chemical cleaning of boilers Station needs to understand DWD limits without cleaning (*once-thru units based on thickness*)	1	>10 years	5-10 years	<5 years (or unknown)

Cycle Chemistry Program Assessment

		WT	3	2	1
10	Management supported EPRI-based guidelines that include start-up, normal, and upset conditions	2	Yes. Aligns with EPRI guidelines for start-up and upset conditions	Guidelines align but do not included both start-up and upset conditions	Guideline misaligned or no guideline in place
11	Chemical dosing control: Under the new requirement of controlling boiler and feedwater chemistry in a regime of frequent startup and shutdown, the performance of the chemical dosing equipment becomes critical	2	Automated Control and Optimized		Manual Control and/or Non-Optimal
12	What percentage do you meet internal targets for CC control?	1	>95%	>90%	<90% or not tracked
13	Drum Units: Feedwater treatment selection and implementation	2	Alignment with EPRI	Either Selection or implementation out of alignment	Both selection and implementation out of alignment
14	Drum Units: Boiler water treatment selection and implementation	2	Alignment with EPRI	Either selection or implementation out of alignment	Both selection and implementation out of alignment

Cycle Chemistry: FAC Program

		WT	3	2	1
15	Supercritical Units: Feedwater treatment selection and implementation	2	Alignment with EPRI	Either selection or implementation out of alignment	Both selection and implementation out of alignment
16	Number of repeat situations and actions	1	No repeat situations	>2 repeat situations	>4 repeat situations
17	Is there a plant specific FAC program that is followed	2	Yes		No
18	Do you have a corporate/plant FAC Mandate	3	Yes		No
19	Predictions Inspection of FAC Prone Areas: Percent of units (plant) which have conducted analysis and determined susceptible FAC locations.	3	100%	<75%	<50%
20	Cycle Chemistry Control of All-Ferrous Feedwater Systems: Percentage of units with all-ferrous FW systems that operate with either AVT(O) or OT	3	100%	<75%	<50%
21	Corrosion/FAC in Heater Shells: Percentage of carbon steel pressure vessels operating between 50℃ and 250℃ (heater shells in conventional units) that have been inspected.	2	100%	<75%	<50%
22	Feedwater Iron Concentration Monitored and controlled	2	<2 ppb	2– 5 ppb	>5ppb
23	Corrosion/FAC in feedwater pipes: Percent susceptible that have been inspected	2	100%	>75%	<50%
24	Corrosion/FAC in Heater Drain Lines: Percentage of units where the heater drain lines operating between 50℃ and 250℃ have been inspected using NDE	1	100%	<75%	<50%

Cycle Chemistry: Plant Layup Practices Assessment

		WT	3	2	1
25	Operation of FW Heater Emergency Drains (percentage time open) -- Fleet guidelines used to minimize use	1	<5%	5-10%	>10%
26	Corrosion FAC in Attemperator Lines: Percentage of units where the attemperator lines have been inspected using NDE	1	100%	<75%	<50%
27	How often is the FAC program guideline revised and updated?	2	< 2 Years	Every 2–5 years	>5 Years
28	Has the FAC program been updated for low load operation?	2	Yes		No
29	FAC program determines wear rate and NDE evaluation for minimum available thickness	3	100%	>75%	<50%
30	NDE Data is used to re-evaluate and change other susceptible locations needed for future inspection	2	100%	>75%	<50%
31	In the past year, has the unit come offline for more than two days during a forced outage?	1	No		Yes
32	In the past year, has the unit cooled down to ambient pressure/temperatures during a forced outage?	3	No		Yes
33	In the last two years, how many of the boiler or superheater/reheater tube failures were attributed to waterside corrosion (corrosion, fatigue, pitting or gouging)?	3	0		1 or more
34	Does the unit have copper alloy feedwater heaters or condenser	3	No		Yes
35	Does the unit have condensate polishers?	3	Yes		No

Cycle Chemistry: Wet Lay-Up Practice
(Water remains in unit while off-line)

		WT	3	2	1
36	Steam drum and primary superheater are capped with nitrogen as the pressure decays to ambient. No air can enter the boiler drum while the unit is off.	3	Yes		No
37	The reheater tubing is capped with nitrogen or steps are taken to remove any remaining moisture	2	Yes		No
38	The shell sides of feedwater heaters are blanketed with nitrogen as the pressure decays to ambient.	2	Yes		No
39	Deaerator is capped with nitrogen or maintained under positive pressure with steam	1	Yes		No
40	Vacuum is maintained on the condenser as long as possible and dehumidified air is circulated past the LP Turbine after vacuum is broken	2	Yes		No
41	Sample panel and on-line analyzers are properly laid-up and prepared for subsequent start	1	Yes		No
42	The pH of the boiler is elevated to protect the boiler prior to shutdown	3	Yes		No

Cycle Chemistry: Dry Lay-Up Practice
(Boiler, DA, hot well drained dry)

		WT	3	2	1
43	Boiler, feedwater heaters, and deaerator are all drained while the water is still hot	3	Yes		No
44	Dehumidified air or nitrogen is used to purge the tubing and minimize corrosion in the boiler and superheater loops	2	Yes		No
45	Dehumidified air or nitrogen is used to minimize corrosion in the deaerator and on the feedwater heaters	2	Yes		No
46	Dehumidified air used to keep the turbine and reheater dry	3	Yes		No

Cycle Chemistry: Start-Up Practice

		WT	3	2	1
47	Following a dry layup, boiler is filled with high purity water that is deoxygenated (<200 ppb) and chemically treated per startup boiler chemical treatment guidelines.	3	Yes		No
48	Unit uses polishers or filters to remove condensate contamination on startup	2	Yes		No

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High-Level Flexibility Assessment Template 9 Steam Turbine/Generator

Steam Turbine/Generator Assessment

		WT	3	2	1
1	**Flexible operations training and procedures for the Steam Turbine/Generator (STG) have been adjusted for flexible and transient conditions**	3	Yes Operators are competent and clearly understand all implications of flexible operations Procedures updated regularly	Partially Operators need improvements and/or issues need to be addressed	No Operators do not understand implications of flexible operations and/or challenges faced with non-optimal performance; Procedures outdated
2	**Temperature matching and reduction of over-temperature operation:** • Minimize boiler upsets/steam temperature spikes; • Manage steam turbine differential expansion between rotating and stationary components	3	No issues Operators follow OEM recommendations for startup and transient loading. Operators pay close attention to differential expansion monitors located at critical axial locations Operator training has been provided to help improve temperature matching and reduce over-temperature operation	Temperature control needs improvement	Poor control of temperature and temperature differentials
3	**Operators follow the OEM's recommended starting and loading procedures.**	3	Variable (sliding) and/or hybrid variable pressure operation utilized; Installed steam bypass system; Installed thermocouples used to monitor critical temperatures and temperature differentials during starting, loading, and unloading.	Needs improvement	Poor start-up and loading performance issues exist

Steam Turbine/Generator Assessment

		WT	3	2	1
4	**HP/IP Casing Humping Mitigation** Or base-to-cover temperature differential optimization: *Casing upper-lower differential temperature will reduce clearances and affect restart time when cycling frequently. Collateral impacts can include: Increased startup time, horizontal joint leakage and shell distortion*	3	No issues controlling Application of Steam turbine casing insulation systems and/or auxiliary heating for the casing Thoroughly inspect the critical rotor and casing regions during maintenance outages.	Startup time and temperature differential control need some improvement Sometimes inspect	Poor Control of temperature differentials Not inspected
5	**Creep/Fatigue damage mitigation on high-temperature components**	3	Adhere to OEM recommendations for starting, loading, and unloading to minimize thermal fatigue. Maintain good operating records to allow for more accurate estimates of component damage, including fatigue and creep damage. Minimize boiler upsets and keep main and reheat steam temperatures at rated conditions.	Periodic temperature excursions exist and needs improvement	Poor control of temperatures is frequent Significant operating records of excursions need improvement

Steam Turbine/Generator Assessment

		WT	3	2	1
6	**Steam Temperature Control at set-points and ramping**	3	Good control (close to set-point); Well tune control logic; temperature differentials and deviations are controlled; BOP system that impacts steam temperature control is well maintained.	Fair control but needs improvements	Steam temperature control is challenging; attemperator non-operational (or issues).
7	**Excessive use of hood sprays as exhaust temperature increases erosion damage in Last Stage Blades (LSB)** *Especially with flow recirculation that will result in uneven heating); Hood Spray operation is considered a transient demand function and not designed for continuous use.*	3	Hood spray demand operating range and setpoints are periodically checked; Assessing feasibility of flow control is completed (rather than on/off valves); During maintenance outages, exhaust hood water spray nozzle heads are inspected (nozzle spray orientation and effectiveness) to ensure that direct impingement on the last stage blades does not occur; Improving hood spray nozzle to atomize spray and better controls to prevent over-spraying; Ensure that the condensate or any other exhaust hood water spray source chemistry is within recommended guidelines; Ensuring that LP Hood Exhaust Temperature is below 49C (120F) without sprays is important for reducing risk of L-0 blade erosion.	Some inspections conducted; Control is not optimal	Hood spray effectiveness and control is not being addressed

Steam Turbine/Generator Assessment

		WT	3	2	1
8	**Turbine cycle heat rate at part load operation**	2	Optimized for best achievable heat rate	Needs some improvement	Poor control of heat rate; Needs optimization
9	**Thermal performance monitoring of Turbine Cycle Heat Rate**	**3**	Continuous Monitoring in a M&D center for trends in performance; correction curves established; Unusual performance investigations conducted.	Periodic HP/IP thermal performance tests conducted annually to detect equipment degradation and prepare for major outages	No tests performed
10	**SH steam requirements** (pre-roll); **steam line warming; seal steam** (aux steam availability); Operations understand all load characteristics and steam demands	3	No issues Good control	Needs improvement Current performance impacts turndown	Issues exist
11	**Last Stage Blades Vibrations due to Dynamic Instabilities (Flutter)** *Some blade designs are more susceptible; Difficult to detect without a dedicated monitoring system; Damage accumulation rate varies with specific operating condition and design*	3	Awareness of the impact Appropriate monitoring has been taken into consideration (exhaust temp., flow, pressure, blade tip timing monitoring) LP exhaust flow protection diagram which provides avoidance zones is understood and actively applied during operation. All instances of operation in these zones are recorded.	Some actions have been initiated; However, the Impacts of low exhaust flows are unknown	Unaware No monitoring exists Needs to be addressed

Steam Turbine/Generator Assessment

		WT	3	2	1
12	**Operating hours and starts management**	3	STG operating hours recorded, characterized (cold, warm, hot) and validated by history evaluation; All loading cycles and operational upsets (differential temperature heat/cool variations, over pressurization/temperature, minimal loading) are recorded.	Operating hours and number of cold, warm and hot starts are recorded.	STG unit actual operating hours and numbers of starts are not recorded or monitored.
13	**Minimization of valve throttling at reduced or very low loads** **Steam valve functional checks**	3	Turbine main steam Valve control has been optimized to mitigate wear and performance issues. Full arc control mode can help reduce the thermal stress on both the turbine first-stage nozzle block and reduces the temp. drop through the high-pressure turbine; In addition, the higher cold reheat steam temperature leaving the high-pressure turbine limits the drop in the hot RH steam temp. to the intermediate pressure turbine; That being considered, minimization of operating time on the main and reheat steam bypass valves is warranted and considered.	Valves optimization needs improvement	Poor control of main control valves

Steam Turbine/Generator Assessment

		WT	3	2	1
14	**Unit has proper valve materials as designed for low load operation:** This is considering that increased wear due to Solid Particle Erosion (SPE) on valve components is more common during flexible operations.	3	Valve materials and design have been addressed and upgraded	Some valve improvements are needed	Valves materials are worn, vulnerable and/or need improvement
15	**Low Load Steam Purity:** Operating at low load leads to increased deposition on turbines, this combined with extended offline periods can lead to increased pitting corrosion damage which can lead to potentially catastrophic failures in the steam turbine. Units operating at lower loads can have significant increased risk of salt deposition in the turbine which can lead to corrosion damage when offline. Steam purity limits which are protective at full load, may not be protective at minimum loads, in which case even when within limits, salts may deposit.	3	Maintain control of water chemistry, Follow OEM, EPRI, or knowledgeable third-party expert recommendations regarding turbine steam purity. Low load steam purity is managed appropriately Short term and long-term shutdowns include corrosion and pitting mitigation systems	Low load steam purity concerns exist Some mitigation actions exist for preventing corrosion and pitting. But, need improvement or are not always deployed.	Low load steam purity is not controlled No offline protection systems exist Turbine deposition is an issue

Steam Turbine/Generator Assessment

		WT	3	2	1
16	**Water/Steam Chemistry Program**	2	Continuous water treatment; All steam admission lines are sampled; Steam chemistry meets OEM guidelines; Variances are alarmed, and operators follow action levels. Air in-leakage is closely monitored and eliminated as soon as possible.	Meets OEM manual for the steam turbine; Daily grab samples, but not from all required locations; Variances are alarmed. But action levels are now always followed depending on commercial penalties for load reductions.	Basic water treatment (grab samples analyzed daily); action levels not always followed.
17	**Offline Steam Turbine Preservation Managed for various modes of operation:**	3	**Hot Standby:** When immediate dispatch response is required; Boiler and DA pressures maintained; Condenser vacuum maintained; Use of film forming products has been shown to help reduce corrosion **Wet Layup:** When outage is days and/or less than a few weeks and no access to water/steam side of Boiler or DA is required; ability to produce high purity water is limited; Capacity to maintain a nitrogen blanket or dehumidified air. **Dry Layup:** Planned when layup will be weeks or months and boiler/DA access is required and/or sufficient time to refill system is required; Optimal steam turbine lay-up is always dry; 35% relative humidity or less maintained; Nitrogen blanket or dry lay-up with dehumidifiers used for long term preservation.	Some action. But not defined well (or enforced) Strategy for duration of layup modes and the corresponding actions needed; For example, if the hot well is not drained, <60% relative humidity may be difficult to attain.	No preservation methods taken; Unit is shut-down and depressurized; Condenser hot well is not drained. Turbine exhaust hood humidity is not monitored or controlled.

Steam Turbine/Generator Assessment

		WT	3	2	1
18	**Steam Turbine Generator Alarm management**	2	Dedicated personnel working to improve the alarm management system continuously; KPIs used to measure and trend performance; Alarm flooding rare	Alarms are reviewed periodically & prioritized. Critical alarms are wired directly to the panel. Graphics simulate panel alarms	Alarms screens are continuously scrolling or frequent due to nuisance alarms, malfunctioning field devices and improperly programmed limits and deviations.
19	**Online General Condition Evaluation of the HP/IP and LP turbine**	3	Operator rounds (noise, vibration, insulation condition) and continuous monitoring of critical parameters (steam parameters, rotor axial positions, differential expansion, bearing vibration, shaft eccentricity and speed, valve positions, metal temps, thrust bearing temp, condenser back pressure, shaft voltage, etc.); Could include technologies such as blade vibrations, rotor torsional vibrations, HP turbine windage probes, etc.)	Operator rounds completed and control room monitoring of most critical parameters (not all)	Main Steam turbine performance not checked other than by minimal operator rounds. Some turbine data is reviewed in control room.

Steam Turbine/Generator Assessment

		WT	3	2	1
20	**Turbine gland steam seal system operational checks**	2	Continuously measured online by the DCS (M&D applicable) Checked during operator rounds; functionally checked annually.	Checked at the header; readings taken during operator rounds; periodic inspection for leakage.	Not monitored
21	**Vibration monitoring program**	3	Vibration monitoring program; diagnostics rules and trending via software (e.g., APR) is ongoing.	Vibration alarms annunciated in control room; investigation and analysis by plant engineer to review amplitudes and phase angle trends	Not reviewed or monitored unless a high vibration is acknowledged by an operator
22	**Vibration measurements and monitoring systems for STG rotor train**	3	Proximity, Velocity, Amplitude and phase angles for each bearing; Manual vibration checks to verify functionality; Continuous vibration data acquisition and diagnosis.	Proximity probes, Velocity measurements; Vibration amplitude for each bearing;	Relative shaft displacement measured by using shaft riders or proximity probes (X, Y phase angles)
23	**Bearing health checked during operations**	2	Bearing oil pressures and metal temperatures monitored from DCS and M&D center; Redundant thermocouples; Bearing flanged joints and oil baffles are checked; jacking oil pressures also checked periodically during every start-up/shut down.	Bearing metal temperature, oil drain flows, bearing metal header temperature; bearing flanged joints; oil baffles; jacking oil pressures	Bearing metal temperature and lubrication not checked

Steam Turbine/Generator Assessment

		WT	3	2	1
20	**Turbine gland steam seal system operational checks**	2	Continuously measured online by the DCS (M&D applicable) Checked during operator rounds; functionally checked annually.	Checked at the header; readings taken during operator rounds; periodic inspection for leakage.	Not monitored
21	**Vibration monitoring program**	3	Vibration monitoring program; diagnostics rules and trending via software (e.g., APR) is ongoing.	Vibration alarms annunciated in control room; investigation and analysis by plant engineer to review amplitudes and phase angle trends	Not reviewed or monitored unless a high vibration is acknowledged by an operator
22	**Vibration measurements and monitoring systems for STG rotor train**	3	Proximity, Velocity, Amplitude and phase angles for each bearing; Manual vibration checks to verify functionality; Continuous vibration data acquisition and diagnosis.	Proximity probes, Velocity measurements; Vibration amplitude for each bearing;	Relative shaft displacement measured by using shaft riders or proximity probes (X, Y phase angles)
23	**Bearing health checked during operations**	2	Bearing oil pressures and metal temperatures monitored from DCS and M&D center; Redundant thermocouples; Bearing flanged joints and oil baffles are checked; jacking oil pressures also checked periodically during every start-up/shut down.	Bearing metal temperature, oil drain flows, bearing metal header temperature; bearing flanged joints; oil baffles; jacking oil pressures	Bearing metal temperature and lubrication not checked

Steam Turbine/Generator Assessment

		WT	3	2	1
24	**Turbine gland steam seal system operational checks**	2	Continuously measured online by the DCS (M&D applicable) Checked during operator rounds; functionally checked annually.	Checked at the header; readings taken during operator rounds; periodic inspection for leakage.	Not monitored
25	**Vibration monitoring program**	3	Vibration monitoring program; diagnostics rules and trending via software (e.g., APR) is ongoing.	Vibration alarms annunciated in control room; investigation and analysis by plant engineer to review amplitudes and phase angle trends	Not reviewed or monitored unless a high vibration is acknowledged by an operator
26	**Turning gear operational checks**	3	Turning gear motor amperage, jacking oil pressures and rotor speeds checked during operation; motor ventilation openings are checked for obstructions	Turning gear and drive checked daily for noise, vibration, leaks; Turbine speed and oil pressures checked.	Not usually checked unless it won't engage after the STG reaches zero speed after a shut-down.
27	**Turning gear "off-line" checks:**	2	**Short-term:** TG in operation. **Intermediate term:** TG out of service. **Long-term:** PM Tasks (air actuator, greasing, etc.). System exercising 1wk-1mo in conjunction with lube oil system in service – not just bearing film oil		

Steam Turbine/Generator Assessment

		WT	3	2	1
28	**STG controls and protection system tests and checks**	3	All tests are performed by OEMs and/or insurance companies; oil pressure switches calibrated annually.	Overspeed trip test (MHC) or simulated test (electronic overspeed devices) is performed once per year to check for functionality and trip speed levels.	Turbine overspeed tests are not performed, or procedures and expertise is inadequate, resulting in improperly performed tests.
29	**Hydraulic control system tests, inspections and analysis**	3	**EHC skid checked during operator rounds** **Short-term.** Pumps/filtration on. Temperature & Level Monitoring **Intermediate term.** Pumps off. Level monitoring and reservoir inspection 1x per shift. **Long-term.** PM Tasks (Vapor extractor and coolers (drained) out of service). System exercising on bypass 1wk (portable conditioning). Off bypass - valve stroking at 1mo. Fluid sampling (RULER, solids, water).	EHC system checked once per week for leaks; pressure drop across filters; fluid temperatures and levels; motors, pumps & piping checked for vibration.	EHC piping and skid are not checked.

Steam Turbine/Generator Assessment

		WT	3	2	1
30	**Regular maintenance of non-return valves on extraction lines and feedwater heaters is recommended to prevent water backup into the turbine; All low-pressure casing drains inspected and cleared if plugged.**	3	Non-return valves are regularly maintained All inspected and in good condition	Valve maintenance has room for improvement	Non-return valves are not often checked or maintained
31	**Water induction risk increases with more unit starts. Thus, protection systems must be optimized:** Inspect all controls, thermocouples, valves, drains, traps, etc. for proper operation	3	Good protection system in place and functionally validated Water level elements; alarms; transmitters, interlocks and protection systems; steam line drain valves; simulated panels and alarm graphics; system owner assigned to all turbine auxiliary systems essential to turbine water induction prevention.	FW heater level alarms and trips are periodically tested; Main and RH low point drains tested; System needs functional checks and/or evaluation	Issue exist; No checks on the steam drains and valves

Steam Turbine/Generator Assessment

		WT	3	2	1
32	**Generator condition assessment checks during operation**	2	Operator inspections; critical parameter monitoring from control room; unit performance monitoring; monitoring & diagnostics center/advanced pattern recognition monitoring; Electro-Magnetic Signature Analysis (EMSA); Action levels identified.	Monitored from control room; operator rounds.	Not checked or only on random operator rounds
33	**Generator stator cooling water system**	2	M&D center; APR monitoring; action levels based on expert advice; system also checked during operator rounds; generator liquid detectors are checked and tested periodically. **Stator Cooling Water System Layup** **Short-term** (t<3d): cooling water system circulating **Intermediate/Long-term** (t>3d): cooling water system 'force drained' with vacuum.	Operator rounds: cooling water pressures, temperatures, differential pressures; water chemistry; pump vibration; temperature control; valve position; Hydrogen leakage checked.	Not usually checked or only on random operator rounds

Steam Turbine/Generator Assessment

		WT	3	2	1
34	**Generator Moisture Mitigation and Preservation Program**	**3**	Off-line guidance document for generator layup is current and managed accordingly. Monitor dew point and hydrogen gas purity continuously. Monitor seal oil for moisture content by periodic sampling. Unit has in operation a hydrogen dryer with ability to regenerate desiccant.	Off-line guidance document for generator layup needs improvement Hydrogen pressure maintained, unless equipment is open for maintenance; stator cooling and hydrogen systems – in service. Hydrogen dryer present but not actively removing moisture and regenerating the desiccant. Gas purity values below OEM recommended levels indicating moisture or contamination.	No program in place No preservation actions

Steam Turbine/Generator Assessment

		WT	3	2	1
35	**Generator hydrogen cooling system operational checks**	2	M&D/APR monitoring and performance analysis; action levels defined; proactive leakage tests. H2 leakage is below OEM recommended values. Hydrogen filling and purging procedures in place with proper safety precautions.	Operator rounds and/or periodic checks for pressure, temperature, dew point and purity; Hydrogen dryers and coolers visually inspected: Hydrogen consumption checked regularly. H2 leakage is above OEM recommended values. Hydrogen filling and purging procedures known revisions needed.	Hydrogen pressures, temperatures, purity and leaks are not checked. No specific hydrogen filling and purging procedures. Personnel work without specific procedures.
36	**Generator Air/Gas Cooling System Layup**	2	**Short-term.** Keep pressurized. System performance monitoring **Intermediate term.** Degas. Monitor cooling water temperatures (dew point). **Long-term.** Degas. PM Tasks (coolers (drained) out of service).	Layup program needs improvement Inconsistent	No layup program in place and/or not enforced/utilized

Steam Turbine/Generator Assessment

		WT	3	2	1
37	**Hydrogen seal oil system operational checks**	2	M&D/APR monitoring for continuous condition monitoring and analysis; online sensors for monitoring seal oil quality; emergency seal oil pumps tested periodically. No oil leakage out of the belly drains.	All main components checked during operator rounds (motors, pumps, piping, valves, regulators, tanks, reservoirs, gauges); DCS monitoring. Minor oil leakage out of the belly drains of the generator.	Hydrogen seal oil system not checked. Increasing trend of oil leakage out of the belly drains. Past history of oil in generator.
38	**Generator Air cooling system Operational checks**	2	M&D/APR monitoring for continuous performance monitoring & analysis in addition to operator rounds. Slot RTD and air inlet and exit temperatures inputted into M&D/APR monitoring.	Air and cooling water temperatures, differential pressures are monitored; checked during operator rounds for abnormal operations.	Generator cooling air systems not checked.
39	**Excitation System Operational checks**	2	M&D/APR monitoring for continuous performance monitoring & analysis in addition to operator rounds; action levels well defined; regular inspections; cleanliness; thermography; fault indicators	Visually checked during operator rounds for oil leaks, brush arcing and wear; bearings checked for high vibration and wear; excitation system voltage and current and other DCS trends; Vibrations; Wear and Fault indicators	Excitation system and parameters not checked

Steam Turbine/Generator Assessment

		WT	3	2	1
40	**Generator Excitation System Layup**	2	Defined program and approved procedures in place and followed for long term layup of brushless exciter or collector assembly.	Program needs improvement or Inconsistent	No Program in place
41	**Steam Turbine Generator Advanced health monitoring technologies**	2	Advanced algorithms; M&D center; APR monitoring; Action levels addressed; programmed; Corrective actions implemented in a timely manner	Some thermal performance software is used but not continuously; PI trends are used;	No special monitoring technology is used
42	**Data Resolution Sampling and Management Practices**	2	Archived data is integrated, available and readily retrievable; Multi-source data can be retrieved and reviewed remotely; alarm lists and sequence of events designed properly to capture points in correct sequence. Data that is not in the DCS is recorded electronically during auxiliary operator rounds, downloaded and readily available for trending and analysis. Increased Sampling Rate	Data is readily available; PI graphs and trend modules have been set up and can be easily used to detect changes and unusual machinery readings; PI is used to reconstruct events to determine root and apparent causes.	Basic data historian but granularity not good enough to reconstruct relationships of different parameters. Sampling has not been adjusted

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High-Level Flexibility Assessment Template 10 Balance of Plant

Balance of Plant Assessment

		WT	3	2	1
1	Boiler Feed Pump (BFP) flow stability and system design	2	Design and performance assessment conducted to evaluate potential issues with flexible operations: valve issues, valve seat wear, actuators; Steam supply at emergency minimum loads; Fluid drive operation at bottom of range; Suction piping (strainers, plugged FWH tubes, etc.) that can lead to cavitation.	Flexible operations have been taken into consideration. However, issues exist, and modifications and/or upgrades are needed	BFP performance has not been addressed for flexible operations and/or is non-flexible.
2	Economizer Recirculation Line Pre-warming/DA system	2	Recirculation line on the feedwater system added (upstream of the feedwater control valve back to the condenser for feedwater warmup from steam in the deaerator);	Periodic thermal transients occur. Needs improvement	Thermal transients from flashing or cavitation are common; Hydraulic instability has led to bearing failures; For constant-speed BFPs, high DP can cause cavitation: Can damage control valve trim; can produce pipe hammer No protection systems exist
3	Feedwater regulating valves Optimized	2	Established strategy for replacing valve seats on a frequency dictated by the wear on inspection; Works with OEMs to determine the valve seat and trim best suited to the operating regime; Variable-speed drives installed on feedwater pumps to limit the pressure differential across the valve (if needed); HP feedwater regulation valves; Modified cage and plug to prevent startup flow and level issues.	Strategy needs improvement	No strategy; Issues exist

Balance of Plant Assessment

		WT	3	2	1
4	High Pressure Feedwater Heaters	2	High pressure feedwater heaters in the thermal plants can suffer cracking at the Knuckle Radius (a thick sectioned component, with a through wall temperature gradient at a stress concentration point) as a result of the introduction of cold water during start up; More frequent on/off operations compounds the issue; Inspections and Heater replacements are planned as cracks progressed to a point of breaching minimum wall requirements.	Strategy needs improvement	No strategy in place
5	Low load impact on FAC	2	Program in place to monitor and assess DA, FW heaters, turbine drains, etc.	Program needs to be enhanced or improved	No program in place; Or program is inadequate
6	Condenser Condition and Performance	2	Minimal plugged tubes; Design condenser pressure attained across the load range; Online Cleaning System	Plugged tubes at the top of the condenser due to low loads and water impingement exist	Issues exist condenser performance across the load range
7	Vacuum Control	2	Air Ingress and non-condensable gas removal system optimized to ensure proper heat transfer from the steam to cooling water in the condenser.	Sometimes an issue; Needs improvement	Constant issue; Negative impact on heat rate and firing rates

Balance of Plant Assessment

		WT	3	2	1
8	Deaerator Inspections	2	Good performance; No issues	Some issues; Inspection planned	Poor performance; Warrants Inspections and planning for improvements needed to spray system, baffling, valves, etc.
9	Piping systems	2	Visually inspects the movement of the piping systems during operations to ensure freedom of movement. Visual survey and engineering review of the pipe work in both the cold and hot positions to compare the movements of individual supports against design.	Piping system inspections and management needs improvement.	No piping program in place and/or issues exist with hangar support systems
10	Boiler/Turbine Drains	2	Increased drains pipe size installed (as needed) to allow for rapid emptying of condensate; Verified that the route accommodates quick removal of fluids.	Needs improvement	Issues exist
11	Boiler casing, seals & supports	2	Modified inspection frequency and procedures for flexible operations to ensure acceptable condition	Some issues exist; inspections and supports need improvement	Casing, seal and support issues exist
12	Boiler valves	2	All required valves for meeting dispatch demands are optimized.	Needs improvement	Valves condition and automation is non-optimal
13	Boiler Feed Pumps	2	Motorized and/or No issues achieving low load operation; Vibration monitors installed on critical pumps	Steam Driven; Limitations on low load operations	Issues exist with reducing minimum load

Balance of Plant Assessment

		WT	3	2	1
19	Air heater plugging Mitigation	2	Air pre-heating coils (and/or gas bypass) is functional and operating to manage the cold-end temperature; Condition assessment and inspections for optimizing cleaning cycles and ensuring component condition is optimized.	Needs improvement	Air heater plugging is a common issue that results in unit de-rates and/or mal-gas distribution issues.
20	Duct corrosion Mitigation	2	Online (thermal) and offline inspections for ductwork corrosion and integrity; Proactive validation of temperature representation and controls for mitigating dew point corrosion and/or detecting potential air in-leakage paths.	Some issues exist with temperature management and/or duct corrosion mitigation due to air in-leakage; Needs improvement	Safety issues exist with heat loss (when online) and/or due to internal duct corrosion (when offline) exist
21	Insulation Integrity	2	Condition of duct insulation, and repair or replace as needed.	Insulation is overall in fair condition, but some areas need improvement	Overall insulation is in poor condition.
22	Managing Low Load Ash Layout	2	Ash layout can overload ductwork and result in structural failures Ductwork integrity assessments completed to mitigate a collapse through programmatic inspection, cleaning; structural supports and duct condition and expansion joint condition.	Some issues have been reported with ash layout in ducts and there are concerns with ductwork integrity; Needs improvement	Load ash layout and duct integrity is a serious concern that could impact personnel safety and reliability of the generating assets.
23	Air/Gas System Dampers	2	Condition of dampers, maintenance and/or replacement strategy is optimized	Condition of dampers, maintenance and/or replacement strategy needs improvement	Condition of dampers, maintenance and/or current replacement strategy is negatively impacting the performance and reliability of the air/gas management systems

Balance of Plant Assessment

		WT	3	2	1
24	FD, ID Fans	2	Inspections, Turning Gear and overall management is optimized (no issues)	Some issues exist with performance and/or start-up reliability	Issues exist that need to be addressed
25	Fuels Management	2	Fuels management and flexibility practices are optimized for flexible operations; fuels flexibility and storage provisions have been addressed with handling and fire detection and protection systems.	Fuels management and flexibility practices may require increased storage periods for volatile coals that sometimes self-ignite; Detection system and handling provisions need improvement	Fuels flexibility and management is non-optimal
26	Plant Layups	2	All major components and systems have been provided with lay-up guidance and provisions by the chemistry and/or system owners (or subject matter experts)	Plant layup guidance needs improvement	Layups are inadequate and put the major components at risk
27	Freeze Protection	2	Cold weather freeze protection has been considered (as needed)	Freeze protection systems need improvement	Freeze protection is a common problem impacting operations
28	Auxiliary Boiler	2	Auxiliary Boiler (Steam System) is adequate and available	Auxiliary Steam supply system needs improvement	Auxiliary steam supply issues exist; Impact on system availability

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