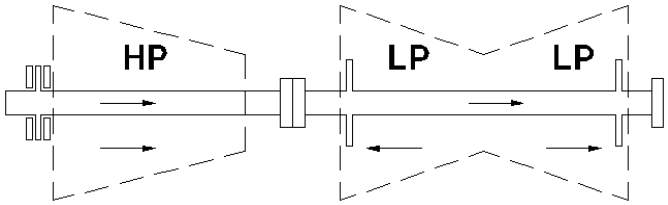
STI Vibration Monitoring Inc.

Field Application Note

TSI - Differential/Rotor Expansion DIFFEXP

Differential Expansion (DE) and/or Rotor Expansion (RE) are very important measurements usually supplied by the Original Equipment Manufacture (OEM) as part of a Turbine Supervisory Instrumentation System (TSI) on large steam turbine generator applications. Although the application of Differential Expansion and Rotor Expansion have much in common, it is important to understand the difference between the two measurements.



Differential Expansion on a turbine is the relative measurement of the rotor's axial thermal growth with respect to the case.

Rotor Expansion on a turbine is the absolute measurement of the rotor's axial thermal growth with respect to the turbine's foundation.

A typical large steam turbine power generation unit will have a thick case, on the order of 12" to 18". Due to the mass of this case, it will expand and contract at a slower rate than the relatively thin (hollow) rotor. During turbine startup, extra care must be used to ensure that the case has been properly heated and expanded sufficiently to prevent contact between the rotor and the case. Several DE or a combination of DE and RE measurements may be employed on a single large turbine generator.

For many years, Power Generation Utilities and other owners of large steam turbines have been retrofitting the original OEM supplied TSI systems with modern TSI systems which are more accurate, and easier and less costly to maintain.

Eddy Probe Transducer Systems have been very successful replacing the older single or dual coil capacitive and inductance type transducer systems. Eddy Probe Transducer systems are available with up to 1000 mils (1") of linear range. When properly applied, these transducers can replace any existing DE or RE transducer system even those with ranges over several inches.

Existing OEM Applications

In general, modernizing or replacing DE and RE transducers and monitor systems is reserved for those machines that were originally equipped with these measurements by the OEM. Usually, the user of the system wants to replace the existing DE or RE system with a modern system. The new system has exactly the same range and alarm set points as the old system. This

Insures that the user follows the original OEM operating instructions and simplifies operator training and understanding.

Large steam turbine rotors were originally manufactured with two (2) types of DE and RE measurement surfaces:

Perpendicular Collar

Many turbines have one or more integral collars machined on the rotor. These collars will usually have smoothly machined faces of 2" to 3" and be several inches thick.

The existing OEM transducer system will usually employ a custom bracket with dual (complimentary) coils one on each side of the collar.

Rotor Ramp

Some turbines will have machined conical surfaces or ramps on the turbine shaft at one or more locations. Ramps increase the operating range of the measurement transducer by the sine of the ramp angle allowing larger measurements or the use of shorter-range transducers.

The existing OEM transducer system will usually employ a custom bracket with dual (complimentary) coils mounted perpendicular to the ramp surface.

Ramp angles can usually be determined by referring to the original OEM Turbine Manuals, or they can be measured if necessary. Common Ramp angles are 7^{o}, 11^{o}, and 14^{o} as examples.

Occasionally a ramp may be machined on a collar. This ramp will usually have a much larger angle with a smaller viewing surface (i.e.: 45^{o}).

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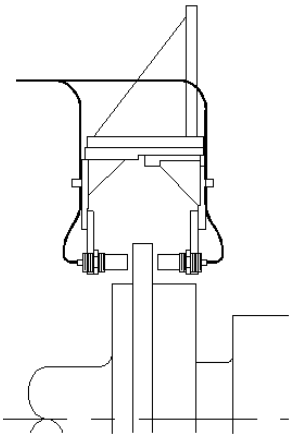
Retrofit Applications

In almost all cases, retrofitting the existing DE or RE transducers with Eddy Probe's is simply a matter of determining the required operating full range with alarm set points, whether its a collar or ramp application, angle of the ramp, and the shaft viewing or target area.

Whenever the expected range exceeds a single transducer range a complimentary system is required. A complimentary system utilizes two (2) Eddy Probe transducers viewing the opposing faces of the collar or ramp. The complimentary system extends the operating full range of the system. This system operates such that as the collar or ramp moves out of the operating range of one transducer it moves into the operating range of the second transducer.

As Eddy Probe systems operate on the proximity theory of operation, they are not affected by oil or other non-conductive material that may come between the target area and the transducer. As the Eddy Probe tip radiates a high frequency RF signal roughly in a 45^{o} conical shape from the probe tip the target area must be three (3) times the tip diameter. Care must be taken to insure that the Eddy Probe transducer is mounted perpendicular to within a few degrees of the target or viewing area. Excessive mounting error will change the calibration factor of the installation.

Perpendicular Collar



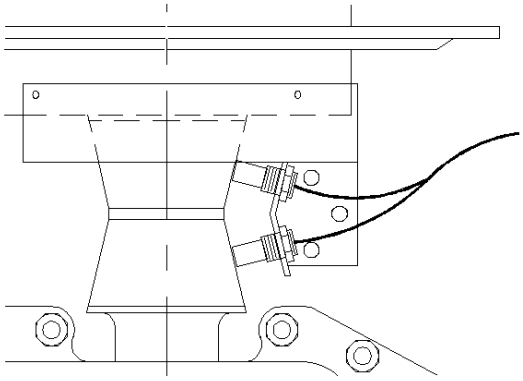
Perpendicular 90^{o} Collars can be measured by either a single Eddy Probe transducer or by complimentary transducers mounted on either side of the collar. The size of the collar face available for the Probe viewing surface and the required measurement range will determine which method is best suited for the application.

The following operating ranges are available. The operating full range for single transducer applications viewing a perpendicular collar is the same as the transducer's linear range.

	Single	Complimentary
CMSS65/68	90 mils	180 mils
CMSS62	240 mils	480 mils
CMCP-1000	1000 mils	2000 mils

Installation of the required Eddy Probe transducer(s) can be made by either modifying the existing DE or RE bracket, or by fabricating a new bracket.

Rotor Ramp



A Rotor Ramp installation can also be measured using either a single Eddy Probe transducer or by complimentary transducers configuration. The size of the Probe viewing surface and measurement range required will determine which method best suites the application.

The operation range of the transducer is calculated by dividing its published linear range by the sine of angle of the ramp. Double the single transducer range for complimentary transducers.

For example, the following operating ranges are available using the following extended range Eddy Probe systems viewing a 14^{o} Ramp.

	Single	Complimentary
CMSS65/68	372 mils	744 mils
CMSS62	992 mils	1984 mils

For example, for a 500-mil measurement range with a 14° ramp, the complimentary P/N CMSS68 system should be used. This will maximize resolution of the monitoring system, and yield the most economical installation.

Installation of the required Eddy Probe transducer(s) can be made by either modifying the existing DE or RE bracket, or by fabricating a new bracket.

Installation

DE and RE Eddy Probe systems operate on the proximity theory. An Eddy Probe system consists of a matched component system: a pickup, an extension cable, and a signal sensor. The signal sensor generates a high frequency oscillating RF signal that is sent through the extension cable to the pickup tip. The pickup tip, having a wound coil of fine wire, radiates an electromagnetic field. As the radiated field is bisected by the rotor surface, eddy currents are created on the rotor surface. As the rotor surface moves closer to the pickup tip, a greater amount of eddy currents are created proportional to the gap between the surface and the pickup tip. The signal sensor contains a demodulator, which measures the increase in eddy currents, and generates an equivalent DC voltage proportional to the gap.

Extra care must be exercised to ensure that the pickup axis is perpendicular to the viewed surface. An error of ±1° can cause a significant error in the measurement.

Calibration

In all cases, it is extremely important to complete a calibration curve or graph prior to installation. This graph allows the engineer to document and graphically visualize how the required mechanical range and alarm set points fit the Probe's system's operating range.

First, prepare an Eddy Probe system calibration curve using the supplied calibration data, or using actual empirical calibration data derived in the field. Then overlay the required full-scale range and alarm set points for the machine on the calibration curve. The two curves should be centered so that there is an equal amount of unused linear range at each end of the Probe curve.

With this graph completed, gapping the Eddy Probe transducers is simply a matter of knowing the mechanical position of the rotor, finding the matching Probe DC Gap on the graph and gapping the Eddy Probe transducers appropriately.

Pickup Calibration - Single DE with Collar

Once the required DE range has been established, the operating range of the pickup must not be exceeded by the DE measurement. The pickups should be calibrated, or adjusted, when the turbine is in a known thermal condition. This condition is almost always when the turbine is in a cold state. The OEM documentation may list the cold set point as the "Green Mark" condition with corresponding DE measurements that the instrumentation system should indicate.

Next, the direction of thermal growth must be determined. The indications may be termed "rotor long" and "rotor short". The OEM may list the two extreme alarm set points as "Red Mark".

For example, consider a turbine with the thrust bearing at the front standard, the DE collar located between the LP turbine and the generator, and the single DE pickup located on the governor side of the collar. The "rotor long" indication will be when the relative gap measurement between the collar and the pickup has increased. The "rotor "short" indication will be when the gap has decreased.

The pickup should be chosen so that the linear range of the pickup exceeds the expected DE range including the alarm set points. The cold set point for the pickup adjustment should allow the center of the DE range to correspond with the center of the pickup's operating range. A simple calculation will provide the required pickup gap for the cold set point.

Pickup Calibration - Single DE with Ramp

The same requirements as listed in the section above apply for a single DE pickup system with a ramp target.

Additional requirements are that the ramp angle must be included in the transducer calibration curve with the gap and alarm set point calculations. If the ramp surface is small, the pickup diameter sizing must be a consideration. Also, the pickup orientation with respect to the ramp must be considered to insure that the ramp will not "grow" out from under the pickup at either alarm extreme.

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Pickup gap voltages (VDC) would be calculated to include the 14° ramp angle as follows:

Cold Gap Volts = Cold Gap x sin (14°)
Rotor Long Volts = Long Gap x sin (14°)
Rotor Short Volts = Short Gap x sin (14°)

Pickup Calibration - Dual DE with Collar

Dual DE pickup systems viewing a collar will have two separate Probe systems that view either side of the DE collar. This application is a complimentary system where the collar should grow out of the range of one pickup and into the range of the other pickup.

One pickup will be installed on the governor side of the collar and the other installed on the generator side of the collar. Generally the pickups will be installed so that when the collar is centered in its operating range, both pickups should be indicating the same gap voltage reading.

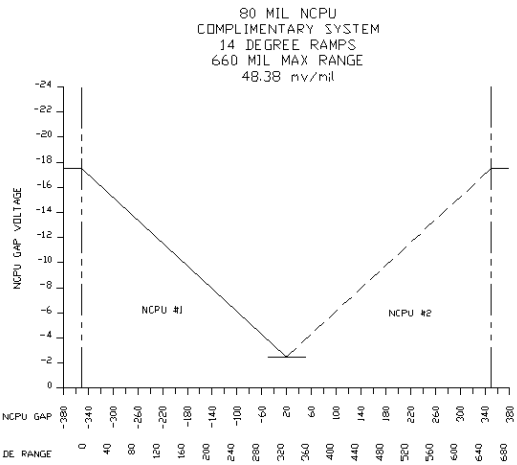
Cold pickup adjustment involves determining the equivalent gap voltage for the pickup on the governor side of the collar. This pickup may be gapped electrically.

The other pickup may be out of its operating range when the turbine is in the cold condition. This means the pickup on the generator side of the collar will have to be gapped mechanically.

Mechanically gapping the generator pickup involves figuring the difference between the cold gap of the governor side pickup and the equivalent gap of the governor side pickup when the collar is centered, and adding this value to the equivalent gap of the generator side pickup when the collar is centered. This calculation will result in an equivalent mechanical gap at which the generator side pickup is to be gapped.

Pickup Calibration - Dual DE with ramp

Dual DE pickup systems follow the same requirements discussed above for collar applications, but the gap voltage or mechanical gap values will incorporate the ramp angle. Certain turbines may have the ramps machined so that the pickups, when installed, are facing away from each other. Other turbines will have the ramps machined so that the pickups face towards each other. Regardless of the orientation, the pickup calibration procedure is the same.



For this application, one the governor side pickup will be calibrated (adjusted or gapped) electrically, while the other will be calibrated mechanically while the turbine is in the cold condition.

This application will have each pickup indicating the same gap voltage when the both ramps are centered on the pickups. The governor side pickup cold set point is calculated for a 11° ramp as follows:

Cold Gap Volts = Cold Gap x sin (11°)

Calculating the required mechanical gap for the generator pickup involves figuring the difference between the cold gap of the governor side pickup and the equivalent gap of the governor side pickup when the ramps are centered, and adding this value to the equivalent gap of the generator side pickup when the ramps are centered. This calculation will result in an equivalent mechanical gap at which the generator side pickup is to be gapped.

DE Installation Checklist

1. Mounting Type: Collar or Ramp
2. Ramp Angle
3. No. of Pickups: Single or Dual
4. Pickup Linear Range
5. DE Cold Set point
6. DE Rotor Long Set point
7. DE Rotor Short Set point
8. Pickup Orientation: Gov Side or Gen Side
9. Target Sizing
10. Pickup Bracket(s) Documented
11. Pickup Calibration Documented
12. Pickup Cold Gap Documented