

Nuclear Reactor Technologies for Small Modular Reactors – Impact on Desalination Potential

Introduction

- The deployment of Small Modular Reactors (SMRs) promises to break the historical cycle of ever larger nuclear power station designs with greater cost over runs and delays.
- Current large reactor designs are all based upon existing, deployed technology, and increasingly that is the classic Pressurised Water Reactor. This is shown in the AP1000, EPR, Hualong One, APR1400, VVER-1200, CAP1400, etc.
- All the SMR designs currently proposed move away from the PWR technology and use, in many cases, technology demonstrated in the 1960s but never full commercialised .

Desalination Technology Issues

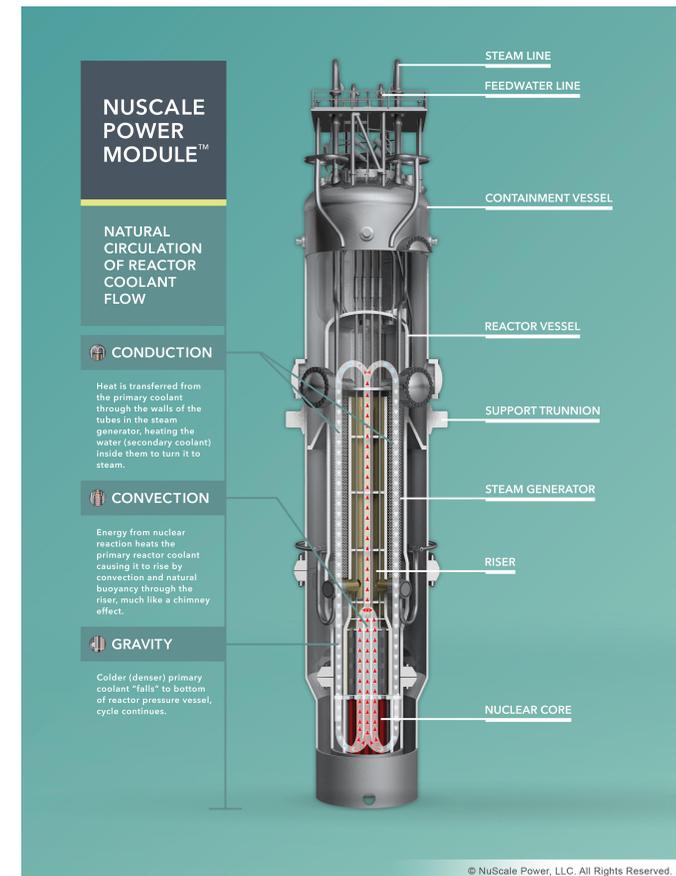
- There are two principal families of desalination technology.
 - Reverse Osmosis (RO)
 - Thermal Desalination
- While RO plants benefit from warm raw water supply (up to some 40°C) the primary energy input is the high pressure pumping of the water through the membranes.
- Thermal processes (MED, MVC and MSF) rely on converting the liquid water into steam, and therefore the primary energy input is heat, around 100°C).
- Therefore the key question in applying SMRs to Desalination Plants is whether it is better to extract heat energy for Thermal Desal, with the prospect of losing overall efficiency, or using electricity directly for RO.

Impact of Desal on Power Conversion

- A normal Rankine cycle steam plant will get higher thermal efficiency the lower the heat sink temperature (T_{cold} e.g. the sea)
- The impact of removing “low temperature” steam from a Rankine cycle plant on efficiency is greater if the T_{hot} of the system is lower.
- A direct cycle Brayton gas turbine plant (e.g. PBMR 400) would reject heat at over 100°C without any efficiency loss.

Impact of potential SMR Technology - I

- Integral Light Water Reactors (e.g. NuScale)
 - Technology largely based upon PWR & BWR
 - Rankine Cycle with net efficiency about 28%
 - Significant Impact on efficiency if steam taken for Thermal Desalination
 - Lends itself to Reverse Osmosis technology



Impact of potential SMR Technology - II

- Alternative Technologies using Rankine Cycle
 - These are technologies using higher temperature coolant than LWR (helium, sodium, lead, molten salt etc)
 - Technology largely based on experience of “prototype” reactors from 1960s and 1970s.
 - High temperature coolants leads to steam conditions similar to advanced fossil plant, with efficiency of about 40%.
 - This would mean a more limited impact of thermal desalination on efficiency



HTR-PM – Chinese HTGR with Rankine steam cycle, 567°C steam and 40% efficiency

Impact of potential SMR Technology - III

- Direct Cycle Gas Cooled Reactor
 - Technology a meld of combustion gas turbine and 1980s HTGR technology.
 - Uses the Brayton cycle with a primary circuit reject heat of about 120°C.
 - Overall thermal efficiency 40%-50%
 - Could provide thermal energy to Thermal Desalination plant with no loss of plant efficiency.

