Free Climbing of Transmission Towers:

To Attach or Not Attach – An Examination of the Case for Change

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Abstract

To a background of change internationally, and increasing attention from OSH, the industry is re-examining the safety of traditional free climbing of power line structures.

Of the available attachment methods for towers, trials show the dual lanyard technique is the most practical. However this method comes with some significant disadvantages, not the least of which is an increased injury hazard due to added complexity.

A detailed study has shown there are no known cases of a properly trained line worker falling from a tower while using permanent climbing steps, over an estimated 3.3 million structure ascents. This makes the climb / descend process an extraordinary safe work activity. It also introduces the great difficulty that any change to current practice may impact adversely.

However falls are continuing to occur during “positioning” on the structure, and when attaching at the work position.

Therefore a partial attachment policy with the following general characteristics has been recommended for transmission line towers:

- Climbing workers to be fully trained and tested for competency.
- Workers not climbing or descending on permanent climbing steps, to be attached at all times when above 3m from ground level.
- Prior to free climbing, a risk assessment process is to be followed to determine if there are special circumstances, which elevate climbing fall risk. If the risk is significantly higher than normal, attachment would then be mandatory.

The position with regards to climbing poles is to be the subject of a separate EEA study.

1. BACKGROUND

Free climbing in the power transmission and distribution industry is under the OSH spotlight, as it moves to reduce fall accidents across industry. Internationally the practice of free climbing is reducing, with full attachment increasingly common.

In December 1998 an EEA seminar was convened at Omaka, to examine at the practicalities of a full attachment policy. A key outcome was that several of the more promising methods needed full scale evaluation in a real work environment, to test viability.

In May 1999 Transpower commissioned a testing programme (in conjunction with its line Contractors) of the attachment methods identified at the Omaka Seminar. At the conclusion of the test programme, a comprehensive report on the options for towers was written.

2. WHAT'S HAPPENING OVERSEAS?

The move to full attachment during climbing has gathered considerable momentum in the power industry overseas.

In the UK, a full attachment policy for transmission has been in place for over 12 months. *(**Note:** Full attachment for distribution poles was to have been in place by early 1999, but this deadline has been moved out several times and it is now not expected before mid 2000 at the earliest).*

In Australia, the industry has officially adopted full attachment, although with a marked degree of reluctance in some quarters. Actual implementation is known to vary from company to company, work crew to work crew.

In the USA free climbing has survived in many locations. IEEE Standard 1307 –1996 allows a "qualified climber" to "climb and change work positions without utilising fall protection equipment.

3. ACCIDENT TRACK RECORD, EXPOSURE AND INJURY RISK.

3.1 Track Record in NZ.

To establish factual NZ data for transmission, a search was carried out for records of falls from transmission line towers. Approx 8,000 NZED and Transpower accident records from 1927 to 1999 were researched. The results are summarised in Table 1.

TABLE 1: Recorded Falls from Transmission Line Structures, 1927 - 1999				
Fall Location	**%**	**Typical Cause**	**Injuries**	**Fatalities**
Climbing or descending	4	Inexperienced temporary worker, in very poor weather conditions.	1	0
Moving on Structure	35	Slipped, loss of balance, knocked by tower panel, etc	9	0
From Work Position	61	Failure to attach at work position.	7	0
		Failure of the safety equipment itself.	4	1
		Conductor parted from tower support point (Two accident events) (1)	4	0
Total Injuries and Fatalities (1)			25	1

Note: *(1) 24 accident events. Two accidents involved injuries to two workers.*

3.2 Risk Exposure

What has been the actual exposure to fall risk over the above period?

There have been approx 25,000 transmission towers built in NZ, each requiring an estimated 60 lineman ascents to build and wire. For maintenance, the current work profile suggests approximately 24,500 tower ascents are required per year. (This is somewhat less than in recent years, but more than in the very early days of the industry, so it's probably a reasonable average to use over the past 75 years or so.)

Table 2 summarises this data.

TABLE 2: Estimate of Tower Climbing Exposure in New Zealand Transmission Industry			
Tower Construction	25,000 towers	60 climbs per tower	1,500,000 climbs
Line Maintenance	24,500 climbs per year	75 years	1,800,000 climbs
Total:			3,300,000 climbs

Note that 3.3 million tower climbs over 75 years equates to about 44,000 climbs per year, or 180 per working day.

3.3 Discussion

It is almost certain that not all fall accidents were recorded in the files searched. Therefore, the true number of injury and fatality falls over the past 75 years will be greater than indicated in Table 1. It is suggested that a reasonable worst-case assumption is that total accidents would not exceed twice that in Table 1, say 50 events and 2 fatalities. On that basis, the past injury rate would be one per 70,000 climbs, and the death rate (assuming two fatalities), one in every 1.6 million climbs.

Further analysis also reveals:

- The chances of being killed during a fall are small (4%).

- Only 1 of 24 fall events related to the climb / descend process.
- 4 falls (including the one fatality) occurred solely due to failure of the safety equipment in use at the work position. *(**Note**: Modern equipment is obviously better and may have prevented those falls).*
- 7 falls relate to a failure by the worker to attach at the work position.
- Many of the falls related to tower construction activities in which non-attachment at the work position was routinely tolerated. (***Note**: That situation no longer prevails).*
- 9 falls (the biggest single category, at 35%) relate to unattached workers falling during "positioning" activities.

If we consider a scenario where all workers had been attached with good quality modern safety equipment during all tower positioning and work position activities, (excluding climb/descend) there would in theory have been no fatalities and only one injury fall. Further, the one injury fall would have been prevented by adherence to basic training and safety requirements.

4. DESCRIPTIONS OF THE AVAILABLE ATTACHMENT METHODS

4.1 Dual Lanyard Technique

Two lanyards, and two tower attachment clips are mounted to the rear of a workers harness. In use the worker attaches one lanyard to the structure then moves the length of that lanyard in the direction he wishes to travel. The second lanyard is then attached. The worker then returns (or reaches up/down) to the initial position, unclips the first lanyard, and moves up in the direction of travel to the limit of the second lanyard. So the process continues. The longer the lanyards, the greater the freedom of movement, **but** the bigger the potential fall distance.

4.2 Mountaineering Technique

A climber begins at ground level carrying a collection of strops and karabiners. A fall arrest line is attached to his harness. As the climb progresses, a colleague on the ground pays out the line through a restraint. The climber periodically attaches a strop and karabiner to the structure, passing his fall arrest line through each karabiner. Thus, a series of anchorage points is created up the structure, at any time limiting the maximum fall rope length to the distance back to the last attachment point.

4.3 Climbing Step Methods.

These methods utilise climbing steps permanently fitted to the climbing leg of the tower.

Method 1 uses special climbing step bolts that have a spiral (pig tail) formed at the outer end, into which a fall arrest rope can be inserted. The special climbing steps are installed on one side of the tower leg, so as to form a continuous column. In use a fall arrest rope is attached to the climbers harness in the normal way, and is passed out by a colleague on the ground. As the worker climbs, he feeds the rope into the spirals on the climbing steps. The fall rope length is thus limited to the distance back to the last step bolt attachment.

Method 2 uses either standard climbing steps (if they are strong enough) or modified steps. A climber uses the twin lanyard technique, but with smaller snap hooks. Holding one in each hand the hooks are alternately attached and removed from climbing steps as the climb progresses. Obviously the step bolts must have a formed end attachment of some type to prevent the snap hook being pulled off in the event of a fall.

4.4 Hook on a pole.

This method uses a hook assembly attached to a fibreglass pole. The worker uses a safety line, which is attached to the hook. The worker uses the pole to reach above his head to attach the hook to a suitable location. The worker then climbs to that level, temporarily attaches to the tower with a pole strap, and again uses the pole to place the hook further up the structure.

4.5 The Corner Rope Technique

This method is targeted at tower painters, and other jobs that involve moving over the entire tower structure. A free hanging rope is installed down the outside corner of each tower leg. (Other attachment techniques are needed initially to install the ropes). Each rope is tied off at the tower top arm, at the waist, and at ground level to a suitable anchor point. Each rope is positioned and tensioned to hold it clear of the tower leg.

The worker uses a body harness, lanyard and a rope grab type fall arrest device attached to one of the tower ropes. Workers can move halfway across the tower face on each side of the tower leg.

4.6 Steel Wire Rope or Rail Systems.

This system permanently installs a tensioned steel wire rope or steel rail the length of the structure, (usually up the climbing leg). The rope or rail is attached using special brackets every few metres along the run. A small travelling fall arrest device is clipped around the wire/rail, for attachment to the workers harness.

5. FIELD TESTING RESULTS.

5.1 Overview

Twenty six evaluation forms were received from twelve separate field trials. These forms recorded the time required to climb and descend the structures, both free climbing and using the specified attachment technique, as well as listing comments on ease of use, practicality, introduced safety hazards etc.

Considerable spread occurred in the data, as evaluation times were effected by such variables as structure height, job type, worker skill, etc. Conversely, comments on the pros and cons of the various techniques were very consistent.

5.2 Dual lanyard technique (Attached to tower steel).

Considered the most viable technique. Climb and descend times varied widely, but a reasonable median compared to free climbing was around two and a half time’s as long.

Key advantages are simplicity, and the fact that it can be used to reach any part of a tower. Key disadvantage was the risk of slipping or tripping during the repetitive installation and removal of the lanyard clips. Workers constantly change hands while working with the lanyards, and often stretch up and down to the extremes of their reach in order to attach and remove the lanyard clips. There is absolutely no doubt that the risk of a short fall to the limit of the attached lanyard is enormously elevated and this is a major disadvantage of this technique when applied to tower steel.

Note: *A short fall on a lanyard onto a transmission tower carries a high risk of injury due to impact with the tower steel or climbing steps. Depending on whether the lanyard is attached to the front or the rear of the harness, the worker will tend to be thrown head back or head forward during the fall arrest, and the potential for very serious impact injuries including horrific head injuries is obvious.*

Contractors were convinced that a change from free climbing to dual lanyards (for climbing/descending in normal conditions) was in itself far more hazardous than retaining free climbing.

5.3 Mountaineering Technique

A very slow and unpopular technique. Trial times were six times slower than free climbing. Disadvantages included the time required to attach the multiple Karabiner, the weight of the equipment, the need to remove all the loops again when descending, the enhanced fall distances when the worker is climbing above the last attachment point, and the need to rely on another worker to properly "belay" the rope.

5.4 Climbing Step Methods

Unfortunately neither of the two methods were able to be trialed, however both show good potential.

Method one, using the pigtails, should be quite rapid to use provided the pigtails are well designed so the climbing rope can be inserted quickly. The second climber has to free the rope from the steps in order to progress. The major disadvantages are that the structure has to have half (or all) the existing steps replaced, and another worker is needed to "belay" the climbing rope.

Climb and descent times are estimated to be about twice that of free climbing. Method two seems to have better potential.

Method two, is very simple and inexpensive provided it is possible to use the existing steps. Disadvantage is that the climber has to hold the clips in his hand instead of fully concentrating on grasping the step bolts, thus creating a greater likelihood of losing grip and falling.

Note: *Transpower climbing steps are made with 16 mm (older steps 5/8") dia steel bar. Tests in Australia showed that 16 mm dia steps bent significantly when tested with a falling "dummy". In Queensland tests, 16 mm steps "sheared off". NZ tests are needed to establish the strength of the local step designs.*

This method (along with hook on a pole) is now in regular use by NSW TransGrid staff, where additional climb time is of the order of one and a half times that of free climbing.

5.5 Hook on a pole.

This method was not favoured. Test results showed climb / descent time averaging around three times longer than free climbing.

One Canadian design tested used a spring-loaded gate. This was relatively heavy, quite tricky to use, and when the pole was fully extended, was very long and “floppy”. Further, with the pole extended considerable windage loads were generated, making it unsuitable for use in any windy situation. Conversely a simple “homemade” trial hook used an open C design on a live line stick. (A broadly similar design is now in use in Australia in NSW and Queensland, and when combined with a stiff 3 m pole, some Australian linemen preferred it to the dual lanyard method in some circumstances).
Biggest disadvantage with this method is the need to pause and attach to the structure with a pole strap each time the hook needs repositioning.

5.6 The Corner Rope Technique

This method was not trialed specifically for this report, but had been earlier tested for practicality by one of the tower painting companies. They did not favour it over dual lanyards. It involves considerable setting up time making it unsuitable for routine maintenance work.

5.7 Steel Wire Rope or “Rail-lock” Systems.

A trial was carried out of the wire rope system. The major advantage of this system (once installed) is ease of use, leading to very low impacts on productivity. The major disadvantage is very high cost, not only to install, but also (in the longer term) for maintenance and replacement to ensure continued safety especially in corrosive locations. Time impacts are of the order of 1.3 times that of free climbing.

Already used as an option where inexperienced climbers require repeated access, eg comms towers.

6. COST SUMMARY.

A condensed estimate of the probable long-term cost impacts of each method is summarised in **Table 3**.

TABLE 3: Typical Effects on Cost and Productivity of Each Attachment Method.

Method	Average % Increase in Climb/Descend time	Typical Equipment Cost per Worker per Year	Typical Equipment and installation Cost per tower
Dual lanyards	250 %	$570	$0
Mountaineering technique	600 %	$920	$0
Climbing steps Method 1 (pigtails)	200% (est)	$400	$1000
Climbing steps Method 2	150 %	$570	$0(1)
Hook on a Pole	300 %	$500	$0
Corner Ropes	Not Evaluated		
Steel Wire / Rail.	130 %	$600	$1600

Note: *(1) Assumes existing 16 mm climbing steps are adequate.*

7. OPTIONS FOR THE FUTURE

The following options were examined in detail:

OPTION 1: Do nothing.
Continue with the status quo of not attaching during climbing, descending, or positioning, but require attachment at the work position.

OPTION 2: Adopt partial attachment.
Do not require attachment where workers are climbing or descending on permanently installed climbing steps, but require attachment when the worker moves off the climbing steps. Attachment would be by dual lanyards onto tower steel.

The next 3 options require full attachment at all times but implement this in various ways.

OPTION 3: Full attachment using existing climbing steps.
This is the simplest and cheapest method of implementing full attachment. Dual lanyards would be attached to the climbing steps during climbing or descending, and attached to tower steel when positioning out onto crossarms or the tower body. (Assumes existing climbing steps are strong enough).

OPTION 4: Full attachment, but not using climbing steps.
If the existing 16 mm diameter steps cannot be used for attachment, then this option works around that problem. Towers would have to be climbed using dual lanyards attached to tower steel instead of step bolts.

OPTION 5: Full attachment to new 20 mm tower climbing steps.
Same as option 3, but with replacement of all 16 mm climbing steps with new strengthened steps.

8. ANALYSIS OF THE OPTIONS

8.1 Costs.

A detailed analysis of the cost of the five attachment options was carried out for a 10 year period. **Table 4** summarises the cost of the five options.

TABLE 4: Overall Cost Summary						
#	Option	Cost of Loss of Productivity per yr	Equipment Cost : 200 Workers per yr	Total Repetitive Annual Cost	Modify Structure cost (one off)	Total cost over 10 years (yr 2000 $)
		$ 000	**$ 000**	**$ 000**	**$ M**	**$ M**
1	Do nothing	**$ 0**	**$ 0**	**$ 0**	**$ 0**	**$ 0**
2	Partial Attachment (Assume lanyards last 3 years)	**$ 797**	**$ 38**	**$ 835**	**$ 0**	**$8.34 m**
3	Full attachment, using dual lanyards on existing climbing steps.	**$ 992**	**$ 76**	**$ 1,068**	**$ 0**	**$10.67 m**
4	Full attachment using dual lanyards attaching to structure steelwork.	**$ 1,382**	**$ 160**	**$ 1,542**	**$ 0**	**$15.42 m**
5	Full attachment using dual lanyards on all new climbing steps	**$ 992**	**$76**	**$ 1,068**	**$ 25.5 m**	**$36.17 m**

8.2 Discussion of the Options

Option 1 (Status quo) is desirable for zero cost and no productivity implications. However the accident analysis clearly shows a problem with falls during positioning. Failure to address this could be a breach OSH requirements to take "all practicable steps" exposing the employer to prosecution.

Option 2 (partial attachment) has numerous advantages. It resolves the problem with Option 1 by eliminating the one remaining area of significant risk, i.e. positioning on the structure. The fall risk of climbing / descending is not covered, but this risk is proven to be negligible. Furthermore, the negative safety implications of attachment during climbing outweigh the risk reduction achieved. The cost implications of Option 2 are the lowest of the viable options, it is easily implemented, and most contractors (except tower painters) will not be seriously affected.

Option 3 is next lowest cost option, should option 2 be unacceptable. Option 3 however has the potential to deliver a poorer overall safety outcome than option 2 due to an increase in incidental injuries. Also, Australian experience suggests that Transpower 16 mm step bolts may have inadequate strength for use as fall arrest attachments. This needs to be established beyond doubt because if they are not able to be used the next cheapest option is -

Option 4: The extra cost of the significant reduction in productivity is ongoing and permanently embedded.

Option 5 attempts to lower the productivity impact of option 4 by replacing the climbing steps. Unfortunately the gains in productivity do not cover the very high capital cost of installing new steps.

Note: *If the cost of changing the steps is reduced 50%, (to $12 m), the work in Option 5 still remains uneconomic. However the costs of replacing steps can be reduced massively (perhaps by 90%) if step replacement is progressively implemented as a part of normal maintenance work. This approach would result in the step replacement programme taking perhaps 30 years to be completed, but the low cost involved makes it worthwhile implementing as a long term strategy, especially if (as expected) testing shows the strength of the existing steps to be marginal.*

9. RECOMMENDED FUTURE TOWER CLIMBING OPTION

Option 2 has been recommended to Transpower as the future strategy for tower climbing: i.e.

1. Workers should be attached at all times during the positioning process. (i.e. at any time when moving off the permanent climbing steps and higher than 3 m above ground level), in addition to the currently required attachment at the work position.
2. The current use of free climbing should be retained for the climb / descend process only, and only on permanent climbing steps or ladder sections.
3. Free climbing should be subject to a formal site risk management process, so that situations of significantly elevated risk can be identified, and attachment techniques implemented where necessary.
4. The strength of the various types of existing 16 mm climbing steps needs to be determined, so their capability for use as part of a fall arrest system can be clarified.
5. If the strength of the existing climbing steps is found to be unsatisfactory, then they should be progressively replaced when the existing steps need changing due to normal deterioration processes.

10. WHERE TO FROM HERE?

At the date of completing this paper (1 May 2000) the following plans were in place by the EEA Safety Strategy and Policy committee:

1. The Transpower commissioned report on tower climbing safety to be completed, and presented to OSH as the industry position on tower climbing.
2. That the EEA commission a separate investigation into the safety situation related to pole climbing (both transmission and distribution). On receipt of that report, an industry position with regard to attachment during pole climbing will be developed.

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(**Disclaimer**: The opinions expressed in this paper are those of the author and not necessarily those of Transpower NZ Ltd, the EEA or any other organisation.)

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