345KV SF6-FREE CIRCUIT BREAKER PILOT PROJECT

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Hitachi Energy

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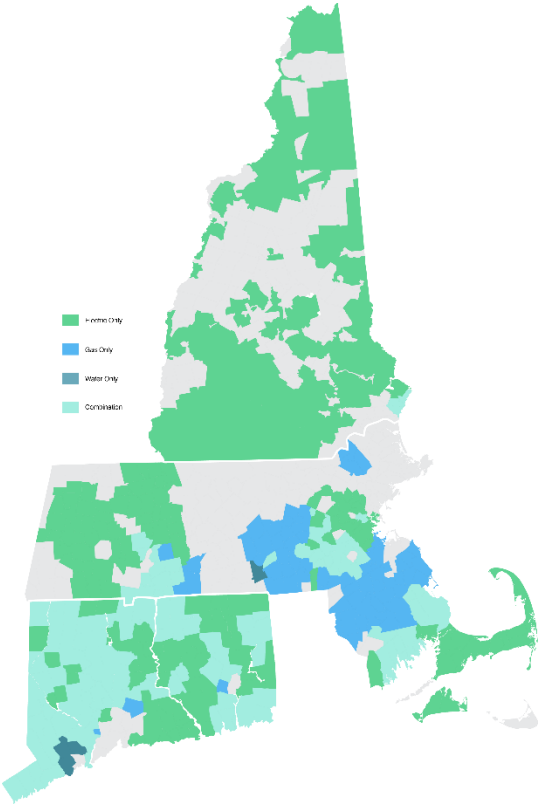
Agenda

- About Eversource
- SF6 Carbon Neutrality
- Approach to ‘Zero by 30’ & Current Progress
- Replacing SF6 in High Voltage Equipment
- Hitachi Energy EconiQ Technology
- Pilot Project: Hitachi EconiQ 345KV DTB Installation
- Equipment Commissioning
- Pilot / Proof of Concept
- Conclusions

Who is Eversource?

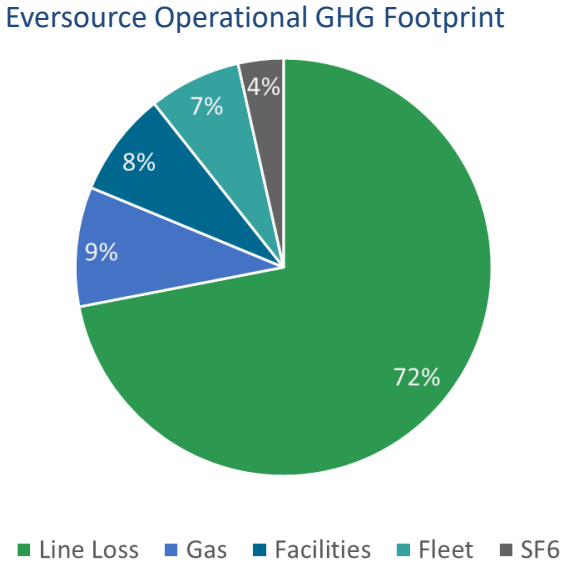
ENERGY BRINGS US TOGETHER!

- New England's largest utility serving 4.4 million customers across CT, MA and NH.
- Services include electric, natural gas & water
- Our Company Initiatives:
  - Safety
  - Reliability
  - **Sustainability**
  - Community
  - Diversity, Equity & Inclusion



Carbon Neutrality

- **SF6 Emissions: Zero by 30**
  - In 2019 Eversource announced industry leading goal to be carbon neutral by 2030.
  - SF6 is approximately 4% of Eversource GHG footprint
  - Focus group established aggressive SF6 emission reduction goals despite challenges and unknowns



Target SF6 Emission Rates										
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
1.0%	1.0%	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%	0.7%	0.7%	0.6%

Zero by 2030 Effort: Approach

- **Focus Group Approach:** Emission reduction was separated into two primary groups:

1

Short-Term: Reduce leakage of Existing Equipment:

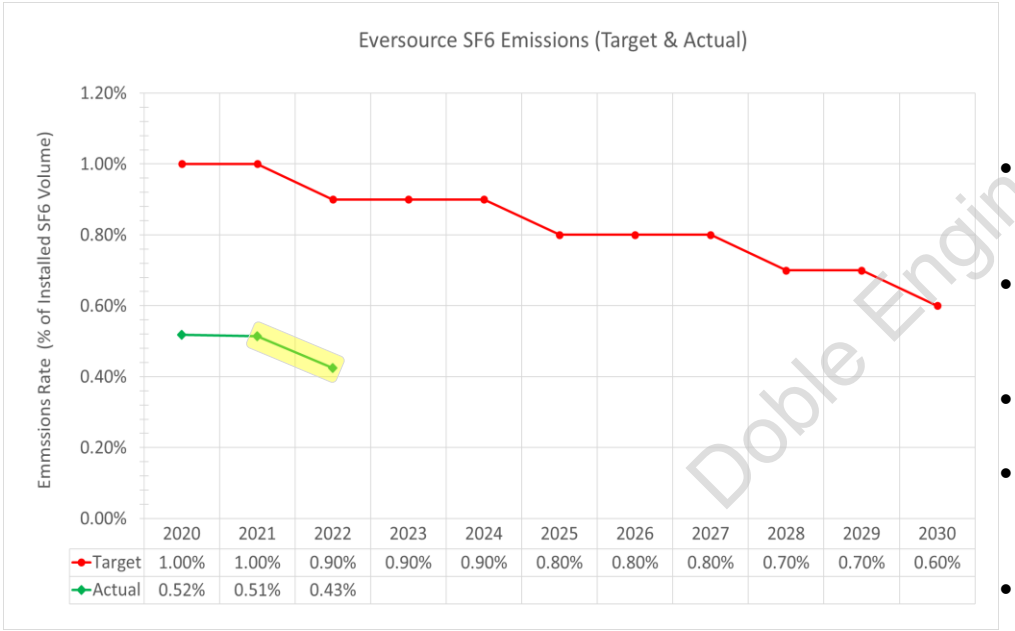
- Implement improved methods to seal and/or slow leaking SF6 equipment until maintenance can be performed during approved Transmission system outage
- Modified equipment commissioning practices to reduce emissions during installation/filling
- Improved inventory and reporting practices
- More accurate data management (CASCADE) to identify needs via reporting and plan maintenance accordingly.
- Replace older SF6 insulated equipment with newer SF6 Insulted equipment with lower guaranteed leakage rates

2

Long-Term: Reduce Volume of SF6 on System:

- Reduce volume of new SF6 insulated equipment added to the system as part of system expansion/modifications (new equipment & facilities)
- Replace existing SF6 insulated equipment with Non-SF6 equipment via asset condition-based obsolescence replacement projects/programs.

‘Zero by 30’ Effort: Challenges



Long-Term SF6 Emissions Reduction Challenges

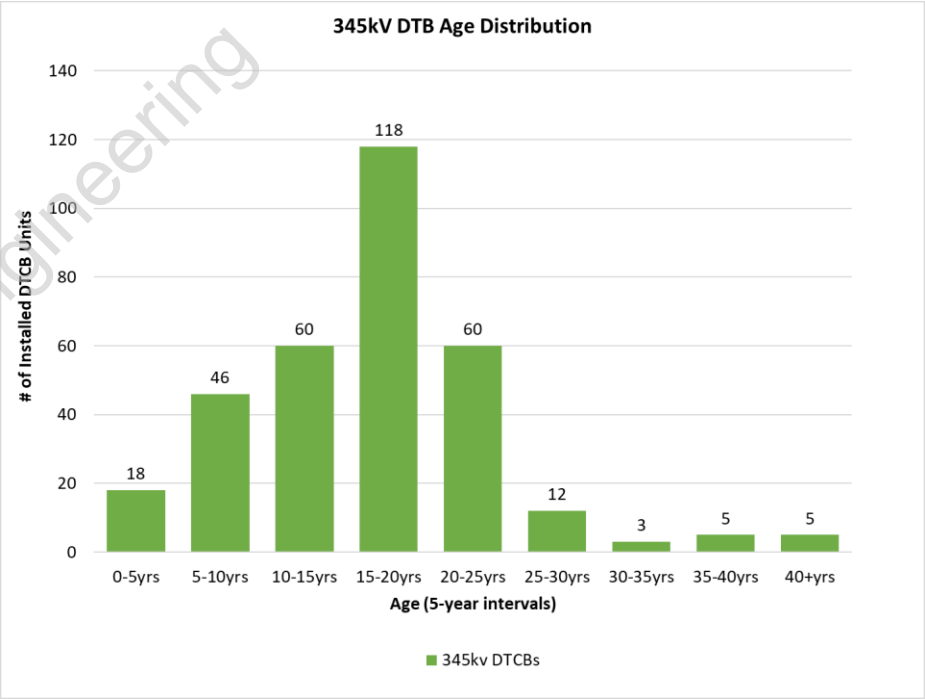
- Emissions reductions via continuous improvement of maintenance practices have been successful
  - 17% Reduction between 2021 and 2022
- Further reduction of emissions rates by via maintenance practices is expected to taper off
- New equipment guaranteed 0.5% leakage per year, older units do not meet that specification.
- Aging fleet of SF6 insulated equipment
- Expected acceleration of transmission system growth.
- Expected increased regulatory scrutiny and/or mandates
- Unavailable SF6 Alternatives

‘Zero by 30’ Effort: Top Priority

AGING FLEET OF 345KV DEAD TANK CIRCUIT BREAKERS

- 345kV DTBs represent approximately 52% of installed SF6 volume on our electric system
- 345kV DTB Population-
  - 327 – 345kV DTCBs units installed (and growing)
  - 3000A, 63kA rated
  - Average Age of installed units = ~18yrs
- Obsolescence/end of life for majority of the fleet at least 15-20 years out.
- Studies show leakage rates increase overtime
- Aging population represents a significant risk in achieving and maintaining carbon neutrality goals

❖ NEED : A true one-for-one SF6-free replacement option



Replacing SF_6 in High Voltage

EconiQ supports the urgent call to reduce the impact of greenhouse gas emissions in the global power industry.

Equipment that uses an eco-efficient gas mixture remains as compact as the conventional SF6 solution.

Eco-efficient gas mixture **with 3.5% of F-gas**

CO_2 / O_2 / C4-FN

86.5 mol% CO_2	10 mol% O_2	3.5 mol% C4-FN

THE PROS

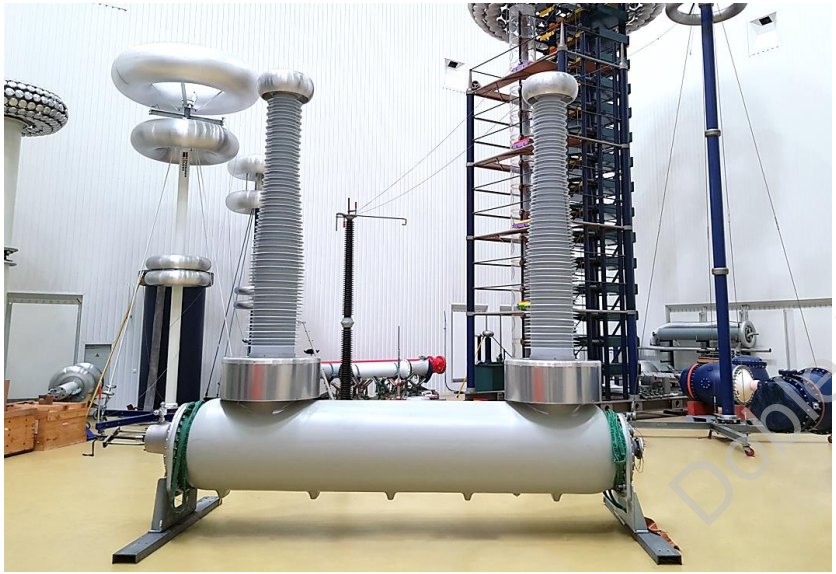
- Same technical **performance, size and reliability** as SF_6
- Developed and **available today**
- **Lowest carbon footprint** in life cycle assessment (low material use)

THE CONS

- **Diluted mixture of natural gases with 3.5% of F-gas with a Global Warming Potential of approximately 400**
  (which is non-toxic, does not accumulate in water, plants, or s
  and decomposes in the atmosphere into natural substances)

420 kV Circuit Breaker

Dead Tank Breaker Variant



Fully type tested as described in IEC and IEEE
High end ratings including shunt reactor switching, capacitive sw. class C2 and up to 75 ms DC time constant at 63 kA

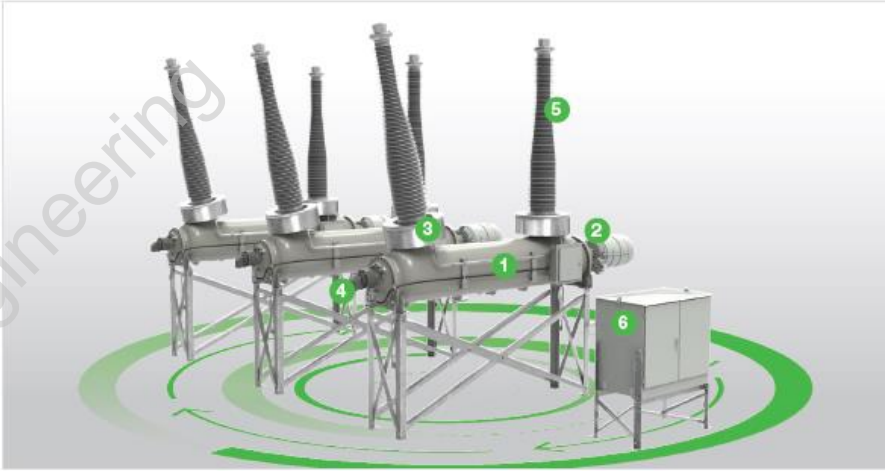
All test duties successfully performed

Rated voltage	U_r	420 kV
Rated lightning impulse withstand voltage	U_p	1,425 kV
Rated switching impulse withstand voltage	U_s	1,050 kV
Rated power frequency withstand voltage	U_d	650 kV
Rated continuous current	I_r	5,000 A
Rated short-circuit breaking current	I_{sc}	63 kA
Rated short-time withstand current (3s)	I_k	63 kA
Rated peak withstand current	I_p	171 kA
Rated first–pole-to-clear factor	k_{pp}	1.3 / 1.5
Capacitive load switching	class	C2
Capacitive voltage factor	k_c	1.4
Rated capacitive currents	I_l, I_c	400 A
Shunt reactor current switching	Acc. to IEC 62271-110 and IEEE C37.015	
Rated frequency	f_r	50 Hz / 60 Hz
Mechanical endurance	class	M2
Electrical endurance	class	E2
Rated operating sequence	O-0.3s-CO-3min-CO or CO-15s-CO	
Operating temperature	-30 °C … +40 °C	

420 kV Eco-Efficient DTB

Eversource Pilot Project – Circuit Breaker

Performance data – 420PM63-HA		
Rated voltage	kV	362
Rated frequency	Hz	60
Rated continuous (nominal) current	A	3000
Rated short-circuit (interrupting) current	kA	63
Rated first-pole-to-clear factor (kpp)	-	1.5
Rated capacitive switching voltage factor (kc)	-	1.4
Minimum operating temperature, no heater (with tank heater)	°C	-30 (-50)
Rated mechanical endurance	class	M2
Rated electrical endurance	class	E2
Independent (single-) pole operation	-	HMB-8



Dead Tank Breaker type
EconiQ 420PM63-HA

1. Circuit-breaker
2. Operating mechanism
3. Current transformer
4. Pressure relief device
5. Bushing
6. Local control cubicle

Manufactured in Mt. Pleasant, PA, USA

Pilot Project

Hitachi eco-efficient breaker345kV, 63kA Non-SF6 DTB Installation

PILOT PROJECT SELECTION CRITERIA:

- Isolated circuit breaker replacement project
- Minimal 345kV System Impact
- Existing breaker position
- Not a reactive switching application
- Schedule alignment – Preferred 2023 ISD
- Authorized capital project funding

Pilot Project

Design & Installation Considerations

Differences:

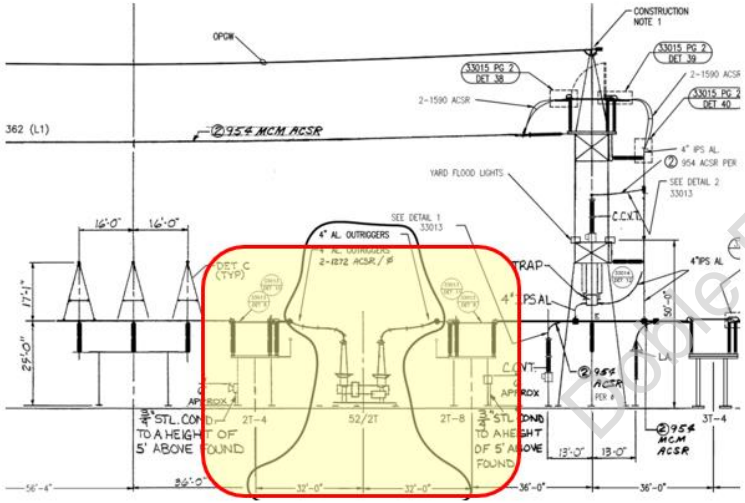
- Larger operating mechanism HMB-8.16 vs. HMB-4.1
- Weight Difference: ~6K lbs. heavier
- Interphase wiring cable tray not included in design.
- Modified control cabinet layout.
- Different components for gas monitoring & handling.

Similarities:

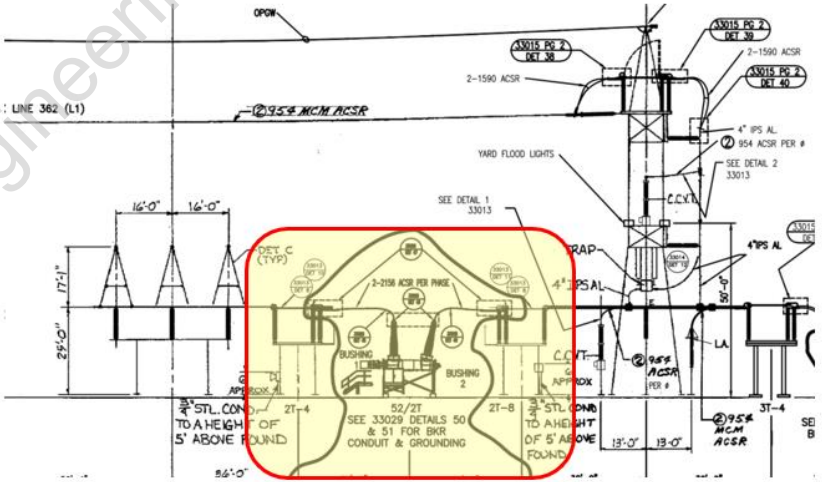
- Footprint is comparable to standard SF6 counterpart.
- No changes to schematics from standard design required*.
- Uses many of the same spare parts/components as its SF6 counterpart.
- Testing & commissioning activities are essentially the same as its SF6 counterpart.

Pilot Project

Hitachi eco-efficient breaker 345kV, 63kA Non-SF6 DTB Physical Layout-



BEFORE



AFTER

Pilot Project

BEFORE

AFTER

Commissioning

Gas Handling, Filling & Quality Testing

- Pre-mixed cylinders of the gas were provided as part of project scope.
- Each phase required a total of twenty-four (24) cylinders to fill to rated pressure (135psi) -
- Actions taken to accelerate gas filling -
    - Cylinders were pre-loaded and stored in a heated conex container to warm to ~60 °F (15.5 °C).
    - Evacuation and vacuum of adjacent poles performed simultaneously.
- Gas quality tested each time cylinders were transferred into the mixing equipment and after filling of each phase.

Commissioning

Leak Checks

- Leak checks were performed on all tubing, fittings, rupture disks, flanges and devices (ex. density monitors)

Density Monitor Setting Verification

- C4-FN density monitors were tested for proper operation-
  - Test performed using pressurized CO_2.
  - Pressure was adjusted to ensure device contacts operated at the appropriate pressures.

Commissioning

Functional Checks & Operational Testing

- All testing, operational alarms and checks were performed in accordance with Hitachi Energy and Eversource commissioning standards and included the following:
  - Point-to-Point Wiring Checks (schematics & three-lines)
  - Verification of Operating Mechanism Functionality & Interlocking Schemes
  - Circuit Breaker Timing & Travel
  - Main Circuit Resistance (Ductor)
  - Power Factor

Key Milestone Time-Line

- ✓ NDA established between Hitachi Energy and ES 7/2022
- ✓ Received Proposal from Hitachi Energy 8/1/2022
- ✓ Hitachi Energy Press Release: published 8/31/2022.
- ✓ PO Issued to Hitachi Energy: 10/07/2022
- ✓ ES New Equip. Evaluation Team Kickoff: 11/16/2022
- ✓ Project Kickoff Meeting: completed 11/21/2022
- ✓ First Submittal of Physical DWGs (Hitachi): 12/02/2022
- ✓ Equipment Delivery: 6/30/2023
- ✓ Planned In-Service: Q4 2023 (Actual ISD – 12/20/2023)
- ✓ Evaluation of New Technology: Q1 2024 – Q4 2025

Pilot / Proof of Concept

- Pilot of the equipment will be run Q1 2024 – Q4 2025
- Routine monthly inspections and maintenance activities will be performed to assess performance of the circuit breaker.
- Gas sampling & analysis will be performed quarterly (4x per year)
- Functional testing will be performed bi-annually (2x per year)
    - Timing, Travel, Insulation Resistance (Ductor), Power Factor

Conclusions

- Having an SF6-free option for high voltage applications is a **game changer**!
- Familiarity with legacy Hitachi Energy equipment played a key role in the successful execution of this project.
- Plenty of work left to be done and challenges that remain.
- Results of our pilot/proof of concept will be a major factor in decision making for the future.

Contact Information

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