The Case of the Missing CVTs

Tom Parkinson

2 September 2015

In Memory of Abraham Wald

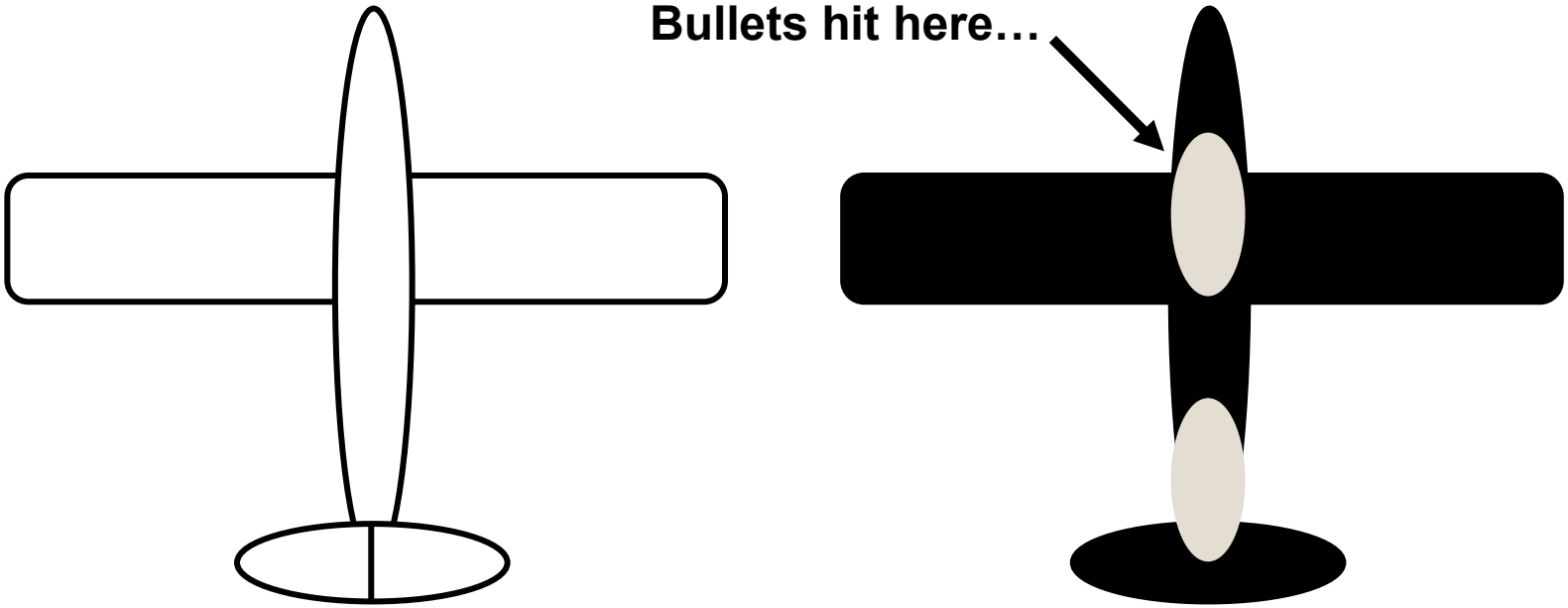
THE LANTAU GROUP
strategy & economic consulting

Statistical Research Group

- Was founded in Britain in December 1941 as part of the World War II effort
- Engaged Abraham Wald, a statistician, to estimate the survivability of aircraft encountering enemy ground fire
- Bombers needed to be reinforced to improve their odds of survival, but such armor was heavy – so Wald's job was to determine where the armor should go
- Wald built up a database of bullet holes from returning bombers and constructed a simple diagram showing where the bullet holes hit.

Wald's Database

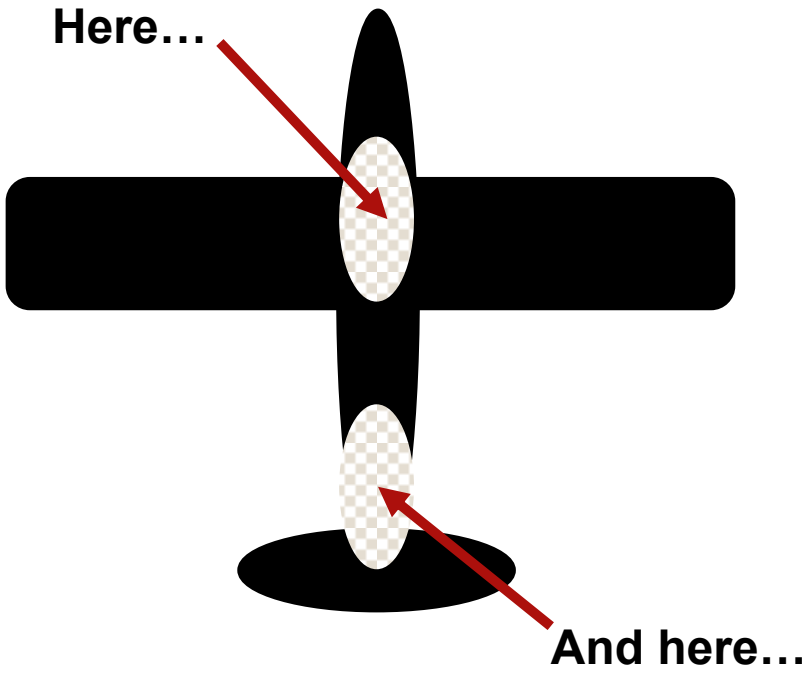
Wald's diagram showed the areas where bullet holes concentrated via black shading on the schematic drawing of a bomber



So where did Wald recommend placing the reinforcing armor?

Wald's Recommendation

Wald recommended placing armor where there were no bullet holes!



Why?

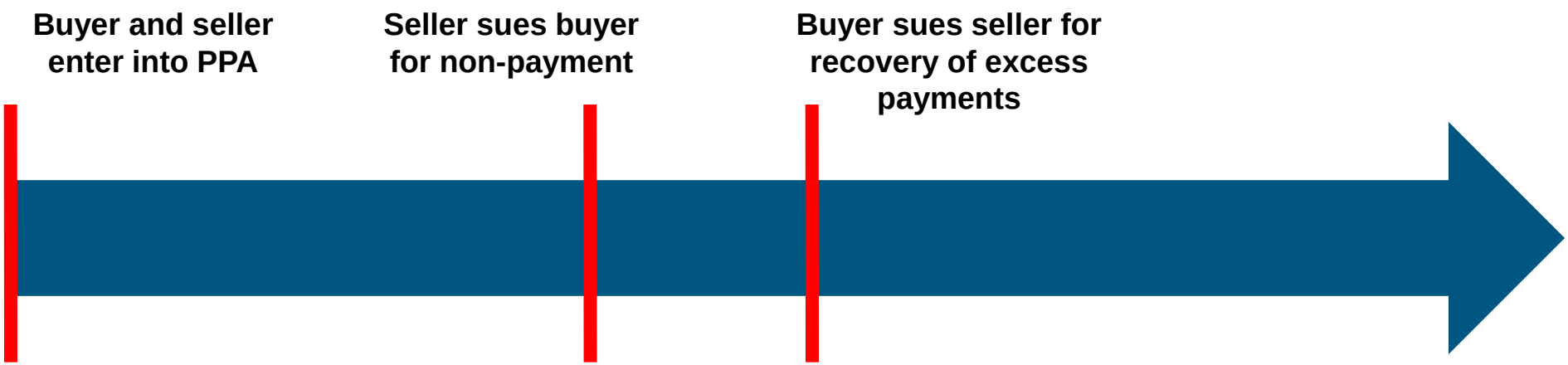
- Wald reasoned that the distribution of bullet holes was random
- But the selection of planes in his database was decidedly ***not*** random…
- His analysis included only the planes that returned – in other words, the survivors!
- If the distribution of bullet holes was random, then the planes that did ***not*** survive must have a heavy concentration of bullet holes in the white areas.

Wald's research gave rise to the term, "survivorship bias"

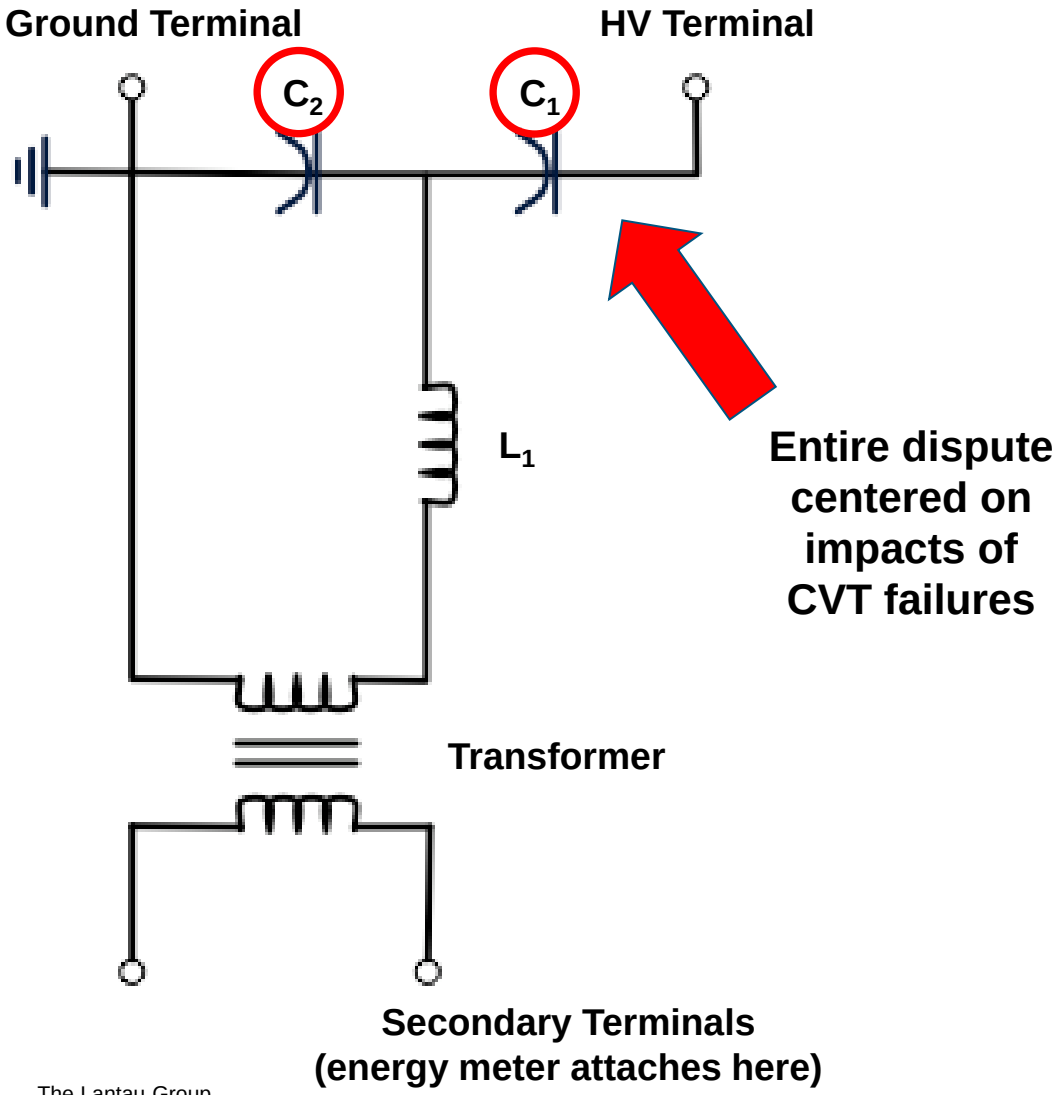
Overview

The commercial issue involved a straightforward PPA contract that gave rise to a claim and counter-claim

- Buyer and seller entered into a plain-vanilla PPA for power from a baseload gas-fired plant
- Years into the contract, a dispute arose concerning an operational issue and the invocation of an associated contract term that allowed the buyer to withhold payment
- Seller sued the buyer for non-payment
- Subsequently, the buyer uncovered evidence that the energy meters at the plant were over-stating the actual energy delivered
- Buyer filed a counter-claim for recovery of excess payments.

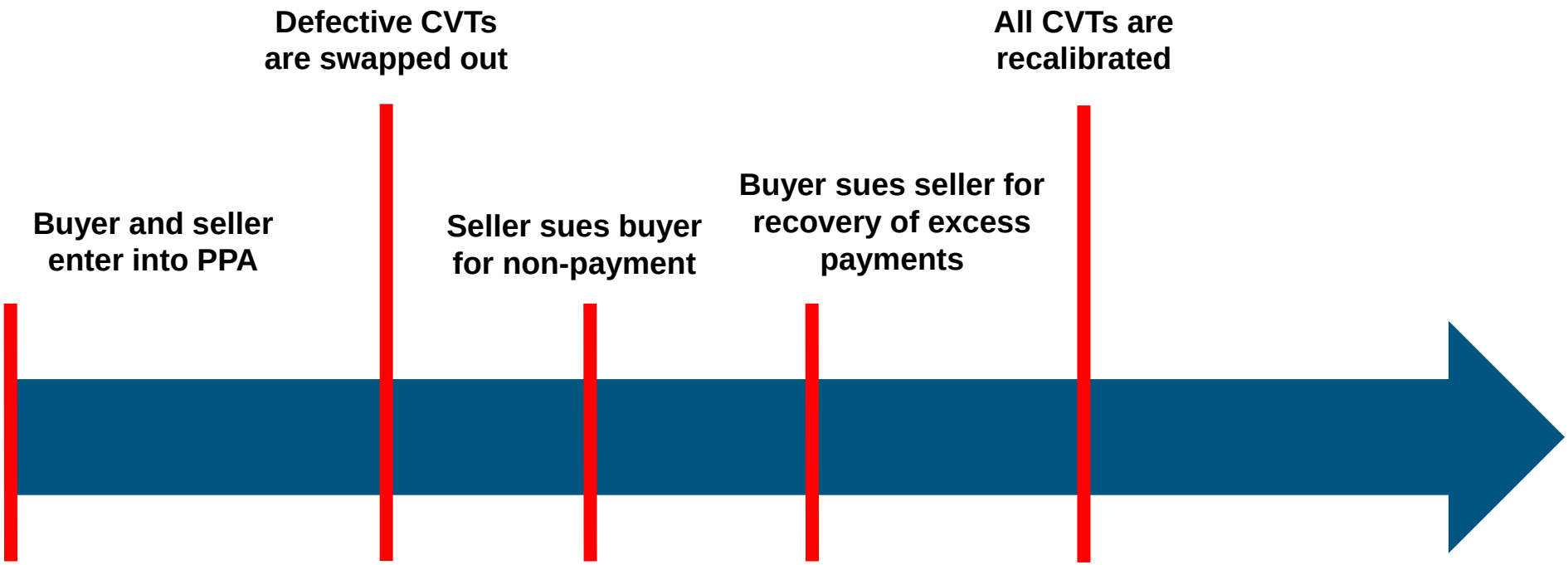


The measurement errors related to failures of capacitive voltage transformers (CVTs)



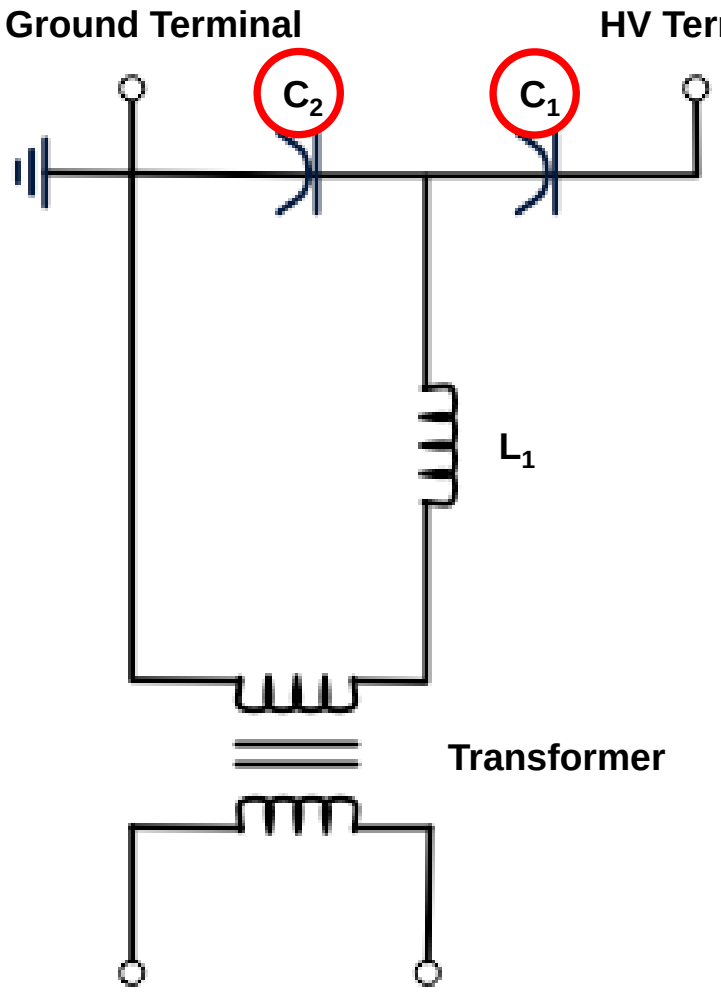
The CVTs gave rise to several pertinent issues in the chronology

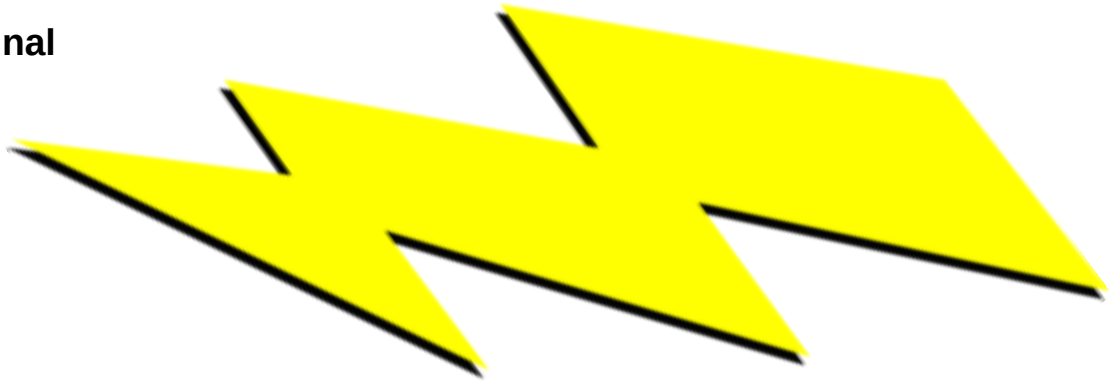
- Prior to any dispute, six CVTs were identified as defective and were swapped out for new units
- After the buyer filed the counter-claim, all CVTs were recalibrated.



Overview

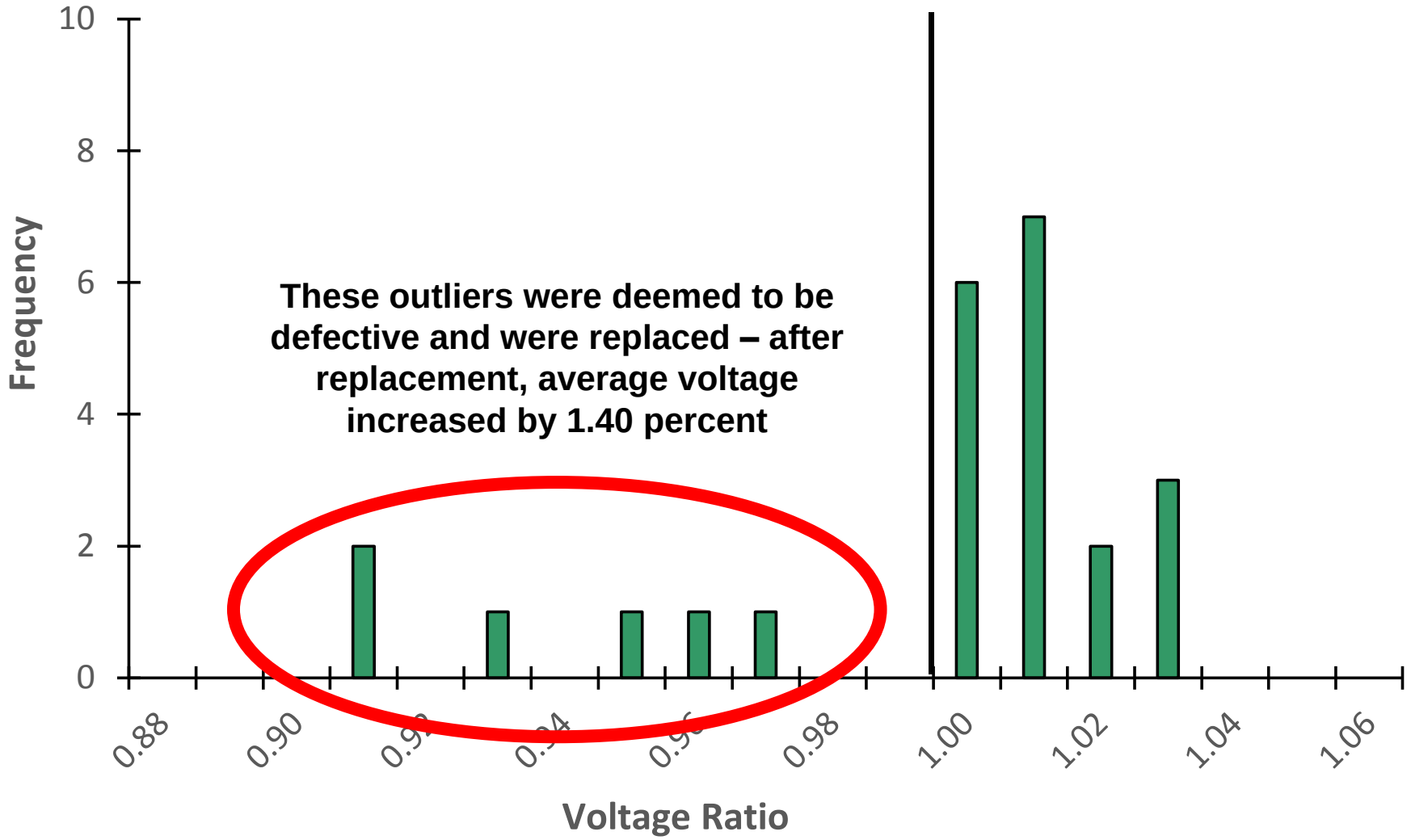
The measurement errors related to failures of the capacitive voltage transformers (CVTs) – which led to six being swapped out



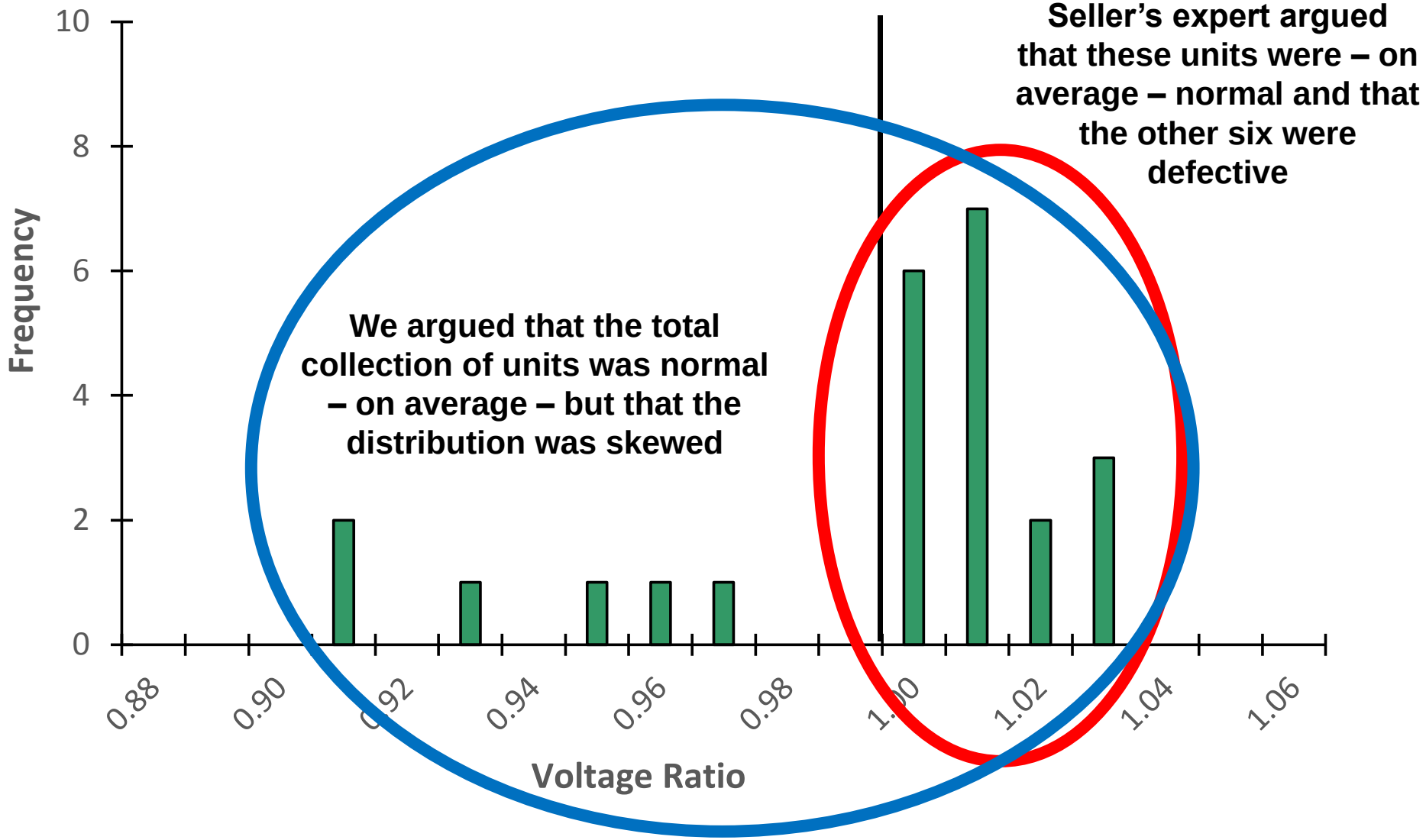


- Station operators recorded voltages at each of the 24 CVTs once a month
- Operators identified anomalous voltage levels for 6 of the 24 CVTs and called in the supplier
- Supplier concluded that there were voltage inaccuracies due to random failures in capacitor elements… and attributed failures to lightning strikes
- CVTs with anomalous voltage readings were replaced.

This figure displays average voltage measurements by CVT – relative to the average of all 24 CVTs – since there was no absolute standard (at the time)

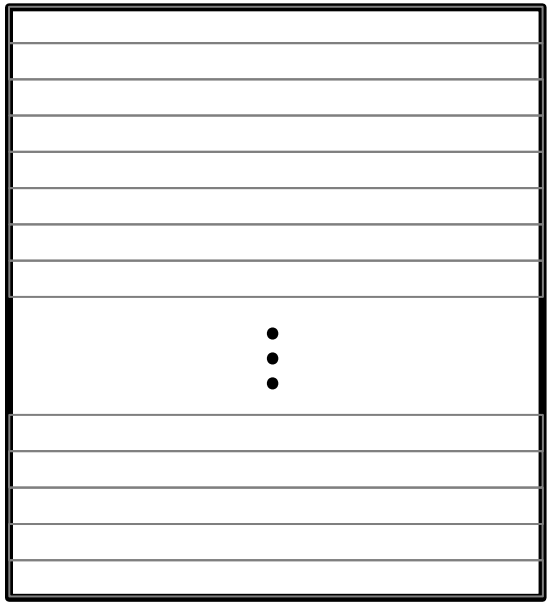


The damages case centered on the resolution of one central question – what defined “normal voltage”?

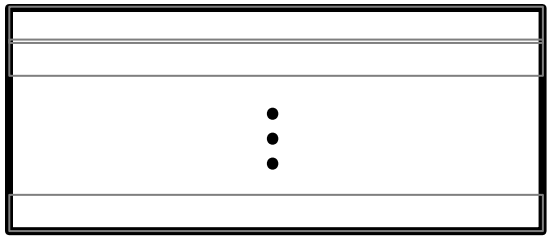


Overview

The two capacitors in each CVT – C_1 and C_2 – were composed of different numbers of identical capacitive elements



C_1 – 191 elements

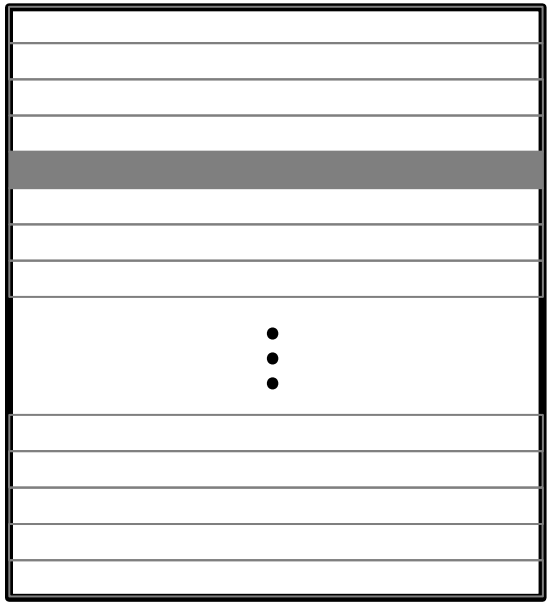


C_2 – 17 elements

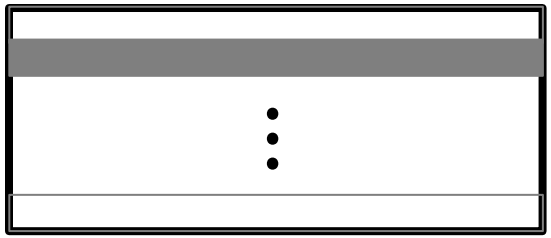
We hypothesized that lightning induced random failures in both types of capacitors

Secondary Terminals
(energy meter attaches here)

By that logic, the likelihood that an element of each capacitor failed is proportional to the number of elements in the capacitor



C_1



C_2

Capacitor C_1 –

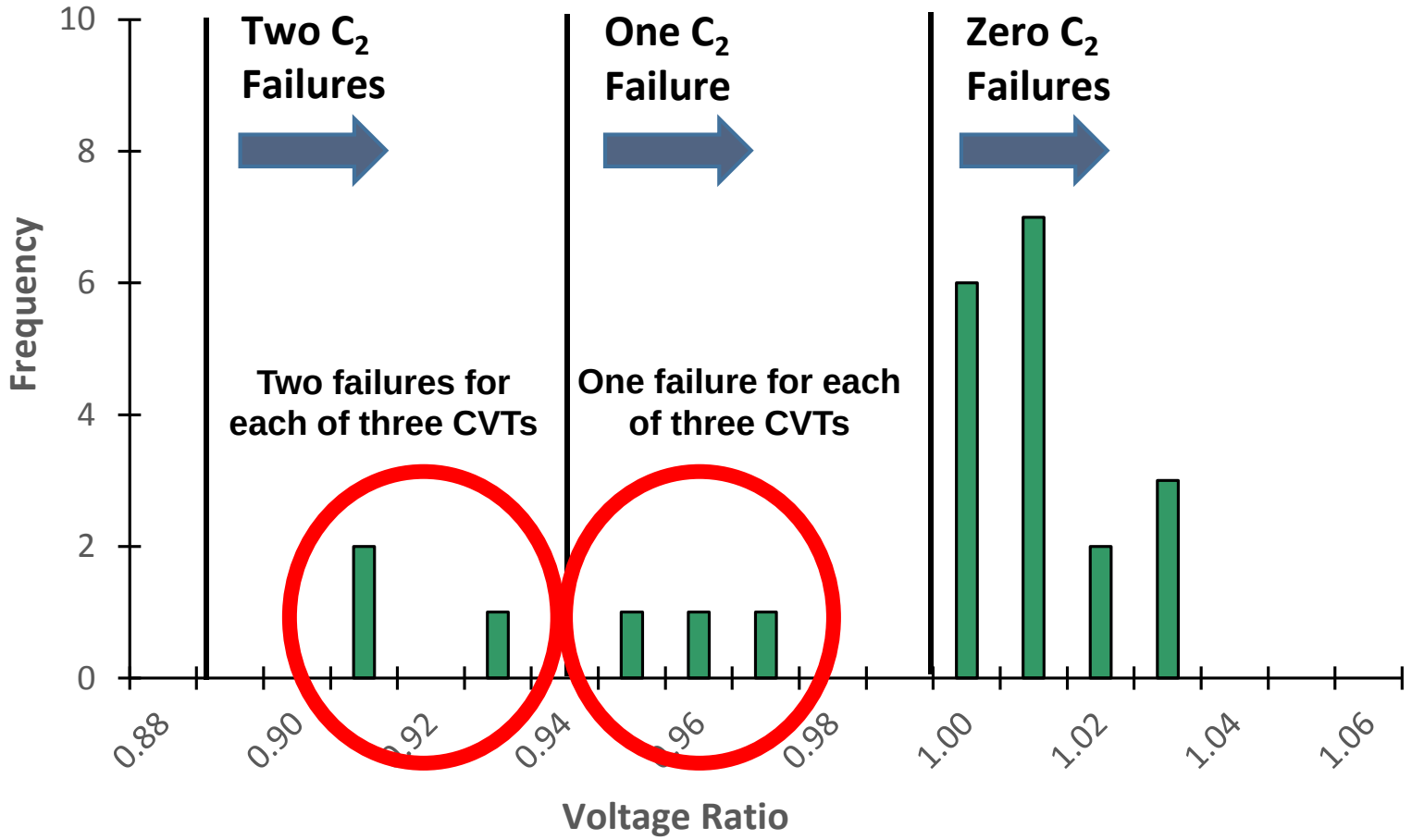
- Likelihood that an element in capacitor C_1 failed – given that a failure occurred – is thus 191/(191+17) = 91.83 percent
- Reduction in voltage given failure = 1/(191+17-1) = 0.48 percent
- Similarly, reduction in measured energy output = 0.48 percent

Capacitor C_2 –

- Corresponding likelihood of C_2 failure = 17/(191+17) = 8.17 percent
- Reduction in voltage and measured energy output given failure = 191/(17*(191+17-1)) = 5.43 percent

Given this model, the expected change in average voltage given failure equals zero!

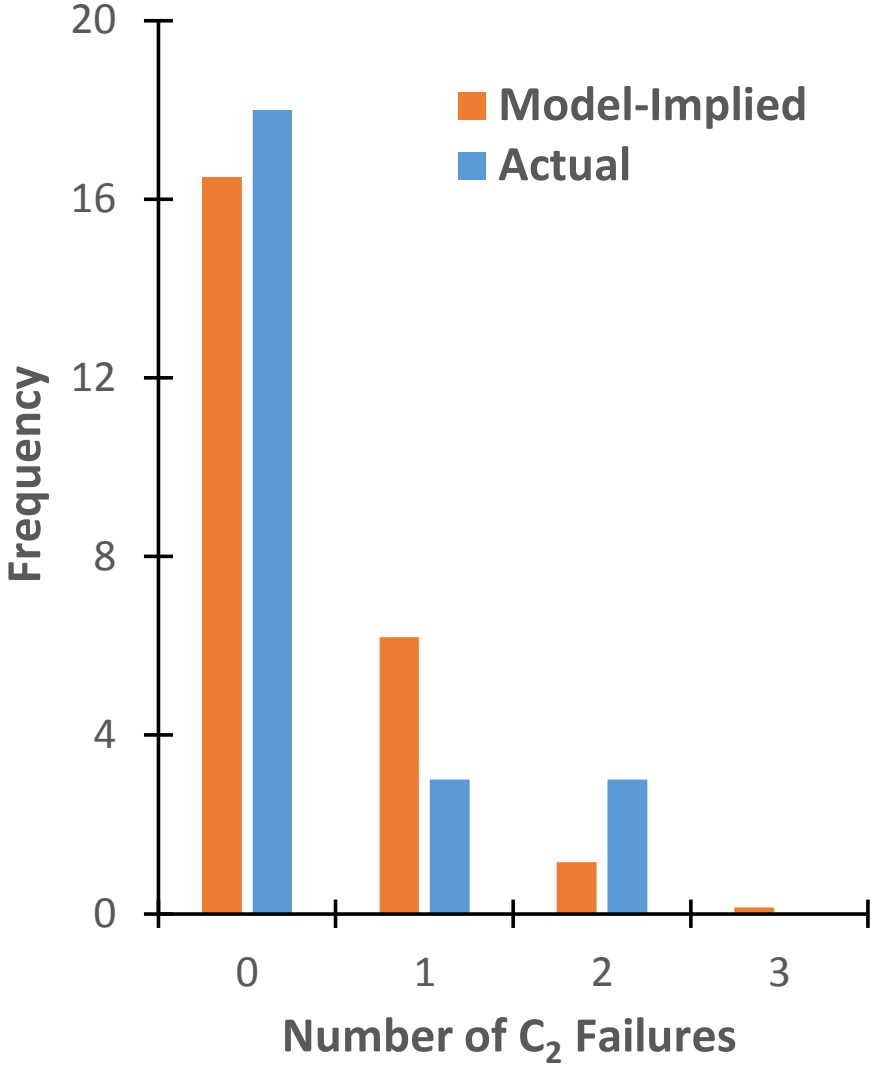
C_2 failures only reduce voltage, whereas C_1 failures can only increase it (by a small amount) – this fact suggests that there are nine total C_2 failures

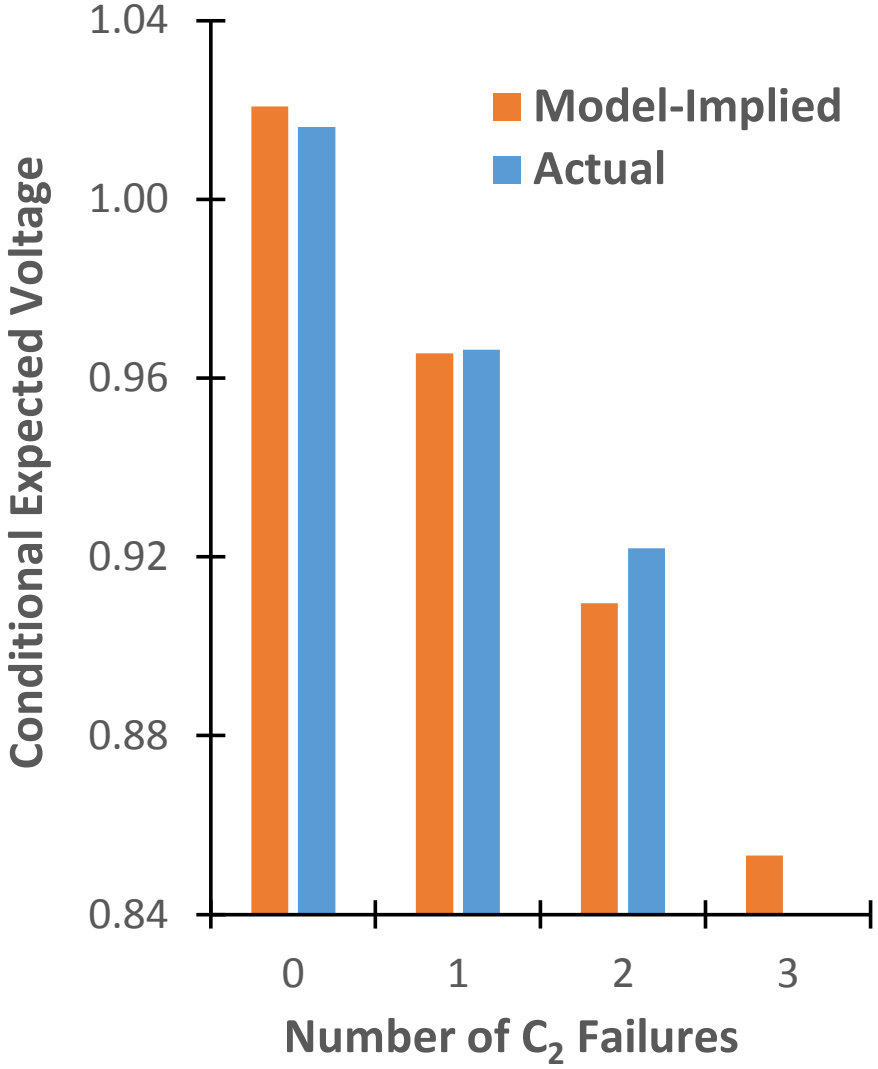


9 C_2 failures across 24 CVTs suggests an average of 4.59 total failures per CVT

Overview

Given the total number of failures, we accurately projected the frequency of observed C_2 failures and the expected voltage given number of C_2 failures



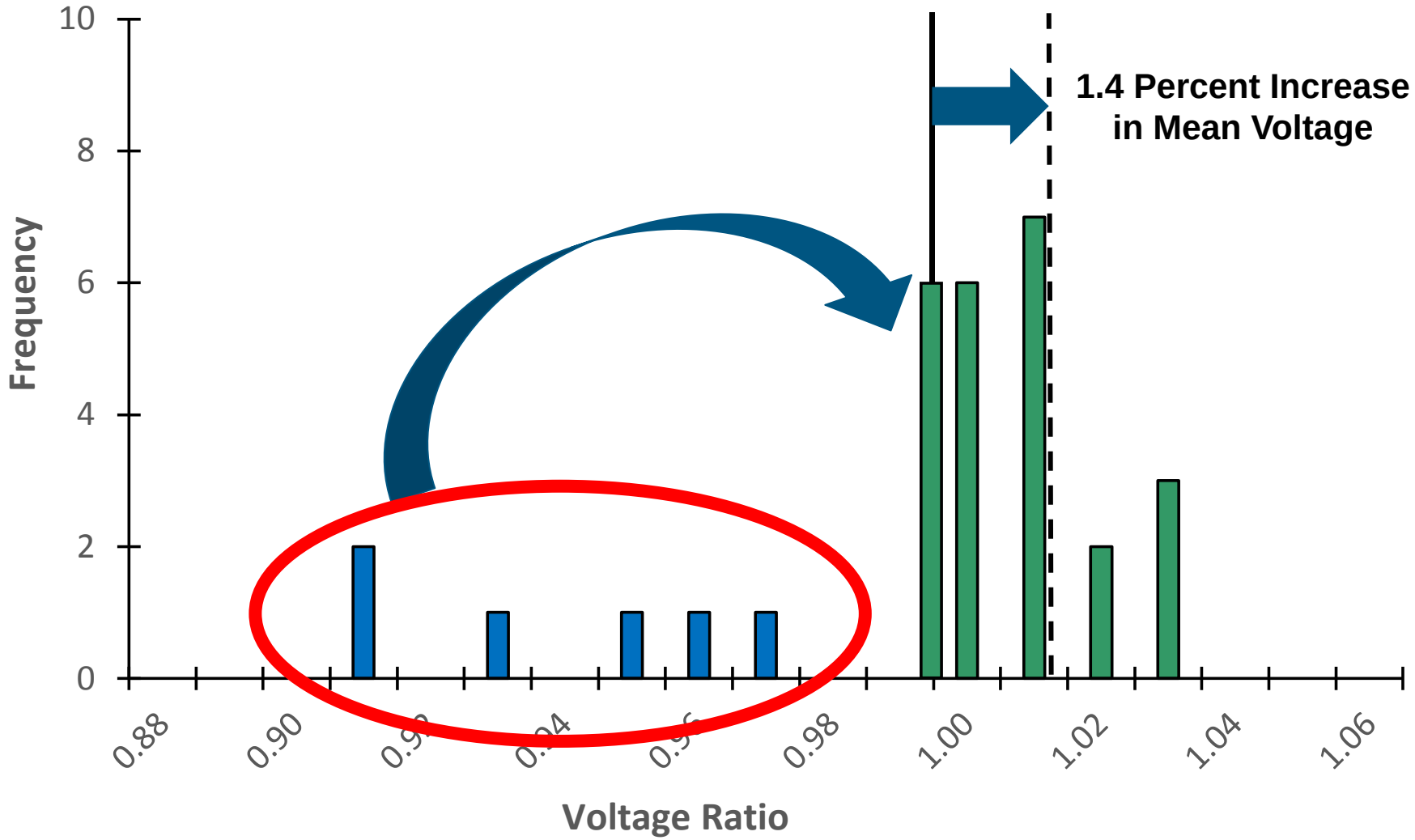


We also estimated accurately the standard deviation of voltage bias and the expected shift after replacement of all CVTs with C_2 errors

Measure	Model-Implied	Actual
Standard Deviation of Voltage Bias per CVT	3.55	3.52
Expected Shift in Average Voltage after Replacement of CVTs	1.43	1.40
Standard Error of Mean Average Voltage across Population of CVTs	0.72	–

Since all these analyses relied on an assumption that the capacitor failures were random, the ability of the model to describe actual outcomes suggested that the underlying random assumption was indeed valid

Thus, replacing those CVTs with C_2 failures skewed the voltage distribution of the “survivors” and thereby overstated energy generation by 1.4 percent.

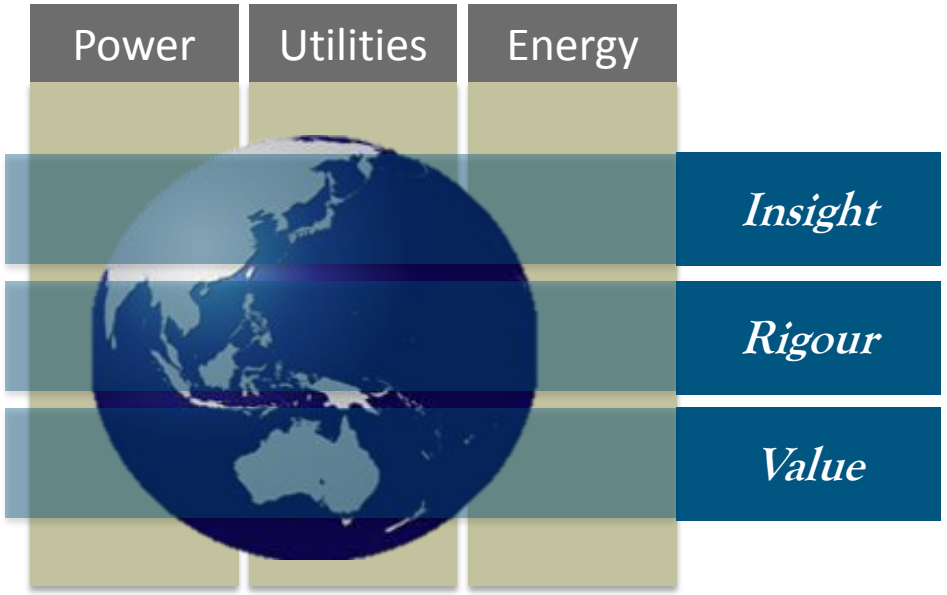


Overview

Conclusions

We represented the buyer in arbitration – buyer collected damages equal to 40 times our fees!

Thank you!



www.lantaugroup.com

For more information please contact us:

Tom Parkinson
tparkinson@lantaugroup.com

+852 2521 5501 (office)
www.lantaugroup.com

The Lantau Group (HK) Limited
4602-4606 Tower 1, Metroplaza
223 Hing Fong Road
Kwai Fong, Hong Kong
Tel: +852 2521 5501