Hawai‘i Powered

Hawaiian Electric’s Protection Roadmap

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

ESIG Webinar
July 20, 2023

Hawaiian Electric

Agenda

- Company carbon emission goals
- Protection objectives
- Existing protection
- Upcoming challenges
- Limitations of existing protection
- Future protection
- Difficulty level of future transitions
- When the protection needs to change
- What might accelerate or slow this needed change

Company Goals

- Hawaiian Electric is committed to reducing carbon emissions in 2030 by as much as 70 percent below 2005 levels.
- To achieve this, the future grid will vastly change due to these decarbonization goals by removing traditional generation sources
- The protection system will need to adapt to maintain our protection objectives.

Protection Objectives

- To isolate power system faults, equipment failures or any other unusual or extreme condition which puts the power system in jeopardy.
- To minimize the extent and duration of the resulting forced outage.
- To prevent power system instability resulting from system disturbances.
- Public safety

Existing Protection Elements

Existing	Location
Permissive Overreaching Transfer Trip (POTT)	Transmission and some sub-transmission
Line Current Differential	Transmission and some sub-transmission
Phase Distance	Transmission and some sub-transmission
Directional/non-directional Phase/Ground Overcurrent	All
Bus Differential	Transmission and some sub-transmission
Transformer Differential and overcurrent	Transmission and some sub-transmission
Breaker Failure	Transmission and some sub-transmission
3-5 cycle Circuit Breakers	Trans and sub-trans 3cy, distribution 5cy
Circuit Switchers	All
Fuses	All
Electromechanical Relays	All

Challenges

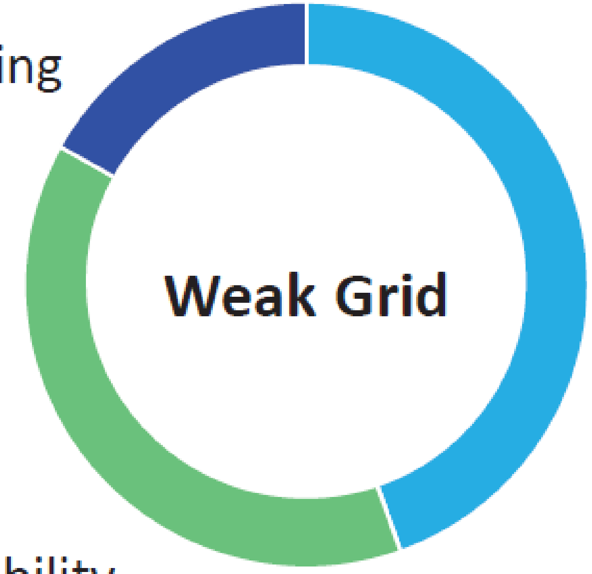
- With the shift to inverter-based generation, there are knowns and possible unknowns as to how this will affect the existing protection and may cause it to mis-operate.

Known Challenges	Unknown Challenges
Available fault currents decreasing (less spinning reserve, in-feed from DER increasing)	How inverters will react/output under certain situations
Weakening system, lower critical clearing times	Inverter simulations vs actual performance
Inverters dropping out faster than relays can clear a fault	Not knowing what we don’t know
Evolving standards for inverters, many changes which will impact simulation models	
Inverters affecting relay directionality	
Practicality of upgrading old protection schemes	

A Closer Look at Weak Grid Challenges

Low short circuit MVA

- Challenges system protection
- May be solved by increasing inverter current rating



High $\frac{\Delta V}{\Delta I}$

high sensitivity of IBR terminal voltage to its current injection

- Challenges stable operation of today's IBR
- May be solved by GFM control

High $\frac{\Delta f}{\Delta t}$

low system inertia

- Challenges frequency stability of power system
- May be solved by GFM control

* GFM inverter is not the only/unique solution to weak grid challenges, other solutions exist such as utilizing synchronous condenser

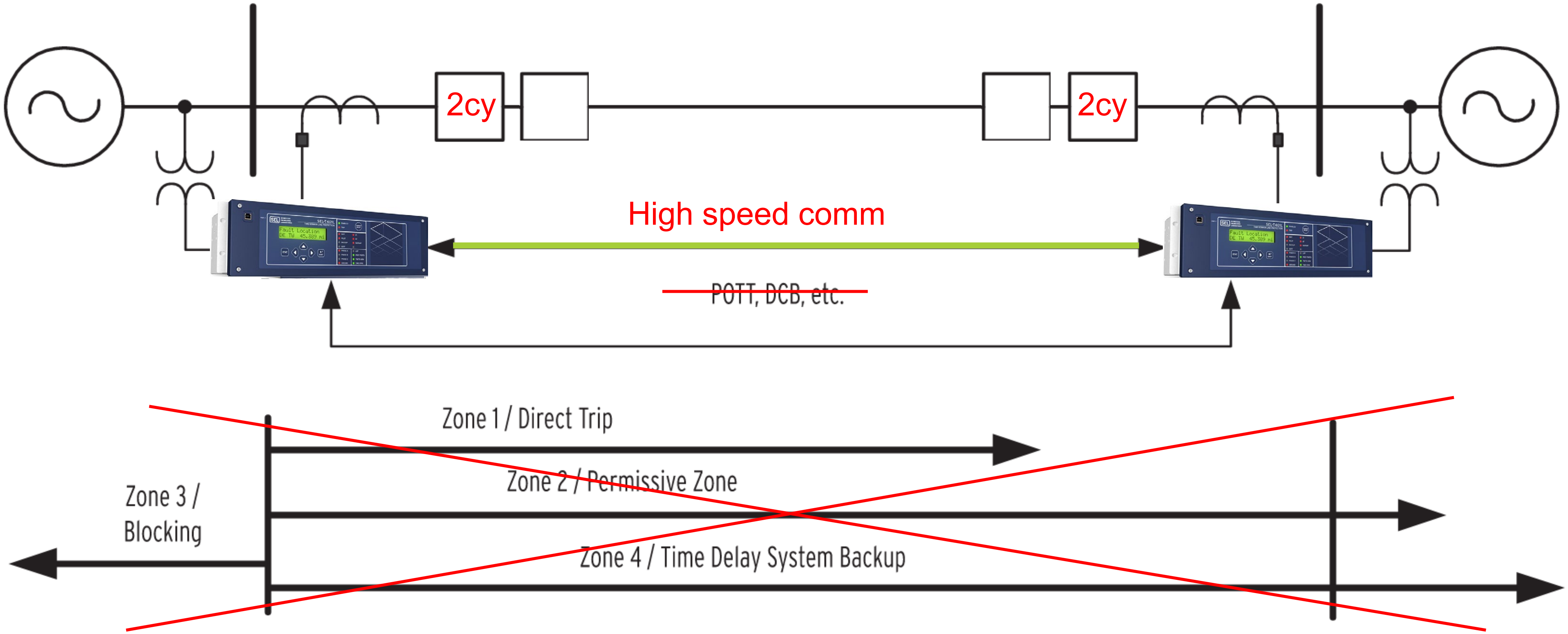
Limitations of Existing Protection

Existing	Limitation
Permissive Overreaching Transfer Trip (POTT)	Can misoperate with inverter based generation
Line Current Differential	While fast, could be faster
Phase Distance	Can misoperate with inverter based generation
Directional/non-directional Phase/Ground Overcurrent	Slow, misoperate on directionality with inverter based generation, increasingly harder to coordinate
Bus Differential	Linear couplers may misoperate due to inverters
Transformer Differential and overcurrent	Overcurrent is slow and can misoperate on directionality with inverter based generation
Breaker Failure	Can be slow since tripping area is large with high impact
3-5 cycle breakers	While fast, could be faster
Circuit Switchers	While fast, could be faster
Fuses	Slow; not adjustable/adaptable
Electromechanical Relays	Lack of event reporting for post analysis

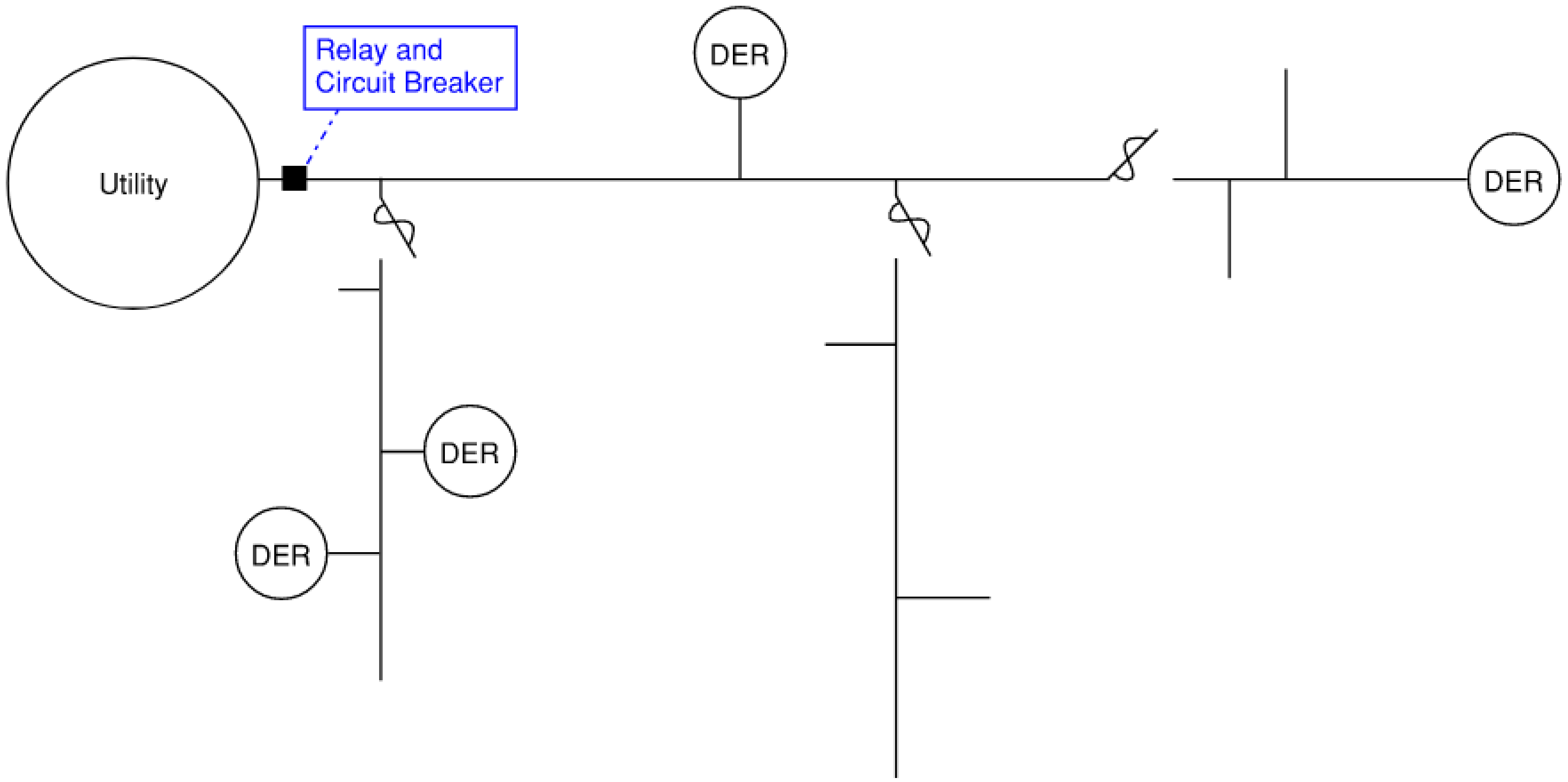
Possible Protection Future

Existing	Future
POTT	Already being phased out for current differential
Line Current Differential	Traveling wave
Phase Distance	Directional phase overcurrent with comm based blocking schemes
Directional/non-directional Phase/Ground Overcurrent	Comm based blocking schemes, adaptive tripping schemes, undervoltage supervision
Bus Differential	CT instead of LCs
Transformer Differential and overcurrent	Same for differential; blocking schemes for overcurrent
Breaker Failure	No BF and overtrip and/or primary and secondary breakers
3-5 Cycle Breakers	2 cycle breakers
Circuit Switchers	Faster circuit switchers
Fuses	“Smart” fuses
Electromechanical Relays	Microprocessor relays

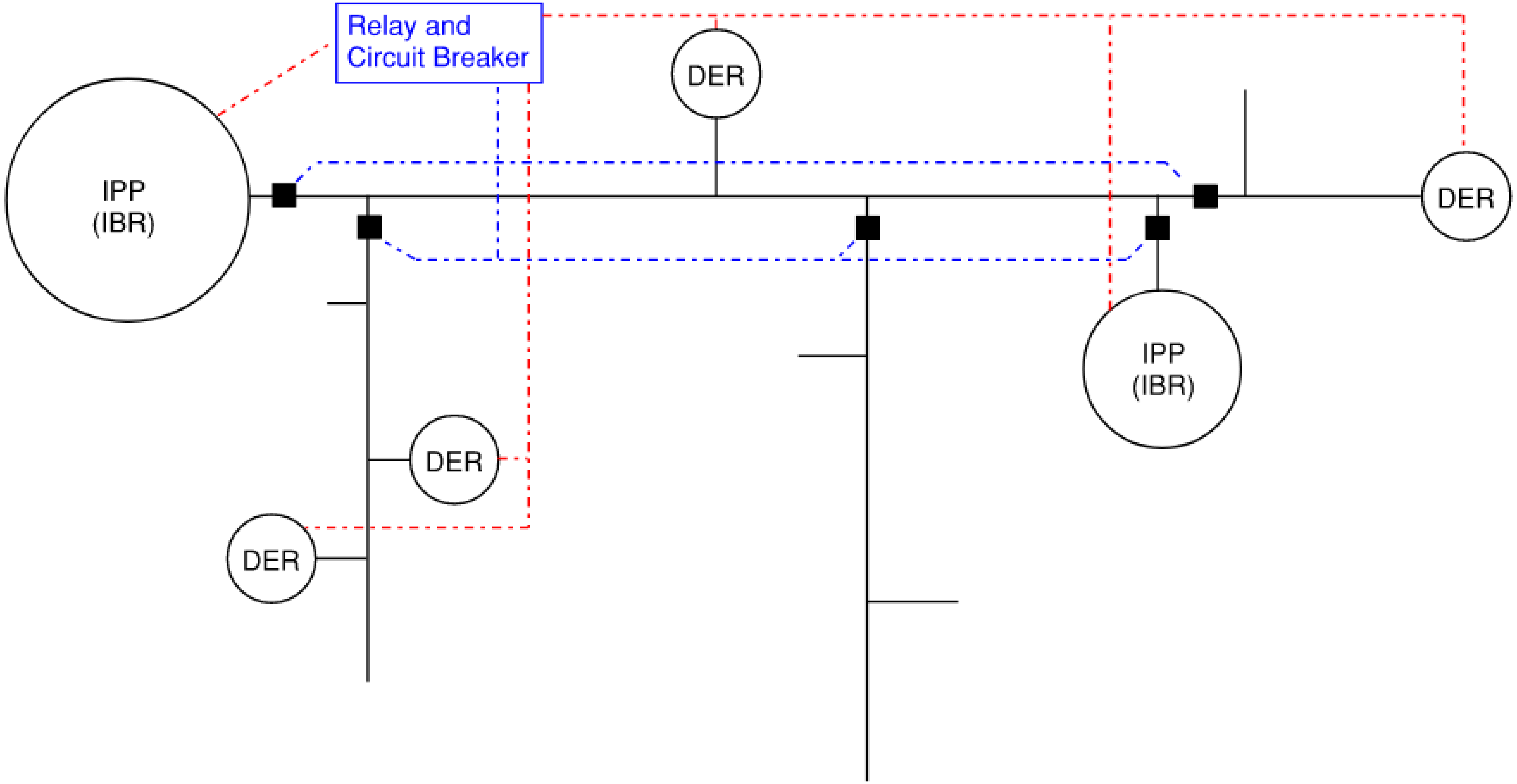
Phase [illegible] with Comm / Wave



Existing distribution system with overcurrent protection



Possible future with communications



Transition Difficulty

Scale from 1-5, 5 being the most difficult

Existing	Future	Difficulty
POTT	Current differential	2
Line Current Differential	Traveling wave	2
Phase Distance	Comm based blocking schemes	3
Overcurrent	Comm based blocking schemes, adaptive tripping schemes, undervoltage supervision	3
Bus Differential	CT instead of LCs	4
Transformer Differential and overcurrent	Blocking schemes for overcurrent	1
Breaker Failure	Backup relay over trip and/or pri and sec breakers	5
3-5 Cycle Breakers	2 cycle breakers	4
Circuit Switchers	Faster circuit switchers	4
Fuses	"Smart" fuses	2
EM Relays	Microprocessor relays	2

What Will Trigger the Change

Existing	Trigger
POTT	Already being phased out for current differential
Line Current Differential	Relay clearing too slow (CCT not being met)
Phase Distance	Fault direction unreliable with IBR behind the relay
Phase/Ground Overcurrent	When max load and min fault levels are within margin
Bus Differential	Linear couplers already being phased out
Transformer Differential and overcurrent	Same as overcurrent
Breaker Failure	Breaker failure is too slow (CCT not being met)
3-5 Cycle Breakers	Breaker clearing too slow (CCT not being met)
Circuit Switchers	CS clearing time too slow (CCT not being met)
Fuses	Fuses too slow or don’t operate due to lack of fault current
Electromechanical Relays	Already being phased out for microprocessor relays

When Trigger Points will Occur

Existing	Trigger	When
POTT	Already being phased out for current differential	Now
Line Current Differential	Relay clearing too slow (CCT not being met)	?
Phase Distance	Fault direction unreliable with IBR behind the relay	Soon
Phase/Ground Overcurrent	When max load and min fault levels are within margin	?
Bus Differential	Linear couplers already being phased out	Now
Transformer Diff and OC	Same as overcurrent	?
Breaker Failure	Breaker failure is too slow (CCT not being met)	?
3-5 Cycle Breakers	Breaker clearing too slow (CCT not being met)	?
Circuit Switchers	CS clearing time too slow (CCT not being met)	?
Fuses	Fuses too slow or don’t operate due to lack of fault current	?
Electromechanical Relays	Already being phased out for microprocessor relays	Now

Predicting when the trigger points will occur

- Timing is currently unknown, difficult to predict, and highly variable.
- Detailed/accurate simulation models are needed to forecast upcoming changes to fault current levels, critical clearing times, how faults will look, and if relays can "see" what is going on adequately.
- We need to monitor and investigate field readings and events:
  - Track trends to be able to extrapolate when the trigger point would occur.
  - Implement automated systems to be able to track changing trends.
- Industry standards and guidelines – may be required to make changes before our set trigger points.
- Different system resource types at different locations may accelerate or delay the need to replace the existing protection.

Resource Impact to Existing Relay Operation

Scale from 0-5, 5 having greatest impact

Resource	Impact to Relay Operation
Synchronous Generators	0
Synchronous Condensers	1
Static Var Compensator (STATCOM)	1
Grid Forming Inverters	0-3
Grid Following Inverters	4-5
Controlled DER	4
Uncontrolled DER (future Ride-Through settings)	4
Uncontrolled DER (current)	5

Hawaiʻi Powered

Mahalo for your time

Questions?