Hawaiian Electric

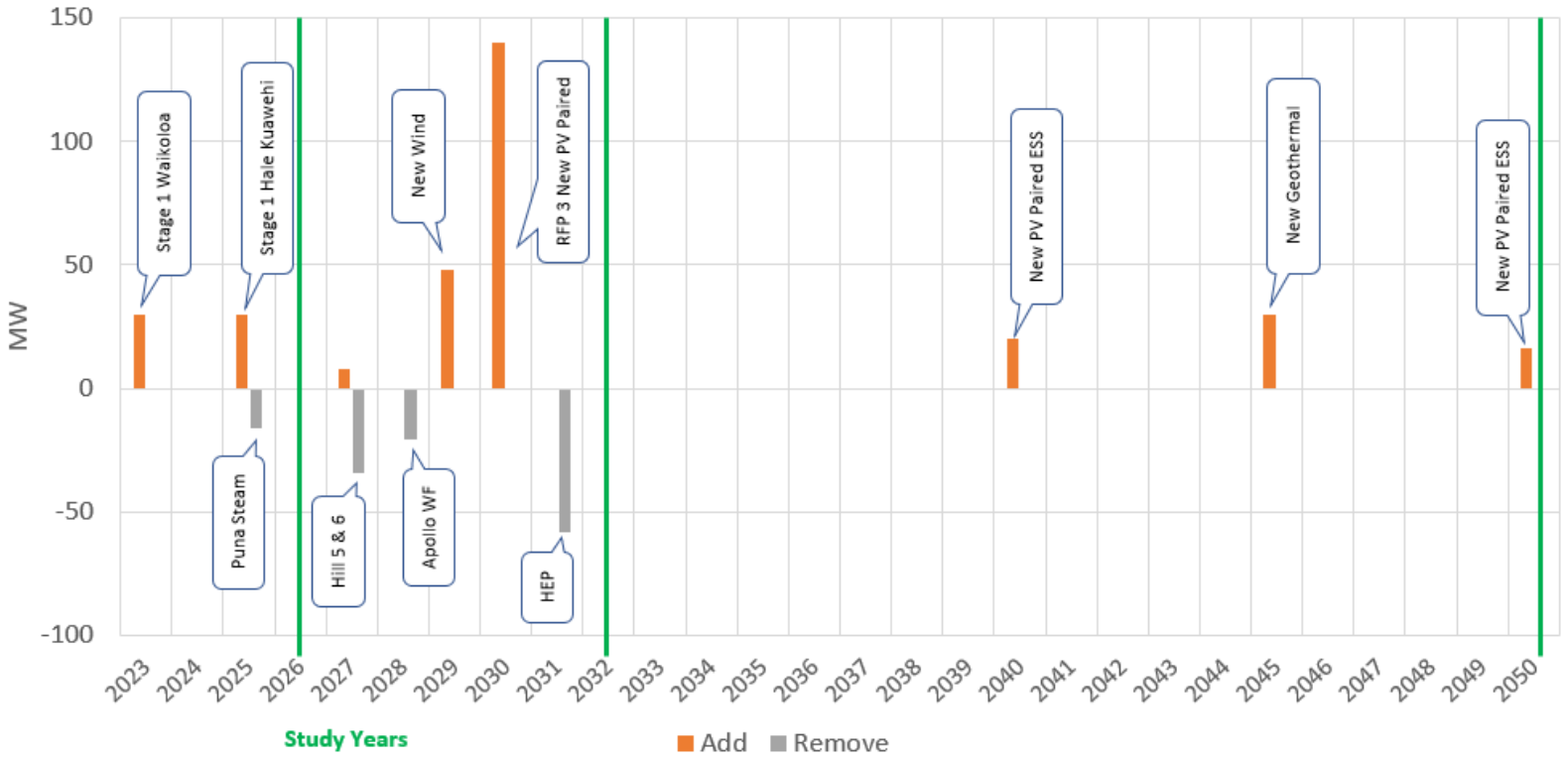
Hawaii Island IGP-SSS: 2026-2050 Steady State Preliminary Results

January 13, 2023

Study Summary

- Study objective – identify transmission steady state grid needs to host the forecasted load and resoure interconnections, from near term to 2050.
- Study approach – Perform power flow analyses for selected years with peak load, without DER contribution.

Studied Years



Use future generations' commission years to determine what years to study.

For future IPP placement, take locations with capacity first.

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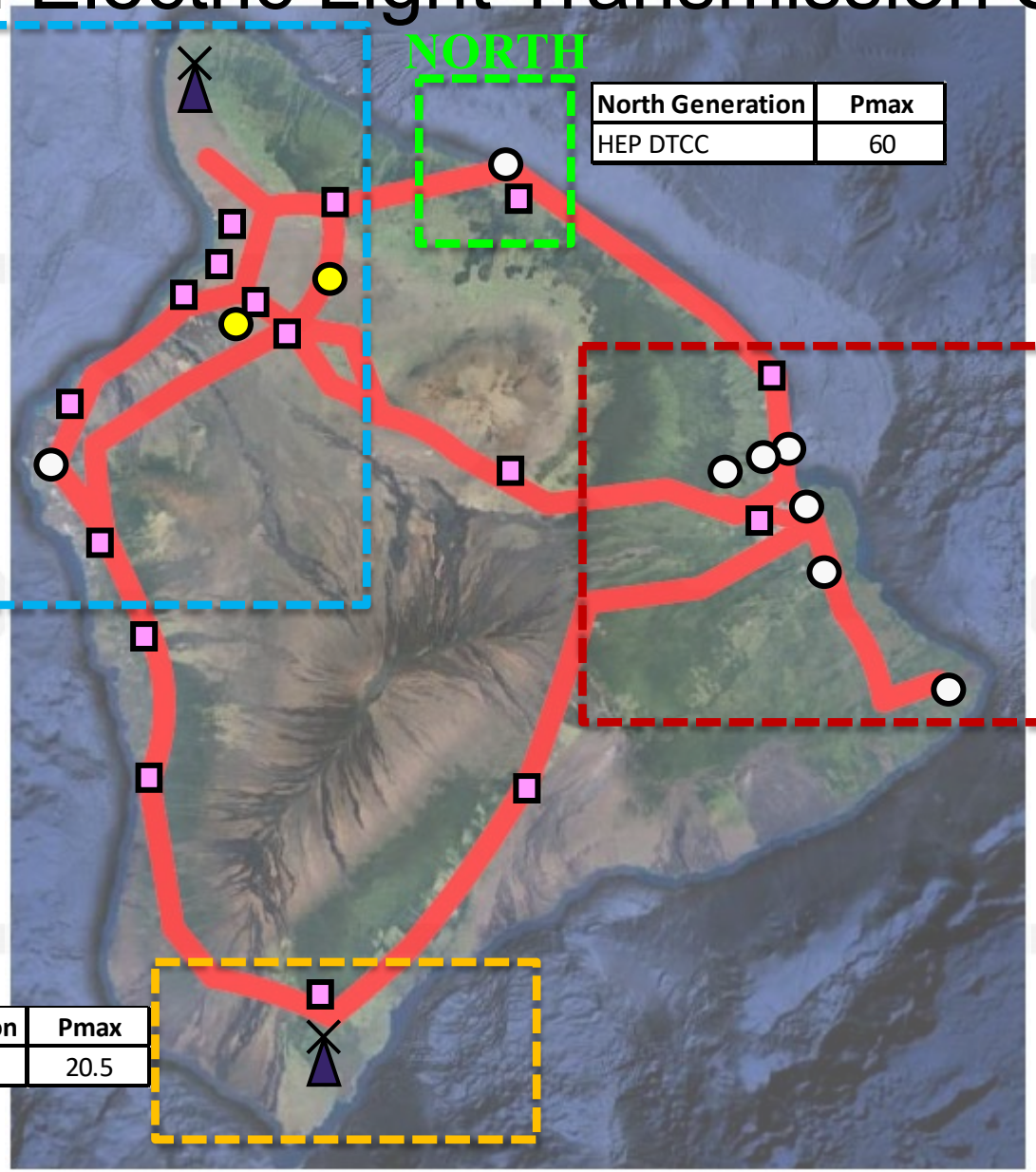

North Generation	Pmax
HEP DTCC	60

West Generation	Pmax
Keahol DTCC	52
Keahole CT2	13.8
Waikoloa	30
Hale Kuawehi	30
HRD WF	10.5
Total	136.3

East Generation	Pmax
PGV	38
Hill 5 & 6	34.2
Puna Steam	15.5
Puna CT3	20
HELCO Hydro	4.5
Wailuku Hydro	12.1
Total	124.3

South Generation	Pmax
Pakini Nui WF	20.5

69 kV

34 kV

Generating Unit(s)

Switching Station (not all shown)

Stage 1 Projects

Wind Farms

2026 Analyses

- No new resource installed
- Assumptions
  - All stage 1 projects commissioned
  - Puna Steam removed in 2025

PV/BESS IBR		Wind		Hydro		Geothermal		Fossil Plant		DER	System Peak Demand
# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	Forecast MW Capacity	MW
2	60	2	31	3	16.6	1	38	6	180	143.7	206

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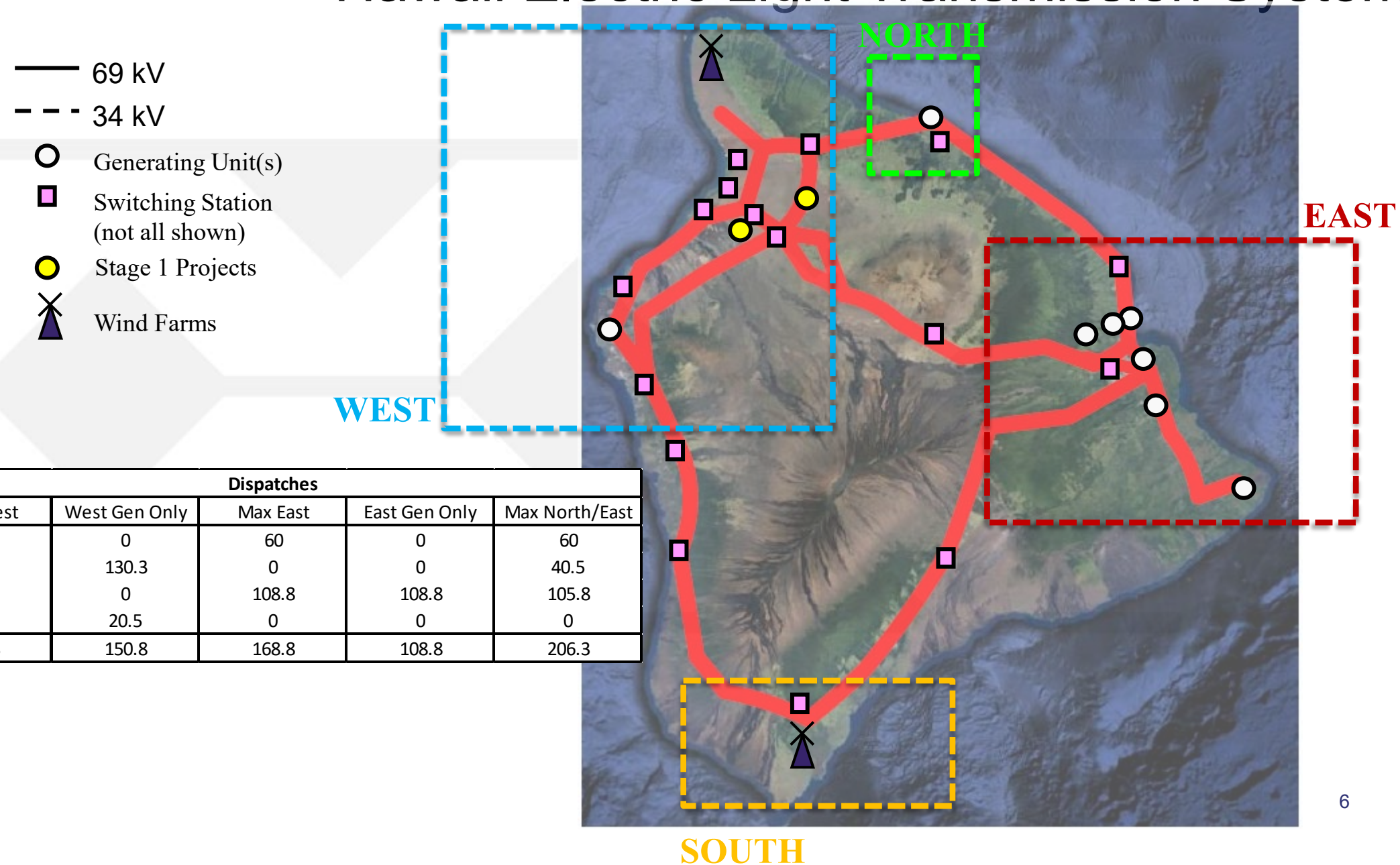

Area	Max Capability	Dispatches				
		Max West	West Gen Only	Max East	East Gen Only	Max North/East
North	60	49	0	60	0	60
West	136.3	136.3	130.3	0	0	40.5
East	108.8	0	0	108.8	108.8	105.8
South	20.5	20.5	20.5	0	0	0
Total	325.6	205.8	150.8	168.8	108.8	206.3

2026 Analyses
Result Summary

- 69 kV line overloading is observed in N-1 contingency, but not with system normal configuration.

Dispatch	# of Contingency with Overloading	Overloading Equipment	Overloading Range
Max West	5	69 kV line	109-126%
West Gen Only	0	-	-
Max East	0	-	-
East Gen Only	0	-	-
Max North/East	0	-	-

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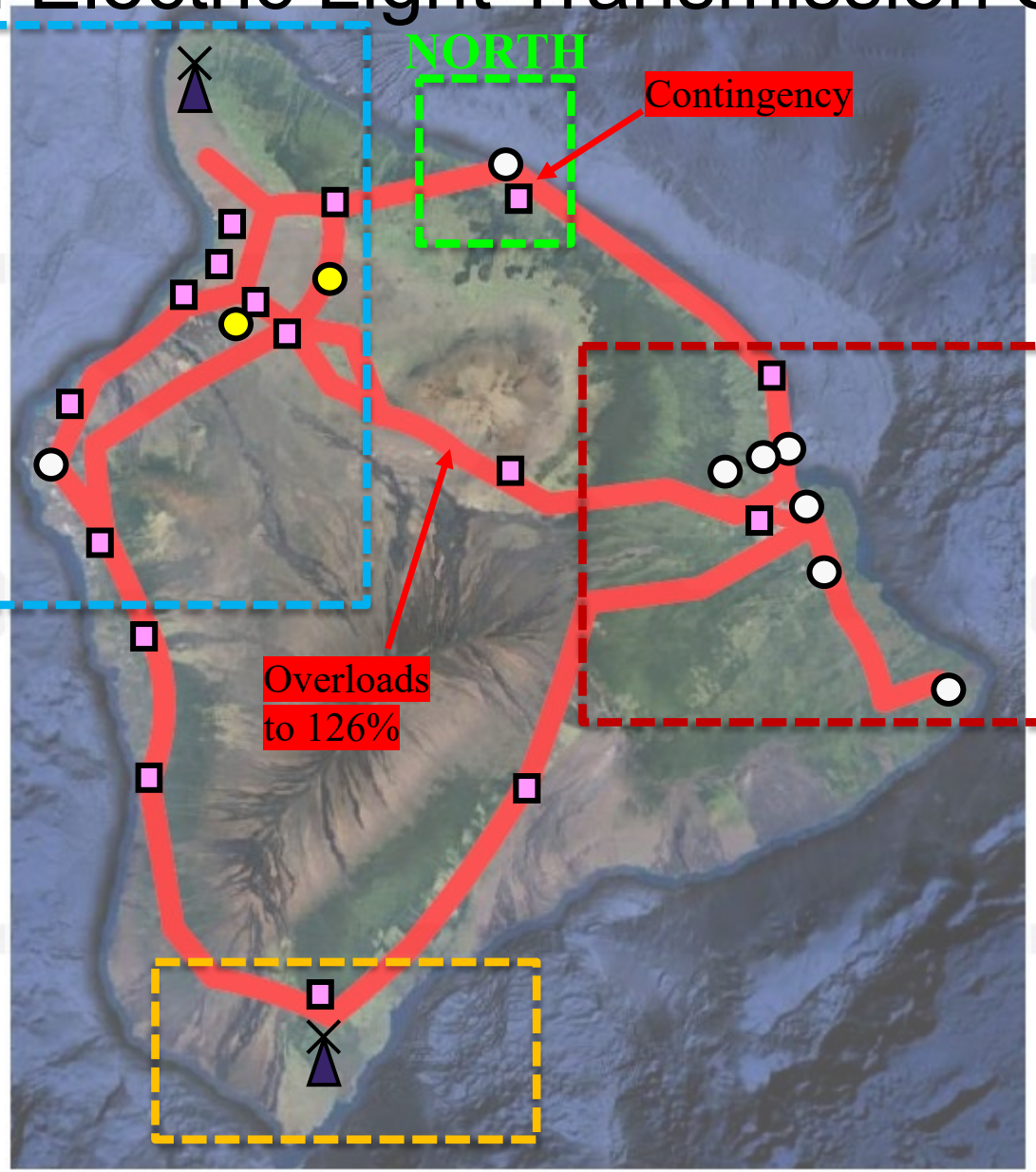

Loss of North route forces HEP and West generation to go through cross-island tie L6200 (35.9MVA Rate B capacity)

Area	Max Capability	Max West
North	60	49
West	136.3	136.3
East	108.8	0
South	20.5	20.5
Total	325.6	205.8

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Wind Farms

2026 Analyses
Result Summary

- Max West case has UV violation in normal configuration (min. Voltage 0.90 PU)
- UV violation is identified in several dispatches, during N-1.

Dispatch	# of Contingency with UV Violation	Min. Voltages	Worst Contingency	Area
Max West	73	0.44	L8800 Honokaa - Haina	North
West Gen Only	23	0.83	L7700 Waimea	North
Max East	1	0.84	L8600 Kahaluu	South/Southwest
East Gen Only	0	0.95	L8600 Kahaluu	South/Southwest
Max North/East	1	0.85	L8600 Kahaluu	South/Southwest

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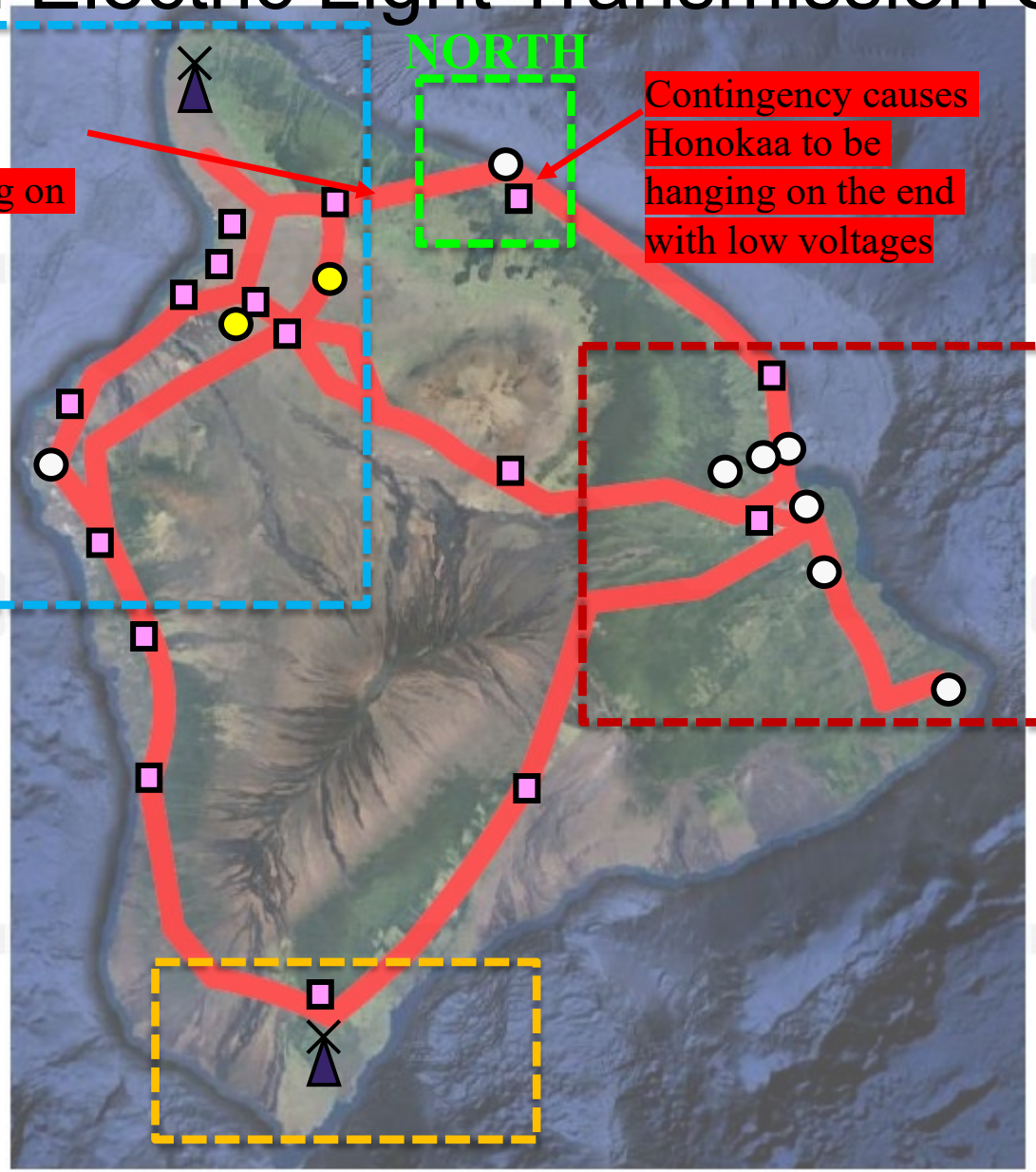


Similar scenario with Waimea contingency. Kamuela is hanging on the end with low voltages

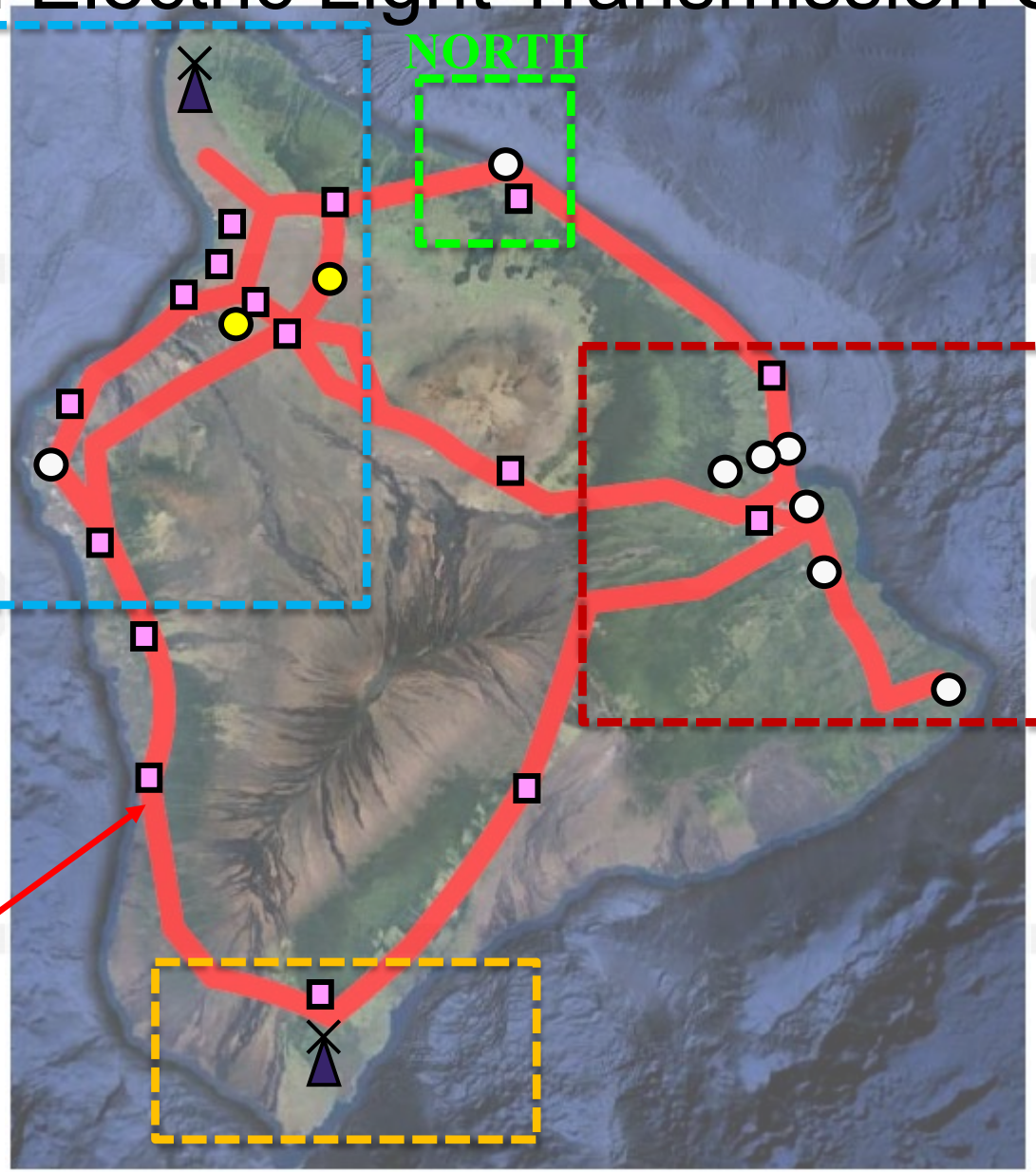
Contingency causes Honokaa to be hanging on the end with low voltages

Max West already has undervoltage issues in normal conditions
Requires voltage support from the East side

Area	Max Capability	Max West	West Gen Only
North	60	49	0
West	136.3	136.3	130.3
East	108.8	0	0
South	20.5	20.5	20.5
Total	325.6	205.8	150.8

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Wind Farms

Hawaii Electric Light Transmission System



Area	Max Capability	Max East	Max North/East
North	60	60	60
West	136.3	0	40.5
East	108.8	108.8	105.8
South	20.5	0	0
Total	325.6	168.8	206.3

ontingency causes Keauhou to be hanging on the end with low voltages

Requires voltage support from the South
Too far from West or East generation

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Wind Farms

2026 Analyses Result Summary

- Mitigation solutions
  - L6200 overloading
    - Reconductor L6200 as 556 AAC
  - Undervoltage violation for North
    - Puna CT3 online (8MW)
  - Undervoltage violation for South/Southwest (one of options listed below)
    - Kamaoa Generation (8.2MW)
    - Kamaoa Reactive Resource (8MVAR)
    - Keauhou Reactive Resource (5.2MVAR)
  - With no L6200 reconductor, displacing West generation to East alleviate overloading on L6200
    - PGV online (14MW) mitigates North voltage violation for Max West & West Gens only
    - Puna CT3 & Hill 6 at Pmin (16 MW total) mitigates North voltage violation for Max West & West Gens only
    - Apollo/Pakini Nui Windfarm at 6 MW mitigates the South voltage violation for Max East, East Gens only, & Max North/East

2032 Analyses

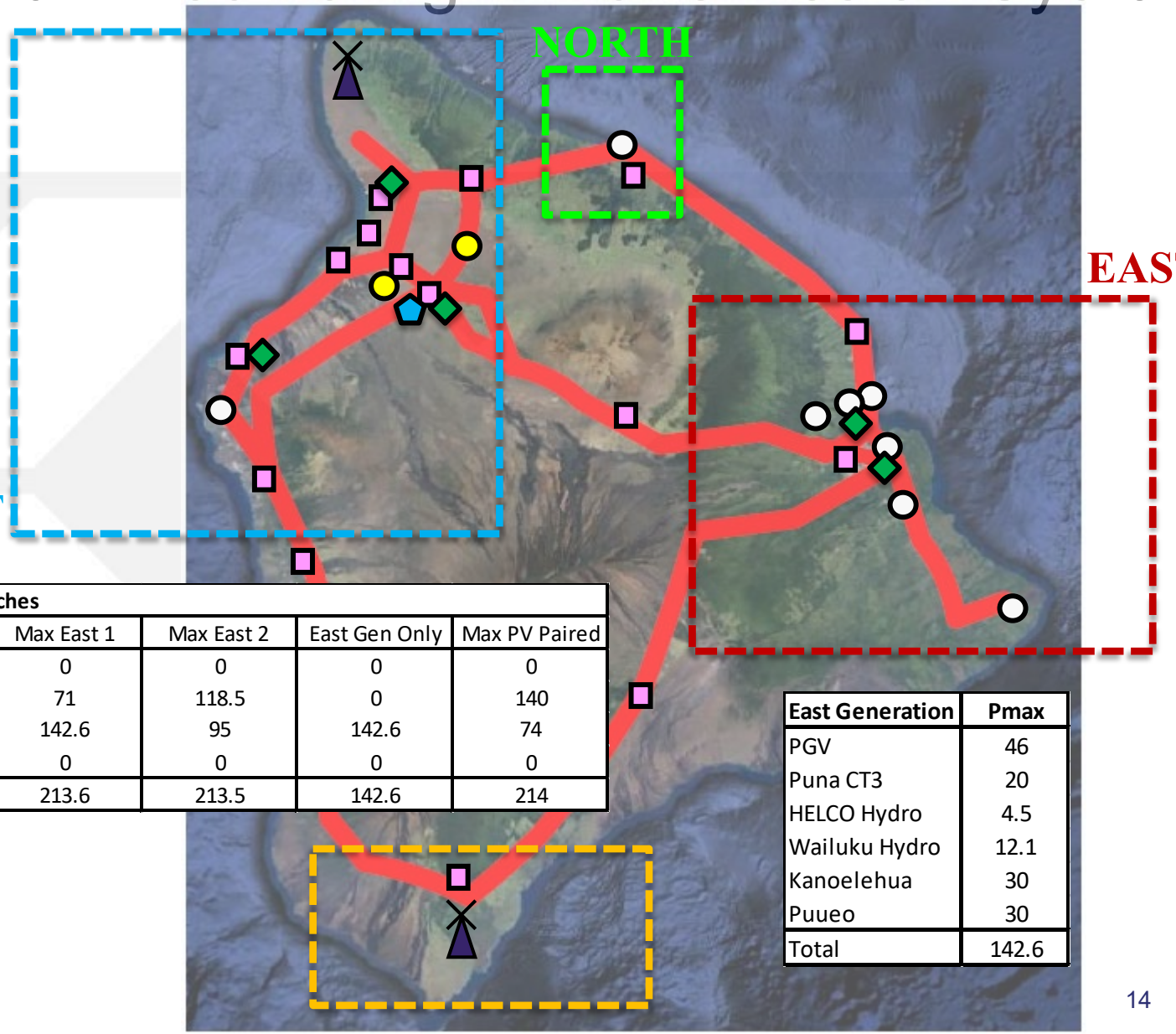
- New resources – Stage 3 140MW interconnection at Puueo (30MW), Kanoelehua (30MW), Ouli (20MW), Poopoomino (20MW), Keamuku (30MW)
- New Onshore Wind (48MW) at Keamuku
- Assumptions
  - Using PGV at 46MW
  - Hill 5 & 6 (34.2 MW) removed in 2027
  - Pakini Nui WF (20.5 MW) removed in 2028
  - HEP (60 MW) removed in 2031

PV/BESS IBR		Wind		Hydro		Geothermal		Fossil Plant		DER	System Peak Demand
# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	Forecast MW Capacity	MW
7	200	2	58.5	3	16.6	1	46	6	85.8	174.4	214

Hawaii Electric Light Transmission System

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind

West Generation	Pmax
Keahol DTCC	52
Keahole CT2	13.8
Waikoloa	30
Hale Kuawehi	30
HRD WF	10.5
Ouli	20
Poopoomino	30
Keamuku	30
Onshore Wind	48
Total	264.3



Area	Max Capability	Dispatches							
		Max West 1	Max West 2	Max West 3	West Gen Only	Max East 1	Max East 2	East Gen Only	Max PV Paired
North	-	0	0	0	0	0	0	0	0
West	264.3	213.5	213.8	145.8	145.8	71	118.5	0	140
East	142.6	0	0	68.5	0	142.6	95	142.6	74
South	-	0	0	0	0	0	0	0	0
Total	406.9	213.5	213.8	214.3	145.8	213.6	213.5	142.6	214

East Generation	Pmax
PGV	46
Puna CT3	20
HELCO Hydro	4.5
Wailuku Hydro	12.1
Kanoelehua	30
Puueo	30
Total	142.6

2032 Analyses
Result Summary

- 69 kV line overloading is observed in N-1 contingency, but not with system normal configuration.

Dispatch	# of Contingency with Overloading	Overloading Equipment	Overloading Range
Max West 1	12	69 kV line	102.6-147%
Max West 2	12	69 kV line	101.9-148%
Max West 3	0	-	-
West Only Generation	0	-	-
Max East 1	1	69 kV line	96.9
Max East 2	1	69 kV line	99.3
East Only Generation	4	69 kV line	96-97.7%
Max Paired PV	0	-	-

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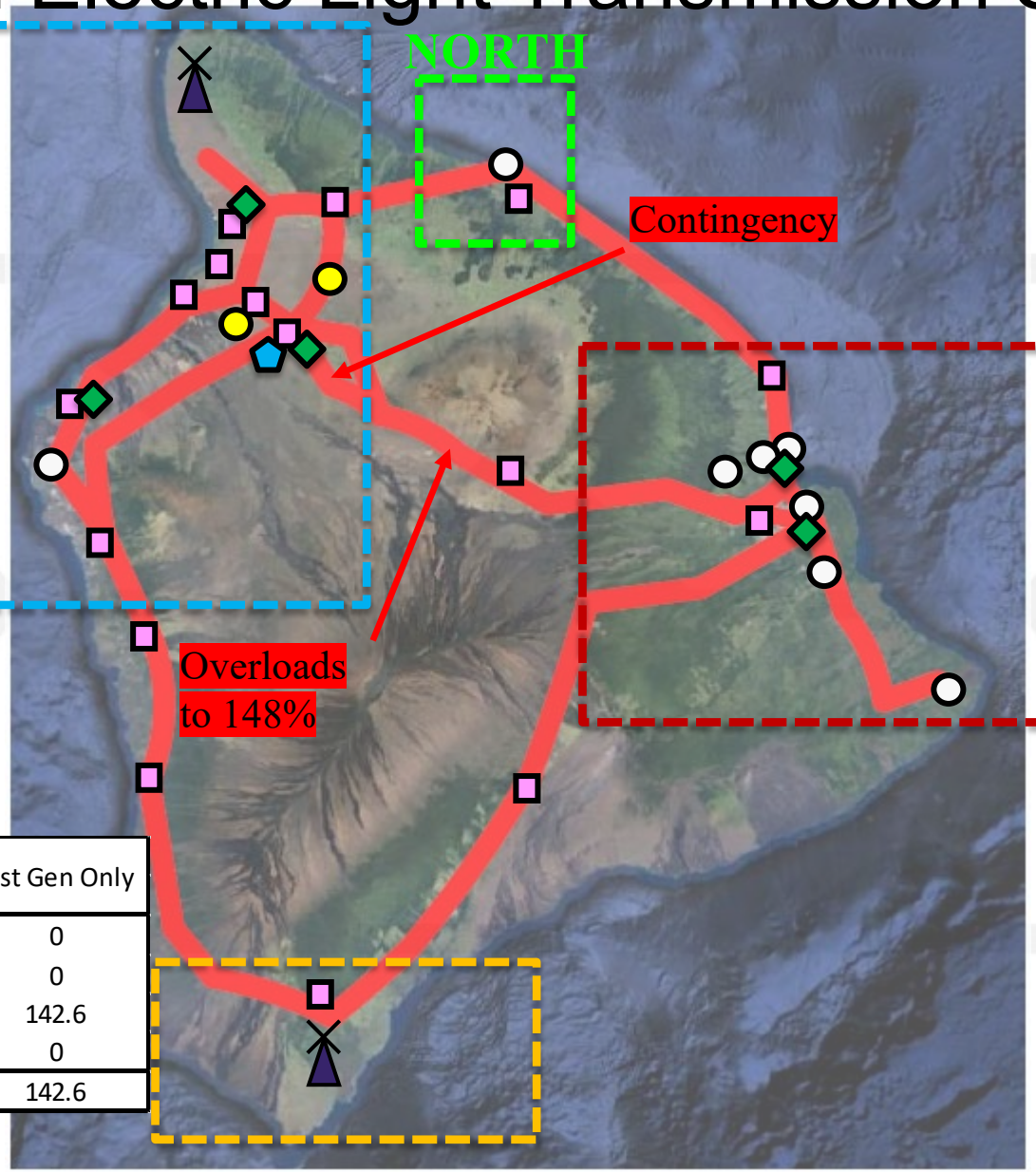


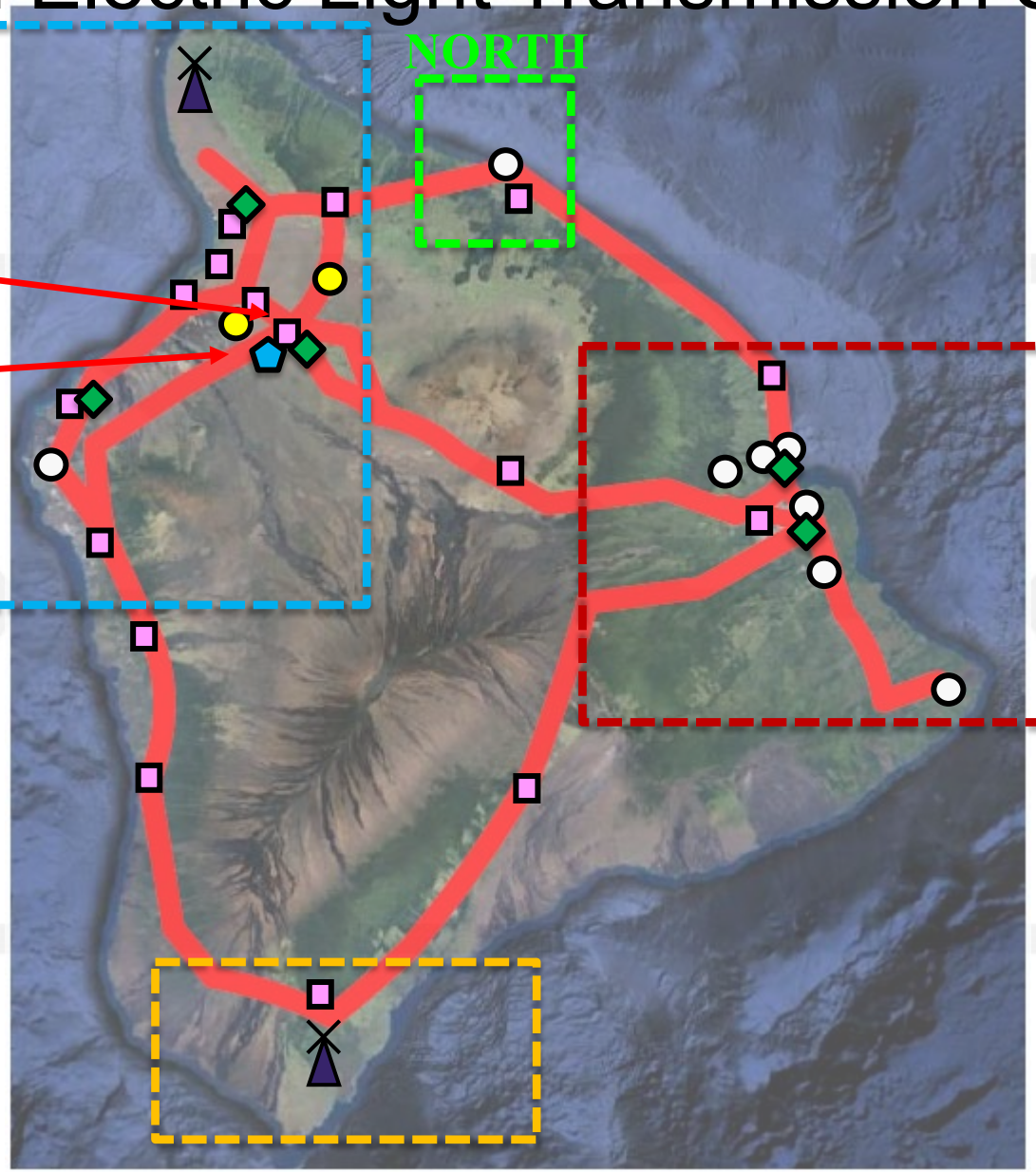
Loss of North route forces and West generation to go through cross-island tie L6200 (35.9MVA Rate B capacity)

Loss of 1 of 2 cross-island tie forces West generation to go through cross-island tie L6200 (35.9MVA Rate B capacity)

Area	Max Capability	Max West 1	Max West 2	East Gen Only
North	-	0	0	0
West	264.3	213.5	213.8	0
East	142.6	0	0	142.6
South	-	0	0	0
Total	406.9	213.5	213.8	142.6

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind

Hawaii Electric Light Transmission System



Overloads to 99.3%

Contingency

Area	Max Capability	Max East 1	Max East 2
North	-	0	0
West	264.3	71	118.5
East	142.6	142.6	95
South	-	0	0
Total	406.9	213.6	213.5

69 kV

34 kV

Generating Unit(s)

Switching Station (not all shown)

Stage 1 Projects

Paired PV/BESS

Onshore Wind

2032 Analyses
Result Summary

- Max West 1 & 2 cases has UV violation in normal configuration (min. Voltage 0.90 PU)
- UV violation is identified in several dispatches, during N-1.

Dispatch	# of Contingency with UV Violation	Min. Voltages	Worst Contingency	Area
Max West 1	72	0.27	L8600 Kahaluu	South/Southwest
Max West 2	72	0.24	L8600 Kahaluu	South/Southwest
Max West 3	1	0.81	L8600 Kahaluu	South/Southwest
West Gens Only	0	0.92	L8600 Kahaluu	South/Southwest
Max East 1	1	0.83	L8600 Kahaluu	South/Southwest
Max East 2	1	0.82	L8600 Kahaluu	South/Southwest
East Gens Only	1	0.90	L8600 Kahaluu	South/Southwest
Max Paired PV	1	0.80	L8600 Kahaluu	South/Southwest

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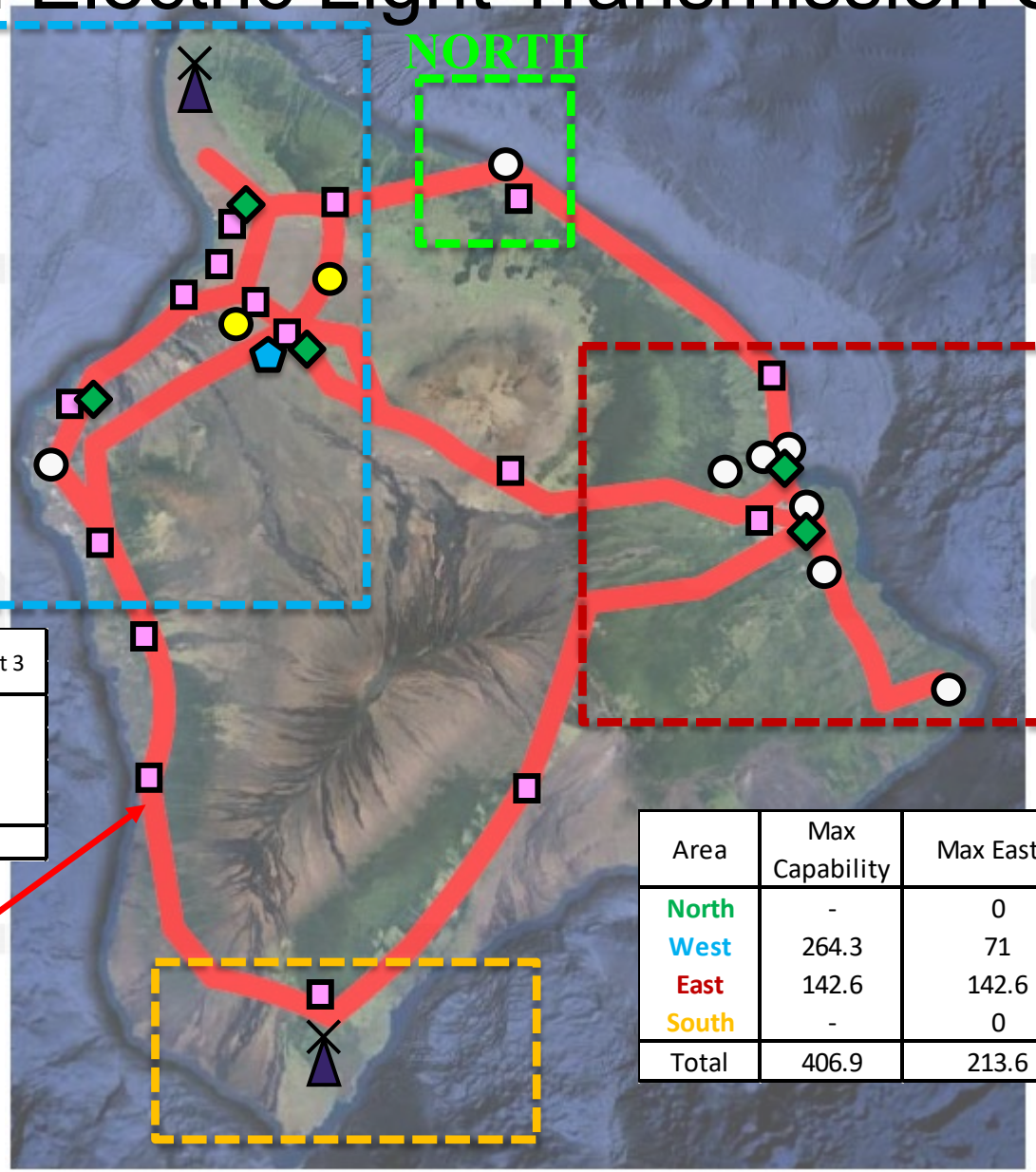

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind

Area	Max Capability	Max West 1	Max West 2	Max West 3
North	-	0	0	0
West	264.3	213.5	213.8	145.8
East	142.6	0	0	68.5
South	-	0	0	0
Total	406.9	213.5	213.8	214.3

Contingency causes Keauhou to be hanging on the end with low voltages

Area	Max Capability	Max East 1	Max East 2	East Gen Only	Max PV Paired
North	-	0	0	0	0
West	264.3	71	118.5	0	140
East	142.6	142.6	95	142.6	74
South	-	0	0	0	0
Total	406.9	213.6	213.5	142.6	214

Requires voltage support from the South
Too far from West or East generation

2032 Analyses Result Summary

- Mitigation solutions
  - L6200 overloading
    - Reconductor L6200 as 556 AAC
  - L8100 overloading
    - Reconductor L8100 as 556 AAC
    - Redispatch Keamuku/Onshore Wind to Ouli and Poopoomino
  - Undervoltage violation for South/Southwest
    - Kamaoa Generation (8.2MW)
    - Kamaoa Reactive Resource (8MVAR)
    - Keauhou Reactive Resource (5.2MVAR)
  - Undervoltage violation for North show after mitigating South/Southwest violations, turning on these units will mitigate North undervoltage violations
    - Puna CT3 online (8MW)
    - PGV online (3MW) (contract Pmin may be higher)
    - Kanoelehua online (7.5MW)
    - Kanoelehua & Puueo (3.75MW each)
  - With no L6200 reconductor, displacing West generation to East alleviate overloading for Max West 1 & 2 cases
    - Puna CT3 (19 MW) + Kano or Puueo (2.8 MVAR) to mitigate North voltage violation
    - PGV (18 MW) to mitigate North voltage violation
    - Kanoelehua (17 MW) + Kanoelehua (20 MVAR) to mitigate North voltage violation
    - Kanoelehua & Puueo (8.5 MW each) + Kanoelehua & Puueo (10 MVAR each) to mitigate North voltage violation
    - Generation at Kamaoa (13.3 MW) or Reactive Resource at Kamaoa (10.4 MVAR) or Reactive Resource at Keauhou (10.4 MVAR) solves the South voltage violation
  - Recommended mitigation combination is L6200 & L8100 reconductor with Kamaoa Generation & PGV online to solve overloading and voltage violation issues

2050 Analyses

- New Geothermal (30MW) added at Haina
- New AggA Paired PV/BESS at Pepeekeo (20)MW and Kaumana (17MW)
- Assumptions
  - L6200 reconductored to 556 AAC

PV/BESS IBR		Wind		Hydro		Geothermal		Fossil Plant		DER	System Peak Demand
# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	# of POIs	MW Capacity	Forecast MW Capacity	MW
9	237	2	58.5	3	16.6	2	76	6	85.8	243.3	295

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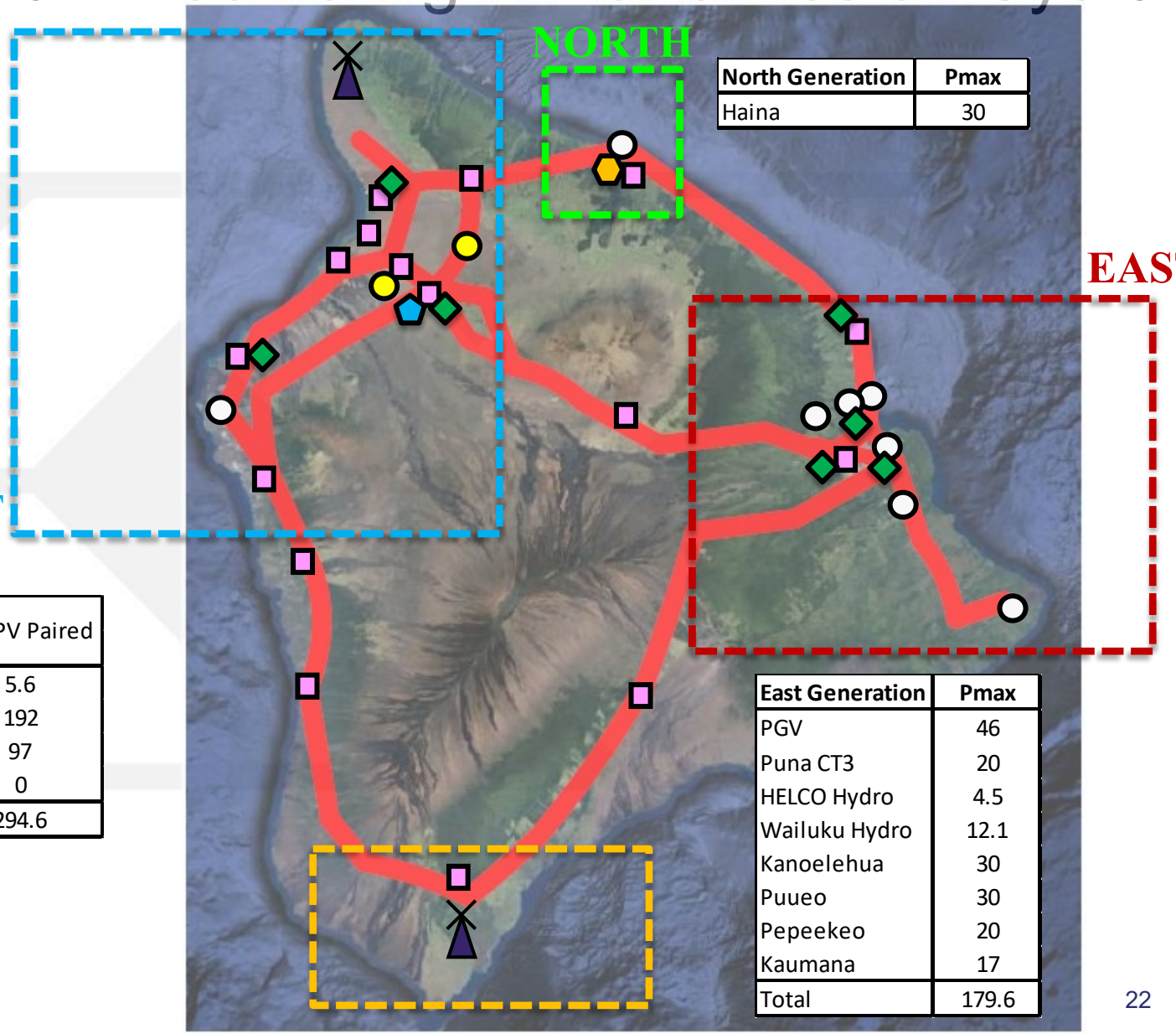
69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind
Geothermal

West Generation	Pmax
Keahol DTCC	52
Keahole CT2	13.8
Waikoloa	30
Hale Kuawehi	30
HRD WF	10.5
Ouli	20
Poopoomino	30
Keamuku	30
Onshore Wind	48
Total	264.3



North Generation	Pmax
Haina	30

East Generation	Pmax
PGV	46
Puna CT3	20
HELCO Hydro	4.5
Wailuku Hydro	12.1
Kanoelehua	30
Puueo	30
Pepeekeo	20
Kaumana	17
Total	179.6

Area	Max Capability	Max West	Max East	East Gen Only	Max PV Paired
North	30	30	30	0	5.6
West	264.3	264.3	85.5	0	192
East	179.6	0	179.6	179.6	97
South	-	0	0	0	0
Total	473.9	294.3	295.1	179.6	294.6

2050 Analyses
Result Summary

- 69 kV line overloading is observed in N-1 contingency, but not with system normal configuration.
- Some cases are not solving easily and show as blown up.

Dispatch	# of Contingency with Overloading	Overloading Equipment	Overloading Range
Max West	17	69 kV line	95.-105.6%
Max East	9	69 kV line	96.4-128.2%
East Gens Only	0	-	-
Max Paired PV	5	69 kV line	95.5-110.1%

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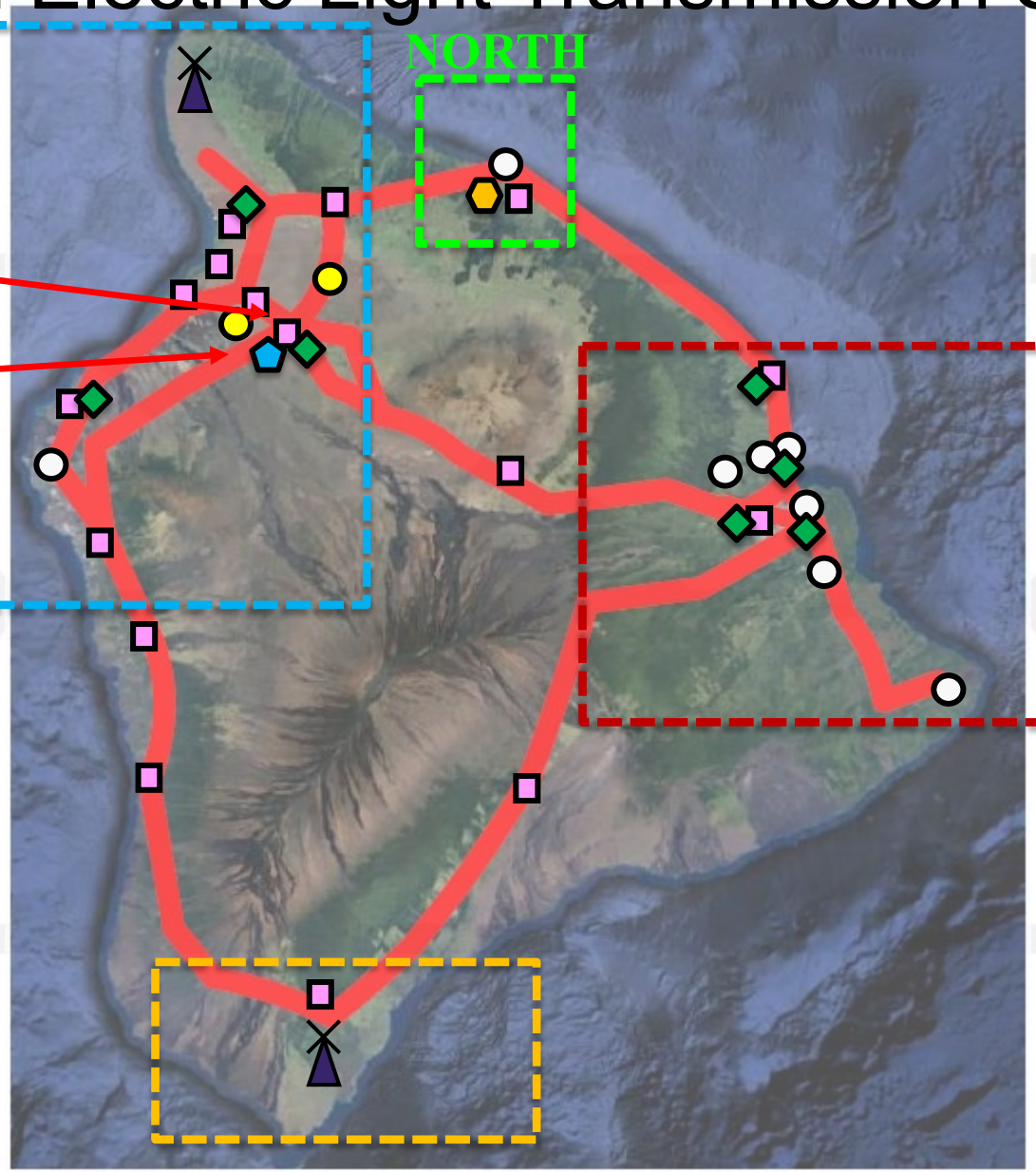


Overloads to 128%

Contingency

Area	Max Capability	Max East
North	30	30
West	264.3	85.5
East	179.6	179.6
South	-	0
Total	473.9	295.1

69 kV

34 kV

Generating Unit(s)

Switching Station (not all shown)

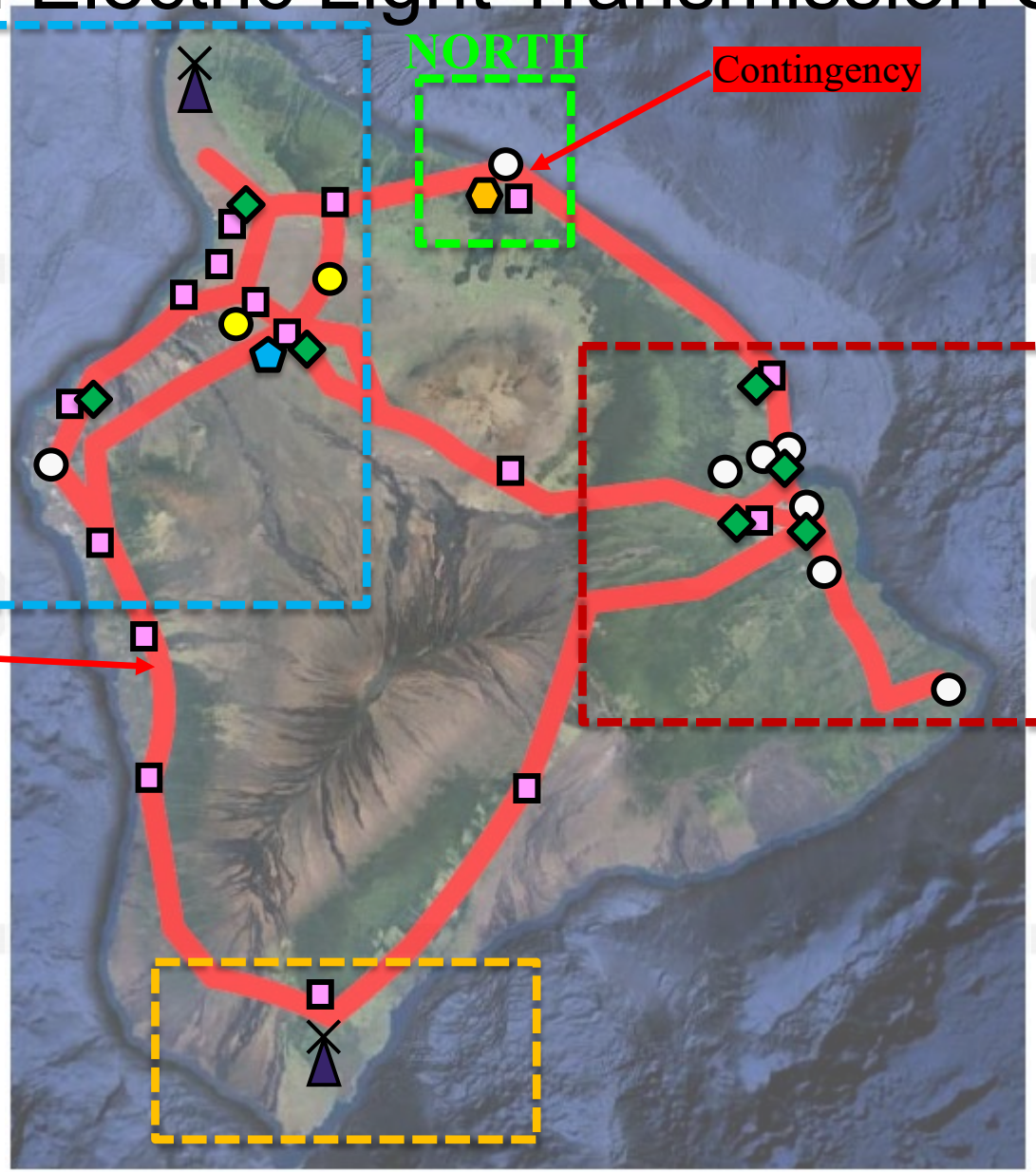
Stage 1 Projects

Paired PV/BESS

Onshore Wind

Geothermal

Hawaii Electric Light Transmission System



Area	Max Capability	Max West	Max PV Paired
North	30	30	5.6
West	264.3	264.3	192
East	179.6	0	97
South	-	0	0
Total	473.9	294.3	294.6

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind
Geothermal

2050 Analyses
Result Summary

- Max West cases has UV violation in normal configuration (min. Voltage 0.90 PU)
- UV violation is identified in several dispatches, during N-1.
- Some cases are not solving easily and show as blown up.

Dispatch	# of Contingency with UV Violation	Min. Voltages	Worst Contingency	Area
Max West	75	0.74	L8600 Kealia-Kahaluu	South/Southwest
Max East	3	0.42	L8600 Kahaluu	South/Southwest
East Only Generation	1	0.89	L8600 Kahaluu	South/Southwest
Max Paired PV	6	0.76	L6300 Puna	South/Southwest

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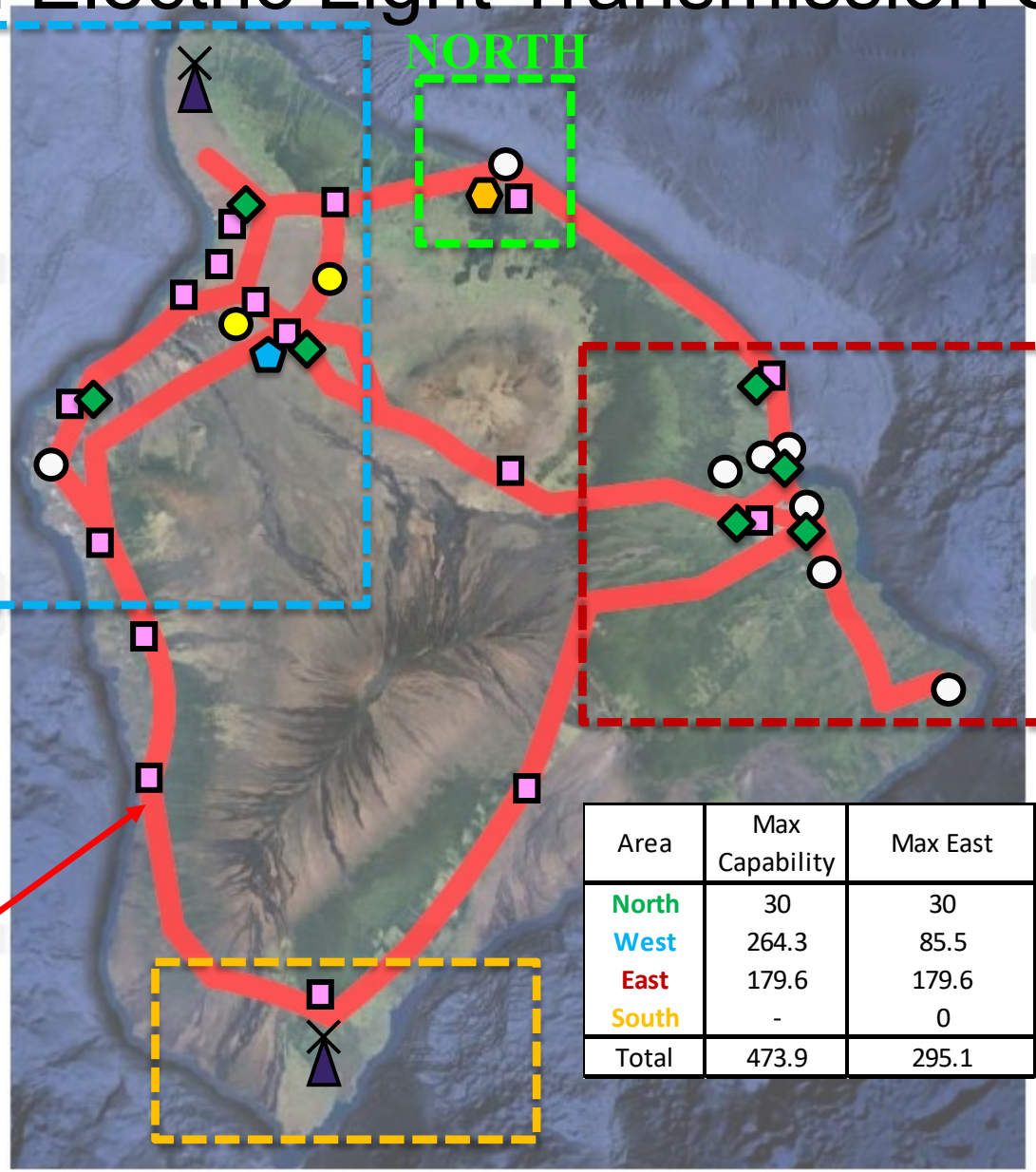

69 kV
34 kV
Generating Unit(s)
Switching Station (not all shown)
Stage 1 Projects
Paired PV/BESS
Onshore Wind
Geothermal

Area	Max Capability	Max East	East Gen Only	Max West	Max PV Paired
North	30	30	0	30	5.6
West	264.3	85.5	0	264.3	192
East	179.6	179.6	179.6	0	97
South	-	0	0	0	0
Total	473.9	295.1	179.6	294.3	294.6

Contingency causes Keauhou to be hanging on the end with low voltages

Requires voltage support from the South
Too far from West or East generation

2050 Analyses Result Summary

- Mitigation solutions (Applied recommended mitigation from 2032)
  - L8100 overloading
    - Reconductor L8100 as 556 AAC
    - Redispatch Keamuku/Onshore Wind to Ouli and Poopoomino
  - Undervoltage violation for South/Southwest
    - Max West case needs 19 MW for Kamaoa Gens
    - Max Paired PV case needs 22 MW for Kamaoa Gens
    - Max East case need 22.5 MW for Kamaoa Gens
    - East Only Gens case does not need any Kamaoa Gens
      - Applied Kilauea switched cap bank thresholds changed to match other cap banks on the system
  - Undervoltage violation for North show after mitigating South/Southwest violations,
    - PGV online (3MW) to mitigate North voltage violations
  - Overloads L8600 does not show up in the results and may have been a solving issue.
  - With mitigations applied, none of the cases have issues solving

Summary Conclusion

- Undervoltage violations in the South at Keauhou for several dispatches and in all studied years
- With Pakini Nui WF retiring, will need generation/reactive power resources in the South
- Even after mitigating the South voltage violations, North voltage violations will show up and some in the East also show up after mitigating the North
- For Max West dispatches, need to have reactive power resources in the East side such as PGV online, Puna CT3 with additional MVARs or using new Stage 3 resources at Kanoelehua, Puueo, Kaumana, Pepeekeo
  - Additional reactive power resources may be required at East locations

Summary Conclusion Continued

Minimum Requirement of East Generation

- With L6200 reconductor, these amounts will mitigate North & East voltage violations
  - For 2026 – 8MW
  - For 2032 – 8MW
  - For 2050 – 8MW
- With no L6200 reconductor, these amount will alleviate the overloading on L6200 but will require additional reactive resources to mitigate the North & East voltage violations
  - For 2026 – 16MW
  - For 2032 – 19MW
  - 2050 was not evaluated (assumed L6200 was reconductored)

Summary Conclusion Continued

- L6200 reconductor will alleviate the overloading on the cross-island tie
- With no reconductor, for Max West dispatches we will need to displace West generation
- More MVAR support is also needed in the East to help mitigate North & East voltage violations with no reconductor
- L81/8900 reconductor will be needed for the line between Keamuku & Anaehoomalu where AES Waikoloa interconnects (small section that still has small line capacity)
  - 2 Stage 1 Projects near Keamuku and Onshore Wind & Paired PV/BESS at Keamuku
  - Redispatch Keamuku/Onshore Wind to Ouli and Poopoomino may solve the overloading, but these are renewable sources
- Not all possible combinations for 2050 were studied

Mahalo

Questions?