

The background of the slide features a close-up of a yellow ACCC conductor on the left and a series of high-voltage power line towers stretching into the distance under a sunset sky on the right.

ACCC®

The World's Most Efficient High Capacity Transmission Conductor

CTC Global Corporation

ACCC® Conductor

CIGRE 2015

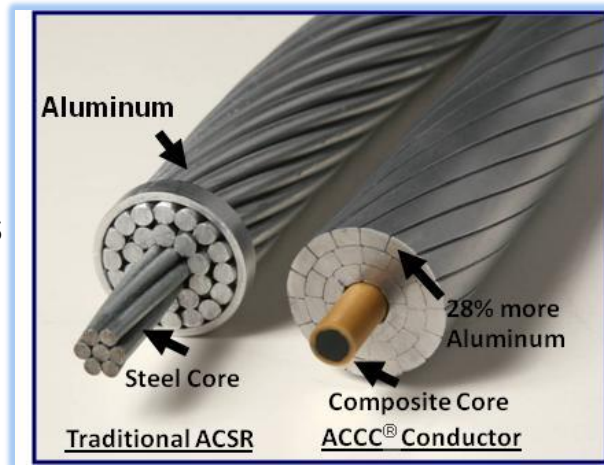
- Twice the Capacity of ACSR
- 30-40% Reduction in Line Losses
- Proven Reliability Worldwide

CTC GLOBAL

Comparing Traditional and Advanced Conductors

ACSR Conductor

- 100 year old approach
- 95+% of transmission lines
- Cheap price and long history of use makes it the default choice of utility grid planners
- Low operating temperature (<95C) and high thermal sag limit capacity of ACSR.

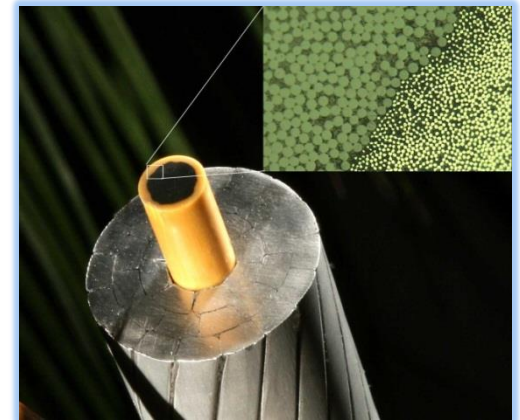


ACCC Provides:

- Increased Capacity
- Reduced Line Losses
- Lower Project Costs
- Increased Reliability

ACCC® Conductor

- Technology developed from 2001 to 2005 and commercialized in 2006
- Hybrid composite core is lighter and stronger than steel allowing 28% more aluminum at no weight penalty.
- Operates continuously up to 180°C with little thermal sag.

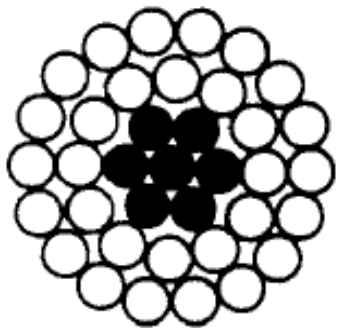


Evolution of Conductor Performance

ACCC conductors combine annealed aluminium with High Temperature technology and an increased Al cross sectional area

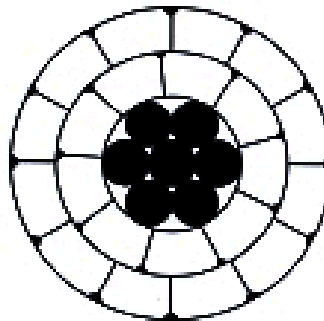
Trapezoidal wires:

- increase the aluminium profile;
- which increases conductivity.



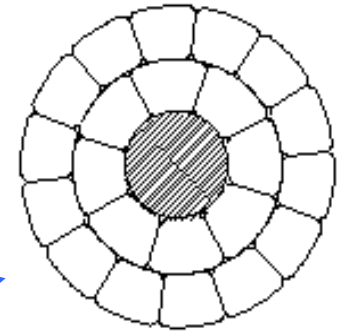
ACSR or ACSS Drake:
concentric round
403 mm² (795 kcmil)
1,627 Kg/km

Introduction of
trapezoidal wire
improves
conductor area



ACSS Swanee:
486 mm² (959.6 kcmil)
1,960 Kg/km

Introduction of
carbon fibre core to
increase conductor to
weight ratio



ACCC 'Drake':
516.9 mm²
1,558 Kg/km

The ACCC core:

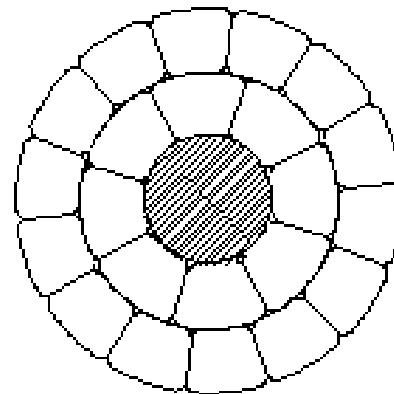
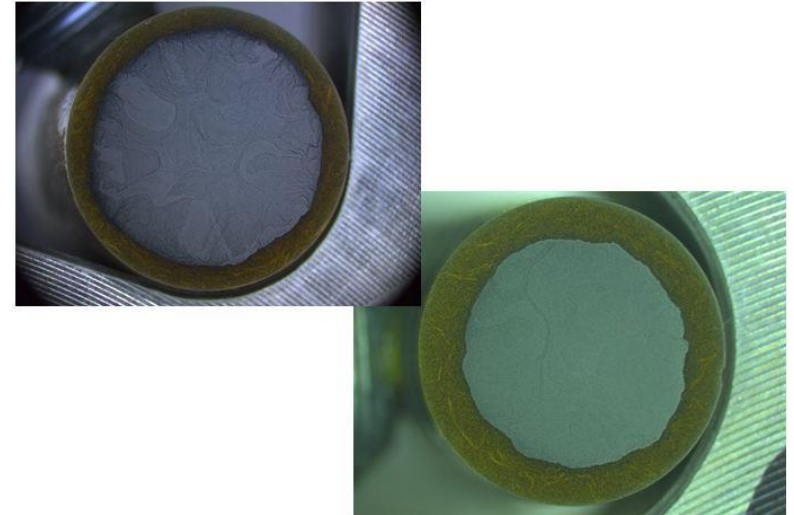
- Increases strength:
(lighter & stronger than steel)
- Allows Further Increases Conductivity
- Core smaller than steel equivalent
allows 28% more Al than ACSR
- Virtually eliminates line Sag

ACCC™ Benefits

- ***Double capacity***
- ***25% stronger than ACSR***
- ***Working temperature up to 180°C***
- ***Allows to increase distance between towers***
- ***Corrosion free***
- ***Reduce line losses (up to 30%)***
- ***Low sag (low thermal expansion)***
- ***Can be used worldwide***
- ***Successfully passed more than 75 types of tests world wide***
- ***Lifetime increase 45 years***

ACCC™ composite core

- ***Consist of high quality carbon and glass fibers (this combination is very often use in aero craft and aerospace technologies) and contain hundreds of thousands carbon fibers***
- ***Retains its properties under influence of high and low temperature***
- ***70% lighter then steel core***
- ***25% stronger***
- ***Very low thermal expansion (low sag)***
- ***Corrosion free***
- ***Not sensitive to UV***
- ***Can be used all over the world***



Recommend Maximum Operating Temperatures

While ACCC® typically runs cooler than other conductor types of the same diameter and weight (due to the added aluminum content), CTC has established maximum recommended operating temperatures based on substantial testing and analysis.

*Max “**continuous**” operating temperature: **180°C***

*Max “**emergency**” temperature: **200°C***

**Defined as 10,000 hours over the life of the conductor*

*Max “**short-term peak**”: **215°C***

**Defined as 8 hour durations – with few yearly events (based on current data)*

*Max “**short-circuit**” temperature: **320°C***

** Defined as 15 minute events*

Benefits of ACCC Composite Core Conductor

1. On “greenfield” (new-line) projects:

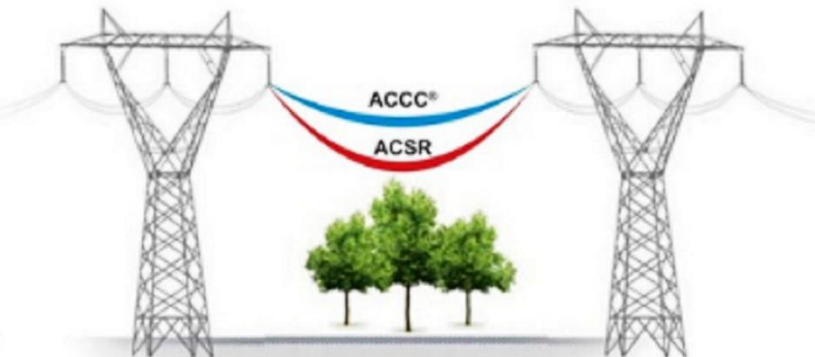
- - reduced infrastructure costs to
- - meet designed current capacity requirements at;
- - **higher** energy efficiency (lower losses) and;
- - with potential for excess capacity to meet n-1 emergency needs.
- - significant cost savings in tower steel combines with;
- - long-term cash flow improvements from efficiency to offer;
- - improvement in economic, visual & environmental impact.

2. On “brownfield” (reconductoring) applications:

- immediate expansion of capacity and **more** power transferred with;
- **higher** energy efficiency (lower losses) and;
- lower project cost through limited permitting and tower modification

“Brownfield” Reconductoring Benefits

- Increase capacity to up to 2 times versus ACSR
- Reduce line losses by over 30% versus ACSR
- Minimize project cost by avoiding tower and foundation improvements
- Extend asset life of towers by maintaining or lowering tension on structure



This installation on one half of a two circuit 220 kV line for the Polish National Grid shows side by side performance comparison of ACCC delivering increased capacity and efficiency at much lower sag.

“Greenfield” Benefits

- Increase distance between towers
- Allows to use light towers and fundament
- One circuit instead of two
- Reduce line losses by over 30% versus ACSR
- Minimize project cost by avoiding tower and foundation improvements
- Extend asset life of towers by maintaining or lowering tension on structure
- Reduce system congestion without tower modification

Diagram 1

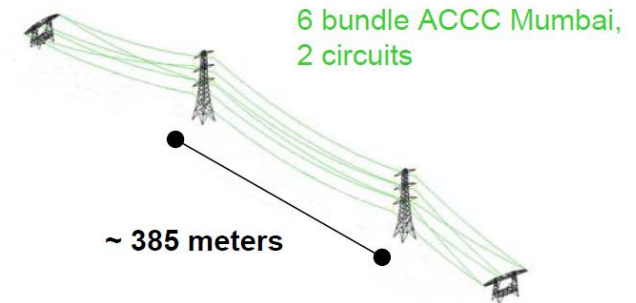
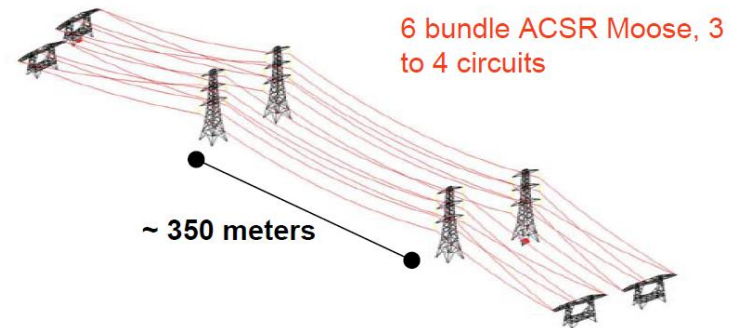


Diagram 2



International sizes of ACCC[®] Conductors

INTERNATIONAL SIZES							
ACCC [®]	Aluminum Area	Conductor Diameter	Core Diameter	Weight	Core Rated Strength	Conductor Rated Strength	Max. Resistance DC @ 20°C
International Size	(mm ²)	(mm)	(mm)	(kg/km)	(kN)	(kN)	(ohm/km)
HELSINKI	153.7	15.65	5.97	480	60.4	69.0	0.1860
COPENHAGEN	223.0	18.29	5.97	670	60.4	72.9	0.1279
REYKJAVIK	226.2	18.82	7.11	703	85.7	98.5	0.1263
GLASGOW	239.8	19.53	7.75	750	101.7	115.2	0.1192
CASABLANCA	276.7	20.50	7.11	843	85.7	101.3	0.1033
OSLO	317.7	22.40	8.76	992	130.2	148.0	0.0900
LISBON	318.6	21.79	7.11	957	85.7	103.7	0.0896
AMSTERDAM	371.3	23.55	7.75	1113	101.7	112.6	0.0769
BRUSSELS	425.3	25.15	8.13	1276	112.0	135.9	0.0672
STOCKHOLM	467.2	26.39	8.76	1406	130.2	156.4	0.6120
WARSAW	514.5	27.71	8.76	1539	130.2	159.1	0.0556
DUBLIN	528.8	28.14	9.53	1595	153.8	183.5	0.0541
HAMBURG	553.4	28.63	8.76	1647	130.2	161.3	0.0517
MILAN	574.7	29.11	8.76	1705	130.2	162.5	0.0498
ROME	599.5	29.90	9.53	1793	153.8	187.5	0.0477
VIENNA	636.2	30.43	8.76	1872	130.2	165.9	0.0449
BUDAPEST	675.3	31.50	9.53	2003	153.8	191.8	0.0424
PRAGUE	697.7	31.78	8.76	2050	130.2	169.4	0.0411
MUNICH	740.2	32.84	9.53	2190	153.8	195.4	0.0388
LONDON	766.0	33.40	9.78	2268	162.1	205.2	0.0373
PARIS	820.7	34.16	8.76	2386	130.2	176.3	0.0349
ANTWERP	951.9	36.86	9.78	2779	162.1	215.6	0.0301
BERLIN	1015.5	38.20	10.54	2974	188.3	245.5	0.0282
MADRID	1023.6	38.20	9.78	2977	162.1	219.7	0.0279

ACCC Extensively Tested Worldwide

Core Testing:

- 2.1.1 Tensile Testing
- 2.1.2 Flexural, Bending & Shear Tests
- 2.1.3 Sustained Load Tests
- 2.1.4 Tg Tests
- 2.1.5 CTE Measurements
- 2.1.6 Shear Testing
- 2.1.7 Impact and Crush Testing
- 2.1.8 Torsion Testing
- 2.1.9 Notched Degradation Testing
- 2.1.10 Moisture Resistance Testing
- 2.1.11 Long Term Thermal Testing
- 2.1.12 Sustained Load Thermal Testing
- 2.1.13 Cyclic Thermal Testing
- 2.1.14 Specific Heat Capacity Testing
- 2.1.15 High Temperature Short Duration
- 2.1.16 High Temperature Core Testing
- 2.1.17 Thermal Oxidation Testing
- 2.1.18 Brittle Fracture Testing
- 2.1.19 UV Testing
- 2.1.20 Salt Fog Exposure Tests
- 2.1.21 Creep Tests
- 2.1.22 Stress Strain Testing
- 2.1.24 Micrographic Analysis
- 2.1.25 Dye Penetrant Testing
- 2.1.26 High Temperature Shear Testing
- 2.1.27 Low Temperature Shear Testing

Mechanical Conductor Testing:

- 2.2.28 Stress Strain Testing
- 2.2.29 Creep Testing
- 2.2.30 Aeolian Vibration Testing
- 2.2.31 Galloping Tests
- 2.2.32 Self Damping Tests
- 2.2.33 Radial Impact and Crush Tests
- 2.2.34 Turning Angle Tests
- 2.2.35 Torsion Tests
- 2.2.36 High Temperature Sag Tests
- 2.2.37 High Temperature Sustained Load
- 2.2.38 High Temperature Cyclic Load Tests
- 2.2.39 Cyclic Ice Load Tests
- 2.2.40 Sheave Wheel Tests
- 2.2.41 Ultimate Strength Tests
- 2.2.42 Cyclic Thermo-Mechanical Testing
- 2.2.43 Combined Cyclic Load Testing
- 2.2.44 Conductor Comparison Testing

Systems & Hardware Testing:

- 2.4.55 Current Cycle Testing
- 2.4.56 Sustained Load Testing
- 2.4.57 Ultimate Assembly Strength Testing
- 2.4.58 Salt Fog Emersion Testing
- 2.4.60 Static Heat Tests
- 2.4.61 Suspension Clamp Testing
- 2.4.62 Thermo-Mechanical Testing
- 2.4.63 Cyclic Load Testing

Electrical Conductor Testing:

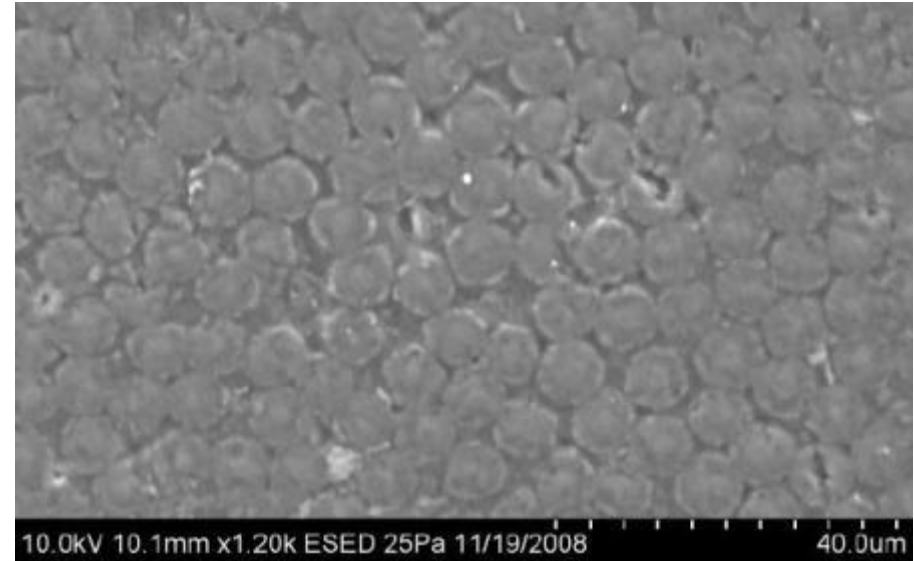
- 2.3.45 Resistivity Testing
- 2.3.46 Power Loss Comparison Testing
- 2.3.47 Ampacity
- 2.3.48 EMF Measurements
- 2.3.49 Impedance Comparison Testing
- 2.3.50 Corona Testing
- 2.3.51 Radio Noise Testing
- 2.3.52 Short Circuit Testing
- 2.3.53 Lightning Strike Testing
- 2.3.54 Ultra High Voltage AC & DC Testing

Field Testing:

- 2.5.64 Ambient Temperature
- 2.5.65 Tension, Sag, and Clearance
- 2.5.66 Conductor Temperature
- 2.5.67 Electric Current
- 2.5.68 Wind Speed and Direction
- 2.5.69 Solar Radiation
- 2.5.70 Rainfall
- 2.5.71 Ice Buildup
- 2.5.72 Splice Resistance
- 2.5.73 Infrared Measurements
- 2.5.74 Corona Observations
- 2.5.75 Electric and Magnetic Fields
- 2.5.76 Wind and Ice Load Measurements
- 2.5.77 Vibration Monitoring
- 2.5.78 Typhoon Test

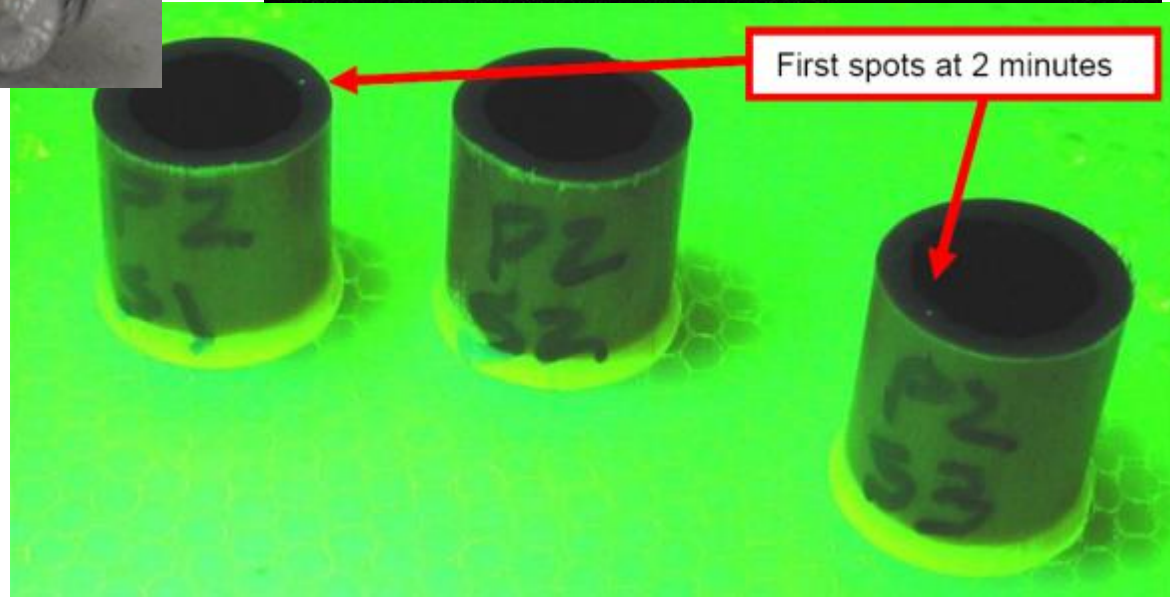
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Bending Tests



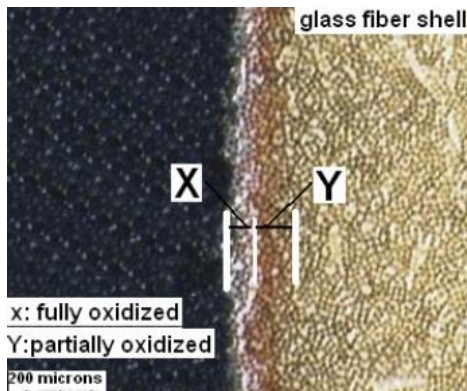
Conductor bent 90 degrees
10 times around a 6 inch
radius. No visual damage to
core was noted.

Dye penetrant did appear
after 2 minutes in the outer
glass strands showing some
degradation.



Thermal Oxidation Tests

Core sample cooked at 220°C for one year



Oxidation limited to ~60 microns in depth

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Irvine, California 92614 USA
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CTC GLOBAL

Ice & Wind Load Testing



Substantial Experience 30,000 km at >320 project sites



Countries:

- USA
- China
- France
- UK
- Poland
- Spain
- Portugal
- Mexico
- Chile
- Qatar
- Indonesia
- Belgium
- Brazil
- Germany
- South Africa
- South Korea
- Russia
- India
- Costa Rica
- Columbia
- Congo
- Mozambique
- Netherlands
- Nigeria
- Vietnam
- Malaysia

US Utilities:

- AEP
- APS
- PacifiCorp
- NV Energy
- Austin Energy
- Xcel Energy
- MI PUD
- KS PUD
- KAMO
- OG&E
- Ozark Electric
- WAPA
- STEC
- Entergy
- Riverside PUD
- Florida Power & Light
- Keys Energy
- Progress Energy
- Mohave Electric
- SCANA
- National Grid
- Alexandria (LA) PUD
- Duke Energy
- Oncor
- CIPCO
- Black Hills Power
- Com Ed
- TECO

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Ozark Electric Cooperative, Inc.
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energy
services

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Powering a world in progress

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POWER

MOHAVE
electric cooperative
A Touchstone Energy® Cooperative

GRUPO ice

amprion

AEP AMERICAN®
ELECTRIC
POWER

City Power
Johannesburg

ITC

国家电网公司
STATE GRID CORPORATION OF CHINA

IEG

OXY

edp

WATER | ENERGY | LIFE
CITY OF RIVERSIDE
PUBLIC UTILITIES

A few CTC's finish conductor producers

- *General Cable (USA)*
- *Lamifil (Belgium and Russia)*
- *Taihan Electrics Wire (South Korea)*
- *KMI (Indonesia)*
- *Starlite (India)*
- *Apar (India)*
- *Far East Cable (China)*
- *Unkomtech (Russia)*
- *EMTA (Turkey)*
- *I.M.S.A. (Latin America)*



New Line

Project Name: Orbita – Kaluga

Location: Russia

**Project Goal: Install New Line
for WV and Skoda factory**

Conductor Size: Brussels

Conductor Length: 320 km

Voltage: 220 kV

Energized: 2013



Reconductoring Project

Project Name: PacifiCorp 90 South to Oquirrh, Utah

Location: Kansas, USA

Project Goal: Increase Ampacity (use existing structures)

Conductor Size: Drake

Conductor Length: 30 km

Voltage: 138 kV

Energized: 2005

Over 100 existing structures saved

Heavy Ice Application

Project Name: NV Energy Line 107 (Reno to Carson City)

Location: Nevada, USA

Project Goal: Increase Ampacity (existing structures)

Conductor Size: Linnet

Conductor Length: 90 km

Voltage: 120 kV

Energized: 2009

Corrosive Marine Environment

Project Name: CFE Carmen to Noreste

Location: Mexico Bay

Goal: Increase ampacity reduce line sag, avoid corrosion

Conductor Size: Hawk

Conductor Length: 32 km

Voltage: 230 kV

Energized: 2009



Long Span Application

Project Name: Chilectra El Salto to Torre 8 Line

Location: Chile

Project Goal: Increase Ampacity – (existing structures)

Conductor Size: Linnet

Conductor Length: 28 km

Voltage: 110 kV

Energized: 2009

11/11/2009

Wind Farm

Project Name: NEO Energia 80 turbine upgrade

Location: Spain

Project Goal / Type: Increase Ampacity (existing structures)

Conductor Size: Amsterdam

Conductor Length: 57 km

Voltage: 66 kV

Energized: 2008

Extra High Voltage Application

Project Name: Amprion Gmbh

Location: Germany

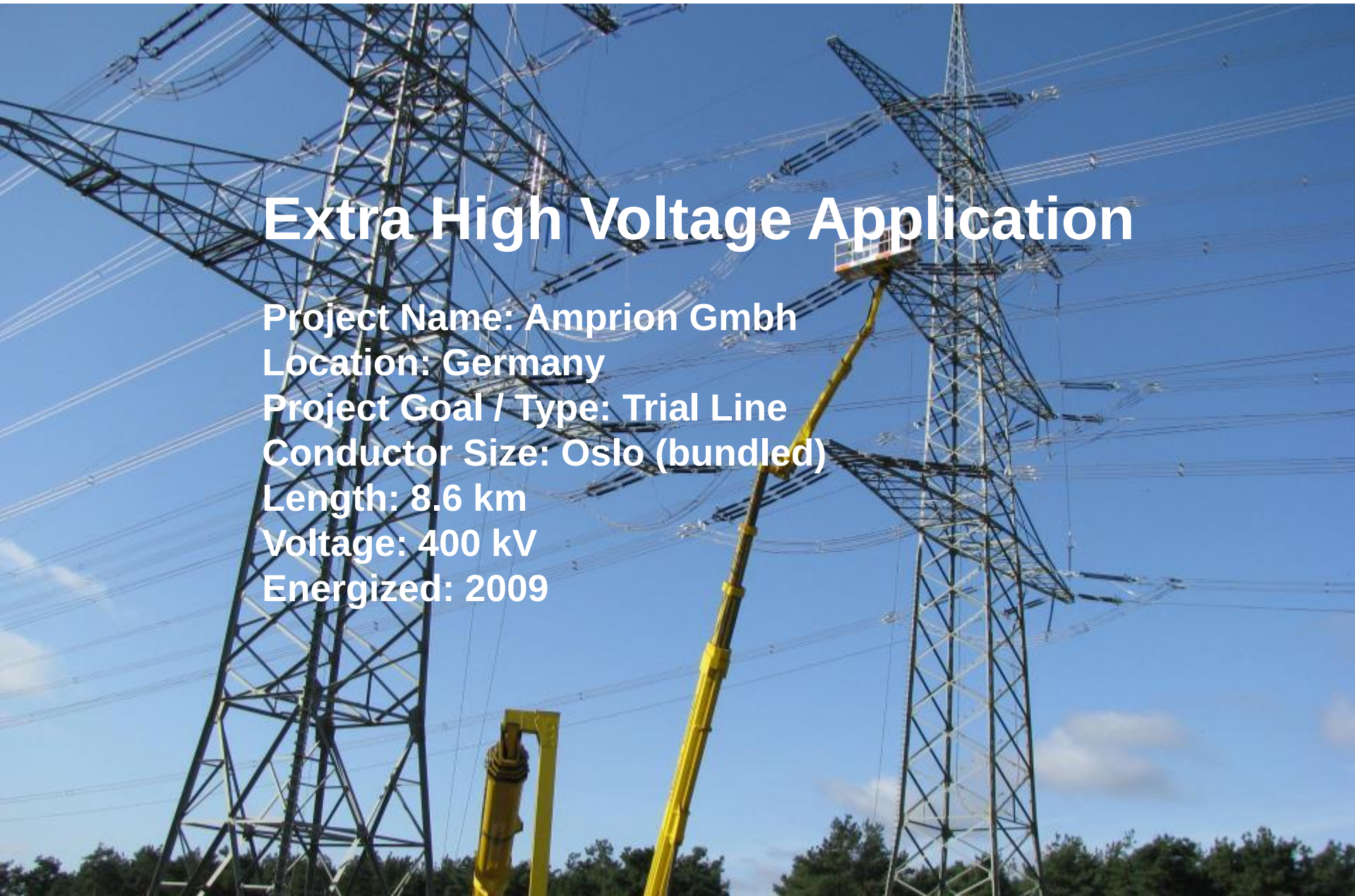
Project Goal / Type: Trial Line

Conductor Size: Oslo (bundled)

Length: 8.6 km

Voltage: 400 kV

Energized: 2009



Extreme Wind Survival

Project Name: NV Energy Line 107 (Reno to Carson City)

Location: Nevada, USA

Project Goal: Increase Ampacity (existing structures)

Conductor Size: Linnet

Conductor Length: 90 km

Voltage: 120 kV

Energized: 2009

100+ mph Winds: 2010 Conductor Undamaged

Extreme Wind Survival

Project Name: NV Energy Line 107 (Reno to Carson City)

Location: Nevada, USA

Project Goal: Increase Ampacity (existing structures)

Conductor Size: Linnet

Conductor Length: 90 km

Voltage: 120 kV

Energized: 2009

100+ mph Winds: 2010 Conductor Undamaged

Fire Storm Survival

Project Name: NV Energy Line 107 (Reno to Carson City)

Location: Nevada, USA

Project Goal: Increase Ampacity (existing structures)

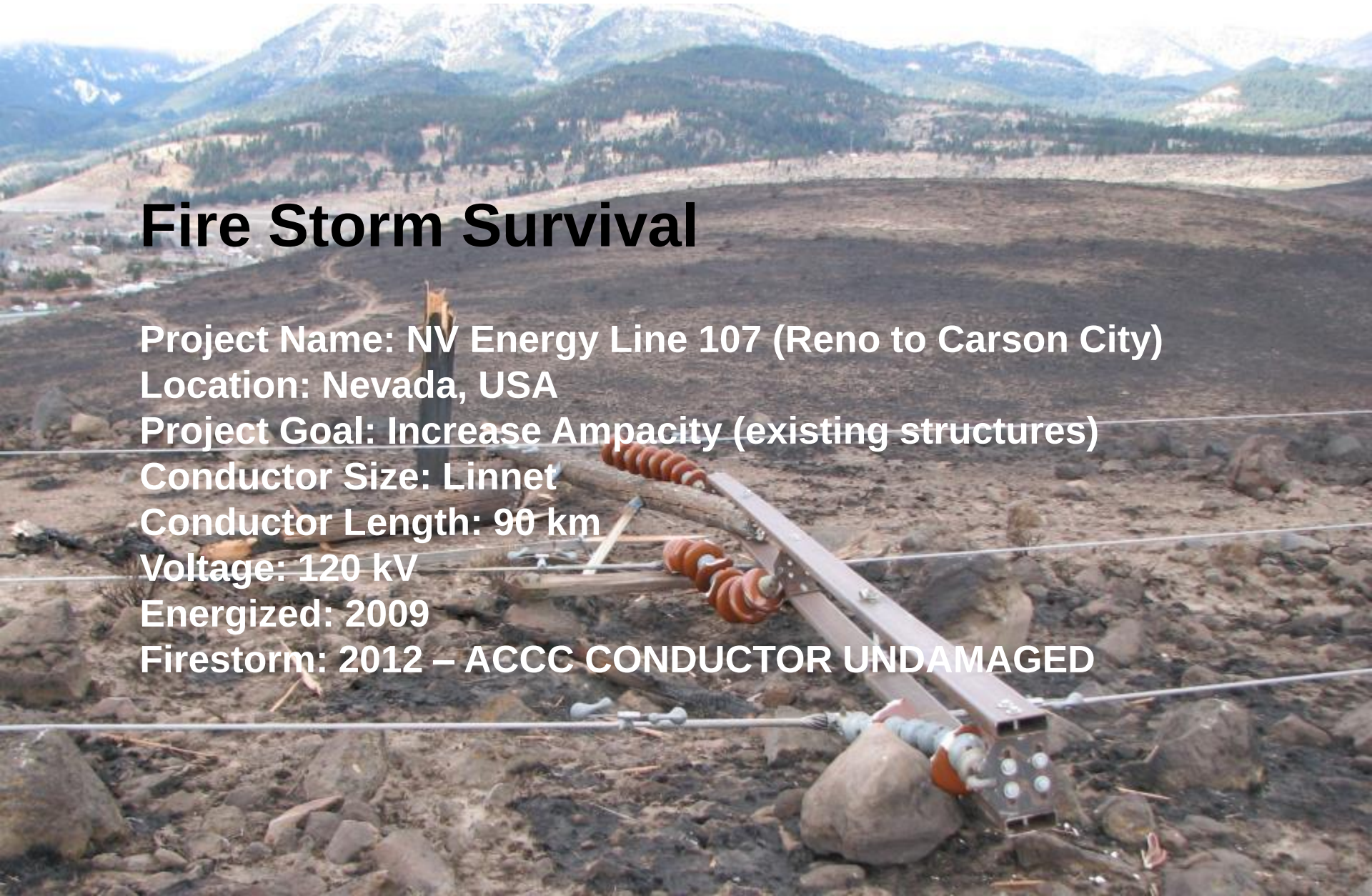
Conductor Size: Linnet

Conductor Length: 90 km

Voltage: 120 kV

Energized: 2009

Firestorm: 2012 – ACCC CONDUCTOR UNDAMAGED



River Crossing

Project Name: River Mondego

Location: Portugal

Project Goal: Increase Amps - Reduce Sag

Conductor Size: Amsterdam

Span Length: 475 Meters

Voltage: 60 kV

Energized: 2012



EF5 Tornado

Date: 20.05.2013

Location: Oklahoma, USA

Peak wind: 340 km/h

Line: 69 kV on steel monopoles to carry McClain power plant (OG&C)

Conductor: ACCC Drake (56 km)

Energized: 2006



CCP Software Program:

Conductor Comparison Tool for System Planners & Engineers



Conductor Information
CCP™

Type	ACCCB	ACSR	ACSS
Size (kcmil - Code Word)	1025 - Drake	795 - Drake	795 - Drake
Aluminum Area (kcmil)	1025.6	795.0	795.0
Diameter (in.)	1.108	1.108	1.108
Rated Strength (lbf)	41,200	31,500	25,900
Weight (lb/ft)	1.0518	1.0940	1.0934
DC Resistance at 20°C (ohms/km)	0.01634	0.02138	0.02078
AC Resistance at 25°C (ohms/km)	0.01689	0.02208	0.02160
AC Resistance at 75°C (ohms/km)	0.02017	0.02633	0.02574

Conductors per phase	1	1	1
Ampacity (A) at Temperature (°C)	100	100	170
Ampacity (A) at Rated Operating Temp (°C)	100	100	200
Ampacity (A) at Maximum Temp (°C)	200	100	250

Line Loss			
Steady-State Temperature (°C) at Peak Ampacity	85	101	99
First Year Line Losses (MWh)	25,326	36,055	35,155
ACCCB 1025 - Drake - Reduces First Year CO ₂ Generated by (MT)		6,055	5,494
ACCCB 1025 - Drake - Reduces First Year Line Losses by (MWh)		9,729	8,929
ACCCB 1025 - Drake - Reduces First Year Line Losses by (%)		27%	25%
ACCCB 1025 - Drake - Reduces First Year Line Losses by (\$/Year)		778,310	706,280
ACCCB 1025 - Drake - Line Loss Savings per ft of Conductor (\$/ft)		2.46	2.23
ACCCB 1025 - Drake - Reduces 30 year line loss by (\$)		36,115,374	32,881,729
ACCCB 1025 - Drake - Reduces 30 year CO ₂ generation by (MT)		289,948	256,571

Revenue Attainable during Peak Capacity (Limited by Max Sag)			
Peak Power Available for Delivery (10 hrs.) (MVA)	3,916	2,258	2,213
Potential Revenue for Power Delivered (\$)	3,132,993	1,806,516	1,770,667

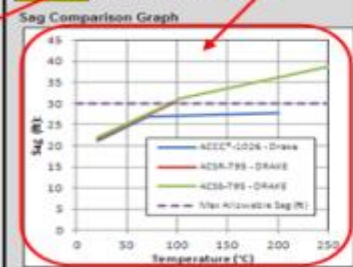
Initial Sag and Tension:			
% RTS	15%	20%	24%
Sag at Initial Sagging Temperature (ft)	21.30	21.70	22.00
Initial Tension at Sagging Temperature (lbf)	6,180.0	6,300.0	6,216.0

Sag/Tension at Above Stringing Temperature:			
Temp (°C)	85	101	99
Sag at Peak Operating Amps	27.00	30.60	30.90
Tension (lbf)	4,872.0	4,452.0	4,427.0
Temp (°C)	150	75	200
Sag at Rated Operating Temperature	27.60	27.90	36.20
Tension (lbf)	4,761.0	4,694.0	3,774.0
Temp (°C)	200	100	250
Sag at Maximum Temperature	27.70	30.60	38.70
Tension (lbf)	4,739.0	4,471.0	3,534.0
Max. Temp (°C)	200	95	91
Sag (ft)	27.70	30.10	30.00
Tension (lbf)	4,739.0	4,548.0	4,553
Ampacity (A)	1,847	1,029	1,006

Wind / Ice or Cold Temperature Sag/Tension:			
Sag (ft)	39.20	31.40	36.20
Tension (lbf)	11,705.0	14,796.0	

Units	Language	Voltage Type
US Units	English	AC
Environmental Inputs		
99.1	Sun Radiation (W/m²)	
30	Ambient Temp. (°C)	
2.00	Wind (ft/sec)	
1000	Elevation (ft)	
0.5	Water Absorptivity	
0.5	Emissivity	
90	Wind Angle (deg.)	
0	Azimuth of Line (deg=0, E=World)	
32	Latitude (neg = South)	
June	Month	
21	Day of Month	
12	Time (24 hrs.)	
Clear	Atmosphere	
Load and Generation Cost Assumptions		
20.64	Line Length (miles)	
132	Voltage (kV)	
1,033	Peak Op. Amps	
60%	Load Factor	
45%	Loss Factor	
212	Peak Power per Circuit (MW)	
3	Phase/Circuit	
80	Cost of Energy Generation (\$/MWh)	
1,372	CO ₂ (lb/MWh)	
1%	Load Increase/Year	

Initial Sag and Tension:		
1000	Rating (ft)	
21	Initial Sagging Temperature (°C)	
30.5	Maximum Allowable Sag (ft)	



Wind / Ice Conditions	
-5	Temperature (°C)
0.0	Windspeed (mph)
0.00	NESC K-Factor (lb/ft)
1	Radial Ice Thickness (in.)
57.0	Ice Density (lb/ft³)

1. Select Conductors
2. Input Ambient Conditions
3. Compare Ampacity & Temp
4. Input Elect. Load Parameters
5. Assess Line Loss Reductions
6. Evaluate Line Loss Savings
7. Realize Emission Reductions
8. Note Peak Load Revenue
9. Assess Conductor Tension
10. Compare Conductor Sag

CTC Global created CCP™ to help system planners and engineers compare the ampacity, line losses, thermal and ice load sag, and economic aspects of nearly any conductor type and size, so the numerous advantages of the ACCB® conductor can be fully realized.

The user simply selects the conductor types and sizes from drop down menus and enters the appropriate values & assumptions highlighted in the yellow boxes. The program is fully functional and uses standard industry formulas (such as IEEE 738-2006). Outputs are readily comparable to Sag10®, PLS CADD™ and other similar programs. For a copy of CCP™ please contact:

applicationsupport@ctcglobal.com

CTC GLOBAL

ACCC Engineering Manual:

Engineering
Transmission Lines
with High Capacity Low Sag
ACCC[®] Conductors



CTC CABLE
First Edition

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