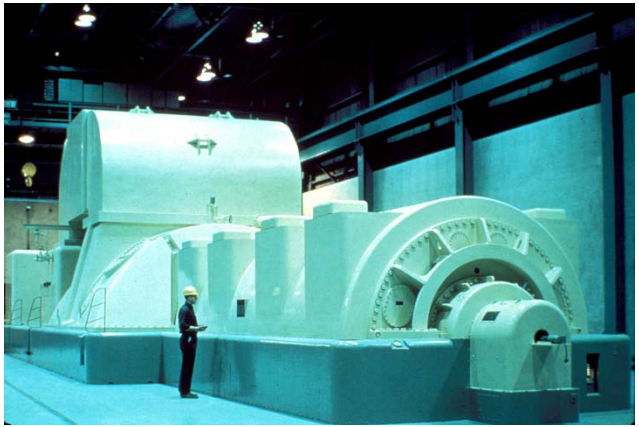
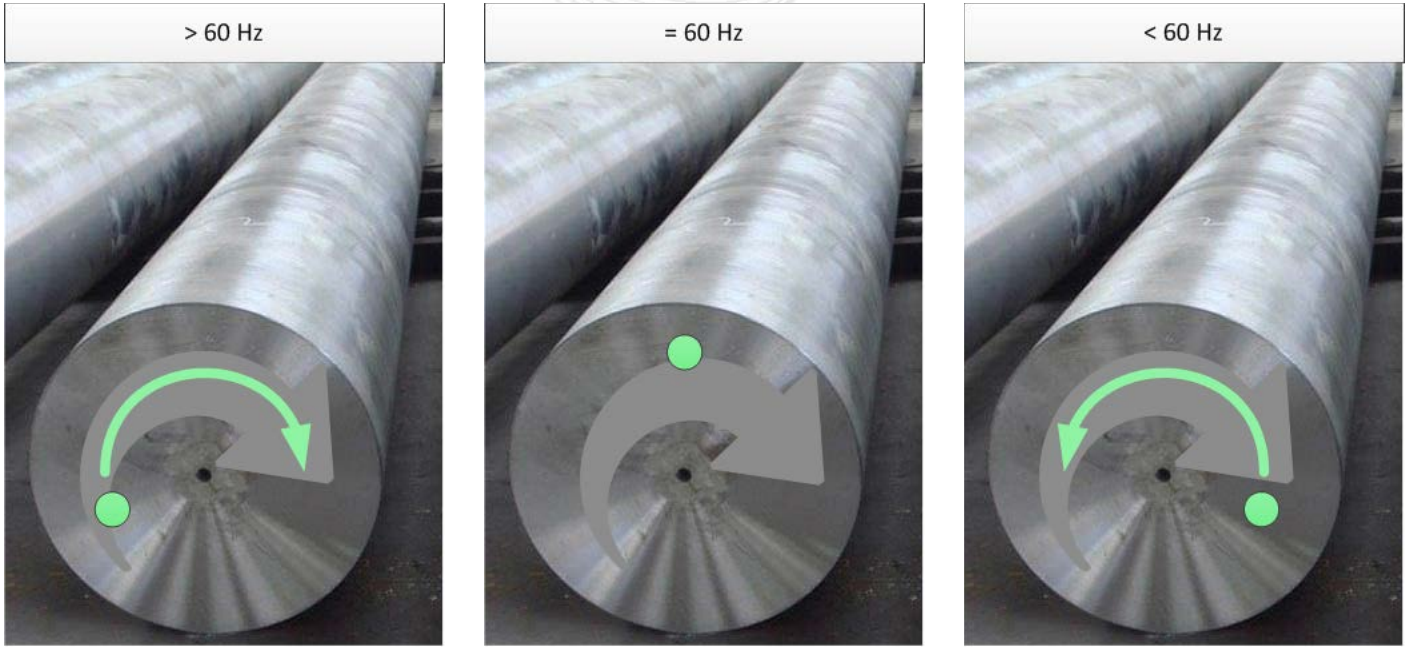
Handling Phase Angle Wrapping When Comparing Two Synchrophasor Measurements

IF ((B > A) AND (B < A +180)) OR (B < A - 180) THEN -ACOS(COS(A-B))
ELSE ACOS(COS(A-B))

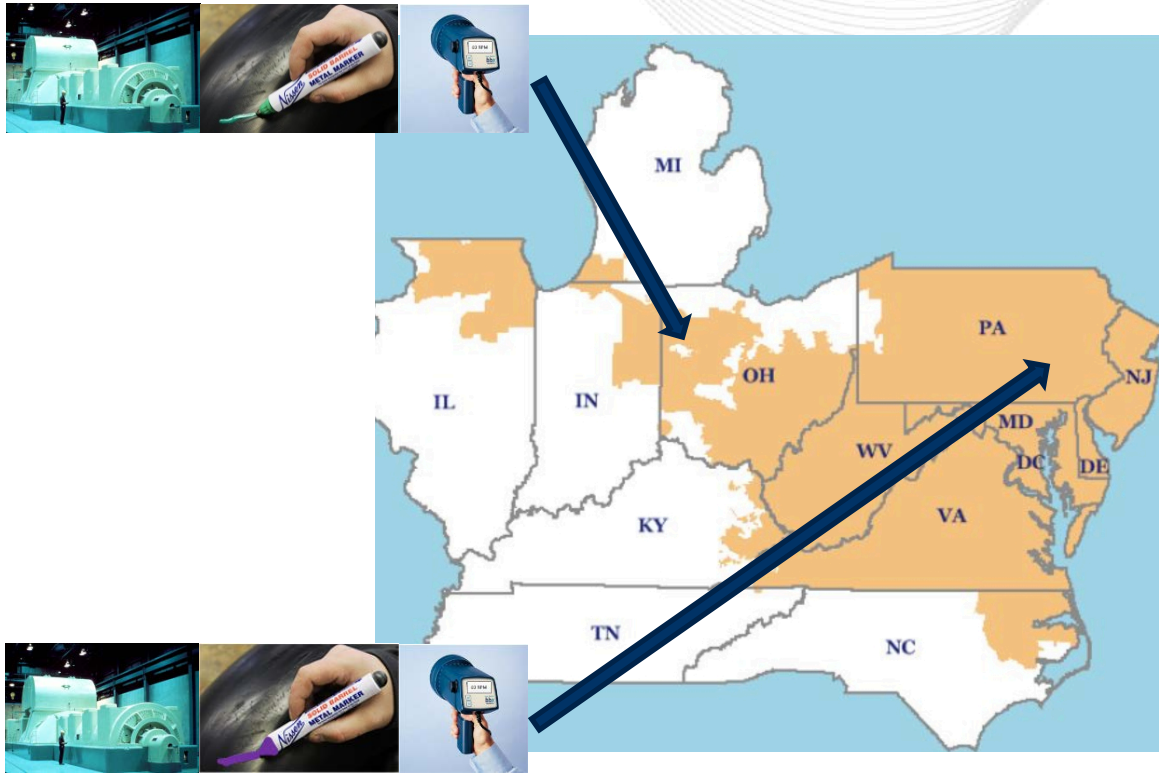
The Basics





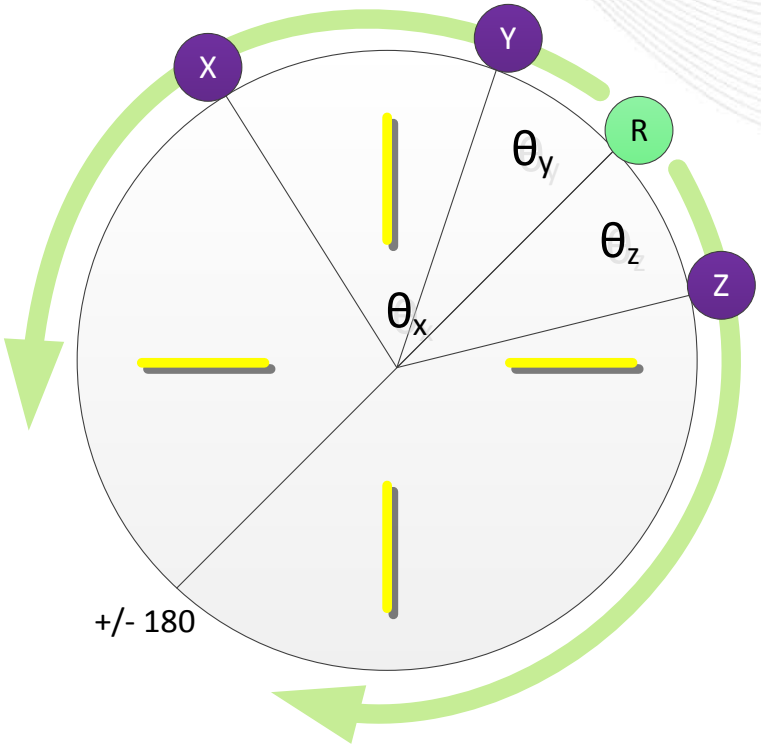
Interesting Notes:

- *Change* of the angle says something about relation to a perfect 60HZ ($\Delta\theta/\Delta t$)
- *Difference between two angles* says some things about relationship of those two nodes($\theta_x - \Delta\theta_{ref.}$)



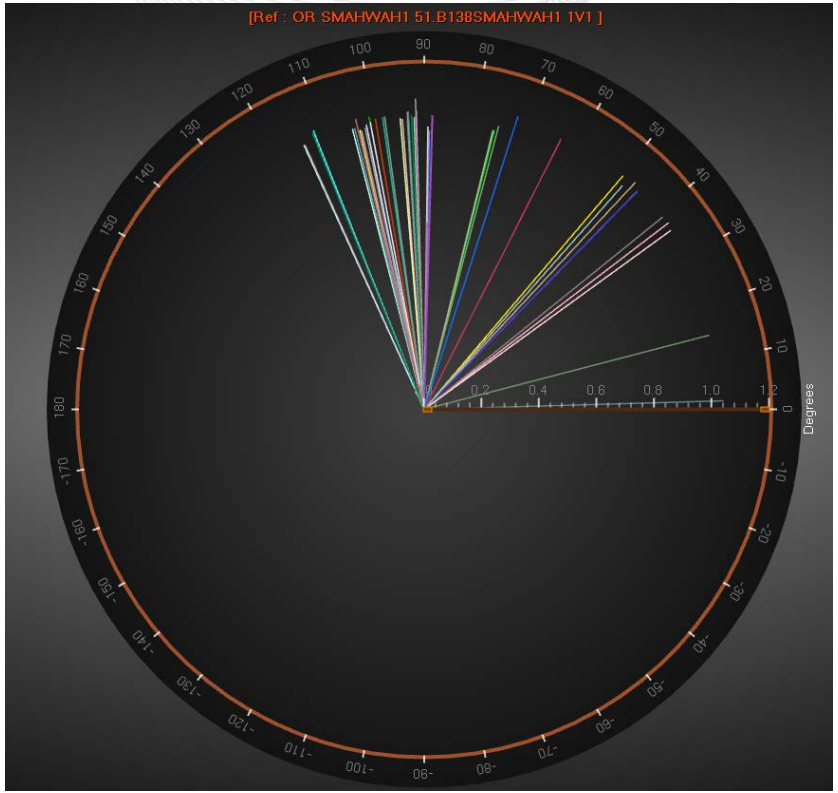
- Two guys each put the paint mark on the same spot on the shaft (i.e. interconnected system with standard phases)
- Two guys each activate the strobe light at the exact same time (i.e. synchrophasor reference wave w/ GPS clocks)

The Goal

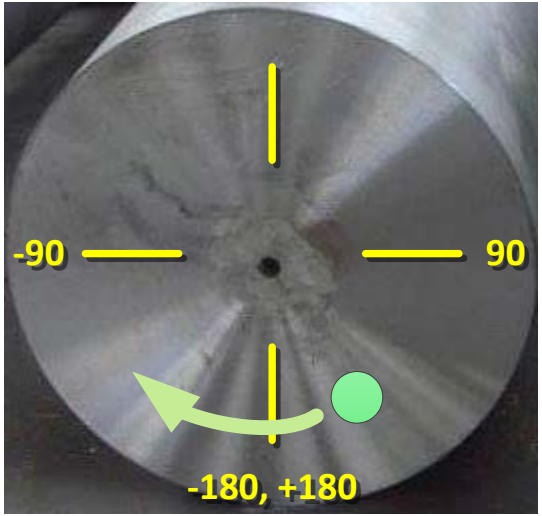


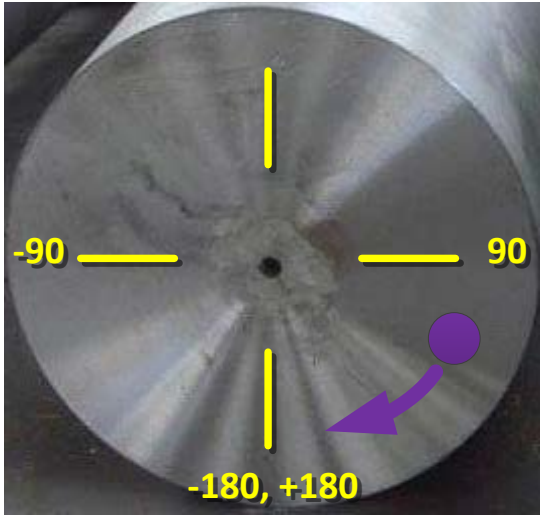
- What we want is **θ**.
- **R** is the chosen reference phasor measurement.
- θ_y and θ_x are negative numbers.
- The **θ** is bound by +/- 180°.

The Goal



Difference of change between two angles ($\theta_{reference}$ - θ_x) becomes mathematically inconvenient right here.





The Problem

Ref. (Δ2°)	X (Δ1°)	(Ref. - X)
171.5	159.5	12
173.5	160.5	13
175.5	161.5	14
177.5	162.5	15
179.5	163.5	16
-178.5	164.5	-343
-176.5	165.5	-342
-174.5	166.5	-341
-172.5	167.5	-340
-170.5	168.5	-339
-168.5	169.5	-338
-166.5	170.5	-337
-164.5	171.5	-336
-162.5	172.5	-335
-160.5	173.5	-334
-158.5	174.5	-333
-156.5	175.5	-332
-154.5	176.5	-331
-152.5	177.5	-330
-150.5	178.5	-329
-148.5	179.5	-328
-146.5	-179.5	33
-144.5	-178.5	34
-142.5	-177.5	35
-140.5	-176.5	36
-138.5	-175.5	37

(Reference - X) formula becomes inadequate.

Some have solved this problem using historical/previous values comparisons. (ex. If PreviousValue was positive, and now PresentValue is negative, then do something special). This works fine, except…

- In some cases may be resource expensive to constantly access PreviousValue, which becomes relevant with large payloads to process and databases that are not efficient with small data access operations.
- Not all applications/platforms have historical/previous values available for use at all (real-time EMS systems).

The Trig Solution

Ref. (Δ2°)	X (Δ1°)	acos(cos(Ref. - X))
171.5	159.5	12
173.5	160.5	13
175.5	161.5	14
177.5	162.5	15
179.5	163.5	16
-178.5	164.5	17
-176.5	165.5	18
-174.5	166.5	19
-172.5	167.5	20
-170.5	168.5	21
-168.5	169.5	22
-166.5	170.5	23
-164.5	171.5	24
-162.5	172.5	25
-160.5	173.5	26
-158.5	174.5	27
-156.5	175.5	28
-154.5	176.5	29
-152.5	177.5	30
-150.5	178.5	31
-148.5	179.5	32
-146.5	-179.5	33
-144.5	-178.5	34
-142.5	-177.5	35
-140.5	-176.5	36
-138.5	-175.5	37

If you do this with cosine:

acos(cos(ref°-x°))

Then the numbers are subtracted as a radial angle, not a linear number, and the problem goes away…

The Trig Solution

Ref. (Δ2°)	X (Δ5°)	Ref - X	acos(cos(Ref. - X))
117.5	85	32.5	32.5
119.5	90	29.5	29.5
121.5	95	26.5	26.5
123.5	100	23.5	23.5
125.5	105	20.5	20.5
127.5	110	17.5	17.5
129.5	115	14.5	14.5
131.5	120	11.5	11.5
133.5	125	8.5	8.5
135.5	130	5.5	5.5
137.5	135	2.5	2.5
139.5	140	-0.5	0.5
141.5	145	-3.5	3.5
143.5	150	-6.5	6.5
145.5	155	-9.5	9.5
147.5	160	-12.5	12.5
149.5	165	-15.5	15.5
151.5	170	-18.5	18.5
153.5	175	-21.5	21.5
155.5	180	-24.5	24.5
157.5	-175	332.5	27.5
159.5	-170	329.5	30.5
161.5	-165	326.5	33.5
163.5	-160	323.5	36.5
165.5	-155	320.5	39.5
167.5	-150	317.5	42.5

But using it neutralizes the math sign (is the angle ahead or behind the reference angle?):

But, you can put the sign back by using linear comparators and quadrant logic; in other words:

I am the reference angle.

Is the other angle in a 180° sweep to my left or my right?

If it is to the left then it is behind and negative.

If it is to the right then it is ahead and positive.

(Explaining the quadrant logic would make for a terrible presentation! But briefly it has to do w/ using the quadrant the reference angle is in and figuring out how the other angle would look in any other quadrant.)

Which results in this, which works in all cases:

```
IF
   ((X > Ref.) AND (X < Ref. +180)) OR (X < Ref. - 180)
THEN
   -ACOS(COS(Ref. – X))
ELSE
   +ACOS(COS(Ref. – X))
```

```
IF
   This was not valuable to anyone
THEN
   I apologize for the previous 16 slides; I meant
   well.
ELSE
   Enjoy! … you owe me a beer.
```