Generation III+ technology: What has gone wrong?

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Gen III+ promises ça 2000

- Gen III+ plants would be safer, but less complex, therefore cheaper ($1000/kW) & less likely to have construction over-runs

- No clear definition of what Gen III+ is but might include passive safety, core-catcher (not USA), modularisation (minimises site-work) & aircraft protection (after 9/11)

- Generic regulatory reviews prior to construction also expected to solve safety issues once and for all. Generic reviews adopted in USA in 1992 and in UK in 2008 but not elsewhere yet

- Standardisation would help reduce costs by avoiding unnecessary design changes

The record

- Many Gen III+ designs proposed, none in operation but 18 under construction: 4 EPRs (Areva), 8 AP1000s (Westinghouse Toshiba) and 6 AES-2006s (Rosatom)
- Other developed designs Toshiba and Hitachi upgraded versions of ABWR, Mitsubishi APWR, upgraded Korea APR1400
- Expected cost now ca $8000/kW
- We review cost escalation & delays from start of construction onwards to assess ‘buildability’. Often significant delays and extra costs before but not caused by buildability issues
- All except 2 reactors are 2-9 years late, all over budget

EPR Projects

Name	Start construction	Forecast complete	Over-run	Forecast cost	Over-run
Olkiluoto (Finland)	5/05	5/09	9 years	€3bn	183%
Flamanville (France)	12/07	5/12	5 years	€3.2bn	165%
Taishan x 2 (China)	11/09, 4/10	2/14, 8/14	2 years	€8bn for 2	?

AP1000 projects

Name	Start construction	Forecast complete	Over-run	Forecast cost	Over-run
Sanmen x 2 (China)	4/09, 12/08	8/13, 8/14	2-3 years	$1940/kW	20%
Haiyang x 2 (China)	9/09, 6/10	5/14, 2/15	18-22 months	$1940/kW	20%
Vogtle x 2 (USA)	3/13, 11/13	4/16, 1/18	2.5-3 years	$13.3bn for 2	33%
Summer x 2 (USA)	3/13, 11/13	3/16, 11/18	2-3 years	$10.4bn for 2	20%

AES-2006 projects

Name	Start construction	Forecast complete	Over-run	Forecast cost	Over-run
Novovoronezh-2 x 2 (Russia)	6/08, 7/09	2013, 2014	12-38 months	$1200/kW	?
Leningrad-2 x 2 (Russia)	10/08, 4/10	2013, 2015	12-38 months	$1200/kW	?
Belarusian x 2 (Belarus)	11/13, 4/14	2018, 2020	0	$13bn	71%

Design philosophies

EPR

- Developed from French N4 – 4 reactors built, bad record, construction time 15 year & German Konvoi - 3 units built, good record esp reliability

- Guiding design principle ‘simplifying system design’, some passive safety but ‘an evolutionary path with an emphasis on active safety features’

AP1000

- Developed from AP600 (Advanced Passive), certified by NRC (1999) but never marketed

- ‘50% fewer valves, 35% fewer pumps, 80% less pipe, 80% fewer heating, ventilating & cooling units, 45% less seismic building volume, 70% less cable. Modularisation allows repetitive construction activities to be performed in a more controlled environment’

Construction record: EPR

- Evolutionary design based partly on unsuccessful design (N4). Little passive safety, no modularisation and appears more complex than predecessors

- Design not stabilised. 10 year review process underway by Areva to reduce costs & complexity in new model. Why should it succeed this time when earlier attempts failed?

- Instrumentation & Control system problematic. Different solutions proposed for France, Finland, UK, USA and China. Is the significance overstated? Is it a convenient excuse for more general failures?

- Serious site quality control issues in France & Finland – welding, concrete

Construction record: AP1000

- Radical new design. Has passive safety reduced complexity? Costs not reduced, no cheaper than EPR
- Appears as prone to delays and cost over-runs as EPR
- Why has the design not stabilised, still continuing flow of design changes 13 years after design completed
- When known design faults are sorted out, eg reactor coolant pumps, will progress be smoother?
- Modularisation seems to have shifted quality control problems from site to factories

Construction record AES-2006

- Appears to be evolved from AES-91 and AES-92 designs exported to India and China

- Incessant design changes. Bartuska (Czech Rep) says AES-2006 a brand nothing more. Leningrad version V-491, Novovoronezh V-392M

- Are delays in Russia just due to finance? Are current schedules realistic or are there more delays to come?

Was safer, simpler and cheaper an impossible dream?

- Gen III+ seems to be failing, several times predicted cost and costs still escalating, delays worse than ever
- Gen III+ designs fall into 2 categories: 1980s designs with added safety: Areva EPR, Hitachi and Toshiba ABWR, Mitsubishi APWR. And radical new designs with passive safety & modularisation – Westinghouse AP1000, GE-Hitachi ESBWR
- First category was inevitably more complex so could not be cheaper or easier to build
- Are problems with AP1000 indicative that passive safety & modularisation did not reduce complexity so not cheaper and not easier to build. ESBWR seems close to abandonment
- If Gen III+ is failing can the nuclear industry convince governments to fund Gen IV, Thorium etc?

Standardisation

- The Gen III+ designs not standardised, incessant design changes with no end in sight. Why? Technology not mature enough, dealing with design errors, differing national regulatory requirements, attempts to reduce costs?

- For 40 years, nuclear industry claims big benefits for standardisation, but this has never happened. Why? Even French programme of 58 reactors comprised 7 different models

- No clarity about what standardisation means. ‘Model T’ or broad design parameters?

- Advantages of rigorous (Model T) standardisation: cost reduction, reduced regulatory burden & uncertainty, cheaper component prices, construction ‘learning’

- Disadvantages: can’t take account of operating experience, can’t take account of technical innovations, standardised design must be designed up to highest requirements, eg expensive high seismic characteristics for site of low seismicity

Generic design reviews

- Resolving all design issues before construction start intuitively seems sensible but can approval be generic and how long can it last?

- Would a generic review have prevented I&C related delays at Olkiluoto & Flamanville? Is the UK solution for I&C fully worked out? Abandonment of NRC process for EPR means no information from there

- US system in place since 1992 but only now being tested

- If the design is not stable, is regulatory approval lasting 15 years credible? What happens to generic approval if there is another ‘9/11’ or ‘Fukushima’?

Skills & capabilities and supply chain

- Problems in Europe and USA suggest loss of skills & expertise a serious problem
- More likely to be due to an ageing of the workforce and workers exiting the industry due to low ordering rather than lack of practice
- Replacing skills will be a slow process and unless there is a strong and predictable flow of orders, how can new workers be persuaded to train?
- Problems in Europe & USA suggest erosion of the supply chain a serious problem
- Companies will not take the risk of building up capabilities or investing in expensive production equipment unless there is confidence in the ordering rate

China

- China and Russia have dominated ordering and construction in the past 8 years but there are doubts about their capabilities
- China has shown in the past it can complete plant on time and apparently cheaply but it has run into problems with Gen III+. How far due to Gen III+ and how far because China overstretched?
- There are doubts about its regulatory capability and its quality control procedures
- Does it have a capability to develop innovative designs independently?
- Can it operate effectively outside China, especially in countries with experienced, strong and rigorous regulatory bodies?

Russia

- Russia claims more than 20 export reactor orders or near orders: Iran, Turkey, Vietnam, Bangladesh, Jordan, Hungary, Finland, Egypt, India, South Africa.

- Most dependent on comprehensive Russian finance but only 4 under construction (China & Belarus) and it is facing delays in Russia because of lack of resources

- Does it have the financial and supply chain resources to carry out more than a small fraction of these

- Its only experience for orders outside Russia in the past 30 years are 2 reactors to China (apparently OK) and 2 to India (poor experience)

- It has an independent design capability but will its designs be acceptable to experienced, open and rigorous regulators?