Accurate Pole Testing Can Increase Resilience of Power Supply Grid and Save Billions of Dollars at the Same Time

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ABSTRACT

Resilience of power supply grid can be increased substantially by more accurate pole inspection and testing. Electric utilities are unnecessarily replacing or re-enforcing electrical poles that still have many years of useful life. Our proof load testing of rejected poles has revealed that around 50% of them had residual strength sufficient for around 20 additional years of serviceable life. The present assessment of poles is very subjective. Poles are often replaced simply on the basis of their age rather than condition. Independent destructive testing of poles has found that the present pole inspection methods reject 60% of safe poles and miss 20% of unsafe poles. According to our statistics, based on the recent results of using our Micro-Stress Pole Testing (MSPT) technology, the expected savings on electricity cost can be approximately 10 billion dollars per annum if all poles across the USA are objectively and precisely tested.

Keywords: pole inspection and testing, pole asset management, mechanical pole test, pole strength analysis, cloud-based system

1 MICRO-STRESS POLE TESTING (MSPT)

Photo 1: General view of MSPT

The Deuar International Group of research companies has developed and perfected over the last 30 years a unique Micro Stress Pole Testing (MSPT) technology which can dramatically improve the utility pole asset management in terms of performance reliability, cost effectiveness and safety to utility personnel and public in general. For example, one utility in New Zealand (owning only about 30,000 poles) has reported that they saved 4 million dollars during the first 9 months of using the MSPT.

1.1 Benefits

Additional major benefits of using the MSPT include:

- Each pole tested and passed by the MSPT can be guaranteed as serviceable for a period of standard pole inspection cycle.
- The MSPT is a perfect risk management tool, allowing for faster and smarter replacement and reinforcement of really dangerous and unsafe poles in a scientifically established priority order.
- The MSPT can accurately test a combined structure of steel reinforced poles.
- The MSPT can estimate the level of safety and remaining serviceable life for each tested and passed pole.
- The MSPT can analyze the residual pole strength and serviceability status anywhere in the world by using an online Cloud-Based System.
- The MSPT can test poles of any size and material.
- The MSPT can be used for pole design and re-design purposes.
- The MSPT can be automated to reduce labor costs for its application.

1.2 Brief Description of MSPT

MSPT applies a relatively small pressure against a pole, always less than its total strength. After the pressure is released the bending back of the pole is measured by highly accurate electronic inclinometers (protractors) attached to the pole.

The bending back of the pole, as recorded by the inclinometers, deflection indicator and corresponding pressure drop are entered into a hand-held computer. Previously, other data such as the pole's diameter, height, timber species etc had been entered into the computer. On the basis of the entered information the computer calculates the pole's total strength.

Each pole is initially subject to a very small preliminary loading (less or equal to ordinary monthly wind pressures) in order to give a first estimate of the pole strength before proceeding to the usual final test load.

The usual final (maximum) test load is much less than the required pole strength and not greater than 30% of the residual pole strength. Consequently, there is no chance of a pole being damaged or pushed over during a test, irrespective of the actual condition of the pole.

There is no danger in the use of the equipment as not only are small pressures involved (comparable to a standard ladder test) but the basic equipment weighs only about 15 kg (33 lbs).

From the safety point of view, the work involved is comparable to hammer-blow sound tests of poles and, similarly, can be carried out by a single operator.

To explain the MSPT in more technical terms, a sophisticated computer structural analysis processes all the measurements and other data (an iteration procedure including a method of consecutive approximations is run until the calculated pole displacements match the measured pole displacements with sufficient degree of accuracy) and determines accurately the following properties of a tested pole:

a) Stiffness or the so called Reduced Modulus of Elasticity (RMOE) of the critical section of a pole
b) Degree of pole degradation, if any

Knowing the value of pole stiffness, the so called Reduced Modulus of Rupture (RMOR) of pole timber can be determined from the empirically proven relationship between the MOR and MOE (see Fig. 1).

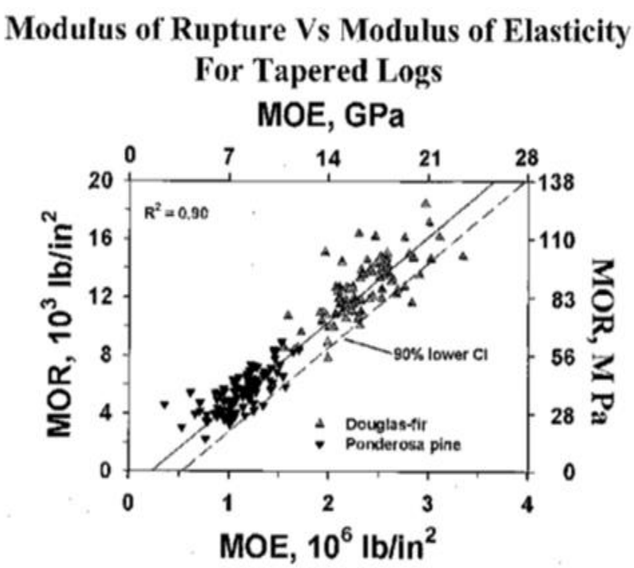

Figure 1: Relationship between MOR and MOE

Having the reduced value of MOR, the total bending strength of a pole can be calculated using the following general relationships:

RMOE = function of (Force, Displacements, Taper, Diameter, Shear Rigidity, …)
RMOR = function of (Empirical Coefficients, RMOE)
Total Bending Strength = function of (Empirical Coefficients, RMOR, Section Modulus)

Knowing the minimum required strength (Design Working Load) of a pole, corresponding to the actual loading conditions on a pole, and approximate rate of the pole decay, an anticipated remaining serviceable life of the pole can be calculated with an acceptable level of accuracy according to the following relationship:

Remaining Life = function of (Design Working Load, Total Bending Strength, Decay Rate, …)

Also, based on the known Standard and Reduced values of MOE, the sizes of typical decay patterns such as internal pipe, external decay (neck) and one side cavity can be estimated without the need for costly excavations and/or destructive pole drilling, using the following general relationship:

Decay Size = function of (Standard MOE, Reduced MOE, Force, Displacements, …)

1.3 Unique Abilities of MSPT

MSPT can:

- Determine the combined strength of timber and steel in reinforced poles.
- Account accurately for extensive natural variability of timber strength properties (see example illustration of the wide MOR variability in Fig. 1). The recent series of destructive laboratory tests of 200 sound Slash Pine specimens has shown that the weakest specimen had MOR value of 40MPa while the strongest specimen had MOR value of 200MPa (with a variability ratio of 1 to 5 !).
- Account for complex shapes and forms of physical and biological degradation of poles (such as knot holes, woodpecker holes, drilling holes, splits, shells, three dimentional cavities and the like).

None of the above abilities of MSPT can be accomplished by any other known methodology.

2 CASE STUDY OF MSPT IN GEORGIA POWER

The total of 234 rejected poles were tested in Fort Gordon near Augusta (36 poles) and Atlanta (198 poles).

Out of 36 poles tested in Fort Gordon 22 poles (61%)

passed the test with the residual strength not less than 66% of the original pole strength. Similarly, out of 198 poles tested in Atlanta 110 poles (55%) passed the test.

Overall, out of 234 poles tested 132 poles (56%) passed the test.

Poles selected for testing were rather expensive. Most of them were High Voltage poles and many of them were either transformer or switch poles. It is estimated that the average cost of replacement of these rejected poles would be around $4,000 per pole. The cost of testing one pole was approximately $200.

As a result the cost savings to Georgia Power were as follows:

Cost of pole testing : 234 x $200 = $46,800
Cost saved on pole replacements: 132 x $4,000 = $528,000
NET SAVINGS: $528,000 - $ 46,800 = $481,200

Hence the net savings were about 10 times greater than the actual cost of testing.

It also should be pointed that out of 102 failed poles MSPT found 21 poles (21%) to be much weaker than originally estimated by the present routine pole inspection process. Thus MSPT is very useful to prioritize the replacement of unsafe poles and indicate which poles should be replaced first.

3 VALIDATION TESTS

Example of independent MSPT validation break tests carried out by Unison Networks (New Zealand) is illustrated in Photo 2 and Fig. 2.

Photo 3: Pole 113116 at failure.
Photo 4: Fracture at ground level at base of Pole 113116.

PHOTO 2: VALIDATION BREAK TEST

MSPT has been also succesfully validated by:

- Georgia Power (USA)
- Queensland University of Technology (Australia)
- National Electric Energy Testing, Research and Application Center (USA)
- Forestry Research Institute (New Zealand)
- Deuar Pty Ltd (Australia)
- Electricity Supply Board (Ireland)

4 SUMMARY

In summary, the MSPT can be superior to any other known pole testing method since it determines the total pole strength on the basis of direct measurements of actual mechanical properties of timber in each tested pole.

STATISTICS FROM MPT40 VALIDATION TESTS IN HAWKES BAY

Values of Predicted Pole Bending Strength versus Actual Break Strength [in kNm]

Adjustment Factor 0.816

General Pole Data

Pole No	Actual Break Strength	Strength Group	Age	Pole Condition	Ground Cond	Pole Height	Pole Type	Orig Dia	Solid Dia	Sling Height	GL Dia	Section Modulus	E (Measured)	MOR (Basic)	Originally Predicted Strength	Original Ratio	Adjusted Predicted Strength	Adjusted Ratio	Comments
	'kNm					m		m	m	m	m	m^3	10^3 'MPa	'kPa	'kNm		'kNm		
113116	139	S2	1966	Fair. neck just below gl	Average	8.0	Free stand	0.312	0.266	0.02	0.312	0.002988	12.13	61051	161.09	1.16	131.39	0.95	
142925	77	S5	2000	Fair	Soft	8.7	Free stand	0.277	0.277	0.27	0.280	0.002156	10.98	53557	101.97	1.32	83.17	1.08	
113113	65.2	S2	1966	Poor. few longitudinal cracks at gl	Soft	8.0	Free stand	0.314	0.270	0.13	0.315	0.003082	7.73	32376	88.12	1.35	71.87	1.10	Carroty Rot?
135159	66.1	S2	1947	Good. brace log on load side	Average	8.5	Free stand	0.240	0.240	0.03	0.240	0.001363	13.15	67699	81.47	1.23	66.45	1.01	
135158	56.8	S2	1947	Fair. brace log on load side. A bit weathered	Average	7.6	Free stand	0.206	0.197	0.03	0.206	0.000862	20.92	118336	90.12	1.59	73.50	1.29	
135432	40	S2	1947	Good. brace log on load side. A bit weathered	Average	8.5	Free stand	0.201	0.197	0.05	0.202	0.000804	14.79	78386	55.65	1.39	45.39	1.13	
135135	62.9	S2	1947	Fair. brace log on load side. A bit weathered	Soft	8.5	Free stand	0.225	0.220	0.05	0.226	0.001127	15.48	82883	82.46	1.31	67.26	1.07	
135134	49.8	S2	1947	Fair. brace log on load side. A bit weathered	Soft	8.5	Free stand	0.194	0.184	0.02	0.194	0.000719	16.06	86663	55.04	1.11	44.90	0.90	
135203	79.2	S2	1947	Fair. A bit weathered. small neck at gl	Soft	8.0	Free stand	0.233	0.208	0.05	0.234	0.001251	12.97	66525	73.48	0.93	59.93	0.76	
125668	95.6	S2	1947	Fair. A bit weathered. neck at gl	Soft	8.5	Free stand	0.269	0.240	0.06	0.270	0.001925	10.28	48995	83.30	0.87	67.94	0.71	
Average	73.16					8.28		0.247	0.230	0.071	0.248	0.001628	13.45	69647	87.27	1.23	71.18	1.00	
Correlation Coefficient (R value)															0.880		0.880		
Standard Deviation																0.217		0.177	
Coefficient of Variation																0.177		0.177	

FIGURE 2: STATISTICS FROM VALIDATION TESTS

Due to its great accuracy the MSPT does not only identifies unsafe and dangerous poles (often missed by other available methods) but also reduces the overall pole management costs by a simultaneous elimination of the great number of unnecessary reinforcements and replacements of poles (which are prematurely condemned/rejected by the other pole inspection methods).