THE AUSTRALIAN EXPERIENCE: WORKS OF AN AUSTRALIAN ELECTRICAL SUPPLY ENTITY

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In Australia, the electricity supply system has three interconnected components – generation, transmission and distribution. Electricity is generated at power stations which use various resources – fuels such as coal, gas, oil, or biomass, water, wind or solar. The electricity is increased in voltage at the power stations and fed into the high-voltage transmission network which transports electricity to the many distribution networks. The voltage of the electricity is progressively reduced at a series of sub-stations spread throughout the networks until it is at its final voltage of 230V - 240 V for supply to homes and businesses. Separate electrical entities cover each of the three components of power generation, transmission and distribution.

Generation Entities

The five types of electricity generation most commonly used in Australia are coal fired; open cycle gas fired; combined cycle gas fired; hydroelectric; and wind. Around 75% of Australia's power generation comes from coal, 15% from gas, 5% from hydro and 5% from other sources. About 200 large electricity generators operate in the National Electricity Market, with the largest generators being Macquarie Generation in NSW with 4844MW capacity, followed by Delta Electricity in NSW at 4547MW, the combined Snowy Hydro in NSW and Victoria at 4269MW, Stanwell Corporation in Queensland at 3251MW and CS Energy in Queensland at 3154MW. The mix of generation capacity consists of baseload, intermediate and peaking power stations. In 2008/09 the generators produced 266 billion kilowatt hours of electricity. Demand is expected to increase this requirement by 25% by 2014/15.

Transmission Entities

Transmission networks transport electricity from generators to distribution networks. A transmission network consists of towers and the wires that run between them, underground cables, transformers, switching equipment, reactive power devices, and monitoring and telecommunications equipment. In Australia, transmission networks consist of equipment that transmits electricity at or above 220kV, along with assets that operate at 66-220kV that are parallel to, or provide support to, the higher voltage transmission network. In Australia, there are transmission networks in each state and territory, with cross-border interconnectors that link some networks. Australia has 8 transmission entities with 50,000kms of lines that transmitted more than 250,000 GWh in 2009. The 8 transmission entities are Powerlink, Queensland; TransGrid and EnergyAustralia, NSW; SP AusNet, Victoria; ElectraNet, SA; Transend, Tasmania; Western Power, WA; and Power and Water, NT. TransGrid, Powerlink and SP AusNet make up more than 70% of total transmission. In addition, 3 Interconnectors, Directlink, Murraylink and Basslink transfer power between state borders for Queensland, NSW, Victoria, SA and Tasmania.

Distribution Entities

Distribution networks move electricity from transmission networks to residential and business customers. A distribution network consists of the poles, underground channels and wires that carry electricity, as well as substations, transformers, switching equipment, and monitoring and signalling equipment. Distribution networks criss-cross urban and regional areas to provide electricity to customers at around 230-240 volts. The total length of the distribution infrastructure is around 860,000 kilometres. Australia has 16 major electricity distribution

networks providing power to almost 11 million customers with around 170,000 GWH delivered in 2009. The 16 electrical distribution entities are ENERGEX and Ergon Energy, Queesland; EnergyAustralia, Integral Energy, Country Energy, ActewAGL, NSW; Powercor, SP AusNet, United Energy, CitiPower, Jemena, Victoria; ETSA Utilities, SA; Aurora Energy, Tasmania; Western Power, Horizon Power, WA; Power and Water, NT. The four largest entities by energy delivered are EnergyAustralia at 31,000 GWH, ENERGEX at 21,000 GWH, Integral Energy at 18,000 GWH and Ergon Energy at 15,000 GWH.

Regulatory Controls

Each state and territory in Australia is responsible for applying electrical safety laws to the generation, transmission and distribution entities within their state or territory boundaries. These laws are however reasonably well harmonised. States and territories apply laws through Acts of Parliament, Regulations, Codes of Practice and adoption of Australian Standards.

Using the Queensland laws as an example, the *Electrical Safety Act 2002(the Act)* is directed at eliminating the human cost to individuals, families and the community of death, injury and destruction that can be caused by electricity. The Act sets out obligations that entities, employers, employees, workers, designers, manufacturers, importers and persons in control of electrical equipment must meet in order to comply with the requirements of the law.

All electrical generation, transmission and distribution entities, have the following obligations as contained in s. 29 of *the Act*:

1. "An electricity entity has an obligation to ensure that its works –
    a. Are electrically safe; and
    b. Are operated in a way that is electrically safe.

2. Without limiting subsection 1, the obligation includes the requirement that the electricity entity inspect, test and maintain the works."

S. 25 of *the Act* defines "works, of an electricity entity, means the electrical equipment, and electric line associated equipment, controlled or operated by the entity to generate, transform, transmit or supply electricity."

The *Electrical Safety Regulation 2002 (the Regulation)* prescribes requirements to meet obligations under *the Act*. The purpose of *the Regulation* includes ensuring electrical safety of electrical workers, other workers, contractors, consumers and the general public, ensuring a safe supply of electricity and ensuring electrical equipment hired or sold is electrically safe.

Part 7 of *the Regulation* relates specifically to "Works of an electrical entity". This part prescribes a way of discharging the electrical safety obligations quoted above. In particular, under s. 131 of *the Regulation* the following requirements apply for the works of an electrical entity:

1. "the works must be able to perform under the service conditions and the physical environment in which the works operate;
2. the works must have enough thermal capacity to pass the electrical load for which they are designed, without reduction of electrical or mechanical properties to a level below that at which safe operational performance can be provided;
3. to the greatest practicable extent, the works must have enough capacity to pass short circuit currents to allow protective devices to operate;
4. the works must have enough mechanical strength to withstand anticipated mechanical stresses caused by environmental, construction or electrical service conditions;
5. the works must be:
    a. designed and constructed to restrict unauthorised access by a person to live exposed parts; and

b. operated in a way that restricts unauthorised access by a person to live exposed parts;

6. design, construction, operation and maintenance records necessary for the electrical safety of the works must be kept in an accessible form;
7. parts of the works whose identity or purpose is not obvious must be clearly identified by labels, and the labels must be updated as soon as possible after any change is made to the works; and
8. electrical equipment intended to form part of the works of an electrical entity must undergo commissioning tests and inspection to verify that the electrical equipment is suitable for the service and can be operated safely when initially installed or altered."

The Regulation also covers areas such as earthing and protection; substations; electric lines and control cables; termination requirements for low voltage overhead service lines; maintenance of works; connections; testing; licensing requirements; clearance heights; and incident notifications.

Where *the Act* or *Regulation* prescribes a way of discharging an electrical safety obligation, the entity must follow what is prescribed. Failure to discharge these obligations carries substantial penalties of up to AUS$1 million (HK$7.5 million) or 3 years imprisonment.

A Code of Practice is a document made under *the Act.* It gives practical advice on ways to discharge electrical safety obligations. Included in a code are ways to identify and manage exposure to risks of injury and property damage caused directly, or indirectly, by electricity. In regard to a Code of Practice, an electrical entity can either follow the procedures contained in the Code or design an alternate solution that is equally effective to, or more effective than the Code.

Queensland has five Codes of Practice – Risk Management; Working Near Exposed Live Parts; Works; Electrical Work; and Electrical Equipment Rural Industry.

The *Electrical Safety Code of Practice 2010 – Works* relates specifically to electrical supply entities and provides practical advice for an electrical entity on how to manage electrical safety risks associated with earthing systems, underground cable systems and supporting structures of overhead lines forming part of the works of an electrical entity.

Safety Management Systems

Across Australia, electrical entities are required by law to implement a safety case or safety management system. In Queensland s. 66 of *the Act* requires that a prescribed electrical entity, other than a generation entity, must prepare a Safety Management System (SMS). Details of the SMS are then contained in Part 9 of *the Regulation*, which prescribes that the SMS must contain details of:

- the system's safety objectives;
- the systems and procedures by which the objectives are to be achieved;
- the performance criteria to be met;
- the way in which adherence to the performance criteria is to be maintained.

Under *the Act* a safety management system must be described in a written document that:

a. comprehensively details the hazards and risks associated with the design, construction, operation and maintenance of an entity's works;
b. details how the entity will manage these hazards and risks to ensure that it discharges its electrical safety obligations; and
c. details what the entity will do to ensure that contractors for the entity will comply with the requirements of the system.

The document must be prepared in consultation with persons broadly representative of industrial organisations of employees and with principal or primary contractors of the entity. An SMS must comply with the requirements in *the Regulation* on how it is to be developed, updated, lodged, audited and validated. The SMS must be audited annually by an accredited SMS Performance auditor (from a list supplied by the regulator) who must verify:

a. continued legislation compliance of the SMS documentation;
b. that the SMS is achieving its objectives;
c. that the SMS is adhering to and maintaining the performance criteria;
d. that the auditing system of the prescribed entity's SMS is effective;
e. that any modification compliance audits have been done where necessary; and
f. that the entity is giving effect to the SMS.

Failure to prepare and implement an appropriate SMS carries penalties of up to AUS$200,000 (HK$1.5 million).

Protection of Supply Lines

Part of the obligations of a supply entity is that their works must be designed, constructed and operated in a way that restricts access to unauthorised persons. However, regulatory rules are also in place to prohibit third parties from coming into contact with supply lines whether the lines are overhead or underground. S. 40 of *the Act* makes it an obligation on all persons to comply with instructions of an electrical entity in regard to its assets and it is an offence to wilfully interfere with or misuse any assets. Breach of these requirements is a prosecutable offence.

S. 208 of *the Regulation* specifically makes it an offence for a person to climb a power pole, ladder attached to a pole or any structure of an electrical entity without authorisation. Climbing a pole, ladder or other structure carries a penalty of up to AUS$20,000 (HK$150,000).

Part 4 of *the Regulation* also provides obligations and rules relating to working around electrical parts, particularly overhead and underground power lines. This part of *the Regulation* applies exclusion zones for persons, operating plant and vehicles, so that they do not enter prescribed distances from the live line, without consulting with the asset owner and then putting in place a safe system of work. Penalties for breach, including not consulting with the asset owner, can be up to AUS$20,000 (HK$150,000).

These rules include the operation of cranes, tip trucks, or agricultural equipment near overhead lines, for temporarily raising lines to transport high loads, for clearing vegetation growth near overhead lines and for excavation work in regard to underground lines.

Above all, the rules require that when any work is being done near power lines the business must consult with, and provide written notice to the entity asset owner on how they will ensure electrical safety of persons and property. The size of the exclusion zone differs considerably depending on the voltage of the power line, whether it is insulated or bare, the work being undertaken, and the type of operating plant or vehicle. The exclusion zone can be up to 8 meters for 400kV.

s. 62 of *the Regulation* also requires persons who intend to do excavation of digging work to "find out from an appropriate source what underground electrical services are at or near the location where the work is to be done" and to implement appropriate "control measures necessary to prevent any person's exposure to the risk of death, illness or injury from contact with, or damage to, the underground service". A Dial-Before-You-Dig telephone and web based service is available in all Australian cities.

Line Damage Case Study

The power supply system to the inner-metropolitan area of Sydney, including the Central Business District (CBD) is supplied by a large number of high voltage (132kV and 330kV) underground cables. An 11kV distribution system emanates from five CBD zone substations with distribution transformers, each with high voltage and low voltage control devices that connect to a low voltage switchboard. The CBD is the commercial and financial heart of Sydney, a city of 4 million people.

Between 30 March 2009 and 28 April 2009, three incidents on the network led to substantial power outages. The primary cause of two of these incidents was damage to underground cables by third parties. In the first incident, a 132kV feeder cable was damaged by mechanical excavation equipment and in the third incident another 132kV feeder cable was damaged by horizontal boring works. These outages resulted in power loss, major traffic disruption, significant numbers of automatic fire alarms going off, a large number of required lift rescues and increased risks of fire from use of diesel generators.

In response to these incidents, the NSW Regulator, in association with EnergyAustralia (the network operator) has undertaken multiple investigations and implemented a number of preventative measures and actions. These include:

1. an increase in the number and frequency of feeder route patrols;
2. increased security at substations and technicians on standby;
3. tightened legislative rules in regard to excavations near cables;
4. deployment of Inspectors to observe and monitor major excavation activity;
5. replacement of inter-tripping relays;
6. improve communication with building site managers;

Major Incidents involving supply assets

In the eight years from 2000/01 to 2007/08 there have a total of 77 fatalities in Australia involving electrical supply assets. Of these fatalities, 72 or 93.5% involved overhead conductors, 3 or 3.9% involved equipment in substations and 2 or 2.6% involved underground cables. Over the same period of time, 20% of the fatalities were electrical workers, 51% were non-electrical workers and 29% were the general public. Examples of some of these fatalities include:

1. a male was walking home at night and contacted an overhead line that had fallen during a storm;
2. a farmer received a fatal electric shock when an irrigation pipe was raised into an 11kV line;
3. the victim received a fatal shock when erecting an extended television antenna approximately 10 metres high that extended into a 22kV overhead conductor.
4. a fencing contractor received a fatal electric shock when he penetrated a heavy duty underground cable with a post hole digger.
5. a construction worker received a fatal electric shock when a boom of a concrete pump contacted high voltage power lines.
6. the victim received a fatal shock when freeing a kite from a power line.
7. a rigger received a fatal shock through induction when installing a new line adjacent to a live high voltage line.
8. an entity worker received a fatal shock when repairing an 11kV line after storm damage.

Victorian Bushfires Experience

Australia has a history of electrical assets causing bushfires, particularly from fallen conductors, conductors contacting trees, clashing of conductors and inefficient fuses. Fires causing significant loss of life and property damage have previously occurred in 1969, 1977 and 1983.

On 7 February 2009, after 3 days of temperatures in excess of 43 degrees C the state of Victoria experienced 15 major fires that resulted in 173 deaths and an estimated AUS$4 billion (HK$30 billion) in damage. This was by far the fire with the greatest level of death and damage seen in Australia. Of the 15 major fires, five were caused by failed electricity assets. Among these fires was the one at Kilmore East, a result of which 119 people died. The Kilmore East fire resulted from conductor failure caused by fatigue on a SWER (single-wire earth return) line. Other fires were caused by fallen conductors due to a failed pole cap, and fatigue and corrosion leading to a broken tie wire and as a consequence of a failed conductor.

In response to the bushfires the Victorian Government established a Royal Commission to undertake an investigation into the causes of the bushfires and to make recommendations on future actions to avoid similar occurrences. The Royal Commission released its report on 31 July 2010, making 67 recommendations relating to Bushfire Safety Policy; Emergency and Incident Management; Fireground Response; Electricity-Caused Fire; Deliberately Lit Fires; Planning and Building; Land and Fuel Management; and Administrative Matters.

The Commission was critical of the age profile and maintenance levels of the electrical assets, in particular the number of poles at more than 50 years of age, the average age of conductors at between 41 and 45 years of age, the number of tie wires at more than 40 years of age and the average age of insulators at 40 years. In regard to Electricity-Caused Fires, the Commission made 8 recommendations:

1. The progressive replacement of all SWER lines and 22kV distribution feeders with aerial bundled cables, underground cables, or other technology that reduces bushfire risk;
2. Distribution businesses to inspect all SWER and 22kV feeders in bushfire areas at least once every 3 years;
3. Distribution businesses ensure that asset inspectors are provided with adequate theoretical and practical training on asset inspection;
4. Distribution businesses adopt, as part of their management plans, measures to reduce the risk of hazard trees, including those outside the clearance zone that could come into contact with an electric power line;
5. Municipal Councils to identify hazard trees as part of their fire prevention plans and to notify electrical entities of the hazard trees;
6. Distribution businesses to disable the reclose function on the automatic circuit reclosers on all SWER lines for the six weeks of greatest fire risk each fire season; and to adjust the reclose function on the automatic circuit reclosers on all 22kV feeders on all total fire ban days to permit only one reclose attempt before lockout;
7. Distribution businesses to fit spreaders to any line with a history of clashing; and to retrofit all spans that are more than 300 metres long with vibration dampers;
8. The State Government strengthen the regulatory framework for electricity safety in relation to prevention and mitigation of electricity-caused bushfires.

The Victorian Government responded to the recommendations of the Royal Commission on 27 August 2010 with acceptance in full or in part to 66 of the 67 recommendations. In regard to the recommendation relating to electricity-caused fires the Government has agreed to a tougher maintenance regime, more inspections, tougher penalties, testing of replacement technologies and the establishment of a new Powerline Safety Taskforce to examine and trial technology options proposed by the Commission including aerial bundled cables and under grounding power.

Technology
While there are a number of areas where technological improvements can improve safety, there are currently two technological advances that are being trialled in Australia.

Resonant earthing is a well established form of system earthing in Europe with applications ranging from 11kV to beyond 220kV in various networks including rail, mining, distribution and transmission. Recent technological advances have been made in power electronics, resulting in a step increase in performance.

The *Ground Fault Neutraliser* is such a resonant earthing device that reduces the amount of electrical arcing at the point where a fault occurs on the network. The device also allows for the early detection of reduced insulation levels and can significantly reduce the threat to human life and risk of fire when a ground fault occurs.

Initial research has identified that the *Ground Fault Neutraliser* has the ability to improve reliability for electricity corporations as well as having considerable potential to improve electrical safety in relation to contact with overhead powerlines. Trials currently under way in Australia have found that for reliability it will reduce customer outages, transient earth faults become self clearing, and there is a reduction in secondary damage. Trials also find that for safety, the fault current and fault voltage are minimised, it reduces conductor clashing and plant failure, reduces probability of flash burns, improved 'step & touch' voltage performance, fault detection sensitivity is improved, and the *Ground Fault Neutraliser* will compensate faster than conventional protection.

The other technological advancement that is being trialled in Australia is the *IntelliRupter PulseCloser* which injects multiple, non disruptive pulses into the line to check for faults before initiating a close operation. This technology eliminates the equipment-damaging stresses associated with power restoration using conventional reclosers thus extending the life of lines, transformers, and circuit breakers. The *IntelliRupter* features a base-integrated control that is accessed for configuration and operation via a secure WiFi link.

Initial trials suggest that this innovative approach improves reliability, operator safety and convenience, and significantly enhances security and reduces the risk of fires.

In addition, Australian electrical entities are also trialling overhead electrical powerline proximity warning devices, intended to warn personnel if mobile equipment moves within pre-selected minimum distances from an overhead line.

Renewable Energy
Australia is rich in renewable energy resources such as solar, geothermal, biomass, wind and hydro. Australia has a target of 20% of Australia's electricity supply is to come from renewable energy sources by 2020. Renewable energy is a clean energy source that can be replenished naturally and used to produce electricity with minimal or nil greenhouse gas emissions.

To assist in meeting this target, in mid 2009, the Australian Government announced a AUS$4.5 billion (HK$33.75 billion) Clean Energy initiative that included:

- AUS$1.6 billion (HK$12 billion) for large-scale solar power stations; and
- AUS$465 million (HK$3.5 billion) for Renewables Australia to promote the development, commercialisation and deployment of renewable technologies.

In June 2010 the Queensland Premier announced funding for the largest solar project in the southern hemisphere with the Kogan Creek Solar Boost Project that will use solar technology to heat feedwater entering the boiler, supplementing the conventional coal-fired feedwater heating process. This means that steam that was previously diverted from the feedwater

system can instead be used to generate extra electricity. The benefit of this project is that it will allow the power station to produce more electricity with the same amount of coal, making the coal-fired plant more fuel efficient and reducing its greenhouse intensity.

Ministerial Council Review

The Ministerial Council of Energy (MCE) in December 2009 agreed to initiate a harmonisation review after the Commonwealth Government committed to work with state and territory governments and the energy supply sector to improve consistency of state-based occupational health and safety rules for the electrical supply industry.

To facilitate this review, governments in December 2010 signed an Intergovernmental Agreement on Energy Supply Industry Safety to:

1. develop a single National Standard for work practices within the electrical supply industry; and
2. Implement a "passport" mobility program to ensure line worker's maintain a documented training and work experience journal that aids in movement between electrical entities.

While work has commenced on both the "passport" and national standard, it is anticipated that this review will take some two to three years to complete.

Summary

In summary this paper outlines:

- Safety Regulations are in place to ensure that entity works are electrically safe and that they are inspected, tested and maintained regularly.
- Failure to discharge obligations can be met with substantial penalties.
- All entities must implement a Safety Management System that is documented and audited annually.
- In the last 8 years there has been 77 fatalities involving electrical supply assets with non-electrical workers being the highest category.
- Protection of supply assets, whether it be from third-party damage or natural disasters is an ongoing problem, with recommendations already being made to underground supply lines.
- Technological advancements are being looked at that will deliver both in terms of safety and reliability.
- Renewable energy sources, particularly solar, are being implemented to improve our carbon footprint.
- We are looking at introducing a single National Standard for supply industry workers.