Environmentally Sensitive Electricity Infrastructure and the 1989 Newcastle Earthquake

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Abstract

In the mid-twentieth, the inherited electricity transmission system had come to be regarded as visual pollution, particularly in urban areas. Affordable, more environmentally sensitive electricity infrastructure had started to be designed, manufactured, constructed and installed. The new electricity infrastructure at the local level reduced neighbourhood environmental impacts. The visual impact of new switchyards and substations was reduced using low profile electrical equipment. In 1971 NSW government created its first Ministry of Environment Control. It instigated an industrial designer to review and report into the visual impact of the NSW electricity transmission system. During the 1989 Newcastle earthquake the low profile structures were found to be more resistant to earthquake damage. After the 1989 Newcastle earthquake an unintended consequence of the low profile equipment was that it was easier to inspect and repair than the taller electrical equipment.

Keywords: earthquake, electricity, substation, visual pollution, environmental impact, low profile.

1. INTRODUCTION - ENVIRONMENTAL AWARENESS

The mid-twentieth century brought a significant increase in environmental awareness worldwide. The visual impact of the electricity transmission system had become a public relations crisis. The first NSW government Minister of Environment Control was appointed on 11 March 1971 (Parliament of NSW, 2019) in fact the first in Australia. Industrial designers at the time produced successful aesthetic industrial, commercial and consumer product designs. The minister instigated an industrial designer to review and report on the NSW electricity system and its environmental impact (Ryan, 1973).

2. UNDERGROUND CABLES

Early environmentalists ideally wanted to put *all* electricity cables underground out of sight. This included long distance high voltage transmission lines and overland towers but this is extremely costly (Flinchum, 1997). In the early 1970's the NSW government made it mandatory to put urban electricity cables underground (McIlwraith, 1997). In the past 50 years, however, there has actually been very little progress in placing the existing overhead cables underground. Only new housing developments and apartments, urban centres, and commercial business districts have been placed underground. In a backward step, to lower costs, early fibre optic cables were added to existing urban electricity poles. The recent National Broadband Network large scale rollout of underground cables shows the high costs involved .

In the 1989 Newcastle earthquake, electricity operators had expected underground high voltage cables to be damaged. The underground cables in the Newcastle area survived the earthquake (with only one cable being suspected of being damaged and therefore it was tested) (Caldwell, 2009).

3. AESTHETIC POWER POLES

A much more economic alternative to placing cables underground was to improve the visual appearance and the placement of pole and tower assemblies. In the late 1960's and early 1970's, serious attempts were made by American industrial designers, such as Henry Dreyfuss Associates for the Edison Electric Institute, to design aesthetic pole and tower assemblies, figures 1 and 2, from 1966 to 1968 (Flinchum, 1997); (Levy, 1997). Similar attempts were made by NSW industrial design consultants and electricity industry engineers (Ryan, 1973).

Some pole and tower designs were not successful due to their higher cost involved and, ironically, they were considered to be too visually prominent, for example, those in figure 1 and figure 2. Hybrid single pole designs with a simpler, stronger structure, with selected colour finishes, at a more acceptable higher cost to conventional poles were adopted. Due to their extra costs, especially in the case of the very tall high voltage tapered poles, they were only adopted at visually critical locations.

Where a high voltage transmission line crossed a highway, only two aesthetic tall poles and insulators immediately adjacent to each side of the highway corridor and within vehicle drivers' narrow field of view would be used. Similarly, a supply line along a main road would use aesthetic wood poles and insulators only on bends where they are in the direct sight lines of drivers and pedestrians. Otherwise standard poles would be used to save on costs.

Figure 1. Scale model of proposed steel tower design 230kV for Edison Electric Institute 1966 -1968 (Flinchum, 1997).

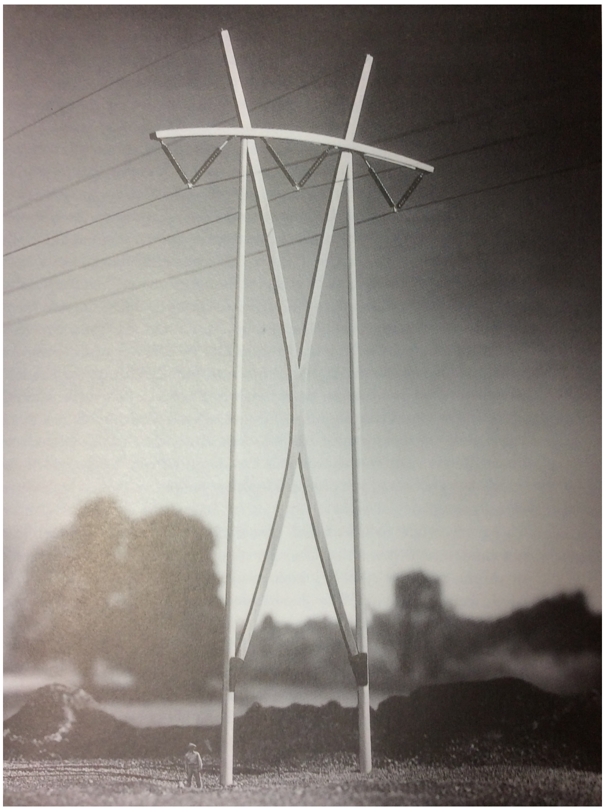

Figure 2. Scale model of proposed wood pole design 230kV for Edison Electric Institute 1966 -1968 (Flinchum, 1997).

The Newcastle electricity system has a mixture of pole and tower types. Hence there will be a mix of performance and interaction in an earthquake. Since the environmentally sensitive poles and towers are placed in critical locations adjacent to roads and crossing roads, failure in an earthquake could have a great impact.

4. LATTICE TOWERS

Older style straight-sided and parallel-sided steel lattice towers, that were visually unpopular last century, are still used. They appear to have become more acceptable over time, even in urban areas, perhaps due to their familiarity.

New computer aided design (CAD) tapered towers are visually more acceptable. In the 1990's, Transfield engineers developed a standardised range of tapered high tensile steel lattice towers using CAD software. Their tower range is highly functional and they can be tailored to cater for specific locations and stresses. In an earthquake the CAD tower performance is more predictable.

5. TAPERED STEEL POLES

Standard wooden straight-sided poles have uneven material strength (material defects) along the poles that can affect earthquake performance and their top assemblies have negative visual impact. Some newer standard poles were coloured green to have more visual appeal. The solution to both strength issues and environmental appeal was to use freestanding strong coated tapered steel poles, figure 3, such as at street corners, road bends, and at the end of overhead lines. Rather than wooden poles with bracing, the tapered poles are self-supporting. The tapered poles appear more natural (in strength and appearance). The poles earthquake performance depends on their foundations.

6. MERCURY SWITCHES

One major 1989 Newcastle earthquake failure was caused by the transformer safety switches. The transformer's mercury safety switches were intended to protect the transformers if there was a problem *within* the transformer. In the 1989 earthquake, the mercury switches were *externally activated by the earthquake* causing *unintended* trips of many still working transformers (Caldwell, 2009). Consequently the electricity supply was unintentionally cut off to many parts of Newcastle and even further away to the north, west and south. Although this was a problem for the electricity system supply and operation, in fact badly damaged local areas were temporarily electrically isolated which provided immediate electrical safety for people and properties. Nevertheless less damaged areas and widespread undamaged locations suffered unnecessary lack of electricity supply.

Figure 3. Tapered steel electricity pole painted green at a street corner. The tapered pole has lightning protection above electricity conductors and fibre optic cable below them. Dibbs Street and Gow Street, Adamstown, Newcastle (photo 2019).

Figure 4. Rigid horizontal insulators in two configurations, alternate sides and same side, along Pacific Highway A43 (was numbered 1), Newcastle (photo 2019).

7. AESTHETIC INSULATORS

The other major failure of the power system in the 1989 Newcastle earthquake, 'was the widespread failure of porcelain insulators, particularly on the *tall*, higher voltage plant'. As many porcelain insulators broke and fell, the mercury switches activated unintended trips, avoiding substation major short-circuits. (Caldwell, 2009).

One major change brought about by environmental considerations was insulator angles. The traditional insulator application is hanging down insulators. New low profile equipment used stronger standing or horizontal projecting insulators, figure 4. The simpler upward and outward projections appear more natural, like tapered trunks and branching of trees. Their earthquake performance was better than the traditional design insulators.

8. SUBSTATION LOW PROFILE EQUIPMENT

New substations must consider local views amongst other environmental factors and regulations. For example, the 2018 proposed Summer Hill Zone Substation, Summer Hill, Sydney, NSW considered the visual impact of the substation upon its neighbours and streets (Gencur, 2018).

The low profile substations are less visually dominant of the local neighbourhood. In Newcastle, the urban substation at Edgeworth has a low visual impact. Referring to figure 5, some of the design features are noted here. In the centre, fenced urban substation with low profile equipment and plain steel roofed brick building. Nearby, two low tree screened approaches. One screen in front of substation near on Main Road and adjacent to creek reserve south of the road. A second screen after substation along Charles Street a western side road with urban housing. At the southern rear are areas of larger trees. The northern location of the figure 5 photograph, on the opposite side of the six lane Main Road, is a park reserve of the creek. There is some reduced concentration of overhead conductors by using underground cables to dispersed poles.

Low profile equipment substation earthquake performance was better than the taller substation equipment. (Caldwell, 2009).

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Figure 5. Urban substation with low profile equipment and some underground cables. Main Road and Charles Street, Edgeworth, Newcastle, (photo 2019)

9. CONTROL CABLES

The 1987 enlarged Glenbawn Dam on the Upper Hunter river, north of Newcastle, NSW, was designed for magnitude 4 earthquake. The dam survived the 1989 earthquake. The dam has an earthquake monitor located on the southern shoulder.

The later added Glenbawn hydroelectric power generation plant is designed for very high operational forces. An emergency shutdown results in large forces on twin water turbines and an electricity generator embedded in reinforced concrete. The facility design can easily resist small earthquake events. The hydropower construction contract specified the facility should be earthquake resistant. The American Society of Civil Engineers hydropower design manual recommend using longer control cables (loose cables) and bolted down control cabinets.

10. SUBSTATION INSPECTION AND REPAIR

In fact, it turned out, as an unintended consequence was that, similar to the mercury safety switches, the environmentally sensitive low profile equipment was actually easier to inspect and repair than taller equipment. Substation access from the ground could be sufficient or ladders could be used (rather than using longer extension ladders, scaffolding, or lift equipment).

11. VEGETATION CLEARANCE

For safety, tall vegetation is cleared from the immediate surroundings of the transmission lines during construction. Tree branches that are considered too close to transmission lines are regularly cleared in forests and urban streets. Regular pruning of vegetation involves ongoing costs and has a major visual impact. There is economic and environmental pressure to limit the width of clearance and the trim frequency (McIlwraith, 1997). However, part of the safety of transmission lines during an earthquake depends on the greater clearance and frequent maintenance of vegetation.

12. CONCLUSION

12.1 Overall earthquake performance

Environmentally sensitive electricity infrastructure installed in the decades before the 1989 Newcastle earthquake performed better than other electricity infrastructure. It was a significant factor in the performance of the electricity transmission system during the 1989 earthquake event.

12.2 Underground cable performance

Underground cables were preferred by early environmentalists but the very high costs of underground construction have limited its wider use. Significantly, in the 1989 Newcastle earthquake, the electricity system underground high voltage cables were undamaged.

12.3 Low profile equipment performance

Environmentally sensitive electricity infrastructure designs resulted in lower profile substations and switchyard equipment had better earthquake performance than tall equipment.

12.4 Pole and tower assemblies' performance

The new structurally stronger and visually simpler power pole and tower assemblies performed better in the earthquake. The poles and towers are placed adjacent to critical locations such as along roads and road crossings.

12.5 Rigid porcelain insulators' performance

The newer environmentally sensitive design in rigid porcelain insulators, both standing upright and horizontal types, performed better in the earthquake than older style porcelain insulators.

12.6 Post earthquake unintended consequences

An unintended consequence of environmentally sensitive infrastructure, that is, low profile equipment in substations and switchyards, was that it was easier to inspect and repair after the earthquake

12.7 Nearby vegetation consequences

Clearing has negative visual impact in forests and farmland as well as in semi-urban and urban areas. Clearing nearby vegetation makes electricity system safer but involves periodic costs.

13. REFERENCES

American Society of Civil Engineers, ASCE, (1991-1995) ASCE Hydropower design manual. *American Society of Civil Engineers,* New York, NY United States.
The ASCE manual earthquake design recommendation is to make control cables longer and to bolt down control cabinets.

Caldwell, R. (2009) Effects of the Newcastle Earthquake of 1989 on the New South Wales High Voltage Transmission System. *Proceedings of the 2009 Australian Earthquake Engineering Society Conference*, Newcastle NSW, Australia. https://www.aees.org.au (18/11/2019).

Flinchum, R. (1997) Henry Dreyfus, Industrial Designer: The man in the brown suit. *Rizzoli International Publications.* New York, NY United States.
Client: Edison Electric Institute 1966 -1968, pp174 -175. Models of proposed electric transmission structures 1968, figures, pp172-173.

Gencur, M. (2018) Review of Environmental Factors, New Summer Hill Zone Substation Version 2, 9 Oct 2018, 124 pages, *Ausgrid,* Sydney NSW, Australia.
https://www.ausgrid.com.au>Sum.. (18/11/2019).
Executive summary, environmental impact assessment, page 15. Section 5.14 visual and aesthetics, page 96. Section 5.14.1 Figure 5-4 Existing visual environment, page 97, Summer Hill Zone Substation, Site context, Adjoining & view corridors.

Levy, E. (1997). The Aesthetics of Power: High-Voltage Transmission Systems and the American Landscape. *Technology and Culture*, vol. 38 no.3, pp 575 - 607 *The John Hopkins University Press* and the *Society for the History of Technology*. doi: 10.2307/3106855. https://jstor.org/stable/3106855. Page 575 (18/11/2019).

McIlwraith, J. (1997) Underground Power Cables: Costs and Benefits. Science, Technology, Environment and Resources Group. *Australian Government*. https://www.aph.gov.au/sitecore/content/Home/About_Parliame...arliamentary_Library/Publications _Archive/CIB/CIB9697/97cib11.
Page 5 underground cables made mandatory, pages 3 & 4 trees. (18/11/2019).

Parliament of New South Wales. (2019). former members. *Parliament of New South Wales*. https://www.parliament.nsw.gov.au/members/formermembers/Pages/former-member-details.aspx?pk=1765. Page 1 (17/11/2019).

Ryan, J. FIDSA (1973) Industrial design consultants report, design of transmission facilities, Electricity Commission of New South Wales, ELCOM, Henry Dreyfuss and Associates, New York, New York US. https://www.idsa.org/members/jim-ryan-fidsa. *Industrial Design Society of America*, Herndon, VA United States, Jim Ryan, page 2 (18/11/2019).

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