Nuclear Power
A Journey of Continuous Improvement

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Our Place in Nuclear History

Innovation
1886 and forever

Implementation & Improvement
1957 through Today

Renaissance
Today and beyond

The path to clean nuclear energy technology.
Innovation

“I don’t look to the past; I think of what I’m going to do tomorrow.”

– George Westinghouse
American engineer, inventor, industrialist
Implementation

These plants, built in the 1970s and 1980s, reliably supply nearly 20% of U.S. energy needs.
Continuous Improvement

- Improved concepts
- Application of lessons learned
- Improved safety
- More efficient operations
- Economic competitiveness
The Renaissance Begins
Today’s Industry of Tomorrow

Sanmen Site Progress: Time Lapse View 2009 to 2013
The Renaissance Continues…

...with the Westinghouse SMR
Westinghouse Small Modular Reactor

Rendering of factory built SMR modules being delivered by rail
Market Drivers for Nuclear & SMRs

The energy industry demands *versatility*

**The Westinghouse SMR delivers:**
- 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
- An economic solution for the industry
- A balanced energy portfolio
Design Philosophy

- **Enhanced safety and security**
  - Based on tested & licensed passive safety systems
  - Reactor & safety systems below ground

- **Best opportunity for cost competitiveness**
  - Most power with the least amount of material
  - Entirely modular design
  - Rail, truck and barge transportable

- **Speed to market**
  - Proven ability to design, license and deploy reactors
  - Existing technical skills, licensed technologies and fuel supply
  - Designing to eliminate supply chain bottlenecks

The most economic SMR
Westinghouse Plant Design

- Single reactor site (standalone)
- Fuel – Modification of standard Westinghouse product (17x17 RFA)
- Forced flow with 8 reactor coolant pumps
- Internal control rod drive mechanisms
- Compact/high pressure containment vessel below grade
- Recirculating straight tube steam generator with steam drum location outside containment vessel
- Nuclear Island is 110’x110’ (34 m x 34 m)
- Embedment is 110’ deep (34 m)
- 24-month cycle length
- Load follow capability
- Total site area: ~15 acres (~6 hectares)
- Instrumentation and Control: Ovation®-based Digital Control System
The Westinghouse SMR

- An integral pressurized water reactor—single >225 MWe reactor
- Innovative packaging of proven components
- The highest levels of safety with fewer accident scenarios
- Leverages AP1000® plant passive safety system designs
- Compact reactor coolant system and containment

An engineered, economic solution for today’s clean energy challenges
Reactors Coolant Pumps Overview

- Seal-less pump design
- Driven with variable frequency drives (VFD)
- Mounted horizontally to reactor vessel below closure flange
- Internally circulating reactor coolant removes pump heat via heat exchanger to plant component cooling water system
Overview of SG

SG Internals

- Tubesheet
- Tubes
- Tube Supports
- Wrapper
- Hot Leg
- Transition Cone / Cold Leg

External / Elevated Steam Drum

- Steam Nozzle to Turbine
- Secondary Separators
- Primary Separators
- Sludge Collector
- Recirculation Nozzle
- Wet Steam Nozzle

Feedwater Nozzle

Steam and Feed Nozzles

Compact Containment → Reduced Plant Costs
Steam Drum Requirements

• **Moisture Separation** — produce dry steam ($\chi \geq 99.9\%$) for turbine
• **Sludge Collection** — provide a settling zone for removal of corrosion products (passive)
• **Blowdown** — for secondary chemistry control
• **Large inventory for decay heat removal** — initial estimates indicate ~80 minutes capacity. This occurs, using gravity flow, between the steam drum and steam generator with no AC power required.

**Robust design employs proven best-in-class separation equipment**
Steam Drum Design

Dry Steam Flow Path
- Wet Steam Nozzle
- Lower Deck Plate
- Primary Separators
- Secondary Separators
- Steam Outlet Nozzle

Recirculating Liquid Flow Path
- Wet Steam Nozzle
- Lower Deck Plate
- Primary Separators
- Lower Drum
- Recirculation Nozzle

Feedwater Flow Path
- Feedwater Nozzle
- Lower Drum
- Recirculation Nozzle

Typical Design Features
Elevated Feeding with Spray Nozzles
- Primary Separators
- Secondary Separators

Leverages existing Westinghouse steam generator technology and experience
Westinghouse SMR Balance of Plant – Objectives

- Cost-informed design
- Simplicity
- Reduce building costs
- Reduce systems and components
- Reliability
- Installation schedule
- Shipping concerns
- Capability for future dry cooling
Westinghouse SMR Balance of Plant – Turbine

- **Design Features**
  - Two casings
  - 40” LSB (~1 meter)
  - Inline moisture separation (no reheat)
  - Single flow HP, Opposed flow LP
  - 3600 RPM
  - 5 feedwater heaters
Westinghouse SMR Balance of Plant – Generator

• Air-Cooled
  Simpler
  Less maintenance
  Lower insurance costs
  Faster install

• 2 Pole

• Brushless exciter

• Totally Enclosed Water to Air Cooled (TEWAC) configuration
How Small is Small?

25 Westinghouse SMR containment vessels fit in a single AP1000 plant containment vessel

Westinghouse SMR NSSS island fits in the AP1000 plant shield building
Nuclear Island Layout

Compartments isolate safety system components for enhanced safety and security
SMR Safety

• **>7 Days of passive heat removal in Ultimate Heat Sink (UHS)**
  – Capability to add additional inventory to UHS tanks for indefinite cooling

• **100% reliance on natural forces**
  – Evaporation, condensation, gravity

• **No AC electric power required for plant safety for >7 Days**
Safety Methodology

- **Reactor shutdown**
  - Control rod drive mechanisms
  - Boric acid injection from Core Makeup Tanks (CMTs)
- **Reactor decay heat removal**
  - Steam Generator with gravity feed from steam drum
  - Core Makeup Tank closed circuit cooling to Ultimate Heat Sink (UHS) tank
- **Reactor inventory addition**
  - Core Makeup Tank injection
  - In-Containment Pool (ICP) injection
  - Long-term recirculation
- **Containment heat removal**
  - Convection and condensation of steam inside containment
  - Heat transfer through containment wall to an external pool
  - External pool automatically refilled by UHS tanks
The Westinghouse SMR

- An integral pressurized water reactor—single >225 MWe reactor
- Standalone unit; no shared systems
- Innovative packaging of proven components
- The highest levels of safety with fewer accident scenarios
- **AP1000®** plant passive safety system designs
- Compact reactor coolant system and containment

An engineered, economic solution for today’s clean energy challenges
Modular Construction

- Traditional large scale reactor economies of scale can be countered through application of modular construction techniques
- SMR maximizes modular design in all aspects of plant
- Modular design drives work normally completed at the construction site to the factory where quality is better controlled, overall cost are reduced and schedule certainty increased
- Modules are designed for road and rail transport to site and scalable to other forms of transport
- SMR uses the AP1000 plant licensed modular wall and joint design
Load Follow Capability

• The Westinghouse SMR is designed to respond to various load change transients
  – Daily and weekend load follow operations
  – Extended reduced power operation
  – Grid frequency response (load regulation)
• Load follow operations utilize MSHIM™ operating strategy
  – Power maneuvers accomplished without cycling of boron systems

The Westinghouse SMR is flexible and responsive to frequent changes in electrical demands
Sample Change in Power Output vs. Time during Load Follow and Frequency Control
Westinghouse AP1000 Plant/SMR Fuel Comparison

**AP1000 Plant**
- 157 Fuel Assemblies
- 17 x 17 RFA
- 14 ft. (~4.25 m) Active Length
- 18 Month Fuel Cycle

**SMR**
- 89 Fuel Assemblies
- 17 x 17 RFA
- 8 Ft. (2.4 m) Active Length
- 24 Month Fuel Cycle
Westinghouse SMR Program Progress

• Completed first SMR fuel assemblies
• Completed an application to respond to the recent Department of Energy (DOE) Funding Opportunity Announcement (FOA) to accelerate the licensing and deployment of SMR technology
• Signed a Memorandum of Understanding with State Nuclear Power Technology Corporation (SNPTC)
• Entered into an agreement with Burns & McDonnell Engineering Company, Inc. in Missouri to further the development and licensing of the Westinghouse SMR
• Several pre-meetings held with the U.S. Nuclear Regulatory Commission (NRC); additional meetings scheduled for 2013
• Significant progress made on the Design Certification Application for submittal to the NRC in the second quarter of 2014
• Continuing to work closely with our COL partner Ameren Missouri and the state of Missouri on economic development
Ameren Missouri and Westinghouse Partnership

Objectives

• Submit a COLA for deploying the Westinghouse SMR at the Callaway Energy Center
• Design, license and deploy the Westinghouse SMR to market first
• Utilize Ameren’s utility perspective to optimize design and operations strategy
Strong Industry Team

www.nexstartalliance.com
Potential Challenges

• Deployment of new nuclear in a challenging energy market (i.e., natural gas prices)
• Public perception and siting of small reactors (i.e., emergency planning zone - EPZ)
• Economic challenges of capital costs and economies of scale
• Operational costs related to staffing, security and maintenance
• Nuclear waste and fuel cycle considerations

• Development and licensing costs for first-of-a-kind (FOAK) development
• Political support as a clean energy alternative versus wind and solar
The Westinghouse SMR Benefits

- Fossil fuel plant replacement
- Small utility, remote/grid-limited application solution
- Load follow ability
- Economic solution
- Balanced energy portfolio
Questions
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