The Journal of CPRI,
Vol. 9, No. 3, September. 2013 pp. 449-458

Safe Method to Erect Towers with Electro-Rheological Fluids

Kalyana Sundaram* Ameya V Datrange**
Ranjit Patil, Prashant Ravella**, Sandeep Mungala**

Power sector is one of the fastest growing sectors expanding to remote and inaccessible sections of the Indian Subcontinent. High customer expectations of uninterrupted power supply exist even during occurrence of natural calamities via the distribution and transmission networks. It is a challenge to erect any tower in a short period. Erection of towers involves safety issues of the workmen falling down. Hence there is a need to look at non acrophobic devices such as telescopic towers which can be operated from close to the ground level. Our paper here describes one method to address such a challenge whereby a tower could be constructed quickly without the need of support scaffolding arrangements and without the need for workmen to suffer batophobia.

Keywords: *Telescopic Masts, Quick Erect Antenna Systems, Masts Systems*

1.0 INTRODUCTION

A Transmission tower is a tall structure, usually a steel lattice tower, used to support an overhead power line [1]. They are used in high-voltage AC and DC systems, and come in a wide variety of shapes and sizes. Radio masts and towers are, typically, tall structures designed to support antennas (also known as aerials) for telecommunications and broadcasting, including television. They are among the tallest man-made structures. Similar structures include electricity pylons and towers for wind turbines.

Typical height ranges from 15 to 55 meters (49 to 180 ft), though the tallest are the 370 m (1,214 ft) towers of a 2700 meters long span of Zhoushan Island Overhead Power-line Tie [2]. Inaddition to steel, other materials may be used, including wood, concrete and aluminium.

Four major functions of transmission towers are in use: suspension towers, terminal towers, tension towers, and transposition towers [3]. Sometransmission towers combine these basic functions.

Emergency restoration system [4] as per grid standards means a system comprising of transmission towers or structures of modular construction, complete with associated components such as insulators, hardware fittings, accessories, foundation plates, guys, anchors or installation tools and they like to facilitate quick restoration of damaged or failed transmission line towers or sections.

2.0 PURPOSE, BACKGROUND ANDPROBLEM DEFINITION

In power sector it is currently important to set up tall structures in least possible time and cost, with minimum manpower. These towers should also be built with a high degree of safety assurance for the erecting and commissioning staff [5].

*Dean and Professor, R&D, Mechanical Engg., Vishwakarma Institute of Technology, Pune, 411 004 (India) E-mail - vit_sundaram@yahoo.com Ph - 09422330650
**ME (Design) student, Vishwakarma Institute of Technology, Pune, 411 004 (India). E-mail – ameya.datrange@gmail.com, Ph - 09890584125 E-mail – ranjit5337@gmail.com. Ph - 09970831143

The drudgery of readjusting positions of towers already set up is also very cumbersome. Current methods are fraught with the risk of having to need people to climb the tall tower during its erecting,commissioning / decommissioning and even the maintenance phases.

We often find that the risk of people falling off from towers during any of these phases is very high and therefore to mitigate this it's necessary to have alternative methods to address this concern. This paper focuses one method to address the safety concerns of people and organizationsthat have to climb tall spaces to build/maintain towers.

We have developed a methodology and design for telescopic hoisting system which can be operated on the ground with more safety to human life, and will also enable to meet user requirements to hoist the transmission system to customizable heights in a controllable manner. Thus readjustment for maintenance or other reasons can also be done effectively.

It is therefore required to provide a telescoping device which will be able to telescope out in an optimized manner, be inexpensive and be mass produced and safely erected with minimum human intervention preferably within a few hours. Claustrophobic risks associated with human beings are to be eliminated or minimized.

3.0 LITERATURE SURVEY

Current Literature indicates the presence of hoisting mechanisms or telescopic towers operated by hydraulic or pneumatic circuits [6]. We also note that towers meet the requirement for the overall assembly to be portable in terms of transportation to sites on a vehicle chassis.

A gin-pole crane can be used to assemble lattice towers [7]. This is also used for utility poles. These towers can be assembled horizontally on the ground and erected by push pull cable. It can also be assembled vertically (in their final upright position). Helicopters can serve as aerial cranes for their assembly in areas with limited accessibility. Towers can also be assembled elsewhere and flown to their place on the transmission right-of-way.These methods are rarely used however because of the large assembly area needed and are generally not preferred in where open spaces don't abound.

The concept of building assemblies which can be folded as well as expanded came into existence which laid to greater flexibility and comfort. Some of the deployable assemblies include telescopic mast (tower) [8], telescoping ladder [9], foldable panel assembly [10], folding truss [11], foldable tent camping unit[12], folding crane[13], folding assembly [14].

Literature search also show preventive measures [15] taken to save life of working personnel.Built up method [16] consists of erecting the towers, member by member. The tower members are kept on ground serially according to erection sequence to avoid search or time loss. The erection progresses from the bottom upwards. The four main corner leg members of the first section of the tower are first erected and guard off. Sometimes more than one contiguous leg sections of each corner leg are bolted together at the ground and erected.

Guard rails are erected on steelwork at ground levelthen the steel and the guard rails are craned into position [17]. Equipment accessories such as independent scaffolds, tower scaffolds, mobile elevating work platforms (MEWPs) and mast climbing work platforms (MCWPs) [18] are fitted with the guard rails.

A harness with a short lanyard makes it impossible for a person to get to a fall position (also called as work restraint) is used as work equipment that protects the individual.Nets or soft landing systems positioned close under the work surface minimizes the distance and consequences of a fall and protect all those at risk.

4.0 PROPOSED SOLUTION

The proposed solution consists of using a modular telescopic assembly and easily portable even on relatively small vehicles, which can be easily moved to the desired field location. It is also another objective of our design to provide enormous flexibility for reusing and repairing, maintenance checks at regular intervals and also reduce the occupational risks involved for skilled personnel.

It is proposed to hoist the telescopic tower using an electro rheological fluid. This fluid has a property of changing its state from liquid to solid (90% solid) on application of voltage. Our chosen electro-rheological fluid has particle diameter of 50 micrometers. This fluid meets the requirement of being in the solid state on application of a specified voltage of 4kV/mm [19]. It is required that the potential should be kept continuously applied to have the desired solid state of the fluid. On removal of electric field the solid regains its liquid form and can be recycled for reuse/ use in other application.

Thus when we wish to decommission or fold back the tower, the voltage is being removed and consequently the fluid turns into liquid state. This fluid is then extracted out and stored in the storage tank.

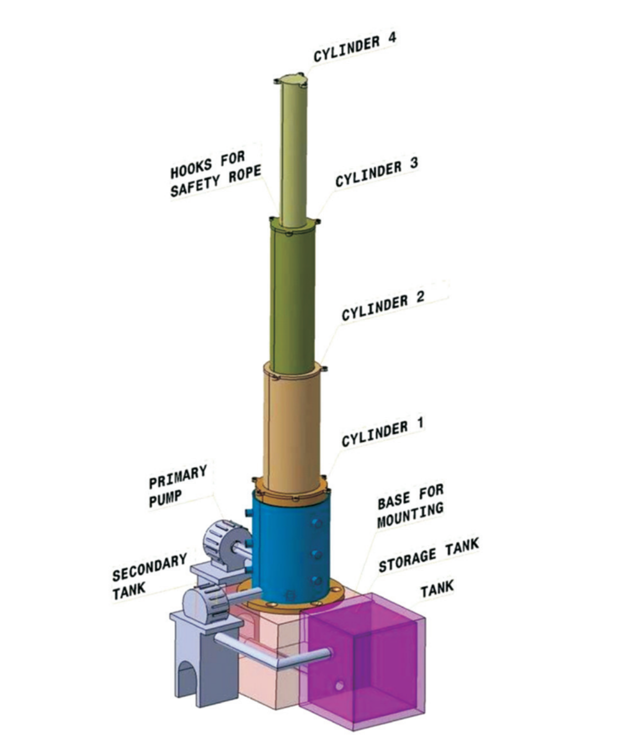

FIG. 1 TELESCOPIC ASSEMBLY (CYLINDRICAL SECTIONS)

5.0 DESCRIPTION OF THE TELESCOPIC ASSEMBLY

The system comprises of a compact assembly of telescopic cylinders witha pre-defined cross section as shown in Figure 1. The device is basically divided into two sub-assemblies viz. Section Assembly and Power Assembly.

The section assembly consists of the following parts:

a) Cylindrical sections (1-4)
b) Hooks for guy wire attachment

As shown in Figure 2, each pair of mating Telescopic Cylindrical Section(s) i.e. cylinder-1 through 4 can be extended till the maximum height is reached. The pair of matingcylinders has anti jamming rollers inbuilt at the internal ends.

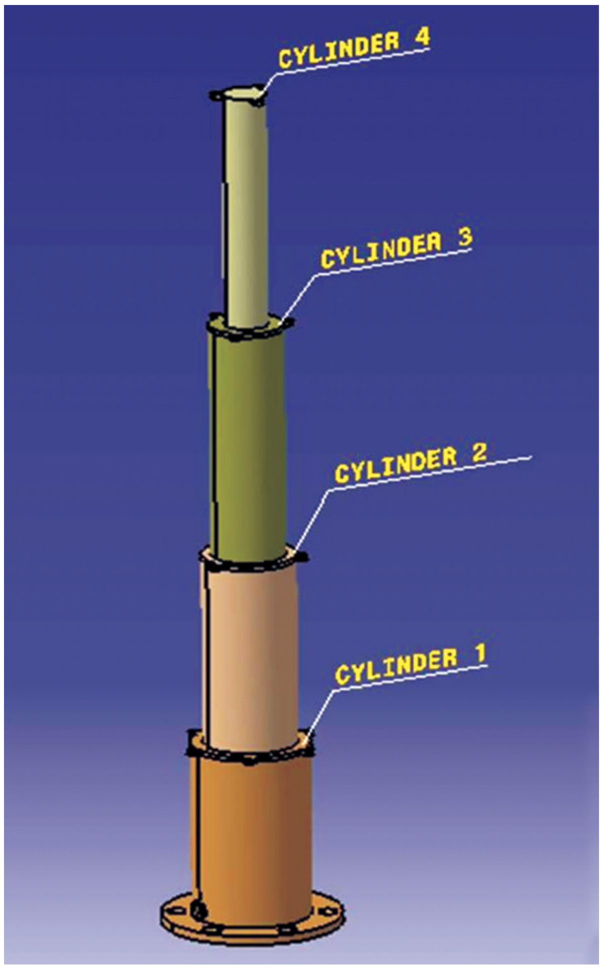

FIG. 2 TELESCOPIC SECTIONS

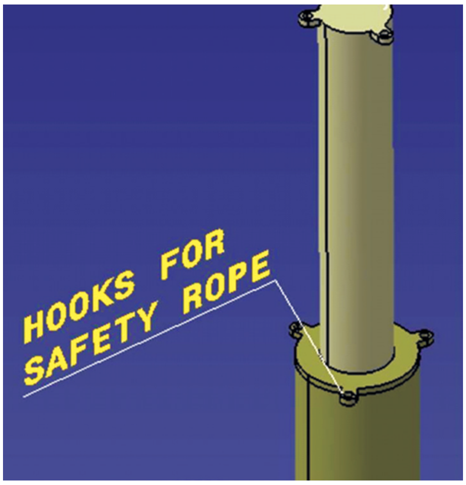

FIG.3 HOOKS FOR GUY WIRES

As shown in Figure 3, hooks are attached to the cylinders at selected places to serve as anattachment for making a guyed structure which will help in hoisting theassembly.Non return valves are provided at entry and exit of the fluid from cylinder(s) which can allow movement of the fluid in only one direction. Seals can be provided internally in the telescopic cylinder to preventleakage of theworking fluid.

The power assembly consists of the following parts:

a) Storage tank
b) Primary pump
c) Secondary Pump
d) Power supply pack

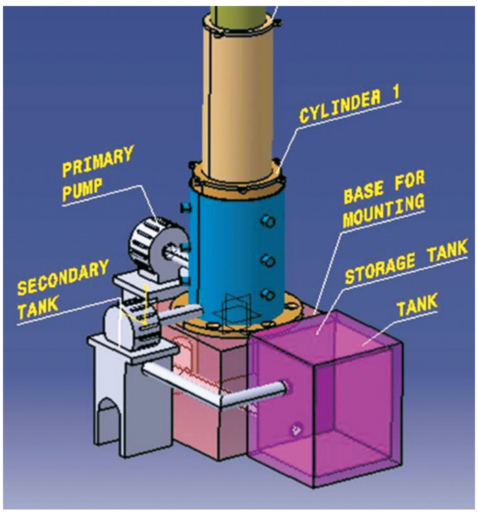

FIG.4 POWER ASSEMBLY

As shown in Figure 4, the primary pump is used to pump the electro-rheological fluid inside the telescopic mast. Due to fluidic pressure from inside the masts, each telescopic section gets ejected out subsequently. The power supply pack is interfaced with a control panel which regulates theelectro-rheological properties of the working fluid. As the tower reaches its maximum height the potential is applied at the terminals shown in Figure 5, by virtue of which the ER fluid gets solidify and holds the masts in its position. When thetelescopic mast is to be folded,secondary pump is used to extract the fluid from the mast back to the storage tank.

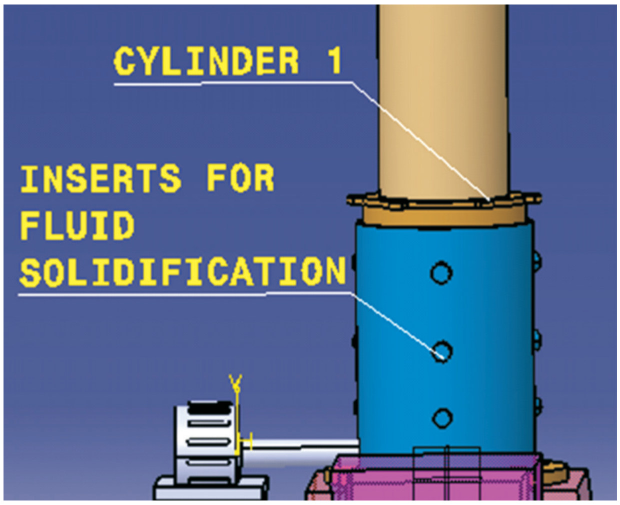

FIG.5 VOLTAGE TERMINALS

6.0 WORKING

The assembly is erected by following the process outlined below:

1) The folded set up of section assembly manufactured from the factory and the set of power assembly is dropped on the foundation bolts at the desired site.

2) The pumping storage tank and accessories are connected (Figure 4).

3) The electro-rheological fluid is thenpumped with the help of primary pump into the mast.

4) The fluid is pumped till it startsbuilding pressure inside the cylindrical sections.

5) Pushing of the consecutive cylinders in upward directions is observed and accordingly the valves are operated.

6) A guy wire is attached to eachcylinder at its top end as soon as it reaches its maximum length, to provide the structural integrity (Figure 3).

7) Additional supportingcables /guyed wires can be suitably attached to the hooksprovided on each Cylinder(s)to give more stability against bending due to wind force.

8) This process is repeated till all cylinders are fully raised.

9) Electric Potential is applied to the Electro-rheological fluid with the help of the inserts in the lower half of the bottom most cylinder of tower assembly (figure 5).

10) Potential is kept applied tillthe working fluid changes its phase to 90% solid as a result of which the mast will be held in its fully extended position.

11) The pump and its accessory attachments are removed and the telescoped tower is now ready for use.

12) This whole setup can be easily mounted on a vehicle chassis or frameand that can be transported to locations for setting up the telescopic tower.

7.0 CALCULATION

For designing the towers it is important to understand the nonlinear relationships of power required for hoisting the tower and the associated pressures which would be demanded at different hoisting stages.

Shown herewith are the general formulae derived from first principles and an example for a typical five stage telescopic tower.

TABLE 1

GEOMETRICAL SHAPE

Cylinder Number	Height (L) m	Outer Dia. (D) m	Inner Dia. (d) m
1	L_1=1	.400	.394
2	L_2=1	.354	.348
3	L_3=1	.308	.302
4	L_4=1	.262	.256
5	L_5=1	.216	.210

The geometrical sizes of the cylinders have been shown in Table 1. Pressure and Power Requiredare calculated as shown below. The subscripts indicate the respective cylinder number.

7.1 Pressure: (p)

$$p = \frac{Volume \times Density \times gravity}{Area}$$

$$p = Height \times Density \times gravity$$

Pressure required for erecting the cylinder number 5

$$p_5 = L_5 \times \varrho_s \times g$$

Pressure required for erecting the cylinder number 4

$$p_4 = p_5 + L_4 \times \varrho_s \times g + L_5 \times \varrho_l \times g$$

Pressure required for erecting the cylinder number 3

$$p_3 = p_4 + L_3 \times \varrho_s \times g + L_4 \times \varrho_l \times g$$

Pressure required for erecting the cylinder number 2

$$p_2 = p_3 + L_2 \times \varrho_s \times g + L_3 \times \varrho_l \times g$$

Pressure required for erecting the cylinder number 1

$$p_1 = p_2 + L_1 \times \varrho_s \times g + L_2 \times \varrho_l \times g$$

Here,

$$\varrho_s = Ddensity\ of\ structure = 7754\ kg/m^3$$
$$\varrho_l = Density\ of\ fluid = 1400\ kg/m^3$$
$$g = Acceleration\ due\ to\ gravity$$

Below graph of height v/s pressure is shown from this graph we can see a pressure required to hoist deferent numbers of section is increase with number of sections.

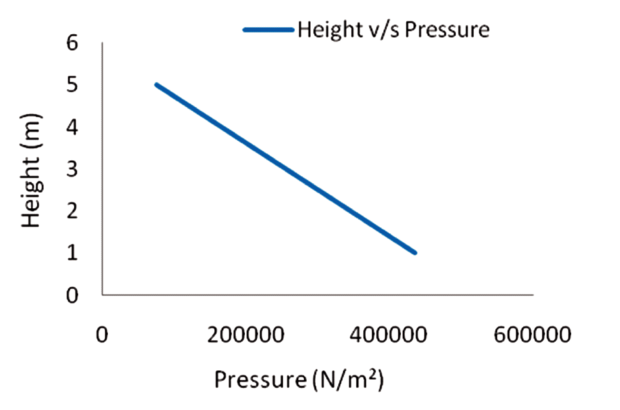

FIG 6. GRAPH OF HEIGHT V/S PRESSURE

7.2 Power: (P)

The power required to lift the cylinder is given by:

$P = pressure\ required\ to\ lift\ the\ cylinder \times flow$

To pump the fluid with above pressure and fluid we have to take flow as **Q =.3 m^3/ sec**

The computed values are shown for the cumulative effect of the respective cylinders in Table 2.

For required pressure and head we select a pump of following specifications:

Pump size	350 mm
Capacity (Q)	3000 m^3/ hr (= 0.8 m^3/ sec)
Motor rating (P)	160 kW

TABLE 2

POWER REQUIRED FOR HOISTING.

Cylinder Number	Pressure(N/m^2)	Power (kW)
1	435269.70	130
2	345468.96	103.6
3	255668.22	76.7
4	165867.84	49.7
5	76066.74	22.8

Below graph of height v/s power is shown from this graph we can see a power required to hoist deferent numbers of sections. For first section power required is less and then is increase with number of sections.

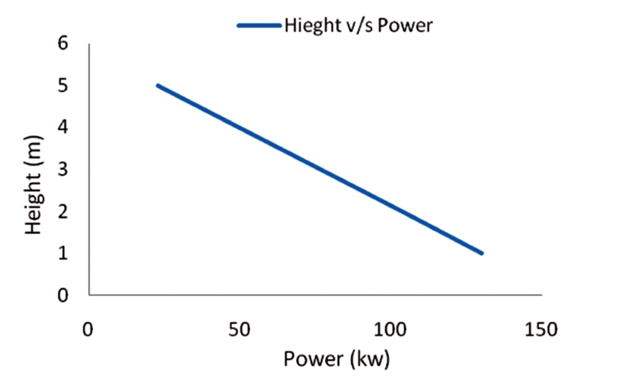

FIG.7 GRAPH OF HEIGHT V/S POWER

8.0 MERITS AND DEMERITS

The above described system has several merits and demerits which are outlined below:

8.1 Merits

1. Able to lift the telescopic tower upto a proposed height.
2. Easy to upgrade the mechanism, in case to attain larger heights.
3. Total device is easy to disassemble.
4. Construction is easy and requires less time.
5. As it is foldable, it is portable.
6. Overall weight is low compared with that of the tower.
7. Acquires less space.
8. Number of mechanisms can be increased if the tower weight increases.
9. It can be moved across to a required location very easily in a mobile platform such as a truck or a prime mover.
10. Driving operation is easy, once motorized.
11. Working height for humans is low.

12. Probability for automation is high.
13. It has productivity and customization advantages.
14. Can be reused for multiple requirements and across locations.
15. It can hold a great potential for maintenance especially in ERS (Emergency Restoration Services)
16. Ease for industry in standardization of towers with varied heights.

8.2 Demerits

1. Guy wires are needed to reduce stability problems which in turn increase the space requirement.
2. Maintaining the property of the working fluid is a major task under different conditions.
3. Voltage needs to be applied continuously till the desired solid state is permitted.
4. Electro-rheological fluid changes its phase on cut-off of voltage.
5. Availability of the Electro-rheological fluid is major issue in remote areas.
6. Additional power consumption is liable for pumping systems.
7. Insulation is required or certain parts.
8. Leak proof device is required toprevent the working fluid from leaking out.
9. Interlocking of the cylindrical sections.

9.0 CONCLUSION

This paper describes the overall concept of using a hydro-pneumatic enabled telescopic device with varied applications in the erection of telescopic towers for a required height.

The proposed device can be operated from the ground level with a prime objective of providing life safety.

10.0 FUTURE SCOPE

There exists scope to investigate an optimum type and low density electro-rheological fluids. Time optimization to carry out solidification of the fluid along with the thickness of electrical insulation needs to be determined for an efficient design.Maximum height of the tower, weight and space reduction are also some areas which can be investigated for improvement. Enhancement of Load carrying capacity and eccentric weight handling such as those required for instruments / attachments coupledwith stability analysis holds scope for structural investigations. Theapplicability of the device to be amenable to upgrades of electro and magneto rheological fluids are some constraints which when resolved will result in a successful commercialization of this concept.

ACKNOWLEDGMENT

Authors wish to thank the support of management of CPRI and the Mechanical Engineering Dept., Dept. of ideas, VIT, Pune to conduct there search work.

REFERENCES

[1] Donald Fink and Wayne Beaty, “Standard Handbook for Electrical Engineers 11th Ed”.Mc-Graw Hill, 1978.

[2] “Environmental, Health and Safety Guidelines for Electric Power Transmission and Distribution”, International Finance Corporation, April 2007.

[3] Chapter 2, Transmission Lines, Volume 4, Construction Management, “Power Grid Corporation of India Limited”, June 1996.

[4] “Transmission Emergency Restoration Systems for Public Power” by Dr. Keith E. Lindsay.

[5] “Health and safety in construction”, HSG 150, The Stationery Office 2006.

[6] Catalogues: Telescopic Device Manufacturer- Blue Sky Masts Elevating Solutions; Pneumatic Telescopic Masts Manufacturer- Kadevi Industries Limited, Hyderabad; Guyed Telescopic Devices- ROHN Products LL; Total Masts Solutions- Communication Devices, Amitasha Enterprises Private Limited, Nagpur.

[7] Broadcast Tower Technologies, "Gin Pole Services", Retrieved 2009-10-24

[8] Donald Edward Wellman, "Telescopic Masts or Towers", US Patent No.: 3817397

[9] Harford E. Goings, "Telescoping Ladder", US Patent No.: 3858684

[10] Stephan G. Kimmet, "Folding Panel Assembly", US Patent No.: 7422046

[11] William D. Nygren, William Howard Tobey, "Folding Truss", US Patent No.: 6076770

[12] Pierre R. Giroux, "Foldable Tent Camping Unit", US Patent No.: 3724893

[13] Don Surverkrop, "Folding Crane", US Patent No.: 3754666

[14] Christine L. Lapace, Ronald J. Lapace, Steve Ladau, Charles R. Smalley, "Folding Assembly", US Patent No.: 6953134

[15] "Falls from height– Prevention and risk control effectiveness", by BOMEL Limited, for the Health and Safety Executive, 2003.

[16] "Work at Height Regulations 2005" SI 2005/735. The Stationery Office 2005.

[17] "National code of practice for the prevention of falls in general construction", Appendix 9: Guardrails – Safety Considerations.

[18] "Health and safety executive", Tower Scaffolds, HSE information sheet no. 10, Revision 4.

[19] Stangroom, JE, "Electro-rheological Fluids", Phys. Technol. 14 (6): 290–296, 1983.

Others:

[20] "National code of practice for the prevention of falls in general construction", Appendix 8: Scaffolding – Safety Considerations.

[21] Tam, W Y, Sheng P, "New Electro-rheological Fluid: Theory and Experiment", Phys. Rev. Lett. 78 (15): 2987–2990, April 1997.

[22] Simmonds, "Electro-rheological valves in a hydraulic circuit", IEE Proceedings-D 138 (4): 400–404, July 1991.

[23] "Construction (Design and Management) Regulations 1994", SI 1994/3140,The Stationery Office 1994.

[24] "Prevention of falls- Basic steps to preventing falls from heights", 1st Edition, Worksafe Victoria, Advisory Service, Melbourne, June 2005.

[25] Shire, Gavin G., Karen Brown, Gerald Winegrad, "Communication Towers: A Deadly Hazard to Birds", American Bird Conservancy, Earth justice, June 2000.

[26] "Avian Collisions at Communication Towers - Sources of Information", U.S. Fish and Wildlife Service, June 2009.

[27] "Design of latticed steel transmission structures", Section C2.3, American Society of Civil Engineers, ASCE Standard 10-97, 2000.

[28] "Management of Existing Overhead Transmission Lines", CIGRE Technical Brochure, 2000

[29] "Transmission Emergency Restoration Systems for Public Power", by Keith E. Lindsay.

[30] "Tall Tripod Systems for real estate photography and panoramic presentations", by Waltraude Schramm - Moeller and Thomas Moeller, Muenchen.

[31] "Tall Pneumatic Telescopic Masts- 7-10.5 meters for movie productions, lighting and Wifi applications", by Waltraude Schramm-Moeller and Thomas Moeller, Muenchen.

[32] "Tall Pneumatic telescoping Masts/ Tripods - 12 - 17 meters for professional photographers", by Waltraude Schramm-Moeller and Thomas Moeller, Muenchen.

[33] "Innovative Tripod Photo Systems for Real Estate Brokers - Ultimate tool for real estate photography

[34] (Indoor & Outdoor)" by Waltraude Schramm- Moeller and Thomas Moeller, Muenchen.

[35] http://en.wikipedia.org/wiki/Transmission_tower

[36] http://en.wikipedia.org/wiki/Electrorheological_fluid

[37] http://www.electrical4u.com/methods-of-transmission-tower-erection/

[38] http://www.clarkmasts.com/military_scam_series.php

[39] http://www.totalmastsolutions.com/military-masts.html

[40] http://www.comrod.com/getfile.php/Utvikling/Telescopic%20Masts%20advantages.pdf

[41] http://www.photo-towers.com/

[42] http://www.photo-towers.com/special-offer-1.html

[43] http://www.photo-towers.com/telescoping-mast.htm

[44] http://www.telescopicmastcanada.com/

[45] http://www.armyproperty.com/Equipment-Info/QEAM.htm

[46] http://www.qxtt.com/?gclid=CKvC-tzpt6sCFQUb6wodO2hueQ

[47] http://www.3starinc.com/rohn_h30_telescopic_antenna_mast.html

[48] http://www.blueskymast.com