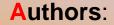
#### **Cloud-Based End-to-End Testing of Protection Schemes**



Dhanabal Mani (Megger, US) Sai Chandra Reddy Thota (Megger, US) Abel Gonzalez (Megger, Canada)



#### Agenda

- Pilot Schemes POTT & PUTT
- Test Considerations
- Test Setup
- Test Cases
- Results & Analysis
- Summary/Conclusions



## **Pilot Schemes POTT and PUTT**

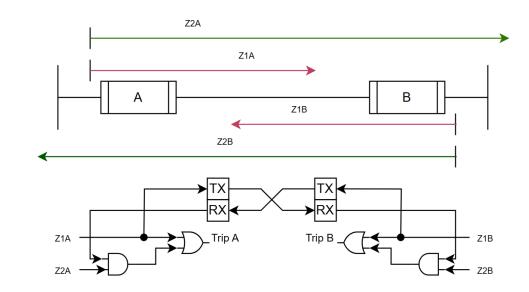




#### PUTT

PUTT schemes use both underreaching (Z1A and Z1B) and overreaching (Z2A and Z2B) elements.

Each terminal will trip directly for its underreaching element, and the permissive signal sent accelerates the tripping of the other end's overreaching element.



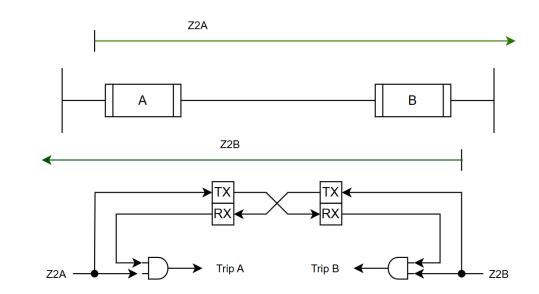
PUTT



#### POTT

## POTT schemes use overreaching elements.

As long as both relays see the fault with their overreaching element the scheme trips.



**POTT Scheme** 



## **Testing Pilot Schemes**

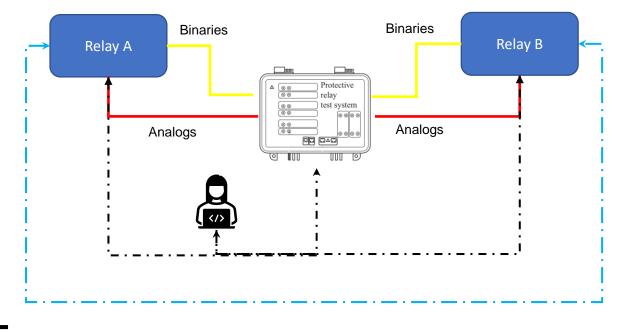


**N**A



#### **Bench Back-to-Back Testing**

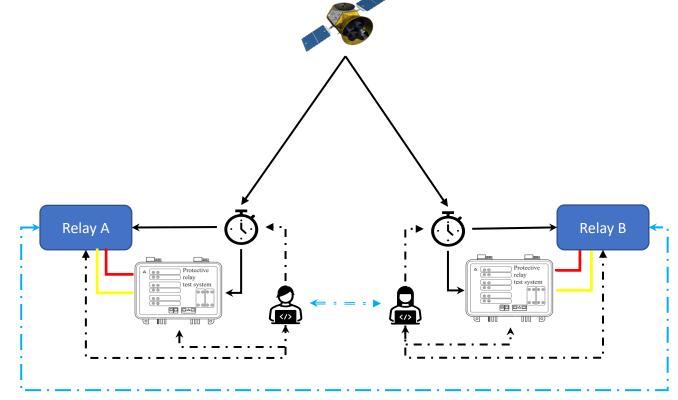
• Helps in understanding, troubleshooting, and developing relay settings. (Laboratory Test Environment)





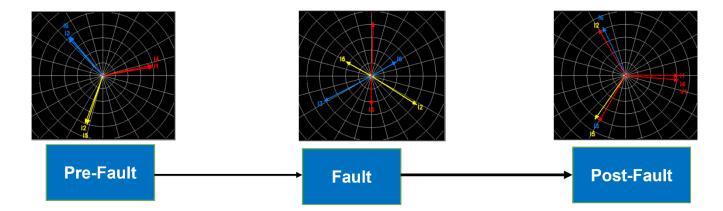
## **Traditional End-End testing**

Two users communicate, coordinate, and simultaneously do the testing at each end.





#### **Traditional Static Testing**



#### Local

ψ		C	URRENT			VOLTAGE						
GGG		I (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)			
ሪ	11	0.800	-10.00	50.000	٧	V1	66.40	0.00	50.000			
ሪ	I2	0.800	110.00	50.000	Ú	V2	66.40	240.00	50.000			
ሪ	I3	0.800	230.00	50.000	Ú	V3	66.40	120.00	50.000			

8		С	URRENT			VOLTAGE						
U S		I (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)			
പ	11	7.400	-88.00	50.000	۵	V1	44.00	0.00	50.000			
പ	12	7.400	32.00	50.000	Ú	V2	44.00	240.00	50.000			
പ	13	7.400	152.00	50.000	Ú	V3	44.00	120.00	50.000			

ψ		CI	URRENT				VOL	VOLTAGE				
GGG		I (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)			
ს	I1	1.000	0.00	50.000	۵	V1	66.40	0.00	50.000			
പ്	I2	1.000	240.00	50.000	Ŵ	V2	66.40	240.00	50.000			
ഗ	13	1.000	120.00	50.000	ŵ	V3	66.40	120.00	50.000			

#### Remote

	ģ		C	URRENT			VOLTAGE							
	GGG		I (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)				
	ନ	I1	0.800	-12.00	50.000	Ŵ	V1	66.40	0.00	50.000				
	<del>ل</del>	I2	0.800	108.00	50.000	٧	V2	66.40	240.00	50.000				
_	ሪ	I3	0.800	228.00	50.000	Ŵ	V3	66.40	120.00	50.000				



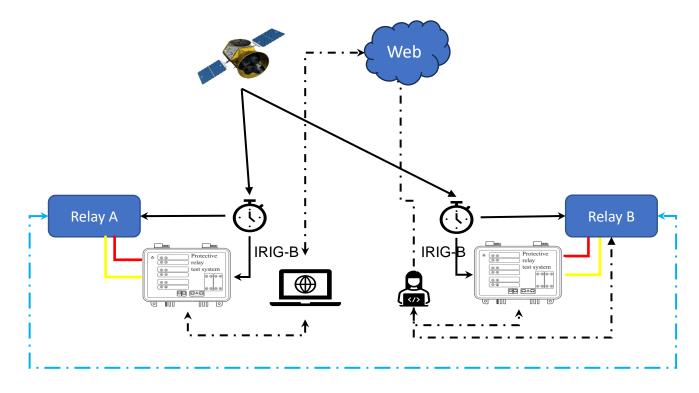


ψ		CI	URRENT						
CCC	I (A)		φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)
പ്ര	I1	4.000	90.00	50.000	٧	V1	46.00	0.00	50.000
പ	I2	4.000	210.00	50.000	ف	V2	46.00	240.00	50.000
ሪ	I3	4.000	330.00	50.000	Ú	V3	46.00	120.00	50.000

ψ		С	URRENT				VOL	TAGE	
999		I (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)
<mark>ل</mark>	I1	1.000	5.00	50.000	٧	V1	66.40	0.00	50.000
ഗ	I2	1.000	125.00	50.000	Ú	V2	66.40	240.00	50.000
പ	I3	1.000	245.00	50.000	Ú	V3	66.40	120.00	50.000

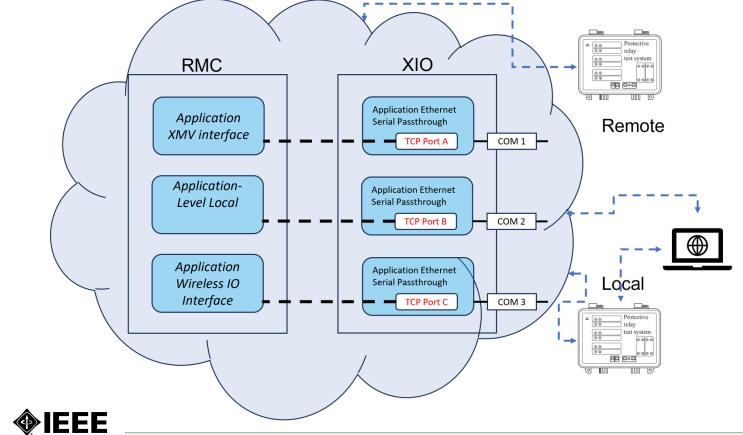
### Web based End-End testing

• Using the cloud, One user can do the testing of Pilot Scheme from one end.





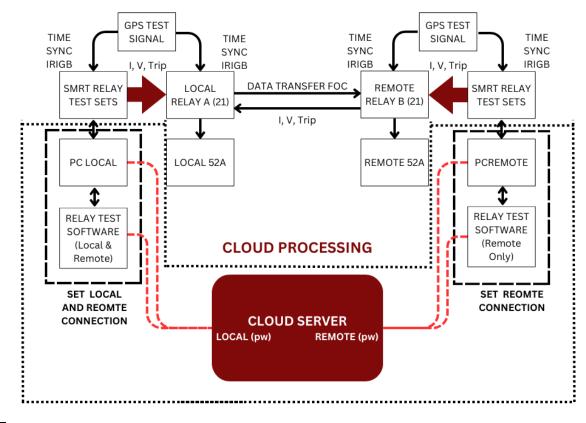
#### **Architecture – Cloud Explained**



Power & Energy Society\*

PES

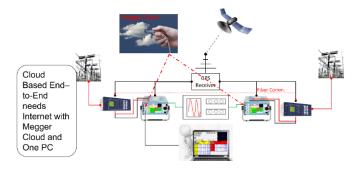
#### **Architecture – Cloud Explained**



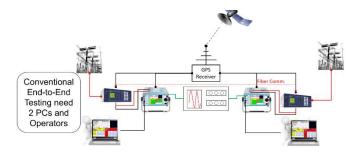




• Every case was tested using both a conventional setup and a cloud-based setup



Cloud-based Test Setup



Conventional Test Setup



#### **Traditional Test POTT**

	Prefault											
Inputs 1×	Image: State 1 Image: State 1   State Name: Pretaut											
Ö	93		S 🐼 🗌	Wa	it IRIG			12 -90	$\mathbb{Z}\times\mathbb{Z}$			
ι ψ		C	URRENT				VOL.	TAGE				
CCC CCC		l (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)			
<mark>ل</mark>	I1	5.0000	0.000	60.000	٧	V1	69.000	0.000	60.000			
പ	I2	5.0000	-120.000	60.000	٧	V2	69.000	-120.000	60.000			
പ	I3	5.0000	120.000	60.000	٩	V3	69.000	120.000	60.000			

Drofoult

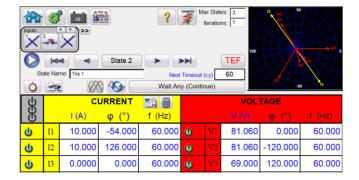
#### Fault

		3 3 1 1 1 1 1 1 1 1 1 1 1 1 1	State 2	) > ) Nex	Max States: 3 terations: 1 1 1 1 1 1 1 1 1 1 1 1 1 1					
<del>CCC</del>			URRENT					TAGE		
U		I (A)	φ (˘)	f (Hz)			V (V)	φ (°)	f (Hz)	
ഗ	<b>I</b> 1	10.000	-54.000	60.000	۵	V1	35.371	-47.260	60.000	
ഗ	I2	10.000	126.000	60.000	۵	V2	35.371	-72.740	60.000	
പ	13	0.0000	0.000	60.000	۵	60.000				



Relay A

Inputs INPUTS Sta	2×	3	State 1		20	ax Stat	- /		
999		C   (A)	URRENT φ (°)	f (Hz)			VOL <sup>-</sup>	TAGE Φ (°)	f (Hz)
မ ပ	I1	5.0000	0.000	60.000	Ú	V1	69.000	0.000	60.000
ധ	I2	5.0000	-120.000	60.000	Ú	V2	69.000	-120.000	60.000
പ	I3	5.0000	120.000	60.000	ŵ	V3	69.000	120.000	60.000





#### **Traditional Test POTT**

=>ser

Relay 1 Station A Date: 03/08/2024 Time: 23:46:47.174 Serial Number: 1170370041

FID=SEL-411L-1-R124-V2-Z015003-D20201009

# 6 5 4 3 2	DATE 03/08/2024 03/08/2024 03/08/2024 03/08/2024 03/08/2024	TIME 23:46:30.0135 23:46:30.0135 23:46:30.0135 23:46:30.0320 23:46:30.0320	ELEMENT Z2P TRIP TMB2A Z2P TMB2A	STATE ASSERTED ASSERTED DEASSERTED DEASSERTED DEASSERTED
2				
1	03/08/2024	23:46:30.2135	TRIP	DEASSERTED

= >|





#### Web Based Test POTT

#### Prefault

#### Fault

				Max States: 3 Iterations: 1							Max States: 3 Iterations: 1									
			le Name	e: Prefault	State 1		ait IRIG	(		12 -9		St Ö	ate Nan	ne: Trip 1	State 2	Next	Timeout (cy y (Continue			
		90 00 00		С I (А)	URRENT φ (°)	f (Hz)			VOLT	TAGE φ (°)	f (Hz)	GGG		с <b>ι</b> I (А)	J <mark>RRENT</mark> φ (°)	f (Hz)		VOL V (V)	TAGE φ (°)	f (Hz)
Relay A	(	5	11	5.0000				V1	69.000			Ś	11	10.000	-54.000		-	35.371	-47.260	1 Charles and a second second
incluy A		5	12	5.0000	1.000			V2		-120.000		ڻ د	12	10.000	126.000 0.000	60.000 60.000	-	2 35.371	-72.740	
		5	13	5.0000		60.000 60.000		V3	69.000 69.000			 С U	13	10,000	-54.000		-	3 69.000 4 81.060		
Rolay R	E	5 5	15	5.0000		60.000		V5		-120.000		لان ال	15	10.000	126.000				-120.000	
Relay B		<u>ს</u>	16	5.0000	120.000	60.000		V6	69.000			<del>ن</del>	<u>16</u>	0.0000	0.000	60.000	۷ 🕲	69.000	120.000	60.000



#### Web Based Test POTT

Rela Stat	ay 1 tion A			Date: 03/08/2024 Time: 21:10:12.317 Serial Number: 1170370041
FID	SEL-411L-1-R	124-V2-Z015003-	D20201009	
# 5 4 3 2 1 = >			ELEMENT Z2P TRIP TMB2A Z2P TMB2A TMB2A TRIP	STATE ASSERTED ASSERTED DEASSERTED DEASSERTED DEASSERTED DEASSERTED





#### **Traditional Test PUTT**

	Pretault								
Inputs 1×	2 2 Ate Nam		State 1		-	ax Stat		90	
Ö	93	. 🕅	0 🐼 🗌	Wa	ait IRIG			12 -90	
ŝ		С	URRENT				VOL.	TAGE	
GGG		l (A)	φ (°)	f (Hz)			V (V)	φ (°)	f (Hz)
<mark>ل</mark>	11	5.0000	0.000	60.000	Ú	V1	69.000	0.000	60.000
ധ	I2	5.0000	-120.000	60.000	ٺ	V2	69.000	-120.000	60.000
പ	I3	5.0000	120.000	60.000	ம்	V3	69.000	120.000	60.000

Durfrult

#### Fault

Inputs St O	2 	3 3 me: Trip	State 2	) > ) Nex	1		- /	PO PO PO PO PO PO PO PO PO PO PO PO PO P	
36		C I (A)	URRENT φ (°)	f (Hz)			VOLT	TAGE φ (°)	f (Hz)
<mark>ل</mark>	11	10.000	-54.000	60.000	ý	V1	35.371	-47.260	60.000
ധ	I2	10.000	126.000	60.000	Ú	V2	35.371	-72.740	60.000
പ	13	0.0000	0.000	60.000	۵	V3	69.000	120.000	60.000



Relay A

Inputs X Sta	2×		State 1		50	ix Stat			
995		- 000 C I (A)	URRENT φ (°)	f (Hz)			VOL <sup>®</sup>	TAGE Φ (°)	f (Hz)
<del>ن</del>	I1	5.0000	0.000	60.000	Ú	V1	69.000	0.000	60.000
ሪ	I2	5.0000	-120.000	60.000	Ú	V2	69.000	-120.000	60.000

Inputs 1 St C	2 2 A A A ate Nar		State 2	Next	-				
99		C I (A)	URRENT φ (°)	f (Hz)			VOL <sup>-</sup> V (V)	TAGE φ (°)	f (Hz)
<mark>ل</mark>	I1	10.000	-54.000	60.000	ý	V1	81.060	0.000	60.000
ധ	I2	10.000	126.000	60.000	٧	V2	81.060	-120.000	60.000
ധ	I3	0.0000	0.000	60.000	Ċ	V3	69.000	120.000	60.000



#### **Traditional Test PUTT**

=>ser

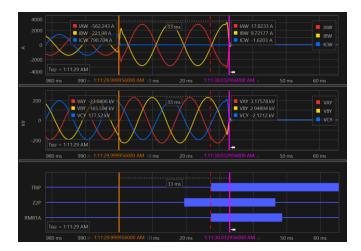
Relay 1

Station A

Date: 02/25/2024 Time: 01:24:33.563 Serial Number: 1170370041

#### FID=SEL-411L-1-R124-V2-Z015003-D20201009

#	DATE	TIME	ELEMENT	STATE
6	02/25/2024	01:11:30.0182	Z2P	ASSERTED
5	02/25/2024	01:11:30.0267	TRIP	Asserted
4	02/25/2024	01:11:30.0267	RMB1A	Asserted
3	02/25/2024	01:11:30.0452	Z2P	DEASSERTED
2		01:11:30.0472	RMB1A	Deasserted
1	02/25/2024	01:11:30.2267	TRIP	Deasserted





#### Web Based Test PUTT

Prefault

#### Fault

					?	<b>*</b>	lax States: 3 Iterations: 1	16 9 13		Inputs	/ <u></u>			?	Max S Itera	ations: 1	12 10 90	
		te Name	e: Prefault	State 1		ait IRIG		12 5	N N N N N N N N N N N N N N N N N N N	SI O	-	ne: Trip 1	State 2	Next	Timeout (cy)			
	900		CI I (A)	URRENT φ (°)	f (Hz)		VOL <sup>.</sup> V (V)	TAGE φ (°)	f (Hz)	GGG		Cl   (A)	J <mark>RRENT</mark> φ (°)	f (Hz)		VOL V (V)	TAGE φ (°)	f (Hz)
	ს	I1	5.0000	0.000	60.000	Ú	V1 69.000	0.000	60.000	Ś	11	10.000	-54.000	60.000	Ú V	35.371	-47.260	60.000
Relay A	y	I2	5.0000	-120.000	60.000	٢	V2 69.000	-120.000	60.000	S	I2	10.000	126.000	60.000	ن v	35.371	-72.740	60.000
	ს	I3	5.0000	120.000	60.000	ம்	V3 69.000	120.000	60.000	C	13	0.0000	0.000	60.000	Ú V	3 69.000	120.000	60.000
	ს	I4	5.0000	0.000	60.000	Ú	V4 69.000	0.000	60.000	<mark>ل</mark>	I4	10.000	-54.000	60.000	<b>Ú</b> V	4 81.060	0.000	60.000
Relay B	ს	15	5.0000	-120.000	60.000	Ú	V5 69.000	-120.000	60.000	Ś	15	10.000	126.000	60.000	ن ن	81.060	-120.000	60.000
	ს	I6	5.0000	120.000	60.000	Ú	V6 69.000	120.000	60.000	<mark>ل</mark>	I6	0.0000	0.000	60.000	Ú V	69.000	120.000	60.000



#### Web Based Test PUTT

Relay 1 Station A

Date: 02/25/2024 Time: 02:03:49.156 Serial Number: 1170370041

FID=SEL-411L-1-R124-V2-Z015003-D20201009

13     03       12     03       11     03       10     03       9     03       8     03       7     03       5     03       5     03       3     03	2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024 2/25/2024	01 11 30.0182 01 11 30.0267 01 11 30.0267 01 11 30.0472 01 11 30.0472 01 11 30.247 01 11 30.2267 02 22 00.0187 02 02 200.0187 02 02 200.0227 02 02 200.0322 02 202.00.0372 02 02 200.0377 02 02 200.0437	22P TRIP RMB1A 22P RMB1A TRIP 22P TRIP RMB1A 22P 22P 22P 22P 22P RMB1A
2 03			

STATE ASSERTED Asserted Asserted Deasserted Deasserted ASSERTED ASSERTED DEASSERTED DEASSERTED Deasserted





## Conclusions



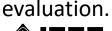
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### Summary

- The proposed method centralizes control at one end of the line,
- ٠ Streamlines the testing process and significantly reduces the need for highly trained personnel.
- Training requirements and costs are lower. ٠
- Centralized control improves the test's manageability & and repeatability of ٠ results.
- Unlike traditional methods limited to individual trip tests, this approach allows the user to automate testing.
- Its versatility extends to regression testing, type testing, and commissioning testing.
- With automated reporting, the results remain untouched and incorruptible, providing a much more reliable and trustworthy tool for analysis and







# **Questions?**

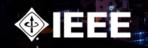
**Manage** 

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Reads.



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