

IEEE NPSS School on Nuclear Power for Sustainable Development



THE OHIO STATE UNIVERSITY

Overview of iPWR – SMR Simulator

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The simulator represents a **150 MW(th) / 45 MW(e) integral PWR** and includes natural/forced circulation plus passive systems such as

ADS — Automatic Depressurization System

PIS — Passive Injection System

GIS — Gravity Injection System

PDHR — Passive Decay Heat Removal System

It supports exercises including load changes, reactor trips, loss of feedwater, turbine runback, SGTR, main steam-line break, RCP trip, and station blackout.



Load changes:

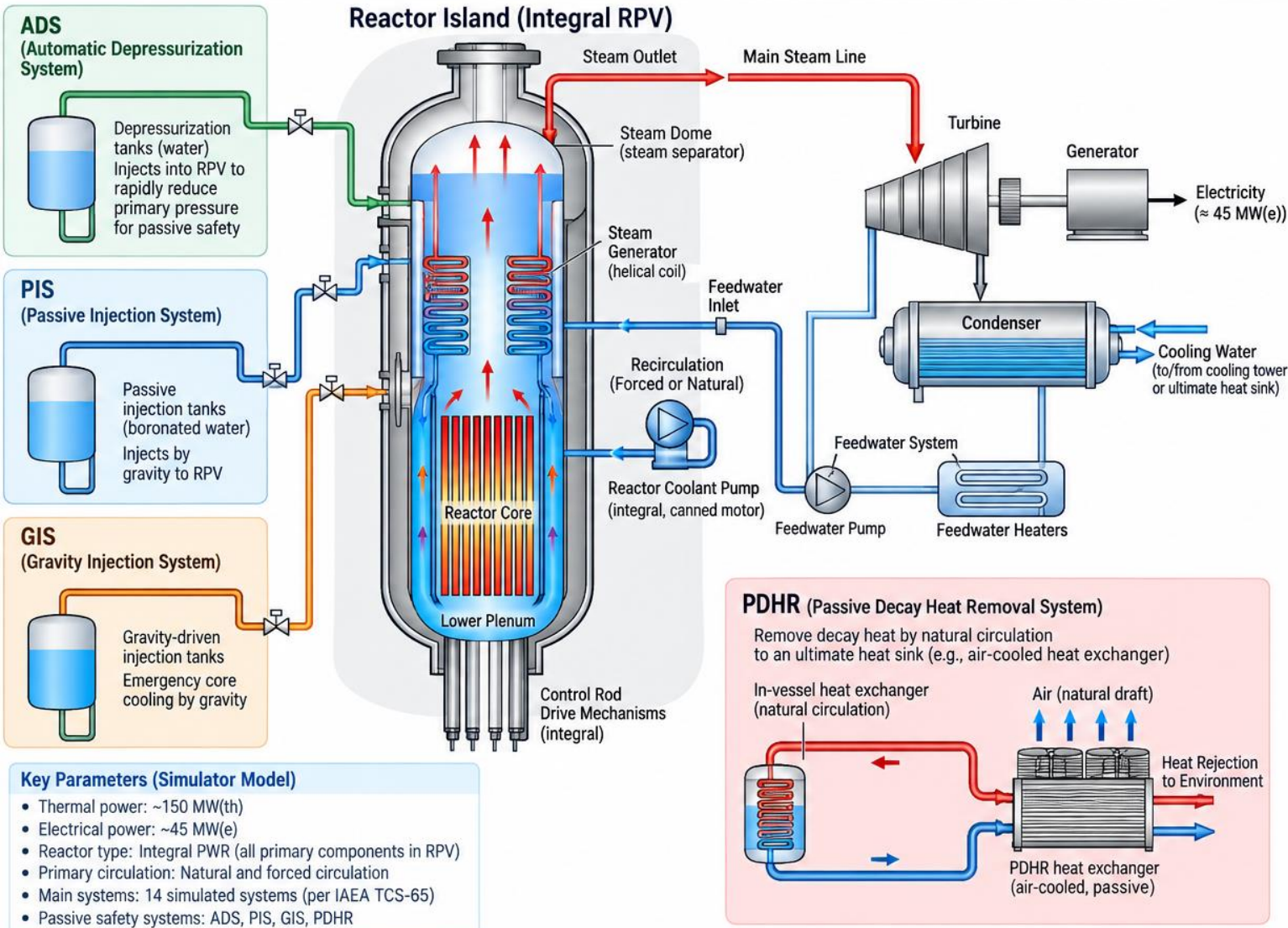
Load decreases → turbine takes less steam → steam pressure rises → reactor power is reduced → steam generation decreases → plant settles at the new lower power.

1. **Turbine load decreases.** The turbine control valves partially close, so the turbine accepts **less steam**.
2. **Steam accumulates.** The reactor/steam generator is initially still producing approximately the same amount of steam, but less is flowing to the turbine.
3. **Steam pressure rises.** This tells the plant control system, in effect: “**We are producing more steam/heat than the turbine currently needs.**”
4. **The reactor control system reduces reactor power.** Depending on the iPWR control logic, this can involve **control-rod insertion** and associated temperature/power feedback.
5. **Less fission heat → less steam generation.** Eventually steam production again matches what the turbine consumes, and steam pressure returns toward its setpoint.

IAEA iPWR Simulator

Integral Pressurized Water Reactor (iPWR) – Approx. 150 MW(th) / 45 MW(e)

- Integral PWR with primary components in a single reactor vessel
- Natural and forced circulation
- Passive safety systems: ADS, PIS, GIS, PDHR
- Used for operator training and transient analysis



Typical Simulator Exercises

- 1 Load changes (e.g., power increase/decrease)
- 2 Reactor trips (e.g., automatic or manual)
- 3 Loss of feedwater (LOFW)
- 4 Turbine runback
- 5 Steam generator tube rupture (SGTR)
- 6 Main steam-line break (MSLB)
- 7 Reactor coolant pump trip (RCP trip)
- 8 Station blackout (SBO)

Legend

- Main steam (steam)
- Feedwater / Condensate
- Primary coolant (cold)
- Primary coolant (hot)
- ADS injection
- PIS injection
- GIS injection
- PDHR natural circulation
- Pump
- Isolation/Check Valve



Reactor trips

A **reactor trip** means the reactor is **automatically or manually shut down very rapidly** for safety. It is also commonly called a **reactor scram**.

In a PWR, a trip typically causes the **control rods to rapidly insert into the reactor core**, absorbing neutrons and stopping the self-sustaining fission chain reaction.

The word “**trip**” comes from electrical and mechanical engineering. It means a protective device has been **triggered to quickly stop or disconnect equipment** when an abnormal condition occurs. **circuit breaker tripping** in your house:

So:

- **Reactor trip** = rapid shutdown of the reactor
- **Turbine trip** = rapid shutdown/disconnection of the turbine
- **Generator trip** = generator disconnected from the electrical grid
- **Pump trip** = pump stops, often because of a protective signal

SCRAM is often expanded as “**Safety Control Rod Axe Man.**”



In a nuclear power plant, **turbine runback** means the turbine's power is **automatically and rapidly reduced to a lower level**, but the turbine is **not completely shut down**.

This is different from a **turbine trip**:

- **Turbine runback**: rapid, controlled **reduction** in turbine load; turbine remains operating.
- **Turbine trip**: turbine is **shut down**, with steam admission rapidly stopped.

Load change → normal, deliberate change in power

Turbine runback → automatic rapid reduction to a lower power

Turbine trip → rapid shutdown of the turbine

Why perform a runback?

A runback is used when some equipment can no longer support full-power operation. For example, loss of a feedwater pump or other balance-of-plant equipment may mean the plant can safely operate at reduced power but not at 100%.



SGTR stands for **Steam Generator Tube Rupture**.

In a PWR, the steam generator normally keeps two water systems physically separated:

Primary side: radioactive reactor coolant

Secondary side: water/steam going to the turbine

The two sides exchange heat through thousands of thin metal tubes:

An **SGTR** occurs when **one or more steam-generator tubes rupture**, creating a direct path between the primary and secondary systems.

Because the **primary system pressure is much higher** than the secondary pressure:

Tube breaks → primary coolant leaks into secondary side → primary inventory decreases + radioactive material can enter the steam system.

This is why SGTR is an important accident scenario.

A key distinction:

LOCA: primary coolant leaks out of the reactor coolant system.

SGTR: primary coolant leaks **into the secondary system through a failed steam-generator tube**.



A **Main Steam-Line Break (MSLB)** is a rupture of one of the **large pipes carrying steam from the steam generator to the turbine**.

For a PWR, think of the normal path as:

Reactor → heats primary coolant → Steam Generator → steam → Main Steam Line → Turbine

An MSLB means:

Steam Generator → ✗ broken main steam pipe → large amount of steam escapes

What happens after the pipe breaks?

Because the secondary side is pressurized, a large amount of steam can escape very rapidly.

1. Secondary pressure drops rapidly

Steam escapes through the break, causing steam-generator pressure to fall.

2. Steam generator removes more heat from the primary system

Lower secondary pressure means a lower steam saturation temperature. The steam generator therefore cools the primary coolant more strongly.

3. Primary coolant temperature decreases

This is particularly important in a PWR.

4. Reactor power may initially tend to increase

Because PWRs normally have a **negative moderator temperature coefficient**:

↓ **coolant temperature** → ↑ **water density** → ↑ **neutron moderation** → ↑ **reactivity**

So an MSLB is interesting because a secondary-side pipe rupture can create a reactivity increase in the core.

5. Reactor protection trips the reactor

The protection system detects abnormal conditions and initiates a **SCRAM/reactor trip**.

6. The plant isolates the broken steam line/steam generator and maintains core cooling and decay-heat removal.



Accident	What breaks?	Main consequence
SGTR	Steam-generator tube	Primary coolant leaks into secondary system
MSLB	Large main steam pipe	Secondary steam escapes rapidly
LOCA	Primary-system piping	Primary coolant escapes