Transformer Maintenance

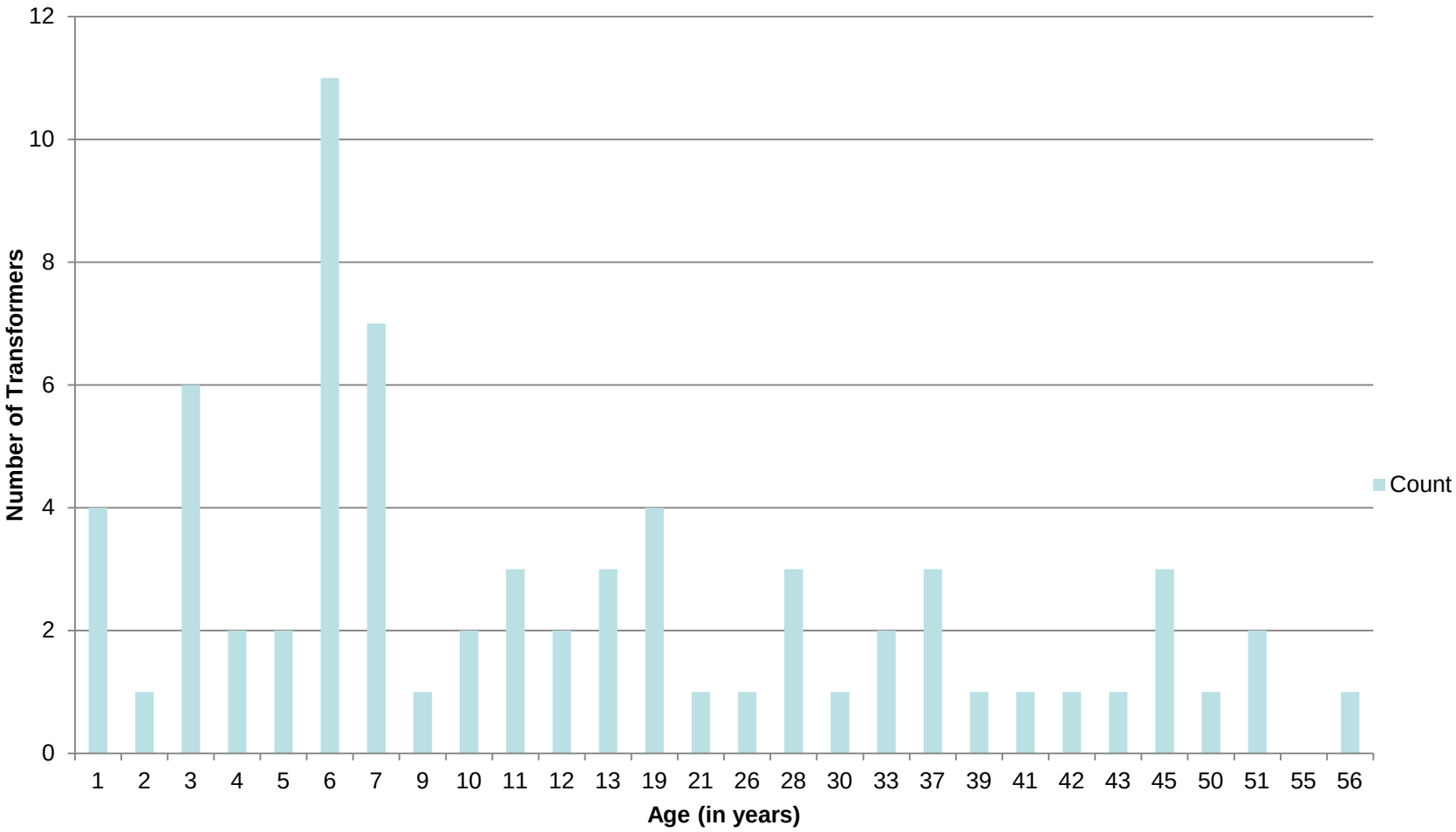
October 17, 2013

Prepared for: ***VELCO Operating Committee***

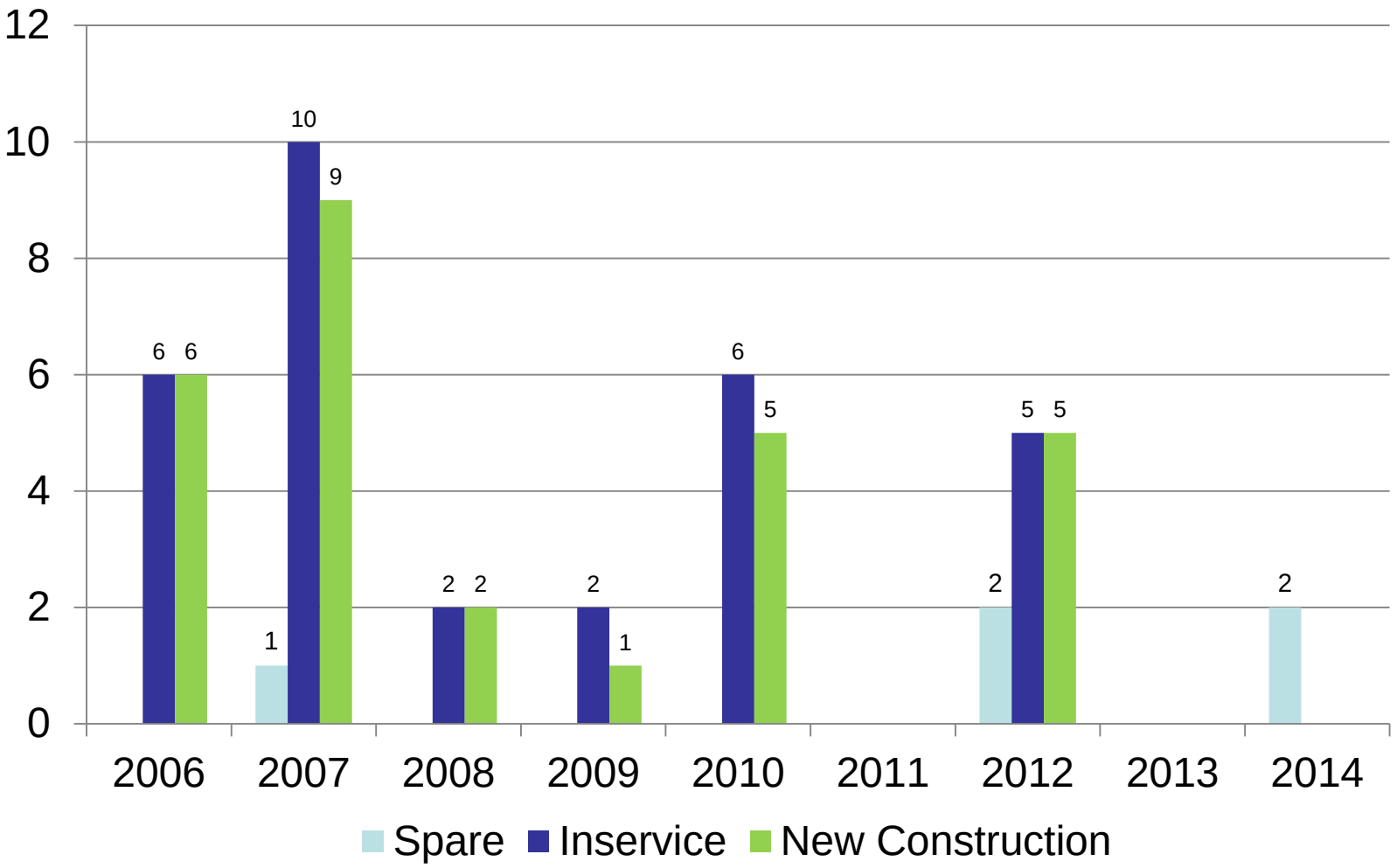
Transformer Inspection & Diagnostic Testing

- Conduct visual inspections monthly
- Dissolved Gas Analysis testing is performed twice annually. Transformers showing elevated gas levels are tested more frequently.
- Oil quality testing is performed annually including spare transformers.
- Power Factor Testing is conducted every five years.
- Transformer turn ratio tests are performed during the Power factor tests.
- Sweep Frequency Result Analysis (SFRA) testing is performed during the Power Factor tests for older transformers to obtain a baseline. This testing is also performed for acceptance testing of new transformers.
- Tap changer maintenance is performed per manufacture recommendation or if testing results warrant more in depth inspections.
- VELCO has recently enlisted Weidman Associates to perform an in depth analysis of twenty transformers in the fleet for condition and expected longevity based on the test results and loading information.

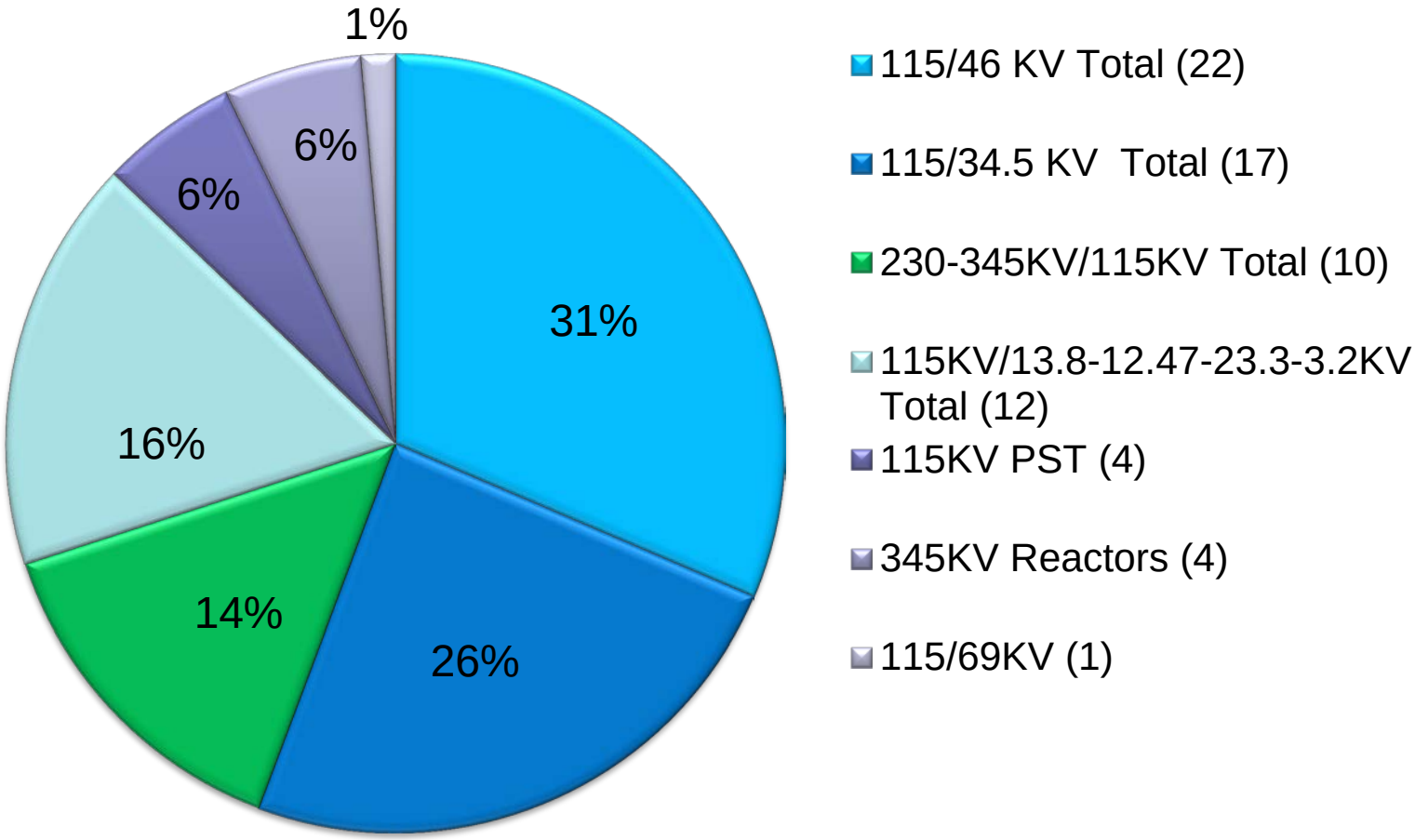
Number of Transformers by Age



Transformer Purchases by Year



Transformer Breakdown on the VELCO System



Spare Transformers

Substation	Serial #	Manufacturer	Voltage	MVA	Year Manufactured
Essex Facts	20760103	Mitsubishi	115/3.2	25.8/34.4/43	1999
Mobil Substation	97063910	Pauwels	115/12.47	12/ 20	2007
Queen City	6995045	West	115/13.8	30/40/50	1963
Taft Corners	6991852	West	115/13.8	25/33.3/41.6	1965
Highgate Converter	7288717	ASEA	115/23.3	240/120/120	1985
St. Johnsbury	C659447	GE	115/34.5	15/20/25	1957
Essex (Transportable)	K547335	GE	115/46/34.5	30/40/50	1974
New Haven	E39631211	Delta Star	115/46	33.6/44.8/56	2011
New Haven	E39621111	Delta Star	115/34.5	33.6/44.8/56	2011
Bennington	6537115	West	115/69	16/20	1960
Saint Albans	100810	SMIT (Dual Winding)	115/34.5/46	30/40/50/56	2002
Granite	H409118	GE	230/115	180/240/300	1971

Two new spares ordered in 2013. One 115/46.5 kV and one 115/34.5 KV. Expected delivery 1st quarter 2014.

Elevated DGA Test Results

Priority	Substation	Location	Serial #	Manufacturer	Voltage	Year Manufactured	Notes
1	Hartford	H77	RJP3217-1	West	115/46	1975	Slightly Elevated Ethylene and Carbon Monoxide
2	Highgate	T2	D568239	GE	115/46	1963	Slightly Elevated Ethane
3	Irasburg	H39	D566686	GE	115/46	1962	Slightly elevated Ethane
4	Bennington	H37	L252636A	GE	115/46	1980	Elevated Ethane. Performed Weidman studied in 2013. Study indicated condition not concerning at this time.
5	Berlin	X90	9A1073	Wagner	115/34.5	1970	Slightly elevated Ethane and Hydrogen
6	Coolidge	T1	K547202	GE	345/115	1975	Step increase of Acetylene in October 2010. Internal inspection performed in October 2013. No conclusive findings. Transformer oil processed to establish baseline DGA. Oil testing is now done bi-monthly.

Actions

- Perform DGA testing every three months to determine rate of rise of combustible gases.
- Review Weidman study (Due in Q4 2013) for their recommendations on these transformers.

Summary of Restoration of Radial Load

Location	Transformer	High Side Voltage (kV)	Low Side Voltage (kV)	Vermont Distribution Utility (VDU)	Potential mitigating actions
CHARLOTTE SUBSTATION	T1	115	12.47	GMP-C	Mobile substation will need to be placed in service to restore load. Estimated 16 hour restoration: 4 hours to transport, 6 hours for hookup, and 4 hours to commission.
EAST AVENUE SUBSTATION	T1	115	13.8	BED	Automatic switchover will close the East Ave B64-65 breaker to allow load pickup on East Ave T2 Transformer (115/13.8 kV). Restoration time is less than 5 minutes.
EAST AVENUE SUBSTATION	T2	115	13.8	BED	Automatic switchover will close the East Ave B64-65 breaker to allow load pickup on East Ave T2 Transformer (115/13.8 kV). Restoration time is less than 5 minutes.
FLORENCE SUBSTATION	H84	115	46	GMP-R	Close normally open switches at GMP-R Salisbury and West Rutland to provide alternate 46 kV supply to area. Restoration time is less than 5 minutes. Reconfiguration of 46 kV may be necessary to accommodate line loadings.
LYNDONVILLE SUBSTATION	T1	115	34.5	LED	Close the normally open LED 843 switch to provide alternate 34.5 kV supply to area. Restoration time is less than 2 hours to dispatch field personnel to site.
NEWPORT SUBSTATION	T2	115	46	VEC	Newport T1 transformer (116/43.8 kV) is energized from the 115 kV but normally out of service. Close the normally open 155 switch (46 kV) to place this onsite spare in service. Restoration time is less than 2 hours to dispatch field personnel to site.
NORTH FERRISBURG SUBSTATION	T1	115	12.47	GMP-C	Mobile substation will need to be placed in service to restore load. Estimated 16 hour restoration: 4 hours to transport, 6 hours for hookup, and 4 hours to commission.
QUEEN CITY SUBSTATION	T1	115	13.8	BED	Close normally open switches on the BED 13.8 kV system to provide alternate 13.8 kV supply to the area. Start Burlington GT as needed. Restoration time is less than 30 minutes.
SHELBURNE SUBSTATION	T1	115	12.47	GMP-C	Mobile substation will need to be placed in service to restore load. Estimated 16 hour restoration: 4 hours to transport, 6 hours for hookup, and 4 hours to commission.
ST. JOHNSBURY SUBSTATION	X22	115	34.5	GMP-R	Close the normally open LED 843 switch to provide alternate 34.5 kV supply to area. Restoration time is less than 2 hours to dispatch field personnel to site.
TAFTS CORNERS SUBSTATION	T2	115	12.47	GMP-C, VEC	Mobile substation will need to be placed in service to restore load. GMP-C can switch some and possibly all load over to GMP distribution except near peak load conditions. Restoration time is less than 2 hours to dispatch field personnel to site.
VERGENNES SUBSTATION	T1	115	34.5	GMP-C	Vergennes T2 transformer (115/34.5 kV) is energized from the 115 kV but normally out of service. Close the normally open X72 breaker (34.5 kV) to place this onsite spare in service. Restoration time is less than 5 minutes.

Maintaining a Healthy Transformer Fleet

Transformer Fleet Maintenance

- Maintaining a healthy transformer fleet is critical to providing reliable service to VELCO's customers and interconnecting utilities; this is achieved by coordinating the work of several groups within VELCO.

- Planning group periodically studies how transformer failures impact the system and identifies where spares or second transformers are required.
  - Updated study to be completed first quarter 2014; determine need for spares or new units.

- Asset Maintenance group uses a balance of Preventative and Reliability Centered Maintenance to assess and monitor the condition of in-service units.
  - Complete a comprehensive evaluation of in-service units by H.V. Weidman by Q4 2013.
  - Substation Assessment Project ("SAP") study all aspects of VELCO's oldest substations.
  - Completion of the study and SAP may identify the need to purchase new units

New Transformer Procurement Plans:

- Engineer and procure:
  - 345/115 KV transformer to replace the Coolidge transformer in 2015
  - 115/13.8/12.47 spare transformer in 2015. This would replace the present Queen City spare.
  - 115/46 KV spare transformer in 2015. Location to be determined.
  - 115/ 34.5 KV spare transformer in 2015. Location to be determined.