Impact of Inverter-Based Resources with Dynamic Reactive Current Control on Protection Relay under Three-Phase to Ground Fault

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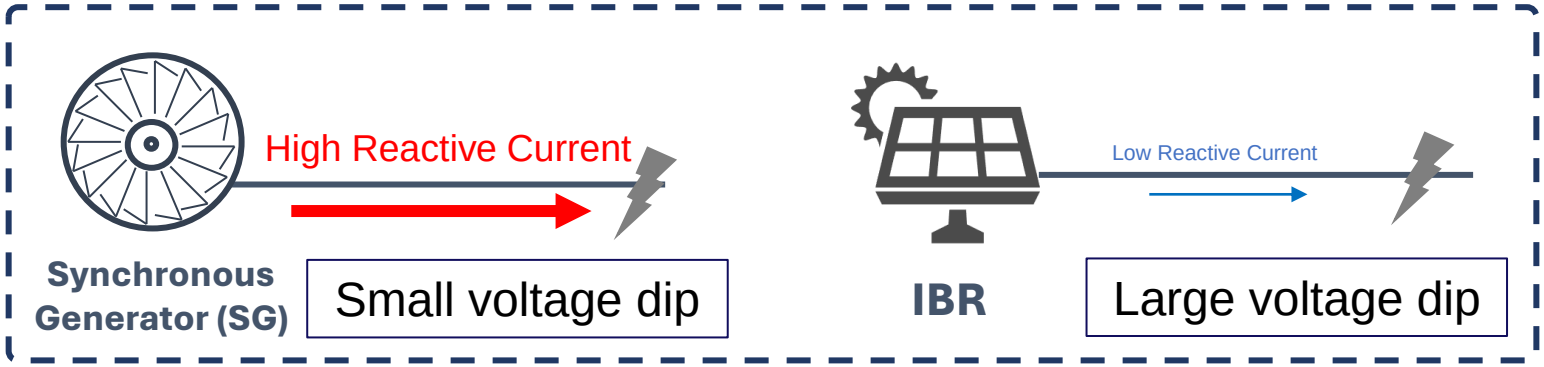
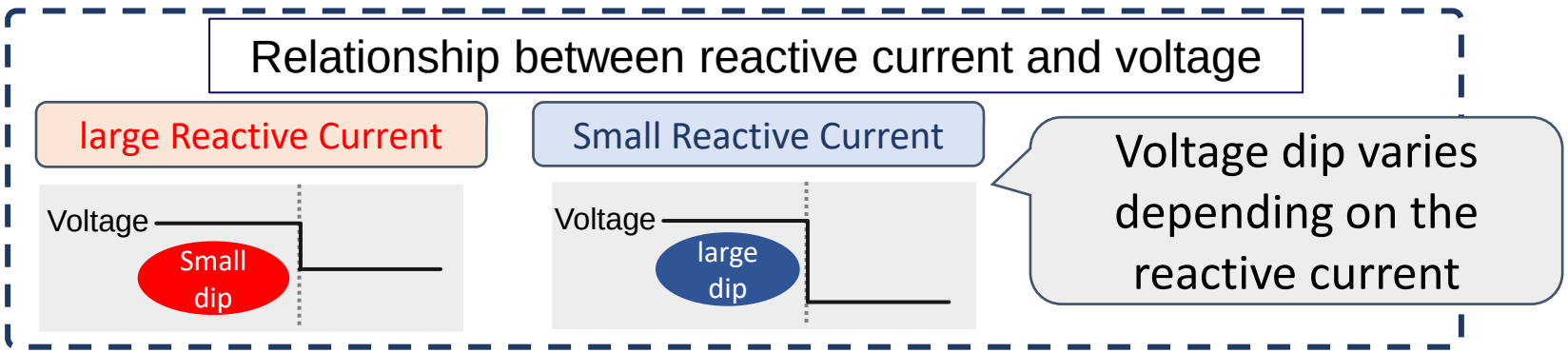
1.Introduction

- Large Integration of Inverter-Based Resources (IBRs) is proceeding
  - Causing to large voltage dip



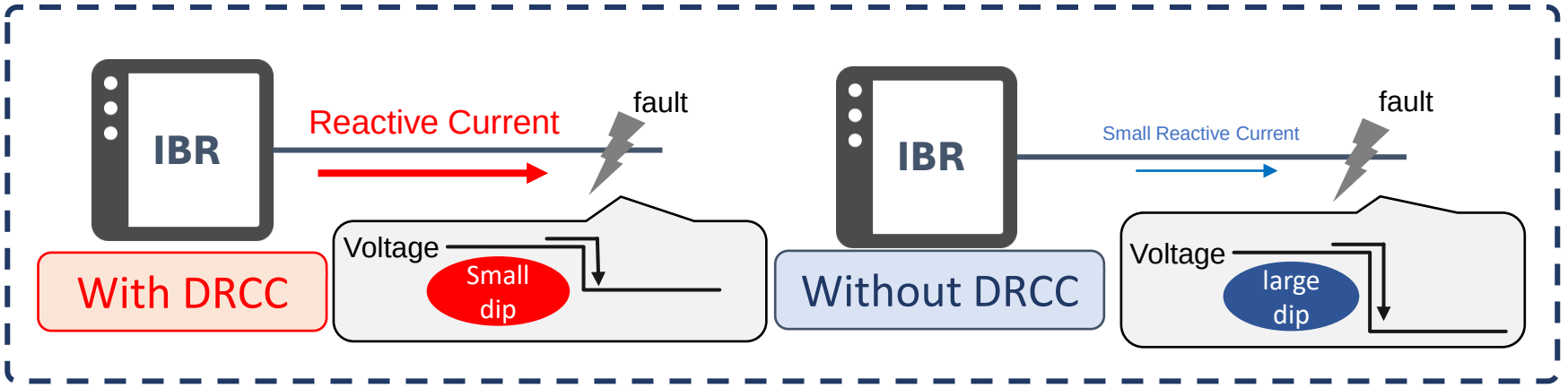


IBR : renewable energy, battery energy storage system ···etc
SG : thermal power, hydroelectric ···etc

1.Introduction

- Dynamic Reactive Current Control (DRCC) add to IBRs
  - To maintain voltage by reactive current of IBR
- What is DRCC?

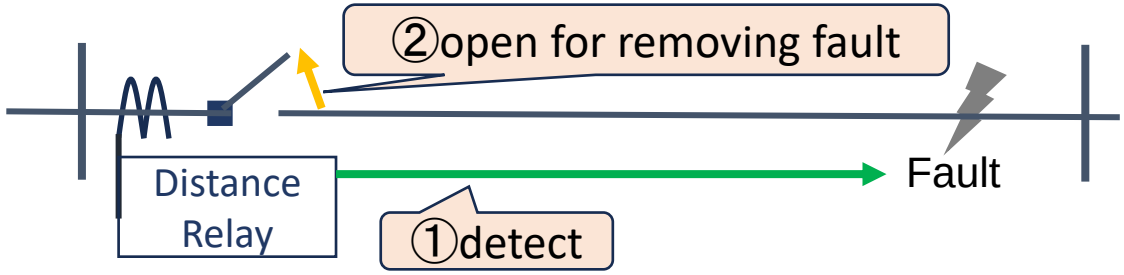
  →Control function to supply reactive current under power system fault



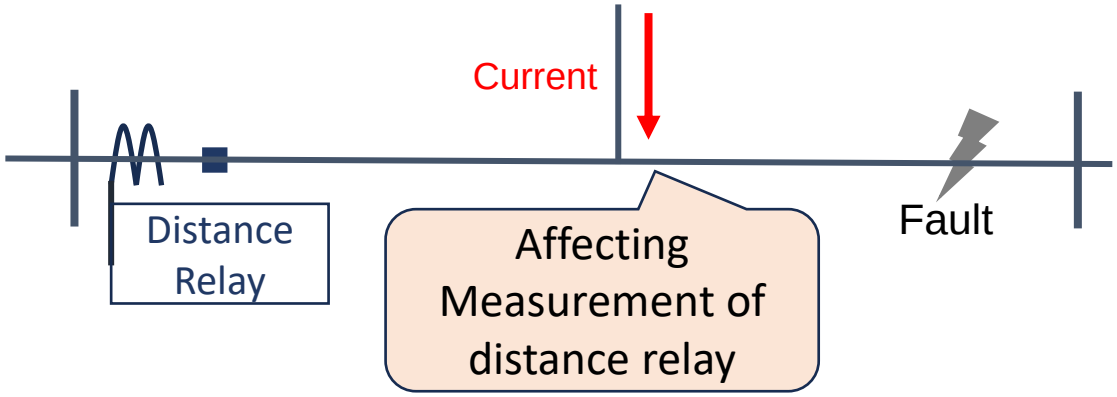
- Introducing DRCC to IBR has discussed in Japan
  - DRCC hasn't been introduced to IBR in Japan yet

1.Introduction

- Distance relay : Protective relay for detecting power system faults

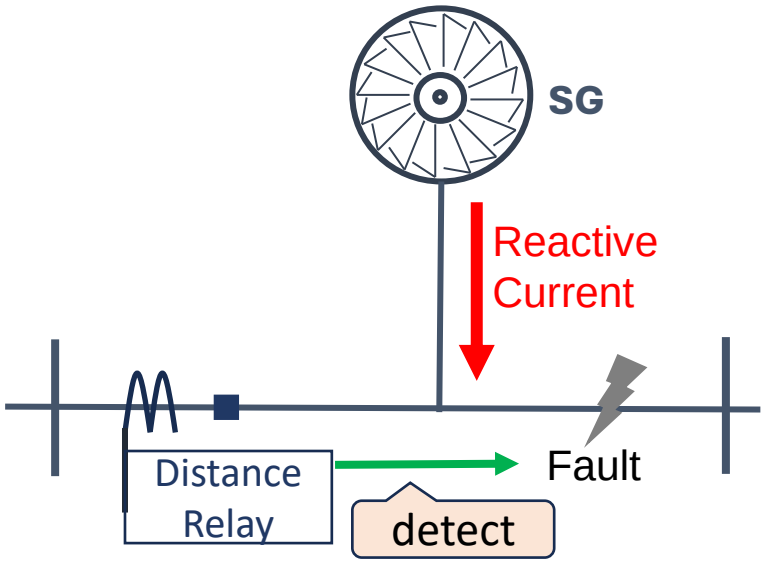


- The current at the power line branches affects distance relays
  - In Japan, energy sources are often connected to power line branch

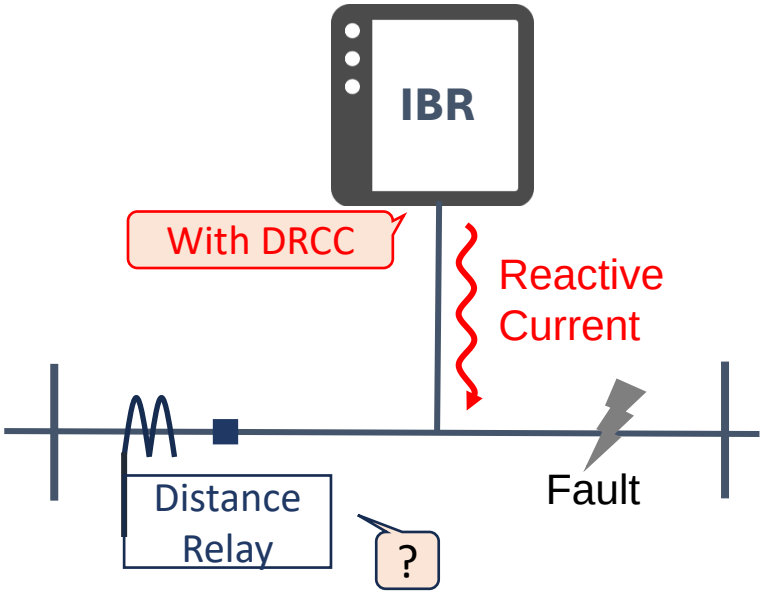


1.Introduction

- Distance relay detected fault by reactive current of Synchronous Generator



- Unclear : impact of IBRs with DRCC at the branch on distance relay



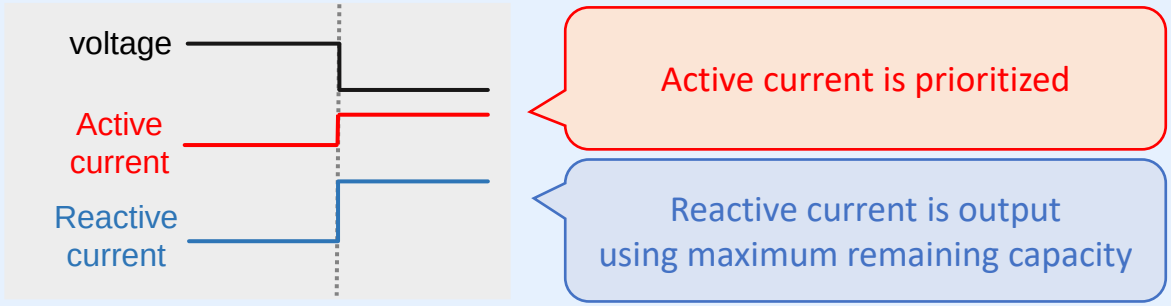
Investigate :
- ①Fault Current※ by IBR with DRCC
- ②Impact on Distance Relay

※Fault current : active and reactive current under fault

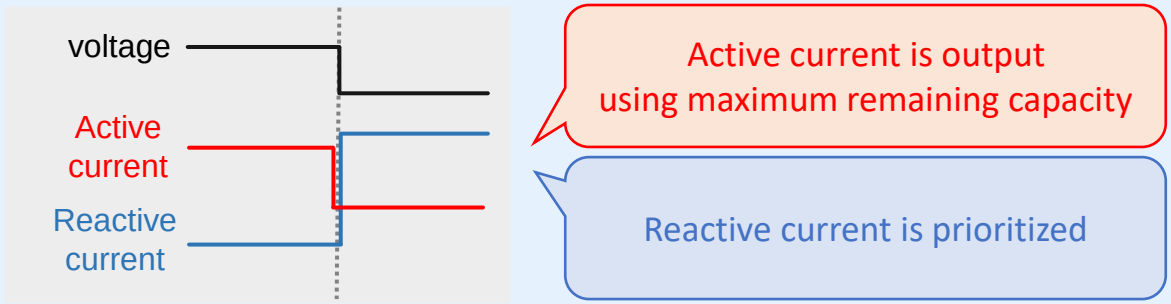
1.Introduction

◆ DRCC operation changes depending on current priority modes

active current priority mode[1)]: ・Active current is prioritized
(P mode) ・Reactive current is output by remaining capacity of IBR



reactive current priority mode[1)]: ・Active current is output by remaining capacity of IBR
(Q mode) ・Reactive current is prioritized



1) IEEE Std 2800-2022. 7.2.2.3.4(pp.73-75)

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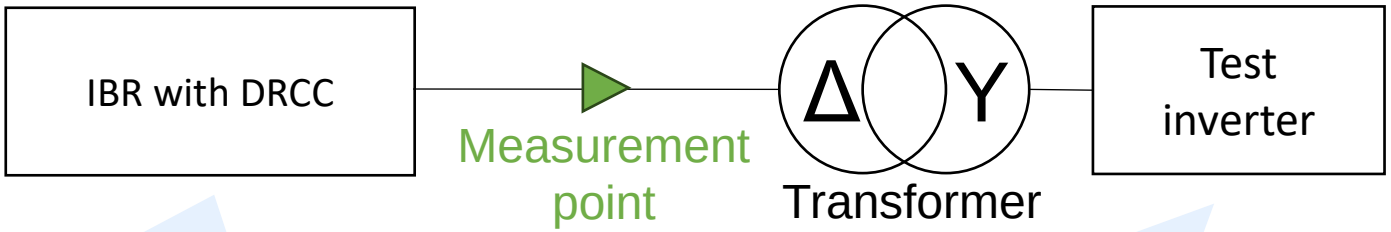
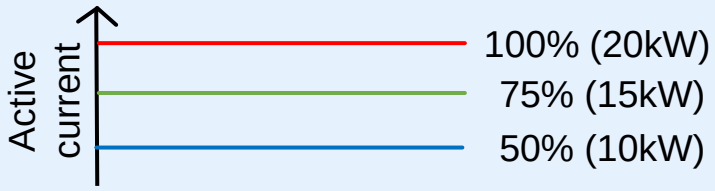
Test condition : Fault current by IBR

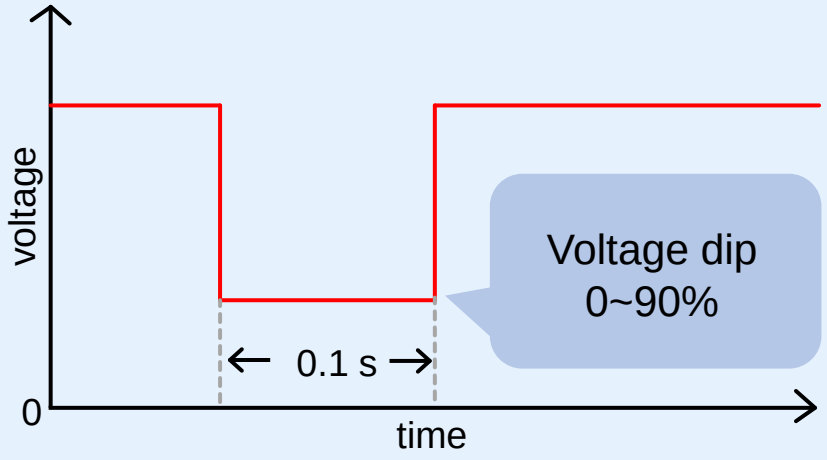
- Examinations of current injection during fault by IBR
  - by CRIEPI's power system simulator



Parameter

- Current priority mode
  - P mode/Q mode
- Pre-fault Output
  - 50%/75%/100%





simulating a fault by voltage change

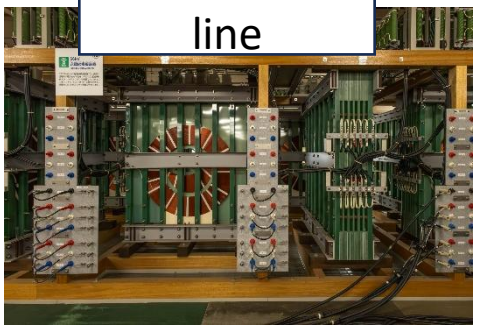
What is CRIEPI's power system simulator?

- Use CRIEPI's power system simulator (analog simulator) for tests using commercial IBR

appearance

DC Power Unit

Generator



Transmission line

Commercial IBR

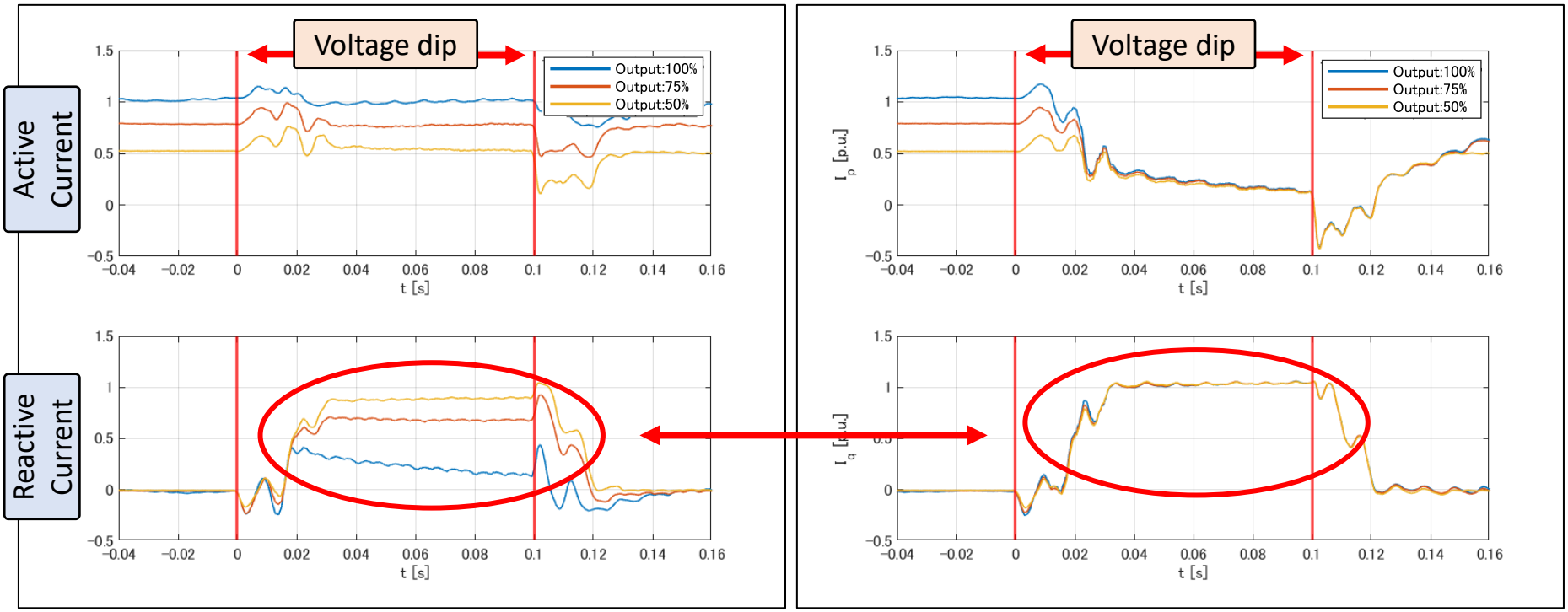
Transformer

etc…

Current under pre-fault output change

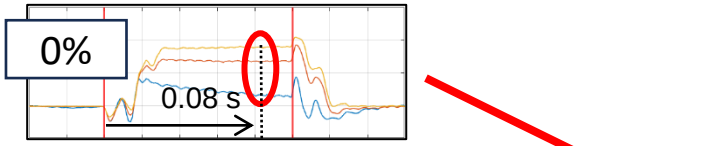
P mode

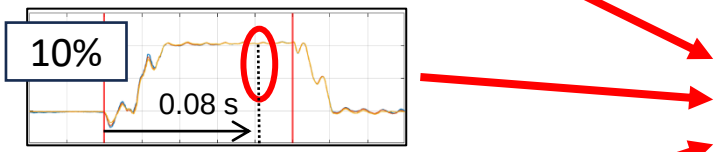
Q mode



Reactive current differs between P-mode and Q-mode

Current characteristics under pre-fault output change

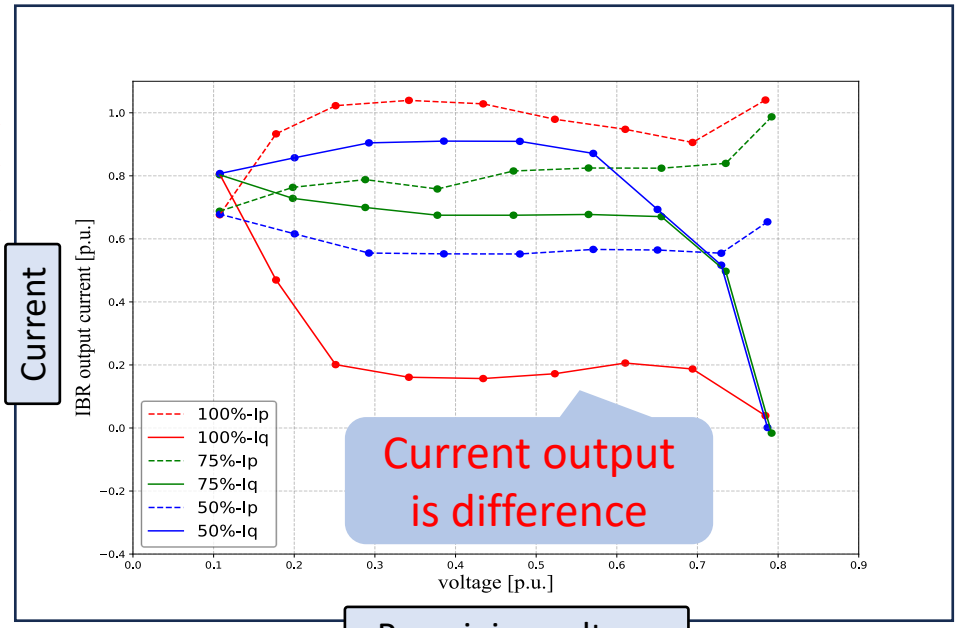




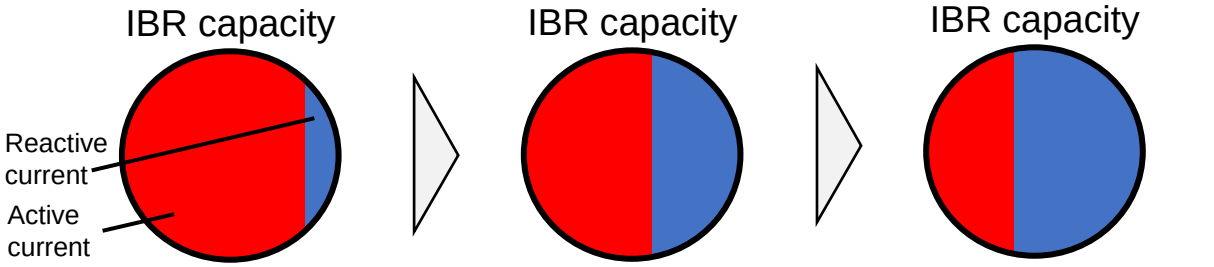
Plot current under fault
with 0~90% remaining voltage

Active current
Reactive current

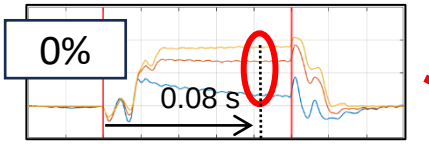
P mode

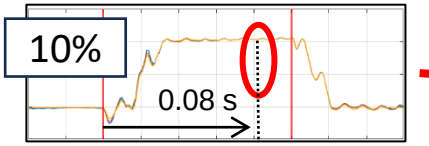


In case of P mode, the larger the Pre-fault output, the smaller the reactive current



Current characteristics under pre-fault output change

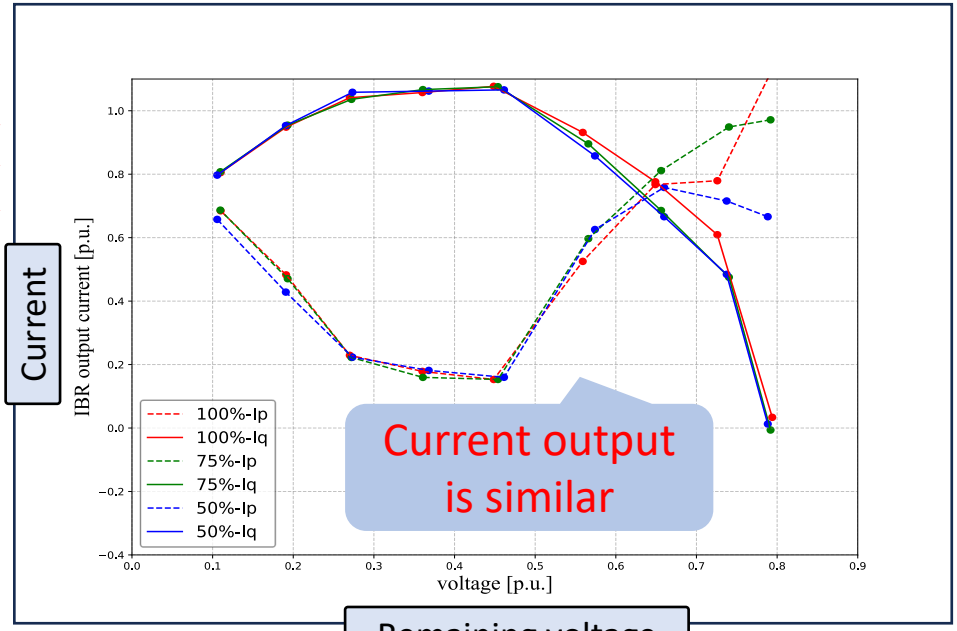




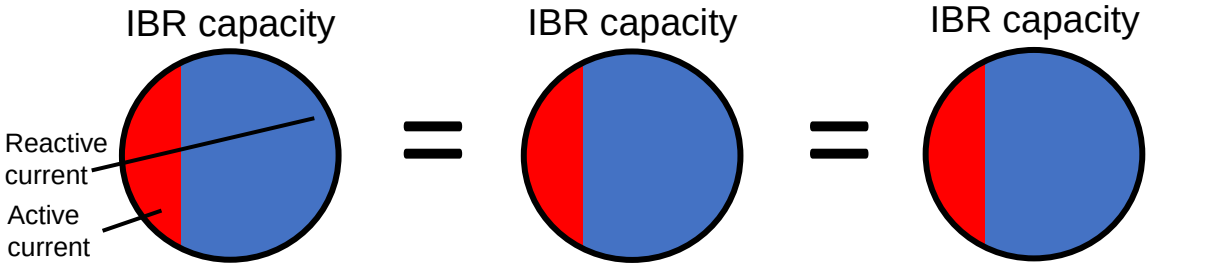
Evaluate current under fault with 0~90% remaining voltage

Active current
Reactive current

Q mode



In case of Q mode, similar current was measured regardless of pre-fault output



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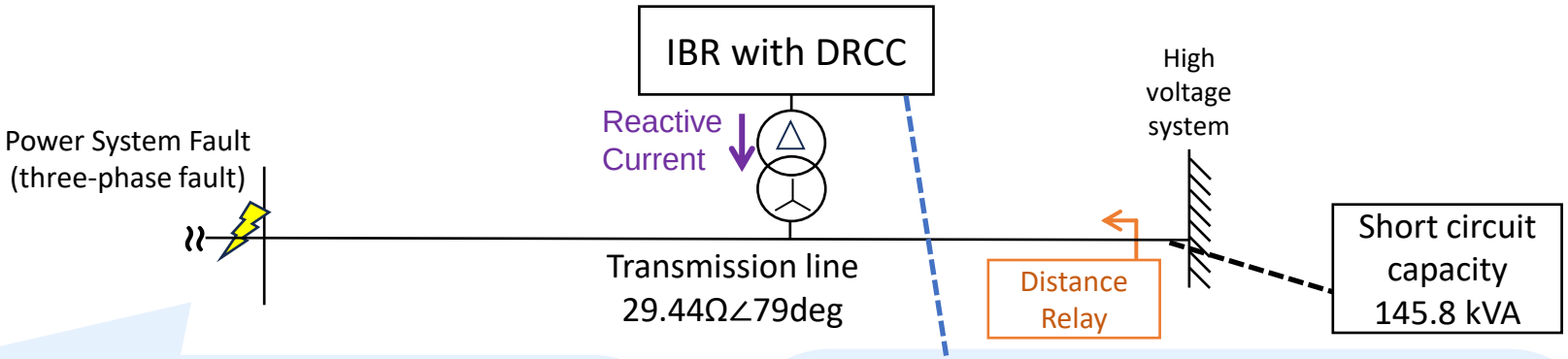
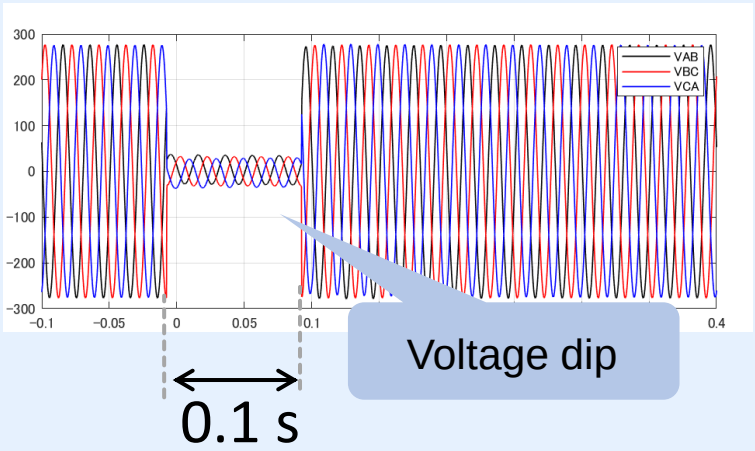
Test condition : Impact on protection relay

- Examinations of impact on measurement of distance relay

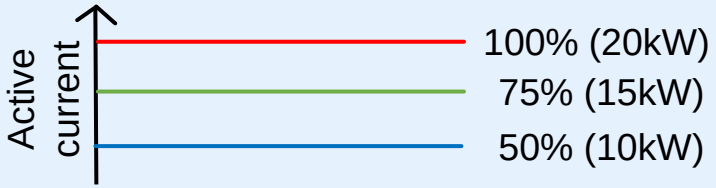




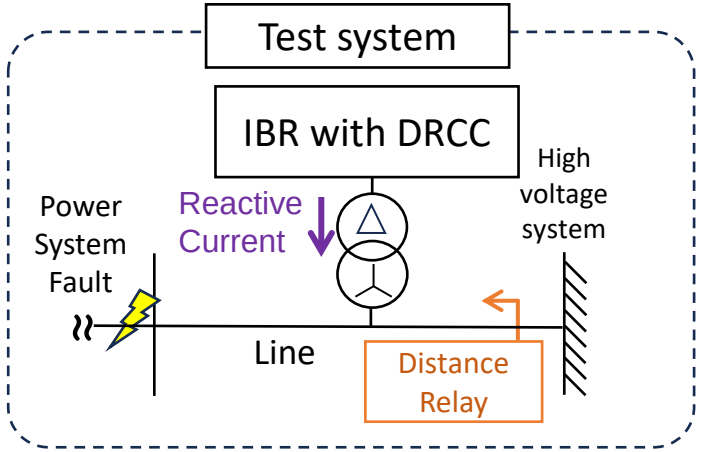
simulating a three-phase fault

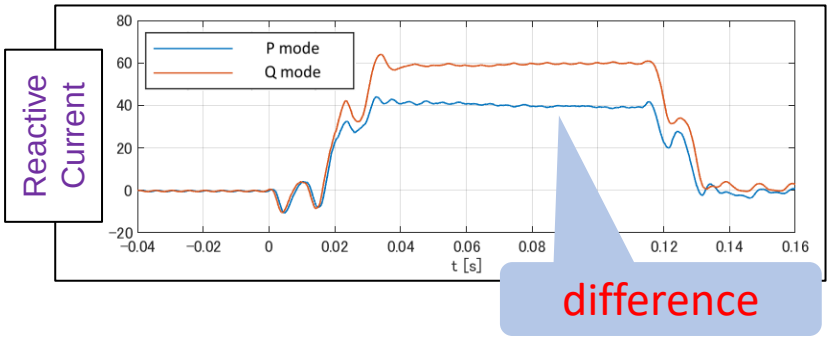
Parameter

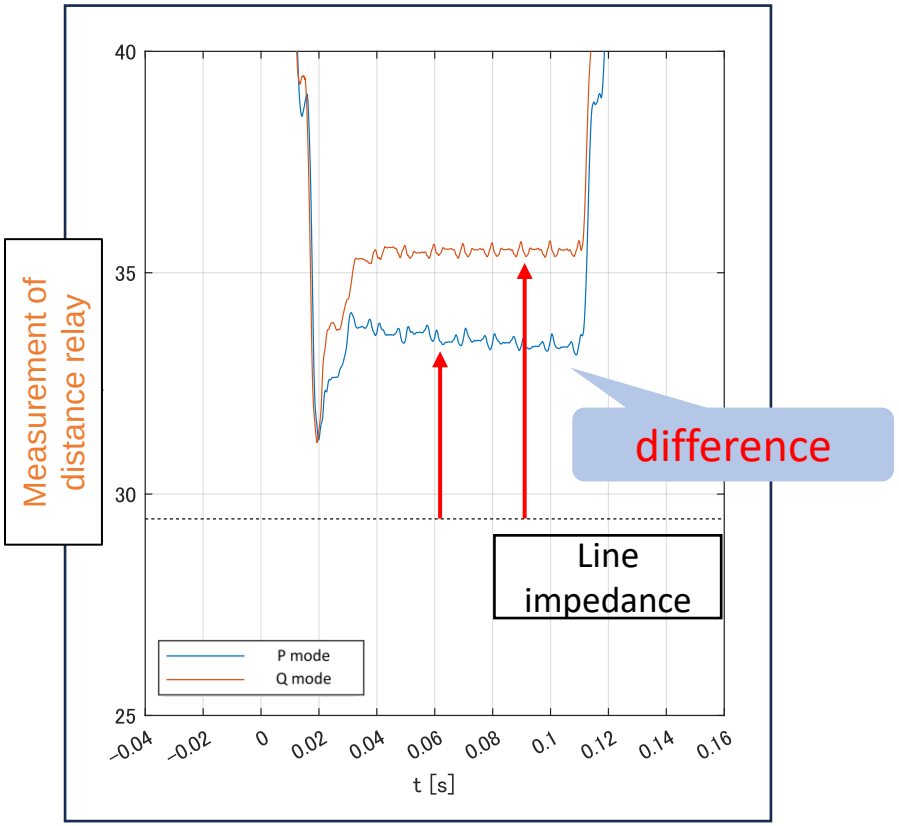
- Current priority mode
  - P mode/Q mode
- Pre-fault Output
  - 50%/75%/100%



Impact by DRCC mode

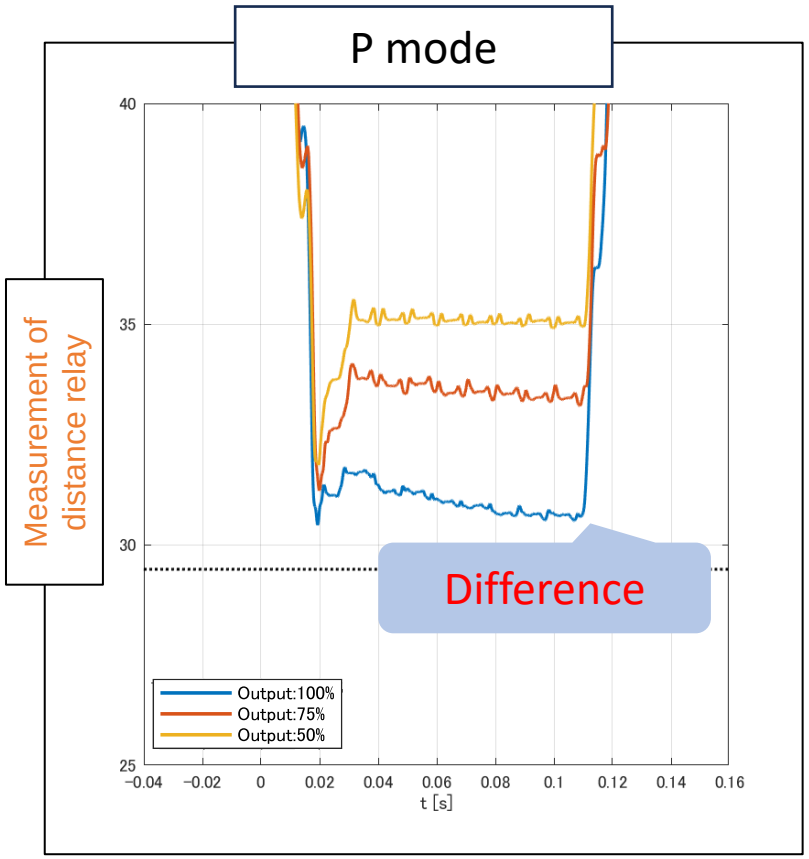


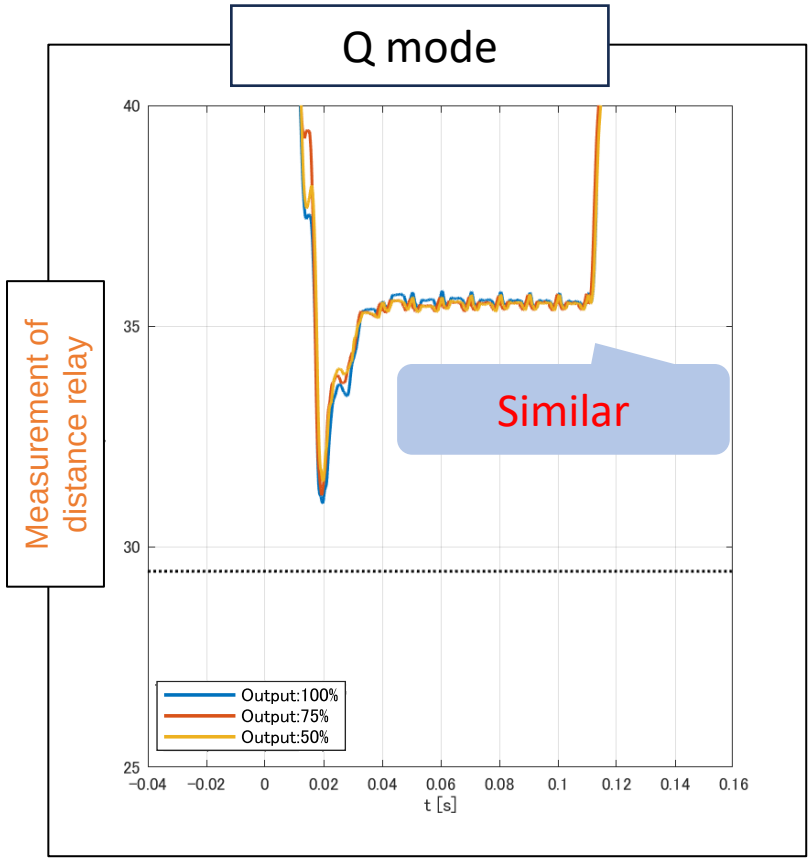




Distance relay measurements vary depending on reactive current at the power line branches

Impact by pre-fault output





・In case of P mode, distance relay measurement differs depending on pre-fault output

・In case of Q mode, distance relay measurement is similar regardless of pre-fault output

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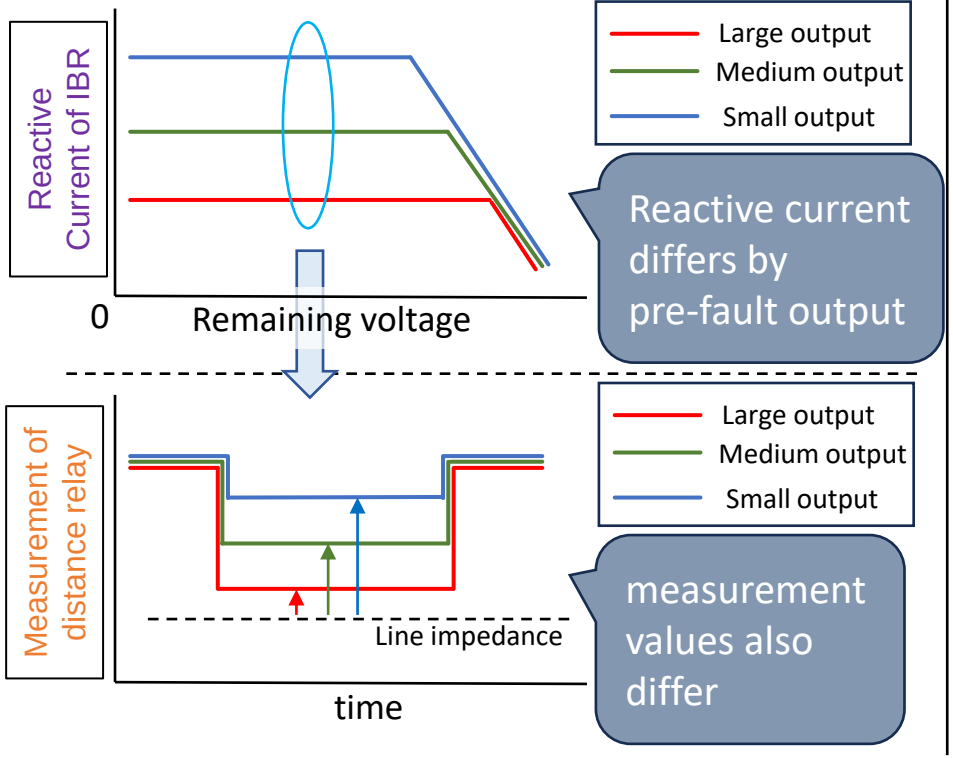
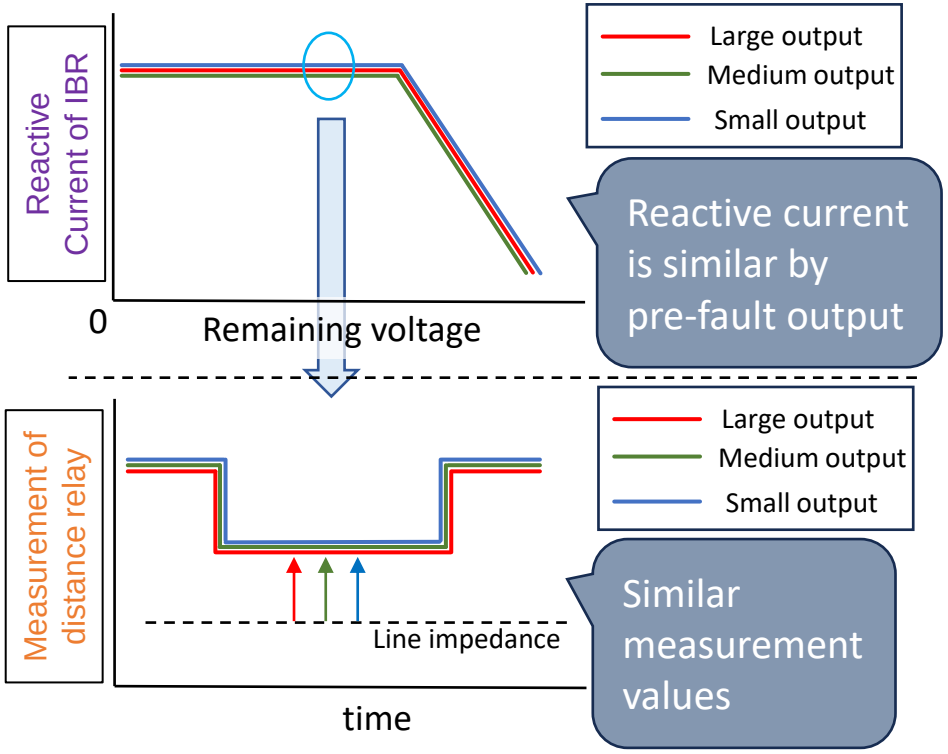
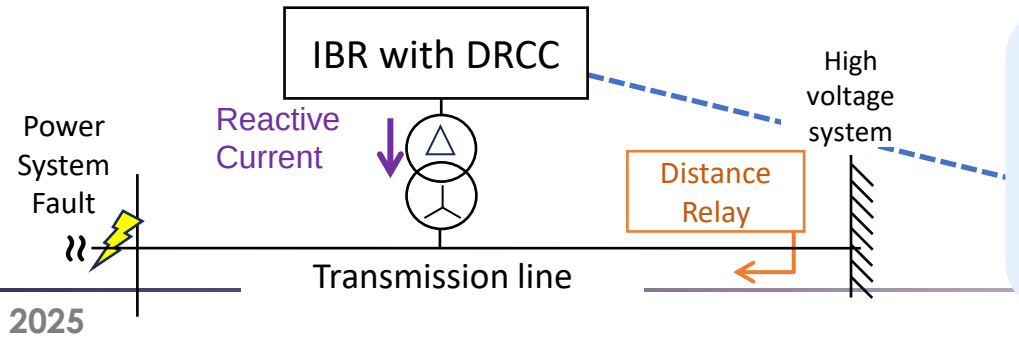
Summary : result of experiments

P mode



Q mode

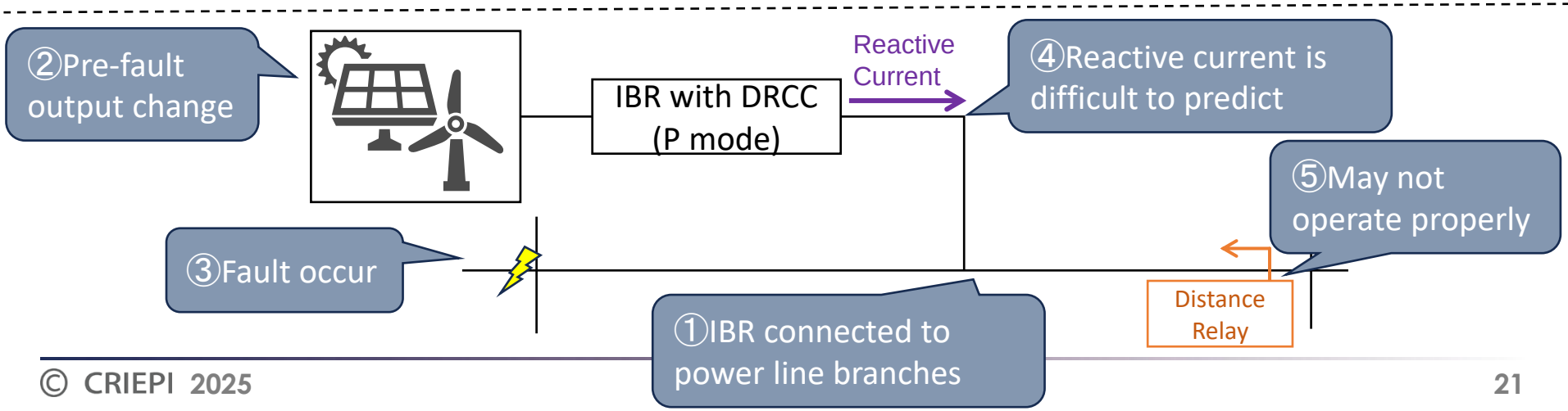




- DRCC mode
  - P mode/Q mode
- Pre-fault Output
  - 50%/75%/100%

Conclusion

- Investigation of the impact of IBRs with DRCC on distance relays using experimental data
- In case of P mode
  - The reactive current differ depends on pre-fault output
  - The reactive current injected by the IBR affects the distance relay measurements.
- In case of Q mode
  - Reactive current is similar regardless of pre-fault output
  - Distance relay measurements are also similar



[Appendix]Effect of current in branch on distance relay

In case of current from power line branch, the impedance calculated by the distance relay will have a measuring error.

the impedance calculated by the distance relay

$$Z_D = Z_A + Z_B + \frac{I_B}{I_A} Z_B$$

measuring error

Power system including current from branch : I_B