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# Reliability by design – separable connections on OH lines and what designers should be aware of

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## Background

Electrical connections on OH lines:

- Critical for the reliable and long-lasting current-carrying performance
- Susceptible to electromechanical forces and the environment
- **Separable electrical connections** - the most difficult to achieve and maintain
- **Separable electrical contacts** - the key component of any ABS

Field observations of conventional ABS in NZ and Au – visual and acoustic:

- Bad contacts - pitting, erosion, burns, heavy arcing, etc in less than a year in service
- ABS maintenance - focused on contacts (cleaning, greasing, re-alignment…)
- A common thread – exposure to vibrations

Making things worse:

- ABS maintenance reduced due to live-line work restrictions
- Consequences - more ABS failures (e.g. Operational Constraints, unreliable, hazardous, etc.)

We need a more reliable, long-lasting ABS with less maintenance

# Deficiencies of the conventional ABS design

Key requirement - a low-resistance contact between the contact blade and fixed contact fork because this contact carries a full load current

The flaw in the design - the spatial relation between contacts and pivoting insulator:

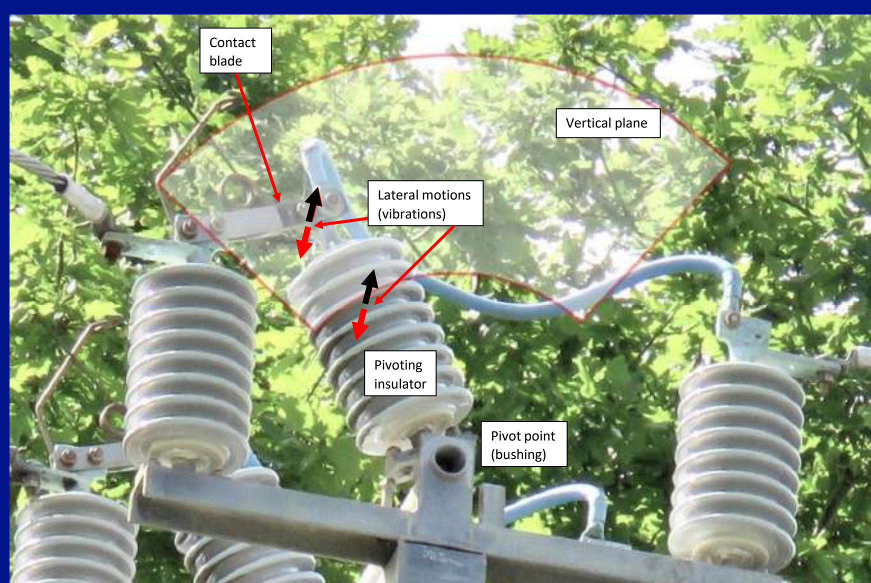
- **The pivoting insulator and the contact surfaces of the blade move in the same (vertical) plane e.g. they are parallel to each other**

Consequences:

- A sideways movement of the insulator causes equivalent vibrations of the blade/fork in the same direction, causing:
  - Fretting wear on one side
  - Micro-arcing, pitting, and erosion on the other side
  - Gets even worse with moisture, sea spray, pollution, thermal changes, galvanic processes…
  - Self-perpetuating

The flawed **Mechanical design** has significant negative effect on the **Electrical performance** of OH power lines.

# Conventional ABS

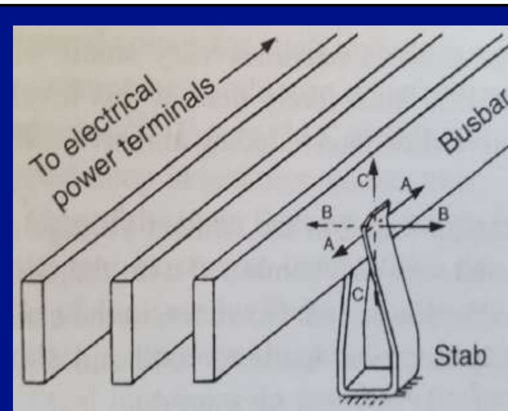



Note:
Some alternative designs with 2 insulators per phase only - suffer from similar issues with contacts. They are sensitive to vibrations and contacts require perfect aligning.
Many distribution companies allow only ABSs with 3 insulators per phase.

# The direct analogy with bus-stab contacts in substations

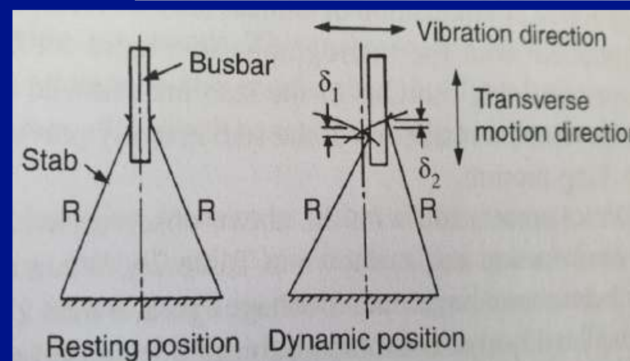
Three types of motions (vibrations) on busbar stabs (aka bus fingers):

- A-A direction: Slide motion due to variations in electrical load (e.g. thermal expansion and contraction)
- B-B direction: Electromagnetically induced vibrations due to heavy currents in adjacent busbars
  Note: The ABS contacts are exposed to similar vibrations




- C-C direction: Transverse displacements (fretting vibrations) perpendicular to both thermal and electromagnetically induced vibrations
- The frequency is 100 Hz

Note:
A bus-stab contact does not carry the load current. However, the micro arcing at such contacts has been confirmed with the acoustic inspection instrument.

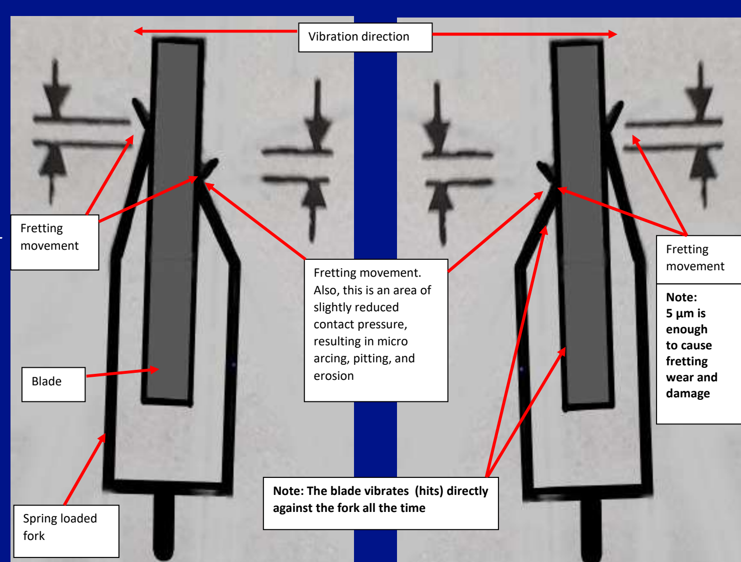



# Main electrical contacts of conventional ABS

The same failure mechanism as with bus-stabs, just caused by different vibrations.

The consequences are much worse because the ABS contacts carry a full load current:

- When the blade moves to the right, the fork on that side moves upward, resulting in fretting wear
- At the same time, the opposite finger contact moves downwards, resulting in:
  - Weaker spring effect
  - Reduced contact pressure
  - Increased contact resistance
  - Micro arcing, burning, pitting, and erosion
- A self-perpetuating process

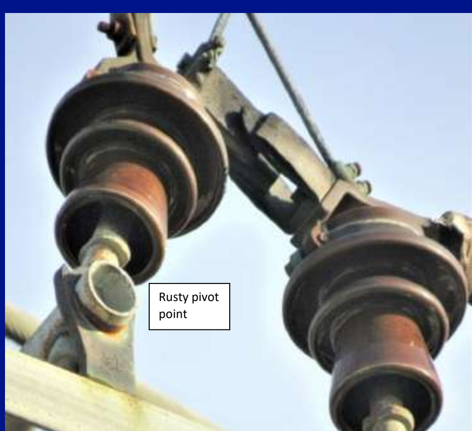


# Real-life examples: A 33kV ABS on a line exposed to Aeolian vibrations

Heavy arcing, fretting wear, pitting, and erosion in less than a year in service
- The line is perpendicular to the steady wind
- Vibrations felt on the pole with a bare hand

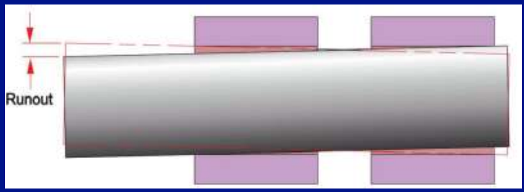

# Real-life examples: 11kV ABS in a closed position

Heavy arcing, fretting wear, molten metal, pitting, and erosion of the main contacts
- The ABS along the main road
- Rusty pivot point (bushing)



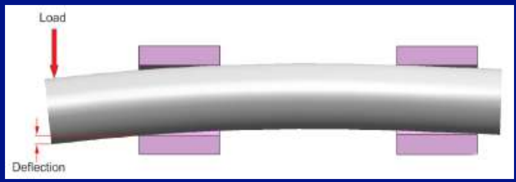

# Why are there relative movements between the fixed part of the ABS assembly and the pivoting insulator with the contact blade?

- The pivoting insulator pivots on a shaft around an axis with a bushing (a sleeve bearing).
  - Typical radial clearance of bushings is 0.05-0.10 mm (50 - 100 μm)
  - For comparison – the thickness of human hair is 5 μm
  - Even a small clearance can result in shaft deflection, runout, vibration, and axial motion




An illustration of shaft dynamic runout

- If the bushing radial clearance is only 5 μm, and the middle ABS insulator vibrates:
  - The lateral displacement of the blade is approx. 1.5mm (at 330 mm distance from the pivot point)
  - It produces the transverse (fretting) motion of contacts of approx. 7.5 μm
  - A perfect condition for fretting wear




An illustration of shaft deflection due to side load

# What can cause vibrations that affect contacts of conventional ABS

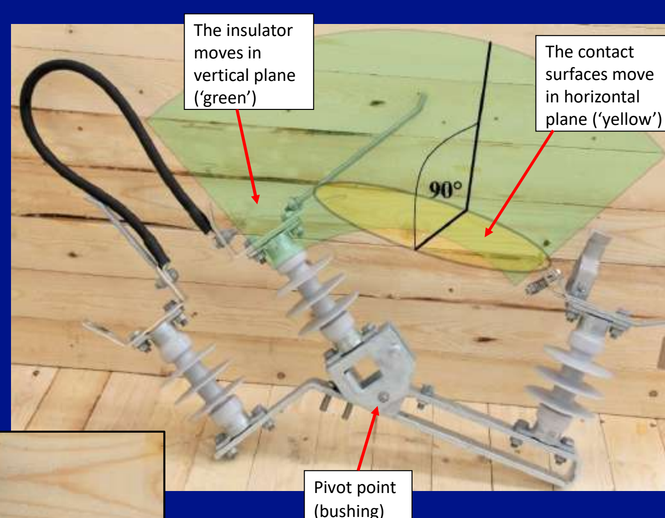
- ABS operation:
  - During closing/opening - any vibration of the pivoting insulator
  - In the stationary closed state - any vibration will form a small gap between the contact surfaces and micro-arcing. Note: the contacts carry a full load current.
- Operation of other hardware on the same or adjacent poles
- Mechanical vibrations due to high winds
- Aeolian vibrations - transferred from the OH conductors to the pole hardware
- Mechanical vibrations from the traffic
- Vibrations induced via the road surface bumps, loose soil, or reclaimed land

## New design of ABS (Note: New to New Zealand)

## The key difference

- The middle insulator and contacts are at 90° to each other (e.g. in different planes)
- Lateral vibration of the middle insulator won't affect the contact surfaces between the blade and fork
- If the insulator vibrates, the blade slides between the fork fingers – it does not hit the fork

Note:
The lateral sliding distance is in **μm** and doesn't affect the contacts




# A proof of vibrations on OH lines - direct and indirect

Direct confirmation:

- Vibrations - subtle, in **µm**
- However, human skin can sense vibrations up to 1,000 Hz, with peak sensitivity around 250 Hz
- By simply putting a hand on a power pole or supporting structure in an area exposed to Aeolian vibrations, one can feel vibrations
- A good example is the 33kV power lines in the Western Australian mining areas
- In New Zealand, by putting a hand on a concrete pole next to the road with the passing traffic, most people will be able to feel vibrations

Indirect confirmation:

- Many loosened nuts & bolts on OH power lines hardware
- If there were no vibrations, they would simply not get loose
- The initial loosening may start with thermal expansion, but will continue and self-perpetuate with mechanical vibrations

# Energy (thermal) losses from ABS' during normal operation

All separable connections have a higher contact resistance than permanent connections. Therefore, they have higher energy losses.

Conventional ABS with bad contacts:
- A major increase in contact resistance over time
- Significant heating (energy) losses
- If in-operable, it just sits there and continuously dissipates heat
- Due to energy losses alone - the true cost over the service life can exceed the original price
- Additional costs – regular maintenance, SAIDI, feeder faults, replacements…
- The risk of bush fires from arcing contacts and molten copper

The new ABS design:
- Stable contact resistance
- No increase in heating (energy) losses
- High reliability over the entire service life
- Virtually maintenance-free
- The true cost over the service life does not increase

# The results speak for themselves

The new ABS design:

- In use for more than 40 years
- It successfully survived the test of time
- Maintenance - non-existent or minimal (not even greasing is required)

Feedback from distribution companies that adopted this design:

- Improved network reliability, resilience, SAIDI/SAIFI
- Reduced risk of feeder faults due to failed ABS contacts
- Improved public and personnel safety
- Reduced risk of bush fires
- Modular and compact design
- Easy to install – one person can carry individual components

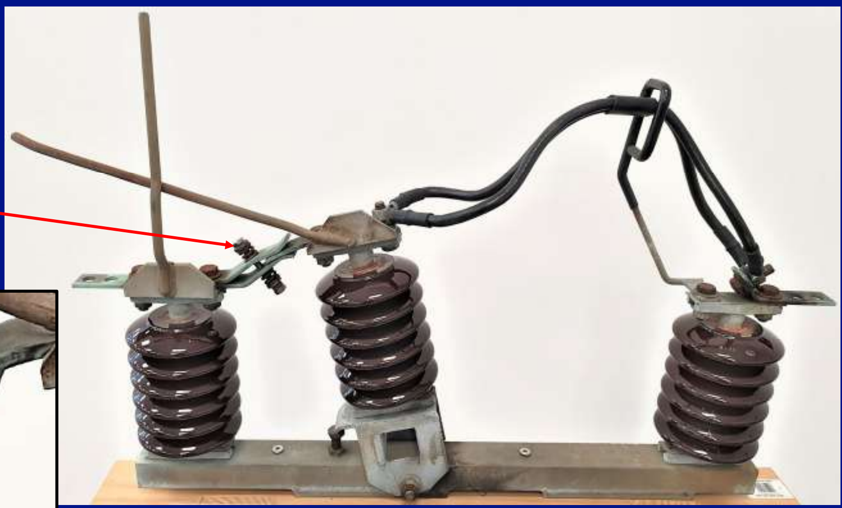
# Conclusions and recommendations

- There are thousands of ABSs based on a conventional design in New Zealand
- Most of them are along the roads, exposed to vibrations from traffic, winds, Aeolian, vegetation, etc.
- There is a steady increase in ABS failures with a significant impact on SAIDI/SAIFI

Mechanical and electrical designs of OH lines are inseparable:

- Flawed mechanical design can have heavy consequences on electrical performance of OH lines
- Sometimes an old but proven design can be a much better solution

A picture is worth a thousand words – a recently replaced ABS with near-perfect contacts after 40 years in service



*"Good design is actually a lot harder to notice than poor design, in part because good designs fit our needs so well that the design is invisible"*

**Don Norman - *"The Design of Everyday Things"***

# Any questions?

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