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~~Low~~ High Impedance Faults

- Open-circuit, Downed-conductor Faults

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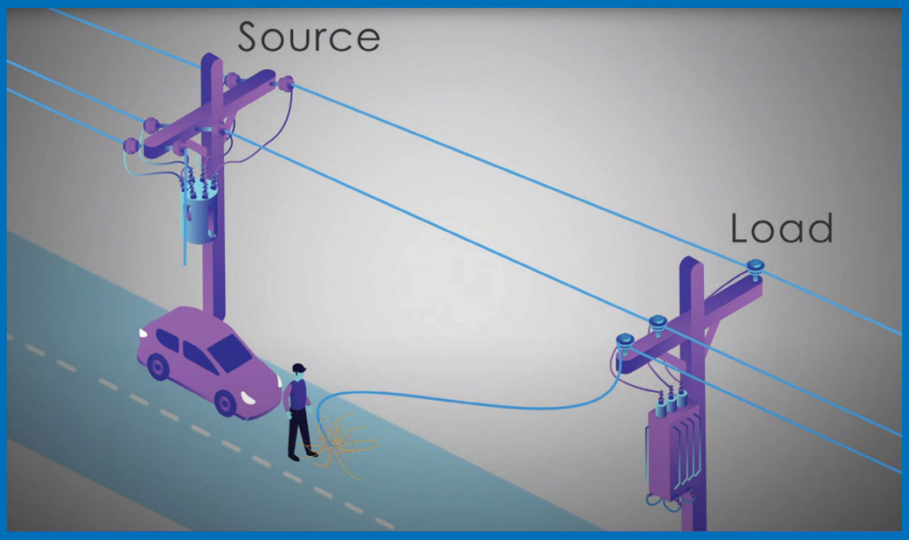
Open circuit, downed conductor fault



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Introduction

- Westpower experienced a serious public safety near-miss involving an open-circuit downed-conductor event
- There was no effective protection available to reliably detect these types of fault
- Until now, risk mitigation was the only available tool that we could apply

But..

- We had a new Chief Executive who challenged us to come up with a better answer than "we can't do anything about this type of fault"
- And engineers find solutions to some of the most intractable problems

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"The Incident"

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The Near-Miss Event

- On 4 April 2020, a serious near miss occurred involving an open-circuit downed-conductor fault
- The member of the public found a live 11 kV conductor on the road, picked it up and threw it on to the berm – and survived!

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The Faulted Network

- The Zone Sub CB did not see the fault
- Two downstream reclosers with Arc-Sense protection did not see the fault
- The system appeared normal – but a live conductor was on the ground

Background

- We had theorised about using LV phasors to detect HV open-circuit, downed-conductor faults
- We had modelled how they would perform
- We had even tested an early prototype in the HV Test Bay
- But we had never tried it out in earnest
- Could it work?

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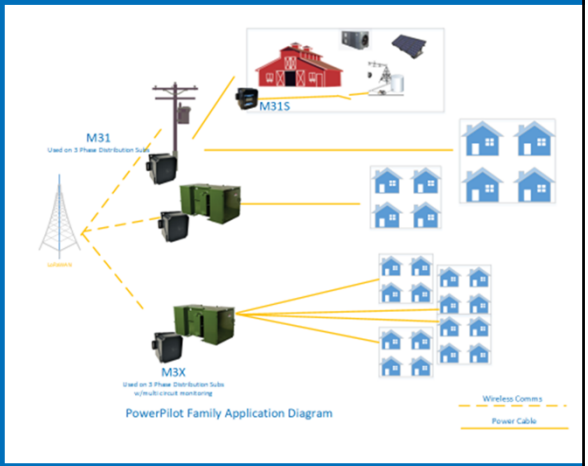
Existing LV Monitoring System

- PowerPilot LV monitoring units were already being rolled out on distribution subs on the Westpower network
- These IoT devices
  - measure LV phasors in real time
  - have edge processing capability
  - communicate via LoRaWAN to the ADMS system



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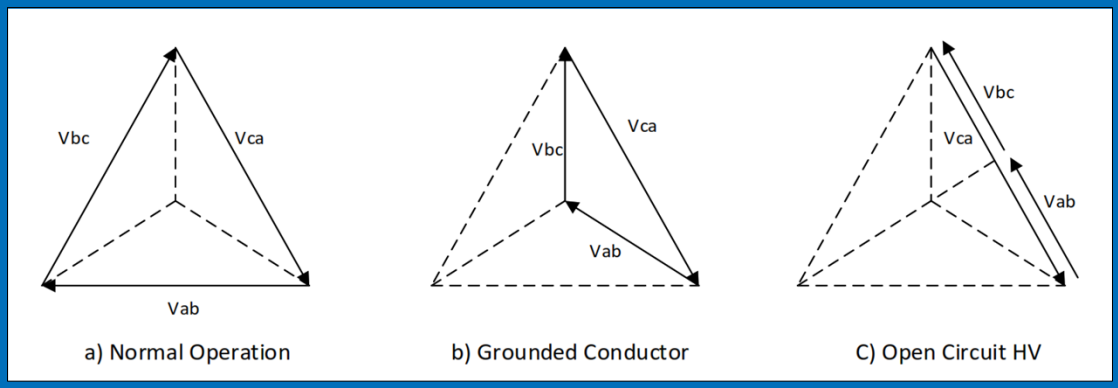
Theory of operation

- HV Phasors change under fault conditions



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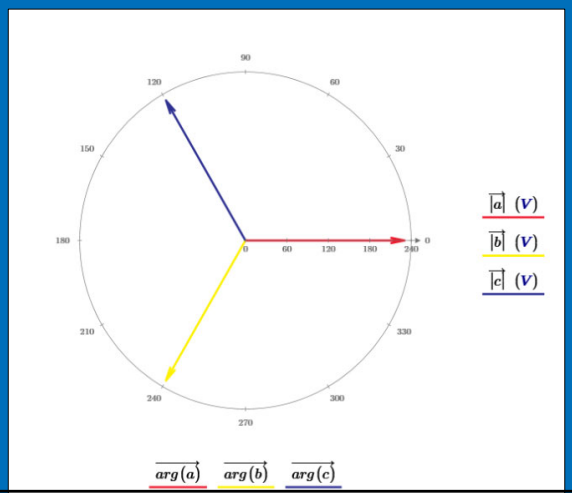
Theory of operation

- LV Phasors – normal operating conditions



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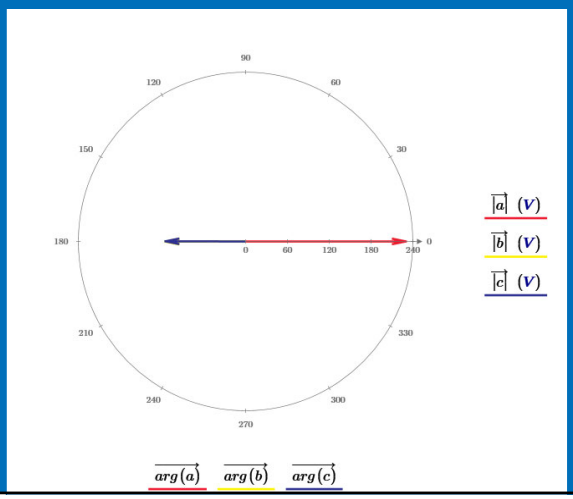
Theory of operation

- LV Phasors – for open circuit fault



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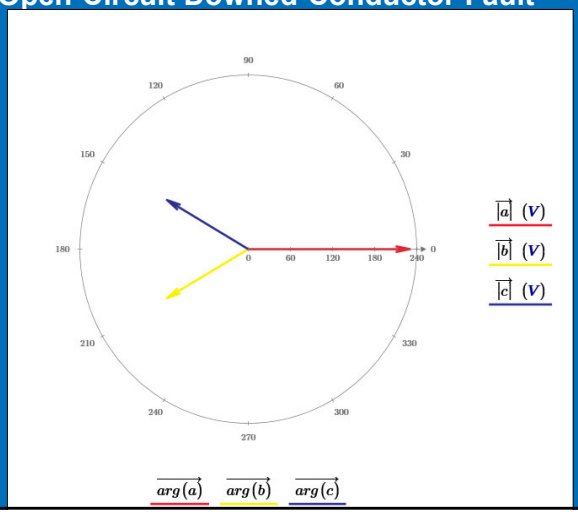
Theory of operation

- LV Phasors for Open-Circuit Downed-Conductor Fault



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Early Trials

- *Wrote a simple algorithm*
- *Coded this in our edge processing language*
- *Tried it our in our HV Test Bay*
- *Used PQ recorders to monitor the phasors*
- *It worked – sort of..*

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Theory vs. Practice

Phasors also affected by

- differing network configurations, both upstream and downstream
- the source impedance feeding the grounded conductor
- neutral impedances
- load characteristics, including imbalance and power factor
- fault impedance
- ground characteristics
- the presence of resonant earthing systems in the network

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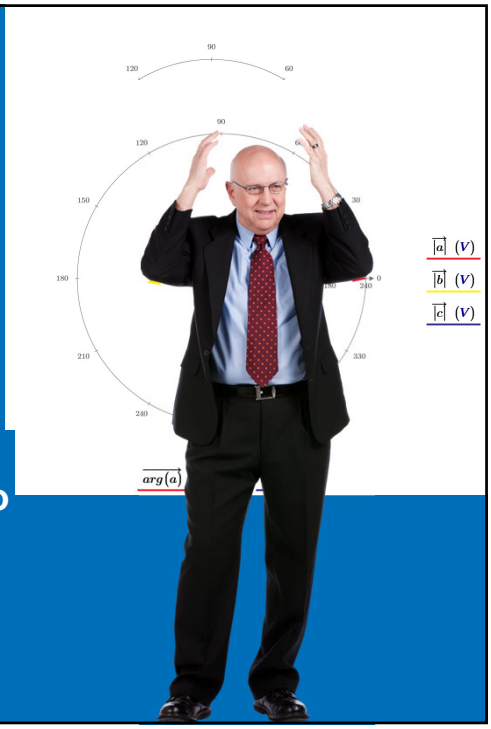
Challenges

- Each new edge case required adjusting the empirical formula
- Some changes “broke” earlier successful predictions
- Some edge cases were very hard to cater for
- So close – and yet so far!



A New Approach

We had test data - so we tried a data science approach using large number of measurements from the test bay recordings

Classical

1. Empirical function (known input) = Output

Data Science

1. Train a function based on large data sets with known inputs and outputs, using a portion of the training data.
2. Test training by applying predictions to the remainder of the training data
3. Apply function to independent input data to predict the output

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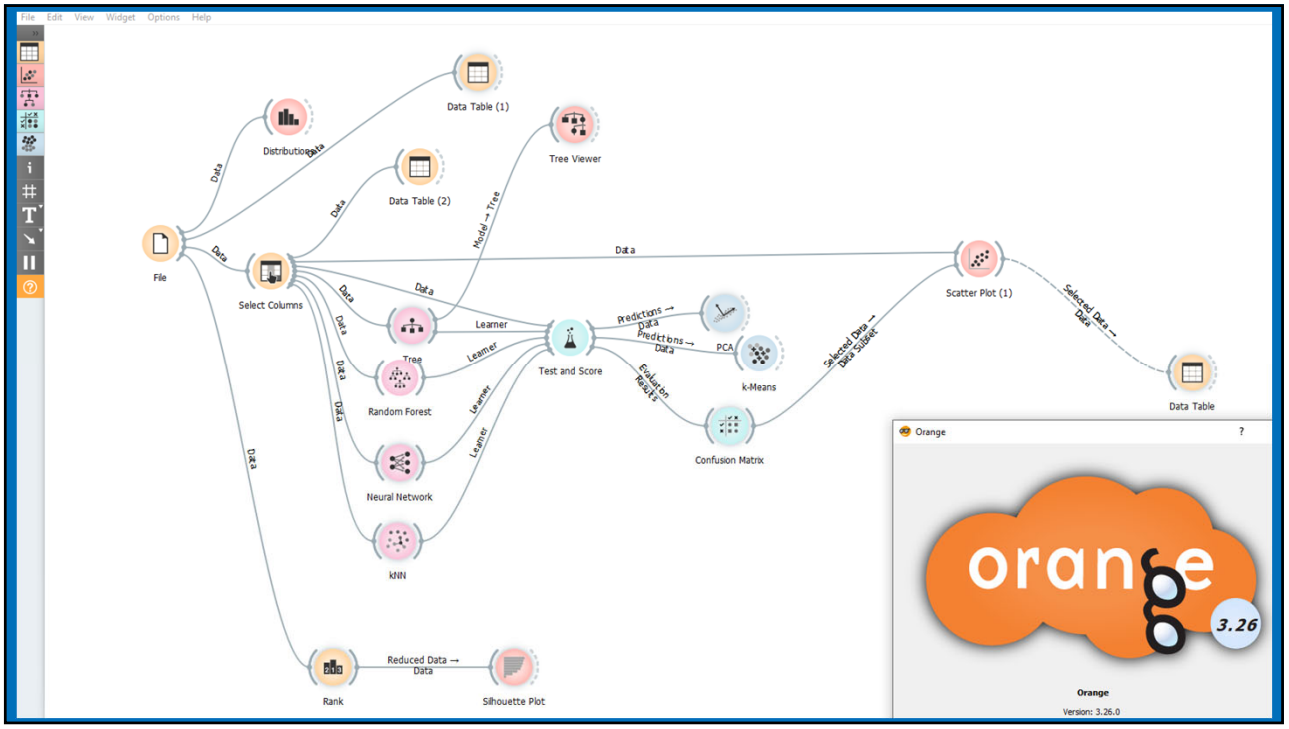
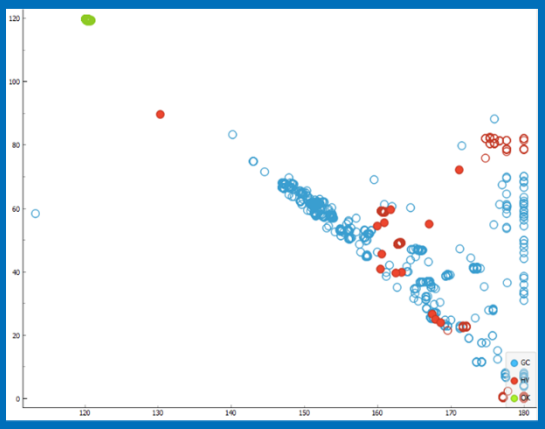


Data Classification

- Looking for patterns



Actual \ Predicted	GC	HV	OK	Σ
GC	843	3	0	846
HV	13	276	0	289
OK	0	0	1121	1121
Σ	856	279	1121	2256

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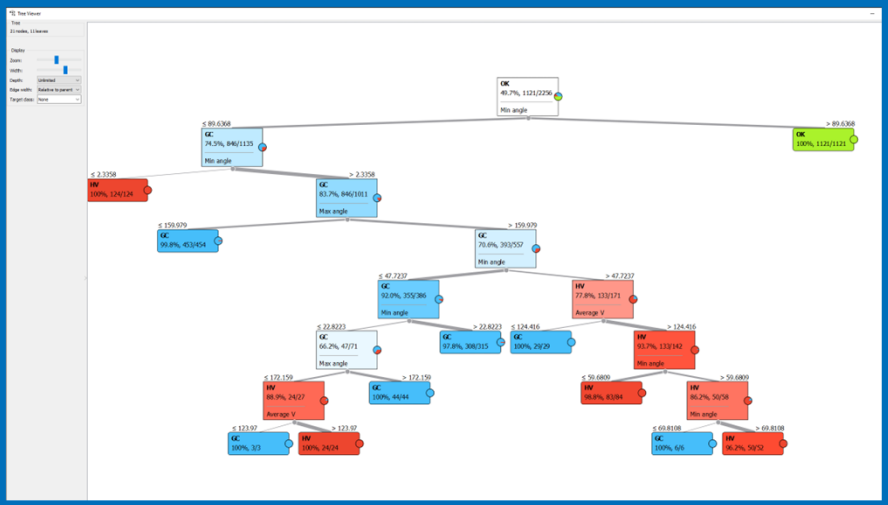
Model Output



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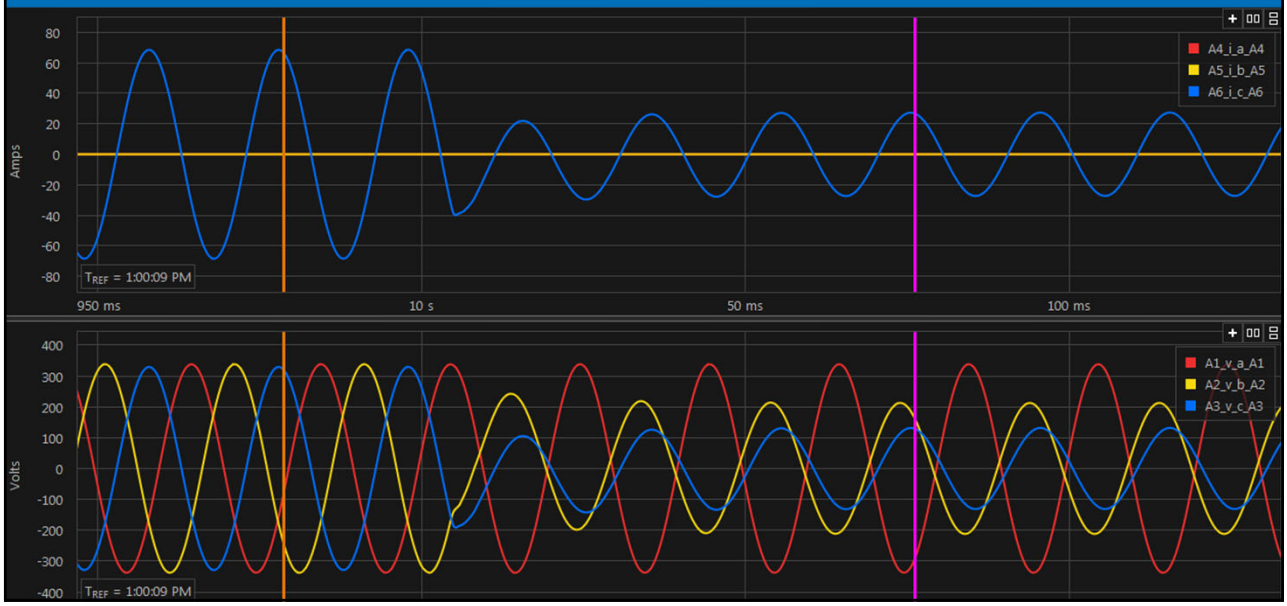
Simulations



Next steps

- Normalise the input data
- Create large number of edge cases using simulations
- Re-train the prediction models
- Have the performance of the equipment and algorithms independently audited and verified
- Install more units on Westpower's network
- Wait for the next in zone open-circuit downed-conductor fault to fully validate the performance

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Questions

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