Dulhunty Industries Pty. Ltd. founded in 1991 and
Dulhunty Engineering (China) Ltd. founded in 1996

Acquired by AIL in 2003 and listed on Australian Stock Exchange
DULHUNTY POWER

Locations:
Sydney, Australia
Yangzhou, People’s Republic of China
Bangkok, Thailand
Kuala Lumpur, Malaysia
Auckland, New Zealand
Kiln, MS, USA
Hong Kong

Staff: 150+ people
DULHUNTY POWER

Dulhunty Power China
Dulhunty Power Thailand
Dulhunty Power Malaysia
DULHUNTY POWER

Production and warehouse area
DULHUNTY POWER
DULHUNTY POWER

Production and warehouse area
DULHUNTY POWER

Production and warehouse area
Key Personnel include:

MR. PHILIP DULHUNTY
Founder of Dulhunty Power
Life Honorary Member of CIGRE and IEEE
who has over 50 years experience in the Electricity Supply Industry, and holds many patents for vibration control products.
PHILIP DULHUNTY

- founded Dulmison in 1948
- Dulmison grew to be the largest manufacturer of products for power transmission and distribution products outside USA with factories in USA, UK, Thailand, Indonesia, Hong Kong
- Developed world class vibration control products
- Dulmison was sold to AWA in 1986, then sold to Morgan Crucible, UK in 1992 and then to Tyco USA in 2000.
Jack Roughan

- Former Global Engineering Manager for Dulmison for Tyco Energy division products with over 30 years experience in Electricity Supply Industry.
- Hired to expand the product range and markets for Dulhunty Group
Dr. Sarah Sun Chao is a specialist in modelling of vibration phenomena.

Mr. Brian Mathieson is a specialist in field testing of vibration of transmission lines. Brian was formerly Dulmison New Zealand and Dulmison UK General Manager and has over 30 years experience in Electricity Supply Industry.
Mr Yun Wang
- specialist in aluminium gravity die casting and in casting and heat treatment of cast iron.
CONSULTANTS

Tom Smart  former Dulmison UK and PLP UK Engineering Manager with over 30 years experience in design of vibration control products.

Don McLean  laboratory test instrumentation specialist
VIBRATION CONTROL:
- Produce one of the best range of vibration control products in the world
- Provide computer analysis of damper and spacer damper performance
- Laboratory test facilities
- Field test services
Dulhunty has sold its Vibration Control products to:

**Australia**  
- Transgrid (NSW)  
- Powerlink (Queensland)  
- SPI Powernet (Victoria)  
- ETSA (SA)  
- Western Power (WA)

**New Zealand**  
- Transpower
Reference List (continued)

USA
- AEP Jacksons Ferry – Wyoming 765kV
- Dominion Power - 500kV project
- Allegheny Power - Trail Project

Thailand
- EGAT

Malaysia
- TNB, SESCO

China
- Various power authorities.

Canada, Mexico, Peru
Vibration Dampers, Spacers, and Spacer Dampers
CONDUCTOR VIBRATION

- Aeolian Vibration
- Subconductor Oscillation
- Galloping
Types of Vibration

- **Aeolian Vibration**
  - Caused by Vortex shedding
- **Subconductor Oscillation**
  - Wake induced movement
- **Galloping**
  - Caused by ice buildup
AEOLIAN VIBRATION

- Most common type of vibration affecting transmission lines.

- Caused by low speed laminar wind flows that shed vortices from upper and lower surfaces alternately resulting in alternating lift forces on the conductor.

- Frequency of vortex shedding is dependent on wind speed.
- Vibration frequency is proportional to wind speed and inversely proportional to conductor diameter.

- Winds of 0.5 to 7 m/sec over flat terrain or large bodies of water are most conducive to Aeolian Vibration.

- Aeolian vibration occurs in the frequency range 5 to 100 Hz with maximum amplitudes approaching one conductor diameter at the lower end of the frequency range.
Vibration amplitude is determined by wind energy input and the energy dissipated by the self damping of the conductor, fittings, and external damping devices.
Vibration Damage

- Vibration can cause serious damage
Vortex Shedding
Vortex Shedding

- 0.5 to 6.5 m/sec

- Frequency = \( \frac{185 \times v}{d} \)
- \( v \) = wind speed (m/sec)
- \( d \) = conductor diameter (mm)
Resonant Response

- Resonant Response of Transmission Line Conductors
- Similar to guitar string
- Lowest resonance (Fundamental) when whole conductor moves like a guitar string
**Fundamental Resonance**

- Frequency = \( \frac{1}{2S} \times \sqrt{\frac{T}{m}} \)

  - \( S = \text{Span Length} \)
  - \( T = \text{Tension} \)
  - \( M = \text{Mass} \)
Resonant Response

- Resonant Response at each increment of fundamental frequency
Resonant Response

- At resonance, a small force will result in a large vibration amplitude
- Resonance occurs at every $\frac{1}{4}$ Hz
- Lock in of vortex shedding to resonant frequency
Vibration Damage

- Vibration can cause serious damage
Vibration Dampers

- Vibration Dampers are used to control aeolian vibration
- Vibration Dampers work by absorbing energy
Standing Waves

- The resonant pattern is called a Standing Wave.

- Standing waves are formed by the combination of travelling waves.
Standing Waves

Energy absorbed by span end (AB)

(ER) Reflected Energy

(EI) Incident Energy

Node

Antinode
Standing Waves with Damper

Energy absorbed and dissipated by Damper (ER)

Reflected Energy (EI)

Incident Energy

Energy absorbed by span end (ESE)

Standing Waves with Damper
Node (Has non zero displacement amplitude)

Antinode

A+B

A-B
Damper placement

Factors affecting placement

- Range of Temperature
- Span Length
  - Conductor Tension
- Terrain Considerations
  - Wind Speed Range
Vibration Damper

- ISWR Measurement
Energy Balance

Energy is put into the conductor by the wind

Energy is dissipated by the Dampers and by conductor self damping
Energy Balance

• Vibration amplitude will increase until the energy from the wind is balanced by the energy dissipated by the dampers plus the energy lost in self damping

• \( P_W = P_D + P_{SD} \)

• \( P_W = f(Y/d) f^3 d^4 \)
• \( P_{SD} = f(Y^4) \)
• \( P_D = \eta \times \frac{1}{2} \sqrt{T.m} \)
Energy Balance

- Used to calculate damper requirements
Vibration Damper

- ISWR Measurement
Impedance Testing
Impedance Testing
Field Testing
Field Testing

- Compare measured vibration with “Safe” Amplitude
- Estimate lifetime from comparison with Fatigue curve.
Fatigue Life

**Stress Amplitude**

(N/mm$^2$), [mm]

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<tr>
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</table>

**Number of Cycles**

(10^2, 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, 10^9, 10^10)
Aeolian Vibration

- Caused by Vortex Shedding
- Characterised by
  - Low speed winds
  - 5 to 50 Hz vibration
  - Up to 1 conductor diameter movement
  - May result in serious damage to conductor strands
THE “4D SERIES” VIBRATION DAMPERS
FROM DULHUNTY POWER
THE “4D SERIES” VIBRATION DAMPERS FROM DULHUNTY POWER

- Designed to absorb vibration by dissipating the energy of the vibration as heat in the messenger cable.

- To work effectively, the damper impedance closely matches to the characteristic impedance of the conductor.
4D Dampers have four resonant frequencies covering the whole spectrum of vibration.
Patented method of attachment the result of our research and development program with Australian Defense Industries (ADI).

- Involves use of specially designed messenger cable that is pre and post formed to Dulhunty Power’s standard.

- Weights are attached using a patented cementing process that only attaches outer strands of the messenger to the weight, thus allowing the inner strands to slide longitudinally during dynamic bending.
Every 4D damper is proof tested for pull-off strength

performance in tests shows the method of attachment to be superior to dampers where weights are wedged, cast, or compressed on.
Tests conducted at Australia Defense Industries laboratories confirm the high efficiency of Dulhunty dampers over the full range of frequencies.

Field recordings confirm the performance of the Dulhunty 4D Dampers.
Spiral Dampers

- Effective on
  - Small conductors
  - Steel earthwires
- Location is not critical
Wire Products

- Armour rods
  - Help to prevent damage at suspension points
Bundled Conductors

- Bundled Conductors are subject to
  - Aeolian Vibration
  - Subconductor Oscillation
  - Galloping
Bundled Conductors

- **Aeolian Vibration**
  - Same issues as for single conductors
  - Controlled in Bundle Conductors by energy dissipation in Spacer Dampers
  - Number of Spacer dampers in each span determined by energy balance
Subconductor Vibration

- Wake Induced Movement on Bundled conductors
- Characterised by
  - Medium to Strong winds
  - Low frequency (up to 2 Hz)
  - Large amplitude circular motion
SUBCONDUCTOR OSCILLATION

- Occurs on any bundled conductor configuration having pairs of sub-conductors lying in the same horizontal plane.

- The upstream conductor sheds a turbulent wake which results in complex interaction of aerodynamic and mechanical forces on the downstream conductor – thus causing sub-conductor oscillation.
Sub-conductor oscillation is often seen as an anti-phase elliptical motion of the sub-conductors with the major axis of the ellipse in the horizontal plane.
Subconductor Oscillation

- Complex Motion

Combined motion produces “orbit” of subconductors
Vibration frequency determined by mechanical characteristics of bundle/spacer system and amplitude by the balance between energy input by the wind and energy dissipated by the aerodynamic and mechanical damping of the system.
Subconductor Oscillation

- Threshold Windspeed
- Many Variables
  - Number of Subconductors
  - Spacing of Subconductors
  - Angle of Attack (Tilt) of Bundle
  - Type of Spacer Dampers
  - Location of Spacer Dampers
Usually occurs in wind speeds of 5 to 25 m/sec over flat terrain or large bodies of water which results in vibration frequencies of 0.5 to 4 Hz with amplitudes sufficient to cause sub-conductor clashing in the middle of sub spans.
Subconductor oscillation is a function of Wind Velocity (V) and its Turbulence level, the Angle of Attack (OC) the conductor Separation to Diameter Ratio (S/D) and can occur on sections of the line or individual spans and individual phases within a span.
Other than anti-phase, motion can be represented by “bundle rocking” and “bundle snaking” (a bulk sideways motion of the sub-conductors).
Subconductor Movement

A. Subspan Mode or Breathing

B. Vertical Galloping

C. Horizontal Galloping or Snaking

D. Rolling or Twisting
Subconductor Vibration

Subconductor Oscillation may cause

- subconductor clashing
- Wear of suspension assemblies
- Breakage or damage to spacer dampers
Subconductor Oscillation

- Other Variables
  - Conductor Surface
  - Suspension and Tension String arrangements
  - Conductor Tension
Control of Subconductor Oscillation

- Spacer Dampers
  - Reduce amplitude of Movement
- Unequal Subspan Spacing
  - Increase threshold windspeed
- S/D Ratio
  - Increase threshold windspeed
GALLOPING

- Affects both single and bundled conduction.
- Characterised by a low frequency (< 1 Hz), high amplitude (several meters), and bulk vertical motion of a phase span with 1, 2 or 3 half wavelengths per span.
- Can occur in both icing and non-icing conditions with normal wind flows of approximately 5 – 40 m/sec over flat, unobstructed terrain.
Galloping

- Usually caused by ice buildup on conductors
- Characterised by
  - Low frequency (1-2 Hz)
  - Movement may cause rapid damage to the conductor and serious structural damage to towers
Galloping

- Areodynamic instability of conductors
- May occur on single conductors or bundled conductors
- Large amplitudes of motion
- May result in line outages due to flashover
Galloping

![Diagram of galloping mechanism](image)

- **a.** Wind causes drag on the Conductor, leading to ice accumulation.
- **b.** Wind also causes lift, contributing to the galloping effect.
- **c.** Lift and drag act together, maintaining the galloping motion.
Galloping Damage

- Breakage of Spacer Damper
Galloping Damage

- Tower Failure
Galloping

- Controlled by
  - Remove the ice, or prevent if from forming
  - Use of interphase spacers
  - Use of detuning pendulum on conductors
  - Use of aerodynamic drag dampers.
Galloping

Detuning Pendulum
Galloping

Aerodynamic Drag Damper
Spacer Dampers

- Spacer Dampers are Designed to Control
  - Subconductor Oscillation
  - Aeolian Vibration
  - Assist with control of Galloping
SPACER-DAMPERS

- Maintain separation of sub-conductors
- Control aeolian vibration
- Control subconductor oscillation
Contoured to eliminate corona and minimize R.I.V.

Allow maximum clamping pressure without damage to the conductor.
SPACER DAMPERS

- Twin, Triple, Quad and Hex Configurations
Subspan Spacing

- Staggered Spacing for control of Subconductor oscillation.
- End span spacing for rollover recovery.
Testing of Spacer Dampers

- Mechanical Test facilities at Dulhunty Power Thailand and China factory locations
- Electrical Tests in EGAT Bang Na Laboratory, and also Wuhan HV research institute.
Testing of Spacer Dampers

- Damping Performance
  - Log Decrement Test
- Strength
  - Compression & Tension
- Fatigue performance
  - Fatigue tests
- Field Tests
Testing of Spacer Dampers

Compression Test

Tension Test
SPACER DAMPER TEST RIG for

- Longitudinal Deflection Test
- Vertical Deflection Test
- Clamp Slip Test
SPACE DAMPER

- Transverse (Torsional) Deflection Test
Testing of Spacer Dampers

- Fatigue Tests

Vertical  Longitudinal  Transverse
Field Testing of Spacer Dampers
QUAD SPACER DAMPER

Flexible Hinge
- Provide articulation in all directions
- High Fatigue endurance
- High resistance to weathering and ageing
- Impervious to Ozone
- Wide temperature range
- Controlled Resistance
- Optimised stiffness and Damping

Clamps
- Minimum Corona & RI
- High Slip Strength without damage to conductor
- Galvanised, Stainless or Aluminium
  - Shearhead bolts
  - Belleville washers available

Construction
- high strength Aluminium Alloy
- arms angled to give horizontal and vertical flexibility
- Optimised mass and rotational inertia
SPACER DAMPER HINGE BUSH
±15° NOMINAL ARM MOVEMENT

±7.5° NOMINAL ARM MOVEMENT

Ø762mm (30") PCD
TWIN SPACER DAMPER
TWIN SPACER
AEP Spacer Dampers

- Specification included high requirement for vibration control
  - 55m max subspan length
  - Staggered Subspan lengths

- Conductor clamp
  - Use quick action clamps for ease of installation
Delivery

- Samples 6 weeks
- Production 1600 per week after approval of samples
Spacer Installation

- AEP 6 bundle Spacer Damper
Spacer Damper for NGC

- Design
Spacer Damper for NGC

Logarithmic decrement = 0.98