CHAPTER 15

CDFI Brochures

Jean Carlos Hernandez-Mejia & Nigel Hampton

This chapter represents the state of the art at the time of release. Readers are encouraged to consult the link below for the version of this chapter with the most recent release date:

http://www.neetrac.gatech.edu/cdfi-publications.html

Users are strongly encouraged to consult the links below for the most recent releases of Chapter 4, Chapter 6, and Chapter 10.

Chapter 4: How to Start
Chapter 6: Dissipation Factor (Tan Delta)
Chapter 10: Monitored Withstand Techniques

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15.0 *CDFI* BROCHURES

The brochures that follow are arranged such that they may be directly printed (front and back) to make a trifold pamphlet. They are designed to be taken out to the field and used as quick references for those techniques that the *CDFI* has developed criteria for.

The following brochures are included:

1. Tan δ Diagnostics of Distribution and Network Cable Using *CDFI* MV Test Protocl
2. Monitored Withstand Tan δ Using the CDFI MV Test Protocol PE-Based
3. Monitored Withstand Tan δ Using the CDFI MV Test Protocol Filled (i.e. EPR, Kerite, & Vulkene®
4. Monitored Withstand Tan δ Using the CDFI MV Test Protocol Paper – PILC

INTERPRETATION

Actions following a Further Study diagnosis might include

- review data for a rogue measurement in the sequence – most common in the first acquisition
- check insulation type so that correct assessment table is used
- re clean terminations & repeat measurements
- compare with previous tests or other results from other phases of this cable
- if Filled insulations are tested check specific variety of material; if identified as discharge resistant or mineral filled XLPE consult CDFI / NEETRAC for guidance
- conduct IEEE400.2 Standard (30 mins) VLF Withstand whilst monitoring Tan δ – see Monitored Withstand Brochure for guidance
- place on "watch list"

Actions following an Action Required diagnosis might include

- review data for a rogue measurement in the sequence – most common in the first acquisition
- check insulation type so that correct assessment table is used
- re clean terminations & repeat measurements
- compare with previous tests or other results from other phases of this cable
- if Filled insulations are tested check specific variety of material; if identified as mineral filled XLPE consult CDFI / NEETRAC for guidance
- conduct IEEE400.2 Standard (60 mins) VLF Withstand whilst monitoring Tan δ – see Monitored Withstand Brochure for guidance
- Retest in near future
- place on "watch list" & consider remedial actions for the circuit

FURTHER HELP

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NEETRAC

www.neetrac.gatech.edu

Diagnostic Tool
http://www.neetrac.gatech.edu/cdfi-publications.html

Final Report available for download at:
http://www.neetrac.gatech.edu/cdfi-publications.html

Other Useful Documents:

1. Perkel, J.; Del Valle, Y.; Hampton, R.N.; Hernandez-mejia, J.C.; Densley, J., "Interpretation of dielectric loss data on service aged polyethylene based power cable systems using VLF test methods," IEEE Transactions on Dielectrics and Electrical Insulation, Year: 2013, Volume: 20, Issue: 5, pp.1699 - 1711
2. Hernandez-Mejia, J.; Perkel, J.; Harley, R.; Hampton, N.; Hartlein, R., "Correlation between tan δ diagnostic measurements and breakdown performance at VLF for MV XLPE cables," IEEE Transactions on Dielectrics and Electrical Insulation, Volume: 16, Issue: 1, Year: 2009, Pp. 162 – 170.
3. Olearczyk, M.; Hampton, R.N.; Perkel, J.; Weisenfeld, N., "Notes from Underground," IEEE Power and Energy Magazine, Year: 2010, Volume: 8, Issue: 6, Pages: 75 – 84.
4. IEEE Std. 400™ – 2012: IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above.
5. IEEE Std. 400.2™ – 2013: IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz).

The CDFI data have been incorporated in the most recent update of IEEE Std. 400.2 - 2013

CDFI

(CABLE DIAGNOSTICS FOCUSED INITIATIVE)

TAN δ DIAGNOSTICS OF DISTRIBUTION & NETWORK CABLE SYSTEMS USING THE CDFI MV TEST PROTOCOL

DOE AWARD NO. DE-FC02-04CH11237

FOR FURTHER DETAILED INFORMATION CONSULT
http://www.neetrac.gatech.edu/cdfi-publications.html

Georgia Tech NEETRAC National Electric Energy Testing, Research and Applications Center

Prepared by NEETRAC under GTRC Project # E-21-RJT

Historical figures of merit within CDFI for US utility cable systems over a period of 11 yr. Figures of Merit are based on more than 4,000 separate field measurements at VLF.

Condition Assessment [E-3]	No Action Required	Further Study Advised	Action Required
Assessment of PE-based Insulations (i.e. PE, XLPE, WTRXLPE)			
Stability for TD_{U_0} (standard deviation)	<0.1	0.1 to 1.0	>1.0
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	<6.7	6.7 to 94.0	>94.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}-TD_{U_0}) - (TD_{U_0}-TD_{0.5U_0})\}$	<2.0	2.0 to 50.0	>50.0
	&	or	
Mean TD at U_0	<6.0	6.0 to 70.0	>70.0

A minimum of 6 measurements should be made at each voltage level; to determine the parameters detailed above.

In these tests (all materials) the "operational U_0" is used to determine test voltages.

The user *may* elect to add a measurement at $2U_0$ of engineering information if this does not exceed the IEEE Std. 400.2 - 2013 test voltage withstand voltages.

Condition Assessment [E-3]	No Action Required	Further Study Advised	Action Required
Assessment of Unidentified Filled Insulations			
Stability for TD_{U_0} (standard deviation)	<0.1	0.1 to 1.2	>1.2
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	<3.0	3.0 to 30.0	>30.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}-TD_{U_0}) - (TD_{U_0}-TD_{0.5U_0})\}$	<1.0	1.0 to 18.0	>18.0
	&	or	
Mean TD at U_0	<25.0	25.0 to 150.0	>150.0
Condition Assessment of Mineral Filled Insulations (i.e. EPR) *			
Stability for TD_{U_0} (standard deviation)	<0.1	0.1 to 0.8	>0.8
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	<2.0	2.0 to 40.0	>40.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}-TD_{U_0}) - (TD_{U_0}-TD_{0.5U_0})\}$	<1.0	1.0 to 25.0	>25.0
	&	or	
Mean TD at U_0	<16.0	16.0 to 75.0	>75.0

* Experience has shown that it is difficult to precisely identify the type of filled insulation of field-installed cable. The issues encountered include: incorrect /missing records, obliterated or obscured markings on the cable jacket, indistinct coloring etc. In these cases it is recommended to use the criteria for **Unidentified Filled** data.

Condition Assessment [E-3]	No Action Required	Further Study Advised	Action Required
Assessment of Paper Insulations (i.e. PILC)			
Stability for TD_{U_0} (standard deviation)	<0.2	0.2 to 1.5	>1.5
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	-30.0 to 22.0	-30 to -60 or 22 to 220	<-60.0 or >220.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}-TD_{U_0}) - (TD_{U_0}-TD_{0.5U_0})\}$	<9.0	9.0 to 25.0	>25.0
	&	or	
Mean TD at U_0	<100.0	100.0 to 250.0	>250.0

Consult CDFI website for most recent version.
Version 1
http://www.neetrac.gatech.edu/cdfi-publications.html

An excel tool, which simultaneously assesses all features has been developed to enhance the analyses, especially in the region of Further Study (cable circuits ranked 5 to 15%) & "Action Required" (the lowest ranked 5% of cable circuits). The tool may be downloaded from the CDFI website
http://www.neetrac.gatech.edu/cdfi-publications.html

INTERPRETATION

Cable systems with an evaluation in the "Ramp-up" Phase resulting in a "Red No" require remedial actions in the near future and thus it is assumed that they have not passed the monitored withstand test; then the remedial actions following a "Red No" evaluation should be sequentially undertaken as follows:

- Review data for a rogue measurement in the sequence – most common in the first voltage cycle,
- Confirm insulation type to ensure that criteria apply,
- Verify the integrity of the terminations and if compromised replace them and repeat the test,
- Retest in the near future and observe trends (6 months to a year), or,
- Place on "watch list" and consider system replacement in the near future.

Cable systems with an evaluation of the "Hold" Phase resulting in a "Further Study" may require remedial actions in the near future that should be sequentially undertaken as follows:

- Review data for a rogue measurement in the sequence – most common during the first voltage cycles,
- Confirm insulation type to ensure that criteria apply,
- Verify the integrity of the terminations and if compromised replace them and repeat the test,
- Retest in the near future and observe trends (6 months to a year), or,
- Place on "watch list" and consider system replacement in the near future.

FURTHER HELP

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Other Useful Documents:

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2. First practical utility implementation of monitored withstand diagnostics in the USA; CL Fletcher, J Perkel, RN Hampton, JC Hernandez, J Hesse, MG Pearman, CT Wall, W Zenger*; International Conference on Insulated Power Cables JICABLE11*, Versailles France, June 2011; Paper A.10.2
3. Hampton, R.N..Perkel. J., Hernandez, J.C., Begovic, M., Hans, J., Riley, R., Tyschenko, P., Doherty, F., Murray, G., Hong, L., Pearman, M.G., Fletcher, C.L., and Linte, G.C., "Experience of Withstand Testing of Cable Systems in the USA"; *CIGRE 2010*, Paper No. B1-303
4. IEEE Std. 400 – 2012: IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above.
5. IEEE Std. 400.2 – 2013: IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz).

CDFI

(CABLE DIAGNOSTICS FOCUSED INITIATIVE)

MONITORED WITHSTAND TAN δ USING THE CDFI MV TEST PROTOCOL PE-BASED

DOE AWARD NO. DE-FC02-04CH11237

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http://www.neetrac.gatech.edu/cdfi-publications.html

Georgia Tech NEETRAC
National Electric Energy Testing, Research and Applications Center

Prepared by NEETRAC under GTRC Project # E-21-RJT

Historical figures of merit researched (Monitored Withstand) within CDFI for USA utility cable systems over a period of 7 years for more than 1380 separate measurements.

Tan δ Monitored Withstand Tests are **conducted for 30 min** as recommended by IEEE Std. 400.2 – 2013.

This time ***may*** be amended ***if*** the conditions listed in the Framework and Tables below are fulfilled:

A minimum of 6 measurements should be made at each voltage level; to determine the parameters detailed above.

A TDR Measurement is always "Good Practice" in advance of a Tan δ measurement as it serves to confirm Capacitance measurements and obtain a qualitative estimate of neutral condition.

In these tests (all materials) the "Operational U_0" is used to determine test voltages.

The maintenance test voltages for the "Hold" Phase as specified in the IEEE Std. 400.2 – 2013 are as follows:

"Hold" Phase Recommended Test Voltage Levels				
CABLE SYSTEM VOLTAGE (kV)	**15**	**20**	**25**	**35**
Maintenance Testing RMS (kV)	16	20	24	33
Maintenance Testing Peak (kV)	22	28	34	47

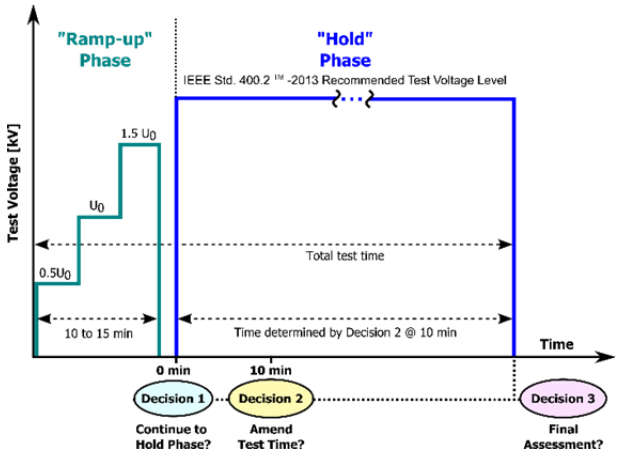
Anticipated Failure rates On Test (FOT) for the "Hold" Phase are approximately as follows:

- 15 Minutes 2.0% per 1000ft
- 30 Minutes 2.7% per 1000ft
- 60 Minutes 3.7% per 1000ft

Georgia Tech NEETRAC National Electric Energy Testing, Research and Applications Center

If used after 2016, consult the CDFI website for the most recent version. Version 1
http://www.neetrac.gatech.edu/cdfi-publications.html

Tan δ Monitored Withstand Framework



Decision 1 – Continue to "Hold" Phase?
After "Ramp-up" – Made online during test

Feature [E-3]	"No"*	"Yes"**	"No"***
Ramp-Up Phase Evaluation			
Stability for TD_{U_0} (standard deviation)	<0.1	0.1 to 1.0	>1.0
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	<6.7	6.7 to 94.0	>94.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}–TD_{U_0}) – (TD_{U_0}–TD_{0.5U_0})\}$	<2.0	2.0 to 50.0	>50.0
	&	or	
Mean TD at U_0	<6.0	6.0 to 70.0	>70.0

* "**Green No**" – Cable system condition is assessed as best performing 80% and thus it is not necessary to continue to "Hold" phase so that time and resources might be saved.

** "**Amber Yes**" – Cable system condition cannot be determined during the "Ramp-up" phase and thus systems pass to the "Hold" phase for consideration in Decision 2 and Decision 3.

*** "**Red No**" – Cable system condition is assessed as being on the poorest performing 5% and thus it is not necessary to continue to the "Hold" phase because the higher risk of FOT is likely to result in inefficient testing and high emergency repair cost. Systems in this category can be acted on in a planned manner by managing optimal time and cost.

Decision 2 – Amend Test Time?
Made online during test

Feature [E-3]	"Reduce to 15 min"	"Extend to 60 min"
Initial "Hold" Phase Evaluation		
Absolute Change in Tan Delta $\lvert TD_{10}-TD_0\rvert$	<0.6	>8.0
	&	or
Tan δ Stability (Standard Deviation – STD_{10})	<0.3	>5.0
	&	or
Tan δ Level (Mean Tan δ – TD_{10})	<14.0	>70.0

Decision 3 – Final Assessment?
Made offline after test

"No Action Required"	"Further Study Advised"	"Action Required"
Final "Hold" Phase Evaluation		
An excel tool, which simultaneously assesses all final features (**Speed 10-15, Speed 0-5, Speed 0-t_{final}, Standard Deviation, and Mean Tan δ**) is under development to enhance the analyses, especially in the region of Further Study (cable circuits ranked 5 to 15%) & "Action Required" (the lowest ranked 5% of cable circuits).		
http://www.neetrac.gatech.edu/cdfi-publications.html		

INTERPRETATION

Cable systems with an evaluation in the "Ramp-up" Phase resulting in a "Red No" require remedial actions in the near future and thus it is assumed that they have not passed the monitored withstand test; then the remedial actions following a "Red No" evaluation should be sequentially undertaken as follows:

- Review data for a rogue measurement in the sequence – most common in the first voltage cycle,
- Confirm insulation type to ensure that criteria apply,
- Verify the integrity of the terminations and if compromised replace them and repeat the test,
- Retest in the near future and observe trends (6 months to a year), or,
- Place on "watch list" and consider system replacement in the near future.

Cable systems with an evaluation of the "Hold" Phase resulting in a "Further Study" may require remedial actions in the near future that should be sequentially undertaken as follows:

- Review data for a rogue measurement in the sequence – most common during the first voltage cycles,
- Confirm insulation type to ensure that criteria apply,
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CDFI

(CABLE DIAGNOSTICS FOCUSED INITIATIVE)

MONITORED WITHSTAND TAN δ USING THE CDFI MV TEST PROTOCOL FILLED (i.e. EPR, KERITE, & VULKENE®)

DOE AWARD NO. DE-FC02-04CH11237

FOR FURTHER DETAILED INFORMATION CONSULT
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Tan δ Monitored Withstand Tests are **conducted for 30 min** as recommended by IEEE Std. 400.2 – 2013.

This time ***may*** be amended ***if*** the conditions listed in the Framework and Tables below are fulfilled:

A minimum of 6 measurements should be made at each voltage level; to determine the parameters detailed above.

A TDR Measurement is always "Good Practice" in advance of a Tan δ measurement as it serves to confirm Capacitance measurements and obtain a qualitative estimate of neutral condition.

In these tests (all materials) the "Operational U_0" is used to determine test voltages.

The maintenance test voltages for the "Hold" Phase as specified in the IEEE Std. 400.2 – 2013 are as follows:

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CABLE SYSTEM VOLTAGE (kV)	**15**	**20**	**25**	**35**
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Maintenance Testing Peak (kV)	22	28	34	47

Anticipated Failure rates On Test (FOT) for the "Hold" Phase are approximately as follows:

- 15 Minutes 2.0% per 1000ft
- 30 Minutes 2.7% per 1000ft
- 60 Minutes 3.7% per 1000ft

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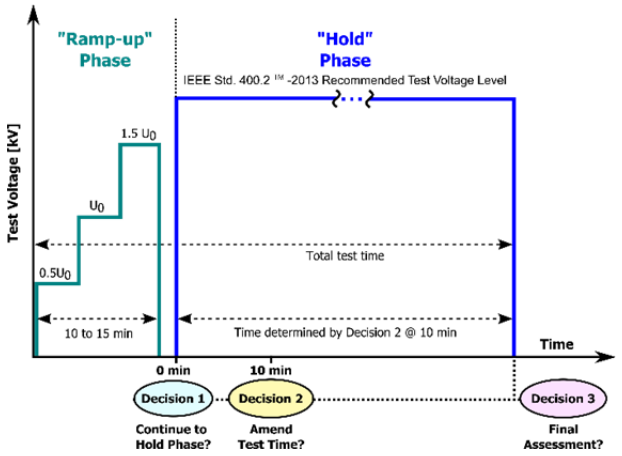
Tan δ Monitored Withstand Framework



Decision 1 – Continue to "Hold" Phase?
After "Ramp-up" – Made online during test

Feature [E-3]	"No"*	"Yes"**	"No"***
Ramp-Up Phase Evaluation			
Stability for TD_{U_0} (standard deviation)	<0.1	0.1 to 1.2	>1.2
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	<3.0	3.0 to 30.0	>30.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}–TD_{U_0}) – (TD_{U_0}–TD_{0.5U_0})\}$	<1.0	1.0 To 18.0	>18.0
	&	or	
Mean TD at U_0	<25.0	25.0 to 150.0	>150.0

* "**Green No**" – Cable system condition is assessed as best performing 80% and thus it is not necessary to continue to "Hold" phase so that time and resources might be saved.

** "**Amber Yes**" – Cable system condition cannot be determined during the "Ramp-up" phase and thus systems pass to the "Hold" phase for consideration in Decision 2 and Decision 3.

*** "**Red No**" – Cable system condition is assessed as being on the poorest performing 5% and thus it is not necessary to continue to the "Hold" phase because the higher risk of FOT is likely to result in inefficient testing and high emergency repair cost. Systems in this category can be acted on in a planned manner by managing optimal time and cost.

Decision 2 – Amend Test Time?
Made online during test

Feature [E-3]	"Reduce to 15 min"	"Extend to 60 min"
Initial "Hold" Phase Evaluation		
Absolute Change in Tan Delta $\lvert TD_{10}-TD_0\rvert$	<0.6	>6.0
	&	or
Tan δ Stability (Standard Deviation – STD_{10})	<0.3	>5.0
	&	or
Tan δ Level (Mean Tan δ – TD_{10})	<13.0	>105.0

Decision 3 – Final Assessment?
Made offline after test

"No Action Required"	"Further Study Advised"	"Action Required"
Final "Hold" Phase Evaluation		

An excel tool, which simultaneously assesses all final features (**Speed 10-15, Speed 0-5, Speed 0-t_{final}, Standard Deviation, and Mean Tan δ**) is under development to enhance the analyses, especially in the region of Further Study (cable circuits ranked 5 to 15%) & "Action Required" (the lowest ranked 5% of cable circuits).

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INTERPRETATION

Cable systems with an evaluation in the "Ramp-up" Phase resulting in a "Red No" require remedial actions in the near future and thus it is assumed that they have not passed the monitored withstand test; then the remedial actions following a "Red No" evaluation should be sequentially undertaken as follows:

- Review data for a rogue measurement in the sequence – most common in the first voltage cycle,
- Confirm insulation type to ensure that criteria apply,
- Verify the integrity of the terminations and if compromised replace them and repeat the test,
- Retest in the near future and observe trends (6 months to a year), or,
- Place on "watch list" and consider system replacement in the near future.

Cable systems with an evaluation of the "Hold" Phase resulting in a "Further Study" may require remedial actions in the near future that should be sequentially undertaken as follows:

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CDFI

(CABLE DIAGNOSTICS FOCUSED INITIATIVE)

MONITORED WITHSTAND TAN δ USING THE CDFI MV TEST PROTOCOL PAPER - PILC

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Tan δ Monitored Withstand Tests are **conducted for 30 min** as recommended by IEEE Std. 400.2 – 2013.

This time ***may*** be amended ***if*** the conditions listed in the Framework and Tables below are fulfilled:

A minimum of 6 measurements should be made at each voltage level; to determine the parameters detailed above.

A TDR Measurement is always "Good Practice" in advance of a Tan δ measurement as it serves to confirm Capacitance measurements and obtain a qualitative estimate of neutral condition.

In these tests (all materials) the "Operational U_0" is used to determine test voltages.

The maintenance test voltages for the "Hold" Phase as specified in the IEEE Std. 400.2 – 2013 are as follows:

"Hold" Phase Recommended Test Voltage Levels				
CABLE SYSTEM VOLTAGE (kV)	**15**	**20**	**25**	**35**
Maintenance Testing RMS (kV)	16	20	24	33
Maintenance Testing Peak (kV)	22	28	34	47

Anticipated Failure rates On Test (FOT) for the "Hold" Phase are approximately as follows:

- 15 Minutes 2.0% per 1000ft
- 30 Minutes 2.7% per 1000ft
- 60 Minutes 3.7% per 1000ft

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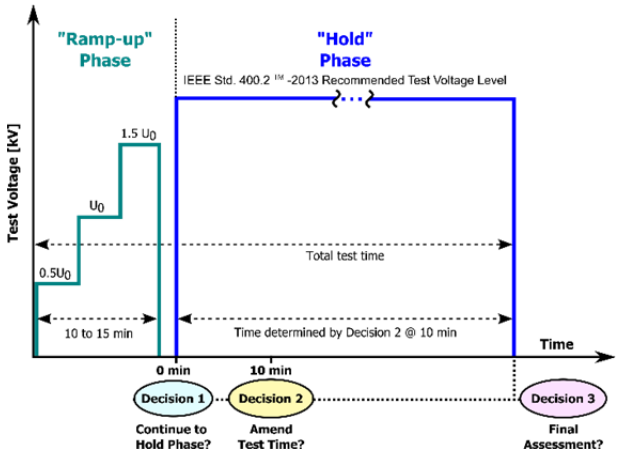
If used after 2016, consult the CDFI website for the most recent version. Version 1
http://www.neetrac.gatech.edu/cdfi-publications.html

Tan δ Monitored Withstand Framework



Decision 1 – Continue to "Hold" Phase?
After "Ramp-up" – Made online during test

Feature [E-3]	"No"*	"Yes"**	"No"***
Ramp-Up Phase Evaluation			
Stability for TD_{U_0} (standard deviation)	<0.2	0.2 to 1.5	>1.5
	&	or	
Tip Up ($TD_{1.5U_0} - TD_{0.5U_0}$)	-30.0 to 22.0	-30 to -60 or 22 to 220	<-60.0 or >220.0
	&	or	
Tip Up Tip Up $\{(TD_{1.5U_0}–TD_{U_0}) – (TD_{U_0}–TD_{0.5U_0})\}$	<9.0	9.0 to 25.0	>25.0
	&	or	
Mean TD at U_0	<100.0	100.0 to 250.0	>250.0

* "**Green No**" – Cable system condition is assessed as best performing 80% and thus it is not necessary to continue to "Hold" phase so that time and resources might be saved.

** "**Amber Yes**" – Cable system condition cannot be determined during the "Ramp-up" phase and thus systems pass to the "Hold" phase for consideration in Decision 2 and Decision 3.

*** "**Red No**" – Cable system condition is assessed as being on the poorest performing 5% and thus it is not necessary to continue to the "Hold" phase because the higher risk of FOT is likely to result in inefficient testing and high emergency repair cost. Systems in this category can be acted on in a planned manner by managing optimal time and cost.

Decision 2 – Amend Test Time?
Made online during test

Feature [E-3]	"Reduce to 15 min"	"Extend to 60 min"
Initial "Hold" Phase Evaluation		
Absolute Change in Tan Delta $\lvert TD_{10}-TD_0\rvert$	<1.4	>5.0
	&	or
Tan δ Stability (Standard Deviation – STD_{10})	<0.6	>5.4
	&	or
Tan δ Level (Mean Tan δ – TD_{10})	<80.0	>180.0

Decision 3 – Final Assessment?
Made offline after test

"No Action Required"	"Further Study Advised"	"Action Required"
Final "Hold" Phase Evaluation		

An excel tool, which simultaneously assesses all final features (**Speed 10-15, Speed 0-5, Speed 0-t_{final}, Standard Deviation, and Mean Tan δ**) is under development to enhance the analyses, especially in the region of Further Study (cable circuits ranked 5 to 15%) & "Action Required" (the lowest ranked 5% of cable circuits).

http://www.neetrac.gatech.edu/cdfi-publications.html