Fault Locating and Testing of Network Circuits

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Operational Objectives

Today's operational objectives of the substation cable fault locating and testing process:

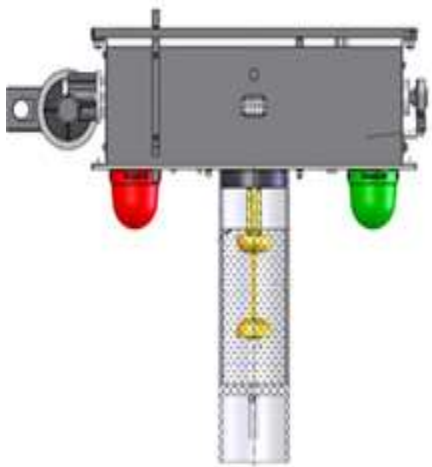
- "Return to Service Time" = Outage time
  - After In-Service Failure Network Feeder should be back in service as quickly as possible, one North Eastern company specifies no more than 14.5 h from when circuit breaker trips to when circuit breaker is closed in again
- Effective and time saving communication with District Operator
  - Waiting time reduced to receiving 1 permit for entire test and or fault locating process
- Substation test set with comprehensive multi functionality
- Automatic data collection and e-reporting for all tests
- Test set with easy-to-use Graphic User Interface (GUI) for station operators
- **ONE** Size fits all substations – no building adaptions or modifications
- Comprehensive and automatic safety provisions
- Comprehensive customer training by OEM/MFG

6 General Performance Criteria expected of State of the Art Network test set

- Mechanical Design
  - System must be “non-directional” regarding its installation and “easily moveable”
  - System must be delivered already fully assembled by manufacturer
  - Mains Feed and HV output cable entering / exiting system through top
  - Optional installation in vehicle or container for quick transport via land, sea, and air, e.g. offshore windfarm applications
- Electrical Design
  - Test set must be capable to address all cable testing and fault locating methods for all types of MV cables with PILC/XLPE and EPR insulation and system voltages between 11 and 35 kV
- System Operation
  - Fully computer controlled system, no manually controlled function
  - Easy to follow SW enabled Graphic User Interface (GUI)
  - Workflow directed by on-screen Step by Step instructions
  - System SW allows only “safe” manipulations by operator

6 General Performance Criteria expected of State of the Art Network test set

- Safety Systems to protect operator
  - Continuous check of adequate system grounding, will immediately shut HV off and discharge and ground system if compromised
  - Redundant discharge and grounding system to dissipate maximum possible energy stored in test circuit during HV test
  - Visible ground in HV output path
  - Analog Kilovolt meter in HV output circuit for residual voltage protection in case of power loss



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6 General Performance Criteria expected of State of the Art Network test set

- Self Diagnostics of system condition
  - System to be “self diagnostic” if malfunction occurs
  - System to issue messages to make operator aware of certain conditions while testing or fault locating
- Test Data acquisition / storage and IT interface
  - Automatic recording and storage of every test / fault location performed to satisfy regulatory as well as company-internal documentation requirements
  - Print-out of all results / graphs
  - Download of results via USB interface
  - Download of results via modem to customer FTP server
  - System to provide life screen sharing with other cable testing or cable fault locating experts within the company

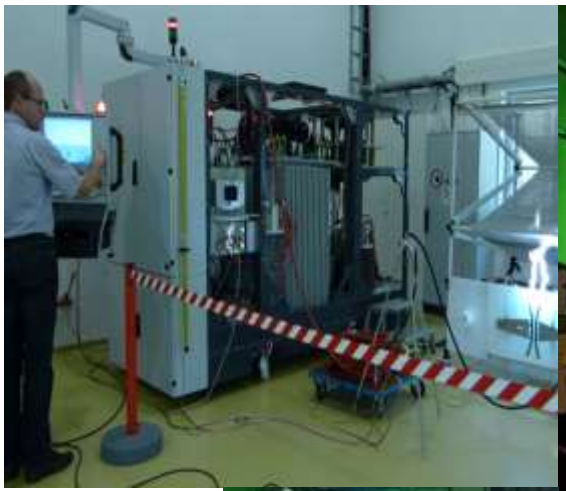
Technical Performance Criteria expected of Cable Testing Module

- Feeder cables up 100,000 circuit feet
- Suitable to test and fault locate Mixed Cable systems
- Several hundred splices per phase
- Network system voltage between 11 and 35 kV
- Delta-connected network transformers
- Network transformers with or without switches on primary side (worst case: transformers remain in test circuit)
- Network protectors on the secondary side always opened
- Cable capacitance between 5 and 25 µF (all 3 phases)
- Maximum test voltage 60 kV RMS per IEEE 400.2 table 3, and 60 kV DC
- Test Frequency 0.1 Hz fixed and DC
- Leakage Current Measurement in both VLF and DC mode
- VLF Cosine Rectangular waveshape required due to high test capacitance and leakage current requirements

Technical Performance Criteria expected of Cable Fault Locating Module

- High Voltage DC Source (Hipot) for fault identification and fault conditioning
  - Identifying the nature of the fault (breakdown test, flashover voltage)
  - Conditioning of high resistance faults which are beyond thumper or power burner capabilites
- Power Burner for fault conditioning
  - Continuous high voltage high current output to change characteristics of the fault
- Multiple stage capacitor design Surge Wave Generator (Thumper) for fault pinpointing
  - High voltage and high energy capacitor discharge output
  - Contant energy philosophy, optimized energy-voltage output
- Thyratron for fault pinpointing
  - Pulsed burning with high currents and long current flow times for improved fault pinpointing
- Extended duty cycle without overheating during prolonged periods of operation

Flexible Operation via Swivel Arm



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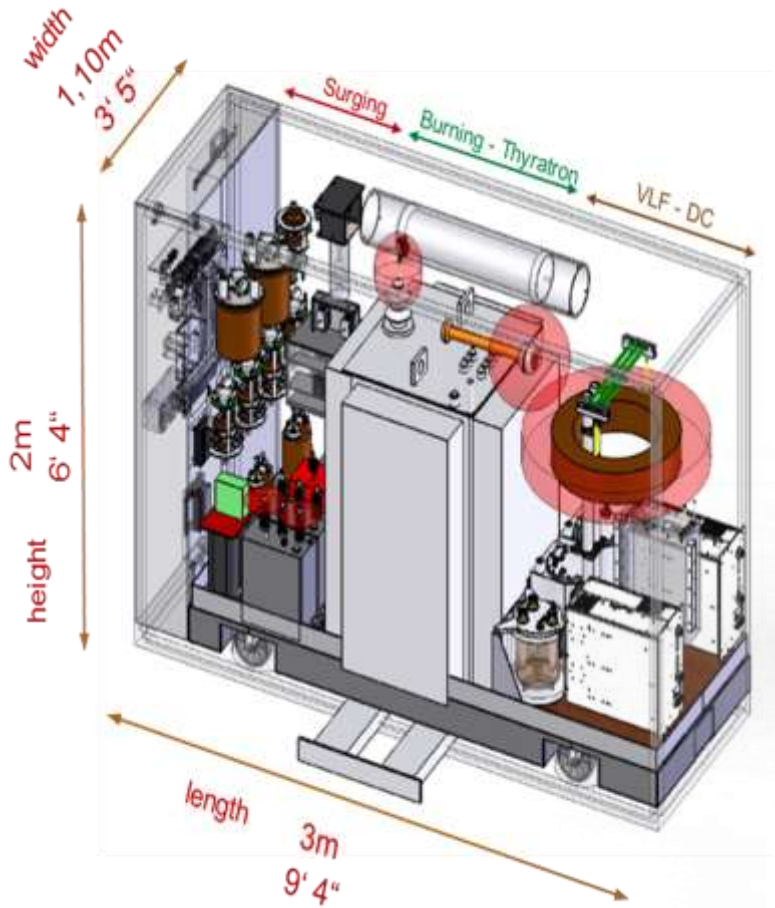
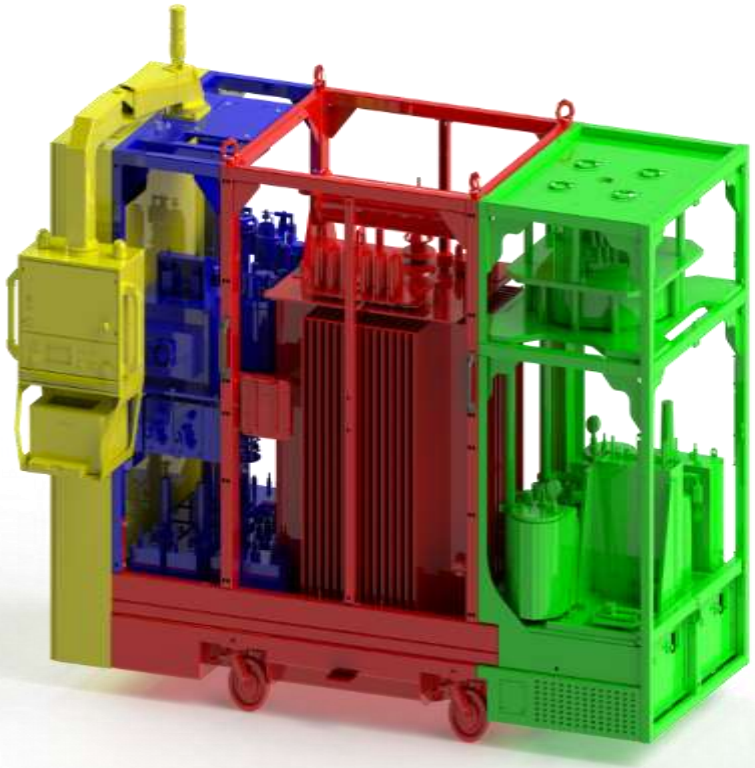
Function Modules of the Network Combination Test Set





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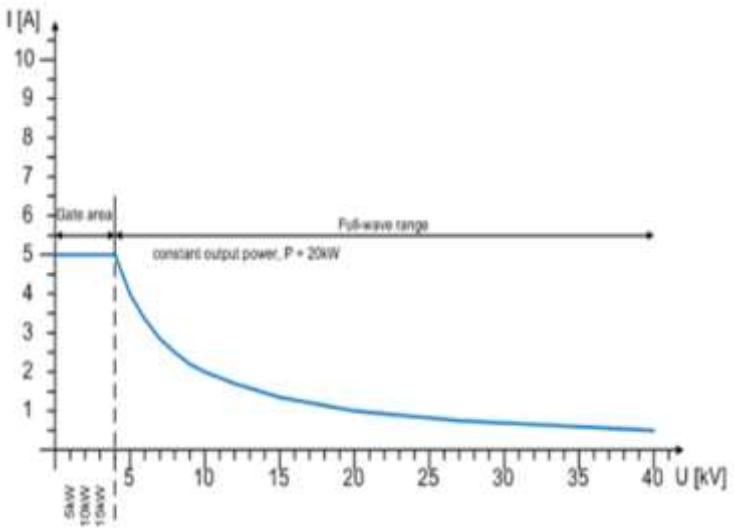
Technical Performance Power Burner



- Self-cooled HV DC souce, 0 ... 40 kV max
- 20 kW continuously variable output, 5 A … 0.5 A
- **Without** diode coupler
- Output curve benchmarks
  - 40 kV 0.5 A
  - 20 kV 1 A
  - 10 kV 2 A
  - 5 kV 4 A
  - 4 kV 5 A
  - 1 kV 5 A
  - 500 V 5 A
  - 250 V 5 A

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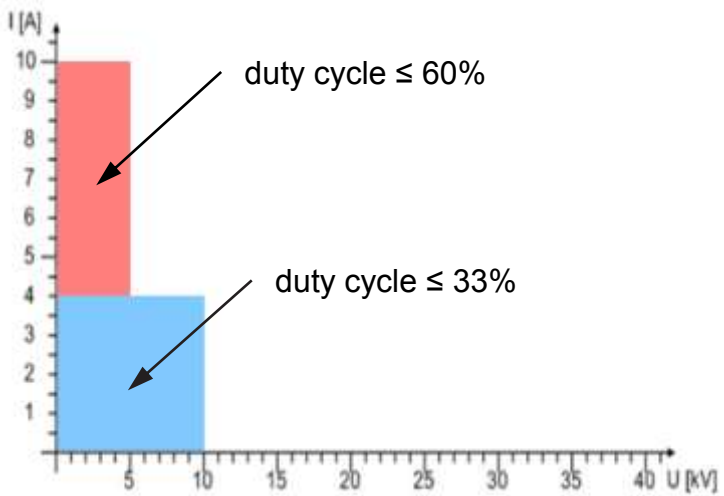
Technical Performance Thyratron

- Pulsed burning
- Timing of current flow 0.5 s ON, 2.5 s OFF
- **Without** diode coupler
- Output curve benchmarks
  - 10 kV 4 A duty cycle 60%
  - 5 kV 4 A duty cycle 60%
  - 5 kV 10 A duty cycle 33%
  - 1 kV 10 A duty cycle 33%



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Technical Performance Surge Generator

- Multiple stage capacitor thumper offers optimum between **energy** vs. **voltage**
- Thumping levels
  - 25 kV 6250 J
  - 12 kV 3600 J
  - 8 kV 3600 J
- Re-charging to full voltage / full energy in 6 s

- Current flow times as a function of

multi stage vs. **single stage** capacitor design

• 8 kV	46 µs	9.6 µs
• 12 kV	28 µs	15 µs
• 20 kV*	20 µs	24 µs
• 25 kV	26 µs	30 µs

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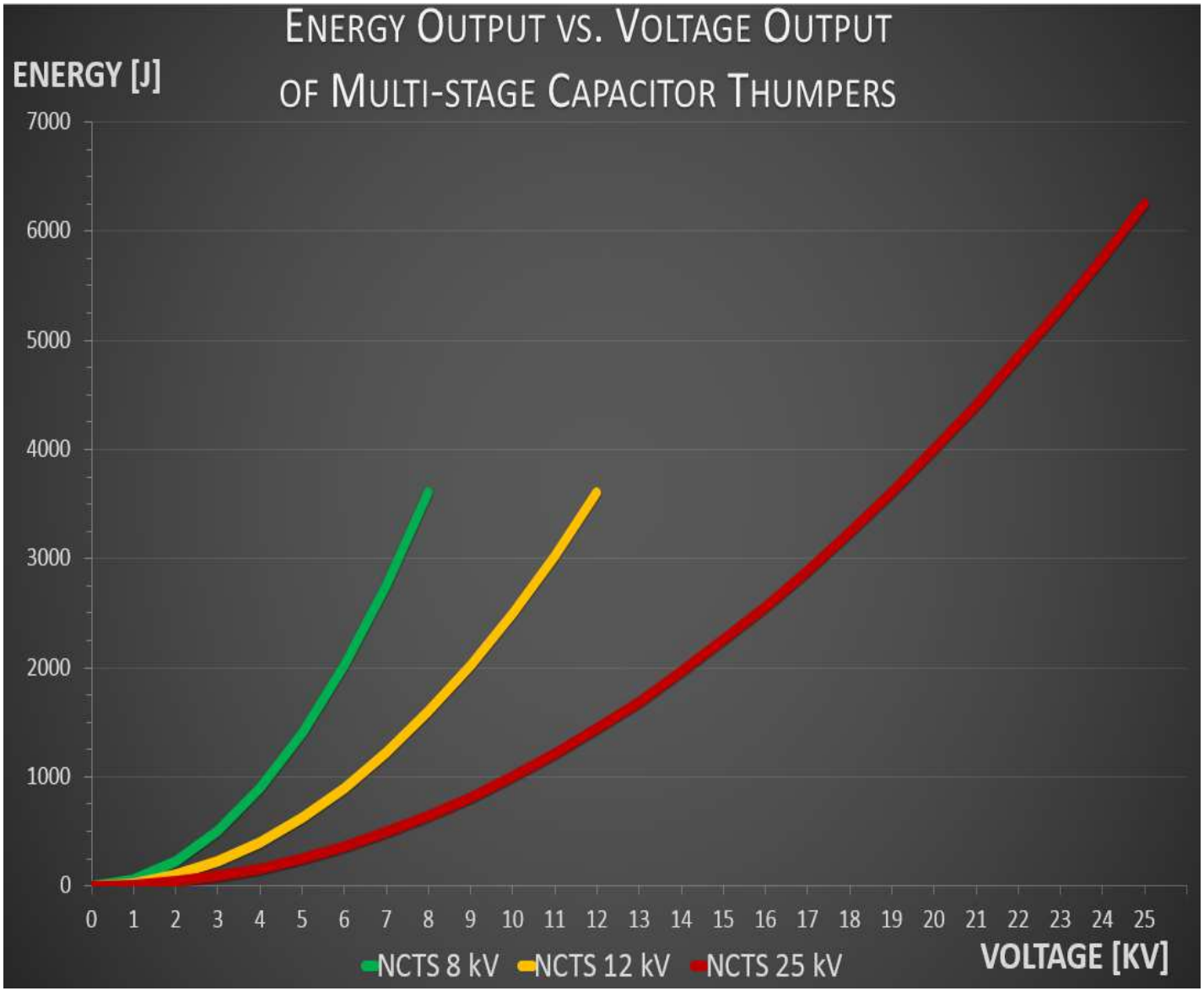
Technical Performance Surge Generator



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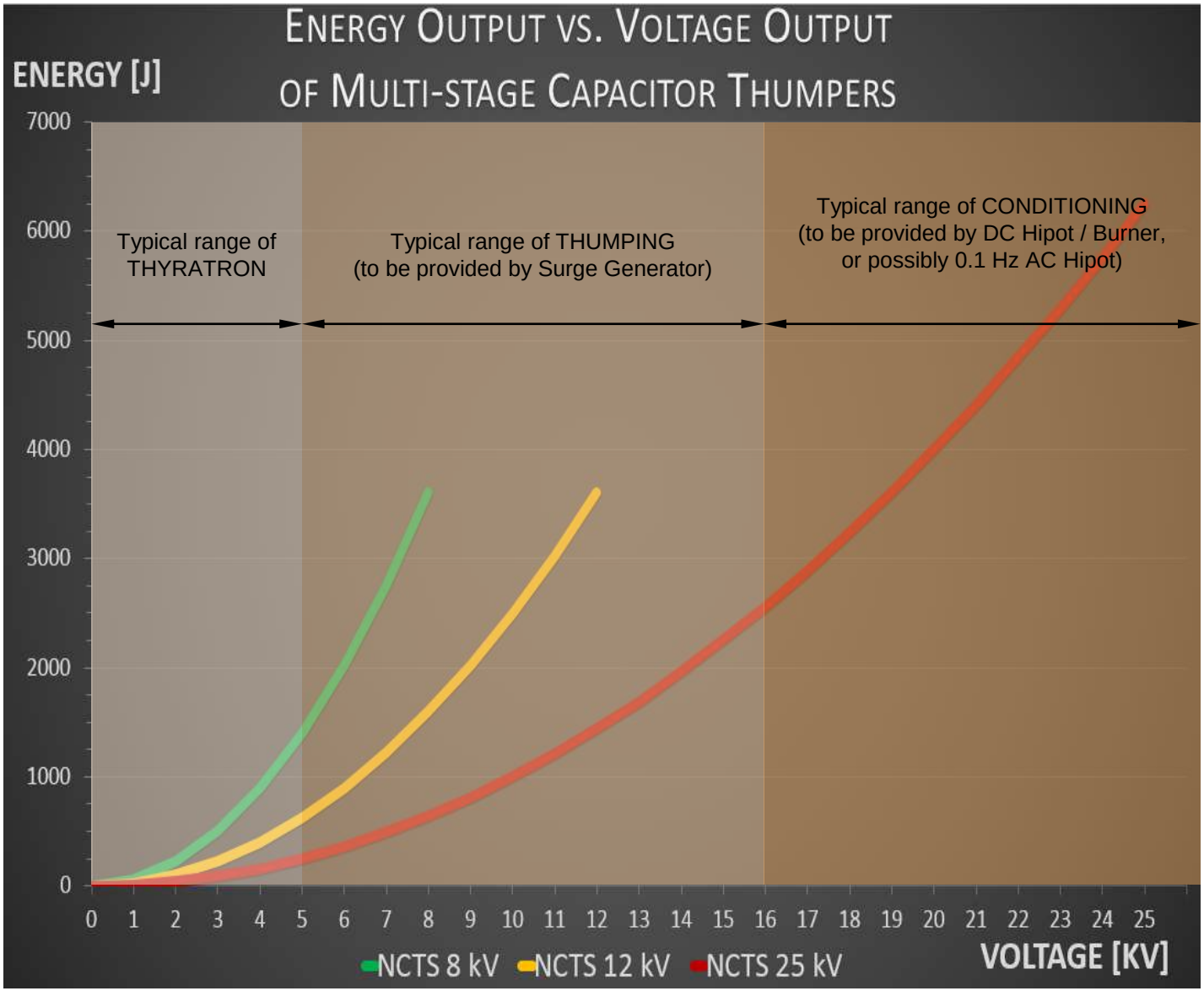
Technical Performance Surge Generator



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Technical Performance VLF AC Hipot

- Most powerful VLF source in the market, compliant with **all** international test standards (Cenelec, IEC, VDE, IEEE400)
- Cosine Rectangular technology with true Leakage Current Measurement
- 60 kV RMS to achieve 3x U_0 for cables rated up to 35 kV
- Can drive very high network feeder loads
  - 25 µF @ 60 kV RMS @ 0.1 Hz
  - 31 µF @ 40 kV RMS @ 0.1 Hz
- Duty cycle allows for extensive prolonged testing

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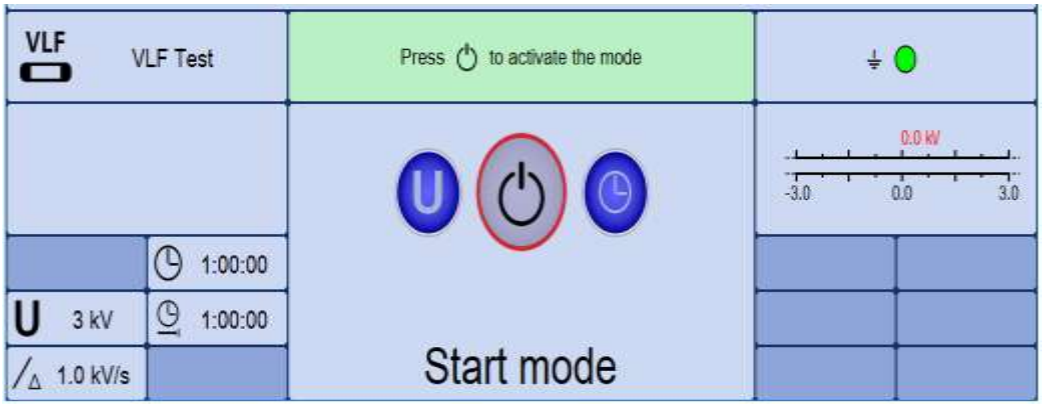
Technical Performance User Interface



- HDW's well-proven **E-Tray**™ philosophy
- Streamlined Turn & Click navigation
  - Selecting (Turn) and confirming (Click) options via single rotary knob
  - Description of the **selected option below** icons, and description of the **next step above** icons
- Step by Step Procedures
  - to ensure safety of initial system setup
  - for initial setup of cable under test and selection of test mode
- Reduced complexity
  - Only the necessary adjustment functions are shown for each operational mode

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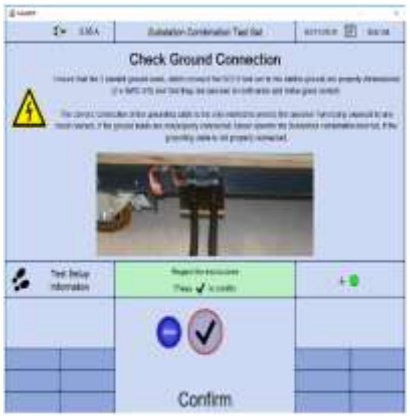
Step by Step Procedure
1. Initial system setup



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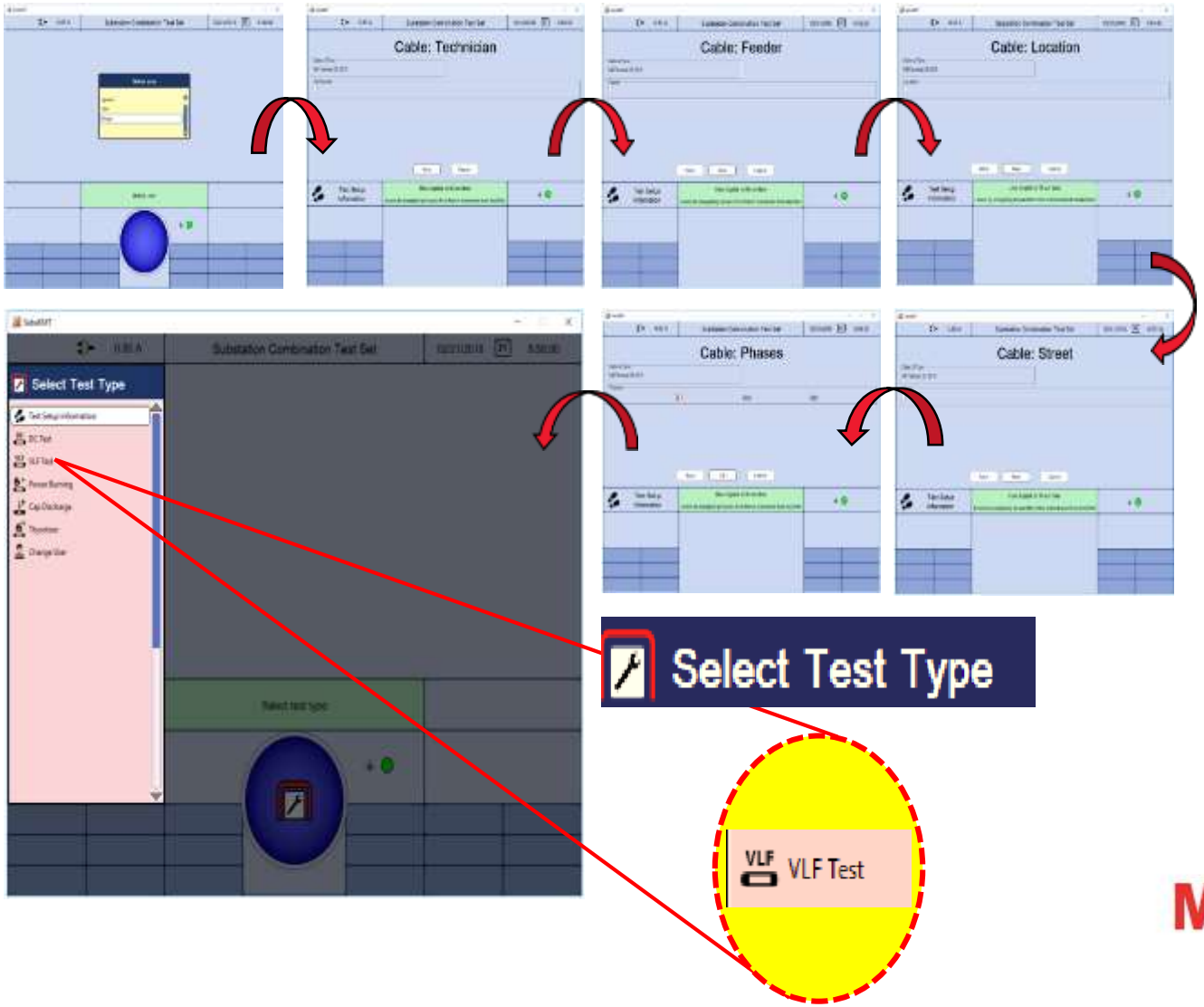
Step by Step Procedure

2. Initial setup of cable under test as well as selection of test mode



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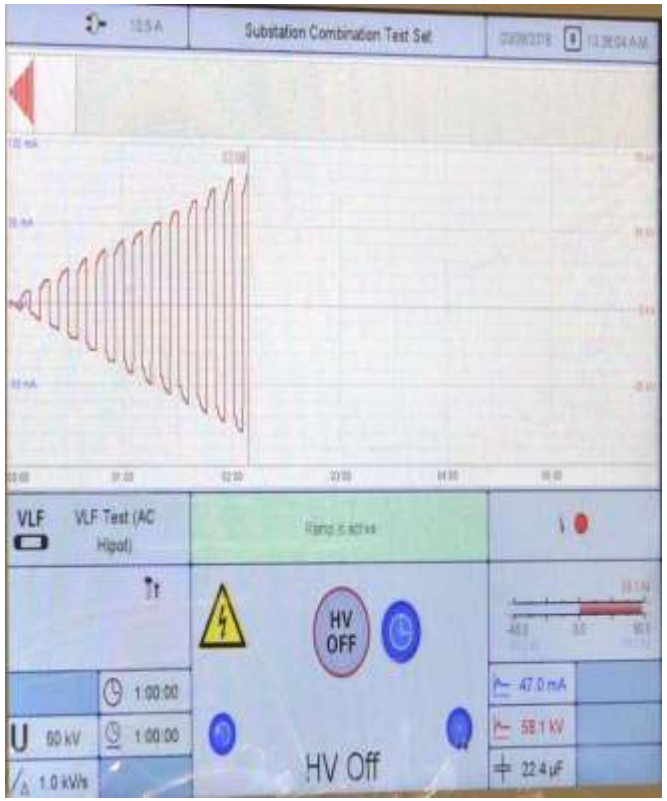
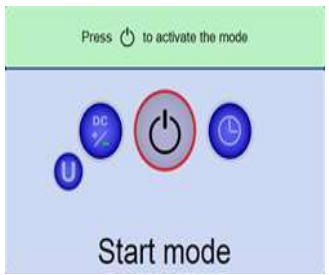
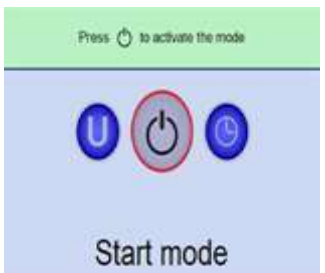
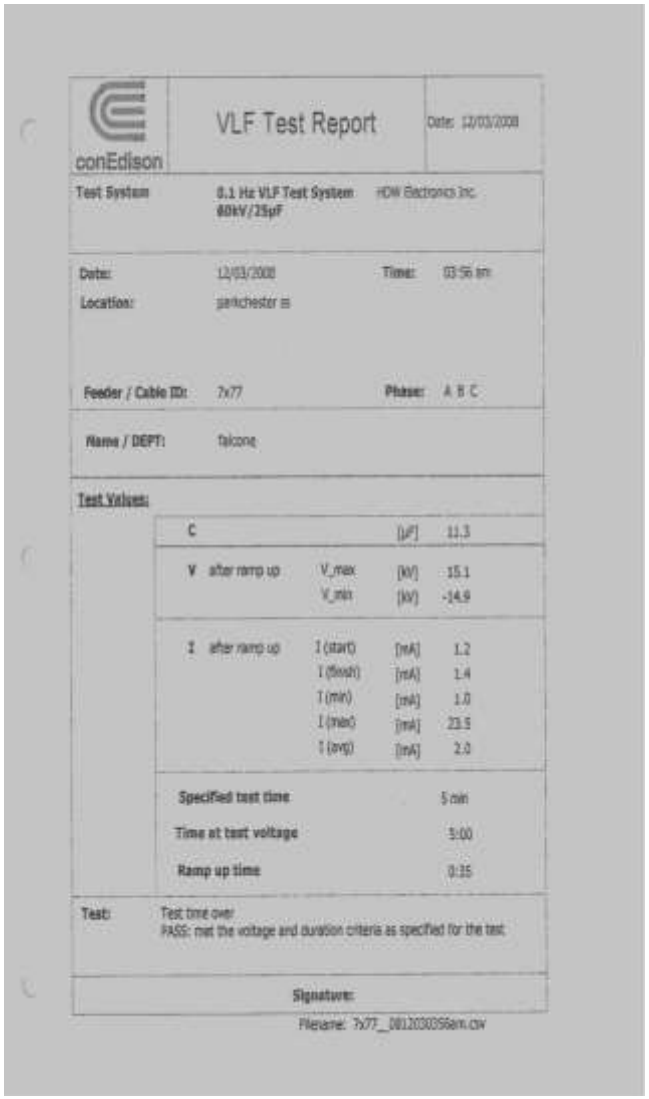
User Interface
VLF Hipot and Protocol Print-out









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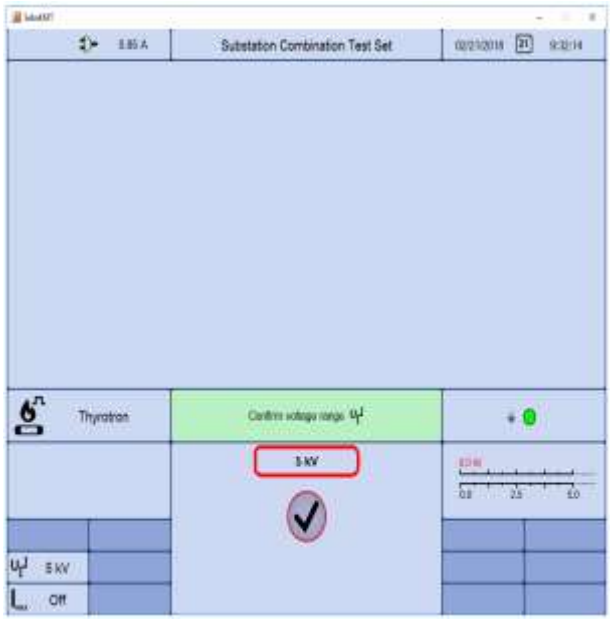
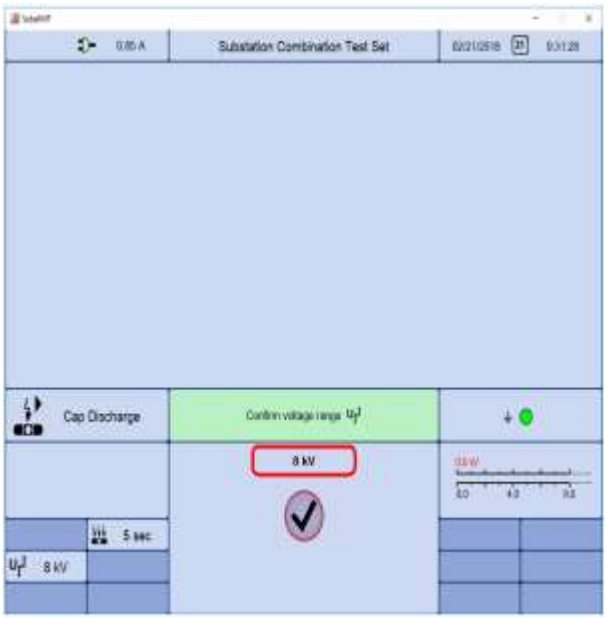
User Interface
Thyratron and Cap Discharge Modes





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Images

Typical Power Burning images of XLPE and PILC under water and in air (Jacob's ladder)

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SUMMARY

What are the advantages of a state of the art network combination test set?

- HW tailored to the demanding requirements of branched network feeders
- SW based architecture simplifies operation for user
  - The user needs to know what to do – but not how to do it
- SW based operation configures the hardware without any manual intervention of the user
- SW applies safety interlocks to provide maximum safety for operator
- SW saves all test data and stores them automatically, or can be linked to an FTP server
- SW prints out all test results
- SW can provide some degree of troubleshooting
- Training new operators becomes easier
  - Document and review the entire workflow and test history of a given situation

The end.

Thank you for your attention.

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Questions?

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At Megger, we understand that keeping the power on is essential for the success of your business. That is why we are dedicated to creating, designing and manufacturing safe, reliable, easy-to-use portable test equipment backed by world-leading support and expertise.

We can assist your acceptance, commissioning and maintenance testing for predictive, diagnostic or routine purposes. By working closely with electrical utilities, standards bodies and technical institutions, we contribute to the dependability and advancement of the electrical supply industry.

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