

# **Techno-Economic of Innovative SMRs Deployment**

*by*

*Mohammed Mahdy*

*Operation Head of Egyptian First Training and  
Research Reactor ETRR-1 , Egypt*

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# Table of content

## ☐ Egypt Current State

- Egyptian First Training and Research Reactor ETRR-1
- Egyptian Second Training and Research Reactor **ETRR-2**

## ☐ Small Modular Reactors(SMRs) Technologies - Economical & Technical Aspects

- Advanced Reactor Designs
- Passive Safety Systems
- Modular Construction
- Hybrid Energy Systems
- Advanced Materials
- Digital Control Systems
- Fuel Innovations
- Remote Monitoring and Maintenance
- Microgrid Integration

## ☐ Conclusions

# Egypt Current State

## ETRR-1

- ETRR-1 reactor is of former Soviet Union origin (WWR-S design standard),
  - It is a tank-in-pool type research reactor,
  - Reached its first criticality in 1961,
  - Has nominal thermal power of 2 MW,
  - Moderated, cooled and reflected by distilled light water,
  - Operates by the well known Al clad, 10% enriched EK-10 type fuel rods in 4×4
- |                                    |  |
|------------------------------------|--|
| ▪ The maximum thermal neutron flux | $2 \times 10^{13}$ n/cm <sup>2</sup> sec.  |
| ▪ The average thermal neutron      | $1.3 \times 10^{13}$ n/cm <sup>2</sup> sec |
| ▪ The max fast neutron flux        | $6 \times 10^{12}$ n/cm <sup>2</sup> sec   |

# Egypt Current State

## ETRR-2

- ETRR-2 General Overview
- Reactor Name: Egypt Second Testing Research Reactor [ETRR2]
- Average Flux:  $8.1 \times 10^{13}$  n/cm<sup>2</sup> sec.
- Maximum Flux:  $2.7 \times 10^{14}$  n/cm<sup>2</sup> sec.
- Reactor Power: 22Mw “thermal power”
- Reactor Type: Open Pool
- Moderator: Light Water
- Reflector: Beryllium

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## ☐ SMRs REACTORS Advanced Reactor Designs

- Integral Pressurized Water Reactors (iPWR)
- Molten Salt Reactors (MSR)
- High-Temperature Gas-cooled Reactors (HTGR)
- Fast Neutron Reactors
- Liquid Metal-cooled Reactors
- Thorium-fueled Reactors
- Microreactors
- Hybrid Energy Systems

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs reactor Passive Safety Systems

- Natural Circulation Cooling
- Gravity-Driven Systems
- Passive Heat Removal Systems
- Hydrogen Igniters
- Inherent Reactor Shutdown Mechanisms
- Natural Decay Heat Removal
- Emergency Core Cooling Systems (ECCS)
- Leaks-Tight Containment

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## ☐ SMR reactor Modular Construction

- Factory Fabrication
- Reduced On-Site Construction Time:
- Cost Savings
- Standardization
- Transportability
- Scalability
- Quality Control
- Remote Monitoring and Maintenance

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs Hybrid Energy Systems

- Renewable Energy Integration
- Combined Heat and Power (CHP) Generation
- Energy Storage Support
- Integration with Natural Gas
- Grid Stability and Reliability
- Load Following and Fast Response
- Decentralized Power Generation
- Microgrid Integration
- Carbon Emission Reduction
- Resilience in Energy Supply

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs reactor Advanced Materials

- High-Temperature Alloys
- Ceramic Matrix Composites (CMCs)
- Refractory Metals
- Graphite Moderators
- Advanced Steels
- Ceramic Fuels
- Carbon-Carbon Composites
- Tristructural-Isotropic (TRISO) Particles
- Advanced Coolants
- Coated Cladding Materials

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs reactor Digital Control Systems

- Real-time Monitoring
- Safety Systems Integration
- Fault Detection and Diagnostics
- Automated Control Strategies
- Adaptive Reactor Operation
- Cyber security Measures
- Human-Machine Interface (HMI)
- Data Logging and Analysis
- Remote Monitoring and Operation
- Redundancy and Reliability

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs Fuel Innovations

- High-Assay Low-Enriched Uranium (HALEU):
- TRISO Particles
- Molten Salt Fuels
- Thorium Fuel Cycles
- Metallic Fuels
- Innovative Cladding Materials
- Fast Neutron Reactor Fuels
- Nuclear Thermal Propulsion Fuels
- Accident-Tolerant Fuels
- Closed Fuel Cycle Innovations

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs Remote Monitoring and Maintenance

- Sensor Networks
- Communication Systems
- Digital Control Systems
- Condition Monitoring
- Predictive Maintenance
- Robotics and Drones
- Augmented Reality (AR) and Virtual Reality (VR)
- Cyber-Physical Security Measures
- Remote Diagnostics
- Teleoperation and Control Centers

# Small Modular Nuclear Research Reactor (SMR) Technologies - Economical & Technical Aspects

## □ SMRs reactor Microgrid Integration

- Localized Power Generation
- Grid Resilience
- Islanded Operation
- Hybrid Energy Systems
- Load Following and Peak Shaving
- District Heating
- Energy Security
- Scalability
- Environmental Benefits
- Grid Independence

# Conclusion & Feedback