Nuclear Combust, Flow and Treat Markets and IIoT Impact

Markets

Operators

Guide

Control

Measure

Pumps

Filtration

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Markets

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Nuclear Power Generation will Grow at 2.3 Percent

- Nuclear power plants will spend $11 billion for combust, flow and treat products and services in 2018.
- Global nuclear power generation is now predicted to grow by 2.3 percent per annum out to 2035, mainly due to 11 percent annual growth in China. China's operating nuclear generating capacity will double over the next five years under the country's recently-published 13th Five-Year Plan.
- Under that plan, over the next five years combust flow and treat hardware and parts expenditures for existing plants next year will be four times greater than for new plants. Guide, control, and measure hardware investments will be ten times greater for existing plants than new ones in 2018. Service and remote monitoring will be 50 times greater for existing plants than the new ones (during the first year of operation).
- Over 90 percent of the combust, flow and treat expenditures will be made by fewer than 50 companies. Thirty-nine percent will be made by just three operators and one supplier.
- Bechtel has completed more than 74,000 megawatts of new nuclear generation capacity, and has performed engineering and/or construction services on more than 80 percent of nuclear plants in the United States and 150 worldwide. It employs 2,200 nuclear professionals, which include approximately 150 internationally recognized technical specialists who have been published widely and have participated in developing industry standards and guidelines. It is a major influence in ten percent of the combust, flow and treat decisions.
- EDF has acquired Areva and then restructured the New NP reactor business to allow minority share purchases by Mitsubishi Heavy Industries and Assystem. In addition to operating 70,000 MW of nuclear power in France the company is negotiating the sale of nuclear power plants in China, India, South Africa and Saudi Arabia. Therefore, it is responsible for 20 percent of the nuclear combust, flow and treat decisions.
- Korea Electric Power (KEPCO) is a nuclear power operator with a capacity of 23,116 MW. It is operating 25 nuclear power units as of 2016 with five under construction. It will make five percent of the combust, flow and treat purchasing decisions in 2018.
- Exelon has consolidated nuclear power operations in the U.S. and is now operating plants with a capacity of over 19,000 MW. It will make four percent of the 2018 combust, flow and treat decisions.
- McIlvaine is forecasting the combust, flow, and treat purchases for the 100 largest power companies as shown on the next chart

Nuclear Power Plant Combust, Flow and Treat Purchases 2018 - $ millions					
	World	**EDF**	**Bechtel**	**KEPCO**	**Exelon**
Percent	100	20	10	5	4
Guide	1400	280	140	70	56
Control	2200	440	220	110	88
Measure	1200	240	120	60	48
Valves	2000	400	200	100	80
Macrofiltration (Belt Presses, Sand Filters)	200	40	20	10	8
Pumps	1100	220	110	55	44
Treatment Chemicals	1400	280	140	70	56
Sedimentation and Centrifugation	300	60	30	15	12
Variable Speed Drives and Motors	600	120	60	30	24
RO/UF/MF Cross Flow Membrane Systems	200	40	20	10	8
Air Purification and Protection	400	80	40	20	16
Total	**11,000**	**2200**	**1100**	**550**	**440**

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Continuous Forecasting of Purchases by Operators and EPCs

- These estimates are very approximate and involve problems with the precise defined scope. Orders are booked in one period. Revenue might be realized in a series of succeeding periods. The purchasing decision may be shared between the OEM, the EPC and the operator. Some decisions will be made at the plant level. Others will be made at the corporate level. However, with the rapid deployment of IIoT more and more decisions will be made at the corporate operator level. Process management system companies will be an increasing influence.
- Forecasts for the individual purchasers provide an important tool for suppliers. Most already have separate sales efforts for the large purchasers. IIoT will result in most decisions being made or specified at the corporate level. So the OEM sales effort will need to expand.
- Forecasts of individual operator purchases are equivalent to pieces of a puzzle. The sales forecast is built upon a picture puzzle for which many of the pieces are missing. The more pieces which are fitted together, the more accurate the picture becomes.
- McIlvaine is providing combust, flow and treat forecasts for more than 550 companies. They appear in the various market reports. The guide, control and measure forecasts for individual nuclear power generators and suppliers are included in **N031 Industrial IoT and Remote O&M** The nuclear valve forecasts appear in the Industrial Valves World Markets which also has a supplemental analysis for the 5000 high performance valves in an Areva system. There are market reports covering each of the subject areas found in MARKETS LINK. The profiles of individual power companies and suppliers are included in the Utility Tracking System **42EI Utility Tracking System**.

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Top 10 Nuclear Generating Countries

2016, Billion kWh

Source: International Atomic Energy Agency
Updated: 4/17

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nuclear. clean air energy.

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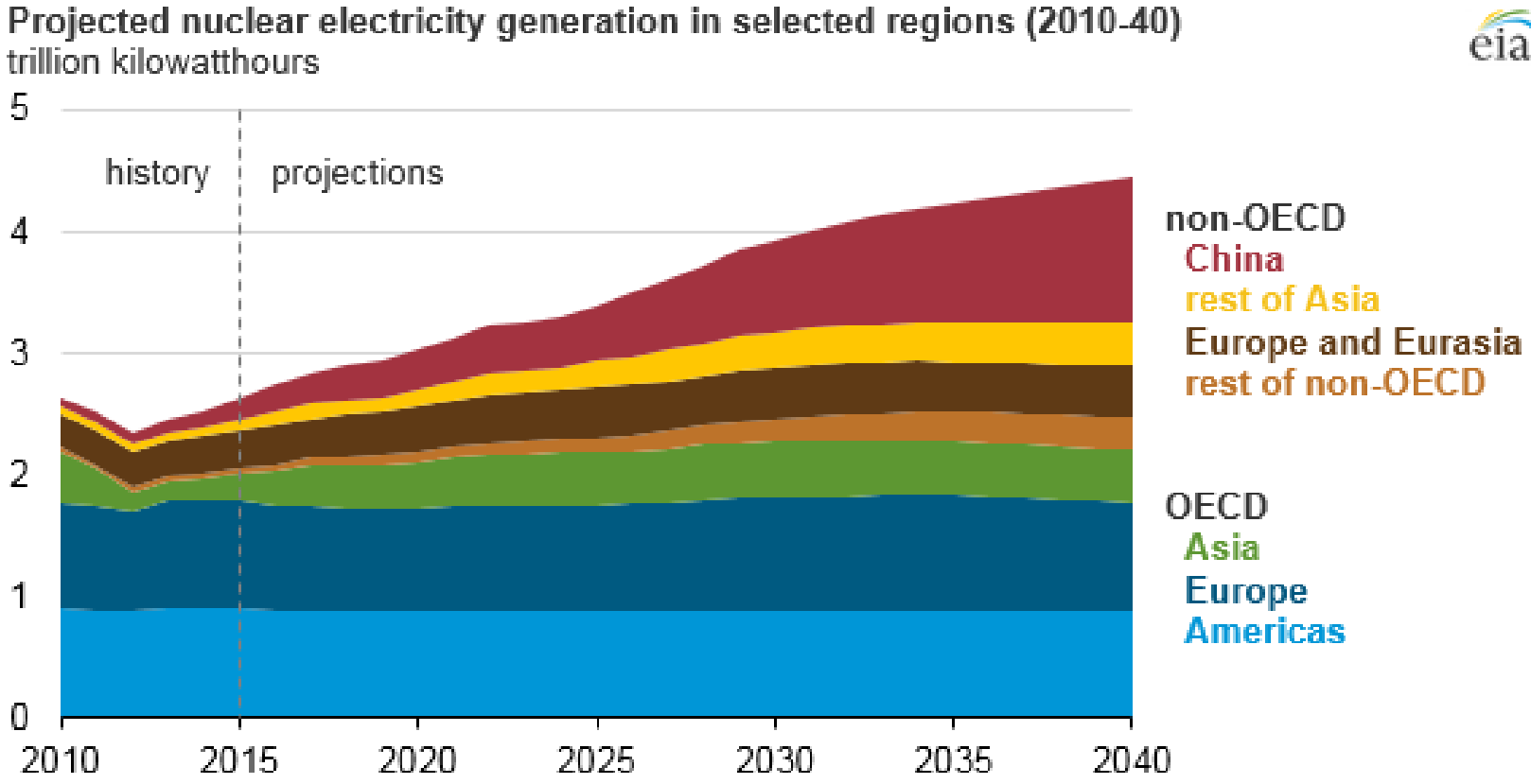
China Key to Nuclear Growth

BP has increased its nuclear power output forecast for 2035 by 7.9% to 927 million tons of oil equivalent (mtoe) in its latest Annual Energy Outlook, published January 25.

Global nuclear power generation is now predicted to grow by 2.3% per annum out to 2035, mainly due to 11% annual growth in China, BP said. "China's rapid nuclear expansion program accounts for nearly three-quarters of the global increase in nuclear generation. This is roughly equivalent to China introducing a new reactor every three months for the next 20 years," BP said in its report.



In comparison, the US Energy Information Administration (EIA) has predicted China will account for around half the global growth in nuclear power out to 2040

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China has Aggressive Nuclear Program

China's operating nuclear generating capacity will double over the next five years under the country's recently-published 13th Five-Year Plan. Under that plan, over the next five years China aims to have all four Sanmen and Haiyang AP1000 units in operation by the end of this year. It also aims to develop Hualong One demonstration projects at Fuqing and Fangchenggang and begin construction on the CAP1400 demonstration project at Shidaowan. China will also start building a number of coastal nuclear power plants and carry out preliminary work for inland projects. Mainland China has 36 nuclear power reactors in operation, 21 under construction, and more about to start construction. Additional reactors are planned, including some of the world's most advanced, to give a doubling of nuclear capacity to at least 58 GWe by 2020-21, then up to 150-250 GWe by 2030, and much more by 2050.

Chinese Five Year Plan – 2018-2022 Includes more than 60 GW in Operation and 30 GW under Construction

As of May 2017, China has 37 land-based nuclear reactors operating with a capacity of 32.4 GW and 20 under construction with a capacity of 20.5 GW.

The **13th Five-Year Plan** formalized in March 2016 included the following nuclear projects and aims:

- Complete four AP1000 units at Sanmen and Haiyang.
- Build demonstration Hualong One reactors at Fuqing and Fangchenggang.
- Start building the demonstration CAP1400 reactor at Rongcheng (Shidaowan).
- Accelerate building Tianwan Phase III (units 5&6).
- Start building a new coastal power plant.
- Active preparatory work for inland nuclear power plants.
- Reach target of 58 GWe nuclear operational by end of 2020, plus 30 GWe under construction then.
- Accelerate and push for building demonstration and large commercial reprocessing plants.
- Strengthen the fuel security system.

A consortium of Chinese organizations is teaming up with state-owned **China National Nuclear Power Company** to develop and produce small, floating nuclear power plants. The new venture will have $150 million in funding and will include Zhejiang **Zheneng Electric Power**, Shanghai **Guosheng Group**, Shanghai-based **Jiangnan Shipyard Group** and **Shanghai Electric Group**. The plants will be able to sail to where they are needed and could be used to operate drilling equipment for offshore oil and gas fields, to power facilities on the remote islands of the South China Sea, to meet heating and desalination needs or to run nuclear-powered icebreakers.

The reactors may also be exported to economies with large populations but scarce land resources, including economies participating in the Belt and Road Initiative, such as Pakistan, Bangladesh and Myanmar. The technology used may involve high temperature gas-cooled reactors which China is jointly developing with Saudi Arabia and the United Arab Emirates.

China is expected to build 20 floating nuclear power stations.

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Operators

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Exelon has Consolidated Nuclear Operations in the U.S.

Exelon is operating over 19,000 MW of U.S. nuclear plants as of 2017. As shown on the 2011 chart it was the leader with 16,715 MW but now as added the 1939 MW of Constellation Energy. Entergy is now the second largest Nuclear operator with 9000 MW of capacity in operation.

Company	Ticker	Market Cap Billion USD	Nuclear Power Generation (MW)	Total Power Generation (MW)	Percent Nuclear Generation
Exelon	EXC	26.34	16715	17973	93.0%
Entergy	ETR	11.68	10128	24299	41.7%
Dominion Resources	D	25.27	5690	27600	20.6%
NextEra Energy	NEE	23.26	5470	18866	29.0%
Duke Energy	DUK	23.95	5173	34600	15.0%
FirstEnergy	FE	15.47	3861	24000	16.1%
Progress Energy	PGN	13.3	3770	19840	19.0%
Southern Co.	SO	31.69	3644	42963	8.5%
PSEG Nuclear	PEG	15.47	3612	15500	23.3%
PG&E Corp	PCG	17.36	2240	8038	27.9%
Edison International	EIX	12.35	2237	15676	14.3%
PPL Corp	PPL	13.02	2093	19300	10.8%
American Electric Power Co.	AEP	16.64	2069	38000	5.4%
Constellation Energy	CEG	6.58	1939	12000	16.2%
Xcel Energy	XEL	11.36	1668	16446	10.1%
Ameren	AEE	6.79	1190	16900	7.0%
NRG Energy	NRG	5.28	1175	25749	4.6%
Pinnacle West	PNW	4.58	1147	6380	18.0%
DTE Energy	DTE	8.19	1122	11084	10.1%
SCANA Corp.	SCG	4.94	644	5084	12.7%
El Paso Electric Company	EE	1.25	623	1643	37.9%
Great Plains Energy	GXP	2.73	545	6100	8.9%
Westar Energy	WR	2.93	545	3080	17.7%
Berkshire Hathaway	BRK.A	202.4	434	7200	6.0%
Sempra Energy	SRE	12.68	430	5500	7.8%
PNM Resources	PNM	1.26	400	2706	14.8%
Central Vermont Public Service	CV	0.297	20	101	19.8%

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KEPCO is the Sixth Largest Nuclear Plant Operator

Korea is a nuclear power stronghold with a capacity of 23,116 MW, which is the sixth largest in the world. Korea is operating 25 nuclear power units as of 2016 with five under construction.

Korea plans to build an additional four nuclear power plants by 2027. Plants under construction guarantee world-class safety capable of withstanding a 7.0 earthquake on the Richter scale. KEPCO's world-class operational capability is demonstrated by only 0.13 interruption/unit/year and 85.3% in throughput, as of 2015, as well as its world-class competitive edge in nuclear power plant construction skills. KEPCO and its group companies armed with rich operational know-how and technological strength have put overseas nuclear power plant business as the key business agenda to create profits in the years ahead.

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Rosenergoatom has 35 Nuclear Blocks

Rosenergoatom is the sole Russian nuclear utility, following consolidation in 2001. *This includes 10 Russian nuclear power stations operating 35 power blocks* (*excluding the Novovoronezh NPP's 6th power block being at the pilot production stage): 18 of them operate VVER reactors (12 VVER-1000 power blocks and 5 VVER-440 power blocks of different modifications); 15 of them with channel reactors (11 power blocks with RMBK-1000 reactors, four power blocks with EGP-6 reactors); and 2 power blocks with fast neutron sodium cooling reactors (BN-600 and BN-800).*

EDF Operates Plants and with Areva is also Building Plants

- EDF's head of new nuclear, Xavier Ursat, said the company is in talks with several countries about selling nuclear power plants, including China, India, South Africa and Saudi Arabia.
- EDF (EDF.PA) is set to complete its takeover of the reactor unit of nuclear group Areva later this year and has taken the lead in negotiating export contracts for Areva's flagship European Pressurized Reactor (EPR).
- "We are in talks with several countries about new EPR contracts," Ursat told reporters at an EDF strategy briefing.
- Ursat said talks with India's NPCIL were progressing well and he hoped a deal for six Areva-designed EPR reactors could be signed in the coming months.
- "India is one of the countries most suited to build new nuclear," Ursat said, adding that the country's strong industrial and academic environment underpinned new nuclear.
- Ursat is also in talks with China about new EPR contracts, although Chinese authorities have said new contracts will have to wait for the startup of the first of two EPR reactors under construction in Taishan, southern China.
- EDF remains in contact with South African nuclear authorities and hopes that a tender procedure that was interrupted earlier this year will resume soon. He also confirmed that EDF is in talks with Saudi Arabia, which is considering a nuclear newbuild program.

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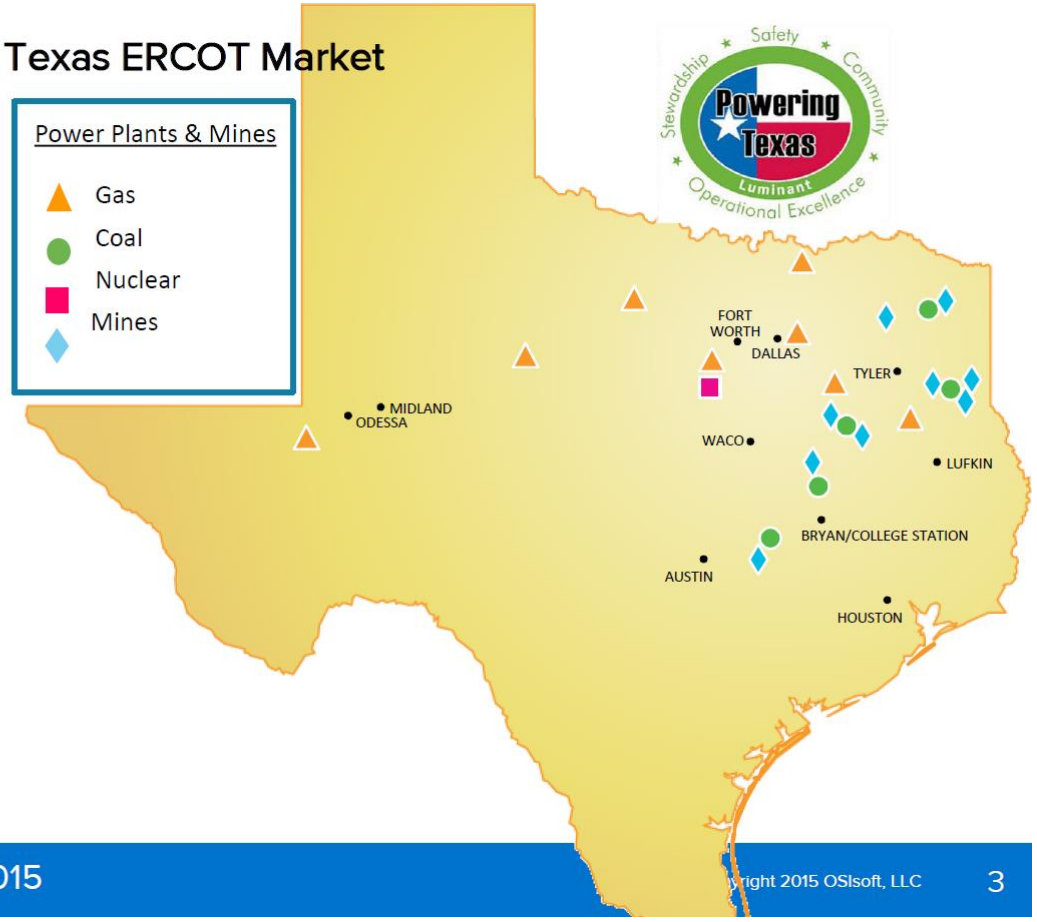
Luminant has Top Performing Nuclear Plant

Luminant's Footprint in the Texas ERCOT Market

- 13,772 MW, including new clean-air generation
- Coal emissions reduced by more than 20% since 2005
- Top U.S. coal producer
- Top-performing U.S. nuclear plant
- Potential nuclear expansion
- Major U.S. wind purchaser



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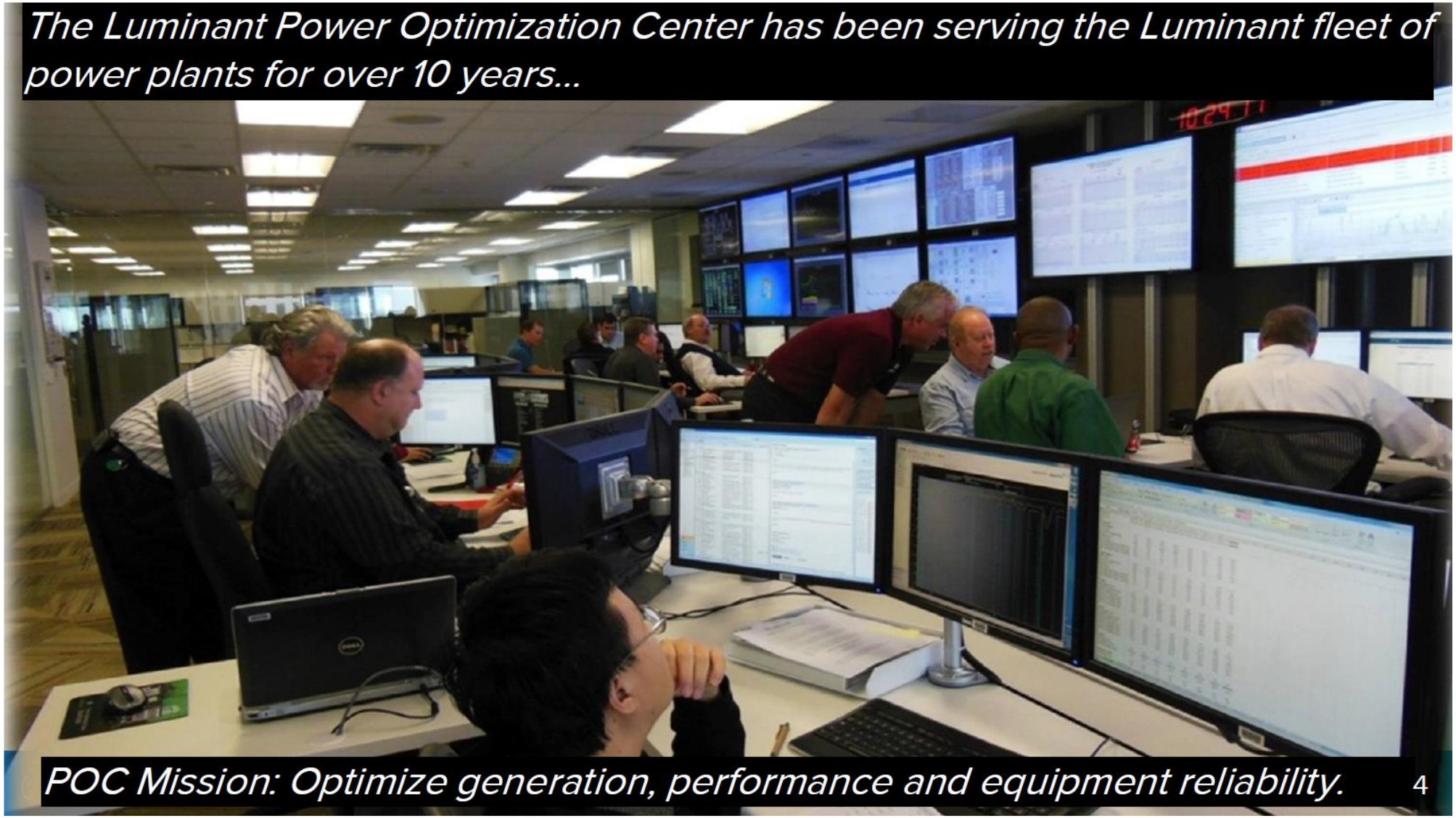
The Luminant Power Optimization Center has been serving the Luminant fleet of power plants for over 10 years…

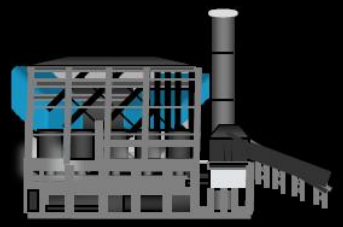


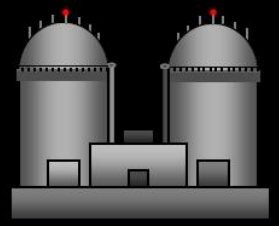
POC Mission: Optimize generation, performance and equipment reliability.

POC Value Stream…

Immediate Opportunities

Long Term Improvements





Asset Health Programs

Engineering Trending

Outage Planning

Plant Systems

Digital Control System

Plant Process Computer

Turbine Vibration Monitoring

Partial Discharge Motor Monitoring

Boiler Tube Leak Detection

Process Chemistry

Plant Data Historian

Emissions Management System

Wireless Vibration Monitoring

Bowl Mill Diagnostics

Generation Challenges

Performance Degradation

Faulty Instrumentation

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POC Client Services

- 24x7 Predictive Monitoring & Diagnostics of Critical Equipment, Plant Systems and Performance
- Plant Start-up and Coastdown Reviews
- Online Chemistry Trending and Analysis
- Online Cycle Isolation Monitoring
- Fleet Watchlist – Reliability and Performance
- Course of Action Program – Emergent Issues
- Expanded Monitoring – Emergent Equipment Issues
- Automated Notifications
- Enterprise Cyber-Security Monitoring

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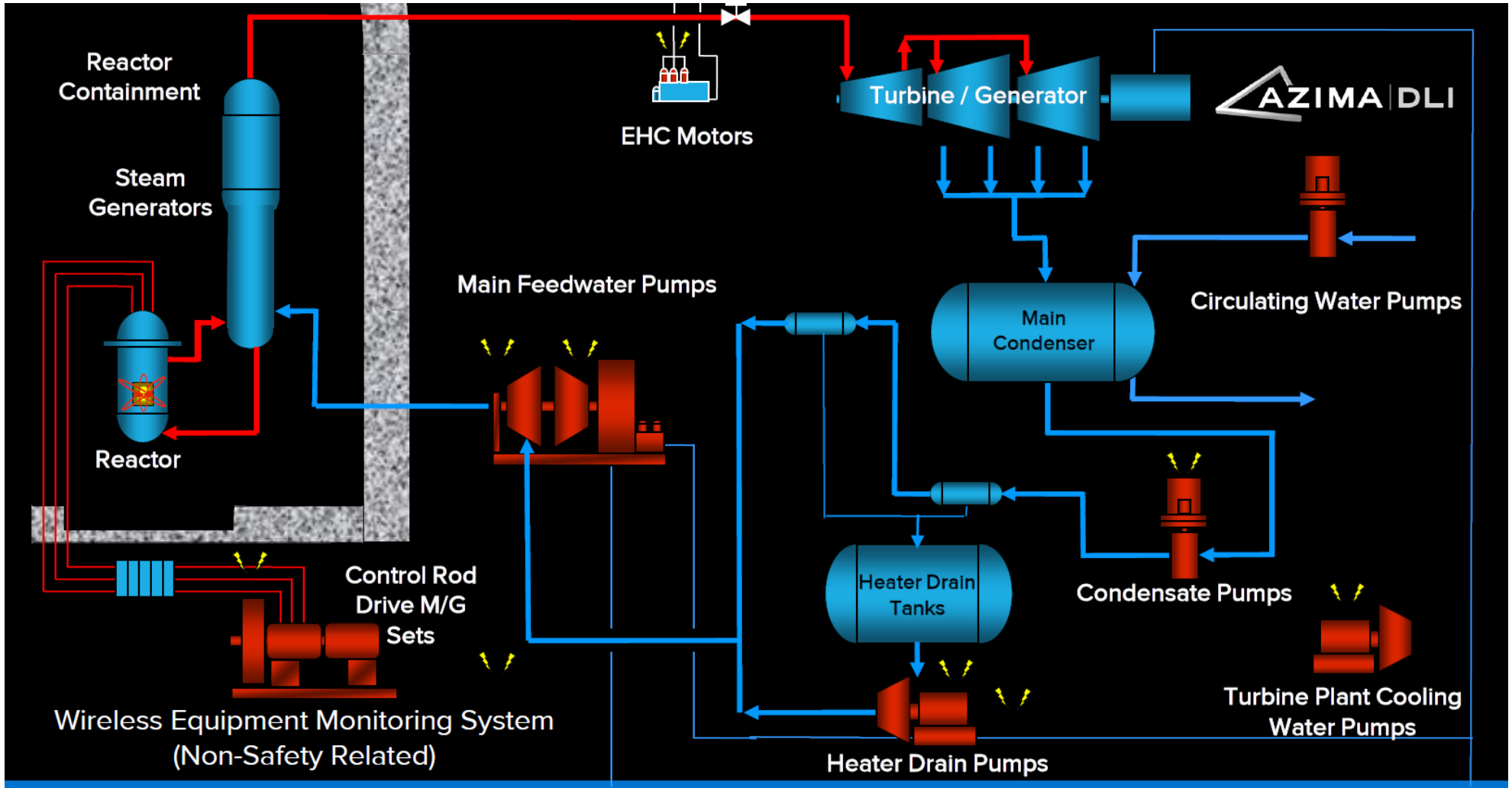

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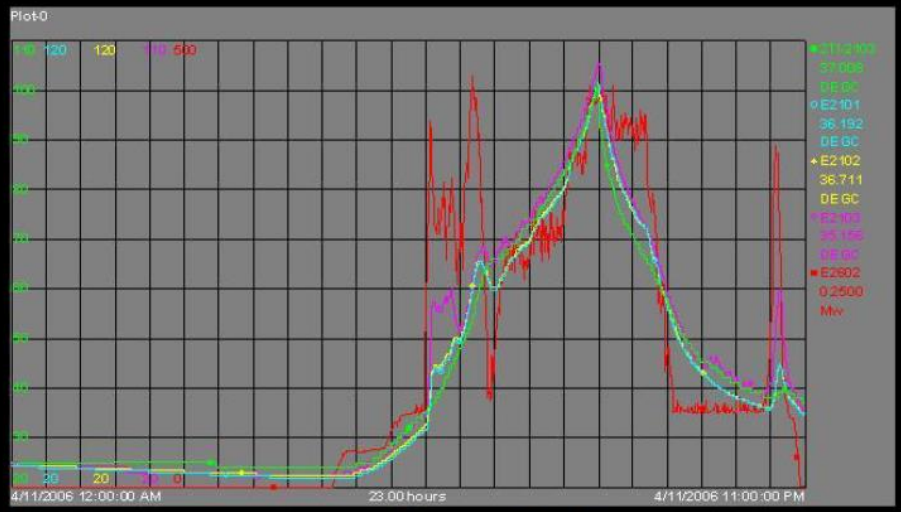
Predicting Failure – Main Power Transformer

Transformer



Winding temperatures peaked at 105°C and returned to 40°C following restoration of cooling fans and oil pumps.

The POC received a Cockpit alarm for a HI winding temperature for a Main Transformer and contacted the Control Room. Plant Operations quickly determined that the cooling fans and oil pumps were not in service and restored normal cooling. Having just returned from a unit outage, a breaker was found to be out of position, effectively blocking the Control Room alarm for high winding temperature. The restoration of normal cooling potentially avoided a catastrophic failure of the transformer and certainly avoided a major inspection.

Avoided Inspection Costs

Potential Lost Revenue

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Additional Examples of Remote M&D Contributions to Operations

- A low-flow alarm for generator primary cooling water was identified associated with a system pressure drop. Maintenance personnel determined that an associated transmitter caused the event.
- A high-temperature alarm was received on a condensate pump motor stator. The temperature was 35°F higher than normal. Operators investigated and replaced the cooling system filters.
- Identified a vibration issue on a main feedwater pump and assisted station personnel in developing an action plan to keep the pump in service until the next refueling outage.
- Identified a high vibration alarm on a control rod drive motor generator set. Performance Optimization Center personnel analyzed the vibration data and identified that the motor inboard bearing might have insufficient grease. Following greasing, vibration on the motor returned to normal levels.
- Identified elevated temperatures on the circulating water pump motor. Operations personnel identified that lubrication and cooling water flow required adjustment to maintain motor bearing temperatures within the expected operating band.

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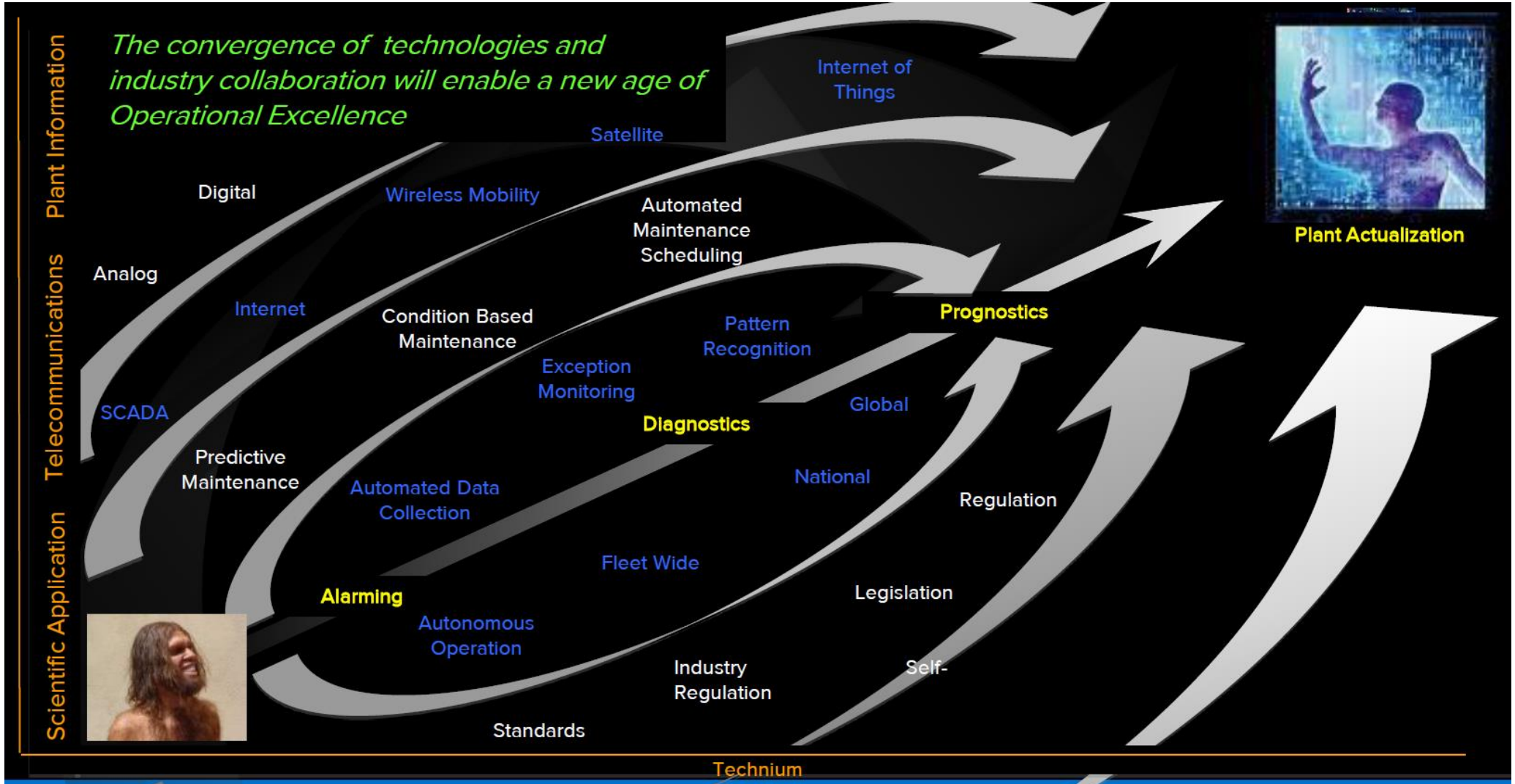

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Expanding Industry Operating Experience programs to include operational data will enable the development of fault signature models accelerating the advancement of prognostic capabilities

Prognostics

Fault Signatures

Pattern Recognition

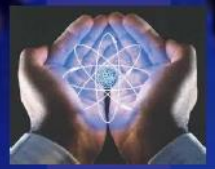
Analysis

Diagnostics

Nuclear Safety

Performance Reliability

Monitoring



The "Internet of Things" will enable us to strengthen safety, reliability and performance...

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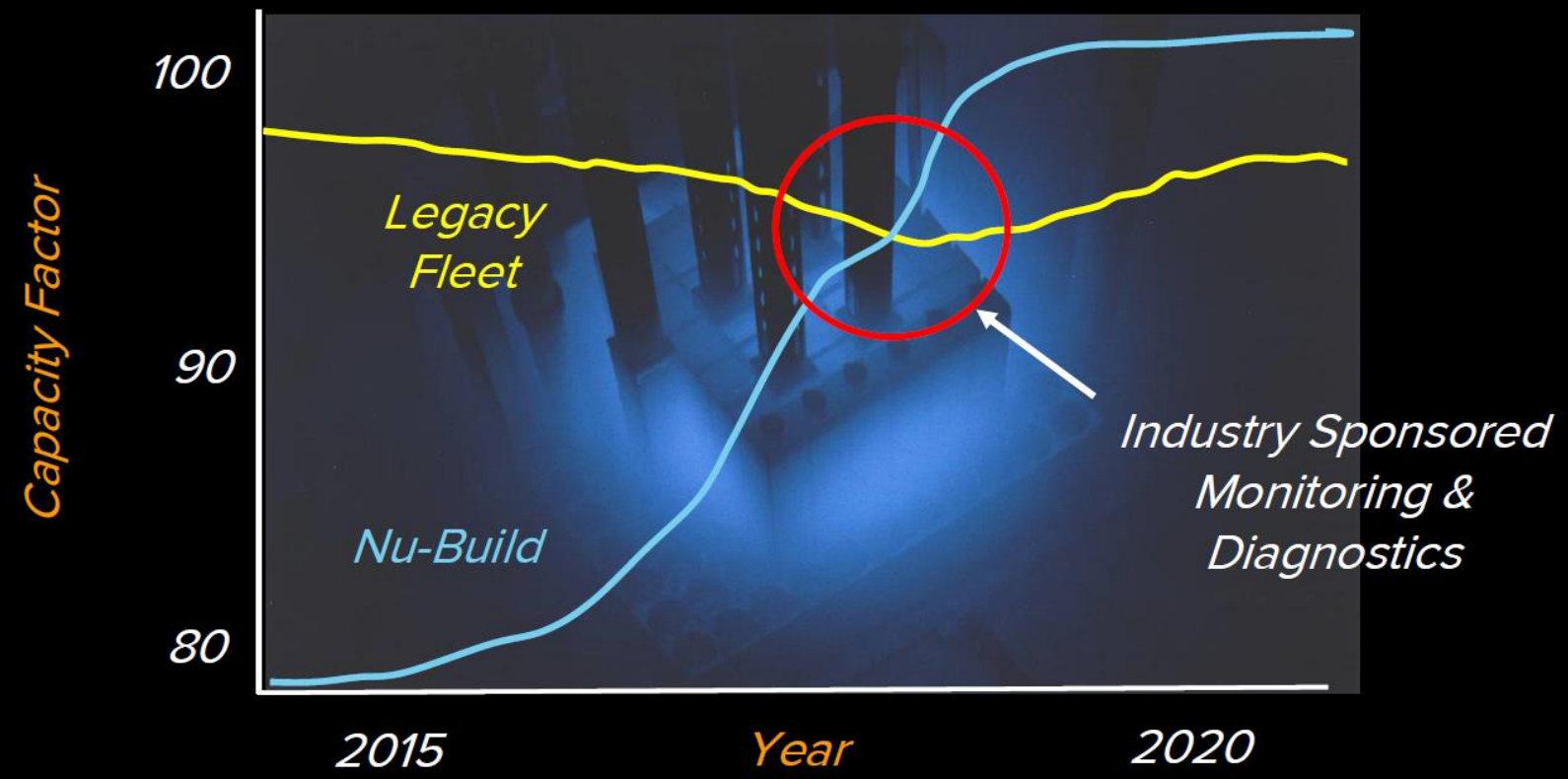
Industry sponsored Remote Monitoring & Diagnostics will play an important role as next generation nuclear facilities come on-line and similarly support legacy nuclear fleet.



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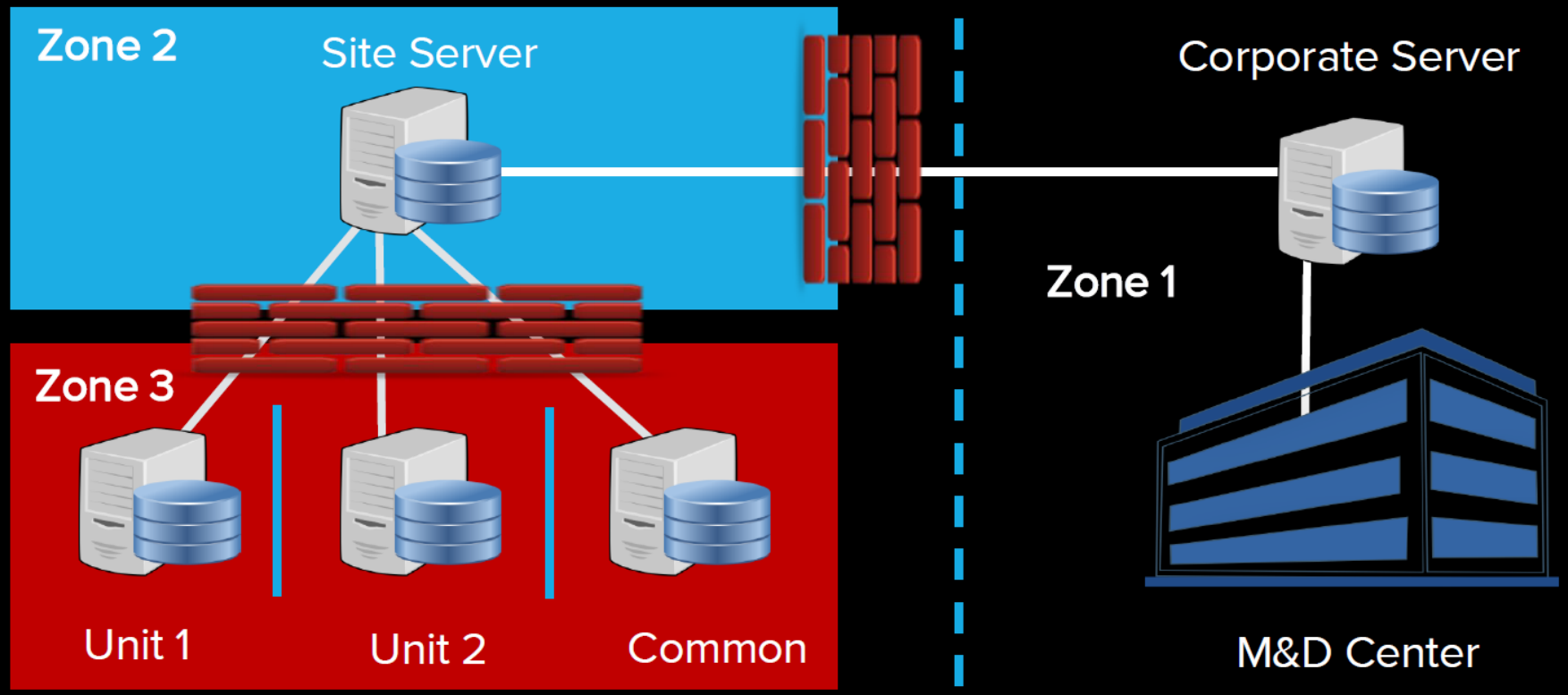
System Architecture Luminant

Zone 2 – at generation sites & does not have ability to impact power generation production

Zone 3 - at generation sites & does have ability to impact power generation production

Zone 1 – not at generation sites & does not have ability to impact power generation production



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- 29 Historians
- 500,000 tags
- 150 interfaces
- 17 years of data

Technology Stack used at Luminant

ANALYZE

HISTORIZE

COLLECT

PI DataLink	Notifications	PI ProcessBook	
PI ACE	Asset Framework	Data Access	Module Database
OPC DA/HDA	PI SDK	PI SMT	Tag Configurator
Allen Bradley RSLinx	AutoPoint Sync (PI APS)	ESC Stack Vision	Foxboro AP51
Foxboro AW70	Honeywell PHD	IT Monitor	MCN Health Monitor
Modbus Ethernet	Modbus Serial PLC	OLEDB Comm Connector	OPC
PI to PI	Universal File & Stream Loader		Westinghouse Ovation

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Guide

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IIoW to Retain Nuclear Knowledge

There is a big potential for providing remote advice using subject matter experts. As the accompanying article points out many nuclear experts around the world are retiring and it will be a challenge to retain that knowledge. Furthermore most new nuclear construction is in countries where there is not many decades of nuclear experience.

The nuclear power industry can benefit from the Industrial Internet of Wisdom (IIoW) to a greater degree than other industries and can become an IIoW leader.

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The nuclear energy sector is characterized by lengthy time frames and technical excellence. Early nuclear plants were designed to operate for 40 years but their service life now frequently extends between 50 and 60 years. Decommissioning and decontamination of nuclear plants will also be spread over several years resulting in a life cycle — from cradle to grave — in excess of 100 years, which gives rise to two challenges for the nuclear industry:

(1) Retention of existing skills and competencies for a period of over fifty years, particularly in countries where no new nuclear power plants are being planned; and
(2) Development of new skills and competencies in the areas of decommissioning and radioactive waste management in many industrialized countries if younger workers cannot continue to be attracted to the nuclear disciplines.

As many nuclear experts around the world are retiring, they are taking with them a substantial amount of knowledge and corporate memory. Typically, these retirees are individuals who can answer questions very easily and who possess tacit knowledge never before extracted from them. The loss of such employees who hold knowledge critical to either operations or safety poses a clear internal threat to the safe and reliable operation of nuclear power plants (NPPs). Therefore, the primary challenge of preserving such knowledge is to determine how best to capture tacit knowledge and transfer it to successors.

These problems are exacerbated by the deregulation of energy markets around the world. The nuclear industry is now required to reduce its costs dramatically in order to compete with generators that have different technology life cycle profiles. In many countries, government funding has been dramatically reduced or has disappeared altogether while the profit margins of generators have been severely squeezed. The result has been lower electricity prices but also the loss of expertise as a result of downsizing to reduce salary costs, a loss of research facilities to reduce operating costs and a decline in support to the universities to reduce overheads. The above factors have led to a reduction in technical innovation and a potential loss of technical competences that have drawn the attention of many concerned parties to the need for effective strategies and policies for nuclear knowledge management.

IIoW needs to Address and Leverage the Sources of

- Explicit codified knowledge
- Explicit non-codified knowledge
- Implicit codifiable knowledge
- Tacit non-codifiable knowledge

To retain and expand the tacit non codifiable knowledge it will be necessary to cultivate subject matter experts and allow them to become subject matter ultra experts (SMUEs).

FIG. 4. Example of a simplified knowledge map.

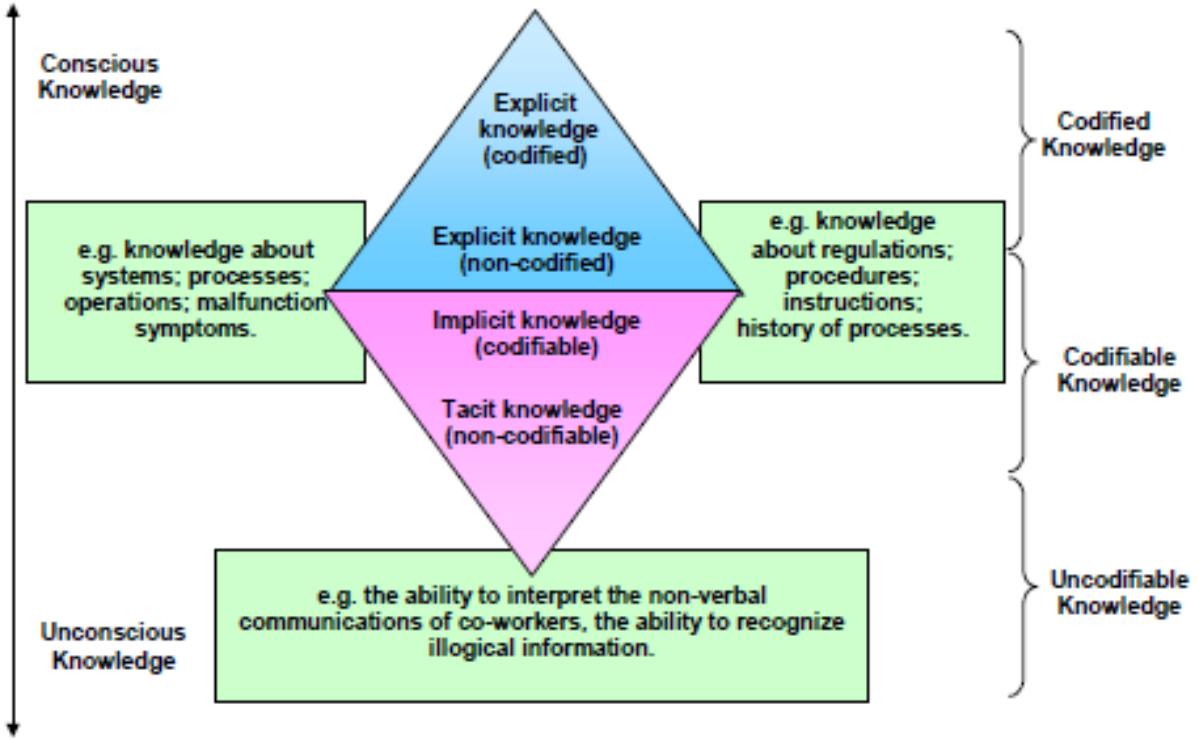

FIG. 5. Explicit, implicit and tacit knowledge.

These three types of knowledge — explicit, implicit and tacit — can be depicted using a diamond model (see Fig. 5). The top half of the diamond represents explicit knowledge — or conscious level knowledge — which has either already been codified or could be codified. The bottom half of the diamond represents unconscious knowledge — both *implicit knowledge* and *tacit knowledge*. The former can be codified if brought to the conscious level. However, the latter cannot be codified directly because it is at the deep-unconscious level. This model helps to demonstrate how important it is to coax departing workers to focus on the

ICERICS provides the Wisdom of the Crowd with Organized Subject Matter Expertise

- A review mission titled "Independent Engineering Review of I&C Systems" (IERICS) was established in 2009 with the aim of conducting peer reviews of I&C design documents, prototype I&C systems, and actual systems already deployed in operating NPPs. The IERICS mission is performed by a group of invited subject matter experts from various IAEA Member States. The review is based on appropriate IAEA documents, such as Safety Guides and Nuclear Energy Series Reports, and its findings are summarized in a mission report, including a list of recommendations, suggestions, and identified good practices. Organizations in IAEA Member States, such as utilities, regulators, technical support organizations, research laboratories and universities can benefit from I&C technical reviews through IERICS Missions that provide a detailed technical assessment on I&C systems, as well as recommendations for improvement
- In all six IERICS missions, the IAEA review teams confirmed that extensive engineering work of high quality had been performed to develop the advanced I&C systems, and in general the reviewed areas met the requirements of the relevant sections of the IAEA Safety Guide NS-G-1.3 (for the first four missions) and SSG-39 (starting from the fifth mission). Specific issues, identified as areas for further improvement, were listed in the issue sheets of the mission reports, as suggestions and recommendations. Good practices were also identified, serving as commendable engineering examples for other NPP I&C system design projects.

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The Fifth and Sixth IERICS Missions

- The fifth IERICS mission was conducted in Beijing, China in April 2016 at China Techenergy (CTEC). The subject of the review was their “FirmSys” Nuclear Safety I&C Platform and System. CTEC designed and developed the first version of FirmSys in 2010 and then improved the design in subsequent versions. FirmSys is a general platform for nuclear safety-class digital control and protection system applications for nuclear power plants. CTEC has implemented it in the modernization and upgrading of existing nuclear power plants and in new NPP designs. The objective of the mission was to provide CTEC with a basis for improving the technical design, safety features and reliability of the FirmSys system by implementing the recommendations and suggestions of the mission.
- The scope of the review included:
- FirmSys Platform V1.1:
  - Main control station;
  - Communication means and networks;
  - Safety control information display;
  - Engineering station;
  - Gateways.
- Both the hardware and software platforms were evaluated

- The sixth IERICS mission was performed at China Nuclear Control System Engineering Co., Ltd. (CNCS) in Beijing, China in November 2016. CNCS specializes in providing end-to-end full life-cycle service for DCS systems for nuclear power plants, including product development, engineering design, system integration and technical service.
- Since 2012, CNCS has focused on the nuclear safety class digital control and protection system – NicSys®8000N – a general system platform for control and protection, which will be used as protection systems and safety-related control systems in nuclear power plants. The NicSys®8000N platform is based on FPGA technology and it consists of standardized circuit boards and configuration files for FPGAs, CPLDs and CPUs. With multiple functions, such as I/O, logic calculation, diagnosis, information display, priority management, etc., the NicSys®8000N platform is capable of implementing the typical application functions such as reactor trip, engineered safety features control, post-accident monitoring and reactor core monitoring.
- The following subjects were requested by CNCS to be reviewed:
- The NicSys®8000N FPGA-based controller;
- Engineering work station;
- S-VDU device including the HMI interface;
- Both the hardware and software platforms were evaluated.
- The conclusions, recommendations, suggestions, comments and good practices were presented and agreed upon with the counterparts at the end of the missions and were documented in the final mission reports.

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Exelon using OSIsoft PI System

- Exelon Corporation is the largest owner and operator of nuclear plants in the United States. With 23 reactors at 14 facilities in Illinois, Maryland, Nebraska, New Jersey, New York and Pennsylvania, Exelon produces nearly 34,000 megawatts and powers millions of homes. Exelon believes the safety of the community and its workers is its highest priority, and that good maintenance ensures safety.
- Industry standards for good maintenance procedures have been based on manual data collection and analysis, time-based maintenance schedules, and resource-intensive preventive maintenance. Plant engineers physically collect plant data from sources all over the plant, including areas that might pose a radiation exposure risk. Collection is scheduled according to worker shifts, perhaps every 12 hours, leaving long periods for a fault to develop.

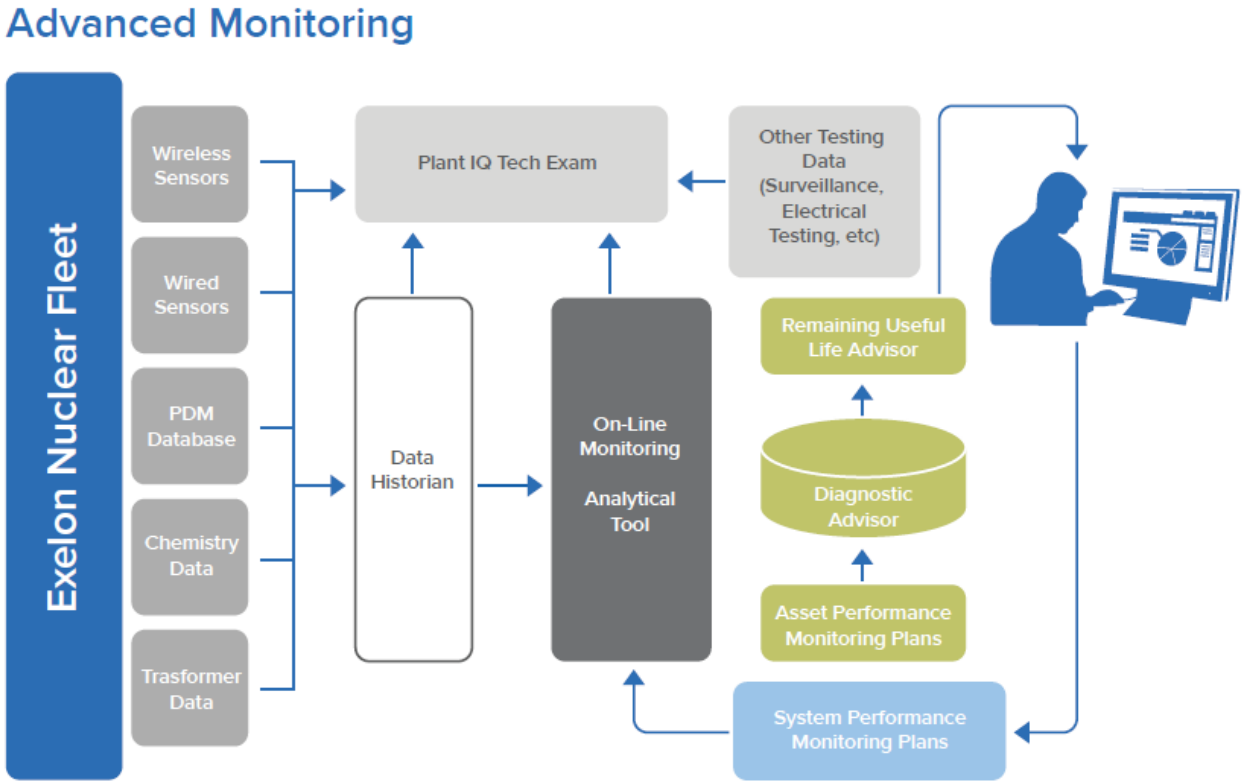

Figure 1. **Exelon's advanced monitoring system enables plant engineers to devote more time** to analyzing data and identifying potential maintenance issues.

,Exelon has employed OSIsoft's PI System for online monitoring to eliminate these problems . Using the PI System, Exelon has optimized the efficiency of its operations, maintenance, and engineering staff. By automating data collection, plant engineers now focus on analyzing data rather than manually collecting data and risking radiation exposure. "With this technology you use a condition-based cycle," said Mohammed Yousuf, Exelon Senior Staff Engineer. "You don't have to access the asset until the asset tells you something is going wrong." Using the PI System and advanced pattern recognition (APR), plant engineers at Exelon collect plant data, retrieve it for analysis, receive alerts for anomalous operating conditions, and correct faults with enough time to prevent system problems that could force the company to derate, shut down a unit, or compromise safety

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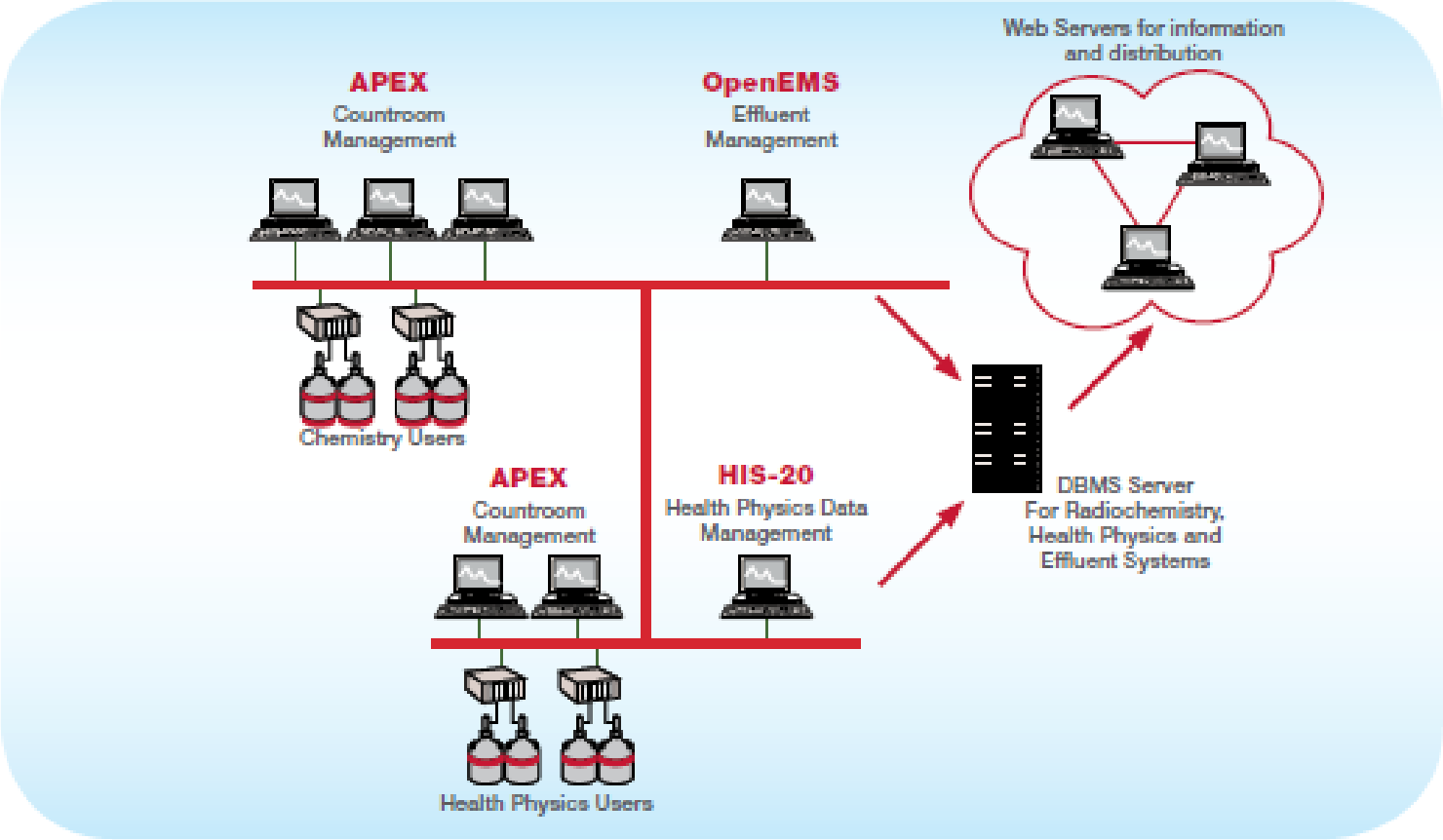
CANBERRA's data management

applications are designed to, not only maximize efficiency in the plant, but also provide an integrated solution for management and reporting requirements. In the rapidly changing nuclear power industry, reducing the time and resources dedicated to routine operations is the key to success. To meet these fundamental needs, CANBERRA applications are designed and implemented to integrate seamlessly, eliminating the need for redundant data entry, system administration and management.



CANBERRA's OpenEMS Effluent Management System provides a solution that integrates with plant equipment and offers a user-friendly, automated method for tracking radiological effluents. While there are many techniques throughout the world for estimating the impact of radiological effluents, they all require extensive calculations and drawing on large amounts of data to produce accurate, reliable results.

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Curtiss Wright Plant Performance

- Curtiss-Wright is an industry leader in the supply of complete turnkey plant monitoring and plant processing computer systems, having supplied systems and products to all of the nation's nuclear utilities and to many non-nuclear power plants. Over the last 20 years, we have delivered more than 35 plant process and related large computer systems to nuclear utilities throughout the United States and 300+ thermal performance monitoring systems to nuclear, coal, and gas fired utilities around the world.
- **FAMOS** is an integrated suite of products for monitoring, analyzing, and optimizing plant performance; monitoring and detecting problems; and accessing vast plant data anchoring your operation. These integrated applications provide an in-depth approach to plant performance and condition monitoring and optimization.
- **StressWave** analysis technology is a state-of-the-art instrumentation technique for measuring friction, shock, and energy shifts in rotating machinery, valves, transformers and a host of other mechanical devices.
- **R*TIME** software is a real-time data acquisition, display, and man-machine interface and control system software program. It presents real time information in a manner that is meaningful, easily accessible and tremendously beneficial. R*TIME provides easy access to menus and displays of real time and historical data through defined icon buttons and pull down menus. The system provides the user with the ability to construct and use color graphic displays with trends (time, x-y and bar), alarms, logs, message files, and many other tools. Data points, displays and trends are fast and simple.

McILVAINE

Curtiss Wright EPHQ and EQ Power Suite

CURTISS-WRIGHT'S ELECTRONIC PERSONAL HISTORY QUESTIONNAIRE (EPHQ) SOFTWARE SOLUTION

- Curtiss-Wright's ePHQ has been proven to provide substantial cost savings by reducing rework associated with illegible, incomplete and lost PHQs. ePHQ provides a smart, flexible, electronic version of the industry standard PHQs defined by NEI 08-06. Built into ePHQ are comprehensive data validation, date gap validation and scope expansion features. These features ensure that the applicant provides a complete, quality PHQ the first time without the need for time-consuming review and unnecessary interaction with the applicant. Furthermore, ePHQ seamlessly integrates with Curtiss-Wright's Security Screening Information System to eliminate manual intervention and paper. In addition, ePHQ reduces turn-around time because the PHQ is completed and returned electronically so that the background can be completed sooner.
- Curtiss-Wright also offers the option of a secure hosting service for ePHQ, reducing internal IT costs while enhancing security

EQ POWER SUITE

- Curtiss-Wright Nuclear is a partner in running a mature, effectively functioning EQ Program that remains compliant with regulations, standards and regulatory commitments and supports the safe, reliable and profitable generation of electricity. CW is the on-call, single-point-of-contact resource providing the tools needed to run the EQ Program, provide access to experts with decades of EQ experience, provide advanced EQ training, and continuous access to regulatory and industry documents and data to aid in the formation, oversight and technical support of the plant's EQ Program.
- Now Curtiss-Wright Nuclear, introduces a comprehensive suite of tools specifically designed to streamline the EQ task, saving both time and money for utilities and engineers. Through license agreements with EPRI to provide both the Equipment Qualification Data Bank (EQDB) and the Environmental Qualification Management System (EQMS), and the recent acquisition of the System 1000™ Materials Aging and Radiation Effect Library, Curtiss-Wright is now able to offer all three tools in one package - the EQ PowerSuite™ (EQPS).

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Curtiss Wright Condition Monitoring

- Scientech StressWave Systems' innovative Stress Wave Analysis (SWAN™) technology (formerly SWANtech) provides superior results over other technologies used in condition monitoring applications, such as vibration analysis, oil and lubrication analysis, infrared thermography.
- **SWAN™ TECHNOLOGY**
- Provides the Earliest Detection of Damage
- Quantifiable Measurement of Damage and Trendable Parameters
- Pinpoints Source of Damage by Measuring the Frequency of Shock and Friction Events that are Indicators of Component Damage
- Eliminates False Alarms
- Accommodates the Widest Range of Operating Environments Including Very Low Speed as Well as High-speed Machinery
- Generic Configurations for Types of Machines
- Simple to Learn and Easy to Use Significantly Reducing Operating Costs
- Provides Continuous Online Monitoring

INTELLIGENT CONDITION MONITORING MODULES

- **SWANguard™ -** is the intelligent condition monitoring module that is the basis for all measurements and data acquisition. The SWANguard+ continuously monitors the connected stress wave sensors and calculates the corresponding stress wave energy and peak amplitude values. Using Scientech's patented Stress Wave Analysis (SWAN™) technology, the SWANguard+ provides superior accuracy in detecting faults, providing a degree of resolution into machine dynamics previously unattainable using traditional diagnostic methods.
- **CONTACTS**
- Steve Scheeren
  T: 954.253.8588
  Email: sscheeren@curtisswright.com

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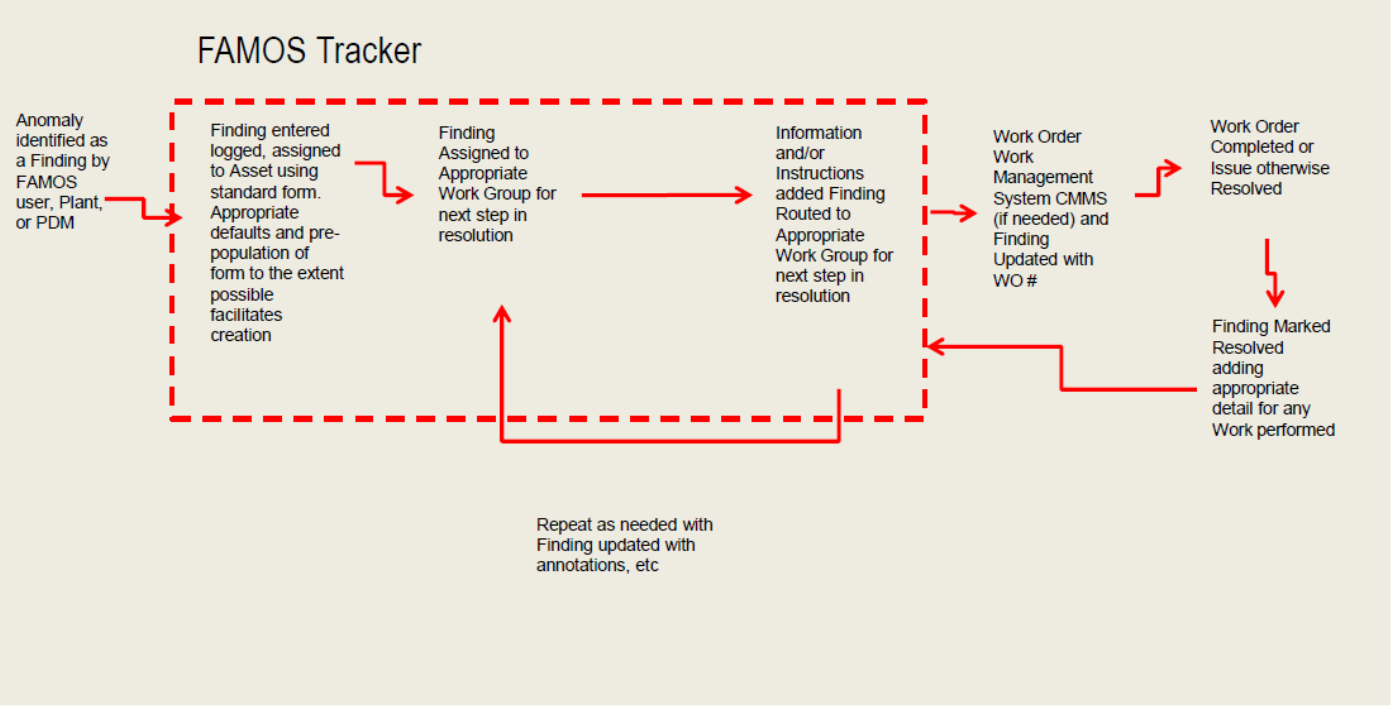
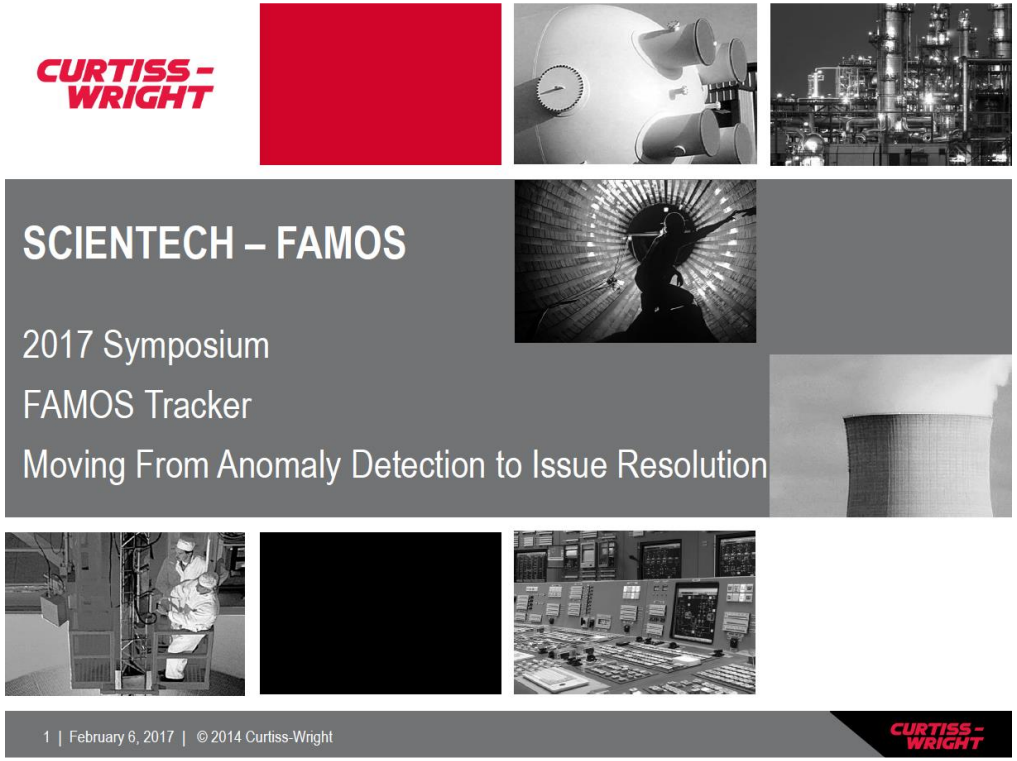
Typical Process Flow



Curtiss Wright FAMOS



Power Industry and Condition Based Asset Management

- **Reduce Operating and Maintenance Cost**
- **Improve Reliability**
- **Manage Risk**
- **Safe Operation**
  - Worker Safety
  - Reduce Collateral Damage
- **Reduce Unscheduled Outage Time**
- **Leverage Investment in Data Acquisition and IT**

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Additional Thoughts

- **Very Helpful During Initial Deployment of Models**
  - Many technical Questions
  - Many instrument issues
- **Provides Accountablity**
- **Knowledge Capture**
  - Similar Events on Other Assets
  - Future Events on the Same Asset
  - Review by Less Experienced Personal for Training
- **Summary of Status and Performance**
  - Cost Benefit
  - Process Improvement

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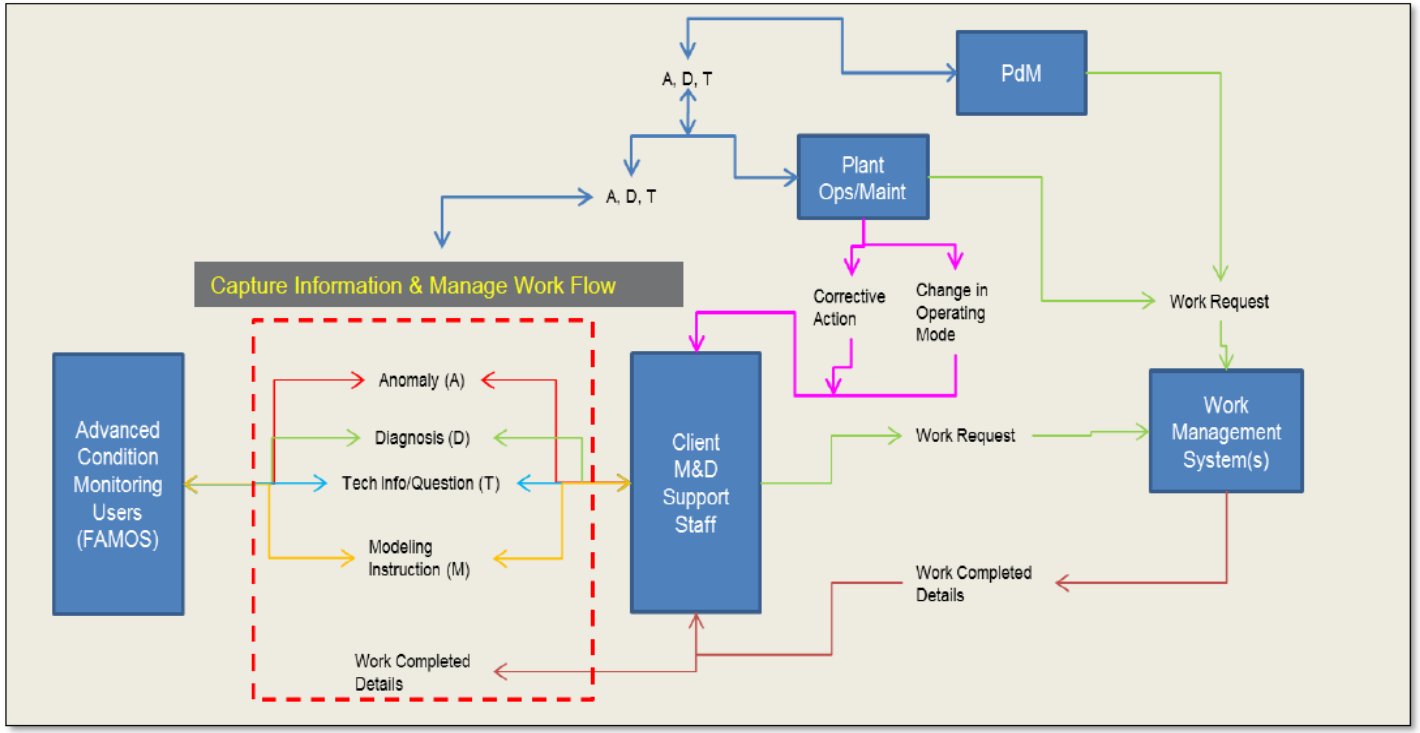
Multiple Real Time and Periodic Assessments Available

- Anomaly Detection and Performance Monitoring (FAMOS)
- Process Control Instrumentation (measurement and trending)
- Lubricant Sampling and Analysis
- Corrosion Monitoring
- Motor Current Analysis
- Acoustic Emissions Detection
- Vibration Measurement and Analysis
- IR Thermography
- Visual Inspection

Monitoring and Diagnostics Information Exchange

Identification and Resolution Involves Multiple Work Groups



HollySys Nuclear Power Plant Automation

- The HOLLiAS-N digital instrumentation and control system platform released in 2006 and the 3rd generation nuclear power instrumentation and control platform product released by HollySys were successfully applied to the modification of the KIT/KPS system in the Daya Bay nuclear power plant. Nuclear power digital instrumentation and control system projects where implementation is currently in progress include set 1 to 4 in Hongyanhe, set 1 to 4 in Ningde, set 1 to 4 in Yangjiang, and set 1 to 2 in Fangchenggang, and the Shidaowan HTR demonstration plant.
- The HOLLiAS-N digital instrumentation and control system platform is the nuclear power industry version of HOLLiAS, HollySys' established DCS platform for thermal power plants. In terms of hardware, electromagnetic compatibility and environmental adaptability are enhanced, and have an earthquake-resistant reinforced structure. In terms of software, there are additional functions such as the IEC62241-compliant alert system, safety parameter calculations, power plant status judgment and management, equipment status management, online control log, and display of digital procedures.
- HOLLiAS-N is a general nuclear power plant DCS platform. It uses application design and engineering application to satisfy requirements for digital instrumentation and control systems by different types of reactors such as 2nd-generation improved pressurised water reactors (PWR), 3rd-generation advanced PWRs, high-temperature gas-cooled reactors (HTR), and fast neutron reactors. It can satisfy functions such as nuclear islands, conventional islands, BOP system control, and advanced main control room monitoring operations.
- Founded in 1993, HollySys is a leading automation and IT solutions provider in the region of China and Southeast Asia, focusing on the areas of process automation, factory automation, railway transport automation and mechanical & engineering (M&E). In 2008, HollySys was listed on NASDAQ under the stock quote HOLI. After more than 20 years of stable growth, HollySys has established more than 60 representative offices in China, Southeast Asia, India, Middle East and Europe.

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After Fukishima there has been Big Investment in Robotic Recovery Vehicle R&D

2015 Recovery Vehicle

- **Recovery Vehicle designed with the following features**
  - Tele-operated for simplistic low cost approach
  - Tethered to allow reliable power, video and a mechanism to manually retrieve
  - Left and right drive motors for skid steering
  - Two actuators, arms and forks
  - Counter weights to keep rear wheels down when lifting 2014 vehicle
  - One pan-tilt-zoom camera and one light source
- **Recovery Vehicle features from 2014 Inspection Vehicle Lessons Learned**
  - Added pitch and roll indicator
  - Added Beta and Gamma electronic dosimeters
- **Recovery Vehicle custom built for $63K**
- **Customer requested low cost vehicle due to high risk of losing the vehicle during deployment**

Conclusions Post 2015 Deployment

- **Overall mission was successful**
  - Inspected areas of tunnel never seen before
  - Cleared 2014 vehicle from inspection path
  - Gained a better understanding of obstacles for future inspections
- **2014 Inspection Vehicle not operable for future use**
- **2015 Recovery Vehicle can not view tunnel wall behind 36" (1 meter) duct**
- **New inspection approach needed**
  - More reliable method to traverse obstacles and water puddles (reduce mission risks)
  - Better method to view behind 36' (1 meter) hanging pipe
- **Resolve technical approach with customer**
  - Customer prefers a low cost, simplistic technical approach vs. higher cost, high tech robotic option
  - Continued successful inspections and deployments will require a higher cost, higher tech approach

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Exelon Asset Management Strategy

Background – Exelon's PPC Long-Term Asset Management Strategy

Original PPC Replacement Plan Approved in 2002 to replace obsolete, legacy PPCs with a fleet-standard solution (Scientech R*Time)

PPC Long Term Asset Management (LTAM) Strategy implemented in 2011 to address Continuous PPC Life Cycle Management

- Continues replacement plan and includes periodic refreshes as part of strategic life cycle management initiative
- Refresh hardware, O/S, and applications every 7 years
- Full system and I&O replacement every 21 years

Replacement Projects Completed:

- Ginna (2001)
- LaSalle (2003/2004)
- Oyster Creek (2004)
- Dresden (2005/2006)
- Clinton (2008)
- Quad Cities (2009/2010)
- Nine Mile Point 1 (2011/2012)
- Byron (2011/2012)
- Braidwood (2011/2012)
- TMI (2016)

Replacement Projects Underway/Planned:

- Limerick (2014 - 2017)
- Nine Mile Point 2 (2015 – 2018)
- Peach Bottom (2017 – 2019)
- Fitzpatrick (????)

Refresh Projects:

- LaSalle (2016)
- Oyster Creek (2016)
- Dresden (in-progress)

Virtualization as an Obsolescence Mitigation Strategy

This Exelon presentation at the 2017 Scientech User Group meeting provides insights in the automation of combust, flow and treat functional changes which become economic when the remaining life of a nuclear plant is limited

The Oyster Creek Challenge

- Per the LTAM strategy, Oyster Creek PPC refresh was planned for 2013
- Due to a unique set of economic conditions and changing environmental regulations facing the plant, ending operations in 2019 was determined to be the best option for the company, employees and shareholders
- Given these economic realities, the team was challenged to research and recommend lower-cost options to the planned full refresh (upgrade Hardware, Applications and OS)
- The Oyster Creek PPC is needed past 2019: Due to emergency plan commitments the system will need to be maintained until 2023 at a minimum, and possibly up to 10 or more years after shutdown based on OE from several decommissioning nuclear plants.

Tom Wachter– Exelon

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PC

Exelon Generation.

Platform Virtualization Is a Lower Cost Alternative For Aging Plant

The Solution

Platform Virtualization

- Upgrade to current computer hardware
- Retain R*TIME Version
- Retain Operating System Version
- No Application Code Changes
- No Significant New Functionality

Pros:

- Much lower cost (less than half the cost of traditional refresh)
- Minimal Testing, Engineering and Validation
- Ability to easily re-host hardware for extended operation
- Maintain high availability to meet regulatory requirements
- Simplified Disaster Recovery

Cons:

- Inability to add functionality (new applications, interfaces, etc...)
- Limited/reduced support model (Scientech, Microsoft)
- "First-of-a-kind" risks and unknowns...

Implementation of Virtualization and Oyster Creek

Oyster Creek Implementation

Hardware for PPC server:

Exelon Corporate Standard Server Offering

- 1U Rack Mount Servers
- Dual RAID Setup with Hot Spare
  - In order to separate Hypervisor Disk I/O and PPC Disk I/O
- Multiple Gigabit NICs for redundancy and management
  - Replicated Existing Network Connections
  - Added VMware Network Redundancy

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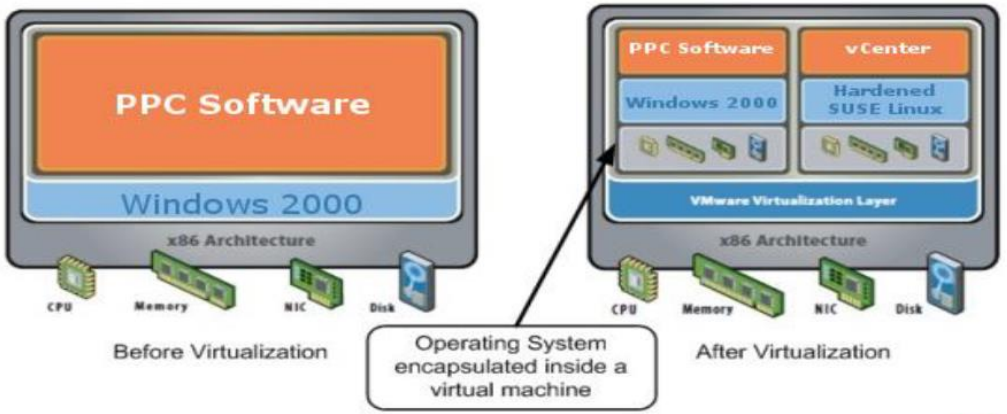
Software on Each Server

Oyster Creek Implementation

Software on each physical PPC server:

VMware ESXi version 6.0.0 (HP Edition)

- VMware vCenter Server Appliance (vCSA) ver 6.0.0 – Virtual Guest Machine
  - The vCenter Server Appliance is a preconfigured hardened SUSE Linux virtual machine, which is optimized for running vCenter Server and the associated services on Linux.
- PPC Server – Virtual Guest Machine
  - The Windows 2000 operating system
  - R*Time 11.9 (No Code Changes!)



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Success with Virtualization since October 2016

Oyster Creek Implementation

- Virtual PPCA was installed on 8/15/16 in parallel with the Physical PPCB . It ran as the primary PPC server until 10/27/16*.
- Virtual PPCB was installed on 10/27/16 with all interfaces fully SAT tested and accepted by Operations. It is still currently running as the primary PPC server without issue.
- To date the a virtualized PPC servers have been running as the primary PPC servers for approximately 5 months without any significant issues related to the virtualization platform. During this time the plant has fully exercised all of the functions including LPRM calibration (TIP RTP Interface) and several full SCRAMs (Control Rod Scram Time SOE data) and code updates.
- PSS was also virtualized at the same time as PPC-A.

*Temporarily switched Physical PPC-B to Active to facilitate code update

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Expanding the use of Virtualization

Next Steps

The successful implementation of a Virtual PPC at Oyster Creek served as a pilot for alternative obsolescence management strategies in the Exelon Nuclear fleet

- 2018 updates to the PPC LTAM Strategy will include platform virtualization as the refresh approach for plants within 5 years of final shutdown
- Considering virtualization as the standard approach for future PPC replacements and refreshes
  - Peach Bottom PPC Replacement is being bid with an option for virtualization
  - Would provide more options for mid-cycle refreshes

Financial Benefits of Virtualization were Proven

Advantages

In addition to the financial benefits demonstrated by the Oyster Creek Refresh, there are a number of other reasons to adopt a “virtual first” strategy:

Development and Testing

- System Portability
- Easily reproduce OS level and above on any hardware that supports the virtualization platform
- Multi Instances can be created for testing and development in tandem

Disaster Recovery

- Simple backup methodology
- Virtual “Hardware” is just a configuration file

Separates Windows Operating System Environment (OSE) and HW

- Allows for simpler server hardware refresh
- Can isolate problems in HW vs SW

Cloud Computing

ATOMLOGIC

ENGINEERING THE DIGITAL WORLD

Is nuclear power ready to move to the Cloud?

1224 Back Creek Loop, Solomons, MD 20688
Phone: +1.410.701.0219 | Web: www.atomlogicllc.com | info@atomlogicllc.com

Define Cloud Computing

- Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.

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Essential Characteristics

- On-demand self-service
  - once services are established, the customer should be able to provision new users, services, virtual machines, etc. without involving the cloud service provider
- Broad network access
  - cloud services are typically accessed over the Internet, as opposed to being on an internal network accessible only over private connections
- Resource pooling
  - there is some degree of shared resources from which services draw as needed
- Rapid elasticity
  - customers' needs may expand or contract, and the service will expand or contract with those needs
- Measured service
  - customers are billed based on some measured consumption. That could be licenses, or CPU cycles, or Gigabytes of storage consumed, or number of mailboxes; whatever the thing measured, that is how customers are billed. You pay for what you use

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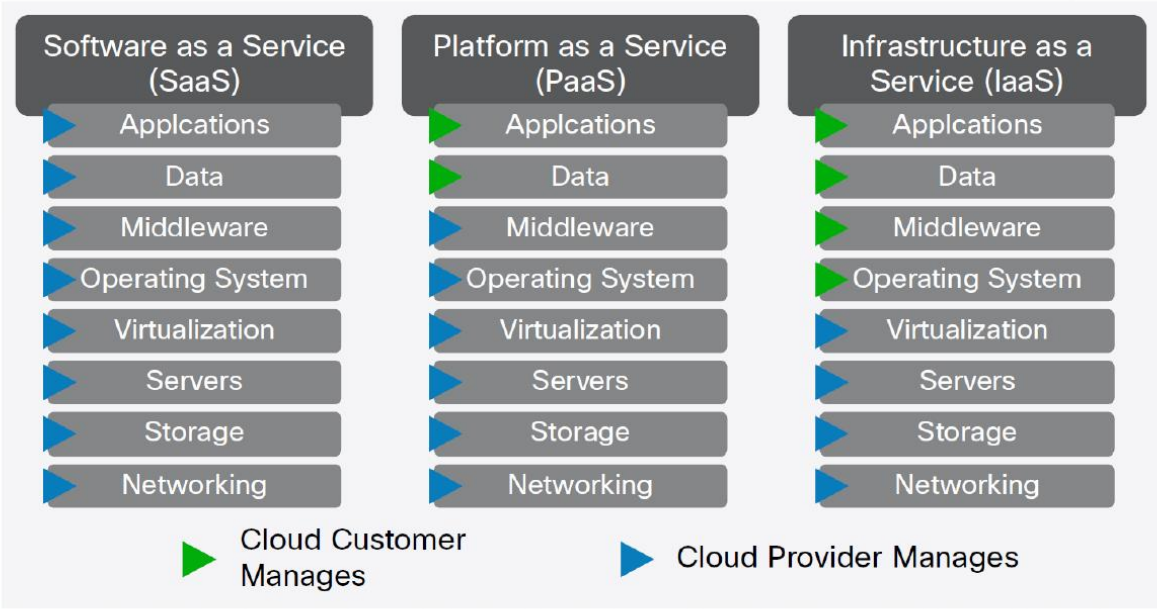
Service Models



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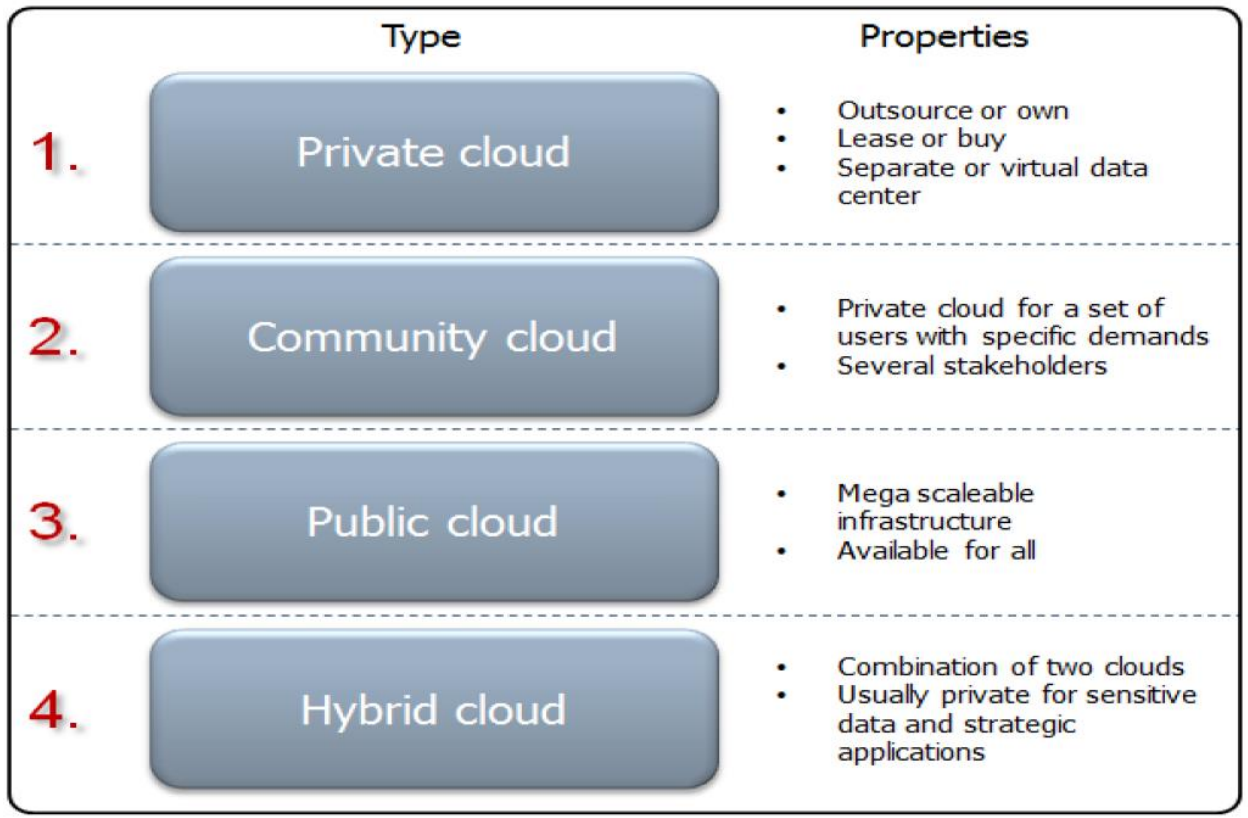
Deployment Models



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Many Suppliers of Cloud Services

FedRAMP

- The Federal Risk and Authorization Management Program (FedRAMP), is a government-wide program that provides a standardized approach to security assessment, authorization, and continuous monitoring for cloud products and services.
- This approach uses a “do once, use many times” framework that saves an estimated 30-40% of government costs, as well as both time and staff required to conduct redundant agency security assessments.
- FedRAMP is the result of collaboration with cybersecurity and cloud experts from
  - General Services Administration (GSA)
  - National Institute of Standards and Technology (NIST)
  - Department of Homeland Security (DHS)
  - Department of Defense (DOD)
  - National Security Agency (NSA)
  - Office of Management and Budget (OMB)
  - Federal Chief Information Officer (CIO) Council

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Who offers Cloud Services to FedRAMP?

- Level 4 – 73 vendors
- Level 5
  - Microsoft’s Azure GovCloud
  - Amazon Web Services GovCloud
  - CSRA’s Autonomic Resources Cloud Platform
- 53 vendors are awaiting approval

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Private Cloud Advantages and Disadvantages

Private Cloud

- Private cloud provides the basic benefits of public cloud
  - self-service and scalability
  - multi-tenancy
  - ability to provision machines
  - changing computing resources on-demand
  - creating multiple machines for complex computing jobs
  - chargeback tools track computing usage, and business units pay only for the resources they use
- Private cloud offers hosted services to a limited number of people behind a firewall or data diode, so it minimizes the security concerns some organizations have around cloud.
- Private cloud gives companies direct control over their data.
- Private clouds disadvantages
  - On-premises IT -- rather than a third-party cloud provider -- is responsible for managing the private cloud.
  - Private cloud deployments carry the same staffing, management, maintenance and capital expenses as traditional data center ownership
  - Additional expenses include virtualization, cloud software and cloud management tools.
- To reduce on-premises IT, cloud providers, such as Rackspace with OpenStack or VMware, can deploy private cloud infrastructures.

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Cloud Disadvantages

- Platform lock-in
  - cloud services tend to be built on one of several possible virtualization platforms, for example VMWare or Xen. Migrating from a cloud provider using one platform to a cloud provider using a different platform could be very complicated.
- Data lock-in
  - since the cloud is still new, standards of ownership, i.e. who actually owns the data once it lives on a cloud platform, are not yet developed, which could make it complicated if cloud computing users ever decide to move data off of a cloud vendor's platform.
- Tools lock-in
  - if tools built to manage a cloud environment are not compatible with different kinds of both virtual and physical infrastructure, those tools will only be able to manage data or apps that live in the vendor's particular cloud environment.

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Conclusions

- Cloud computing enables IT systems to be scalable and elastic.
- End users do not need to determine their exact computing resource requirements upfront. Instead, they provision computing resources as required, on-demand.
- Using cloud computing services, a customer does not need to own data center infrastructure to launch a capability that serves millions of users.

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ATOM LOGIC delivers the highest quality digital Instrumentation & Controls engineering and consulting services in the Nuclear Power industry.

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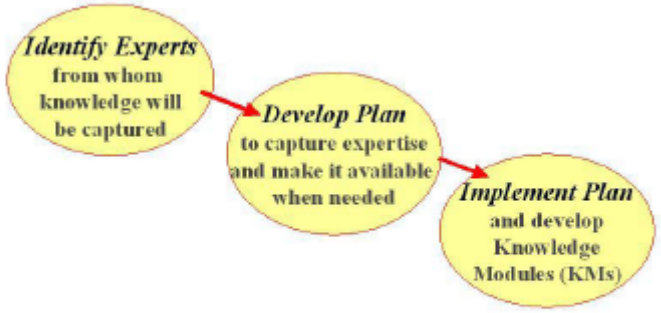
EPRI Knowledge Management and Subject Matter Expert Program- Identify, develop and implement - Fits into the SMUE Concept



EPRI's interactive report contains easy-to-use steps for eliciting, capturing, and passing along the high-value knowledge residing 'in the heads' of expert personnel in the electric power industry. It is especially valuable for managers evaluating and planning for the potential departure of experienced and highly knowledgeable employees. Such experience is often distributed throughout the company, and comes into play in many mission-critical situations involving electricity infrastructure.

EPRI's product provides a three-step process, detailed guidance, and reference materials that may be applied to identify experts and their valuable undocumented knowledge, develop a plan to elicit and capture that knowledge, and implement the plan for knowledge capture and packaging for subsequent use.

Fundamental methods provided in the report include:

- Concept mapping method;
- Critical decision method;
- Critical incident technique;
- Interview methods;
- Knowledge audit method;
- Simulations and constructed scenarios method;
- Task diagram method;
- Self-elicitation techniques;
- Storytelling;
- Updating procedures; or
- Lesson plans.

The tool focuses on tacit knowledge, which consists of unique capabilities, skills, and knowledge developed-or known based on previous experience-by an individual or shared by a team of workers. Experts with this kind of knowledge do certain jobs or tasks more quickly and with fewer errors than others. In a few cases, they may be the only ones who can perform the job or task. They are the ones assigned difficult and demanding activities. If their expertise is not available, potential adverse consequences may include reduced reliability, increased errors, and/or higher costs.

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Control

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Yokogawa Integrated Solutions for Monitoring and Control

Data Acquisition

Nuclear customers world-wide count on the renowned reliability of the DAQSTATION. Industry-accepted and used for control room and other plant applications, there are models and options to fit every need, including the narrow case DX364 and removable-chassis DX1000N. Standard features on all models include universal inputs, high capacity data storage, and Ethernet communications. A full catalog of information is available describing all DAQSTATION models and capabilities.

Controllers

Offering extreme reliability and sophisticated control functions, the Yokogawa YS1700 and UT35A controllers are the ideal choice for many control room and main plant control applications. Both models have bright, easy-to-read displays, multiple analog inputs, and powerful control functions. For qualified control room applications, choose the YS1700 with its dual CPUs for maximum reliability and hard-manual control for added protection. The YS1700's powerful function block programming method and setting tools allow it to control water chemistry, temperature, pressure and many other demanding plant processes. The UT35A can be specified for many commercial applications where reliable, economical control is required in a compact ¼ DIN package. Applications include HVAC, temperature, level, sequence control and more. The included PID control and ladder logic functions use proprietary Yokogawa fuzzy logic technology to achieve highly accurate control. An optional Ethernet interface with Modbus TCP protocol allows both controller models to readily interface with plant information systems and other control and data acquisition equipment. Controller programming can also be achieved using the Yokogawa Parameter Setting software.

Integrated Solutions

Yokogawa can design and build custom monitoring and control systems for many plant applications. Our capabilities include custom software development, custom adapter plates, equipment panels and enclosures, engineering and assembly drawings and qualification and acceptance testing. Recent projects include complete, turn-key diesel generator monitoring systems that retro-fit antiquated systems, providing a level of performance and insight into diesel generator operation previously unattainable. Our manufacturing and engineering department in Newnan, GA operates in a ISO9001 quality facility, and utilizes the latest CAD design tools. In-house capabilities include a machine shop, surface mount printed circuit board fabrication and assembly team to handle any size project.

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M&P International Coda DAS for Remote Piping Monitoring at Korea Hydro & Nuclear

- Piping in nuclear power plants is exposed to severe environmental conditions. For safety rating it is mandatory to inspect the piping systems thoroughly. However, inspection of piping systems in nuclear power plants is not easy in practice because of their length and the radioactive environment.
- Korea Hydro & Nuclear Power selected m+p international's Coda data acquisition system for remote piping monitoring in real-time at their Wolsong Power Plant in Gyeongju, South Korea. The Coda system measures the static and dynamic data of all steel pipes throughout the plant: in the turbine room, in the reactor, etc.
- The networked monitoring system consists of the Coda acquisition software installed on a standard PC and DAQ instruments which are located directly at the pipes. Coda supports more than 250 channels to measure the thermal expansion, temperature, pressure, vibration and weight of the pipes at Wolsong Power Plant. These measurements are taken by using thermocouples, LVDT (Linear Variable Differential Transformer) sensors, pressure transducers and strain gauge load cells.

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AREVA Monitoring and Control Systems

Control system:

The overall design of the I&C system and associated equipment has to comply with requirements imposed by the process, nuclear safety and operating conditions.

- The Instrumentation and Control system comprises several subsystems with their electrical and electronic equipment:
- sensors which supply measured data – pressure, temperature of the primary circuit, the liquid level … - and transform physical data into electrical signals,
- programmable controllers to process those signals, and drive the actuators. These systems, based on a number of input data, provide automatic orders to ensure that process parameters are kept within the range on which the safety is based or to trigger protection actions such as reactor trip.
- monitoring and control means for use by the plant operators (control panels, alarms ...). In the control room, are centralized sufficient and relevant information and remote control means to monitor the plants

I&C architecture: a several level structure
Inside the overall I&C architecture, each system is characterized depending on its functions(measurement, actuation, automation, man-machine interface) and its role in safety or operation of the plant. They are categorized into classes in accordance with their importance to safety.

- **Level 0** – The Process interface comprises the sensors, and the switchgears which supply measured data for control, surveillance and protection systems and for information of the control room staff.
- **Level 1** – The “system automation” encompasses I&C systems to perform reactor and turbo-generator protection, reactor control, surveillance and limitation functions, safety and process automation.
- **Level 2** – The “process supervision and control” (level 2) consists of:
    - the workstations and panels located in the Main Control Room, the Remote Shutdown Station and the Technical Support Centre, which are also called the Man-Machine Interface (MMI),
    - the I&C systems which act as link between the MMI and the «system automation” level

McILVAINE

Eaton provides a Range of Control Components

Eaton's has accumulated a century of innovation and expertise managing electrical power. When the first commercial nuclear reactors were commissioned in the 1970s, Eaton was there. In fact, Eaton's Westinghouse, Cutler-Hammer and Moeller legacy products are installed in more than half of all commercial nuclear plants in the United States and Canada. The company points to:

Reliability

- Upgrade solutions for aging equipment and plant designs, resulting in more reliable system performance
- Solutions to retrofit and modernize motor control center buckets, MV circuit breakers and drives, and LV circuit breakers and contactors

Efficiency

- Modernization solutions to extend aging equipment's useful life
- Pre-engineered configurations to save installation time and expense
- Replacement solutions for Eaton brand MCCs, vintage designs manufactured under the Westinghouse, Cutler-Hammer and Klockner-Moeller names, as well MCCs from other manufacturers
- A common technology platform for faster, easier installation, simpler maintenance, less required training and less inventory

Safety

- Electrical distribution products engineered with safety in mind
- A defined supply chain to mitigate the risk of counterfeit, fraudulent and suspect parts from entering the supply chain
- Nuclear safety-related products available through global nuclear OEM partners

McILVAINE

Eaton provides Sub Station Automation upgrades for AEP

- Eaton in 2016 secured a contract to help American Electric Power (AEP) implement substation automation upgrades to enhance power reliability and real-time response to events.
- “Substation automation systems are integral to supporting an adaptable, secure and responsive infrastructure,” said John Stampfel, vice president and general manager, Electrical Engineering Services and Systems Division, Eaton. “With world-class services and technology, Eaton is well positioned to help AEP modernize legacy substation automation solutions with the real-time data and analytics needed to support a smarter grid.”
- Under the contract, Eaton will evaluate the communications and intelligence systems at designated AEP substation locations. Systems will then be modernized in compliance with industry requirements. Real-time communications and data acquisition capabilities will be supported by Eaton’s Cooper Power series substation gateways. Eaton will also manage all substation system design, project management, installation and commissioning to help ensure a seamless transition to the new technology.
- [Native Advertisement] The engineering service contracts follow previous agreements with AEP to incorporate Eaton’s Cooper Power series SMP gateway and Remote Terminal Units (RTUs), which are used in thousands of substations worldwide to gather data, translate protocols and provide secure remote access to substation intelligent electronic equipment devices. The project is expected to be complete in 2018.
- Eaton's Electrical Engineering Services and Systems team offers a comprehensive portfolio of services tailored for every stage of a power system's life cycle, whether design, build or support.

McILVAINE

Measure

Thermo Scientific Area Radiation Monitoring

Thermo Scientific Area Radiation Monitoring System incorporates the highly versatile and functional Thermo Scientific CNET1500 Network Docking Station Gamma Monitor (CNET 1500 NDS) with the industry leading software monitoring system—Thermo Scientific ViewPoint Enterprise™. **Components and Key Features of Package**:

CNET1500 NDS (with EPD)

- Wired (LAN) or wireless (2.4 GHz) connectivity to ViewPoint server
- Point-to-point or radio base station mode (for connecting to other CNETs or EPD transmitters)
- Multi-range EPD sensor
- Configurable alarm set points
- Audible and visual alarms
- Drop-and-go setup

ViewPoint™ Enterprise Software System

- ViewPoint server and single client workstation
- EPD + CNET1500 NDS Plug-ins
- Fully networkable configuration - remote viewing capable
- Email/text interface
- Full graphing and historical data analysis

CNET1500 W Wireless Network Base

- 2.4 GHz wireless base capability
- LAN compatible
- Remote antenna capable

EPD-G Gamma Radiation Detector

- 0.5 mR/h to 30 R/h range
- Internal alarms/self diagnostics

Onsite support/training

- Complimentary ViewPoint training class (half-day)
- Configuration and Field Set Up Assistance (half-day)

Includes:

- CNET1500 NDS (with EPD)
- ViewPoint Enterprise Software System
- CNET1500 W Wireless Network Base
- EPG-G Gamma Radiation Dosimeter
- Onsite support/training
- **Recommended for:**
- Radiation waste handling activities
- Outage related activities: Steam generator platform coverage; Fuel handling activities;

McILVAINE

Pumps

Forsmark, Sweden, Nuclear Power Plant – Units 1-3 using KSB Pumps and Valves

- **Power output:**
  3,170 MW (2 x 1,000 / 1 x 1170 MW)BWR
- **Customer:**
  Westinghouse Electric Company
- **Operator:**
  ForsmarksKraftgruppAB
- **Commissioning:**
  1980/1981/1985

Operator benefits:

- Reliable installation and commissioning, supervised by KSB Service, Germany
- Safety and availability due to annual maintenance inspections by KSB Service, Sweden
- Higher efficiency due to retrofit and continuous updating of all valves

Scope of supply:

- 14 Condensate PumpsWKT
- 12Feed WaterPumpsRHD
- 3 Condensate PumpsWKV
- 8 Reactor Coolant PumpsPSR
- 13 Boiler Recirculation PumpsLUV
- 2 Feed WaterBooster Pumps YNKN
- 18 Cooling Water Pumps
- Approximately 600 valves, partly with actuators

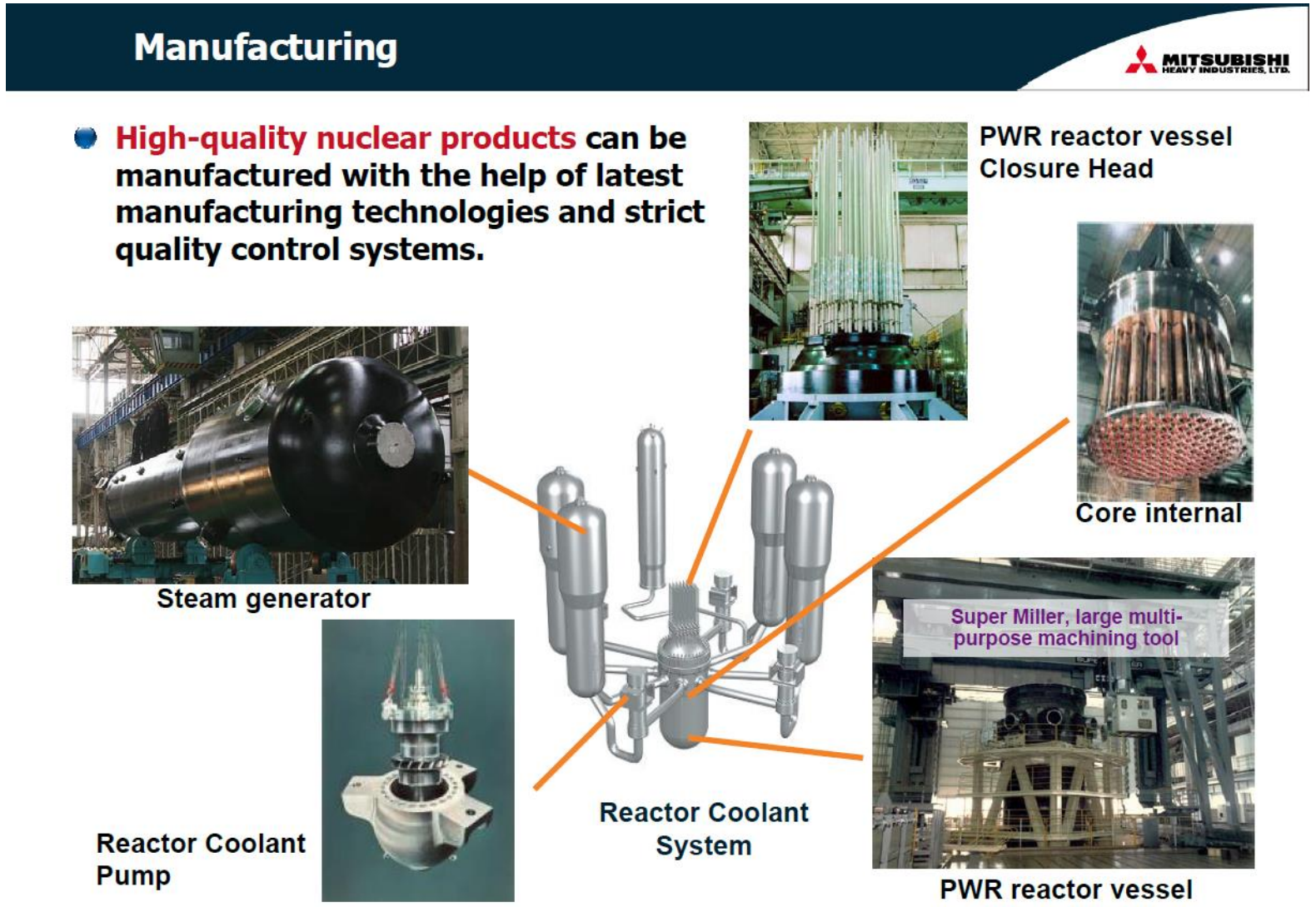
About 5,000 pumps and 150,000 valves from KSB are used in more than 200 nuclear power plants all over the world. This makes KSB a world market leader in nuclear power plant pumps

McILVAINE

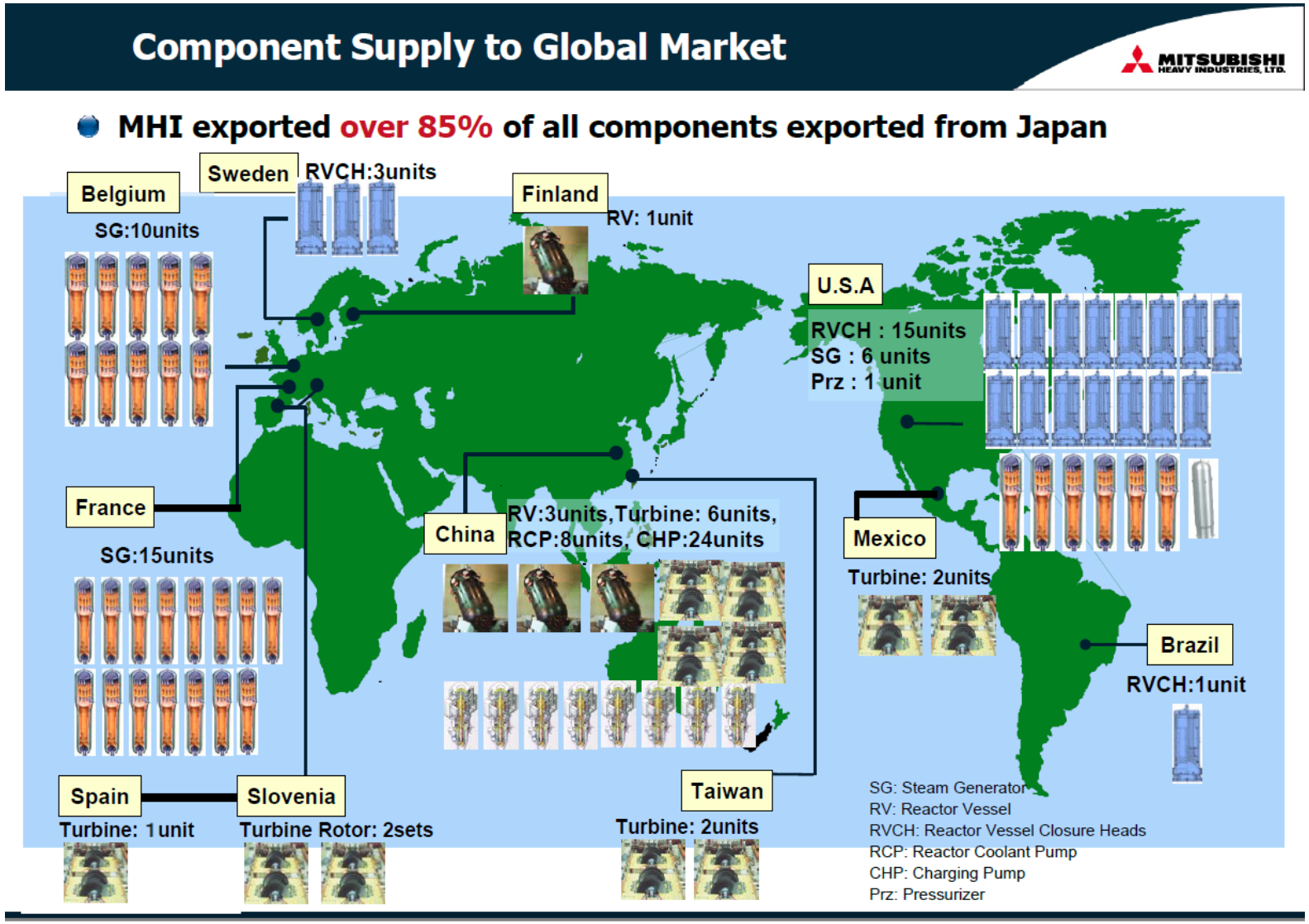
MHI Pumps for Nuclear Plants

- Primary
  - Reactor coolant
  - High pressure injection
  - Filling
  - Residual heat removal
  - Containment Spray
  - Reactor component cooling
  - Seawater
  - Motor driven auxiliary feed water
  - Turbine driven auxiliary feedwater

- Secondary
  - Feedwater
  - Feedwater booster
  - Condensate booster
  - Moisture separator drain
  - Low pressure feedwater
  - Circulating water



Mitsubishi supplies the Pumps and the Complete Plants



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McILVAINE

Filtration

Every aspect of combust, flow and treat in nuclear power plants needs its own decision system and SMUEs. Filtration is an important process.

McILVAINE

Air Filter - Examples

Camfil

- Nuclear facilities have been a customer for Camfil's Absolute filters ever since the early 1960s, when Camfil started to supply the Studsvik nuclear research facility, located not far from Camfil's international head office in Trosa, Sweden. Over the years Camfil has become the leading supplier to the European nuclear power industry, notably in Belgium, Finland, France, Germany and Sweden.
- In Scandinavia, Camfil supplies filters to four nuclear power plants in Sweden and two in Finland. The Finnish plants (TVO) have won a prize for being among the world's safest and most efficient nuclear facilities (close to 40 percent of Finland's power needs come from nuclear energy).
- The Group's French company, Camfil SA, manufacturer of Absolute filters for nuclear plants since 1967, supplies air filters, activated carbon cells and filter housings for virtually all nuclear facilities in France, a total of 59 reactors producing 60 GW of electricity (close to 80 percent of France's power needs).
- Filters and housings are also supplied to seen reactors in China, South Africa, South Korea and Spain. The French subsidiary supplied filters for two nuclear plants at the Lung Ao site in China.
- Each country has its own design specifications, requirements and safety regulations for air cleaning systems for the nuclear power industry.
- In Sweden, Camfil supplies Kombifilter, a combination Absolute/carbon filter, and Trippelfilter, a three-stage filter consisting of a special impregnated carbon filter that is sandwiched between tow HEPA filters of different efficiencies. These filters remove gases and radioactive iodine.
- France is Camfil's largest market for nuclear plant filters. Key products include Acticarb, Sofilair and special filters for glove-boxes. Camfil GmbH is also the main air filter supplier to nuclear plants in Germany and has developed Camcount, a brand new computerised device for testing nuclear filters.

AAF

AAF has provided HEPA filtration products, filter houses, and cooling coils to the worldwide nuclear industry's power plants and fuel processing plants for over 30 years. Many of the technologies and systems which are used to provide cleaned and tempered air for environmental safety systems were developed by AAF. The Three Mile Island Reactor Containment Coolers were designed and made by AAF and operated successfully during and after the accident.

AAF specializes in air cleaning systems that handle toxic, hazardous, and radioactive gas streams safely. One example is the Bag in/Bag Out system which ensures removal of the filter without exposure to personnel.

McILVAINE

Water Filtration in Nuclear Plants - Examples

DOW

- Dow Supplies t its DOWEX™ MONOSPHERE™ ion exchange resins 650C and 550A for condensate polishing, along with DOWEX™ MARATHON™ C, DOWEX™ MARATHON™ A and DOWEX™ MARATHON™ WBA series for brine cleaning will be installed at Ling Ao Nuclear Power Plant (Phase II), which is located adjacent to the Daya Bay Nuclear Power Plant, and together comprise one of the largest, total installed capacity nuclear power bases in China.
- The deep-bed condensate polishing systems in pressurised water reactor (PWR) nuclear power plants filter corrosion products transported from the main condenser to help control secondary cycle steam generator chemistry. It requires complete separation of the mixed resin to improve effluent water quality. Excellent mechanical strength and oxidative stability are also desirable features for less release of high megawatt (MW) > 1000 total organic carbon (TOC) species from cation resin to help minimise downstream sulfate excursions.
- There are a number of special applications as well. They include the fuel pool, radwaste, reactor water cleanup, protection for radioactive exposure in the steam system, and removal of irradiated particulate in the reactor cooling pump.

PALL

- Pall recommends its Ultipor GF Plus filters to optimise the visual clarity in the fuel pool. Pall radwaste filtration systems provide decontamination of liquid radwaste. Complete backwashable systems provide continuous automated service for small- and large-flow applications. Disposable systems are equipped with filter elements that are highly permeable, sturdy and efficient.
- For reactor water cleanup (RWCU), Pall offers PMM septa and Rigimesh septa as alternatives to spiral welded mesh, wedge wire, and coarse metal elements commonly found in RWCU systems.

EVOQUA

- Point Beach installed a Memcor® microfiltration system to replace the chemical feed, clarifiers and multimedia filters. The microfiltration system employs PVDF membranes with a 0.1 micron rating. By eliminating the chemical feeds, the clarifier, and the multimedia filters, the unadulterated backwash wastewater from the membrane filtration system is routinely discharged directly back to Lake Michigan.
- Membrane filtration has greatly improved the water quality at Point Beach Nuclear Power Plant. The plant has significantly reduced its operating costs, increased the reliability of the water treatment plant, and reduced the waste associated with the water treatment system.

McILVAINE

Veolia Cleanup Operations for Both Low and Intermediate Level Radioactive Liquid Waste

Veolia can provide several turn-key solutions, including

- Designing, building and operating: Evaporation and condensation systems
- Chemical pre-treatment systems
- Stabilization systems
- For Very Low and-Low Level (VLLW) radioactive waste, they conduct Final Repository Operations, including: Repository Construction
- Sorting and treating
- Temporary storage
- Waste packaging and logistics
- Quality and conformity control

Facility Management Contracts Include:

- Waste management
- Logistics
- Cleaning and decontamination
- Containment structures
- Legacy wastes management and treatment

Radioactive Waste Repository Operation:

- Operation of VLLW final disposal facility
- Operation of VLLW intermediate storage
- Operation of LL-LLW intermediate storage
- Radiation protection and quality control
- Safety and Environmental Monitoring
- Post-operation Planning

McILVAINE

Veolia System removes Cesium at Fukishima

At Fukushima, the chief concern was removing Cesium from the millions of gallons of wastewater. Cesium was the principal source of radioactive dose at the site and posed the greatest safety risk. It is a strong gamma emitter and one of the few ions found in nuclear waste that can penetrate steel piping.
It was essential to capture the Cesium so workers could more safely navigate the site and begin the historic cleanup.
Veolia's solution was based on ion exchange between sodium and Cesium, using their Ion Specific Media (ISM). Ion exchange materials can capture ions based on both their size and charge.

TEPCO needed more than media – it needed a fully engineered system that it could put in place rapidly. During the crisis, new information emerged from the site daily, and Veolia worked with partners at TEPCO to incorporate the new information to its design in real time. They activated an entire supply chain to design and construct a Cesium-adsorption system in just five weeks.

The 1200 m^3/day (320,000 gallons/day) rated system was assembled at Fukushima in nine days, followed by only one day of cold commissioning and three days of warm commissioning before hot startup with actual wastewater.

The system helped TEPCO achieve cold shutdown status on December 16, 2011 by delivering the following results:

- Rapid eight-weeks for system design, fabrication, delivery and startup,
- Achieved Cesium-removal goal of 99.9%,
- Responsible for more than 70% of radioactivity removed at the site, and
- Processed more than 100,000 m^3 of water

McILVAINE

McILVAINE

Nuclear Valves

Example of The Industrial Internet of Wisdom (IIoW)

The Industrial Internet of Wisdom will Change the Route to Market for Nuclear Valve Suppliers

- IIoW utilizes the data analytics provided by IIoT and provides the interconnection between end users, suppliers, and subject matter experts to create the TCOs and more importantly create new products with lower TCOs. The interconnections need to be as prolific in IIoW as in IIoT. They include
- Assistance to the supplier to understand the markets and opportunities for increased valve sales (provided in the McIlvaine valve, Nuclear Valve, and IIoT and Remote O&M reports
- Supplier personnel in each product group and geography interconnecting with peers around each of the 1000 large purchasers of combust, flow and treat products and services *(McIlvaine is assessing the opportunity for each product for each of the 1000 purchasers and specifically valves for large operators of nuclear power plants, the suppliers of the plants, EPC, and Consultant influencers)*
- Owner-operator personnel in each plant and in each role interconnecting around processes and products used in more than one of the plants *(McIlvaine has a beta site for BHE Energy)*
- All players interconnecting with each other in new ways
  - User controlled groups expanding scope to create decision systems and through digital technologies become international *(Suppliers with lowest TCO can support and sponsor this activity)*
  - Supplier controlled groups focused on total cost of ownership studies
  - Associations expanding role to create decision systems and periodic webinars to integrate with annual meetings
  - Individual User programs for suppliers expanding to create IIoW (*examples are AEP Bro Forum and the SABIC bi annual conference and exhibition)*
- Creation of Subject Matter Ultra Experts (SMUEs). Tomorrow's experts will master the massive TCO data generated from IIoT. The SMUE will need to be very focused and to continually utilize and help create the decision systems around his specialty. The suppliers of the high-performance products with the lowest TCO products will benefit from the SMUE validation of their claims.

McILVAINE

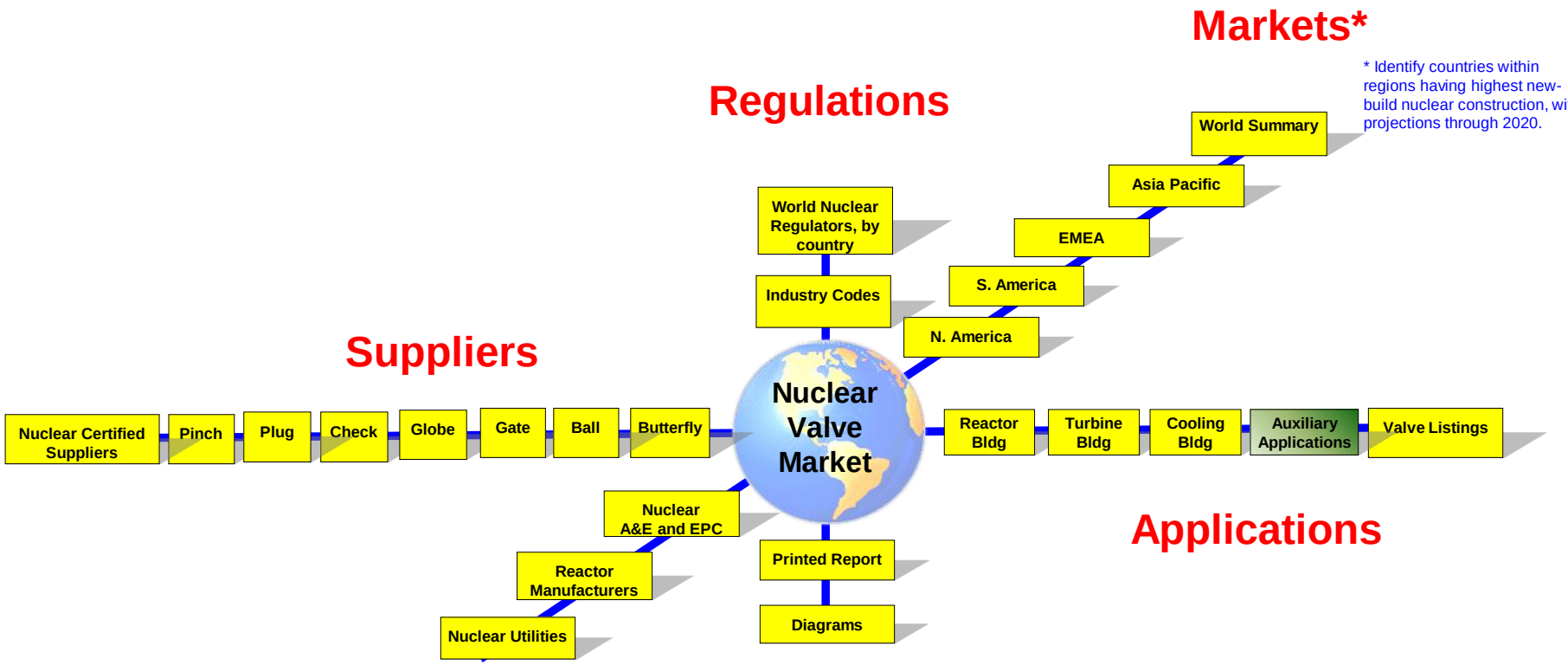
Assistance to the Supplier

- Forecast the markets
- Analyze
  - the regulations,
  - the competitors
  - technology,
- provide process flow diagrams and details on each valve

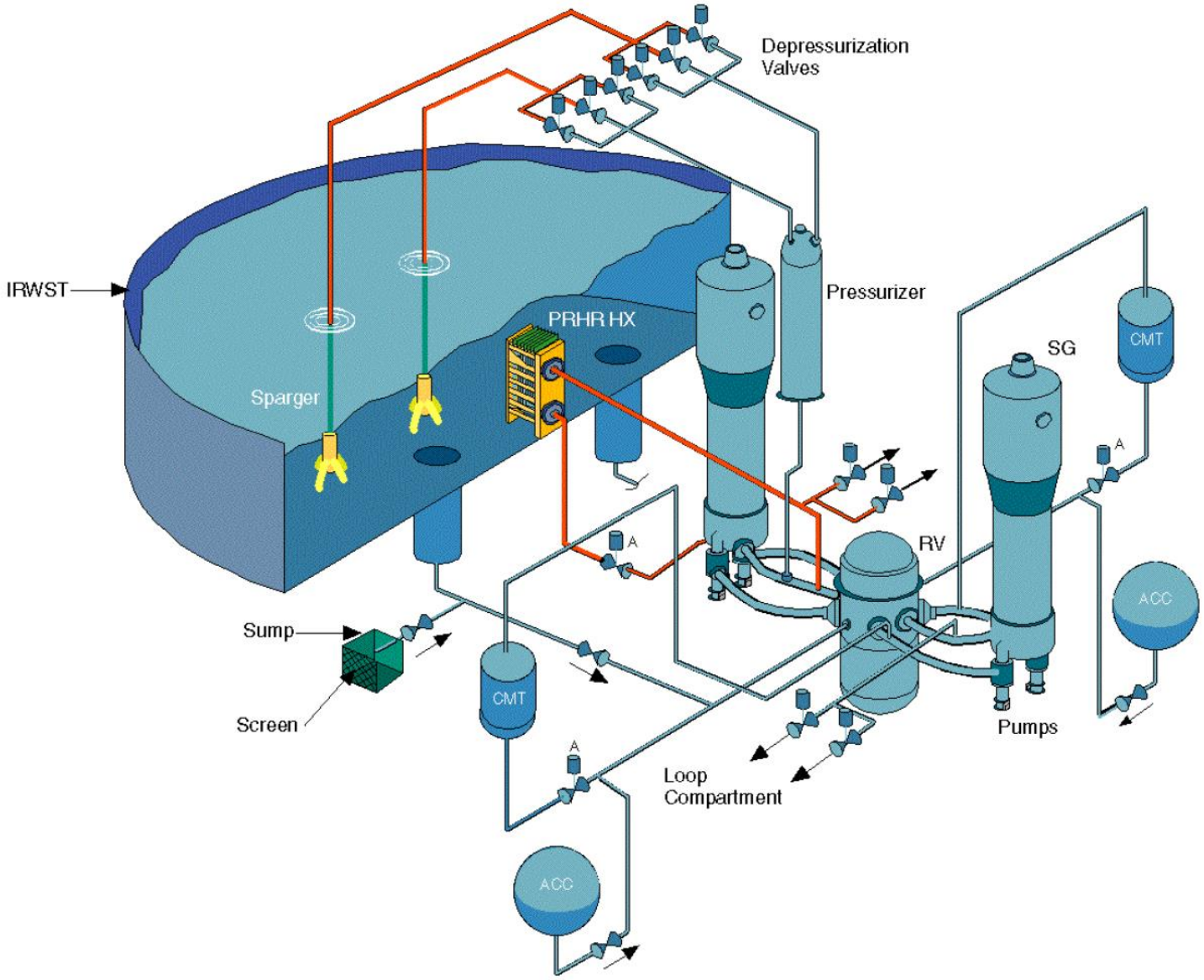
McILVAINE

STRATEGRAPHIC® *
Strategic Planning Tool
Nuclear Valve Study

Yellow cells are hyperlinked to additional report information.



AP 1000 Core Cooling System



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Detailed Forecasts down to the Specific Valves Numbers of Valves for AP1000 Reactor Design by Valve Type

Safety Valves (1)

Valve Class	Valve Type	Operator	Connection	Material	Size	Qty
PV01	Gate & Globe Valves	Motor Operated	Butt Weld	Stainless Steel	3 - 14"	38
PV02	Angle Globe Valves	Manual	Socket Weld	Stainless Steel	1"	5
	Check Valves	Piston Lift Check	Socket Weld	Stainless Steel	1 - 2"	13
	Globe Valves	Manual	Socket Weld	Alloy Steel	3/4 - 2"	161
	Herm.-Sealed Globe Valves	Manual	Socket Weld	Stainless Steel	1 - 2"	104
PV03	Check Valves	Tilt Disc	Butt Weld	Stainless Steel	3 - 10"	37
	Gate Valves	Manual	Butt Weld	Stainless Steel	3 - 14"	20
	Stop Check Valves	Manual	Butt Weld	Stainless Steel	6"	2
PV10	Ball Valves	Manual & Air-Operated	Butt Weld	Stainless Steel	1 - 3"	12
PV11	Butterfly Valves	Manual, Motor & Air-Operated	Flanged	Carbon & Stainless Steel	3 - 28"	38
PV13	Globe Valves	Solenoid-Operated	Socket & Compression	Stainless Steel	1/4 - 1"	22
PV14	Globe Valves	Air-Operated	Butt & Socket Weld	Stainless Steel	1 - 14"	35
PV15	Pressure Regulating Valves		Socket Weld	Alloy Steel	1"	2
PV16	Auxiliary Relief Valves		Flanged	Stainless Steel	1 - 4"	5
PV17	Check Valves	Lift Check	Compression Fitting	Stainless Steel	1/4"	2
	Globe Valves	Manual & Air-Operated	Compression Fitting	Stainless Steel	1/4 -3/8"	28
	Herm.-Sealed Globe Valves	Manual	Butt & Compression	Stainless Steel	1/4 -3/8"	14

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Numbers of Valves for AP1000 Reactor

Safety Valves (2)

Valve Class	Valve Type	Operator	Connection	Material	Size	Qty
PV62	Pressurizer Safety Valves	Self-Actuated	Flanged	Stainless Steel	6"x8"	2
PV63	Pressurizer Spray Valves	Air-Operated w/Positioner	Butt Weld	Stainless Steel	4"	2
PV64	Main Steam Isolation Valves	Pneumatic-Hydraulic Actuated	Butt Weld	Alloy Steel	38"	2
PV65	Main Steam Safety Valves	Self-Actuated	Flanged	Carbon Steel	8"	12
PV66	Main Steam Power Operated Relief Valve	Self Actuated	Butt Weld	Alloy Steel	12" x 8"	2
PV67	Feedwater Isolation Valves	Pneumatic-Hydraulic Actuated	Butt Weld	Alloy Steel	20"	2
PV68	Feedwater Check Valves	Nozzle Check	Butt Weld	Alloy Steel	20"	2
PV69	Feedwater Control Valves	Air w/Positioner	Butt Weld	Alloy Steel	6 - 20"	4
PV70	Squib Valves		Flanged	Stainless Steel	8 - 14"	12
PV78	Needle Valves	Manual	Socket Weld	Stainless Steel	1"	2

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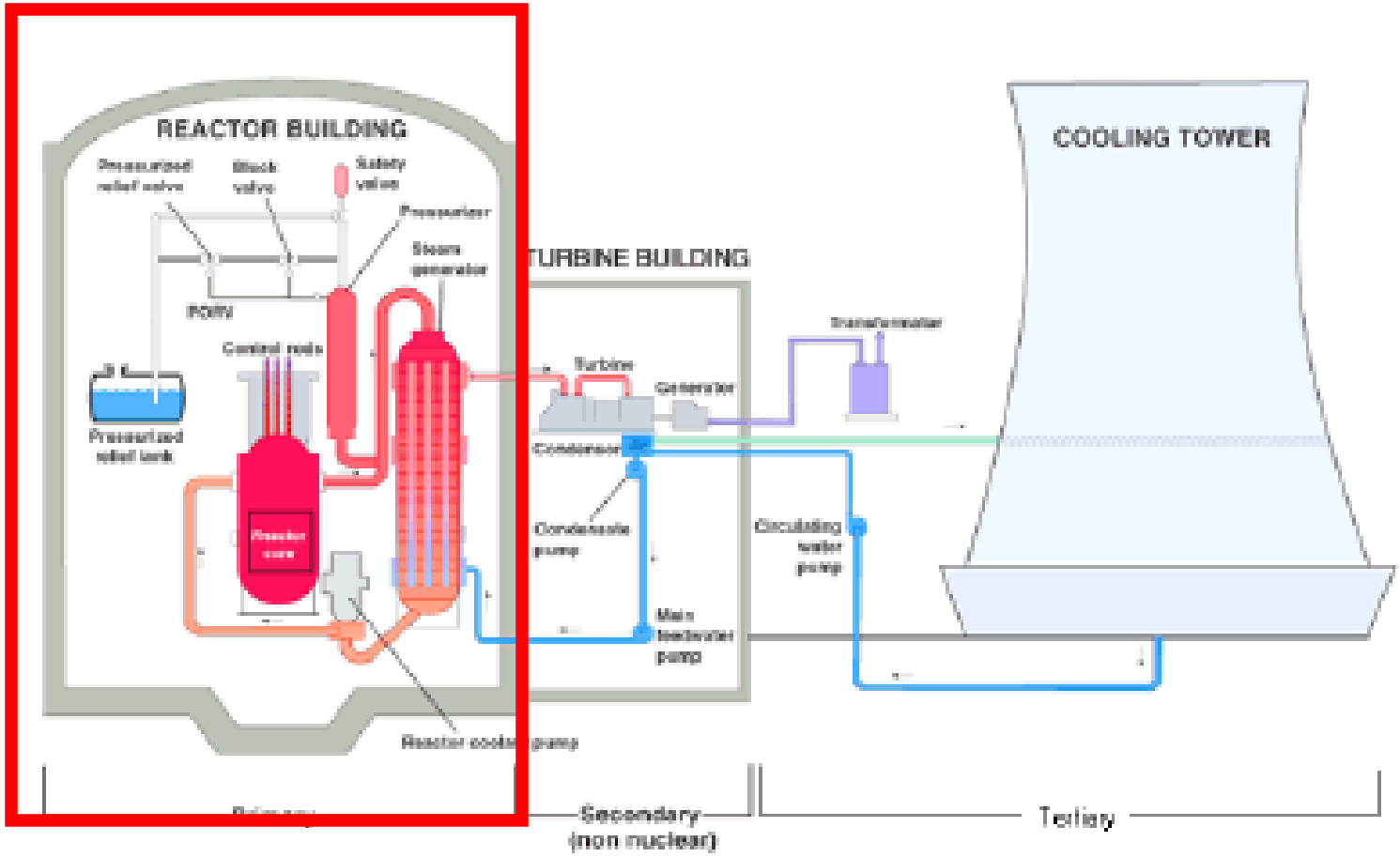
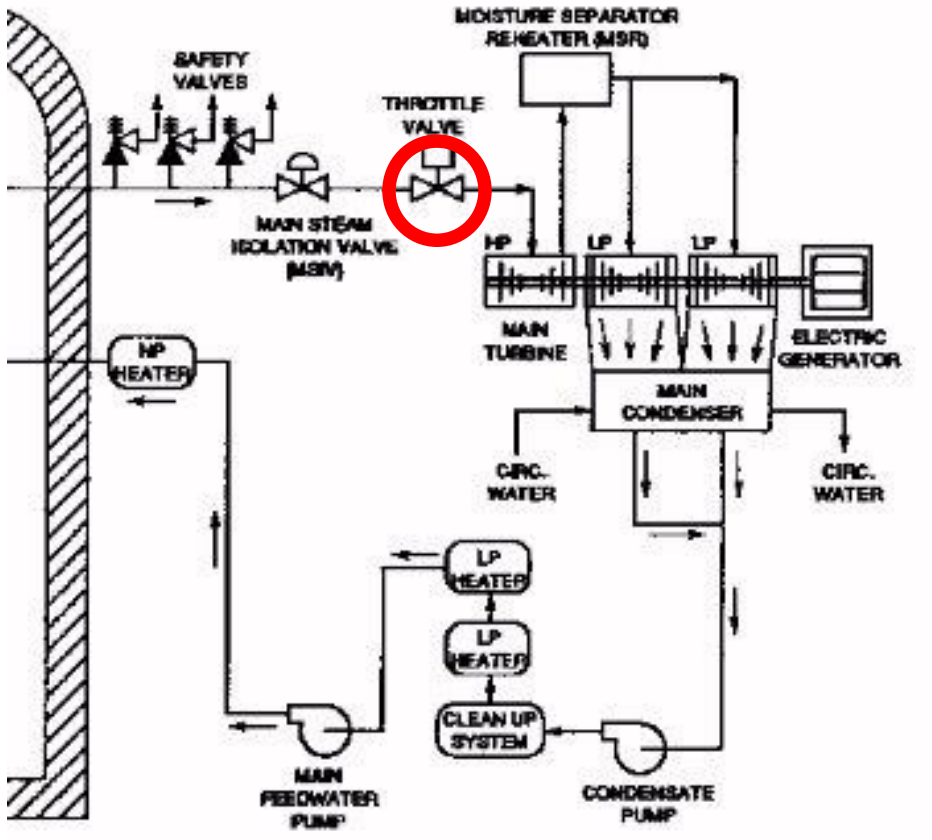
Primary Loop
Reactor Cooling System (RCS)



Secondary System Valves

Main Steam Control Valve



Owner-operator personnel in each plant and in each role need to interconnect around processes and products used in more than one of the plants

Each major power company should have a website and system similar to the system created for BHE. This would include all the nuclear, fossil, solar, wind, hydro and geothermal plants

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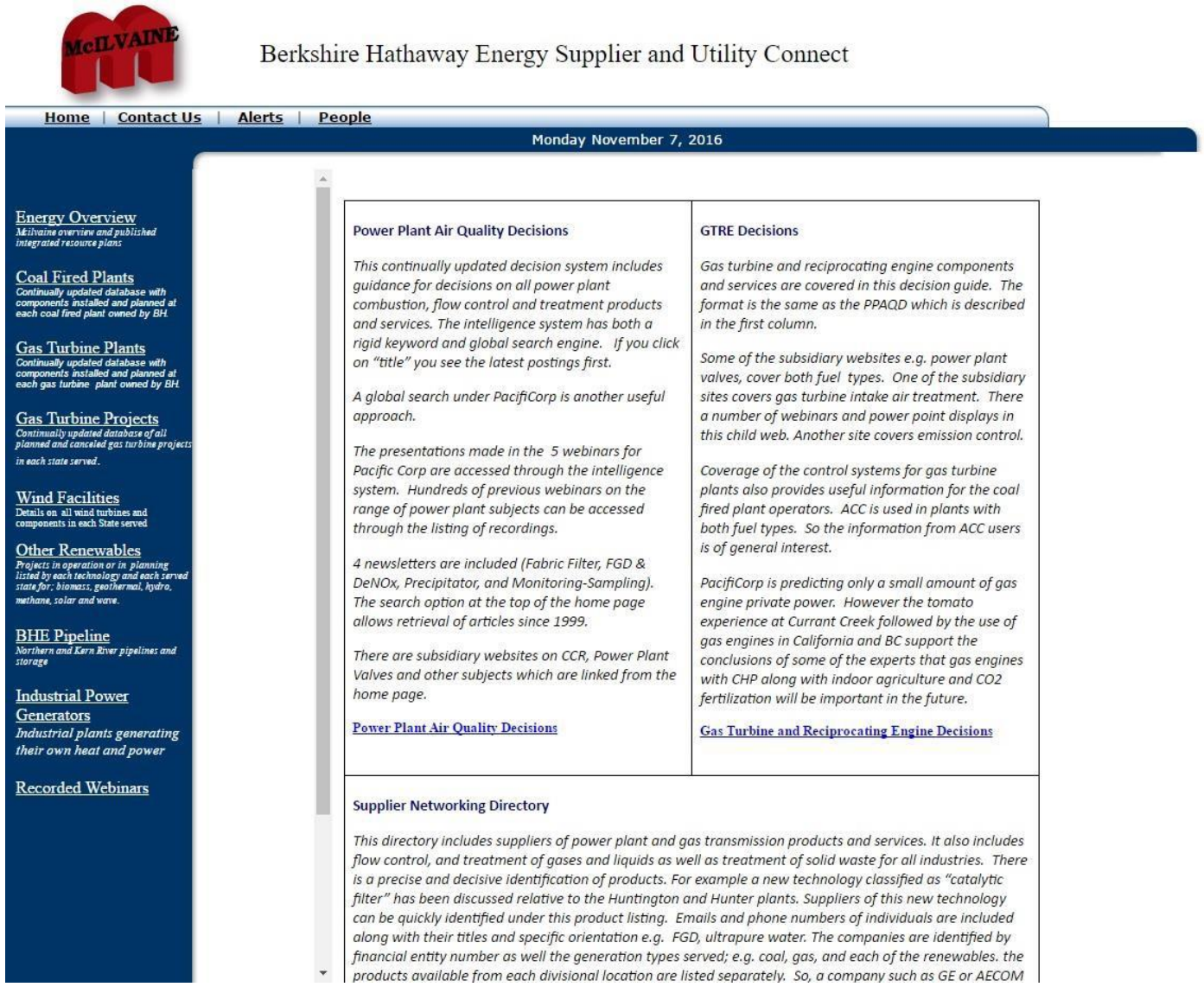
Supplier and Utility Connect - BHE makes Multiple Interconnections Possible



Berkshire Hathaway Energy Supplier and Utility Connect

Home | Contact Us | Alerts | People

Monday November 7, 2016

Energy Overview
Mcilvaine overview and published integrated resource plans

Coal Fired Plants
Continually updated database with components installed and planned at each coal fired plant owned by BH.

Gas Turbine Plants
Continually updated database with components installed and planned at each gas turbine plant owned by BH.

Gas Turbine Projects
Continually updated database of all planned and canceled gas turbine projects in each state served.

Wind Facilities
Details on all wind turbines and components in each State served

Other Renewables
Projects in operation or in planning listed by each technology and each served state for; biomass, geothermal, hydro, methane, solar and wave.

BHE Pipeline
Northern and Kern River pipelines and storage

Industrial Power Generators
Industrial plants generating their own heat and power

Recorded Webinars

Power Plant Air Quality Decisions

This continually updated decision system includes guidance for decisions on all power plant combustion, flow control and treatment products and services. The intelligence system has both a rigid keyword and global search engine. If you click on "title" you see the latest postings first.

A global search under PacifiCorp is another useful approach.

The presentations made in the 5 webinars for Pacific Corp are accessed through the intelligence system. Hundreds of previous webinars on the range of power plant subjects can be accessed through the listing of recordings.

4 newsletters are included (Fabric Filter, FGD & DeNOx, Precipitator, and Monitoring-Sampling). The search option at the top of the home page allows retrieval of articles since 1999.

There are subsidiary websites on CCR, Power Plant Valves and other subjects which are linked from the home page.

Power Plant Air Quality Decisions

GTRE Decisions

Gas turbine and reciprocating engine components and services are covered in this decision guide. The format is the same as the PPAQD which is described in the first column.

Some of the subsidiary websites e.g. power plant valves, cover both fuel types. One of the subsidiary sites covers gas turbine intake air treatment. There a number of webinars and power point displays in this child web. Another site covers emission control.

Coverage of the control systems for gas turbine plants also provides useful information for the coal fired plant operators. ACC is used in plants with both fuel types. So the information from ACC users is of general interest.

PacifiCorp is predicting only a small amount of gas engine private power. However the tomato experience at Currant Creek followed by the use of gas engines in California and BC support the conclusions of some of the experts that gas engines with CHP along with indoor agriculture and CO2 fertilization will be important in the future.

Gas Turbine and Reciprocating Engine Decisions

Supplier Networking Directory

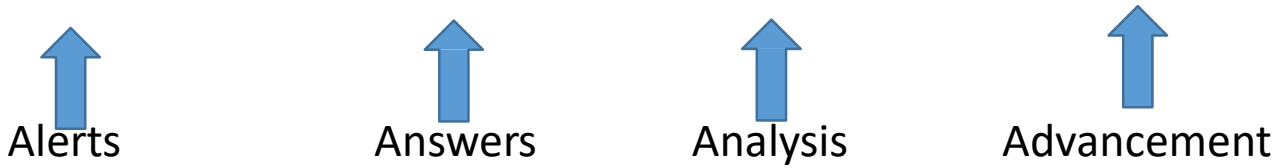
This directory includes suppliers of power plant and gas transmission products and services. It also includes flow control, and treatment of gases and liquids as well as treatment of solid waste for all industries. There is a precise and decisive identification of products. For example a new technology classified as "catalytic filter" has been discussed relative to the Huntington and Hunter plants. Suppliers of this new technology can be quickly identified under this product listing. Emails and phone numbers of individuals are included along with their titles and specific orientation e.g. FGD, ultrapure water. The companies are identified by financial entity number as well the generation types served; e.g. coal, gas, and each of the renewables. the products available from each divisional location are listed separately. So, a company such as GE or AECOM

Many Individuals in a Supplier Company Interact with BHE (valve example)

Function	Product	Customer Plant Locations	Industry		Process		
Sales	Control	WA, OR, UT, WY	Coal	Gas	Water Intake	Steam	Fire Protection
Service	On/Off	NV	Wind	Hydro	Cooling	Comb. Air	Lubrication
Engineering and Manufacturing		IA	Biomass	Geothermal	Ultrapure Water	Waste Water	Process e.g. FGD/Geothermal etc.

Alerts → Answers → Analysis → Advancements

Many Individuals at BHE Interact with the Suppliers (valve example)



Multi Plant Utility Job Categories									
Function	Product	Plant Locations	Industry		Process				
Procurement	Control	WA, OR, UT, WY	Coal	Gas	Water Intake	Steam	Fire Protection		
Maintenance and Operations	On/Off	NV	Wind	Hydro	Cooling	Comb. Air	Lubrication		
Engineering and Planning	Services	IA	Biomass	Geothermal	Ultrapure Water	Waste Water	Process e.g. FGD/Geotherma l Etc.		

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Features of Networking Directories

- Financial entity number to identify all the subsidiaries.
  - Pentair just sold Tyco Valves to Emerson. All the many Tyco addresses and people will now be identified with the Emerson entity number. Multiple Chinese names are linked to the true financial entity.
- Phone numbers and email addresses of individuals who can answer the questions about the use of their products in the power and gas transmission industries
- Decisive Classification of many thousands of products.
  - Spray driers, circulating dry scrubbers and dry sorbent injection are all distinctly different products and are listed separately
  - A company such as Emerson has many subsidiaries and locations which sell only certain of the products. Each product is linked to the locations where information is available
- Excerpted information on all 40,000 companies is displayed at **View and Correct Your Product Listings** (also accessed through Free News at www.mcilvanecompany.com)

McILVAINE

Webinars Provide the Analysis by Linking Suppliers and Experts to the BHE Decision Makers

- Hunter, Huntington NOx Example

- Five webinars conducted for PacifiCorp relative to reducing NOx at the Huntington and Hunter plants demonstrate the power of what PacifiCorp labeled as the input of the "wise crowd"
- 20 people from PacifiCorp and 60 suppliers, consultants, and universities reviewed both front end and back end NOx options.
- Novel technologies never before used in large coal plants were reviewed (catalytic filters, H202/urea reductants, H202/ozone oxidants, in-duct SCR, optimization and reburn.
- The consensus was that some combination other than full size SCR with large vessels is not only possible but probable.
- The savings could be several hundred million dollars
- Additional insights are being published in the Alerts and intelligence system

McILVAINE

Powerful New Potential to Reduce Costs and Improve Operations

- The system identifies all the potential uses of specific products.
- Global sourcing is now a reality because both the supplier and BHE have the understanding of the individual plant needs.
  - Performance and maintenance history. In *Alert 1* McIlvaine identifies an approved bidders list for Currant Creek with only one approved condensate filter supplier. A presentation by another plant shows that this product has been replaced by that of another vendor due to the need for higher efficiency
  - Global specifying. The potential to purchase in large quantities justifies the analysis of lowest total cost of ownership
  - McIlvaine is setting up systems for suppliers to demonstrate lowest total cost of ownership through evaluations by niche experts along with the intelligence system background data.
  - Global purchasing can reduce the cost of the products and the cost of administration while improving operations and maintenance.
- The Huntington and Hunter NOx webinars demonstrate the potential for identifying new and better technology. Jeffrey Immelt of GE says that the power industry needs to develop the "hurry up" pace demonstrated in Silicon Valley. With this system there is instant decision making potential.
- From the supplier perspective the evaluation based on total cost of ownership promises higher margins while global purchasing offers the opportunity for large contracts and the ability to provide service for the fleet.
- The nuclear industry should be a leader not a follower due to the critical nature of the service

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Decision Systems on Nuclear Power Plant Valves must address the 4As: Alerts, Answers, Analysis and Advancement

Answers are provided by

- Case histories, white papers and articles are all posted for
  - quick retrieval
  - organization to facilitate better decision making through decisive classification
- Titles reflect the value
- Summaries indicate the decision options and also provide the words for global searches
- A decisive classification system facilitates retrieval of all and only relevant documents
  - Applications coded by industry and process
  - Products coded by decades of interaction with suppliers, associations, and users
  - Geographies in precise hierarchical system
- Advantages over on line search engines are much more relevant information retrieved in less time and without extraneous documents.
- Recordings and individual power point presentations from webinars are also included.

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Decision Systems supported by Valve Companies Velan Example

- Velan's model of collaborative development began early in the 1950s and 60s. Over the years, the company has worked with a number of nuclear organizations including the US Navy, Atomic Energy of Canada, AREVA, and Westinghouse and utilities such as Duke Energy and Ontario Power Generation to establish new levels of safety, reliability and maintainability of nuclear valves, and electric actuators. Recently, Velan has been at the forefront of qualification testing to address safety issues raised by the Nuclear Regulatory Commission (NRC) and Electric Power Research Institute (EPRI).To ensure that critical motor-operated valves close during “worst case” scenarios, Velan worked closely with Duke Energy and others to design and rigorously test special gate valves that can accommodate larger and heavier actuators that provide greater access for installation of thrust and torque sensors on the stem.

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Continuous Analysis of Problems - High Pressure Coolant Valve Failure Sept 24, 2017

- The Nuclear Regulatory Commission has launched a special inspection at Unit 3 of Browns Ferry Nuclear Plant.
- The NRC said in a written statement it will inspect the failure of a high-pressure coolant injection discharge valve on Unit 3.
- During routine testing Sept. 24, the high-pressure coolant injection system unexpectedly pumped water into the reactor vessel instead of a storage tank, and the Tennessee Valley Authority determined that a failed nut on a valve allowed it to remain partially open, according to the NRC.
- The NRC said the inspection team will review the valve failure and TVA's actions as well as maintenance practices and the history of such valves.
- The onsite portion of the inspection is expected to take several days, the NRC said, and a report documenting the results of the inspection should be issued within 45 days of the completion of the inspection

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User Group Example – Motor Operated Valves

- The Motor-Operated Valve Users' Group (MUG) is a forum of member nuclear utility representatives formed for the exchange of technical information relating to the testing and maintenance of motor-operated valves (MOV) among the utilities and in coordination with other organizations within the nuclear industry for the increased reliability and safety of nuclear power.
- The annual conference & expo of the MOV & AOV Users Groups, the Fluid Leak Management Users Group/Boric Acid Users Group, and the Compressed Air Nuclear Users Group takes place in January 2017 at the New Orleans Marriott

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Digital Interconnection with Periodic Face to Face Meetings with a Decision System Foundation

Could the MOV Group also be slated at a conference such as the Rockwell Process Solutions to delve specifically into controls for motor operated valves?

Rockwell Automation Library of Process Objects: Motor Operated Valve (P_ValveMO)

Version 3.5

Rockwell Process Solutions User Group,

George R. Brown Convention Center, Houston, Texas, USA, November 13–14, 2017

- E05 - Ask the Experts: INTELLIGENT MOTOR CONTROL/PLANTPAX INTEGRATION Easy access to critical information from your intelligent motor controls can improve operations, maintenance, and plant efficiency. Now this access is extended to the switchgear and E-Houses of your facility through IEC 61850. This session allows you to leverage the knowledge of experts in motor control and PlantPAx® Systems to provide best practices and methods for implementing and leveraging a high level of integration. This session features a panel of subject matter experts ready to answer audience questions and discuss current topics and trends

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Mug Approval For MOV Long Life In Limitorque MOV's

- MUG APPROVAL FOR MOV LONG LIFE IN LIMITORQUE MOV'S The recent cancellation of Exxon Nebula EP grease, which had been used in many valve operators, especially those in power stations, offers the opportunity to upgrade. This is possible because a new grease, MOV Long Life, has excellent resistance to age hardening, oil separation and water washout. It also provides above average corrosion protection, good extreme pressure and anti-wear properties as well as being radiation tested to over 220 Mrads. In addition, it is compatible with the calcium complex thickener in Nebula EP. MOV Long Life was also evaluated by the MOV Users Group and compared against both Nebula and Mobilgrease 28. This is given in MOV Users Group Position Paper, "Equivalent Replacement Evaluation for MOV Gearbox Lubricant", CFI 02G-J01, May 6, 2002.
- MUG members can download the 17-page report at; http://www.movusersgroup.com/MUGDocuments/02G-J01.pdf. Others can register on their home page.

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Crane Motor-Operated Valve (MOV) Capabilities

- CRANE has been making MOV systems since the mid-80s. VOTES® Infinity is the result of over 3 years of development and includes the best features from all prior systems.
- The data acquisition process is much easier than with older systems or competitor systems due to the new ASSIST™Technology. In test setup, there is no longer any concern with technicians plugging the wrong sensor into the wrong port, regardless of their level of experience. How many times have you setup a valve and completed a test only to find out that thrust and torque channels were inadvertently swapped? VOTES® Infinity automatically identifies what device has been connected and automatically configures itself for use for each device reducing the effects of human performance errors.
- The entire acquisition process is wizard-driven which starts simply by right-clicking on a valve in the navigation pane and selecting test valve. Automatically-identified sensors are displayed on the setup screen with all pertinent sensitivity and calibration information viewable on the same screen. MOV-acquisition screens and options have been drastically simplified while retaining the ability to completely control the acquisition process. Once the data acquisition process is complete, the data is immediately displayed on the screen and the user is prompted to begin the automated-analysis process.
- Analysis has been greatly simplified while, retaining the advanced-analysis capabilities needed for diagnosing problems. The system provides an Automated-Marking routine for determining all major events in an MOV test. Once data acquisition is complete, the user is prompted to simply select the zero-load and the control-switch trip points. Once these points are identified, the software does the rest.
- In addition to the Automated-Marking, VOTES® software includes a full-featured Manual Analysis routine, allowing the user to display and analyze data. The user can display any number of graphs on the screen and each graph is an Overlay. The Overlay feature allows multiple trace to be displayed in any graph. The data can be from the current test, other tests from the same valve or from other valves.
-
- The VOTES® Contacts Module provides the capability for the system to monitor the open/close condition of up to 6 switch contacts. The module processes signals from 6 pairs of switches and places them into a form, clearly indicating the state of the switches. The user is provided a report with the exact state of each switch at every point in time.
- **High Voltage Attenuator (HVA)Crane** provides the capability for the VOTES® Infinity System to measure all 3 phases of motor voltage. The HVA processes the measurements into Vab and Vac so motor power may be calculated, using the two-watt-meter method.

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U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Motor-Operated Valve Regulatory Activities

Michael F. Farnan

Component Performance, NDE & Testing Branch
Division of Engineering
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

MOV Users Group
January 2017

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Current MOV Issues/Activities

- 50.55a Rulemaking
- Regulatory Guide 1.192 Revision 1
- 2016 MOV Events/Issues/Activities
  - 2016 MOV event summary
  - MOV T-Drains
  - Thermal Overload Protection
  - Active vs. Passive
  - PPM Calc
  - Appendix III Section III-3300(c) – "The inservice test will include a mix of static and dynamic MOV performance testing."

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2016 MOV Event Summary

- OE data (LER, Part 21, Inspection Reports, NOV, etc.) 6 events
  - 3 events due to failed circuitry
  - 2 events due to human performance
  - 1 event due to stem/disk separation
  - 1 event due to disk/seat binding (flexible wedge gate)
- INPO ICES data review – 12 additional events
  - 6 events due to failed circuitry
  - 2 events due to wear, FME or material fatigue
  - 4 events due to human performance

EPRI Performance Prediction Methodology (PPM)

- NRC safety evaluation approves PPM with conditions
- PPM model predicts the thrust and/or torque requirements to operate gate, globe, and butterfly valves under specified fluid conditions and differential pressures
- Key elements for PPM to remain valid:
  - Use of the computer model assumes that the valve is in good condition
  - Model users will need to establish an adequate internal valve preventive maintenance program

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New Way to Monitor Conditions of MOVs

In order to avoid the problems of the classical methods, the method proposed by Pierre Granjon Gipsa-lab / Grenoble University has the following principles.

- First, fault indicators are calculated by using exclusively electrical supply voltages and currents of the MOV. This approach avoids any at-the-valve measurement and allows remote testing since such quantities are accessible outside radioactively contaminated areas.
- Second, mechanical fault indicators are obtained through the analysis of the instantaneous fundamental positive-sequence active power absorbed by the induction machine contained by the MOV. Indeed, the usage of this particular electrical quantity presents numerous advantages: - Apart from losses, it is equal to the mechanical power produced at the induction machine output. Therefore, this electrical quantity is closely related to internal mechanical phenomena occurring in the MOV. - It is estimated by using the three voltages and currents of the induction machine, and therefore realizes some kind of data fusion of the whole information contained in this three phase system. - Its estimator is based on a physical definition and not on any induction machine model contrary to classical methods.
- Last, measurement and analysis of electrical supply quantities are done during steady-state operations of the MOV. Such behaviors have long duration and lead to fault indicators with small variability. Moreover, the measured physical quantities are stationary during these operations, and classical signal processing tools such as spectral analysis can be used without any restriction.

Therefore, the proposed method consists of two main steps: - the real-time estimation of the instantaneous fundamental positive-sequence active power absorbed by the MOV, - the analysis of this instantaneous electrical quantity in order to propose efficient mechanical fault indicators.

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