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SUMMARY OF BENEFITS OF USING FLUID-ACTUATED TELESCOPING TOWERS FOR 20 TO 100 kW WIND TURBINES

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Benefits of Using Fluid-Actuated Telescoping Towers Instead of Conventional Lattice or Monopole Towers to Support Small (20 to 100 kW) Turbines

1. **Can be Factory Assembled Instead Assembled at the Site**
   a) When sized to support small turbines, a fluid-actuated telescoping tower can be fully assembled (except for the blades) at the factory, with the work including mounting the turbine to the tower, installing the wiring and external ladders, etc.
   b) As a general rule products can be assembled in a factory in less time and at a lower hourly labor rate than if the work is done in the field.
   c) It is also a general rule that factory assembly results in a more reliable, higher quality product than field assembly because the factory QA procedures more effectively ensure quality and reliability than field QA procedures.

2. **Can be Transported to the Installation Site Factory-Assembled at No Extra Cost**
   a) The tower and turbine assembly can be configured at the factory with the tower sections slid inside each other and easily transported to the erection site on a standard 48-ft long semi trailer without any special permits being required.
   b) The tower and turbine assembly can also be set into the special tilt-up cradle described as follows, and still be transported to the erection site on a standard 48-ft long semi trailer without any special permits being required.

3. **Special Tilt-up Cradle Eliminates the Need for an On-Site Crane**
   a) The special tilt-up cradle mentioned above is not required, but if the turbine assembly is transported to the installation site in it, the trailer can be backed up to a pre-installed foundation and the cradle used to set the turbine assembly in place without the need of a crane.
   b) This is done by actuating long hydraulic cylinders built into the cradle to tip the cradle up with the turbine assembly still in it, then lowering it down over pre-set bolts anchored into the foundation and securing it in place.
   c) The blades are installed on the turbine assembly by either a small crane that is part of the special cradle, or by on-site construction equipment such as a front-end loader or backhoe, before the turbine assembly is set in place.

4. **After the Turbine is Secured to the Foundation it is Almost Ready to Elevate**
   a) After the turbine assembly is upright and secured to the foundation there is only a relatively small amount of final installation work to be completed before it can be elevated to its final height. (Mostly completing some final wiring connections and performing some final testing.)

5. **The Tower Sections Can be Quickly Extended to Elevate the Turbine**
   a) The turbine is elevated to its full hub height by utilizing an air compressor that can be, but does not have to be, part of the special cradle. It is connected to the tower and pumps air into it to extend the tower sections and elevate the turbine to its full hub height.
   b) The upper-most tower section (#1) is extended first, and when it is fully extended a technician on a ladder attached to the outside of the lower-most section secures a flange at the bottom of section #1 to a flange at the top of the section immediately below it (#2).
   c) After the two upper sections are secured together more air is pumped into the tower until a flange at the bottom of section #2 is pushed up tight against a flange

at the top of section #3. At this point the technician secures the two sections together and, if the tower consists of three sections, the turbine is fully elevated and essentially ready for use. For four section towers repeat one more time.

6. The Tower Can be Collapsed When Major Turbine Repairs Are Necessary

a) If major repairs must be made to the turbine after it is put in service there are two different means by which these repairs can be accomplished without utilizing a costly large crane to remove the turbine when it is at its full hub height.
b) One way is to re-pressurize the tower and reverse the erection process, lowering the sections inside of each other until the tower is in a collapsed configuration. In this configuration the hub height of the turbine will only be 50 feet or less above ground and a much smaller crane can remove the turbine than if it were on a conventional tower and at its full hub height. of typically 80 to 100 feet. Hub heights of 120 to 160 feet can be attained with telescoping towers, depending on whether the tower is comprised of 3-sections or 4-sections.
c) Another way that requires only a very small crane is to initially install the tower on a hinged base secured to the foundation prior to the installation of the tower. When the tower is installed on a hinged base it can be collapsed as previously explained, and then either a gin pole or hydraulic cylinders can be utilized to let the tower slowly tilt down until the turbine is at ground level (See Figures 1 and 2).
d) After the repairs are completed the turbine can be elevated back to its normal hub height by reversing the procedure used to bring it down for the repairs.

7. Hydraulic Tilt-up Towers Require Smaller Foundations if They Telescope

a) A conventional hydraulically-actuated tilt-up tower typically has a hinged joint at the bottom end that makes it possible for the force of one or more hydraulic cylinders to rotate the tower from an initial horizontal position upward until it is in its final vertical position. As shown in Figure 1, the movement of the tower is much like that of the hour hand of a clock moving backward from the 3 O'clock to 12 O'clock positions. When the tower is just starting to rotate upward a very big twisting load is being applied to the foundation that is similar to the twisting load applied to the roots of a tree in a strong wind. This is because the tower is effectively a very long lever sticking out from the foundation, and the foundation has to resist not only the twisting load from the tower itself, but also the very large twisting load resulting from the weight of the turbine and blades pushing down way out at the far end. Hydraulic tilt-up towers thus require a much bigger foundation than those that telescope and can be collapsed before being tipped up. The length of the tower when it is being tipped up determines how much of a twisting load is applied to the foundation and the bending load applied to the body of the tower. Telescoping towers can be reduced to 1/3 of their full length, which also reduces these two loads to 1/3 of what they would otherwise be. Consequently, when they are used in hydraulic tilt-up applications, telescoping towers require much smaller foundations and do not have to have as strong a body as conventional monopole towers. This represents a very significant saving.
b) When a gin pole is used to raise a tilt-up tower as shown in Figure 2., there is essentially no twisting force applied to the foundation -- but a very large horizontal force is transferred into it, and again, a significantly larger foundation is required. If the length of the tower is only 1/3 as long, the force required to raise the tower up is similarly reduced. Even with the use of a gin pole, the amount of pulling force required to elevate a 20 to 100 kW turbine mounted on either a monopole or lattice tower 100 or more feet long is so great that it is not typically done.
c) Figure 3 compares the force required to tilt up conventional vs telescoping towers and illustrates why a conventional tilt-up tower requires a larger foundation..

Tilt-Up Wind Towers

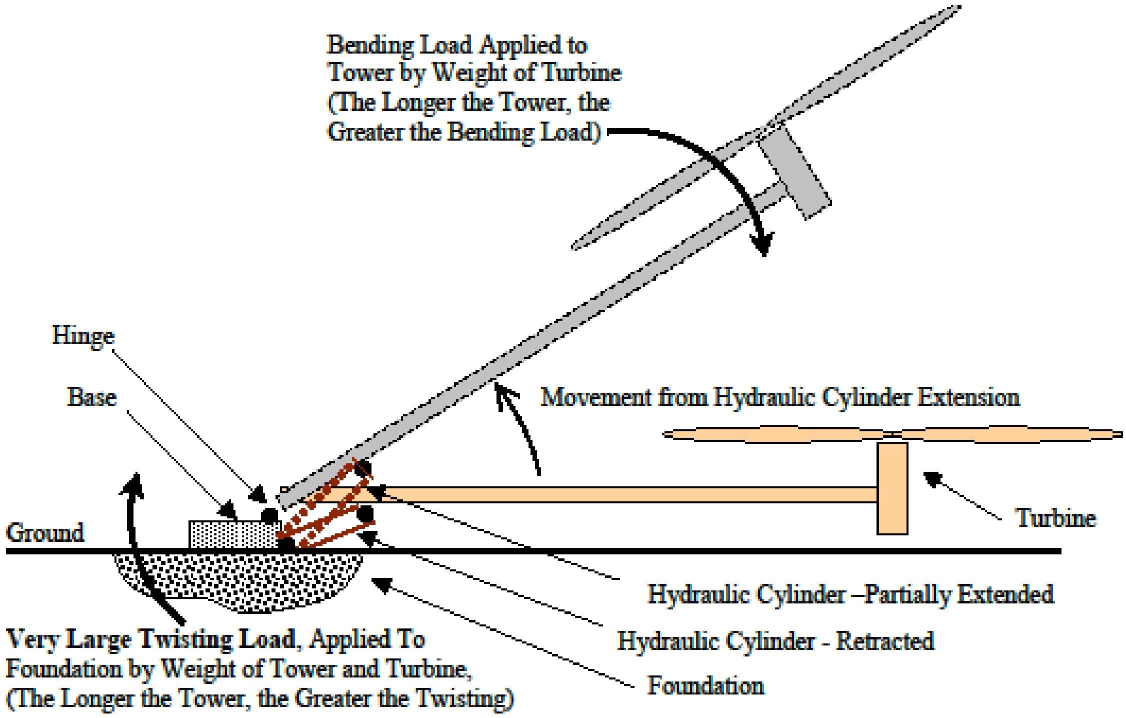


Figure 1. – A Typical Hydraulically-Actuated Tilt-Up Tower

Tilt-Up Wind Towers

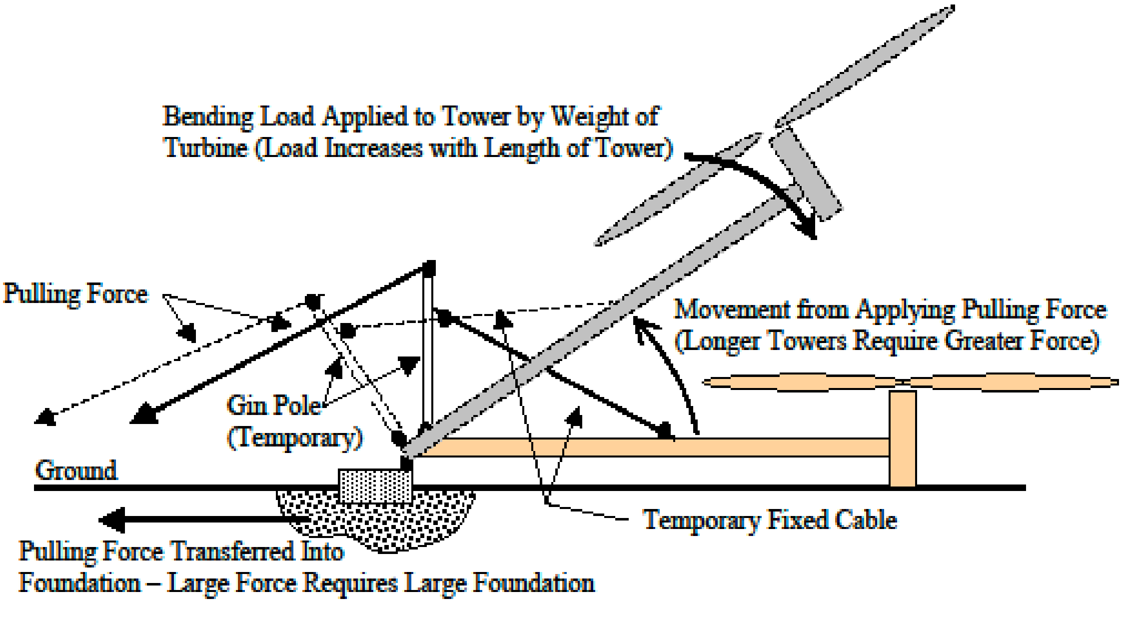
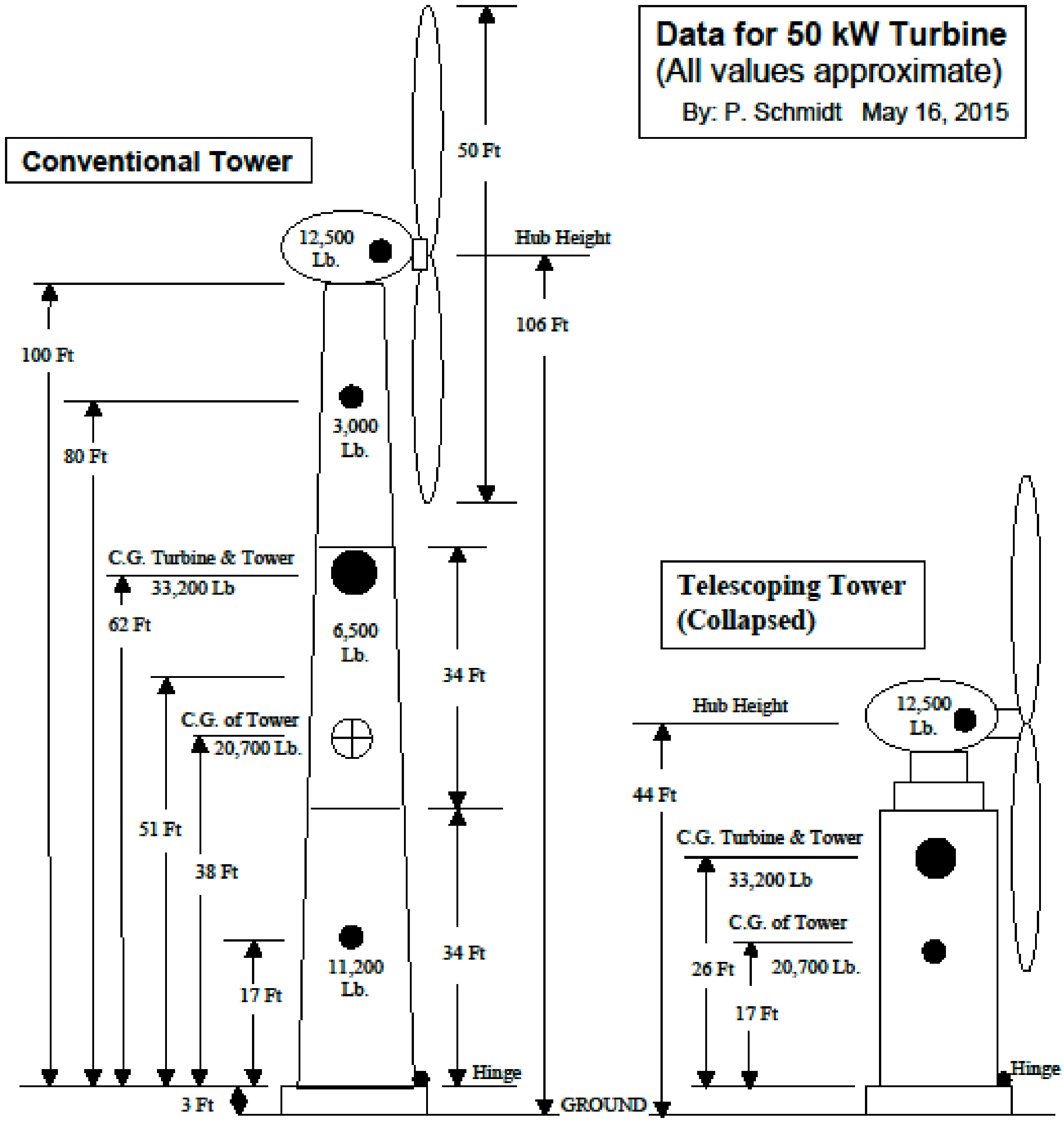


Figure 2. – Use of a Gin Pole to Raise a Tilt-Up Tower



1. **Rotational force (M_C) required to rotate conventional tower with turbine attached from horizontal position upward into vertical position (Actually so large it would not be practical):**
   M_C = Distance from hinge to center of gravity X Total weight
   M_C = 61.8 ft X 33,200 lb = 2,051,760 ft-lb. >>> [Would require (5) 10-in dia cyls @ 5200 psi]
2. **Rotational force (M_C) required to rotate collapsed telescoping tower with turbine attached from horizontal position upward into vertical position (A large force is required, but it can be done):**
   M_C = Distance from hinge to center of gravity X Total weight
   M_C = 26 ft X 33,200 lb = 863,200 ft-lb. >>> [Would require (5) 8-in dia cyls @ 3500 psi]
3. **Maximum rotational force applied to foundation by operating turbine = 1,300,000 ft-lb.**
4. **Extra rotational force (M_{extra}) required <u>to rotate a conventional tower up into vertical position</u>:**
   M_{extra} = 2,051,760 - 1,300,000 = 751,760 ft-lb. <u>REQUIRES 58% LARGER FOUNDATION</u>

<u>Figure 3 –Forces Required To Tip Up Conventional Vs Telescoping Towers</u>