From the Project Manager/Installer's Perspective

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Overview of Project Manager's and Installer's Scope of Work

1. Assessment of Site
2. Choice of Equipment
3. Zoning
4. Permitting
5. Utility Interconnection Agreement
6. Site Work
7. Excavation
8. Foundation
    - Cut & form rebar, build cages, make forms and templates, pour concrete
    - Electrical - grounding, underground wiring & conduit (part of the Electrical Subgroup)
    - Foundation inspection
9. Installation
    - Tower assembly
    - Turbine & blade attachment
    - System erection
    - Final connections and commissioning
10. Final Inspections
    - Construction
    - Electrical
    - Utility interconnection
    - State funding program

Our Area of Smart Wind Focus

Support Structures - Towers and Foundations

Our Challenge - *How Do We Improve The Following:*

1. The Manufacturing Process
2. The Installation Process
3. Maintenance and Serviceability
4. Human and Equipment Safety

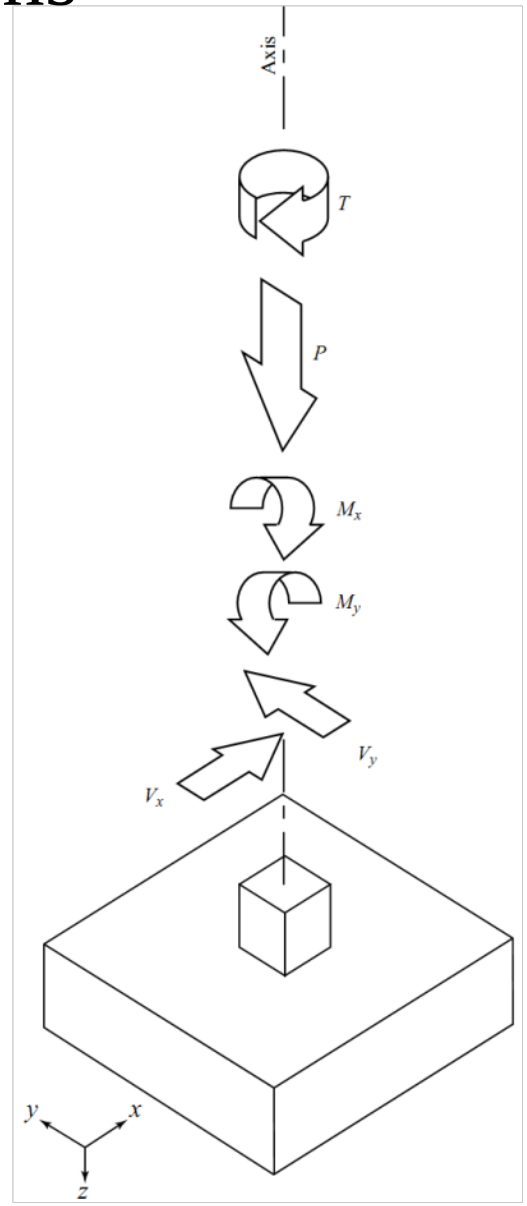
And while doing so, also reduce manufacturing and installation costs?

Towers and Foundations

Engineering Aspects

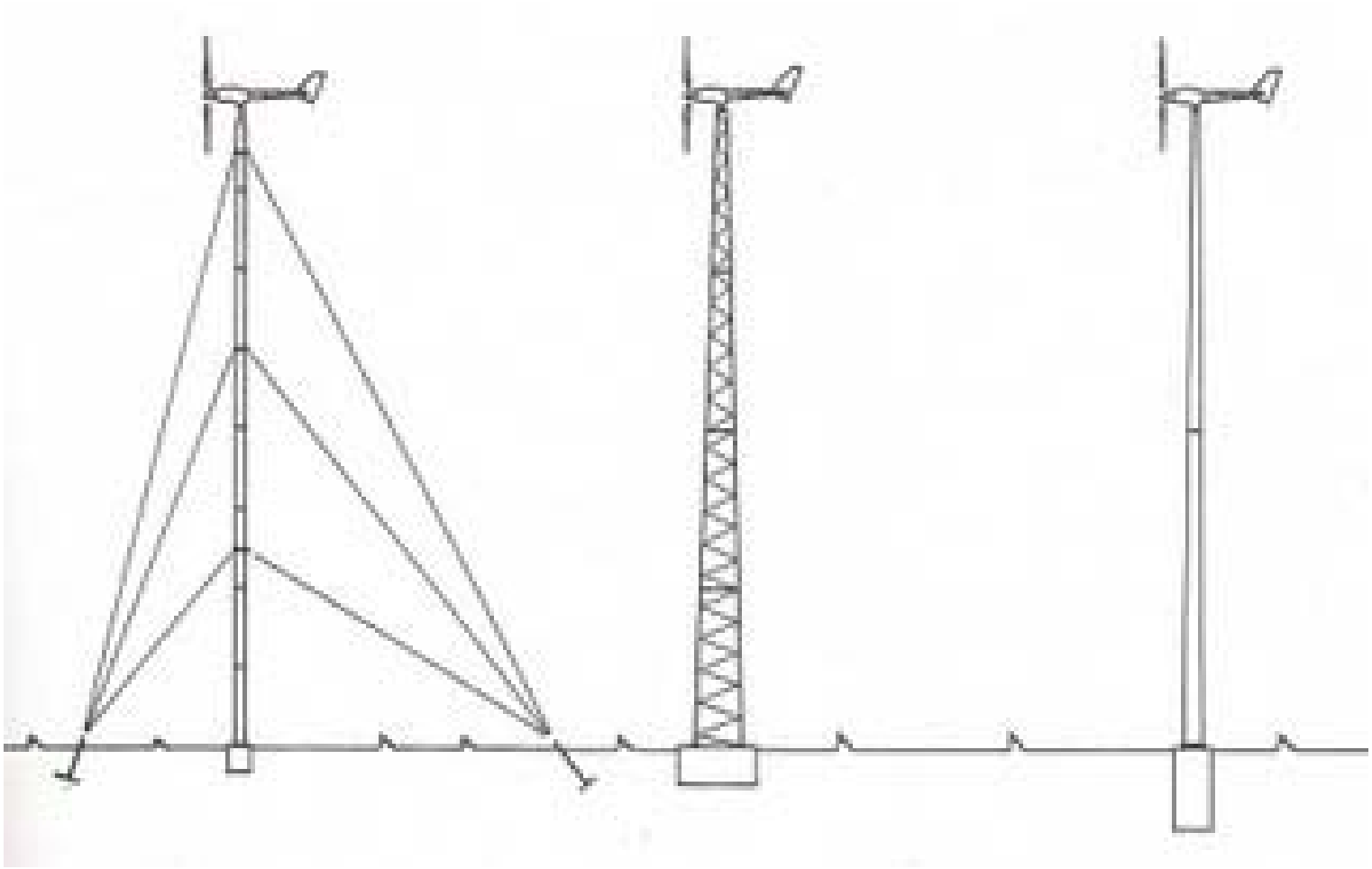
1. Vertical load/weight
2. Horizontal shear force
3. Uplift
4. Overturning moments
5. Rotational force

All of these forces are transmitted to the foundation by the turbine and the tower.



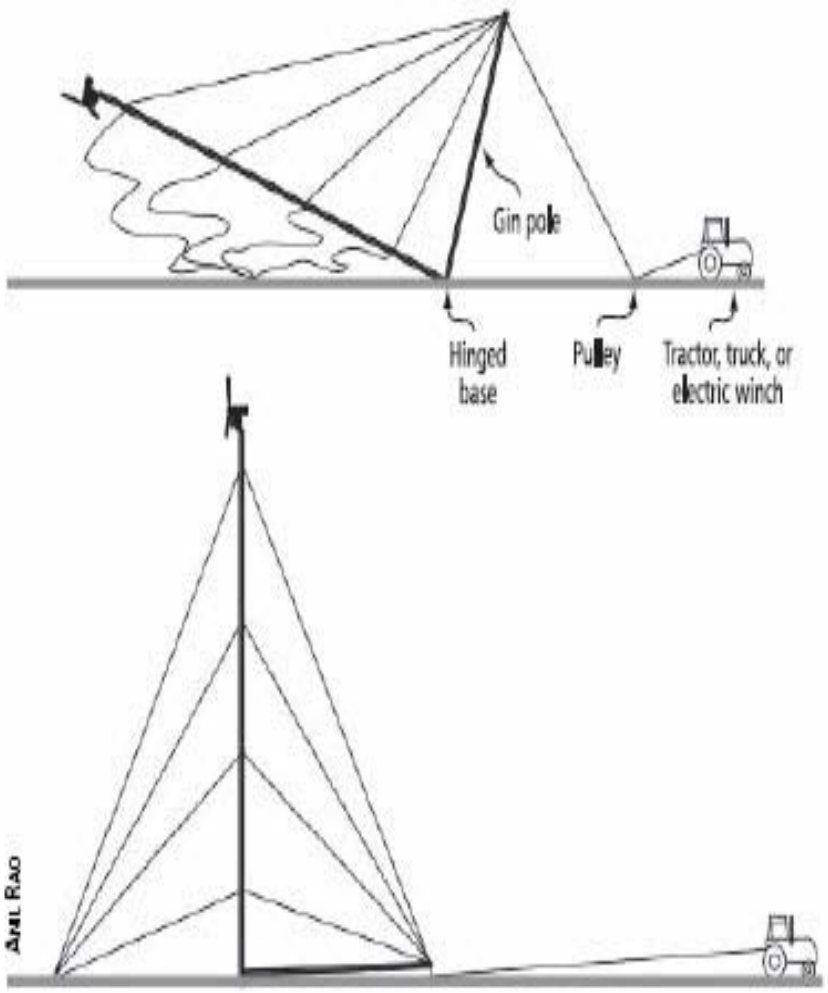
Terrestrial Tower Types/Foundation Types
(for “typical” soil conditions, Class 1 – Class 5)

Guyed Lattice/Monopole Free Standing Lattice Free Standing Monopole

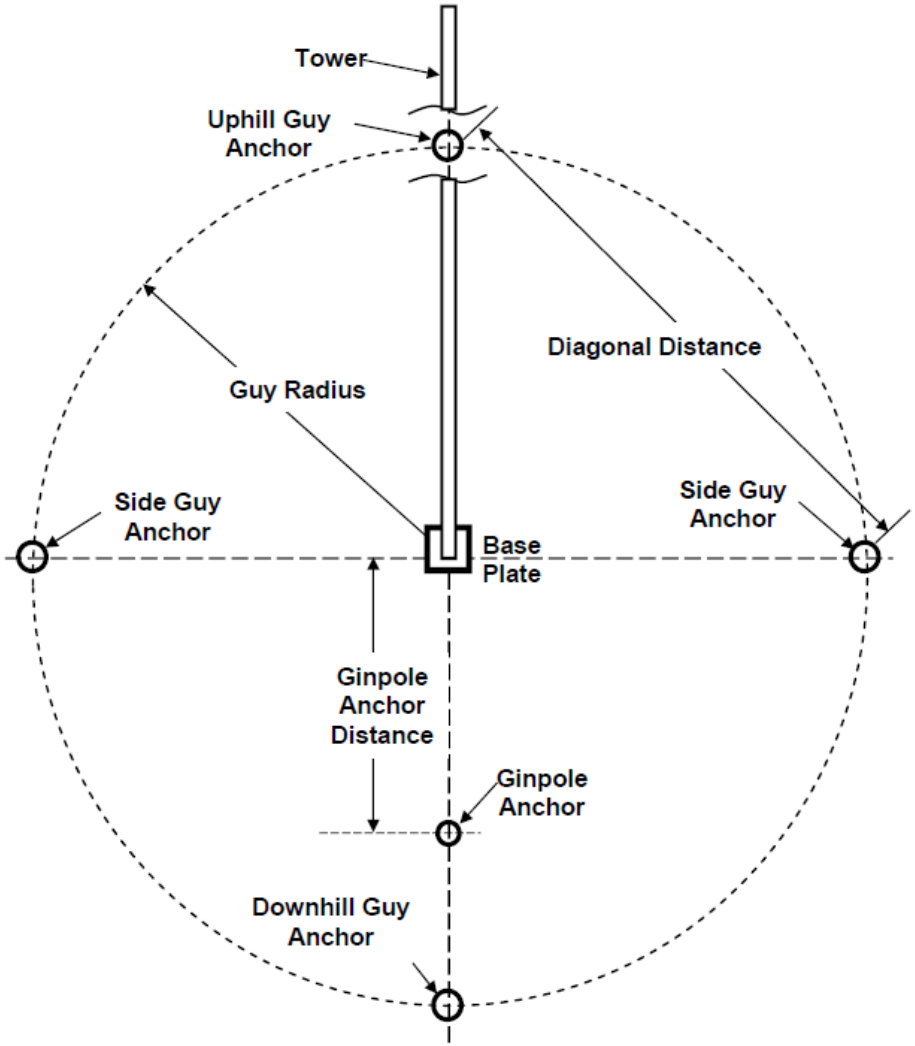


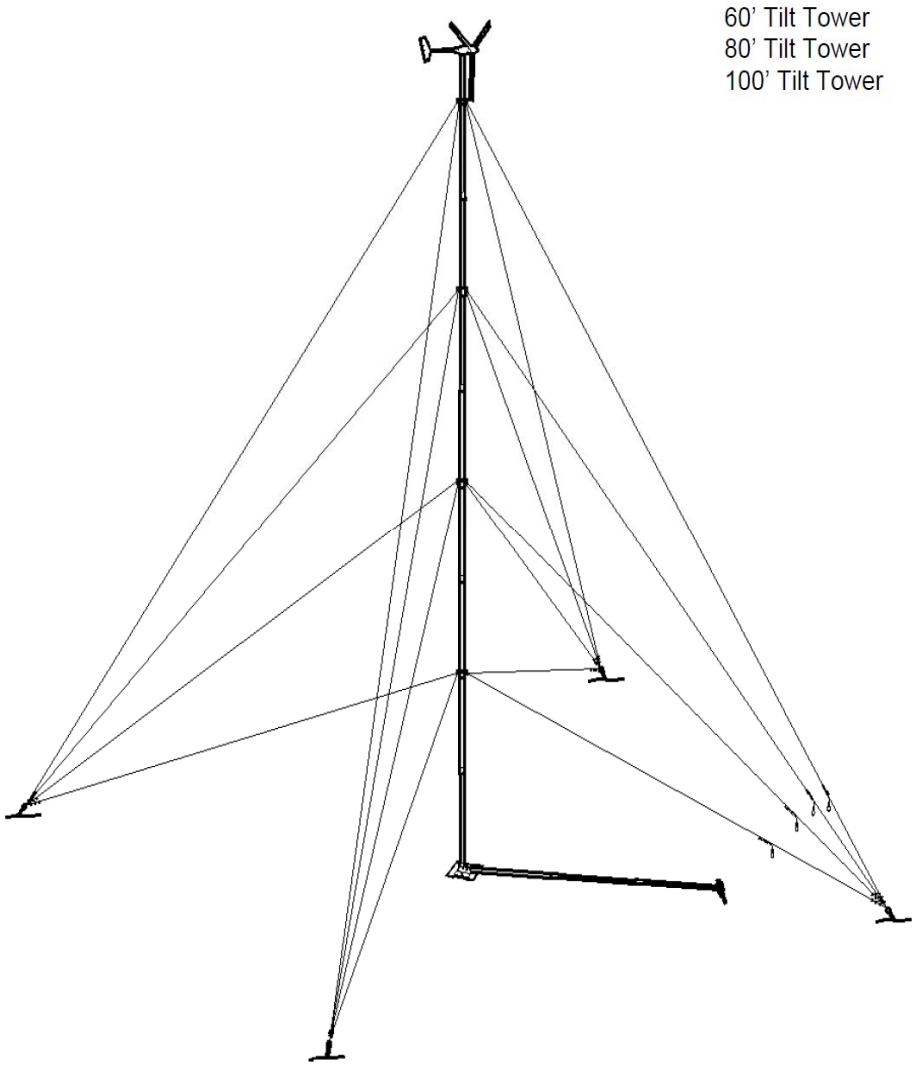
Manual Tilting Towers Using a Winch and/or Gin Poles

1.Typical Foundations - Pier or Pad, Anchors for Guy Wires
2. Typically Small Turbines w/Not Much Head Weight
3. Uses Monopole Tower



Sample Tilting With Winch/Gin Pole Footing Schematic





Tilting With an Actuator Towers

1. Typical Foundations - Pier w/Pad, Caisson
2. Typically Turbines Up To 20 kW
3. Use Hydraulic and/or Electric Tilt Mechanism
4. Use Monopole Towers

Sample Tilting With Actuator Footing Schematic

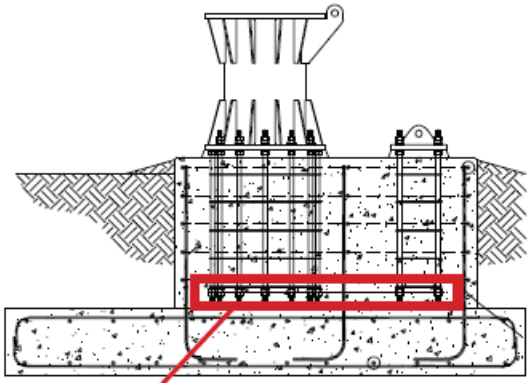


Figure 2. Concrete foundation profile

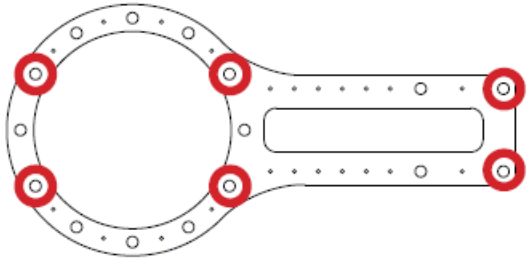
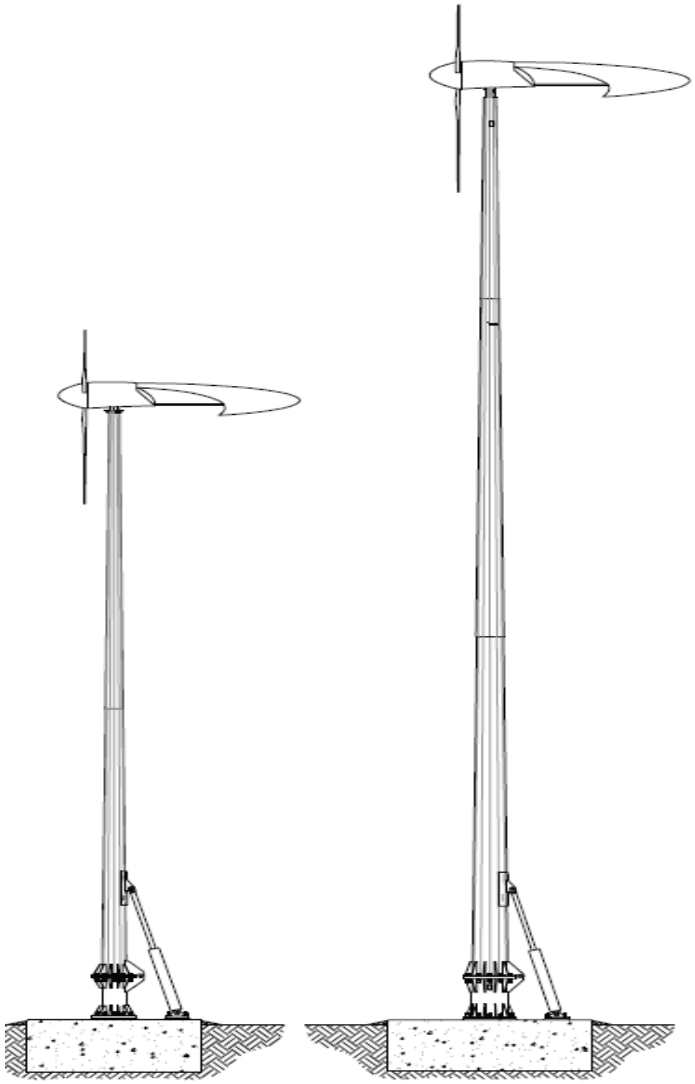


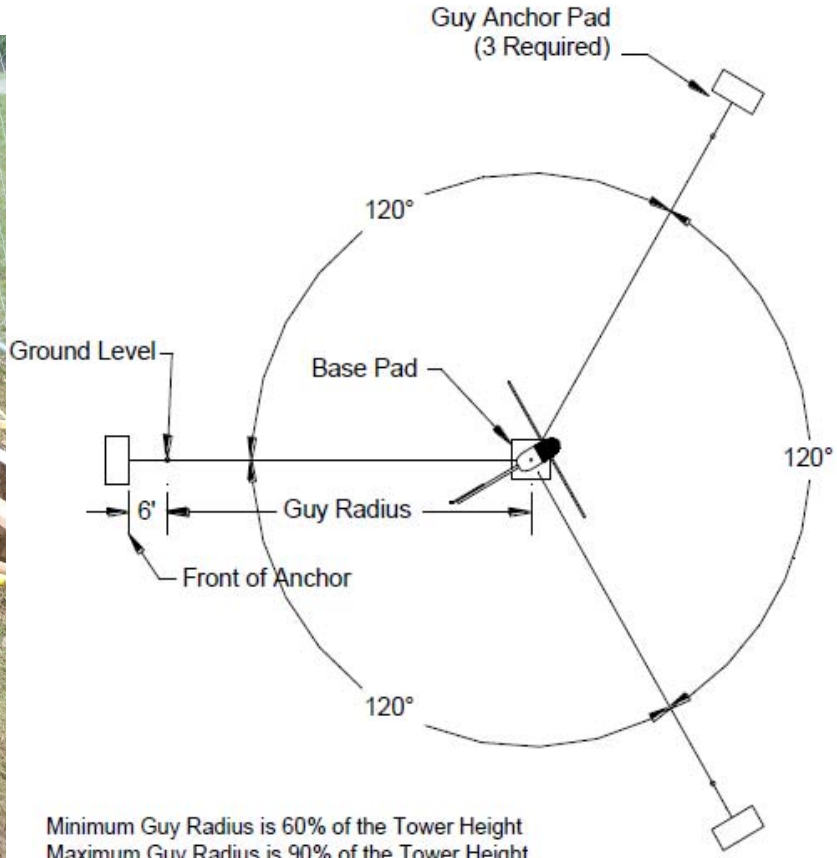
Figure 3. Nut locations on upper side of lower anchor template



Climbable Fixed, Guyed Towers

1. Typical Foundations - Pier w/Pad, Pad, Caisson
2. Typically Turbines Up To 10 kW

Sample Climbable Guyed Tower Footing Schematic

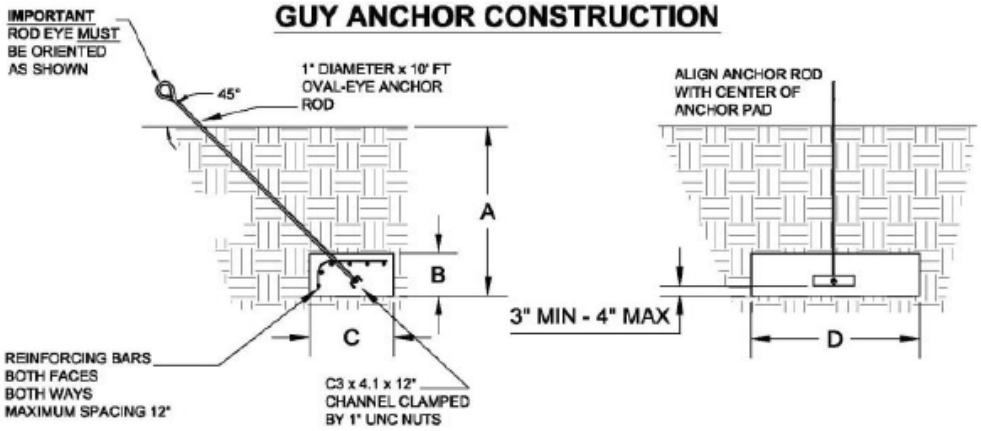


Minimum Guy Radius is 60% of the Tower Height
Maximum Guy Radius is 90% of the Tower Height

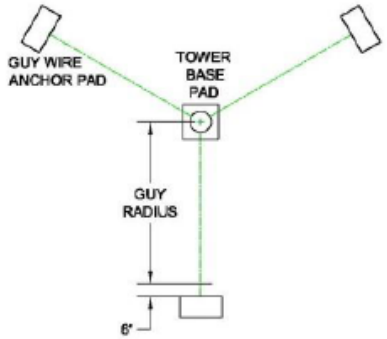
NOTE:
BWC Tower kits are shipped with sufficient guy cable for an 80% radius.
For longer guy radii, the guy cable must be special ordered.

Sample Climbable Guyed Tower Footing Schematic/Guy Anchors

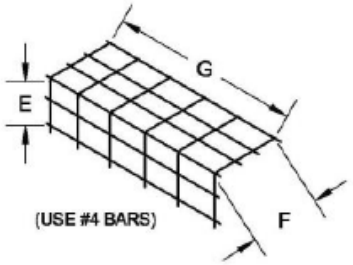
GUY ANCHOR CONSTRUCTION



FOUNDATION LAYOUT



ANCHOR REINFORCING CAGE



DIMENSIONS (IN FEET)

	TOWER HEIGHT		
DIM	60 - 120	140	160
A	6	6.5	6.5
B	1.5	2.5	2.5
C	3	3	3
D	6	6	8
E	1	2	2
F	2.25	2.5	2.5
G	5.5	5.5	7.5

ANCHOR NOTES

1. CONCRETE 3000 PSI MINIMUM.
2. ASTM A-615 GRADE 60 REBAR.
3. COMPACT FILL IN 8" LIFTS TO AT LEAST 100 PCF.
4. WATER TABLE BELOW CONCRETE AT ALL TIMES.
5. MUST EXTEND AT LEAST 6" BELOW FROST DEPTH.
6. AT LEAST 3" CONCRETE COVER REQUIRED OVER ALL REBAR.

Climbable Free Standing Lattice Towers

1. Typical Foundations - Pier w/Pad, Pad
2. Typically Turbines 10 kW to 250 kW

Sample Free Standing Lattice Tower Footing

Sample Free Standing Lattice Tower Footing

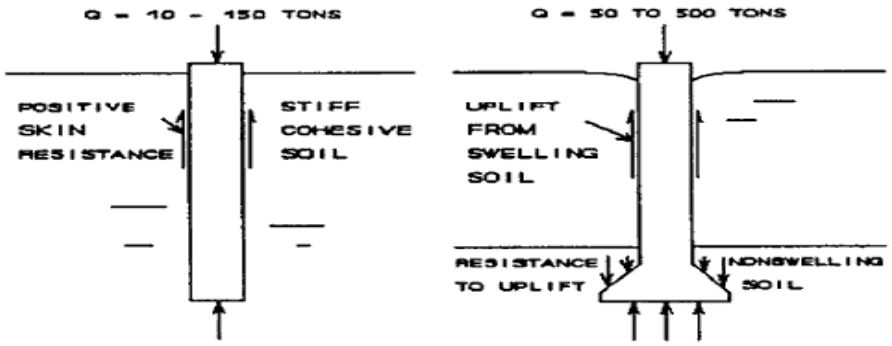
Climbable Free Standing Monopole Towers

1. Typical Foundations - Pier w/Pad, Spread, Caisson
2. Typically Turbines 10 kW to MW+

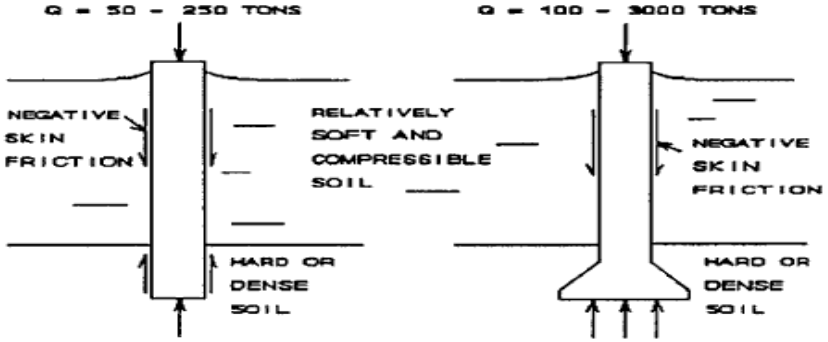
Sample Monopole Tower Footing

Other Footing Types

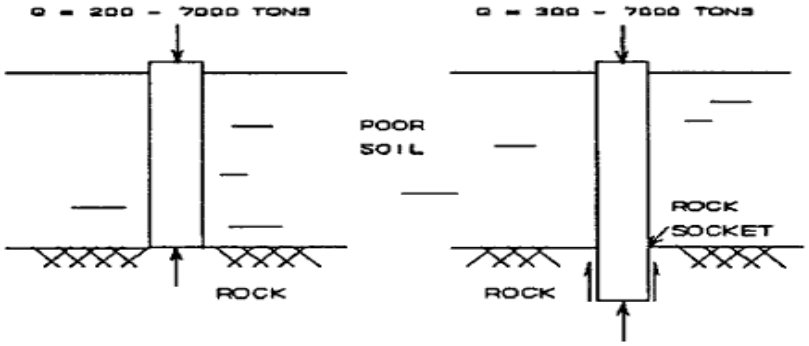
Drill, Drill and Bell, Drill and Anchor (Rock)



a. FLOATING SHAFTS IN HOMOGENENOUS SOIL



b. SHAFTS END BEARING IN HARD SOIL

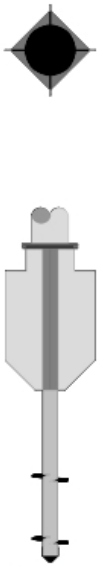


c. SHAFTS END BEARING IN ROCK

Other Footing Types

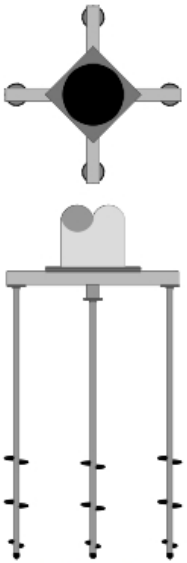
Drill and Anchor (Helical Anchor)

Single pile with angel wing



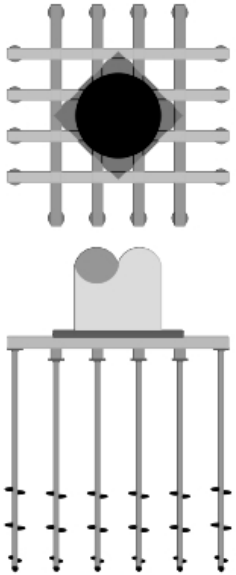
5kW

4 Pile with Simple Cruciform



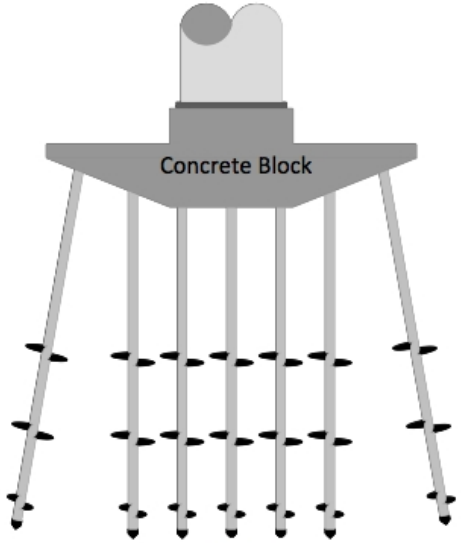
50kW

Multiple Pile Cruciform



500kW

Helical and Concrete Composite



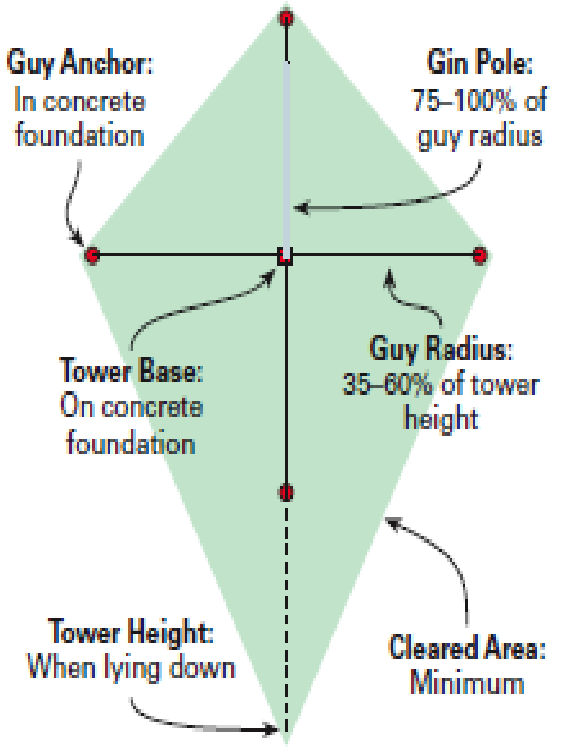
2MW

Helical Anchor

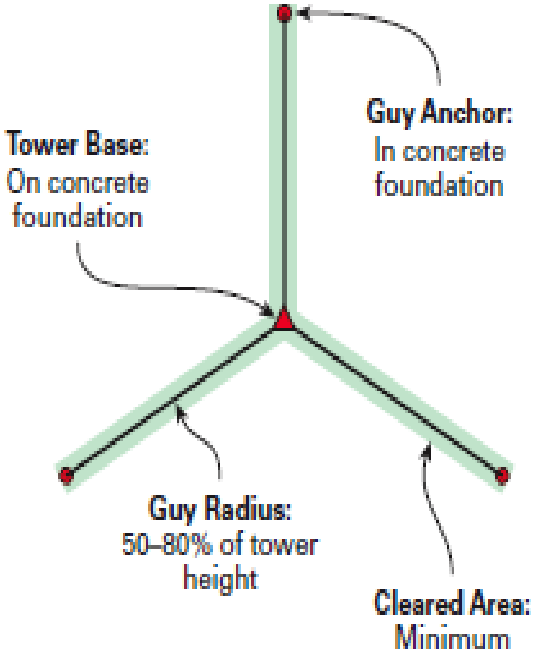
Pros and Cons of Tower Types

Footprint

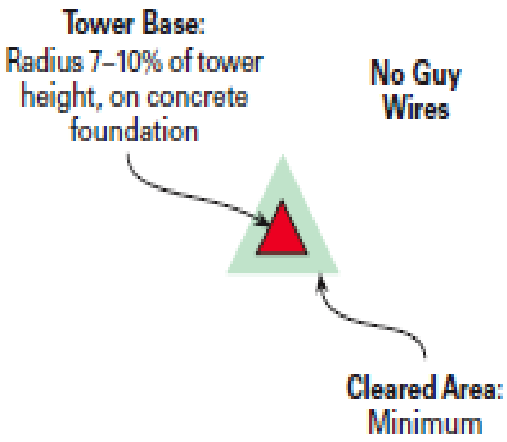
Tilt-Up Tower Footprint



Fixed, Guyed Tower Footprint



Freestanding Tower Footprint



Pros and Cons of Manual Tilting Towers

Advantages

1. No climbing
2. Maintenance and service done at ground level
3. Reasonably cheap by comparison to free standing towers

Disadvantages

1. Large footprint
2. Four sets of guy wires
3. Need fairly level site
4. Used for mostly smaller turbines (10kW or less)
5. Not climbable for minor repairs/service
6. Raising and lowering has inherent risks

Pros and Cons of Tilting With an Actuator Towers

Advantages

1. No climbing
2. Maintenance and service done at ground level
3. Mostly automated tower raising/lowering

Disadvantages

1. Large footprint
2. Need fairly level site
3. Used for mostly smaller turbines (20kW or less)
4. Not climbable for minor repairs & service
5. Raising and lowering has inherent risks
6. More pricey due to lifting mechanisms

Pros and Cons of Climbable Fixed, Guyed Towers

Advantages

1. Lowest cost tower and footing
2. Non-level sites are ok

Disadvantages

1. Three sets of guy wires
2. Large footprint
3. Used for mostly smaller turbines (10kW or less)
4. Must climb for repairs & service
5. Need crane for installation. Adds to cost

Pros and Cons of Free Standing Lattice Towers

Advantages

1. Smaller footprint
2. Non-level sites are ok
3. No guy wires
4. Safer installation than manual tilting towers
5. Taller tower choices

Disadvantages

1. Must climb for repairs & service
2. Climbers must be trained
3. Weather is an overriding factor
4. Need crane for installation. Adds to cost
5. Tools and parts must be carried or hauled up
6. Larger, more expensive footing
7. Labor intensive to assemble
8. More costly than previous tower types

Pros and Cons of Free Standing Monopole Towers

Advantages

1. Smallest footprint
2. Non-level sites are ok
3. No guy wires
4. Slip fit tower sections can be stacked for faster installation
5. Typically tallest tower choices

Disadvantages

1. Must climb for repairs & service
2. Climbers must be trained
3. Weather is an overriding factor
4. Need crane for installation. Adds to cost
5. Tools and parts must be carried or hauled up
6. Larger, more expensive footing
7. Most costly tower type

Installation and Service Safety Issues

General Site Conditions

1. Access
2. Weather
    a. Temperature (heat & cold)
    b. Rain, mud & wind
3. Cranes and system weights
    a. Proper preparation makes for a safe installation
    b. Correct crane staging is essential

Work Baskets, Platforms, Climbing Pegs & Ladders

Work Baskets

1. Something is better than nothing
2. Something well designed is better yet
3. Climb a few towers before you manufacture a solution

Work Baskets, Platforms, Climbing Pegs & Ladders

Platforms

Work Baskets, Platforms, Climbing Pegs & Ladders

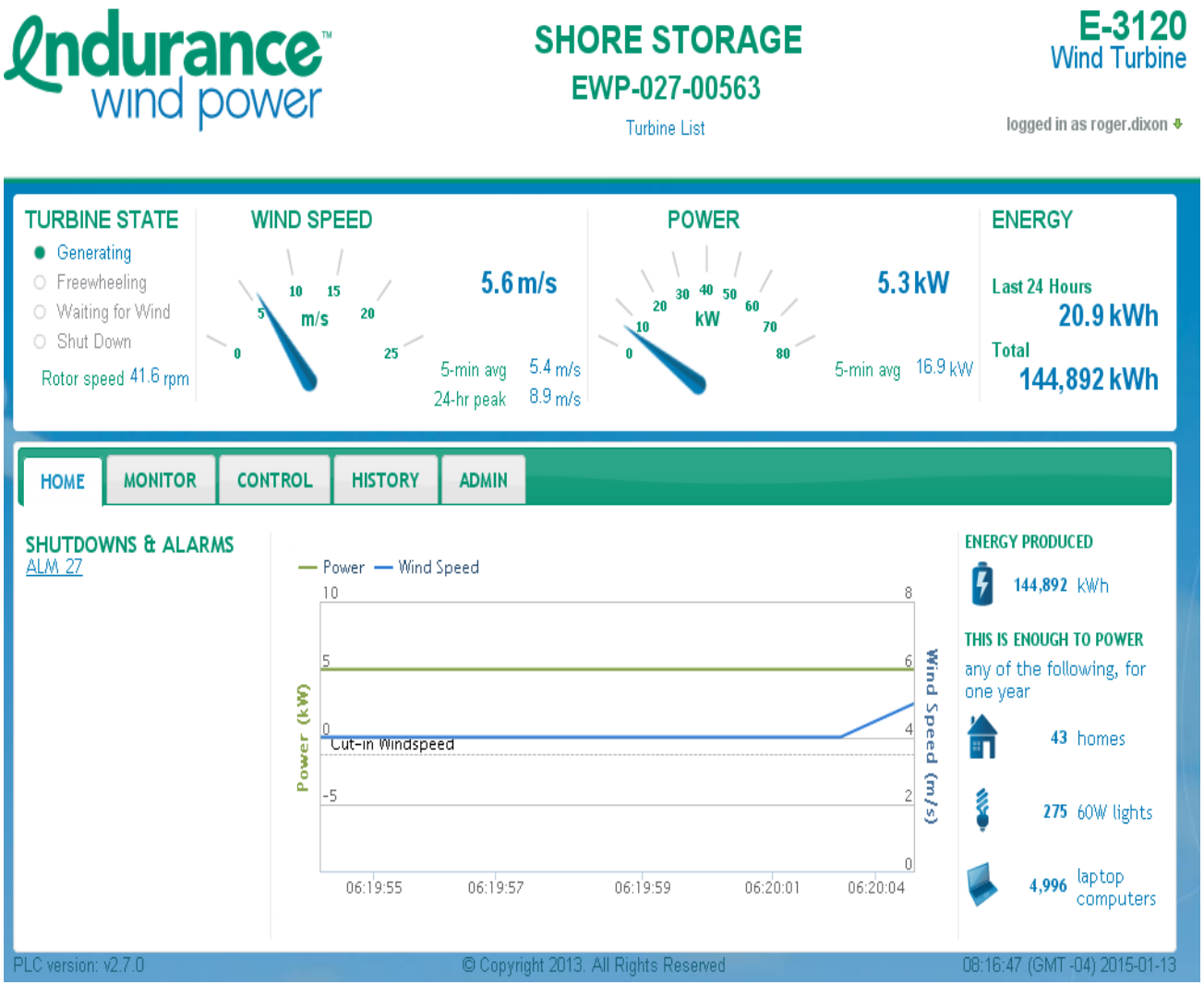
Climbing Pegs vs. Ladders – The Ergonomics of Comfort & Safety

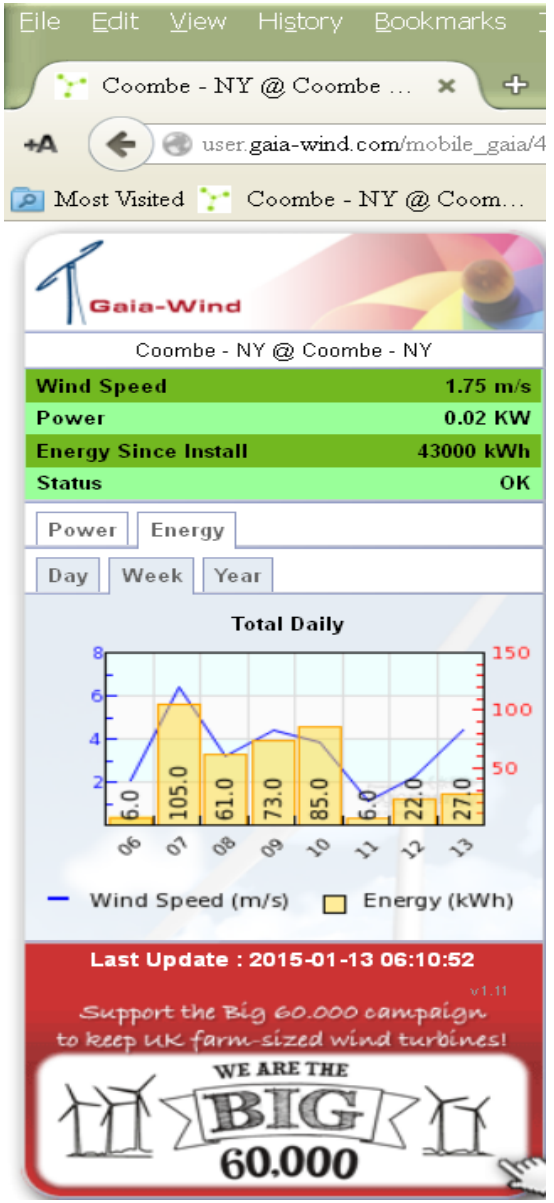
Some Areas of Potential Improvement

1. Modular Footings
    1. ARE Telecom & Wind
    2. AnemErgonics, LLC

Some Areas of Potential Improvement

2. Online Monitoring





Other Areas of Potential Improvement

"Think Outside the Box"

3. Reach and Workability
4. Tie Off Points
5. Yaw Locking Mechanisms
6. Ladders and Safe Climb Systems
7. Climbing Gear

Don't Forget the Human Factors

Credits for Photos and Schematics

1. Mick Sagrillo, Sagrillo Power and Light
2. Gary Harcourt, Great Rock Windpower
3. Ian Woofenden, Home Power Magazine
4. Alan Axworthy, Northern Power Systems
5. Roger Dixon, Skylands Renewable Energy
6. Bergey Windpower
7. ARE Telecom and Wind
8. AnemErgonics, LLC
9. Endurance Windpower
6. Google and the Internet