Westinghouse Small Modular Reactors: Innovative Technologies for a Flexible Energy Matrix

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September 2017
SMR Workshop
Rio de Janeiro, Brazil
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Westinghouse Overview
What are we doing today

The Westinghouse SMR
The LWR Solution leveraging AP1000 Technology

The Westinghouse LFR
Deploying Gen IV technology for the future

The Westinghouse eVinci™ Micro Reactor
Ultimate flexibility of Distributed Generation

Leveraging 130+ Years of Technology Heritage & Global Leadership
Westinghouse Electric Company

• Incorporated in 1886 by George Westinghouse

• Responsible for some of the world’s most important achievements:
  – Airbrake for rail cars
  – Commercialization of Alternating Current (AC) technology
  – 1st commercial radio broadcast
  – USS Nautilus nuclear propulsion (S1W)
  – Pioneer in Commercial nuclear power
    – 1st Commercial PWR Shippingport USA

Nearly 50 percent of nuclear power plants globally are based on Westinghouse technology
Westinghouse is Actively Present in all Nuclear Markets in Latin America

Argentina
- Atucha 1 inspection equipment
- Embalse Life Extension Program
- INVAP Engagement

Brazil
- Angra 1 OEM Services, I&C Modernization
- Angra 2 Inspection Services
- INB Fuel Technology Transfer

Mexico
- Laguna Verde 1 and 2 Outage Support
- Steam Dryer Services
- SFPIS, etc.

Westinghouse is the long term partner in Latin America
Why are SMRs Being Considered?

- A replacement for aging fossil fuel plants
- A solution for the needs of small utilities
- A solution for remote and grid limited applications
- A design with the ability to load follow and adjust to varying grid load swings
- Compatible with the financial capabilities of all electric utility companies
- Provides incremental increases in capacity as demand grows
- An additional option for a balanced energy portfolio

SMRs and Large NPPs are complementary generation sources
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WSMR Technology Overview
- Plant Design Features

• Developed Using a Risk Informed Design Process
• Passive Safety Systems Reduce Core Damage Frequency and Requires no Operator Action for 7 Days
• Below Grade Design is Robust to External Events
• Integral Reactor Design Eliminates Large Break LOCA Class of Design Basis Events
• Utilizes Proven Fuel Design and Control Systems
• Compact High Pressure Containment Results in Reduced Reactor Building Size and Plant Cost
• Modular Construction Deployment Model and High Power Density Limit Economy-of-Scale Impact

Maximizes the use of Licensed & Proven Technology to Reduce Development Time
WSMR Technology Overview
- Reactor Configuration/Specifications

• **Power:**
  - Core Thermal Power: 800 MW(t)
  - Net Electrical Output 240-250 MW(e)

• **Core Design:**
  - 17x17 RFA Fuel (8ft [2.4m] active length)
  - < 5% Enriched U235
  - 89 Fuel Assemblies
  - Soluble Boron
  - 37 Internal CRDMs (Shutdown & Control)
  - 24-Month Refueling Interval

• **Coolant Pumps:** 8 External Horizontal (Seal Less)

• **Dimensions:**
  - Diameter: 11.5ft [3.5m]
  - Height: 91ft [27.7m]

• **Steam Generator:** Recirculating Straight Tube

• **Pressurizer:** Integral with Heaters and Spray
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The Westinghouse Lead Fast Reactor

- Westinghouse is developing a Lead Fast Reactor (LFR) for global commercialization in the 2030 timeframe.

- The LFR addresses the key challenges to nuclear power expansion:
  - Economic competitiveness
  - Public perception (safety, waste) and Government policies
  - Technology versatility in evolving markets (increased emphasis on flexible operation, and possibly missions beyond electricity)

- Westinghouse selected LFR among all the most well-known nuclear technologies, as the one with best potential to meet the key requirements for global commercialization:
  - Safety, Economics, Marketability
  - (other evaluation criteria also considered – e.g., enhancement in natural resource utilization, technology readiness level, etc.)

Westinghouse made its Generation IV choice: LFR
The Westinghouse Lead Fast Reactor

- Solid safety case, addressing post-Fukushima concerns: walk-away safe
- Economically competitive in the most challenging markets
  - Step-change in economics: competitive with natural gas in the US
  - Versatile technology due to flexible operation and potential missions beyond electricity
- Enhanced sustainability from operation in fast neutron spectrum
  - Better utilization of natural uranium resources, with potential to close the fuel cycle
  - Reduced amount and long-term radiotoxicity of nuclear waste
- Built-in scalability
  - Minimizes re-design/licensing efforts for different power offerings
  - Base version sized at 950 MWt (~400 MWe)
- Technology readiness higher than generally thought
  - Increased International interest for LFR technology
  - Impressive testing facilities operated worldwide
  - Prototype LFR by 2030 followed by commercial units

Partnership is a key element of the Westinghouse LFR program
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eVinci™ Micro Reactor

Objective: Demonstrate a full scale, 1 MWe micro-reactor by 2022

Key Enablers

• Rapid demonstration with small, full scale models
• National lab rapid prototyping experience for NASA
• Integrate design & advanced manufacturing
• Heat pipe technology allows easier electrical demonstration
• Leverage reputable materials and fuel
• Utilize performance based licensing process in the U.S. and Canada

2012 – DUFF, Heat Pipe Reactor Demonstration, LANL

2017- KRUSTY, Full Scale Space Reactor Demonstration, LANL
eVinci™ addresses complete energy needs in remote applications
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Fueling the Future Through Innovation

- Advanced cladding materials, such as AXIOM™ and Lined Optimized ZIRLO™
- TRITON11™ revolutionary BWR fuel design
- VVER-1000 and 440, next-generation design for Russian-type reactors
- EnCore™ Fuel; shown here are lead test rods in the Westinghouse Ultra-High Temperature (UHT) test facility
Modeling and Simulation for Fuel Performance

- Consortium for Advanced Simulation of LWRs (CASL)
  - Vision: Create a virtual reactor for predictive simulation of LWRs
  - Challenge areas: DNB, cladding integrity, reactor vessel integrity, crud, fretting, PCI, FA distortion
  - Relates to power uprates, high burnup, life extension aspects
- Overall goals for a true multiphysics approach:
  - Better decision making capability for issue diagnosis and change evaluations
  - Operational enhancements through better understanding of design margin
- VERA: Virtual Environment for Reactor Applications
Summary

- Westinghouse continues to be a **leader** in the nuclear sector
- Westinghouse continues to be **committed** to the successful and safe reactor operations in Latin America and the world
- Investing in **innovation** to drive advanced nuclear technologies
- Westinghouse is developing Small Modular Reactor technologies:
  - LWR Westinghouse SMR – leveraging AP1000™ technologies
  - LFR Design – Gen IV for the future
  - eVinci Micro Reactor – enabling flexibility of applications

*Westinghouse: Partnering with our global Customers to provide safe, reliable, clean, competitive nuclear generation for years to come!*