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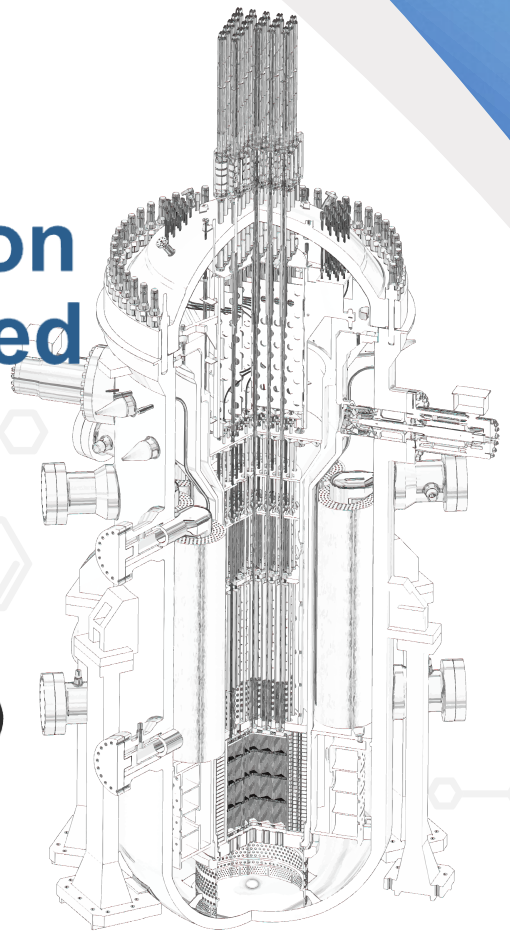
Consideration of a Two-phase Excitation Control Method for Stepping Motor Used in HANARO's Control Rods



Jiye Jeong (jiye8713@kaeri.re.kr)

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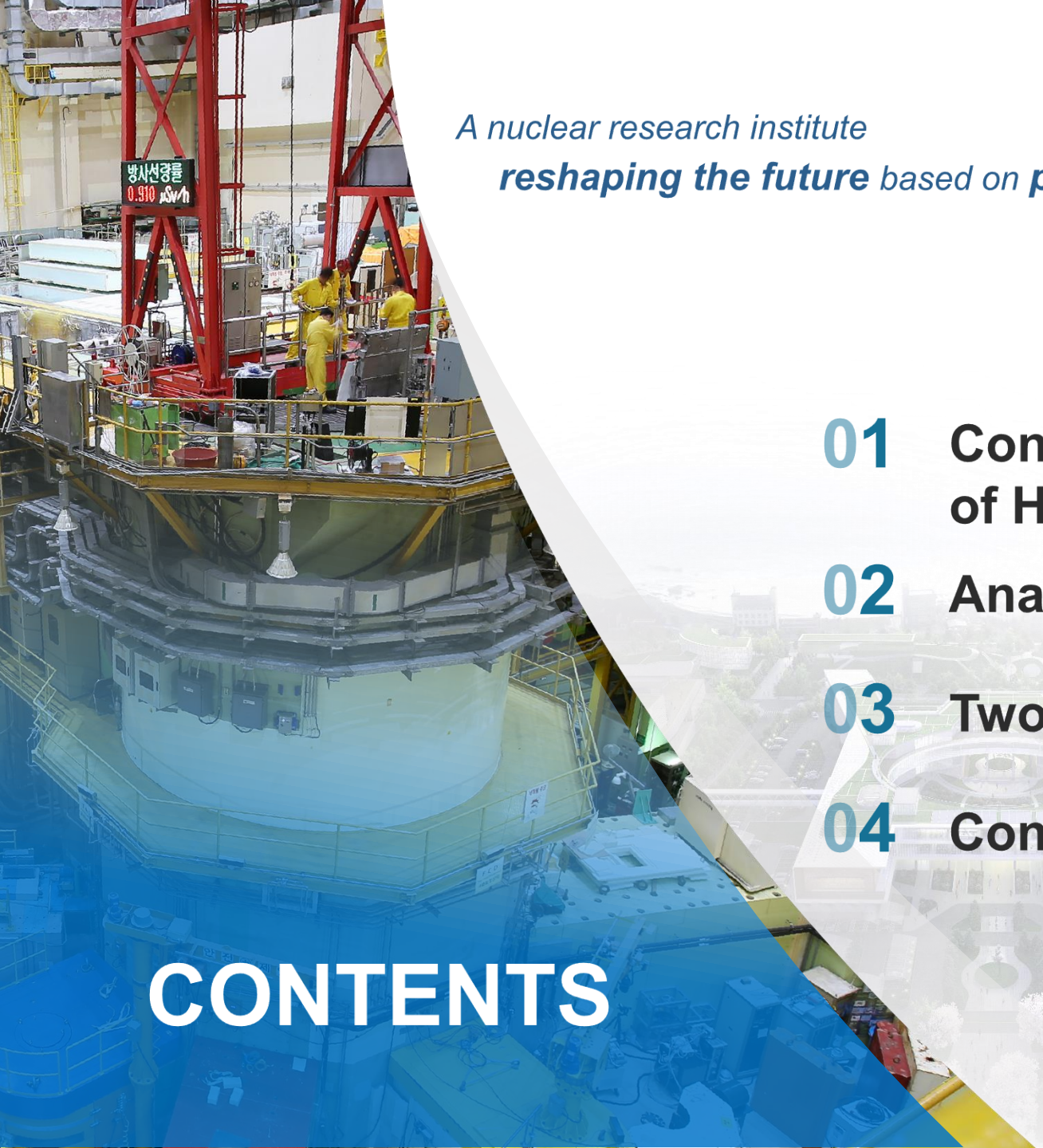

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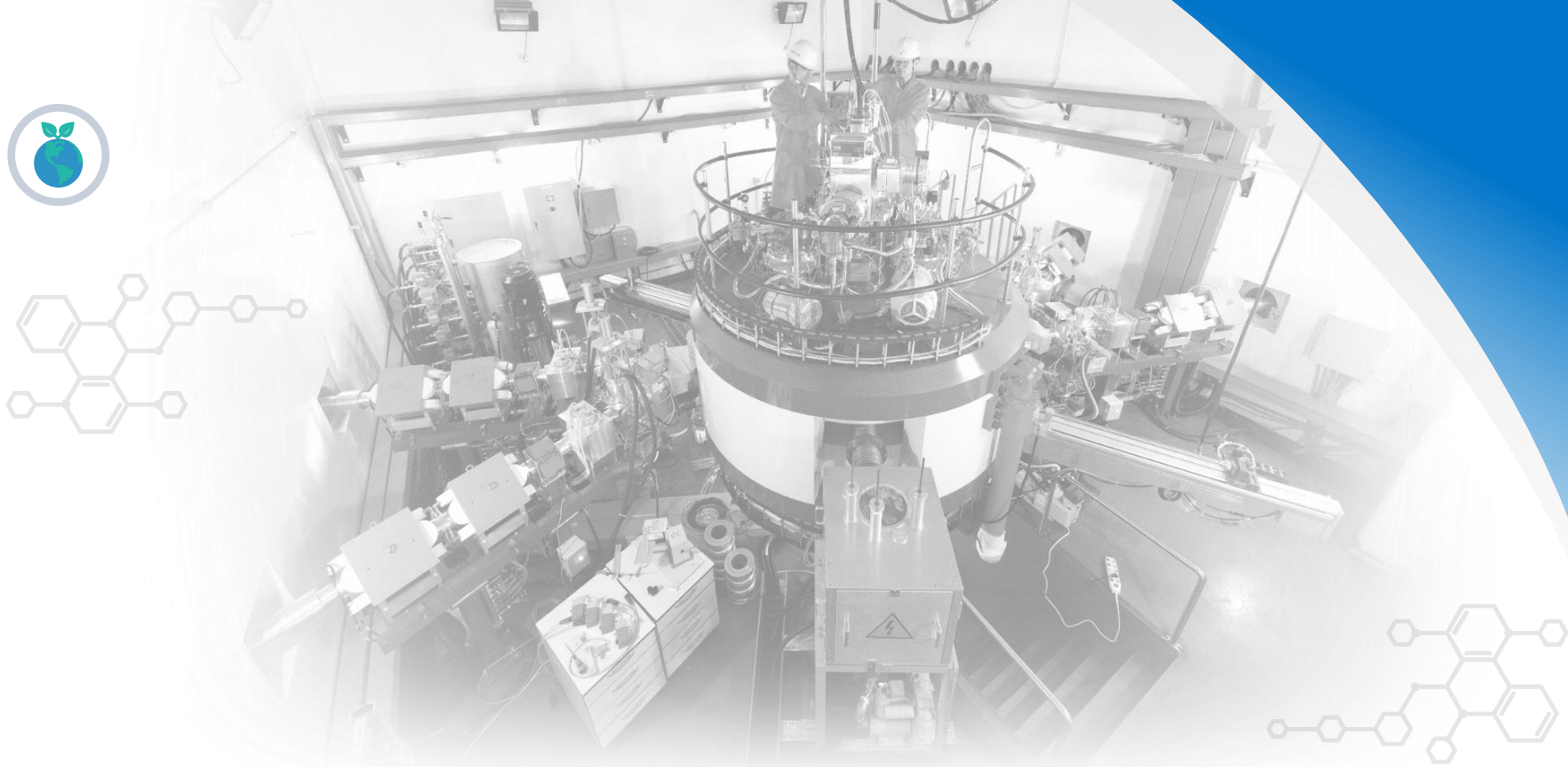

Consideration of a Two-phase Excitation Control Method for Stepping Motor Used in HANARO's Control Rods

01 Control Absorber Rods Drive System of HANARO

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01 Control Absorber Rods Drive System of HANARO

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Introduction of HANARO

- High-flux Advanced Neutron Application Reactor
- 30MW (thermal)
- Safety Design
  - ✓ 318 tons of water tank
    → Cooling & radiation shielding
  - ✓ Natural convection if power failures
  - ✓ Available to open
    → Additional cooling water

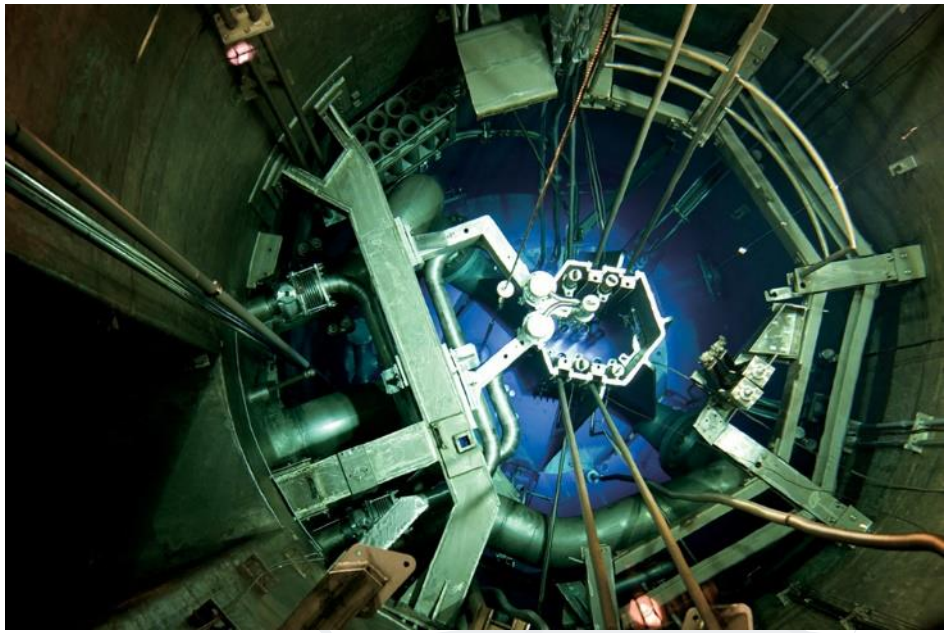

Figure 1. Reactor Pool of HANARO

01 Control Absorber Rods Drive System of HANARO

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Introduction of HANARO

- Four Shut Off Rods (SORs)
  - → Shut down reactor rapidly and safely
  - → Vertical fall by gravity
    - : inserting cylindrical hafnium tubes into the core

- Four Control Absorber Rods (CARs)
  - → Regulate power output
  - → Move up or down

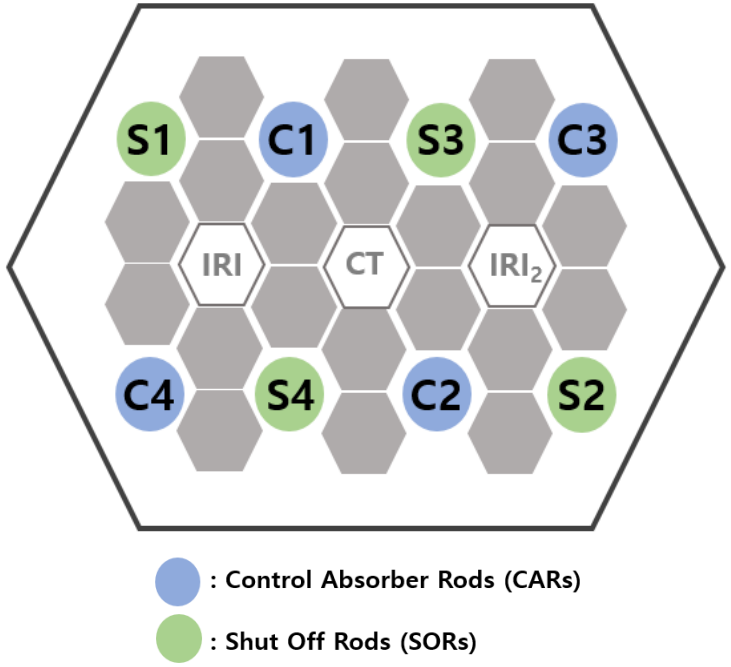

Figure 2. CARs and SORs in the core

01 Control Absorber Rods Drive System of HANARO

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Control Absorber Rods Drive System

- Three parts : Absorber Element Assembly, CARs Drive Assembly, Rod Control System(RCS)

1. Absorber Element Assembly

✓ Control the reactivity of the core directly

✓ Components : hafnium tubes, shrouds, tracks etc.

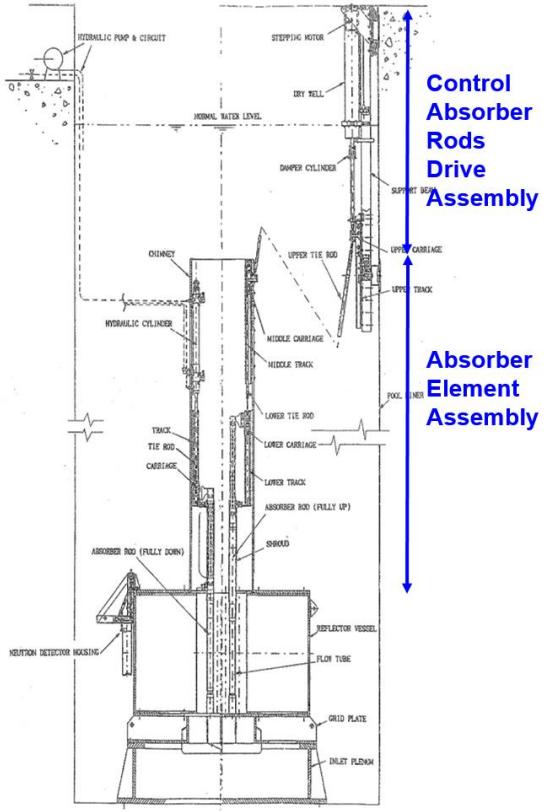

Figure 3. Configuration of CAR

Control Absorber Rods Drive System

2. CARs Drive Assembly

- ✓ Mechanical unit to control rods by receiving drive signals
- ✓ CARs are moved by rotational motion of stepping motor.
- ✓ Components : stepping motors, drive nut, electromagnet, lead screw etc.

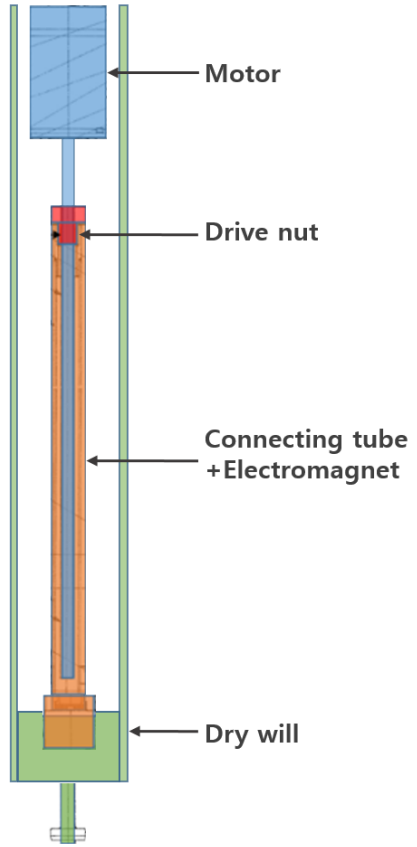

Figure 4. Configuration of CAR Drive Assembly

Control Absorber Rods Drive System

3. RCS(Rod Control System)

- ✓ I&C System to generate and deliver the driving signal of CARs.
- ✓ Four parts : controller, counter card, motor driver and encoder

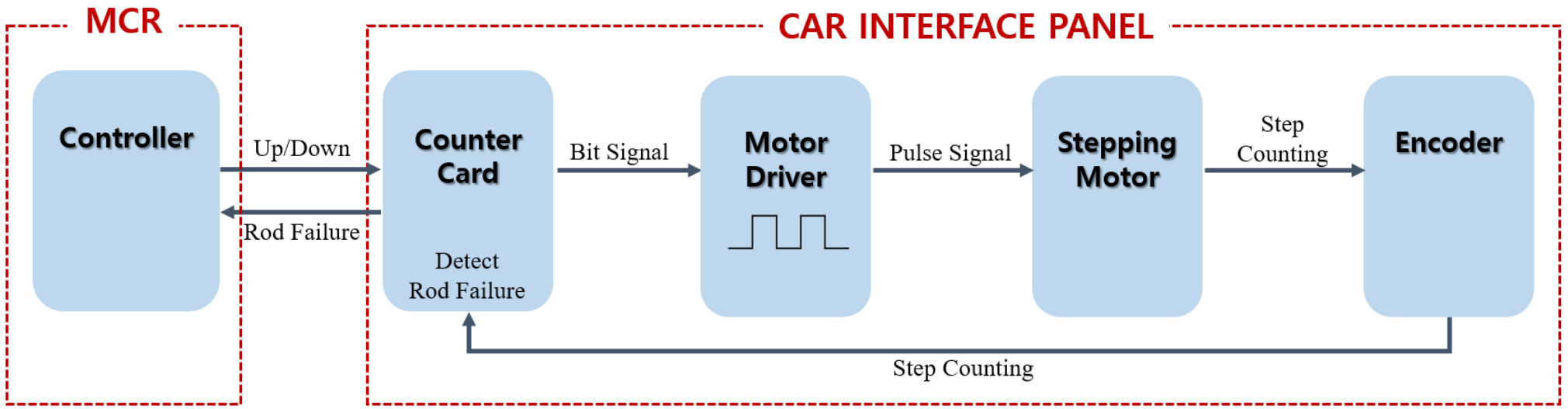

Figure 5. Driving Signal Flow

Control Absorber Rods Drive System

3. RCS(Rod Control System)

a. Controller

- ✓ Generating the driving signals for CARs
- ✓ Reporting failure of CARs

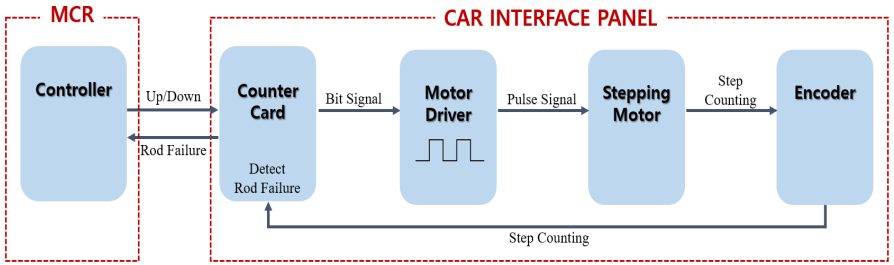

Figure 5. Driving Signal Flow

b. Counter card

- ✓ Converting the signals(the number of steps, direction) into bit signals
- ✓ Detecting failures such as step errors, time-out errors and power supply errors

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Control Absorber Rods Drive System

3. RCS(Rod Control System)

c. Motor driver

✓ Converting the bit signals to pulse signals

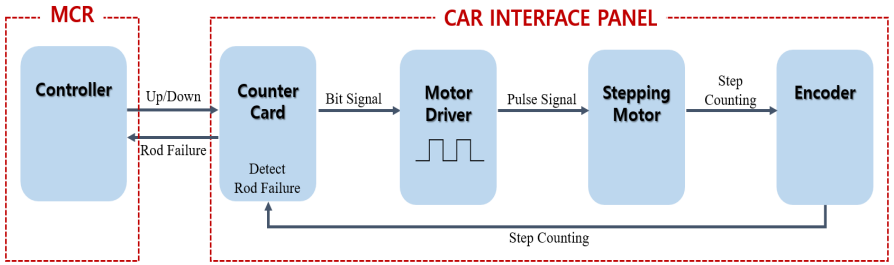


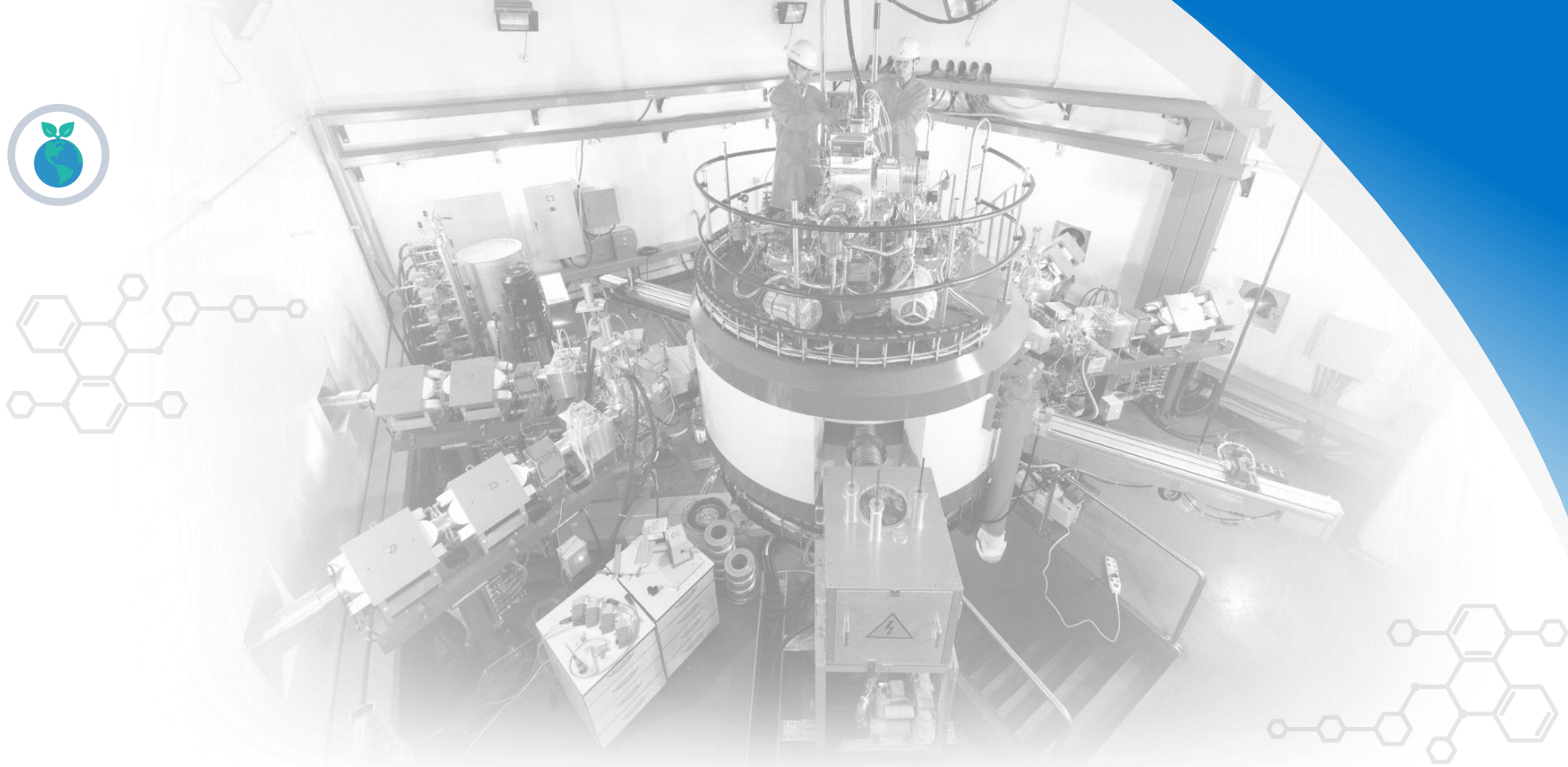
Figure 5. Driving Signal Flow

d. Encoder

✓ Checking and monitoring motor's movement (the number of steps)

✓ The information of movement is compared with order steps.

✓ Generating the error if there is a difference greater than 3 steps



Consideration of a Two-phase Excitation Control Method for Stepping Motor Used in HANARO's Control Rods

02 Analysis of the Current Excitation Method

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02 Analysis of the Current Excitation Method

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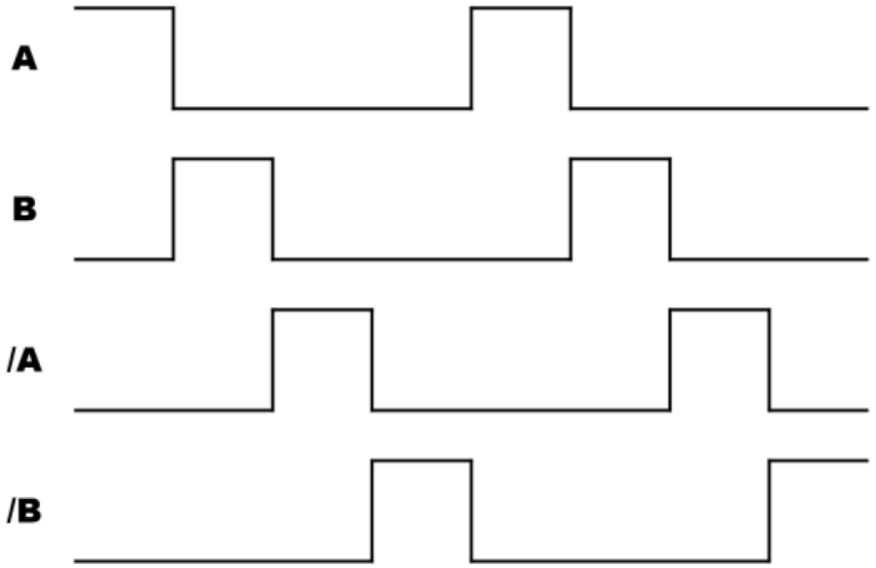
One-phase Excitation Control System

- Stepping motor : commonly used electromechanical device
- One-phase excitation :
  - ✓ Requiring four steps per cycle
  - ✓ 1.8 degree movement per step



STEP	1	2	3	4
Simplified Movement of Motor				

Figure 6. Sequencer of One-phase Excitation Control System

02 Analysis of the Current Excitation Method

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One-phase Excitation Control System

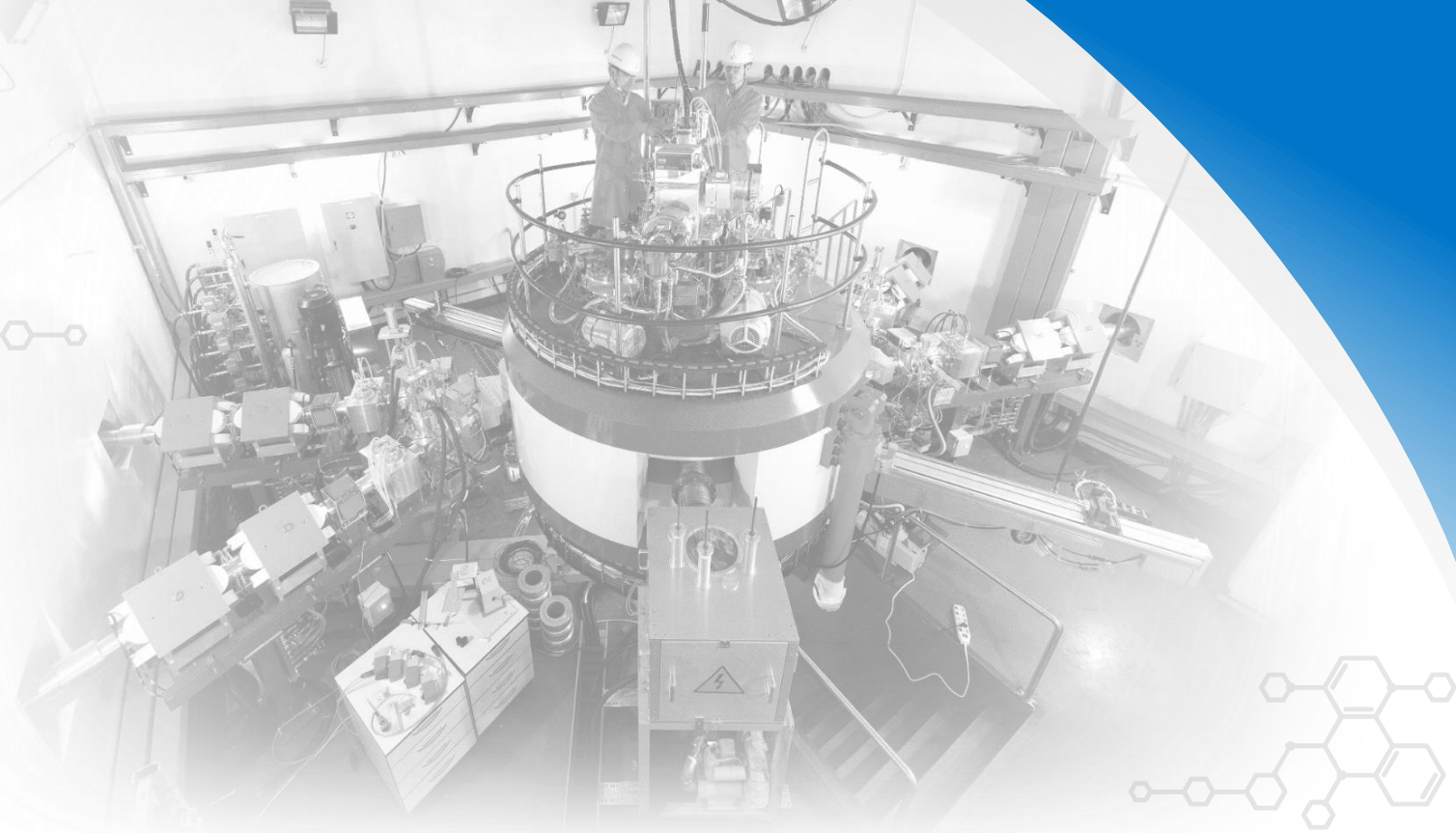
- Lower power consumption
- Easy to maintain and develop
- Vibration and noise
- Slip out of control rods from malfunction of stepping motor

  → Gap between the intended position and actual position

  → Abnormal alarm due to error

  → Reactor shut down due to the alarm

It can be solved by a two-phase excitation control system.



Consideration of a Two-phase Excitation Control Method for Stepping Motor Used in HANARO's Control Rods

03 Two-phase Excitation Method

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03 Two-phase Excitation Method

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Two-phase Excitation Control System

- Higher power consumption with an increased motor strength
- Lower vibration and noise
- Prevent the control rods from slipping out
- More complicated system

→ There are many consideration for implementing.

1) Upgrading the motor driver with the current stepping motor
2) Upgrading the motor driver with 8-lead stepping motor

03 Two-phase Excitation Method

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Upgrading the Motor Driver

- It is efficient to prevent control rods from slipping.

  → When one phase fails to move, **the other phase can hold the control rods in place.**

  Ex) B fails to be excited.

  /A remains excited. → ***NO SLIP***

- PLC[1] & CLPD[2] normally used for motor control system.

  More suitable for smaller-scale motor control systems with specific requirements.

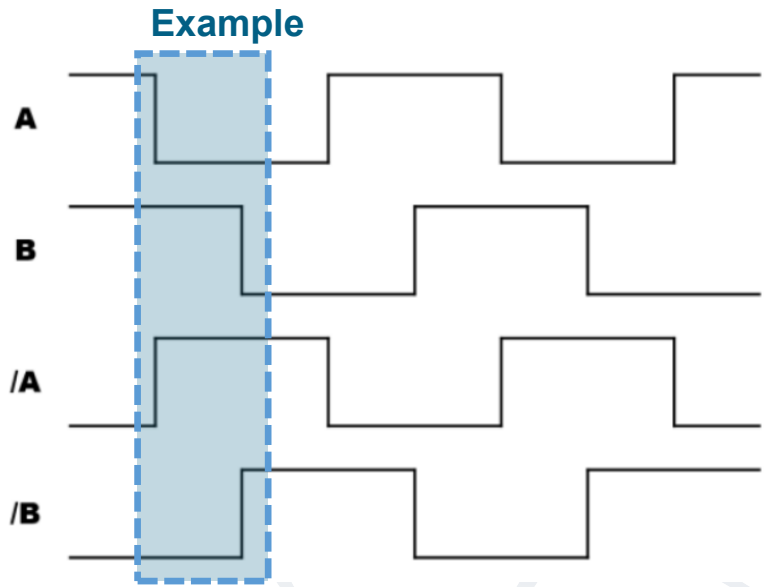

Figure 7. Sequencer of Two-phase Excitation Control System

1) PLC(Programmable Logic Controller) : It offers flexibility and robust processing power.
2) CLPD(Complex Programmable Logic Device) : It provides more fine-grained control over hardware design.

03 Two-phase Excitation Method

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Upgrading the Motor Driver

- CLPD is generally composed of an excitation sequencer, a current regulator and a power module for motor driver (Figure 8).
- Consideration
  - ✓ Add a diode or digital filter to **maintain a constant torque** and **reduce irregular vibration**
  - ✓ Utilizing **current control** to achieve smoother and more accurate
- It depends on the specific control device being used.

  (types of CLPD or brand)

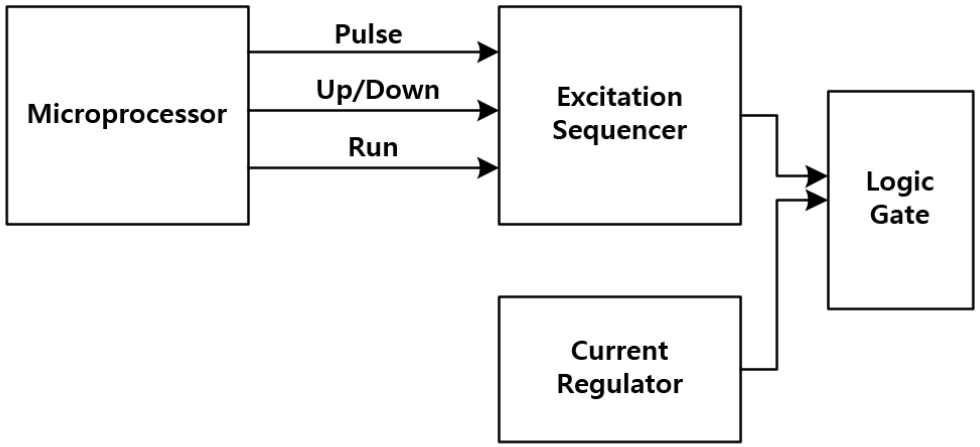

Figure 8. General Configuration of CLPD

03 Two-phase Excitation Method

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Upgrading the 8-lead Stepping Motor

- 4-lead Motor : Possibility of malfunction

  → (Figure 9) If the physical wire of A-phase and B-phase is disconnected.

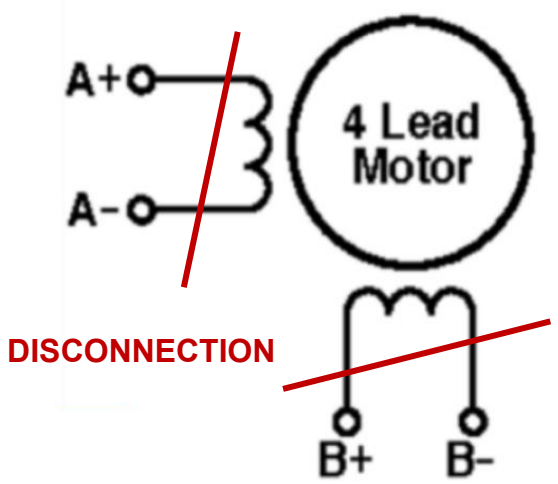


Figure 9. 4-lead Motor

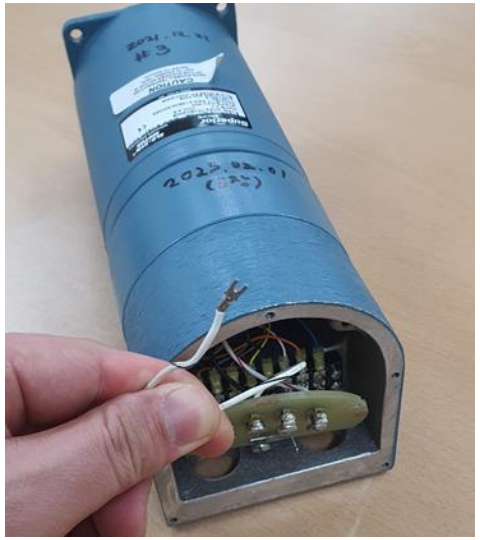


Figure 10. Malfunction

→ [Operational Experience]

One of the phases was loosely connected internally. And it became completely disconnected during operation of reactor.

03 Two-phase Excitation Method

Upgrading the 8-lead Stepping Motor

- Physical redundancy design is necessary.
  → 8-lead motor (Figure 10)
  → The CCF(Common Cause Failure) in the four internal motor wires is very low probability.

- Consideration
  → Higher current consumption
  → More complexed control system

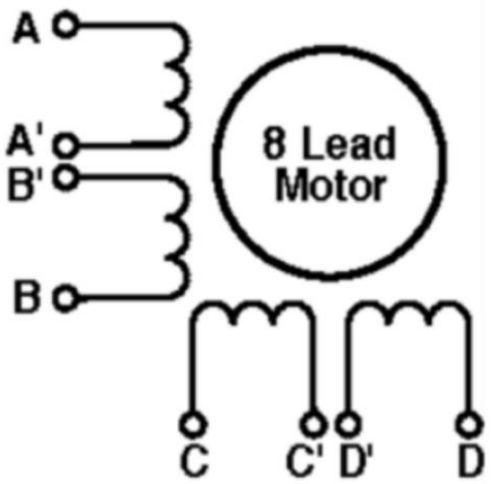
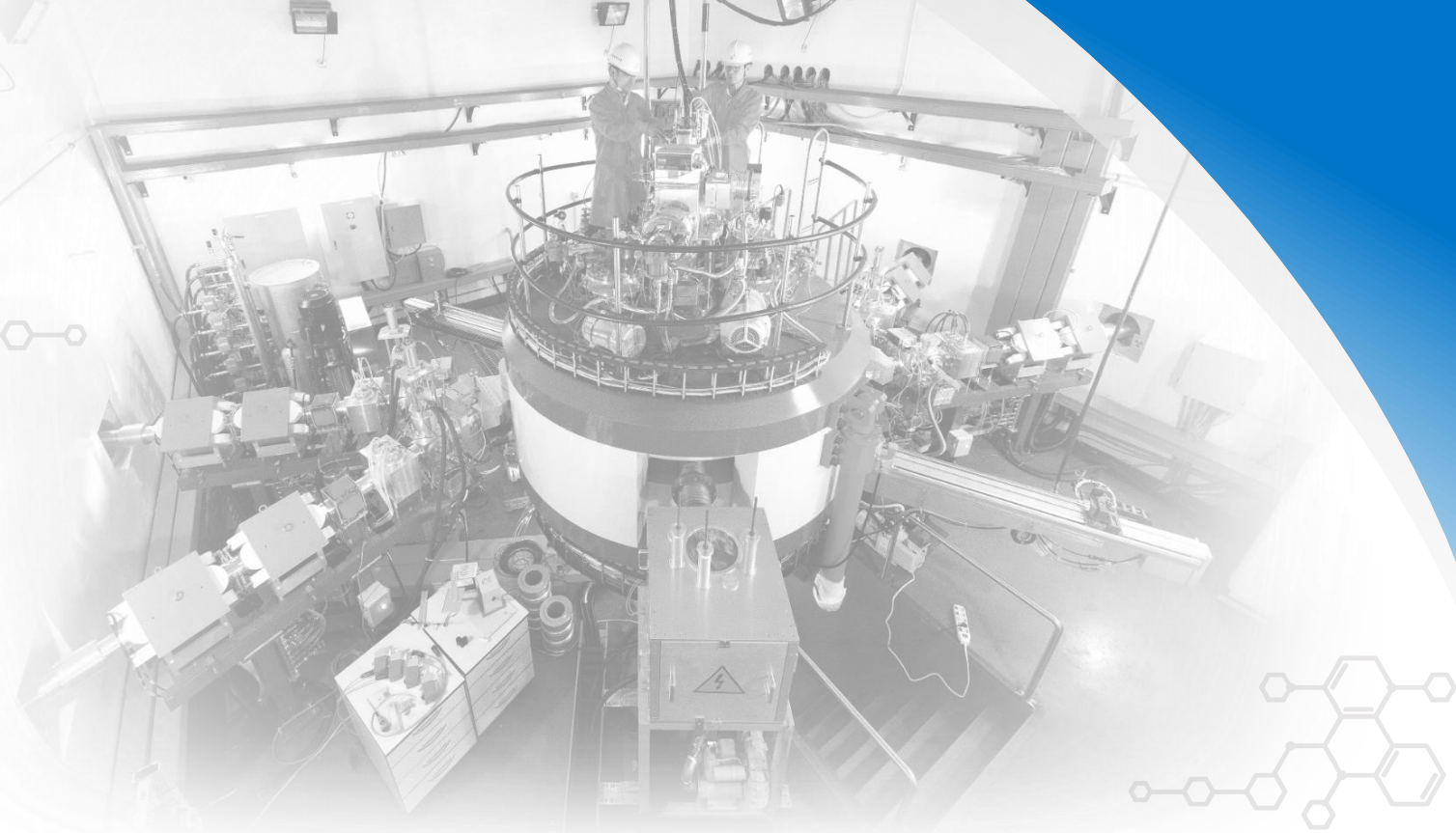


Figure 11. 8-lead Motor



Consideration of a Two-phase Excitation Control Method for Stepping Motor Used in HANARO's Control Rods

Conclusion

04

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04 Conclusion

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Current : One-phase excitation control system

- HANARO has four control rods operated by one-phase excitation control system.
- Whichever phase fails.
  - → It leads to slip of control rods.
  - → It leads to a deviation from the desired position.
  - → It leads to reactor shut down.

04 Conclusion

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Necessary to upgrade of rod control system

- Two-phase excitation control system by upgrading the motor driver.
  → Several considerations such as constant torque or vibration
  → The current stepping motor can be used continuously.

- Two-phase excitation control system with 8-lead motor
  → Physical redundancy design
  → This design is to reduce the unavailability by considering the CCF.
  → It costs more and takes longer, but is safer.

04 Conclusion

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Further study

- Search the motor driver(CLPD) that can control the current stepping motor.
- Design the two-phase excitation control system by considerations that researched.
- If required, the unavailability of the control rod system with the new motor driver will be compared to the unavailability of the control rod system with the 8-lead motor. → criterion for assessing the need for implementing this design.

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THANK YOU

FEEDBACK & QUESTIONS

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