

GE Renewable Energy



# **PREDICTIVE MAINTENANCE & FLEXIBLE ASSET OPERATIONS**

WITH DIGITAL HYDRO SOLUTIONS



# THE FUTURE OF HYDRO IS DIGITAL

In today's challenging energy market hydropower operators face multiple challenges such as increasing price pressure with the rise of intermittent renewable energy, tighter regulations, aging assets, experienced workforce turnover, new operating patterns, staff retention in remote locations, etc. Digital technologies can help turn these challenges into opportunities, putting hydropower at the forefront of the energy transition.

GE Renewable Energy's Hydro digital portfolio includes sensors, data acquisition, data collection & data management systems, predictive analytics, software solutions with advanced user experience, as well as consultancy and advisory services.

They are organized around GE's Hydro APM (Asset Performance Management) software, complemented with services and advanced control functions. Hydro APM is a suite of applications: APM Health, Reliability, and Strategy which can work independently or together to reduce O&M costs, decrease failure risks, and increase revenues across your fleet. When associated with services and advanced control functions, it can enable flexible asset operation (range extension, cycling, smart asset dispatch, etc.) and unlock new revenue streams, for example from ancillary services, while managing the risk on the hydro asset. Making existing assets more flexible is critical for hydropower plant owners to cope with climate change, the deregulation of the energy market and permit the rise of wind and solar within the energy mix.

What is special about GE's digital approach? Take GE Renewable Energy's one hundred years of hydropower machine experience, extensive fundamental and applied research on hydraulic phenomena, coupled with the breadth of GE Digital's IIoT<sup>(1)</sup> portfolio equals an unprecedented understanding of hydro machine behaviour.

Start your **digital transformation** & join

# 100+

**HYDRO PLANTS** relying on GE's  
**HYDRO DIGITAL SOLUTIONS**

# Turn your Data into Value



## COST & FAILURE RISK

- Reduce failure rate up to 50%
- Reduce maintenance OPEX between 5-20%
- Defer CAPEX by up to 20%



## REVENUES & ENABLE FLEXIBLE OPERATION

- Enhance equipment availability by 0.5-2%
- Help to avoid production losses for run-of-river plants
- Recover capacity from under performing assets
- Enhance equipment flexibility and operability



## INFORMATION SHARING

- Use expert insights remotely
- Elevate knowledge of local staff
- Bridge silos across the organization

*note: detailed value assessment required on a case by case basis to quantify the expected outcome for each customer.*

## By



### CONNECT

Provides the foundation to use analytics by enabling the collection of all relevant data (sensors, DCS<sup>(2)</sup>, EAM<sup>(3)</sup>, design data, etc.), as well as management of that data to derive value



### ANALYZE

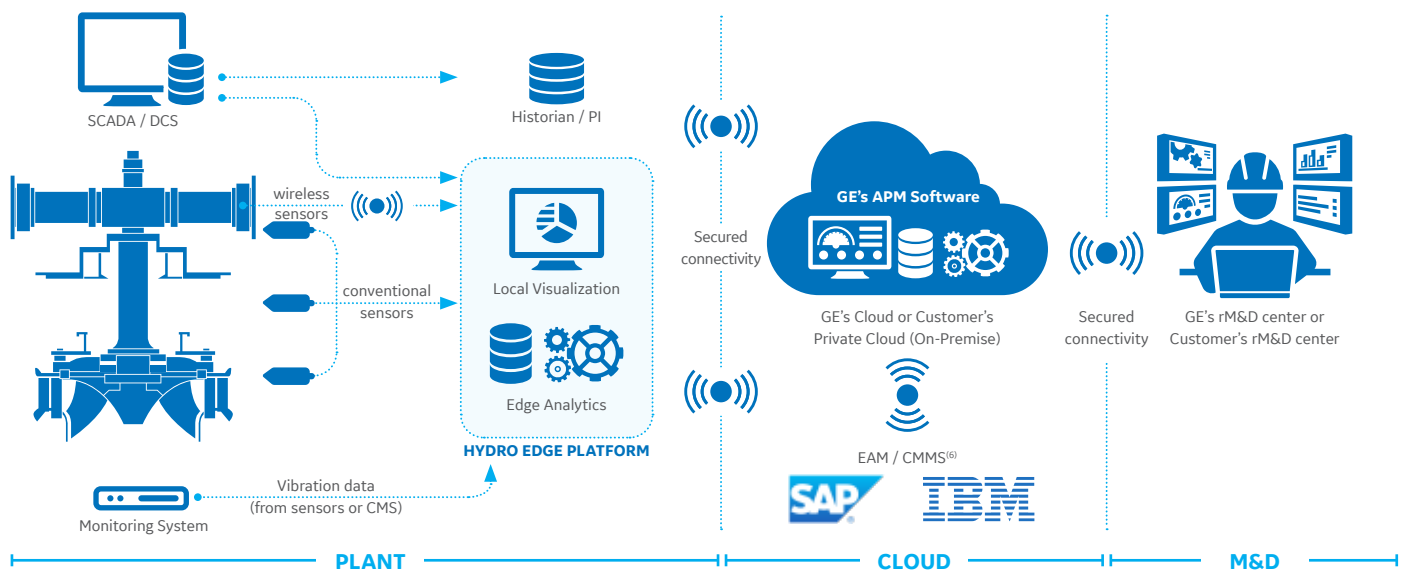
Focuses on understanding the historical, current, and future performance and health of your assets and processes, and visualization of events, with RCM<sup>(4)</sup>/FMECA<sup>(5)</sup> methodology, predictive analytics, and reliability analysis, embedded within GE's APM



### FIX / OPERATE

Performs and captures the right action with the right part & tool at the optimal time. Enable the best trade-off to operate the plant considering the asset health condition.

## With modular and scalable edge to cloud solutions



(1) IIoT: Industrial Internet of Things  
(2) DCS: Distributed Control System

(3) EAM: Enterprise Asset Management  
(4) RCM: Reliability Centered Maintenance

(5) FMECA: Failure Mode and Effect Analysis  
(6) CMMS: Computerized Maintenance Management System

# GE RENEWABLE ENERGY'S APPROACH

GE brings together over 100 years of domain knowledge in hydro solutions with the latest in IIoT technologies to deliver actionable insights that increase operational flexibility and transform operations & maintenance practices.

## GE DIGITAL HYDRO

Asset Performance Management (APM)				
APM Strategy	APM Health	APM Reliability		
		APR Analytics (SmartSignal)	Edge Analytics (Hydro Edge Platform)	OEM <sup>(1)</sup> Design Models
Optimize across availability, reliability, risk, and cost through asset strategies	Unified real time view of asset health	Predictive Analytics - Anomalie detection with Machine Learning	Predictive Analytics - High frequency processing	Predictive Analytics - Embed Highly customized models (FEA <sup>(2)</sup> , CFD <sup>(3)</sup> , Tests ...)

CUSTOMER CHALLENGES	Operation and Maintenance Strategy					
	MAINTAINING competitiveness in challenging power market	✓	✓	✓	✓	
	TIGHTER regulations, INCREASED compliance risk	✓				
	AGING assets and INCREASED operational risk	✓	✓	✓	✓	✓
	DISCONNECTED data and disconnected people	✓	✓			
	Generational TURNOVER	✓				
	SAFETY of Operation			✓	✓	
	Staff RETENTION in Remote Hydro locations	✓		✓		
	Operation Optimization (Flexibility)					
	Intermittent Renewable Energy Integration & Climate Change driving new operating patterns					
	Rough Zone Operation (incl. partial load)		✓	✓	✓	✓
	Power Boost		✓			
	Fast Ramp up/down and mode transitions					
	Cycling (start/stops)		✓	✓	✓	✓
	Smart Asset Dispatch		✓	✓	✓	

### HYDRO EXPERTISE

100+ years of domain knowledge included in the Software

- Failure Modes & Effect Analysis (FMECA)
- Asset Health & Maintenance Indices
- Analytics/Asset Model behavior considering design and physics-based rules

Asset Digital Twins built from drawings, historical operation data, design rules, simulations (CFD, FEA), scale model tests, site tests, which provides insights on incipient failures, performance degradation and Remaining Useful Life.

### IIoT TECHNOLOGIES

Digital portfolio built on the latest technologies

- Conventional and IoT sensors & data collection systems
- Edge Computing: hydro edge platform for high frequency Analytics
- Machine learning software for anomaly detection
- Asset Performance Management software
- Cloud platform and processing.

# UNIQUE COMBINATION OF EXTENSIVE HYDRO EXPERTISE COUPLED WITH LEADING GE'S IIoT SOLUTIONS



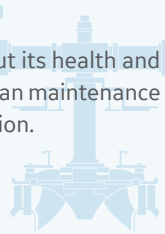
## PRODUCT & SERVICES

Services		Advanced Controls		OUTCOMES
rM&D <sup>(4)</sup>	Assessments	Sequence Booster	Smart Load Dispatch	
Remote Monitoring & Diagnostic with expert advisories	Estimate Asset health, identify operation improvements and range extension opportunities	Improve the starting sequence and mode transitions	Optimize the dispatch rules to minimize wear and/or maximize efficiency	
✓	✓			Reduce Cost
	✓		✓	Control & Reduce Compliance Risks
				Reduce Cost & Operations Risks
				Share information & Increase Productivity
				Capture Knowledge & Reduce Operations Risks
✓				Control & Reduce Operations Risks
				Reduce Local Staff & make their work smarter
✓	✓			
	✓			
		✓		Increase Revenue & Control Risks
	✓		✓	

### SMART HYDRO ASSETS

Machines designed with embedded sensors and processing systems to extract the most meaningful information out of your asset. GE designs smart machines to capture the most critical potential failure of the assets enabling you to act before it turns into a catastrophic failure.

The connected asset shares information about its health and degree of cumulated fatigue allowing you to plan maintenance in a timely manner based on its actual condition.



### HYDRO EXPERT RM&D & GLOBAL SERVICES ORGANIZATION

Remote Monitoring & Diagnostic services are delivered by GE's world-class experts. Engineering know how combined with expert tools allows GE to advise customers on the best appropriate O&M actions.

Global Services organization ready to service your asset when needed.



(1) OEM: Original Equipment Manufacturer

(2) FEA: Finite Element Analysis

(3) CFD: Computational Fluid Dynamics

(4) rM&D: Remote Monitoring & Diagnostic

# Enhance your O&M Practices with GE's Asset Performance Management (APM)

Built on 3 pillars with core capabilities to drive a comprehensive asset management strategy

## Optimize across availability, reliability, risk and costs

- Criticality analysis
- RCM / FMECA
- Strategy library
- Strategy manager
- Reliability analysis



### APM Strategy

What maintenance activities should be performed?

## Predict equipment issues before they occur

- Predictive diagnostics
- Case management
- Root cause analysis



### APM Health

When to replace assets?



### APM Reliability

When is the right time to perform maintenance?

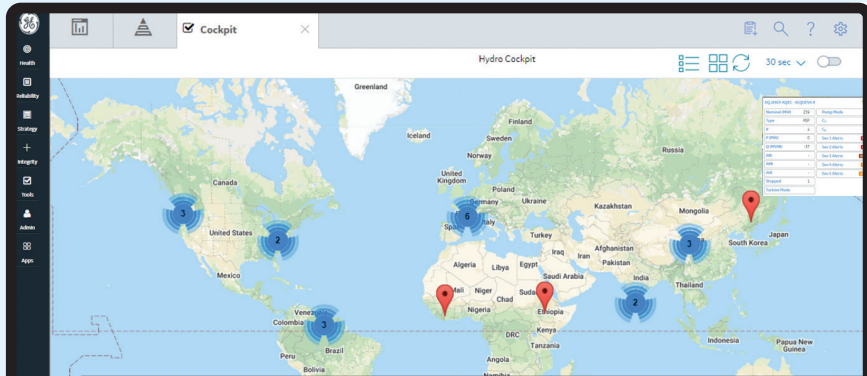
## Anytime, anywhere, unified view of your asset's current state and health

- Rounds (field data collection)
- Asset Health Indices
- Lifecycle Cost Analysis



# Persona-based user experience from fleet view to asset-centric dashboards

Holistic view of your asset with an intuitive UI/UX to navigate from fleet, plant, asset, and visualize specific KPIs related to your asset (status, performance, health and remaining useful life)



## FLEET

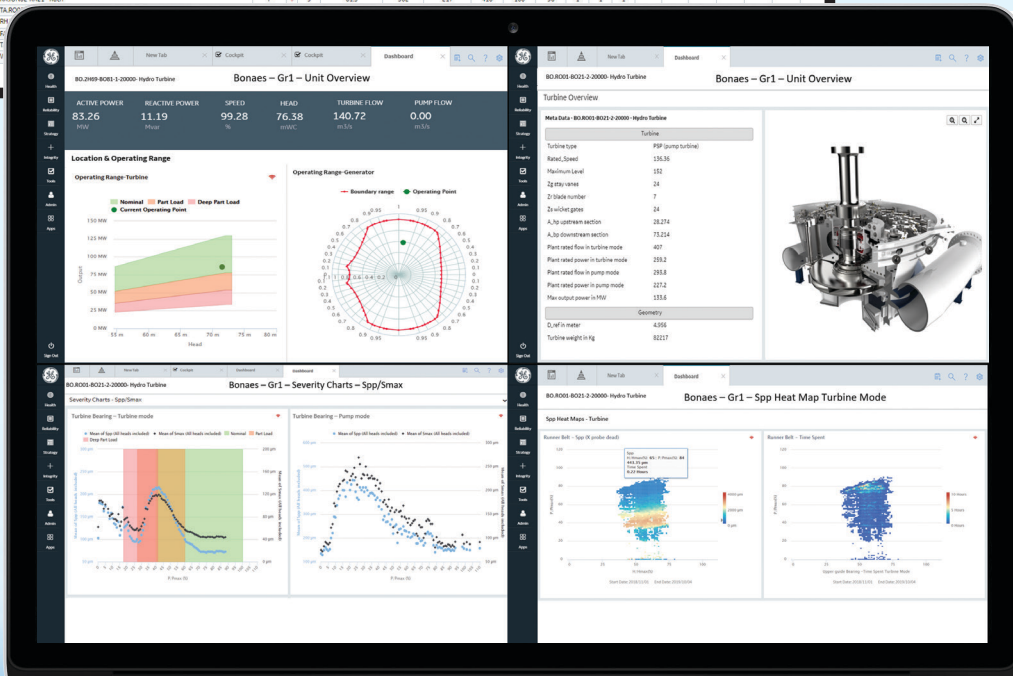
Monitor and prioritize actions across your entire fleet

The 'PLANT' dashboard shows a detailed table of assets. The table includes columns for Plant Name, Type, #, Nominal (MW), P (PSP), Q (PSP), A10, A50, A90, S, T, P, C1, C2, #1, #2, #3, #4, #5. The table lists various plants such as SA-PA05-SAZ1, MD-CR01-MO21, and others.

Plant Name	Type	#	Nominal (MW)	P (PSP)	Q (PSP)	A10	A50	A90	S	T	P	C1	C2	#1	#2	#3	#4	#5
SA-PA05-SAZ1 - Snowy Adams	F	6	150	218	239	505	100	93	1	1	1							
MD-CR01-MO21 - Monchamp	PSP	3	143	104	69	269	100	94	1	1	1							
AL-SU02-W21 - Xijan	F	72	749	2532	2784	59759	100	91	4	7	6	4	3					
BA-PJ05-W021 - Aegion	K	12	215	423	277	971	100	92	2	2	1	1						
CH-SH05-CH21 - Charentais	B	21	27	784	497	412	100	91	1	2	2	1	1					
RA-SAN05-RA21 - Rajahmundry	F	48	480	1691	1207	16365	100	91	1	3	5	2	5					
BO-RO05-BO21 - Bonasas	VS-PSP	6	125	207	144	98	0	72.89	2									
PC-GO05-GO21 - Pann Canyon	PSP	18	91	615	433	842	100	91	1	2	2	1	1					
OU-EL02-OU21 - Otago	F	30	217	1048	708	1319	100	90	2	2	1	2	3					
SR-IND02-SR21 - Sun Rise	F	12	287	393	290	2113	100	92	1	1	1	1	1					
BR-STRO02-BR21 - Brannino	B	60	71	2035	1462	3990	100	91	3	8	5	3	3					
NA-BEG02-NA21 - Benghal	B	30	18	2042	711	784	100	92	1	9	2	2	2					
BN-IND01-BI21 - Purneasab	PSP	6	259	224	160	2823	100	92	1	1	1							
SC-IND05-SC21 - Scheuden	K	6	33	218	129	144	100	91	2									
GU-IND05-GU49 - Chhatra	PSP	6	259	181	156	1548	100	90	1									
HO-STRO02-HO21 - Hoangmai	K	36	162	1205	840	4044	100	91	5	5	1	1						
RA-IND02-RA21 - Rajahmundry	F	9	61.5	302	217	410	100	90	1	1	1							

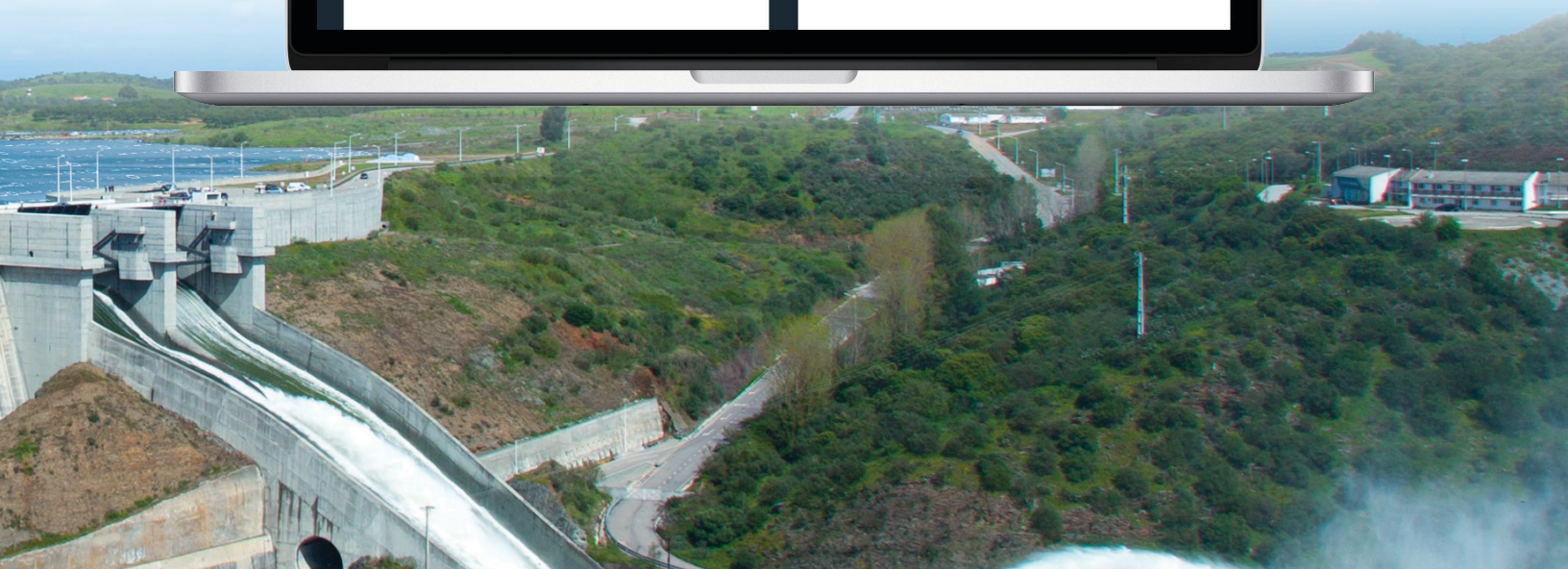
## PLANT

Synthesized view of your plant's assets health, alerts and operating mode



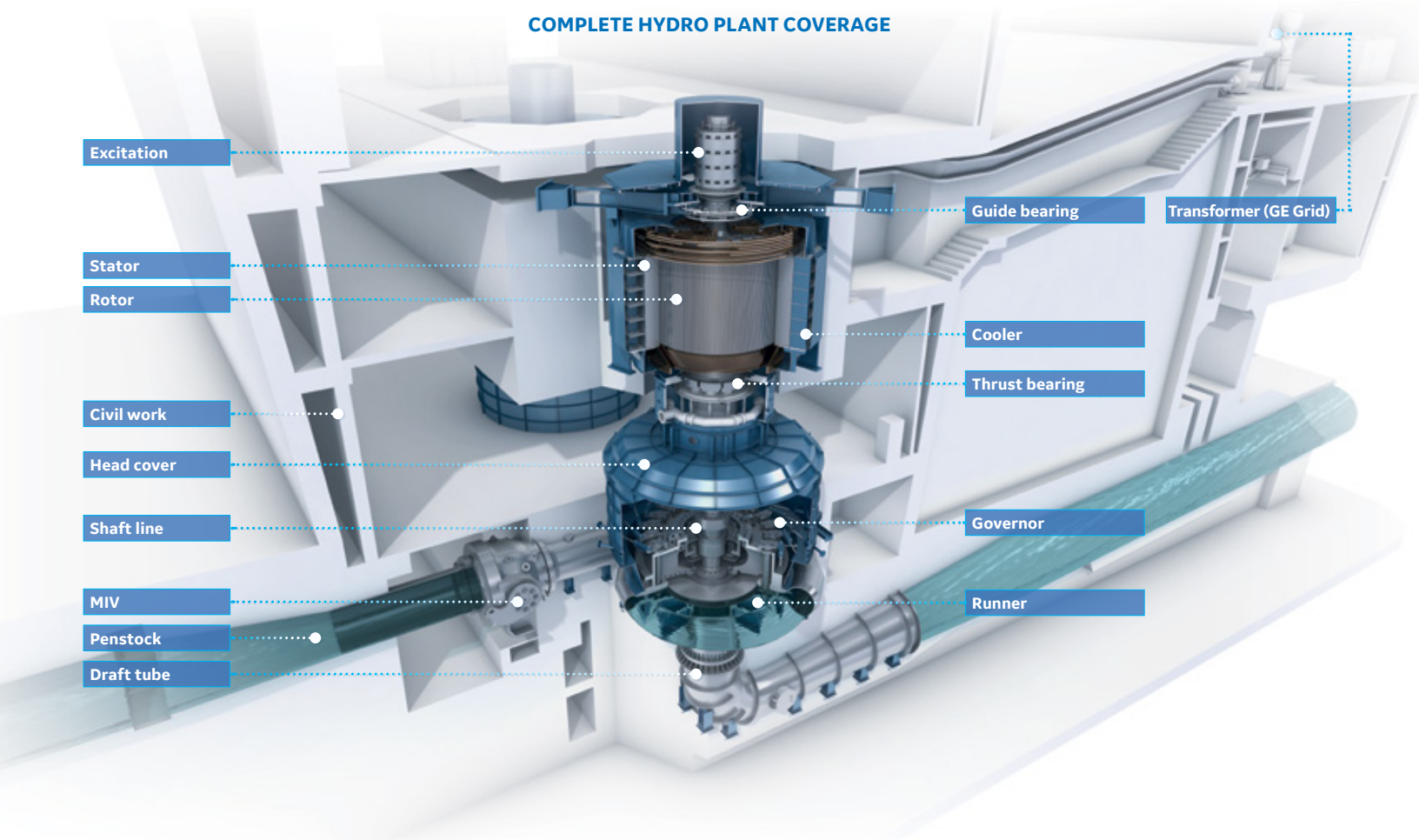
## ASSET

Asset centric dashboards and KPI with deep insights on your assets behavior




# Anticipate Failure and Manage Remaining Life with the capability of hydro domain predictive analytics

GE Renewable Energy continuously develops new analytics to cover the entire hydro plant assets and to target a comprehensive list of failure modes for any sort of machines (Francis, PSP, Kaplan, Pelton, Bulb etc.). These analytics are based on design expertise and site operations feedback, providing insights on incipient failures, performance issue, or remaining useful life of the asset.



GE Renewable Energy uses three different technologies for its predictive analytics, depending on failure criticality and performance expectations:



**ADVANCED PATTERN  
RECOGNITION ANALYTICS**



**EDGE  
ANALYTICS**



**OEM DESIGN  
ANALYTICS**



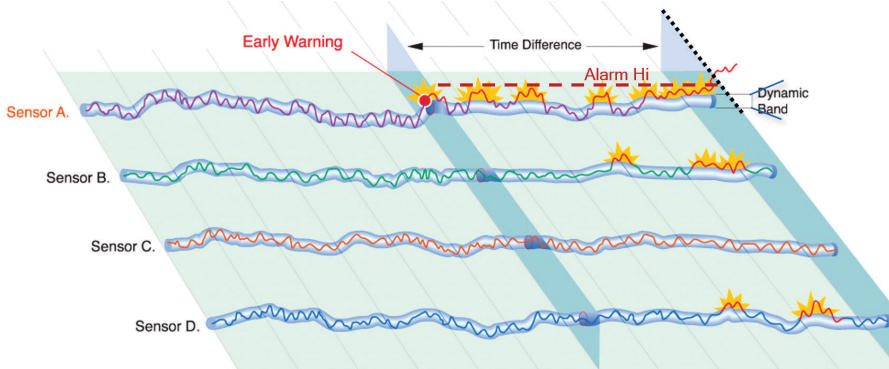
Please contact GE for the complete list of predictive analytics available:  
[www.ge.com/renewableenergy/contact-us](http://www.ge.com/renewableenergy/contact-us)



# PREDICTIVE ANALYTICS TECHNOLOGIES

## ■ APR (Advanced Pattern Recognition) - SmartSignal®

APR analytics are based on SmartSignal® software which provides early warning notifications of anomalies, along with diagnostics and prioritization. It uses a data driven approach with machine learning algorithms and experts' rules to define what is normal/abnormal for the hydro assets. A dynamic envelop is created around the normal expected behavior and an alert is triggered when the actual value deviates too much from the projected one.

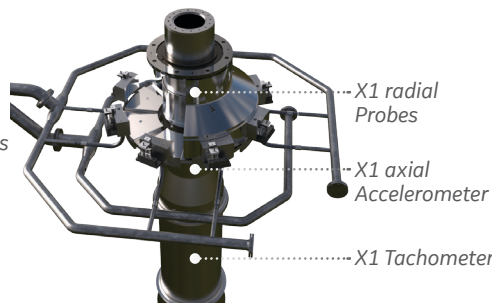
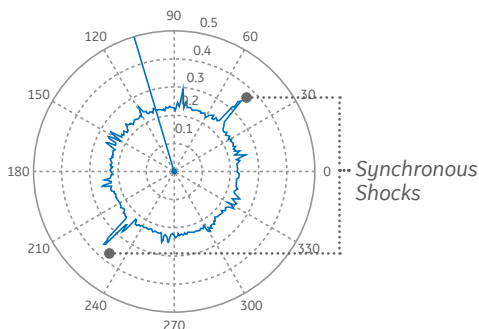


Early Detection - Monitor all signals simultaneously

- ✓ Versatile
- ✓ Self-learning
- ✓ Using available sensors
- ✓ Data driven + experts' rules

## ■ Edge Analytics – Hydro Edge Platform

Edge analytics are used when real time and fast data acquisition is required (e.g. transient/dynamic phenomena analysis). It requires that the GE Hydro edge platform is installed in the plant to capture and process high frequency data continuously. Smart indicators are created from the raw signals and instantaneously contextualized with operational data, detecting abnormal operations or tracking any asset behavior change over time.

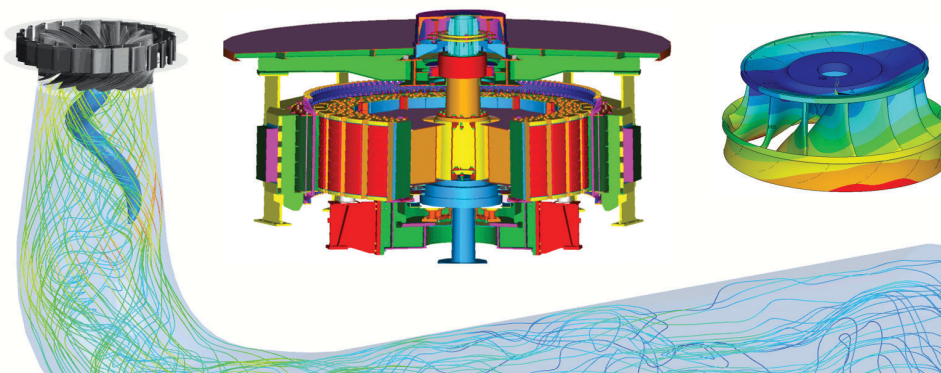


Synchronous shocks in the thrust bearing example

- ✓ High frequency analysis
- ✓ Domain-specific models
- ✓ Self-learning
- ✓ Physics-based and design rules
- ✓ Using GE edge platform and a GE-defined set of sensors

## ■ OEM Design Analytics

OEM design analytics use highly customized models which require OEM data and that generally focus on predicting the asset remaining useful life. They can be used online as part of APM Reliability to quantify and follow the asset life consumption when powered by the actual operating data. They can also be used off-line as part of a health assessment when fed with the asset historical data. And finally, they can run and test different operating scenarios and verify the impact on the asset lifetime.



Hydro assets design

- ✓ Highly customized
- ✓ FEA- and CFD-based models
- ✓ Using a GE-defined set of sensors

# Unlock Operation Optimization & Flexibility

## with a combination of Services, Analytics and Control functions

The rise of wind and solar within the energy mix requires adapting how we generate electricity. This places increased pressure on hydropower to provide flexible and reliable power services, enabling a more resilient electric grid.

Flexibility usually implies operating hydro assets differently: under partial load conditions or increasing the cycling or mode transitions per day which can accelerate equipment damage and lead to possible premature failures.

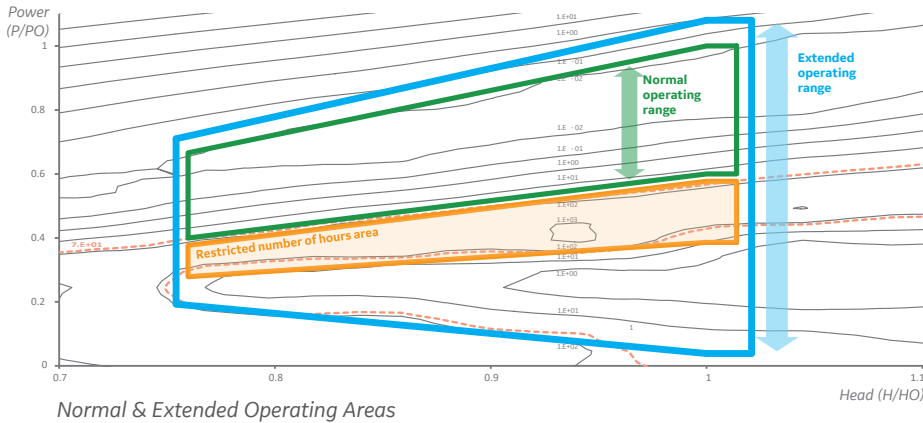
GE's Digital Hydro solutions can help harvesting the full flexibility potential of the hydro assets while allowing better-informed decisions and risk management.



# FLEXIBLE OPERATION APPLICATIONS

## Extend the Operating Range of your Existing Asset

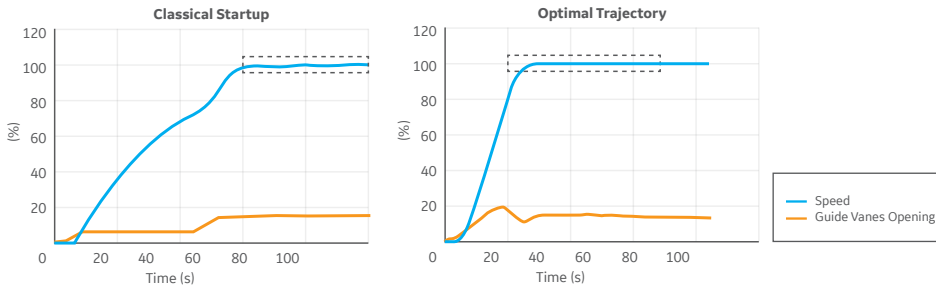
Assess the potential for extending the operating range of a turbine and unlocking new operating areas and patterns, through a mix of historical data analysis, site tests, model tests and advanced modeling. If the assessment determines that the range of operation can be extended, GE provides an advanced monitoring & diagnostic system with specialized visualization to monitor the time spent in each of the new operating zones and provides alerts when the operation time in these zones exceeds recommended limits.



Increase revenue and reduce failure risk

## Speed up the Start-up and Mode Transition with Sequence Booster

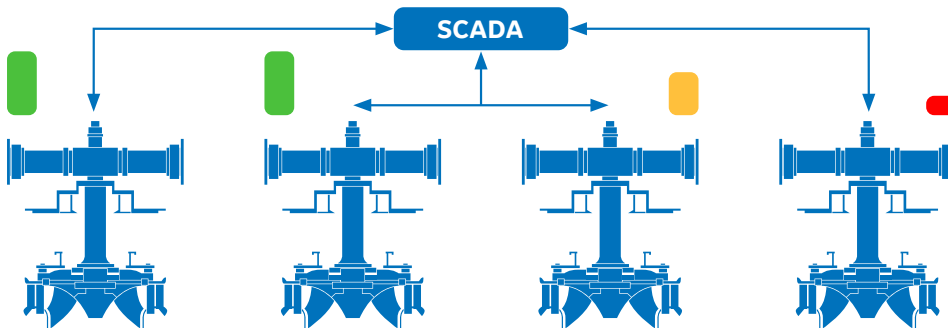
Improve the starting sequences either to switch from one operating point to another more quickly through enhanced control logics or to reduce turbine damage that can come from speed no load operation during the starting sequence.



<70s to start a pump turbine from idle to full power (demonstrated on 2x150MW PSP)

## Optimize your Asset Dispatch Within your Plant with Smart Load Dispatch

Optimize the dispatching of your units within the plant based on machine design and health conditions in order to minimize the wear and tear or maximize efficiency and optimize maintenance.



Optimize the dispatch of your unit based on efficiency, wear, asset health

# Flexibility Use Cases

## Accommodate Increased Intermittent Renewable Energy on the Grid

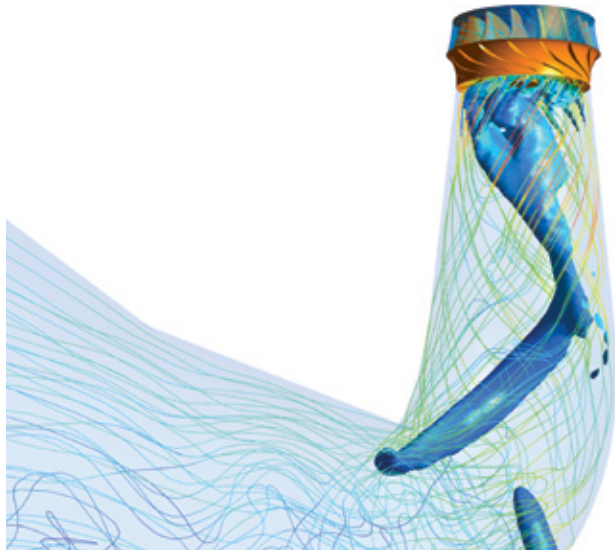
### Challenges

The increase of wind and solar in the energy mix is driving the need for more flexible hydropower assets to ensure stable and safe grid operations.

Partial load operation and more frequent starts and stops can strain the asset beyond its original design limits.

### GE Renewable Energy's Hydro Solution

GE's solution assesses the capacity of the existing asset to operate in off-design conditions and quantifies the impact on asset health when operating under these new conditions. GE monitors the asset over time, leveraging APM solutions, and raises an alert when the time limit is exceeded and an inspection is recommended.



Partial load vortex

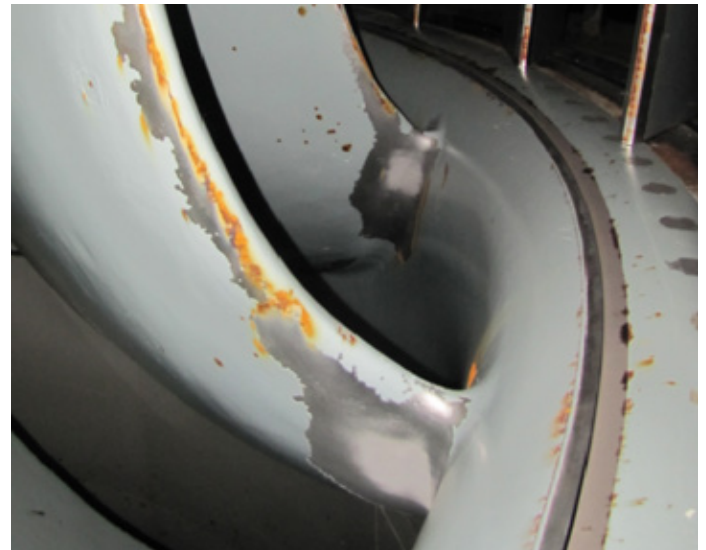
## Deal with New Hydraulic Operating Conditions due to Climate Change

### Challenges

Changes in reservoir levels create different hydraulic conditions from which the asset was originally designed. As a result, the operator might be forced to operate the asset under partial load with a minimal flow or a different head which could lead to cavitation or other negative hydraulic phenomena.

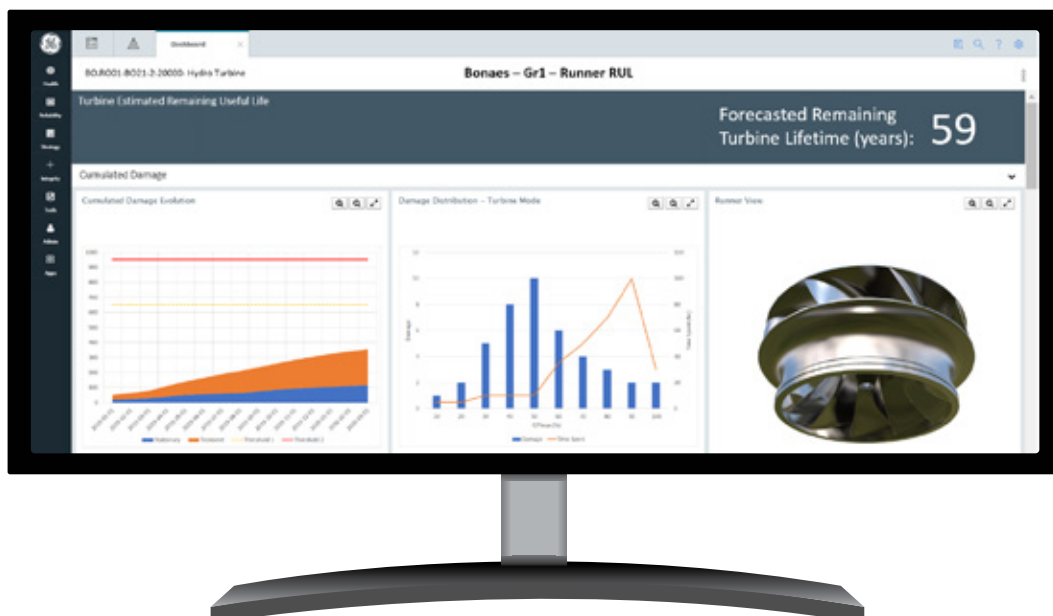
### GE Renewable Energy's Hydro Solution

A custom model, leveraging OEM data is used in the monitoring process to qualify and quantify the cavitation damage. The accuracy of the model can be improved with runner inspections.



Cavitation damage example

## Follow the Remaining Useful Life of your Asset with Specific Dashboards



# Commercial Models Ideal for your Needs

## From standalone software to fully integrated O&M services contracts with performance guarantees

GE Renewable Energy proposes a variety of commercial models to package our products and services in a way that is the most suited to support our customers in operating & maintaining their hydro power assets while meeting their constraints and expectations.

### DIGITAL SOLUTIONS AS A PRODUCT



Our digital solutions can be delivered in the form of software and hardware products. Our Customers are the end users of GE's technology and keep full control of and full responsibility for maintaining and operating their assets.

### ON-DEMAND ASSESSMENT & AUDITS



For on-the-spot needs, you can call on GE's on-demand assessment and audit services. GE comes to you and assesses the state of your entire hydro plant, or of one of its components, or investigates a specific issue you have encountered. GE is using its digital solutions to perform such assessments and audits.

### SERVICES AGREEMENTS



GE also offers fully-tailored digitally-enabled service agreements. GE's service agreement portfolio runs from framework agreements to O&M performance-oriented contracts with flexible guarantees, incentives and risk sharing. GE's digital solutions are leveraged by GE to deliver an unrivaled level of services.



**LOWER**  
maintenance costs



**HIGHER**  
availability



**MAXIMIZED**  
production

# CUSTOMER REFERENCES



## EDP | 23 HPPS – 5.5 GW PREDIX<sup>(1)</sup> APM + EDGE ANALYTICS

### CHALLENGE

- More market volatility
- More stringent regulations
- New operating needs
- Build a multi-fleetwide Remote Monitoring Center (Hydro+Thermal)

### GE SOLUTION (HYDRO)

- APM Reliability (APR + Edge Analytics)
- Asset Operations Flexibility (Partial load extension)
- Remote M&D Services

### OUTCOMES

- Increased Asset Reliability and Improved Maintenance
- Increased revenue from flexible operations



## EXELON | 2 HPPS – 1.6 GW PREDIX APM

### CHALLENGE

- Enhance O&M activities and practices using digital technology

### GE SOLUTION (HYDRO)

- APM Reliability (APR analytics)
- APM Strategy
- Digital services

### OUTCOMES

- Reduced forced outage cost
- Improved operational efficiency
- Improved organization productivity



## ENEL | 29 HPPS – 4 GW APM RELIABILITY (SMARTSIGNAL)

### CHALLENGE

- Implement predictive maintenance strategy using newly built data lake

### GE SOLUTION (HYDRO)

- APM Reliability on-prem (APR analytics)
- Site assessment
- Remote M&D Services

### OUTCOMES

- Increased Asset Reliability and Improved Maintenance
- Increased safety



## LARGE HYDRO OPERATOR | 1 HPP – 1 UNIT - 805 MW APM RELIABILITY (EDGE ANALYTICS)

### CHALLENGE

- Operation in Rough zones
- Erosion cavitation issues

### GE SOLUTION (HYDRO)

- Edge Analytics Cavitation Monitoring
- Remote M&D Services

### OUTCOMES

- Reduced operations risk
- Improved maintenance

(1) GE's Industrial IoT Platform to connect, optimize, and scale digital industrial applications



# 100+ HYDRO PLANTS, 30+GW

Relying on GE Renewable Energy's Hydro Digital Solutions



## BC HYDRO

**32 HPPS – 11 GW**  
APM RELIABILITY (SMARTSIGNAL)

### CHALLENGE

- Changing business environment
- Fewer subject matter experts

### GE SOLUTION (HYDRO)

- APM Reliability on-prem (APR analytics)
- Digital services (support)

### OUTCOMES

- Reduced unplanned downtime
- Improved planned maintenance
- Increased uptime



## MANITOBA HYDRO

**13 HPPS – 6 GW**  
APM STRATEGY (MERIDIUM)

### CHALLENGE

- Absence of integrated database and comprehensive workflows to collect NERC
- Multiple sources of data with various formats

### GE SOLUTION (HYDRO)

- APM Strategy on-prem (Meridium)
- Digital services (support)

### OUTCOMES

- Improved data validation
- Improved analysis opportunities
- Standardized and streamlined reporting capabilities



## DAGACHHU

**1 HPP – 1 UNIT – 63 MW**  
APM RELIABILITY (EDGE ANALYTICS)

### CHALLENGE

- Get real-time insight on critical components
- Move from planned to condition-based maintenance

### GE SOLUTION (HYDRO)

- APM Reliability (Edge Analytics)
- Remote M&D service

### OUTCOMES

- Help to avoid catastrophic failures
- Reduced unplanned maintenance
- Improved planned maintenance



## NYPA

**10 HPPS – 4.5 GW**  
APM RELIABILITY (SMARTSIGNAL)

### CHALLENGE

- Provide customers with low-cost, clean, reliable power with industry-leading infrastructure

### GE SOLUTION (HYDRO)

- APM Reliability (APR analytics)
- Digital services (support)

### OUTCOMES

- Increased reliability
- Decreased operations cost





For more information, visit  
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