PDStar
Online Partial Discharge Detector

Product Manual

Version 2.0.11.808

Power Monitoring and Diagnostic Technology Ltd.

POWER MONITORING AND DIAGNOSTIC TECHNOLOGY LTD.

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1. Product Description

The PDStar is designed to detect the partial discharge (PD) activities occurring in the medium and high voltage power equipment (such as GIS, transformers, power cables, switchgear, and generators) with six-sensor technology to detect partial discharge signal when the power assets are under normal operations. The PDStar and its software organize the test jobs which makes the testing process easier.

During the PD testing job, if no partial discharge signal is found by the PDStar, it does not necessarily mean that there are no partial discharge activities going on within or around the power asset. Partial discharge activity is intermittent. So, performing a periodic PD testing can reduce the chance of missing the PD signal.

It is important to note that not all insulation system failures are caused by partial discharge activities. However, if partial discharge activities are found from a power asset, the partial discharge signals should be recorded and presented in an appropriate report format to the responsible personnel who can perform the needed maintenance and/or preventative actions.

Warning (Safety Instructions)

Before using the PDStar and its accessories, the user must read and understand the succeeding product manual and follow the following safety instructions:

- Follow the safety regulations of the local power companies.
- PDStar and its accessories are limited only to test the low potential and grounded portions of power assets. The user is strictly prohibited from making physical contact with any part of the high voltage components.
- Before performing a test job, please make sure the appropriate power assets are grounded.
- Testing is prohibited, whether it is indoors or outdoors, when a lightning storm is occurring near the substation.
- Do not continue to operate the instrument when damaged.
- During testing, please use the correct connection cable, adapter and/or connector as appropriate.

- All cables should be kept in a nice and neat condition during the test to prevent them from connecting to the operating mechanism or creating a stumbling hazard.
- The instrument should be tested before use to ensure that it functions normally and can effectively save the collected test data.
- When not testing, the unit must be turned off.
- Never physically, electrically, or mechanically damage the instrument during the testing process, such as heating, increasing voltage, shaking, or tapping the unit.
- Do not use the instrument and its accessories in an environment that is in close proximity to explosive or volatile chemicals.
- Only use the appropriate charger for this instrument.
- If PDStar fails and needs to be repaired, please return it to the manufacturer- PMDT, or an authorized local agent for repair.

2. Partial Discharge Theories

2.1. Partial Discharge

Partial Discharge is partial electrical discharge that does not completely bridge the electrodes and insulation. Partial discharge activity increases with the continual deterioration of the insulation system. The accumulative effects of PD gradually deteriorate the insulation's dielectric properties and eventually lead to the insulation breakdown and/or failure. In addition, most mechanical damage can also cause partial discharge.

Partial discharge causes serious damage to power assets, mainly by damaging the insulating material through heat that is being produced by the discharge, the impact of charged particles, verdigris as well as other chemical reactions, emissions, etc. This damage to the insulation system develops slowly from inception of the discharge. The deterioration process is affected by many factors simultaneously. A PD issue is a hazard for the power asset while it is in operation. The correct locating method is to find PD when the asset is under normal operation, and then fix the issue before the unscheduled outage or failure.

Partial discharge mainly includes the following types:

- **Corona Discharge**

Corona discharge usually occurs around the high voltage conductor at a high voltage stress area; for example, occurring at sharp edges or points of high voltage transmission lines or high voltage transformers. This high voltage stress to the electrical field produces ionized air around the area allowing corona activity to occur. Also, if power cable terminations are exposed to air, there is a high probability that the corona discharge will occur.

Corona discharge is caused by an uneven electric field. Many external factors will affect the corona inception voltage, such as the shape of the electrodes, applied voltage, gas density, distance between the poles, and the humidity and flow speed of the air.

- **Surface Discharge**

Surface Discharge usually appears on the surface of the insulating dielectric and is a special gas discharge. It commonly exists at either or both ends of power cables and insulation bushings. Once the electric field strength of the interior of the insulating medium is lower than the field at the edge of the electrode gap and the breakdown voltage along the surface of the medium is relatively low, then surface discharge will occur at the dielectric surface. Typically, the voltage waveform, electric field distribution, air quality, surface state of the insulating medium, and the environmental conditions can affect the surface discharge activity. This type of PD can be intermittent but it will always progressively get worse as time goes on.

- **Void Discharge**

Void discharge usually happens inside the solid dielectric insulation. There could be defects and problems in the material and workmanship at the time of production and processing of the insulation medium as well as in the workmanship during field installation (i.e. terminations, booting or bus transitions installed in the field). This leads to void issues inside the insulation system, such as a small amount of air or impurities in the insulation creates air gaps or particles like dust, dirt, metal shavings, grease, etc. causing improper stress on cable terminations or contaminants under the heat shrink or cold shrink materials. Once insulation is affected by high voltage stress, a partial breakdown or repetitive breakdown of the internal defects can begin to occur. Typically, the medium's characteristics, the size of the void, the position and shape of the void, and types of gas of in the void will affect the occurrence, conditions, and characteristics of the void discharge.

- **Floating Electrode Discharge**

Floating electrode discharge typically occurs between metal-to-metal and/or metal-to-insulation connections. The floating potential of the components will cause the discharge. Floating potential can be caused by a bad connection to the ground or bad connection with the conductors. The potential of the components is not stable and they do not share the same potential as the energized parts and the ground parts. Therefore, the electrical field stress between the conductor/ground and the components causes the discharge activities. This is a very common type of PD occurrence in substations. Floating electrode discharge can last a long time before causing a major issue in the power system due to the strong magnitude of PD signals generated. Thus, the magnitude is not the only factor to consider when evaluating the conditions of the PD signal.

2.2. By-product of Partial Discharge

Partial discharge activities take on the form of pulses or sparks. The development of partial discharge is accompanied by the transfer of electric charges and energy releases to a small area. In addition to these transfers, it can also produce different forms of energy emissions like electromagnetic radiation, acoustic, light, heat, white powdery residue, carbon tracking, nitric oxide gas and ozone, and verdigris affect (which is a green discoloration and corrosion/degradation of various components around the discharge location caused by nitric oxide gas mixing with moisture creating nitric acid). Therefore, for these by-products, the basic online PD detection methods include electrical measurements (TEV, UHF, and HFCT), acoustic measurements, visual inspection, and chemical detection methods. For online PD testing, the electric and acoustic detection methods have been widely used.

Detailed List of Partial Discharge Emissions:

- **Electric** (TEV, UHF, HFCT sensors)
- **Light** (in certain conditions, flashes of discharge sparking can be seen through the view windows or vents)
- **Heat** (infrared; due to the fully enclosed structure of switchgear and other power assets, the testing is limited to line of sight, making many components inaccessible to view online)
- **Acoustic** (acoustic and ultrasonic sensors)
- **Gases** (smell of ozone and nitrous oxide)

Various emissions of PD are not the easiest to distinguish between. Occasionally, the magnitude of the electronic noise is greater than the magnitude of the PD signal in the substation. Also, the mechanical noise will affect the PD testing. Therefore, it is necessary to combine the PDStar with different sensor technologies to solve the many challenges of PD testing in substations.

2.3. Partial Discharge Detection Methods

2.3.1. TEV (Transient Earth Voltage) Testing Method

When a partial discharge phenomenon occurs in switchgear, charges will quickly migrate to the grounded, non-charged body from the charged body (such as the asset's cabinet), generate a high-frequency, electric current-carrying wave on a non-charged body, and spread as rapidly as the velocity of light in all directions. The current-traveling waves tend to focus only on the inner surface of the metal cabinet, while not emanating through the metal cabinet directly.

However, when the electromagnetic waves encounter a disjointed metal that has disconnected the insulation's connections, it will be transferred from the inner surface to the outer surface of the metal cabinet and spread to the free space in the form of electromagnetic waves. This generates transient earth voltage (or TEV) in the outer surface of metal cabinet. TEV's range is usually between a few millivolts and a few volts, but within a few nanoseconds of rise time. The probe can be attached to the outer surface of the switchgear when detecting partial discharge activity.

The TEV sensor is a metal-plated covered with PVC material. The first role of the PVC material is to act as an insulating material, and the second is to protect and support the sensor. When measuring PD with the TEV sensor, place the sensor directly onto the metal surface (or the grounded cover panels) of the switchgear cabinet completing the capacitive coupling creating a 90° angle between the testing device and the equipment being tested. The metal cabinet can be regarded as one part of a flat plate capacitor. The TEV sensor can be regarded as the second part of a flat plate capacitor and the space filled with PVC material. This creates the space between the two plates of a capacitive coupling.

The capacitive coupling to the surface of the metal cabinet will induce the same amount of charge onto the metal plate of the TEV sensor as it travels across the ground plane and induces an electrical signal or TEV signal created by the PD Activity. That induced signal is transmitted by the capacitive coupling to the device and converts that TEV signal to a high-frequency signal, which is the direct ratio between the discharge intensity or magnitude and the detection impedance. After sampling the equipment, characteristic parameters of the discharge intensity and repetition rate of partial discharge in the switchgear equipment become available. Because its detection principles utilize capacitive coupling, TEV sensors must make a completely flush coupling to effectively measure TEV signals produced by PD.

2.3.2. AE (Acoustic Emissions) Testing Method

An acoustic signal is an oscillating wave of sound pressure that is within a frequency greater than the upper limit of the human ear; thus, it is not easily heard and distinguished without the PDStar except in some severe cases. From the perspective of energy, partial discharge consists of an instantaneous release of energy. Electrical energy is produced in the form of sound, light, heat, and electromagnetic energy. It can emit discharges instantaneously when an electrical breakdown occurs in an air gap. Meanwhile, the electrical energy converts into heat, the gas in the center of the discharge begins to expand from the resulting heat and propagates outward in the form of sound waves.

An isothermal zone, with a higher temperature than the environment, is formed within the propagation area after being heated. The gases begin to shrink after cooling down and subsequent waves are produced. The frequency and intensity of the subsequent waves are lower and include various frequency components. They have a very wide frequency bandwidth and the ultrasonic frequency is greater than 20 kHz. As the area of partial discharge is relatively small, the location of the sound being produced by the partial discharge is the source.

There are two acoustic sensors: contact sensor and ultrasonic sensor. AE contact sensors are mounted externally onto power equipment to detect the induced vibration phenomena of the acoustic signals spreading through the surface of the equipment being tested. It is mainly used for PD detection of sealed electrical equipment such as GIS, power transformers, and power cables. However, it can be easily influenced by the ambient noise or mechanical vibration of the equipment as well.

Ultrasonic sensors are utilized to detect the vibration phenomena of the acoustic signals spreading through air. It is mainly used for PD detection in electrical equipment that allows air to escape from the gaps of electrical equipment, such as switchgear and other outdoor electrical equipment. It can convert the ultrasonic signals into audible sound though heterodyne techniques. It is better to determine the existence of the PD as well as the location through listening to the characteristic sound. The sound characteristics are not easily influenced by the disturbance signals.

Since the ultrasonic signal attenuates greatly in the insulation materials of the electrical equipment, the detection range of AE ultrasonic testing is limited; however, it has the advantage of pinpointing the positioning with greater accuracy than with any other means.

2.3.3. UHF Testing Method

The insulating dielectric of electrical equipment has very high structural integrity. The rising edge of the discharge signal has a very short rise time, generally less than 1 nanosecond. The frequency bandwidth of a typical partial discharge signal spectrum's frequency is from a few hertz to hundreds of MHz or even higher than 1GHz. Pulse waves of a discharge propagate not only in the form of transverse electromagnetic waves (TEM waves), but also in the form of the transverse electric waves (TE waves) and transverse magnetic waves (TM waves). The UHF signal produced with partial discharge can effectively propagate along the waveguide formed by the power asset's structure.

UHF detection method is utilized to detect the UHF electromagnetic wave signals (with a bandwidth of 300MHz-3GHz) produced by PD in electrical equipment. External and internal UHF sensors are utilized according to the different conditions under various tests. Since the bandwidth of the on-site disturbance signals are mainly below 300MHz, the UHF detection method is effective in avoiding any disturbance signals. It has high sensitivity and can help to determine the PD types as well as assist in locating the source.

2.3.4. HFCT Testing Method

High frequency current spreads to the ground along the ground strap when PD occurs within the electrical equipment. The HFCT detection method picks up the high frequency current signals though mounting HFCT sensors on the ground straps. HFCT sensors are usually made of Rogowski coils, which have multiple conductive coils around the ring's magnetic core material. High frequency alternating electromagnetic field is caused through the method previously described and an induced voltage occurs when the high frequency current goes through the center of the magnetic core. Since there is no direct electrical connection between the measuring circuit of the HFCT sensors and the power assets, it is a non-intrusive method used frequently in partial discharge detection; therefore, it is not necessary to interrupt the power assets while in operation.

2.3.5. Multi-Methods PD Detection Technology

Essentially, no matter what kind of method is used, there are always some limitations while testing for partial discharge. Operational conditions of high voltage equipment cannot be reflected objectively, comprehensively and truly by only one detection method. There may be a possibility of reaching a false conclusion due to the different types of energy discharges released, along with the practicality and sensitivity of various detection methods being different. Therefore, during the process of partial discharge detection, it is necessary to combine all the above detection methods together for the most accurate partial discharge detections readings possible.

3. Functions and Features

Main features of PDStar are as following:

1. Built-in TEV sensors, using TEV testing method to detect abnormal internal activities of high-voltage equipment, including:

Amplitude Detection Mode: Display the dB value of partial discharge, with green, yellow, and red to indicate the severity of the discharge (thresholds can be set)

Pulse Detection Mode: Display dB value, the number of pulses, and the severity of partial discharges.

2. AE detection method displays the RMS, PEAK, frequency content, period, pulse, and waveform of the acoustic signal.

3. UHF detection methods have three detection modes: Amplitude, Single Cycle Spectrum, and PRPD and PRPS Detection.

4. UHF Amplitude Detection mode can display the magnitude of UHF signal and different colors can indicate the intensity of the PD signals.

5. Under UHF Single-Cycle Detection mode, during one period of power frequency, PD Periodic Spectrum can be displayed which help to determine PD type and severity of PD.

6. Under UHF PRPD and PRPS Spectrums Detection mode, PRPD2D and PRPS3D Spectrums are displayed. PRPD and PRPS are the classical spectrums to determine PD type and evaluate the severity of PD in the insulation system.

7. Accumulating function: under the PRPD/PRPS test mode, users can enable the accumulating function, then the PRPD spectrum can do the pulse signals accumulation, which is better for analysis of the PD type.

8. HFCT detection methods have three modes of operation to display PD data: HFCT Amplitude Detection mode can display magnitude of PD signal. HFCT Periodic Spectrum Detection mode

shows periodic spectrum of PD in one cycle of power frequency. HFCT PRPD and PRPS are the classical spectrums to determine PD type and evaluate the severity of PD in the insulation system.

9. Screen Recording function: Under PRPD/PRPS Screen Recording mode, users can record up to 5 minutes of video of PRPD/PRPS spectrum, the recording will help to see the dynamic PD signals and do a better analysis.

10. Data Storage function: partial discharge test data, which including Acoustic testing data, UHF and HFCT detection patterns, background noise, environmental information, etc., can be instantly stored in the PDStar. Corresponding equipment information provided for partial discharge testing data should be documented and correlated with the test results saved.

11. Advanced Test Data and Jobs management

12. Light sync function helps the PD spectrum to synchronize with the field power frequency as a reference.

13. Power source sync function uses the field power to synchronize the PD spectrum wirelessly.

14. Small size, light weight, easy to carry and use, and rapid on-site detection of partial discharge phenomenon of high voltage electrical equipment.
15. Cluster Analysis (CA) function conducts partial discharge signal sources separation under cluster analysis mode automatically or manually.

16. Thermal Imaging makes it possible to test PD and IR simultaneously by simply attaching the thermal imagining camera to the PDStar main unit. It can detect any abnormal heating and defects effectively.

4. Instrument Operation

4.1. General Introduction

The PDStar has several accessories that work in conjunction with the main unit. This main unit and accessories are described in more detail in the following section and table.

The accessories may be different based on various kit configuration of PDStar from Kit1 to Kit6.

Figure 4.1. PDStar Main Unit and Accessories

<table>
<tr><th>Name</th><th>Function</th></tr>
<tr><td>


</td><td>
Main Unit

</td></tr>
<tr><td>



</td><td>
Thermal Imaging Camera
High-resolution thermal imaging camera that allows partial discharge and infrared testing simultaneously in one single tool by simply attaching the camera to the PDStar main unit. It can detect any abnormal heating and defects effectively.
</td></tr>
</table>

	**UHF Sensor and Signal Processor** UHF sensor for detecting electromagnetic wave signals due to partial discharge; the picture below shows the wireless UHF signal processor, connected with the UHF sensor by a cable, which transmits data to the main unit wirelessly. 
	**AE Contact Sensor** AE contact sensors for detecting the surface vibration produced when an acoustic signal is generated by partial discharge that spreads through the surface of the equipment being tested.
	**HFCT Sensor** HFCT sensor detects current pulse signals generated by partial discharge; the sensor has a clamp configuration, making it easy in application and removal. The picture below the sensor is the wireless HFCT signal processor. It connects with the HFCT sensor by a cable, sending data to the main unit wirelessly. Additionally, there is a 100 MSPS signal processor used to perform advanced cable testing.

	
	**Power Synchronization Device/Charger** After the device is inserted into the power outlet, the main unit can synchronize the frequency signal with the device wirelessly. It is also the battery charger for the whole kit.
	**Encryption software protection device.** The data management software cannot be opened until this device is plugged into the computer's USB slot.
	**Self-checker** This device can be used to troubleshoot the equipment and determines whether TEV and AE testing applications are functioning normally with a simple pass/fail result.
	**Headphones** Used under the AE detection mode, headphones allow users to listen to the ultrasonic signal picked up by the PDStar during the testing.

	**Data Cable** Cable connected to the charger to charge the PDStar and signal processors. Also used to connect the main unit to the computer to allow the user to upload the test data.
	**Optional accessories** **Ultrasonic_Parabolic Dish sensor with Laser** PDStar uses a parabolic dish to collect airborne ultrasonic signals, which can effectively detect partial discharge activity from a distance and pinpoint the issue with the leaser point.
	**Optional accessories** **Ultrasonic Wand Sensor** for ultrasonic testing of hard to reach locations on electrical equipment that the main unit cannot effectively reach. Pay attention to ensure an adequate safe distance from any energized components when in use.

 Power button 

Return key 

Confirm button 

Save button

 Up button  Down button  Left button  Right button

4.2. Startup and Shutdown

The power button  is located in the lower left corner of PDStar panel. Press and hold this button to turn on the device. Press and hold the button again to turn off the device. Note that the user must press and hold the power button for a few seconds during the powering-up and powering-down processes until the PDStar displays the main menu or powers down the device.

4.3. Charge the Batteries

When the main unit and HFCT/UHF signal processors indicate low battery, the instrument should be recharged. The charging port is located at the lower end of the device and hosts a mini USB connection. There is a charging indicator light to indicate the current state of the charging process:

- When the light is ON, this indicates the device is being charged.
- When the light is OFF, it indicates that the device is not in the charging state or it is fully charged.
- While the device is charging, it should be powered off.
- While the device is charging, do not perform any tests.

4.4. Online PD Testing

Online Partial discharge testing positions should be imposed on electric power equipment. For different HV equipment, such as GIS, power cable connectors, switchgear, transformers, etc., the testing positions will be different and will be determined according to the structure of the power equipment. PDStar is mainly used to detect PD for GIS, switchgear, transformers, bus (joint, wear casing wall, supporting insulation), and circuit breakers; however, it is also used to detect in other electrical equipment such as CTs, PTs and cable terminations.

4.5. Main Menu

The main unit displays the main menu after entering the normal operating state. Main menu displays the following applications: **TEV Detection**, **AE Detection**, **UHF Detection**, **HFCT Detection**, **CA Diagnostics, Infrared Testing, RFID, Pairing**, **Audio** and **Settings** as selectable fields. The current option is highlighted on the main menu, by pressing **UP/DOWN** or **LEFT/RIGHT** buttons on the device to highlight a specific option, and then select **OK** on the device to enter the next level of function menus. Press **ESC** button on the device to return to the previous menu. Press **S** button to save the current screen to an image file. The current time, date, and battery status are displayed at the top of the screen.

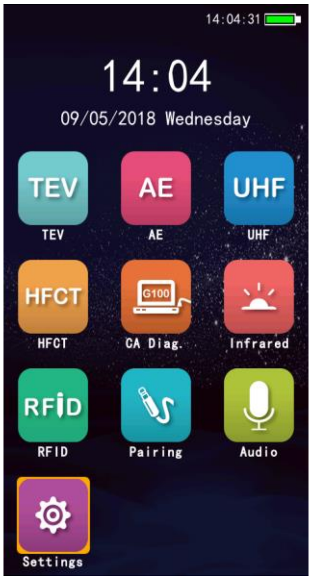


Figure 4.2. Main Menu Options

4.6. TEV Detection, Field Testing and Data Analysis

On the **Main Menu** screen, highlight **TEV Detection** and press the **OK** button on the device to enter the corresponding interface.

TEV Detection has two modes of operation: **amplitude detection** and **pulse detection**.

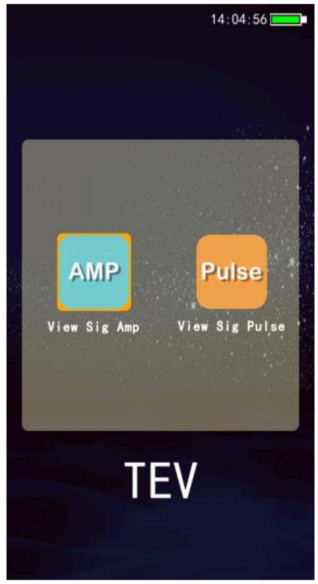


Figure 4.3. TEV Detection Options

4.6.1. TEV Amplitude Detection

The amplitude detection screen displays the amplitude and severity of the PD using the traffic light system by displaying green, yellow, and red colored indicator lights. The amplitude detection mode can display the magnitude of the decibel values of the measured signal in a frequency cycle, and the indicator lights help the user quickly determine whether there is abnormal partial discharge occurring within the device and what the possible discharge type might be. Select **AMP** from the TEV options screen to enter the amplitude detection screen.

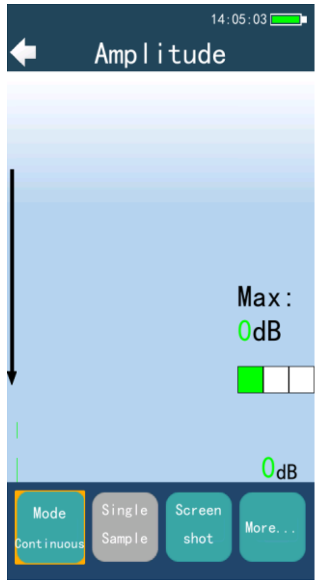


Figure 4.4. TEV Amplitude Detection

- ***Amplitude***: Displays measured TEV value in dB unit.
- ***Color indicator***: Indicates the measured intensity of the TEV results. Green indicates normal; yellow indicates warning; and red indicates an alarm. The thresholds for the traffic light system can be set in the TEV Setting interface.
- ***Data history***: Displays in a different color bar graph to show the last 10 measurements.
- ***Maximum reading***: During TEV mode detection, this displays the maximum of the last 10 readings obtained while in operation.
- ***Detection indication***: With a flashing green arrow or a red double bar indicator, this tells the user if it is continuously testing or paused.

Parameter Settings:

On the TEV options screen, select **AMP** on the device to enter **TEV Amp Detection Settings** interface. The parameter settings are listed at the bottom of the screen:

- ***Mode***: Switching mode to **Continuous** or **Single-shot**. When in Single-shot mode, press **OK** button on the device to trigger single-shot signal detection.
- ***Single Sample***: Take a single sample measurement of TEV.
- ***Screen shot***: Take a screenshot of current screen, it will show as saved as shown below.
- ***Warning***: Set the warning threshold setting for the TEV detection option.

- ***High Risk***: Set the high risk or alarm threshold setting for the TEV detection option.
- ***Load/Delete Data***: Load or delete TEV data.
- ***Default***: Reset and restore the parameters to the system's default settings.

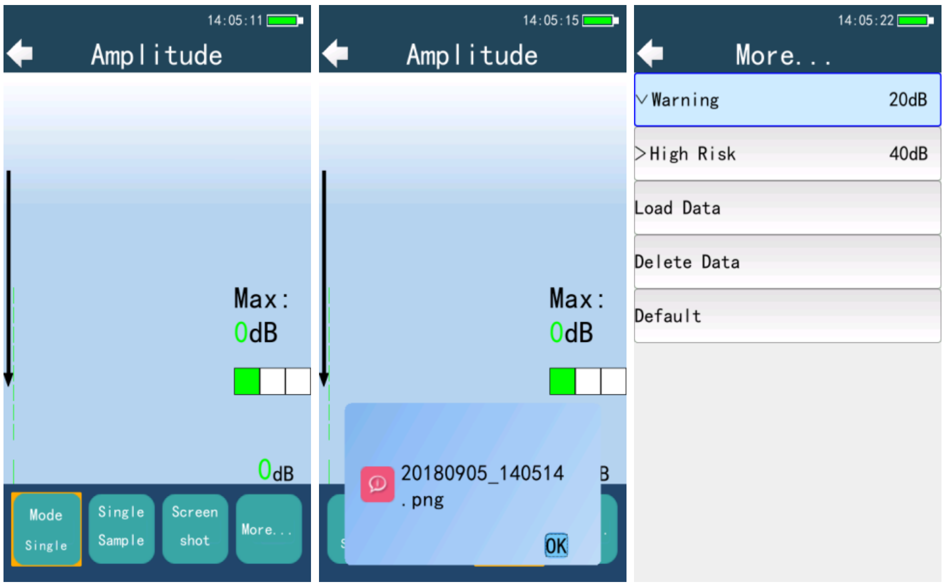


Figure 4.5. TEV Amplitude Settings

4.6.2. Pulse Detection

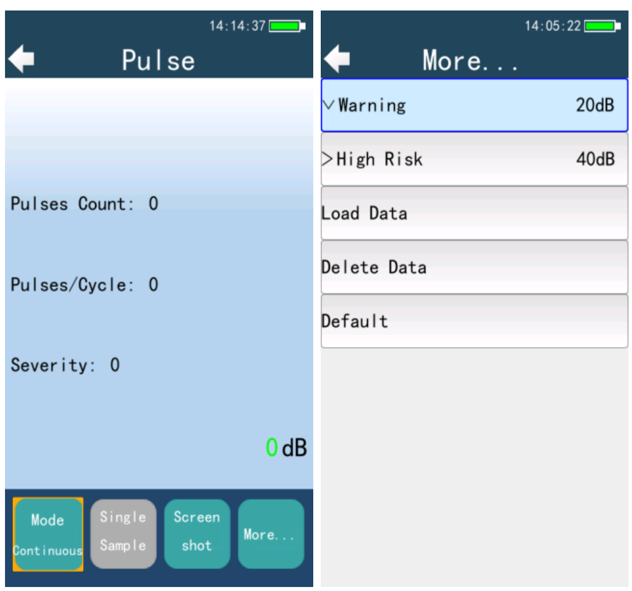


Figure 4.6. TEV Pulse Detection

- ***Amplitude***: Displays in dB the measured TEV value.
- ***Pulse count***: Shows the total number of pulses counts during the "count time"
- ***Pulses/Period***: Shows the average TEV number of pulses for every period.

- ***Discharge Severity***: Shows the severity of the discharge, the value is amplitude (mV) x pulses/period.

Parameter Settings:

From the TEV Pulse detection screen, the parameter settings are listed at the bottom of the screen:

- ***Mode***: Switching mode to **Continuous** or **Single-shot**. When in Single-shot mode, press **OK** button on the device to trigger single-shot signal detection.
- ***Single Sample***: Take a single sample measurement of TEV.
- ***Screen shot***: Take a screenshot of current screen, it will show as saved as shown below.
- ***Pulse Length***: Set the time length of the pulse count, it can be 1 or 2 seconds (s); the system defaults it to 1s.
- ***Warning***: Yellow light shows the warning threshold setting in the TEV detection screen.
- ***High Risk***: The high risk or alarm threshold setting in the TEV detection screen.
- ***Load/Delete Data***: Load or delete TEV data.
- ***Default***: Reset and restore the parameters to the system's default settings.

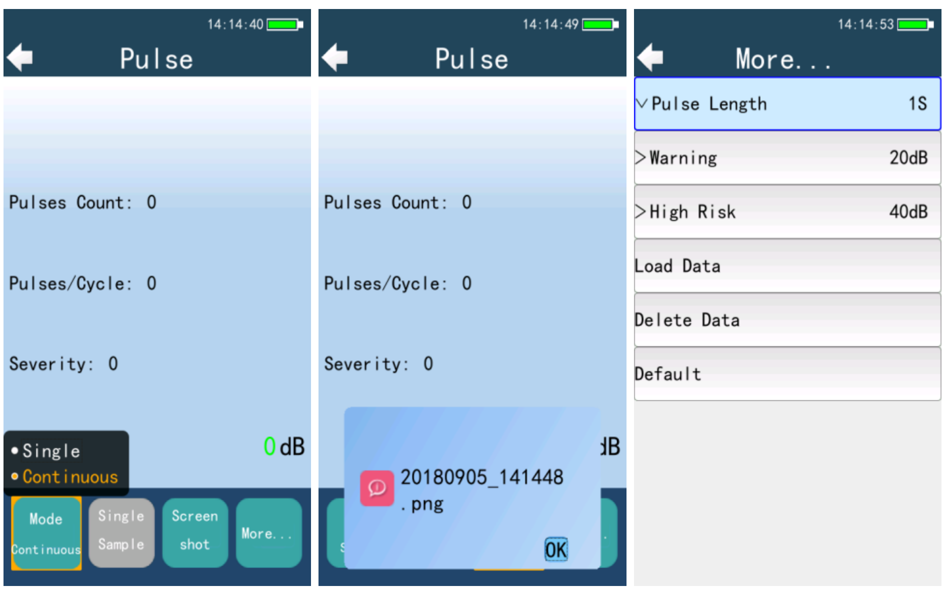


Figure 4.7. TEV Pulse Settings

4.6.3. TEV Field Testing

TEV is applicable to 345kV switchgear testing and in the testing process, the TEV sensor is used by contacting the outer surface of the equipment being tested and this does not affect the normal operation of the equipment. Due to the presence of outside noise interfering in the operating environment of the switchgear, the background noise needs to be verified before conducting the test.

TEV Background Detection: Before starting the test for partial discharge in the switchgear, the background noise level of the system should be tested. The test point should be in the open air and should be selected 1 meter above the switchgear. Metal background values should be taken from the surface of metal products such as metal doors, metal gates, and other non-switchgear equipment, testing the different points' background values in different positions of switch room and also being able to test in place where background values are need to be tested.

Switchgear PD TEV Detection: When using TEV detection, the testing location is the point on the electrical equipment that the sensor makes direct contact with the surface. The detection point is different due to different type of electrical equipment, which is based on the configuration of the power parts. In the switchgear partial discharge testing process, the location of all electrical equipment should first be determined, mainly testing partial discharge of busbar (connections, wall bushing, supporting insulator), circuit breakers, CT, PT, cable joints and other equipment, most of these parts are located in the middle and lower parts of the front face panel of the switchgear and the upper, middle and lower parts of the back panel. We should conduct partial discharge detection in these locations of the switchgear. Test points are shown in Figure 4.8. In the testing process we should ensure that the sensor and switchgear metal panels are **in close contact,** and the sensor should be as close to the observation windows, ventilation louvers and other parts of metal panel that the PD signal can easily escape from. If the detected value is large in magnitude, **it is recommended to measure more than three times to make sure the test results are consistent.**

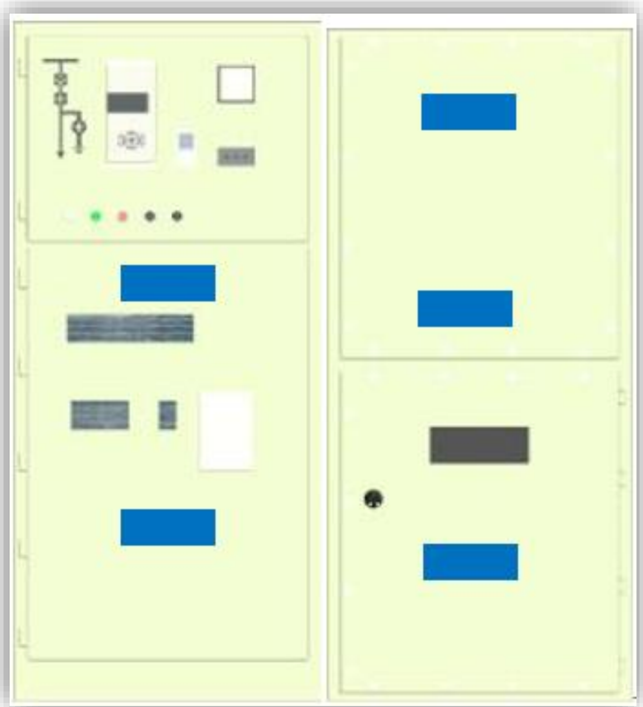


Figure 4.8. Selecting switchgear testing points (Blue points are TEV measurement points)

4.6.4. TEV Data Analysis

By comparing the TEV detection data with other relevant information, it can be determined if PD is present. Test results of switchgear should be compared with detected data of other switchgear of the same types or compared with previous test data of itself for trending. If the test data is larger in magnitude than other switchgear of the same type, or than the previous results, it shows that there is discharge activity in this switchgear, and then infer the possibility of failure. According to a large number of experiments and on-site testing experience, we have concluded the following ways of interpreting data for testing personnel to use:

Threshold Value Determination

Project	Cycle	Standard	Explanation
TEV Detection	1) 6 months to1 year 2) After put into operation 3) After maintenance 4) When deemed necessary	1. Test value <10dB, no concern 2. 10 <test value <20dB, attention, shorten the testing cycle 3. The test values >20dB, using the UHF method for testing, to determine the signal type initially, or use acoustic-electric combination detection, to determine the signal source 4. Test values in the context of a stable situation – background values >10dB, using the UHF method for testing, to determine the signal type initially, or acoustic-electric combination detection, to determine the signal source 5. The value of this test - the last cycle test values >10dB automatically determined by the software after data enters the computer.	Each station should use the same type testing instrument for all switchgears during testing. UHF partial discharge detection and localization testing can be carried out when there are unusual circumstances while collecting test data to make a comprehensive judgment. 1) The new electrical equipment should be tested once after being put into operation for a week. 2) The relative value: Numerical difference between the value of the equipment under test and environmental value(metal). 3) A more permanent on-line monitoring solution that can be carried out when there are abnormalities within the system. [Attention should be attached that TEV detection only test the signal through the capacitive coupling sensor, which can simply display the amplitude of the discharge, no further analysis of the signal type is provided; Being able to conduct UHF detection for abnormal signals, analysis and determine the type of signals.]

Horizontal Comparison Method

Horizontal analysis techniques are applied to compare and analyze the same test results of indoor switchgear, and it's used to find the switchgear that has higher probability of defects.

Indoor switchgear generally shows a horizontal shaped arrangement according to the order number. Since the majority of indoor switchgear are from the same manufacturer, the operating life is also not so different from one to the other, operating environment and electromagnetic environment are also essentially the same, it can be considered that the switchgear which are under normal operation, the insulation level of the switchgear should not be significantly different. Therefore, by calculating the overall average level of the same test result done multiple times, and measuring the degree of deviation from the overall average level for each of the switchgear, it can be determined whether there are insulation defects within.

As there is little difference between the measurement results of each switchgear that are operating under normal circumstances, so basically the horizontal analysis bell curve fluctuates in the overall average, the resulting bell curve should not be very prominent. However, when the test result of switchgear deviates significantly from the overall average, a higher probability of a defect being present can be considered within this switchgear.

Trend Comparison Method (Vertical Comparison Method)

Trend analysis assumes that a certain switchgear insulation level doesn't deteriorate suddenly; continually testing the switchgear should not show a major jump in magnitude. That is the amount of change remains stable and fluctuates up and down around the average level. Therefore, by analyzing the degree of change in the deviation from the average level in a particular partial discharge detection data to determine whether there are insulation defects and the defect severity of the switchgear. Trending analysis is based on the continually collect data, the greater the amount of data, the shorter the interval, the more accurate the results.

4.7. AE Detection, Field Testing and Data Analysis

Select **AE Detection** in the main menu and press the **OK** button on the device to enter the AE Detection interface. There are four modes of operation under AE Detection: **AE Amp Detection**, **AE Phase Spectrum**, **AE Fly Spectrum**, and **AE Waveform**.

When a partial discharge signal generates inside the electric equipment, impact vibration and sound will be produced. AE Ultrasonic measurement method measures partial discharge signals by placing ultrasonic sensor on the outside enclosure of the equipment chamber. The characteristic of this method is there isn't any contact between the sensor and electrical circuit of electrical equipment, without noise from electrical aspects, but being susceptible to the ambient noise or mechanical vibration of equipment when used in the field.

Since the attenuation of the ultrasonic signal in the common power equipment insulation material is large and detection range of ultrasonic testing method is limited, but has the advantage of accurately pinpointing the abnormal signal being produced. Ultrasonic sensors are divided into two types; one is the contact-type ultrasonic sensor for collecting data from the fully enclosed high-voltage electrical equipment, such as the GIS, the transformer and another is a non-contact-type ultrasonic sensor used for collecting data from the open or semi-closed high-voltage electrical equipment such as switchgear, cables, transmission lines, etc.

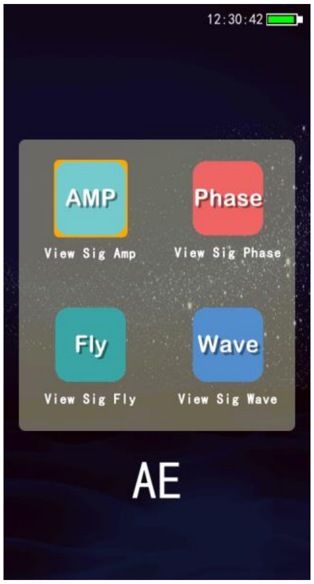


Figure 4.9. AE Detection Options

4.7.1. AE Amplitude Detection

The amplitude detection mode can display the RMS and PEAK values of the measured signal in a frequency cycle, and the relevance between measured signal with frequency content (x1) and double frequency content (x2). Through a combination of different parameters, the user can quickly determine whether there is abnormal partial discharge occurring within the device and what the possible discharge type might be.

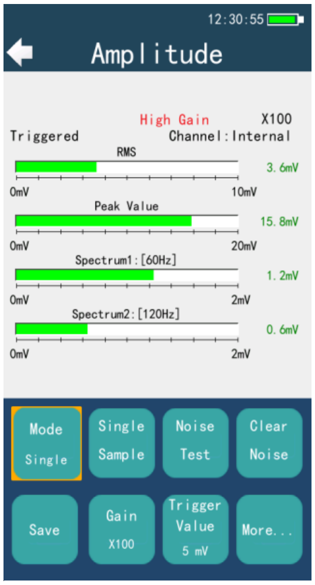


Figure 4.10. AE Amplitude Detection

- ***RMS***: RMS value of the signal in a power cycle
- ***PEAK***: Peak value of the signal in a power cycle
- ***Frequency content 1***: Degree of correlation with the frequency content (x1)
- ***Frequency content 2***: Degree of correlation with the frequency content (x2)

Parameter settings:

From the detection screen, the parameter settings are individually listed as button options at the bottom of the screen, with the “More…” option with more settings:

- ***Mode***: Switch mode to "continuous" or "single shot", when in the "single" mode, press the OK button on the device to trigger single signal detection.
- ***Single Sample***: Take a single sample measurement of AE.

- ***Noise Test***: Test the noise signal value of the background environment, this will be superimposed with the effective signal value as to ignore until the signal amplitude is higher than the background noise, as in the red background. Can record the noise as testing occurs.
- ***Clear Noise***: The recorded background noise measurement value measured before, and cancels overlay display.
- ***Save***: Save the current measurement data displayed. Note: When this dropdown menu is opened, the value displayed on screen at that moment is frozen and won't continue to take data until the menu is closed.
- ***Gain***: Adjusting the magnification of the input signal, to accommodate the input signal of a different size. With 3 settings to choose from that adjusts the gain, x1, x10, x100. When using the magnification of x100, the test range is between 2-20 mV; when using the magnification of x10, the test range is between 10 to 200 mV; when using the magnification of x1, the test range is between 50-1000 mV.
- ***Trigger Value***: Set the waveform signal amplitude threshold displayed, from 1-18mV.
- ***Volume***: Set the volume of the ultrasonic signal output to the headphone. Consists of volume levels from 1 to 9.
- ***Frequency***: Select frequency that displays the frequency component. Optional frequency is 10 ~ 500Hz.
- ***Channel***: Select between internal and wireless channel options.
- ***Unit***: Select a unit of measurement to be displayed as either mV or dB.
- ***Save RFID***: Scroll down until you highlight **Scan RFID & Save** function. After selecting this, put the back of the device near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.
- ***Load Data***: Allows the main unit to display data that is stored on the unit.
- ***Delete Data***: Delete the directory or file of data selected.
- ***Default***: Press **OK** button on the device to confirm the restoration of parameters to the system's default settings.

Record: Record the audible sounds with buttons at bottom of the screen. Recording can be paused and continued until it is saved.

4.7.2. AE Phase Spectrum Detection

Because of the partial discharge signal being generated and that the power frequency of the electric field is relevant, it can be used as a reference for the amount of power frequency present by observing whether the occurrence phase of the tested signal has an aggregation effect to determine whether the signal is produced due to the internal discharge inside the asset. This mode is primarily used for further confirmation that the specific phase occurred by an abnormal signal. This is done in order to determine whether there is a correlation between the abnormal signal and power frequency voltage; and then determine whether the abnormal signal is a partial discharge signal and, if so, find out potentially what type of partial discharge it might be.

Phase spectrum detection uses a synchronous trigger signal of the grid frequency to measure the pulse signal and according to the pulse amplitude and phase of the relative triggered signal, by marking a point in the spectrum and creating the pulse distribution statistics. Different points display different colors according to the probability of a pulse in the peripheral region. This happens after pressing the **OK** button on the device to trigger a single acquisition and after the completion of populating the device with at least 1,000 pulses to complete the data acquisition process and stops automatically after it has acquired all 1,000 pulses. The horizontal axis of a phase spectrum detection mode represents the phase angle (0-360 °), and the vertical axis represents the signal amplitude.

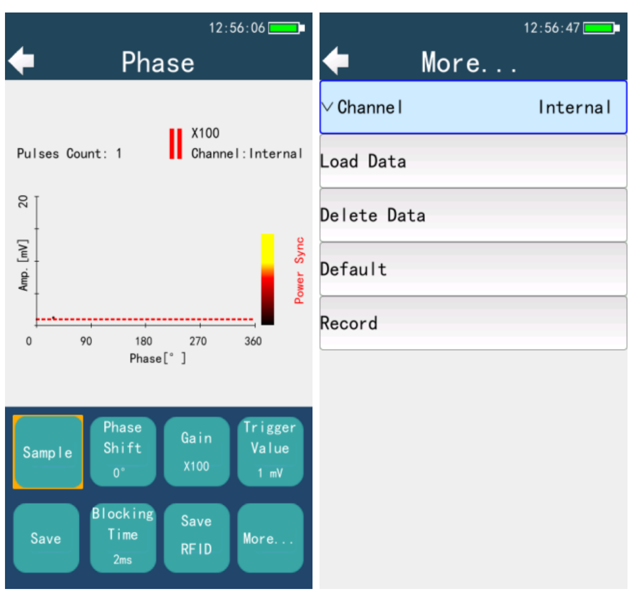
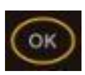


Figure 4.11. AE Phase Spectrum

Parameter settings:
In the detection screen, select **Phase** the device to enter the phase spectrum detection parameter setting interface.

- ***Sample/Stop***: Take a single sample of a data reading.
- ***Gain***: Adjust the input signal amplification to accommodate input signal of different sizes. With 3 settings to choose from that adjusts the gain, x1, x10, x100.
- ***Trigger Value***: Set the waveform signal amplitude threshold displayed.
- ***Blocking Time***: The off time using in triggering samples.
- ***Phase Shift***: Set relative offset of the measured pulse signal to the phase grid.
- ***Frequency Synchronization***: Select the trigger source of synchronous grid phase.
- ***Save***: Saves the currently displayed measurement data on the device's internal storage.
- ***Save RFID***: Once selected, place the device back near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.
- ***Channel***: Select between internal and wireless channel options.
- ***Load data***: Allows the PDStar to display data that is stored on the unit.
- ***Delete Data***: Delete the directory or file of data selected.
- ***Defaults***: Press 

button on the device to set the parameters to the system's default settings.
- ***Record***: Record the audible sounds with buttons at bottom of the screen. Recording can be paused and continued until it is saved.

4.7.3. AE Fly Spectrum Detection

Particles in high voltage equipment will jump and fly because of the effects of the electric field on the particles. Every time the particles collide, a wideband transient acoustic pulse will be transmitted, which will propagate back and forth within the enclosure. Acoustic signals of such particles are the mixed signals which are generated by the partial discharge of the end particles and particles collision within then closure. Pulse mode can record the time and the pulse amplitude generated in the case when the particles collide within the enclosure, and display in the form of flying spectrum. AE Fly Spectrum is used to measure the time of flight of the particles.

The PDStar measures the gap between the pulse signals, and depending on the magnitude and the time interval, using a point in spectrum to show the output and displaying the pulse distribution statistics. Different points display different colors according to the probability of a pulse in the peripheral region. Operation is similar to the phase spectrum detection. After pressing the **OK** button on the device to trigger a single acquisition, the PDStar collects up to 1,000 pulses to complete a data acquisition process and stops automatically. The horizontal axis of AE Fly Spectrum mode represents time, and the vertical axis represents signal amplitude.

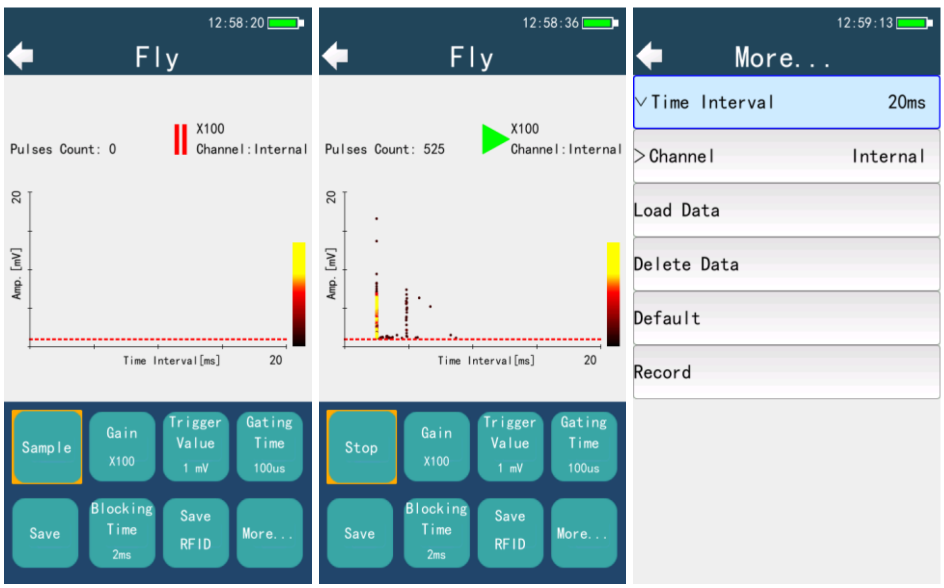


Figure 4.12. AE Fly Spectrum

Parameter Settings:
From the detection screen, the parameter settings are listed at the bottom of the screen:

- ***Sample/Stop***: Take a single sample of a data reading.
- ***Gain***: Adjust the input signal amplification to accommodate the input signal of different sizes. With 3 settings to choose from that adjusts the gain, x1, x10, x100 to adjust the gain.
- ***Trigger Value***: Sets the waveform signal amplitude threshold displayed.
- ***Gating Time***: The sample time after the signal reaches the trigger amplitude.
- ***Save***: Save the current measurement data.
- ***Blocking Time***: The off time used in triggering samples.
- ***Save RFID***: Scroll down until you highlight "Scan &Save RFID" function, after selecting this, put the device back near the RFID tag. The device automatically reads the relevant information of high

voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.

- ***Channel***: Select between internal and wireless channel options.
- ***Time Interval***: The maximum time difference between two pulses
- ***Load Data***: Allows the PDStar to display data that is stored on the unit
- ***Delete Data***: Delete the directory or file of data selected.
- ***Default***: Press **OK** button on the device to set the parameters to the system's default settings.
- ***Record***: Record the audible sounds with buttons at bottom of the screen. Recording can be paused and continued until it is saved.

4.7.4. AE Waveform

AE Waveform spectrums display envelope waveform spectrums of the ultrasonic signal. When collecting the data, period frequency synchronizes to trigger, so you can examine the correlation between envelope signals and the grid. The horizontal axis of the AE Fly Spectrum mode represents the frequency period number and the vertical axis represents the signal amplitude.

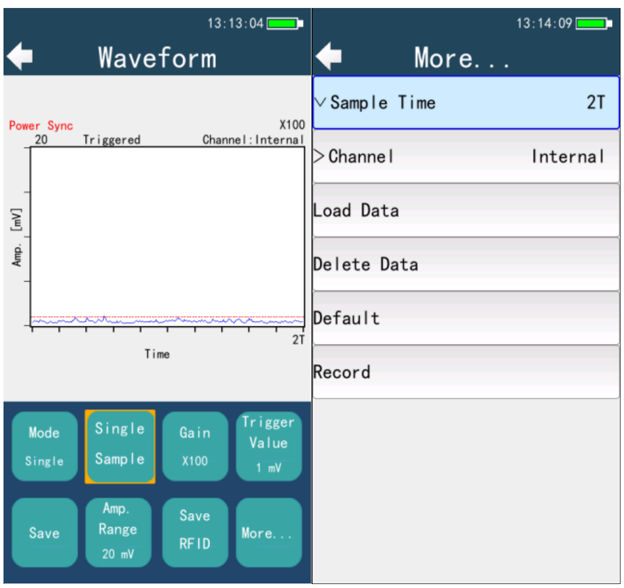


Figure 4.13. AE Waveform

Parameter Settings:
From the detection screen, the parameter settings are listed at the bottom of the screen:

- ***Mode***: Switch mode to continuous or trigger, when in the trigger mode, press the OK button on the device to trigger single signal detection.
- ***Gain***: Adjust the magnification of the input signal to accommodate the input signal of different sizes. With 3 settings to choose from that adjusts the gain, x 1, x10, x100 to adjust the gain.
- ***Single Sample***: Set a trigger acquisition time. 1 to 10 is the adjustable frequency period.
- ***Trigger Value***: Set the waveform signal amplitude threshold displayed.
- ***Save***: Save the current measurement waveforms.
- ***Amplitude Range***: Set the maximum wave amplitude displayed in the interface.
- ***Save RFID***: After selecting, place the device back near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.
- ***Sample Time***: The maximum time difference between two pulses
- ***Channel***: Select between internal and wireless channel options.
- ***Load Data***: Allows the PDStar to display data that is stored on the unit.
- ***Delete Data***: Delete the directory or file of waveform data selected.
- ***Default***: Press **OK** button on the device to set the parameters to the system's default settings.
- ***Record***: Record the audible sounds with buttons at bottom of the screen. Recording can be paused and continued until it is saved.

4.7.5. AE Field Testing

Contact ultrasonic sensor is for collecting data from the metal casing vibration signals that ultrasonic signal generates by partial discharge and is produced when propagating in the metal casing of the equipment under test, which needs to be applied by the following methods:

- The sensor should be directly affixed to the outer surface of the equipment and make sure that the contact surface is smooth with no impurities or dirt present.
- Apply a 1mm thick coating of vacuum grease on the sensor's surface, ensure the gelatinous grease layer contains no bubbles. Ultrasonic signals attenuate quickly in the air. Any small air gap between the sensor and the attachment to the surface may cause the ultrasonic signal not to be

effectively measured. The sensors with a coupling staff should be ensured to be fixed onto the case of equipment with no requirement of external force.

- Since the ultrasonic wave attenuates fast, when conducting partial discharge ultrasonic testing, the distance between the two testing points should not exceed 1m/3.28ft. For testing of GIS, for example, the testing process should include all the gas chambers, as shown in Figure 5.2.
- When conducting partial discharge ultrasonic testing, they should focus on both ends of installed detection equipment, in order to detect potential defects generated during the installation process.

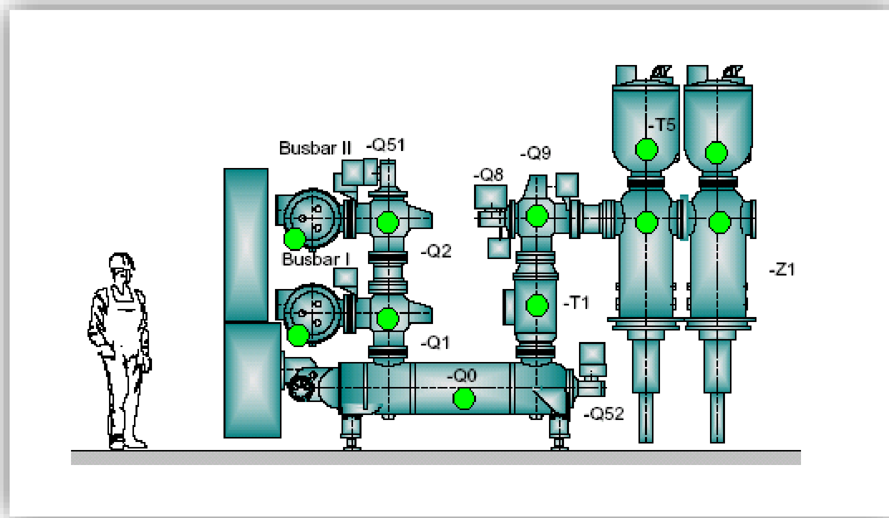


Figure 4.14. GIS AE Ultrasonic Partial Discharge Detection Typical Measuring Points (Green markers shown)

For the application of air-insulated partial discharge phenomenon, the spectrum is very low, often only hundreds of kHz. At this time the non-contact ultrasonic sensor is undoubtedly the most sensitive way for detecting partial discharge activity. In order to make non-contact ultrasonic work normally, there must be an unobstructed path for the air to flow between the power supply and sensors. **For partial discharge activity of internal solid insulation, due to the poor coupling relationship between at attenuation of the insulating medium itself and air - solid, making the ultrasonic signal stimulated by partial discharge difficult to propagated to external high-voltage equipment, so non-contact sensors have a difficult time capturing the discharge activity in the internal insulated medium, such as cable head, insulators, and bushings. However, for creepage and surface discharge that occurs due to the outer insulation, the sensitivity of non-contract sensors performs quite well.**

The non-Contact ultrasonic sensor is used for detecting vibration signals through the air that is an ultrasonic signal generated by partial discharge when propagating through the air. This sensor is implemented by using the following methods:

The sensor should be close to the outer surface of the equipment (close enough to ensure the air passage between the sensor and equipment). Align the direction of the sensor probe toward the suspected malfunction of the equipment; to test switchgear, for example, the testing process should include all the gas chamber, as shown in 5.3.

- **During the testing process the sensor should remain stationary, avoiding any possibly influencing of the test results because of the sensor jittering;**
- **Non-contact ultrasonic sensor should retain an adequate safe distance with the equipment high voltage parts.**

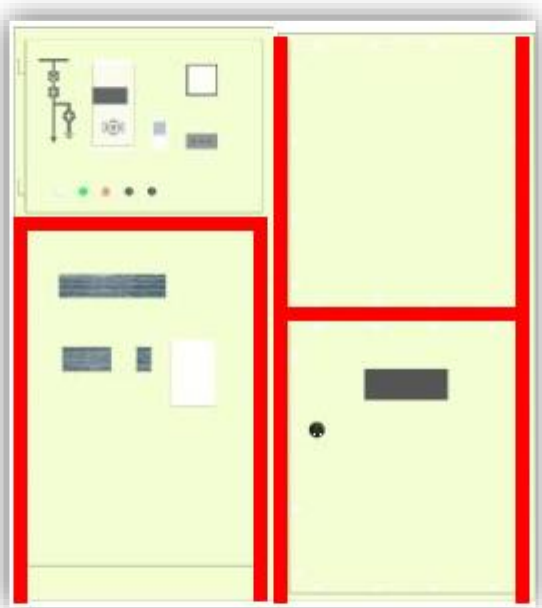


Figure 4.15. Switchgear Ultrasonic Partial Discharge Detection Typical Measuring Points (Red portion shown)

Optional Accessories:

AE Ultrasonic Dish with Laser Pointer: The focused ultrasonic sensor uses parabolic dish to collect ultrasonic signals in the air, which can effectively detect partial discharge activity from a safe distant.

Focused ultrasound transducer has a high-precision laser sight, so that it may get a better alignment with the distant high-voltage equipment, and locate the partial discharge signals. This dish is transparent, allowing users to observe the equipment being testing without obstruction.

AE Ultrasonic Extension Microphone: For ultrasonic testing, out of reach position or edge, corners, and other testing parts that are difficult to test located on the switchgear. Pay attention to ensure adequate safety distance when in use.

4.7.6. AE Data Analysis

When conducting ultrasonic testing, we should pay attention to the real ultrasonic signals generated by the partial discharge for the characteristic cracking sounds (hissing sound) that can be heard with the use of the headset. When recording test data, the ultrasonic maximum stability in this test that should be looked at more closely. And in accordance with the sound, amplitude and other characteristic spectrum signals of detection to determine whether there is partial discharge and what type it might be. According to many experiments conducted by PMDT and testing experience gained while on-site, we have concluded the following testing criteria for personnel to use:

Project	Cycle	Standard	Explanation
Ultrasonic testing	1) 6 months to 1 year 2) After put into initial operation 3) After maintenance 4)When deemed necessary	• Floating electrode discharge; Typical spectrum of this type of defect has the following characteristics: • In the amplitude detection mode, the signal RMS and PEAK are large. There is an obvious frequency content x1 and frequency content x2, and the frequency content x2is larger than the frequency content x1; • In the phase detection mode, the signal has an obvious effect of phase aggregation, showing up as two clusters in a power frequency cycle, that is, "bimodal" feature; • Under waveform detection mode, the signal shows up as a regular pulse signal and two clusters appear within a power	When testing, use the same testing instrument. UHF partial discharge detection and localization testing can be carried out when there are unusual circumstances, collecting test data to do comprehensive judgment. 1) The new equipment should be tested once after being put into operation for a week. 2) A more permanent on-line monitoring solution that can be carried out when there are abnormalities within the system.

		frequency cycle with considerable amplitude. • Corona defects; Typical spectrum of this type of defect has the following characteristics: • In the amplitude detection mode, the signal RMS and PEAK are large. There is an obvious frequency content x1and frequency content x2, and the frequency content x1is larger than the frequency content x2; • Under the phase detection mode, the signal has an obvious effect of phase aggregation, showing up as one cluster in a power frequency cycle, that is, "single peak" feature; • Under waveform detection mode, the signal shows up as a regular pulse signal and a cluster of a large signal and two clusters of signals that one is of significantly large amplitude and another is significant smaller appear within a power frequency cycle. • Free metal particle defect; Typical spectrum of this type of defect has the following characteristics:	

		• In the amplitude detection mode, the signal RMS and PEAK are large, but the frequency content x1 and frequency content x2 are not obvious; • In the phase detection mode, the signal doesn't have obvious effect of phase aggregation, similarly distributing evenly in a power frequency cycle; • Under waveform detection mode, the signal has an obvious high magnitude pulse, but the correlation between this pulse signal and the power frequency voltage is small, which appears with certain randomness. • Under pulse detection mode, the signal showed obvious "triangular hump" shape.	

Table: Ultrasonic Detection Abnormal Spectrum Analysis

Parameter		**Floating Electrode Defect**	**Corona defects**	**Particle defects**
Amplitude detection mode	RMS	High	A little High	High
	PEAK	High	A little High	High
	frequency content x1	Weak	Have	Have

	Frequency content x2	Have	Weak	Have
Phase detection mode		Regular, two clusters of signals, one cycle wave and the amplitude are almost equal	Regular, a cluster of signals one cycle wave or a large signal and small signal	No law
Waveform detection mode		There are laws and a periodic pulse signal	There are laws and a periodic pulse signal	There are certain rules and different cycle pulse signal
Pulse detection mode		No law	No law	Regular, triangular hump shape

4.8. UHF Detection, Field Testing and Data Analysis

From the **Main Menu** screen, select **UHF.** There are three modes of operation under UHF Detection: **Amplitude Detection**, **Phase Spectrum Detection**, and **PRPD/ PRPS Spectrum Detection**.

The basic principle of unique high-frequency detection method is in detecting UHF electromagnetic waves/signals, with a frequency range between 300MHz $\leq f \leq$ 3GHz, generated by partial discharge on the power device by using UHF sensors to get relevant information resulting in the occurrence of this phenomenon to achieve partial discharge live measurements. Depending on the different equipment in the field, you can use built-in UHF sensors and external UHF sensors. As the on-site corona noise in the air mainly concentrates in the 300MHz band or less, the UHF method can effectively avoid noise on-site, with high sensitivity and anti-jamming capability, enabling partial discharge live detection, location, type of defect identification, and so on.

4.8.1. UHF Amplitude Detection

Enter the UHF amplitude detection interface. There are two modes of operation under amplitude detection: continuous and single shot. The amplitude detection screen can display amplitude, and the severity of the PD using the traffic light system: green, yellow, and red lights.

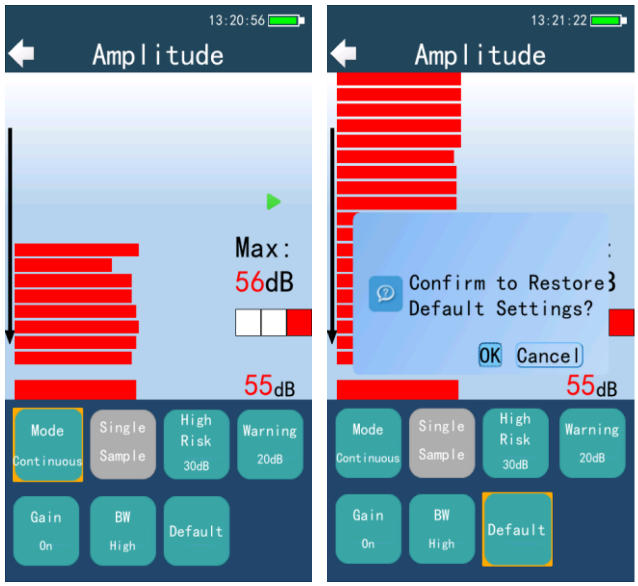


Figure 4.16. UHF Amplitude Detection

- ***Amplitude***: Displays the current UHF signal in dB.
- ***Color Indicator Light***: The traffic light system indicates the measured amplitude of the UHF signal. Green indicates normal; yellow indicates warning; red indicates an alarm. The threshold can be set in the UHF Setting interface.
- ***History***: Displays the last 10 UHF signals on a bar display
- ***Maximum Reading***: While in this operation using the UHF sensor, this displays the maximum of the last 10 signal readings obtained while in operation.
- ***Test Instructions***: This is a display flashing green arrow or red double parallel bar indicator, which informs the user if it is continuously testing or not.

- ****Note***: If the PDStar does not receive a signal from the Signal Processor, it will display ***No Signal*** on the screen. The user will need to sync the two devices together to ensure proper operation.

Parameter Settings:

At the bottom of the **UHF Amp Detection** screen, the following options are listed:

- ***Mode***: Switching mode to ***Continuous*** or ***Single-shot***. When in Single-shot mode, press **OK** button on the device to trigger single-shot signal detection.
- ***Single Sample***: Take a single sample measurement of UHF.
- ***High Risk***: The high risk or alarm threshold setting for the UHF detection option.
- ***Warning***: Sets the background value for the device, allowing for any readings below the background to show up as green until it surpasses the background value where it either displays yellow for warning if it has not met the threshold for alarm to display red.
- ***Gain***: Open pre-amplifier when UHF signals are too weak.
- ***Bandwidth***: Bandwidth selection function. The machine has a built-in multi-band analog signal filter. User can select all, low, or high band pass filtering.
- ***Default***: Press **OK** button on the device to set the parameters to the system defaults.

4.8.2. UHF Single-Cycle Spectrum

There are two modes of operation under Spectrum detection: **Continuous** or **Single-shot**, and the severity of the PD using the traffic light system: green, yellow, and red lights.

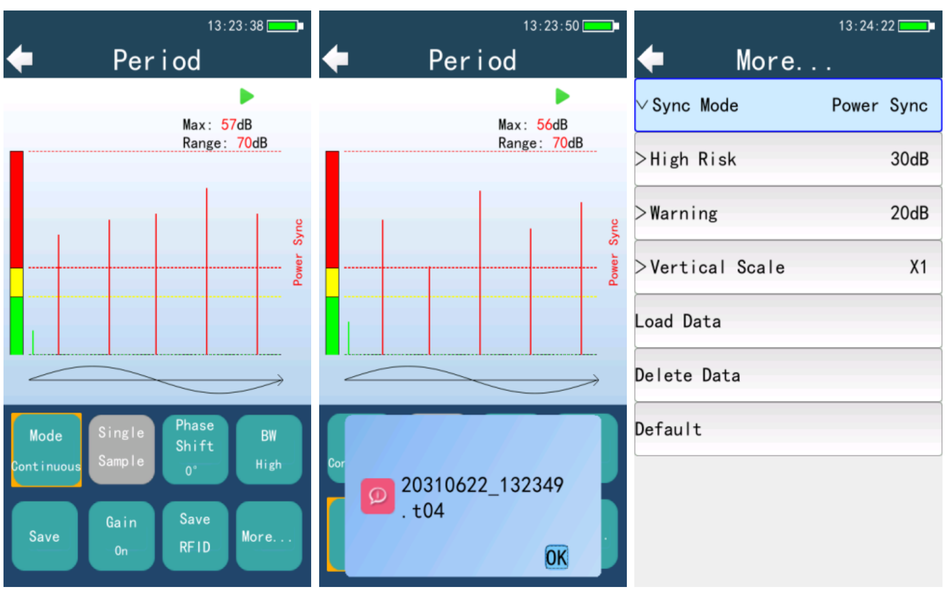


Figure 4.17. UHF Single-Cycle Detection

Parameter Settings:

From the **UHF Spectrum Detection** screen, various options are listed along with the option to select **MORE…** on the bottom of the device screen to view more adjustable settings in the **UHF Detection Parameter Settings** interface:

- ***Mode***: Switching mode to **Continuous** or **Single-shot**. When in **Single-shot** mode, press button on the device to trigger single-shot signal detection.
- ***Single Sample***: Take a single sample measurement of UHF.
- ***Phase Shift***: Set relative offset of the measured pulse signal to the phase grid.
- ***Bandwidth***: Bandwidth selection function, the machine has a built-in multi-band analog signal filter; the user can select all, low, or high band pass filtering.
- ***Save***: Save the current data screen.
- ***Gain***: Open pre-amplifier when UHF signals are too weak.
- ***Save RFID***: Scroll down until you highlight **Save RFID** function, after selecting this, put the device back near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.
- ***Sync Mode***: Users can select **Light** or **Power** synchronization. When you select **Light** synchronization, you need to align the light sensitive sensor of the UHF signal conditioner to the fluorescent and other power frequency lights. When you select **Power** synchronize, you need to plug the chargers in the outlet. The green light should flash on the charger, which means the charger is transmitting the synchronization signal.
- ***High Risk***: The high risk or alarm threshold setting for the UHF detection option.
- ***Warning***: Sets the background value for the device, allowing for any readings below the background to show up as green until it surpasses the background value where it either displays yellow for warning if it has not met the threshold for alarm to display red.
- ***Vertical Scale:*** Set vertical scale value to x1, x2, x4, or x8.
- ***Load Data***: View data previously detected. Shows each one as a file. The detection results are sorted by the date/time it was acquired.
- ***Delete Data***: Delete data previously detected.
- ***Default***: Press **OK** button on the device to set the parameters to the system defaults.

4.8.3. UHF PRPD2D-PRPS3D

PRPD stands for Phase Resolved Partial Discharge. It is the figure of phase - maximum discharge capacity –discharge times. It shows the 2D phase distribution status of each discharge Interval.

PRPS stands for Phase Resolved Pulse Sequence. It is the percentage of phase - period - maximum discharge capacity. It shows the 3D phase distribution status of the percentage of the maximum discharge capacity of each cycle; the map refreshes in real-time.

Figure 4.18. UHF PRPD2D-PRPS3D Spectrums

Parameter Settings:

From the **UHF Spectrum Detection** screen, select the appropriate button on the device to enter **UHF Detection Parameter Setting** interfaces:

- ***Run/Stop***: Allow the process to run or stop in order to obtain signal readings.
- ***Phase Shift***: Phase angle of the pulses can be adjusted. This can help to determine more vividly map type of discharge mode.
- ***Save RFID***: After selecting, place the device back near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.

- ***Accumulation***: The accumulation enable switch can be selected to turn on or off, while under the recording mode, the function will be turned on automatically.
- ***Save Data***: Save the current information being collected with the device.
- ***Bandwidth***: Bandwidth selection function, the machine has a built-in multi-band analog signal filter; you can select full, low, or high band pass filtering.
- ***Record***: Record currently sampled data.
- ***Gain***: Open pre-amplifier when UHF signals are too weak by adjusting gain setting.
- ***Record Time***: Screen recording time can be set as 1 minute, 2 minutes, 3 minutes, 4 minutes or 5 minutes.
- ***Sync Mode***: Select between **Light** or **Power** synchronization. When selecting **Light** synchronization, align the light sensitive sensor of the UHF signal conditioner to the fluorescent lamp and other power frequency lights. When selecting **Power** synchronize, plug the chargers in the outlet. When the green light is flashing on the charger, this means the charger is transmitting the synchronization signal.
- ***Playback***: Screen record playback function will allow access the screen recording file of local storage for playback.
- ***Delete Record***: Delete the saved local screen recording file.
- ***Load Data***: View data previously collected. Shows each item as a file. The detection results are sorted by the date/time the data was collected.
- ***Delete Data***: Delete data previously collected.
- ***Default***: Press **OK** button on the device to set the parameters to the system defaults.

Screen Recording Function:

- **Step 1:** Under the UHF PRPD2D-PRPS3D interface, select the screen recording interface.
- **Step 2:** After entering the screen recording interface, PDStar should be connected to the UHF signal processor; then the progress bar will move, the progress bar time is based on processor signals, and it is normal that the time is not synchronized.
- **Step 3:** After recording, select **Save** to withdraw from the recording mode and save the screen recording file automatically. Also, when the recording time exceeds the setting time, the system will withdraw, save file automatically also. The saved recording data can be reviewed by using the **Playback** function and the local data can be deleted by **Delete Record** function also.

- **Step 4:** Playback of the recording file, in the screen recording playback interface, the progress bar has four buttons: fast forward, rewind, play and pause. Press **OK** to choose play / pause, press **LEFT** to rewind, press **RIGHT** to fast forward. Button can be long pressed, fast forward and rewind schedule can be decided according to the progress bar; after fast forward and rewind button is adjusted, fast forward or rewind button color turns from green to blue. In this process, the PRPD map refreshes the data until the current progress is completed, and when the load is complete, the blue color turns to green and record continues to play, PRPS does not refresh during loading; press **ESC** to exit the current record play screen.

NOTE: The navigational buttons are invalid during the recording.

4.8.4. UHF Field Testing

For GIS, the UHF sensor testing point is non-metallic flange insulation pot, such as insulation pot with a metal shield pouring openings available for testing. GIS basin insulators of some manufacturers are shielded, this means that they are not suitable for detection by external sensors, and thus before testing the user needs to confirm whether GIS basin insulator to be tested is masked (i.e. metal cover around the GIS insulation basin). When testing, we should pay attention to the sensor that should be in close contact with the insulator pots and should be placed in the middle of two bolts confining the basin insulator to reduce the shielding of bolt for internal electromagnetic and external static noise produced by the sensors and bolts; While taking measurements, the user should ensure that the sensor maintains contact with pots insulator as much as possible and to not interfere with current readings because of the signal caused by sensor's movement.

For switchgear, the UHF sensor testing points are the gap on the switchgear, observation windows, vents, etc.

For transformer, due to the structure of the transformer, UHF sensor can only be placed in the vicinity of the transformer casing. Pay attention to keeping a sufficient safe distance during the testing process.

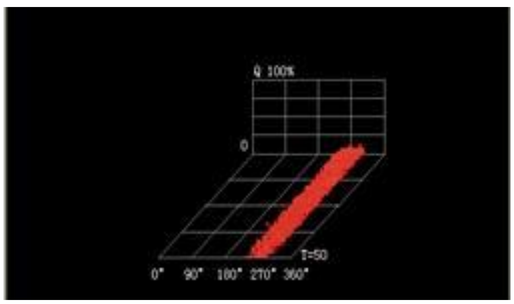
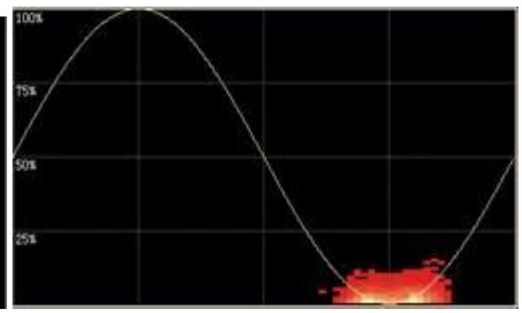
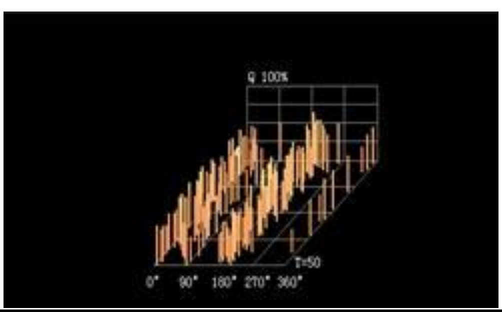
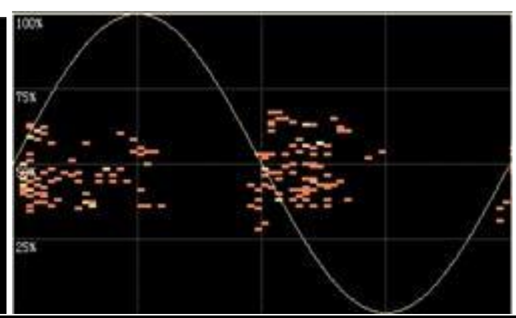
For cable, the UHF sensor testing points are cable terminal, middle terminal, etc.

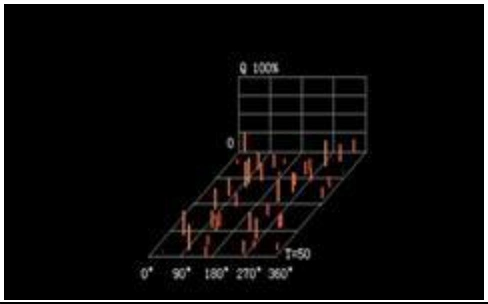
4.8.5. UHF Data Analysis

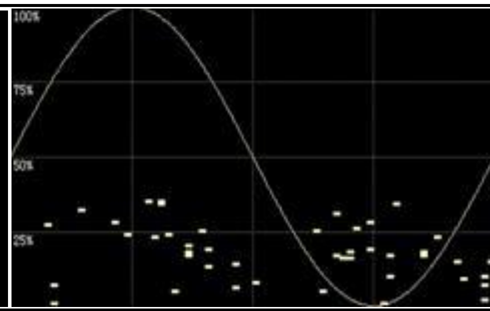
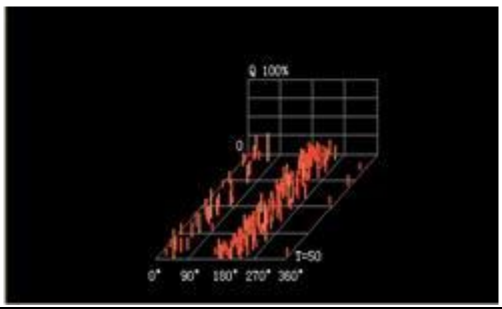
The signal characteristics generated by the partial discharge detected by UHF sensor are different within the spectrum. Therefore, in addition to use the signal time-domain distribution characteristic of more conventional methods; we can also identify partial discharge type by combining with UHF signals frequency distribution characteristics; this is done to achieve the Diagnostic of the type of insulation defect. According to a large number of experiments and testing experience on-site, draw the following judging data for testing personnel to use:

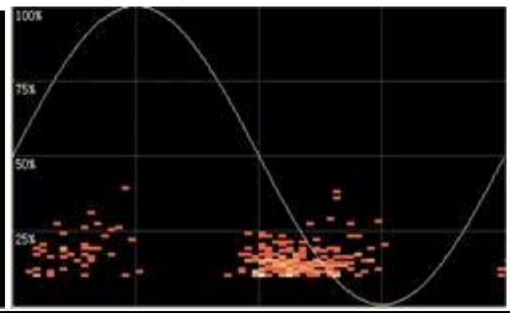
Project	Cycle	Standard	Explanation
UHF Detection	1) 6 months to 1 year 2) After put into operation 3) After maintenance 4) When deemed necessary	Table 5.3.2	When detecting, use the same equipment. Localization testing can be carried out when there are unusual circumstances, collecting test data to do comprehensive judgment. 1) The new equipment should be tested once after being put into operation for a week. 2) A more permanent on-line monitoring solution that can be carried out when there are abnormalities within the system.

Normally during UHF partial discharge measurement, there may be a few possible typical PD signals: Corona discharge, void discharge, freed metal particle discharge and floating electrode discharge. The following table briefly lists the typical spectrums of several of the above listed PD signals, including various types of signal's PRPS and PRPD spectrum.

Type	Characteristics and Spectrums
Corona Discharge	Polarity effect of the discharge signal is very obvious, of which usually appears on the negative half-cycle or positive half cycle of power frequency phase. The discharge signal strength is weak and phase distribution is wide, with a multitude of discharges. However, another half cycle may also appear discharge signal at higher voltage levels, the higher amplitude and the narrow phase distribution and less discharge times.  
Floating Electrode Discharge	This discharge signal usually occurs within both positive and negative half cycles of power frequency phase with certain symmetry. The discharge signal amplitude is large and the adjacent discharge signal time intervals are almost consistent, fewer discharge times and the discharge repetition rate is lower.  
Particle Discharge	This discharge signal polarity effects are not obvious, well distributed in any phase; few discharge times, **discharge** signal amplitude without obvious rules or pattern, the discharge signal time interval unstable. Discharge signal amplitude increases when improving the voltage level, but the discharge interval is reduced. **(Note: When testing the particle discharge, we can assist with AE ultrasonic method to detect and confirm)**

<table>
<tr><td></td><td>


</td></tr>
<tr><td>Void Discharge</td><td>Discharge signal usually occurs both at positive and negative half cycle of power frequency phase with certain symmetry. The discharge signal amplitude is distributed with fewer discharge times .



</td></tr>
</table>

4.9. HFCT Detection, Field Testing and Data Analysis

From the **Main Menu** screen, select **HFCT.** There are three modes of operation under UHF Detection: **Amplitude Detection**, **Phase Spectrum Detection**, and **PRPD/ PRPS Spectrum Detection**.

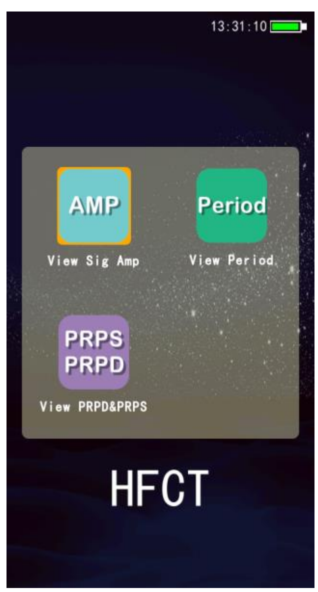


Figure 4.19. HFCT Detection Options

4.9.1. HFCT Amplitude Detection

Select the HFCT amplitude detection interface. There are two detection modes of operation under amplitude detection: continuous and single shot detection. The amplitude detecting interface can display the amplitude, and the green, yellow and red to indicate the severity of the discharges.

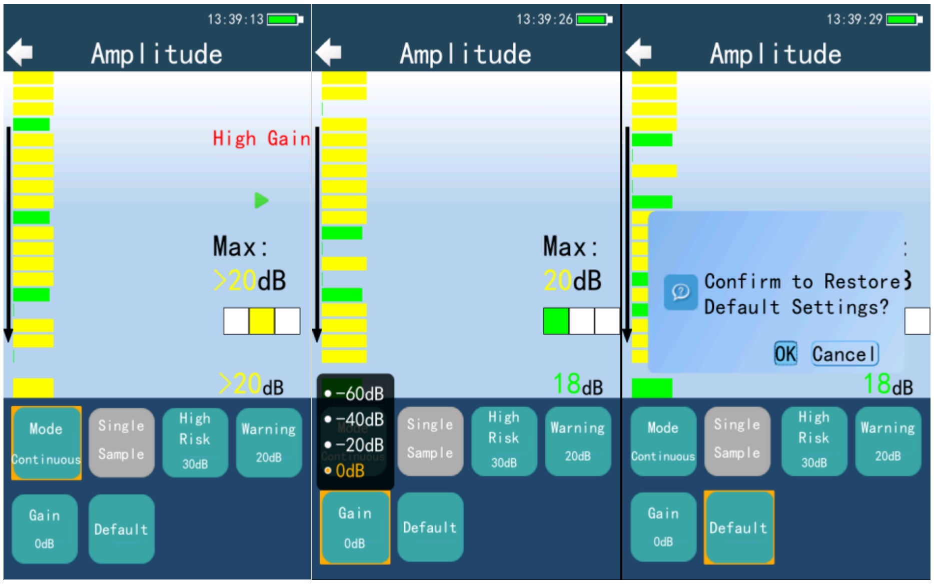


Figure 4.20. HFCT Amplitude Detection

- **Amplitude**: use the form of dB to display the current high-frequency current value.
- **Color Indicator Light**: the traffic light system indicates the measured severity intensity of the high-frequency results. Green indicates normal; yellow indicates warning; red indicates an alarm. The threshold of color light can be set in the high-frequency setting interface.
- **History**: displays in a different color bar graph to display the last 10 measurements.
- **Maximum Reading**: record under the detection mode, the maximum amplitude for the last 10 readings obtained.
- **Detection Instructions**: with a flashing green arrow indicator, the unit tells the user if it is continuously testing or not in single shot mode.

Note**: If the PDStar does not receive a signal from the Signal Processor, it will display ***No Signal on the screen. The user will need to sync the two devices together to ensure proper operation.

Parameter Settings:
In the detection interface, the parameter settings are listed at the bottom of the screen:

- ***Mode***: Switch mode to **continuous** or **single**; when in **single** mode, press the OK button on the device to trigger single signal detection.
- ***Single Sample***: Take a single sample measurement of the HFCT signal.
- ***High Risk***: Red alarm options: Set the alarm threshold of red light on in the high-frequency current detecting interface.
- ***Warning:*** Set the alarm threshold of green light on in the HFCT interface. When the detection signal is between the background signal and red warning signal, the yellow light is on and the tester is in the state of warning.
- ***Gain***: Adjust proper times of amplification.
- ***Default***: Press the **OK** button on the device and set the value under the interface to revert to the system's default settings.

4.9.2. HFCT Single-Cycle Spectrum

There are two modes of operation used to detect HFCT spectrums: continuous and single shot detection, with green, yellow, and red signals to indicate the severity of the discharge on the detection interface.

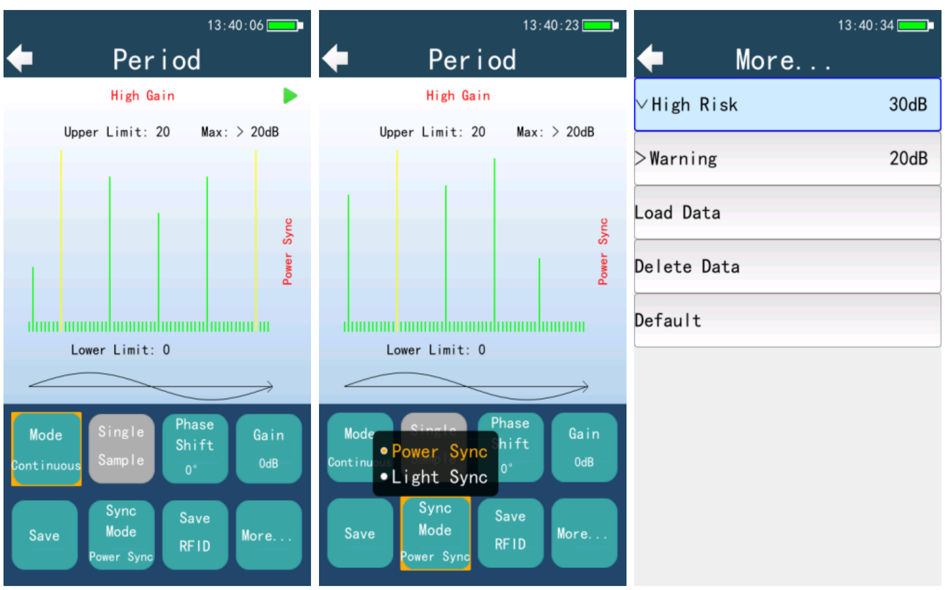


Figure 4.21. HFCT Single-Cycle Spectrum

Parameter Settings:

From the detection interface, the parameter settings are listed at the bottom of the screen:

- ***Mode***: Switch mode to **continuous** or **single shot**; when in a single shot mode, press the **OK** button on the device to trigger single signal detection.
- ***Single Sample***: Take a single sample measurement of the HFCT signal.
- ***Phase Shift***: Set relative offset of the measured pulse signal to the phase grid.
- ***Gain***: Adjust proper times of amplification.
- ***Save***: Save the detection spectrum results of the current interface.
- ***Sync Mode:*** Select **light** or **power** synchronization. When you select the **light** sync, align the light-sensitive sensor of the HFCT receiver on a fluorescent lamp; when you select **power** sync, plug the power charger on a power outlet. When the green light on the charger is flashing, that is the indicator that the device is transmitting the synchronization signal. When no light or power synchronization, it will automatically switch to the **internal** sync.
- ***Save RFID***: Scroll down until you highlight **Save RFID** function, after selecting this, put the device back near the RFID tag. The device automatically reads the relevant information of high voltage electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.
- ***High Risk***: Red alarm options: Set in the interface of HFCT detection, the alarm threshold with red light on.
- ***Warning***: Set the alarm threshold of green light on in the HFCT detecting interface. When the detection signal is between the background signal and red warning signal, the yellow light is on and the tester is in the state of warning.
- ***Load data***: View the saved results of detection spectrum, each test result saved as a file; the data is sorted by the date/time it was taken.
- ***Delete Data***: Remove the acquisition results of the data stored on the device.
- ***Default***: Press the OK button on the device and set the value under the interface to revert to the system's default settings.

4.9.3. HFCT PRPD2D-PRPS3D

PRPD Phase Resolved Partial Discharge. It is the figure of phase - maximum discharge capacity – discharge times. It shows the phase distribution status of each discharge Interval.

PRPS stands for Phase Resolved Pulse Sequence. It is the percentage figure of phase - period - maximum discharge capacity. It shows the phase distribution status of the percentage of the maximum discharge capacity of each cycle; the map refreshes in real time.

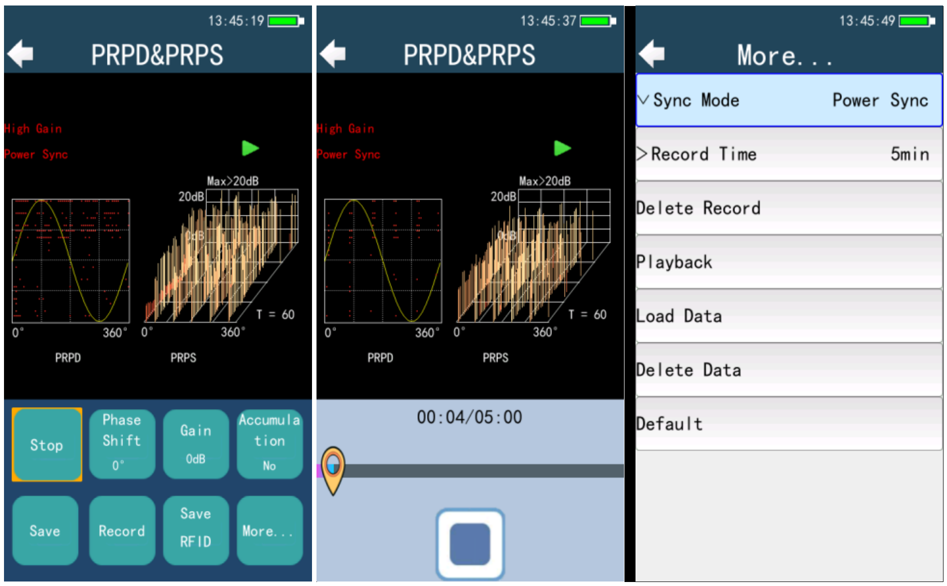


Figure 4.22. HFCT PRPD2D-PRPS3D spectrum

Parameter Settings:

In the detection interface, the parameter settings are listed at the bottom of the screen:

- ***Run/Stop***: Allow the process to run or stop in order to obtain signal readings.
- ***Phase Shift***: Phase angle of the pulses can be adjusted. This can help to vividly determine the map type of discharge mode.
- ***Gain***: Adjust proper times of amplification.
- ***Accumulation***: The accumulation enable switch can be selected to on or off, and under the recording mode, the switch would be on default.
- ***Save***: Save the current data.
- ***Record***: Record currently sampled data.
- ***Save RFID***: Scroll down until you highlight **Save RFID** function, after selecting this, put the device back near the RFID tag. The device automatically reads the relevant information of high voltage

electrical equipment information stored on the tag, and saves the current data and relevant information of electrical equipment.

- ***Sync Mode***: Select **light** or **power** synchronization. When you select the **light** sync, you need to align light-sensitive sensor of the high-frequency current receiver on fluorescent lamp or other civil electricity; when you select **power** sync, you need to plug the power charger on the civil electricity socket. When the green light on the charger is flashing, that is transmitting synchronization signals. When no light or power synchronization, it will automatically switch to the internal sync.
- ***Record Time***: Screen recording time can be set as 1 minute, 2 minutes, 3 minutes, 4 minutes and 5 minutes.
- ***Delete Record***: Delete the recorded file saved to the main unit.
- ***Playback***: Load the recording file save in local memory space for playback.
- ***Load Data***: Select saved data, read and display.
- ***Delete Data***: Delete the directory or file of waveform data selected.
- ***Default***: Press the **OK** button device and set the value under the interface to revert to the system's default setting.

Quick Save Button: On the main button interface, the quick save button **S** to save data directly.

Screen Recording Function:

- **Step 1:** Under the HFCT PRPD2D-PRPS3D interface, select the screen recording interface.
- **Step 2:** After entering the screen recording interface, PDStar should be connected to the processor of HFCT; then the progress bar will move, the progress bar time is based on processor signals, and it is normal that the time is not synchronized.
- **Step 3:** After recording, select Save to withdraw from the recording mode and save the screen recording file automatically. Also, when the recording time exceeds the setting time, the system will withdraw, save file automatically also. The saved recording data can be reviewed by using **Playback** function, and the local data can be deleted by **Delete Record** function also.
- **Step 4:** Playback of the recording file, in the screen recording playback interface, the progress bar has four buttons: fast forward, rewind, play and pause. Press OK to choose play / pause, press **LEFT** to rewind, press **RIGHT** to fast forward. Button can be long pressed, fast forward and rewind

schedule can be decided according to the progress bar; after fast forward and rewind button is loosened, fast forward or rewind button color turns from green to blue. In this process, the PRPD map refreshes the data until the current progress is completed, and when the load is complete, the blue color turns to green and record continues to play, PRPS does not refresh during loading; press **ESC** to exit the current record play screen.

NOTE: The four navigation buttons are invalid during the recording.

Warning: *For user safety protection, users should not substitute any part or whole of the PDStar or accessories since PDStar and accessories are devices strictly used only as instructed in this manual herein. No exceptions in order to protect users from harmful mishandling and usage***.**

Note: *Since PDStar is an independent machinery equipment, and the system itself can not accurately obtain the voltage phase, under normal circumstances which can only use the internal power frequency signal generator to simulate the frequency cycle time. Because the system frequency is not precisely50Hz, so there is a phase difference between the system voltage and power frequency period generated in the machine. In a long pattern detection mode, the case of the phase shift may occur.*

In order to be able to get the system frequency phase, PDStar is equipped with three synchronization methods, including internal synchronization, light synchronization and wireless power synchronous mode. Internal synchronization is a power frequency signal simulated within the main unit. When you select the light Sync, you need to align light-sensitive sensor of the signal receiver on fluorescent lamp or other civil electricity, and charger not only has the function of charging, but also has wireless power synchronization. Plug it in 110V/220V AC power outlet and indicator light is flashing. Then send out radio signals with synchronous power frequency phase, using the main unit to get the signal and through the signal to achieve radio synchronization. This method cannot be affected by the strength of the fluorescent light, but needs 110V/220V AC power outlet in the test environment.

4.9.4. HFCT Field Testing

A high-frequency current transducer (HFCT) is using a Rogowski coil with high frequency core material, which is a ring-type current transformer with a high frequency core. Sensor bandwidth is 300KHz ~ 10MHz, to obtain high frequency current signal occurred when PD of high-voltage equipment. When detecting, make the sensor fasten at the end shield ground strap, high voltage cable ground strap, transformer core and clamp ground strap to obtain signal. There should be no typical spectrums when normal. When suspecting partial discharge, we should compare to other detection methods and analysis comprehensively.

4.9.5. HFCT Data Analysis

Refer to Section 4.8.5.

4.10. CA Module

The PDStar features the superior Cluster Analysis (CA) function with a 100 MSPS HFCT Signal Processor that enables the user to conduct advanced OLPD testing and diagnostics on power cables. The PDSS (Partial Discharge Signals Separation) technology is employed to separate noise from PD signals, and to separate different types of PD signals into different groups. Waveforms, PRPD & PRPS, and pulse spectrums are provided for data analysis to determine the PD type. Main features of the module include that it conducts partial discharge signal sources separation under the cluster analysis mode automatically or manually; it has a variety of sampling rate options from 500 kHz to 100 MHz, and its sampling length, gain and threshold settings are all manually adjustable.

From the **Main Menu** screen, select **CA Diag.** There are three modes of operation under CA Diagnostics Detection: **View Signal Pulses**, **View Signal Waves**, and **View PRPD&PRPS**.

4.10.1. View Signal Pulses

The **View Signal Pulses** option allows for viewing of several signal pulses detected by the HFCT signal conditioner.

Figure 4.23. Pulse Review for CA Module

Parameter Settings:

At the bottom of the **View Sig Pulse** screen, the following options are listed:

- ***Start/Stop Sample***: Take a sample measurement of HFCT signal readings.
- ***Cluster Analyze***: Please see below for more information.
- ***Trigger Value***: Set the trigger value to a value from 0 to 400 millivolts.
- ***Trigger Bandwidth***: Set the bandwidth trigger to a value of 1, 2, 5, or 10 microseconds.
- ***Save***: Save the current screen values to a file.
- ***Gain***: Set the gain value to a value of 0, -20, -40, or -60 decibels.
- ***Phase shift***: Set the phase shift value from 0 to 360 degrees.
- ***Percentage Before Trigger***: Set percentage before trigger value to a value from 5% to 50%.
- ***Pulse Accumulation Count 2000***: Set the pulse accumulation count value to a value of 200, 500, 1000, 2000, or 5000.
- ***Load Data***: Select saved data, read and display.
- ***Delete Data***: Delete the directory or file of pulse data selected.

- ***Default***: Press the **OK** button device and set the value under the interface to revert to the system's default setting.

Cluster Analysis: The **Cluster Analysis** tool is used to analysis the pulses of the signals based on the analysis of both the time and frequency domain. There is a mode selection option between auto and manual. Each cluster can be analyzed individually based on its color: red, yellow, green, and blue are the available selections.

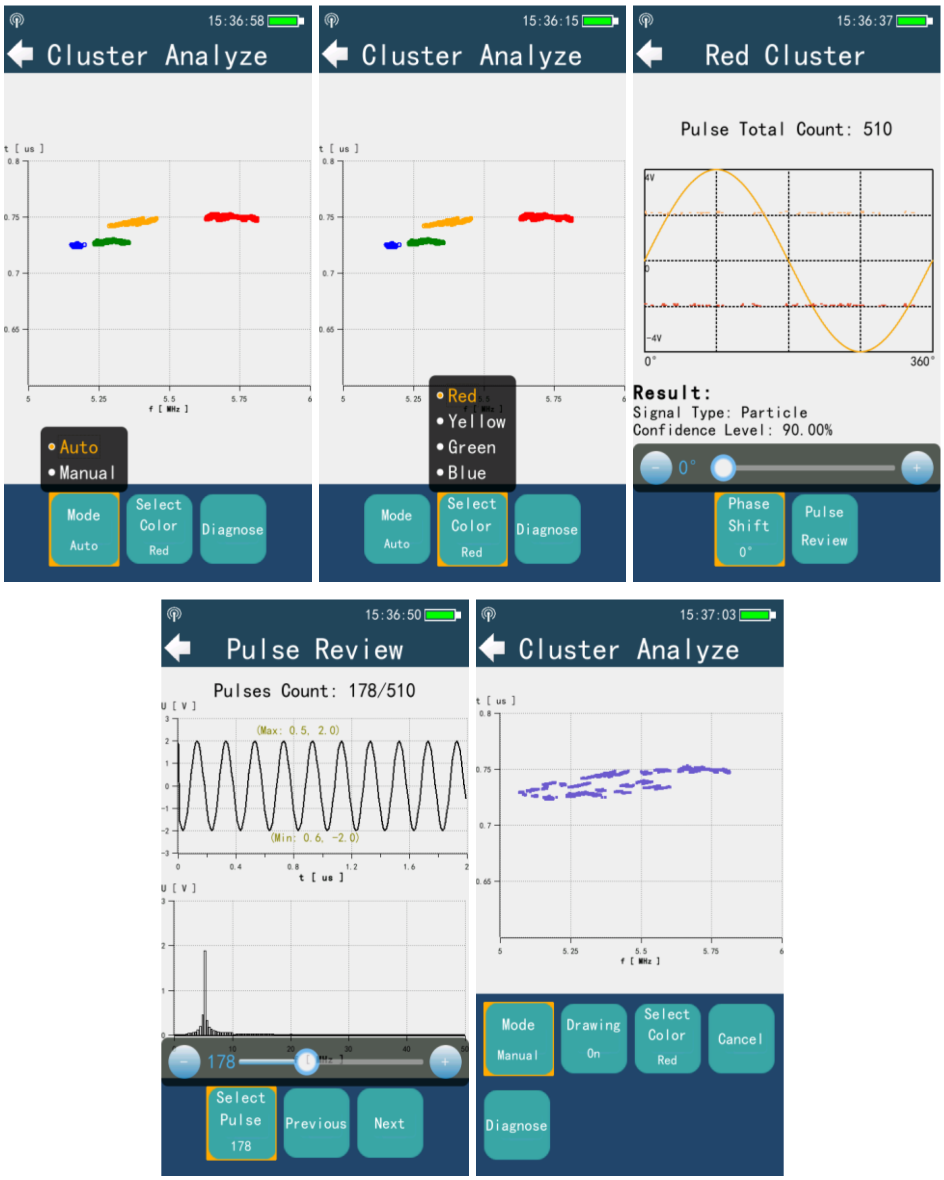


Figure 4.24. Cluster Analysis for CA Module

4.10.2. View Signal Waves

The **View Signal Waves** option allows for viewing of several signal waveforms detected by the HFCT signal conditioner.

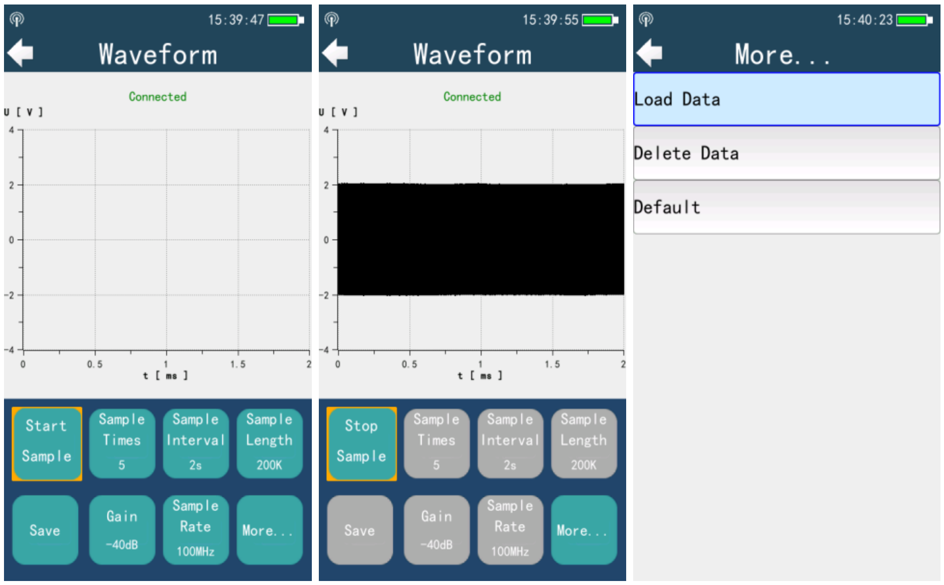


Figure 4.25. Waveform Review for CA Module

Parameter Settings:

At the bottom of the **Waveform** screen, the following options are listed:

- ***Start/Stop Sample***: Take a sample measurement of HFCT signal readings.
- ***Sample Times***: Set the sample time value to a value of 1, 5, 10, 20, 50, or Inf.
- ***Sample Interval***: Set the sample interval value to a value of 2, 5, 10, or 20 seconds.
- ***Sample Length***: Set the sample length to a value of 50K, 100K, 200K, 500K, or 1M.
- ***Save***: Save the current screen values to a file.
- ***Gain***: Set the gain value to a value of 0, -20, -40, or -60 decibels.
- ***Sample Rate***: Set the sample rate value to a value of 500K, 1M, 2M, 5M, 10M, 20M, 50M, or 100M Hertz.
- ***Load Data***: Select saved data, read and display.
- ***Delete Data***: Delete the directory or file of waveform data selected.
- ***Default***: Press the **OK** button device and set the value under the interface to revert to the system's default setting.

4.10.3. View PRPD & PRPS

The **View PRPD&PRPS** option allows for viewing of PRPD and PRPS spectrums detected by the HFCT signal conditioner.

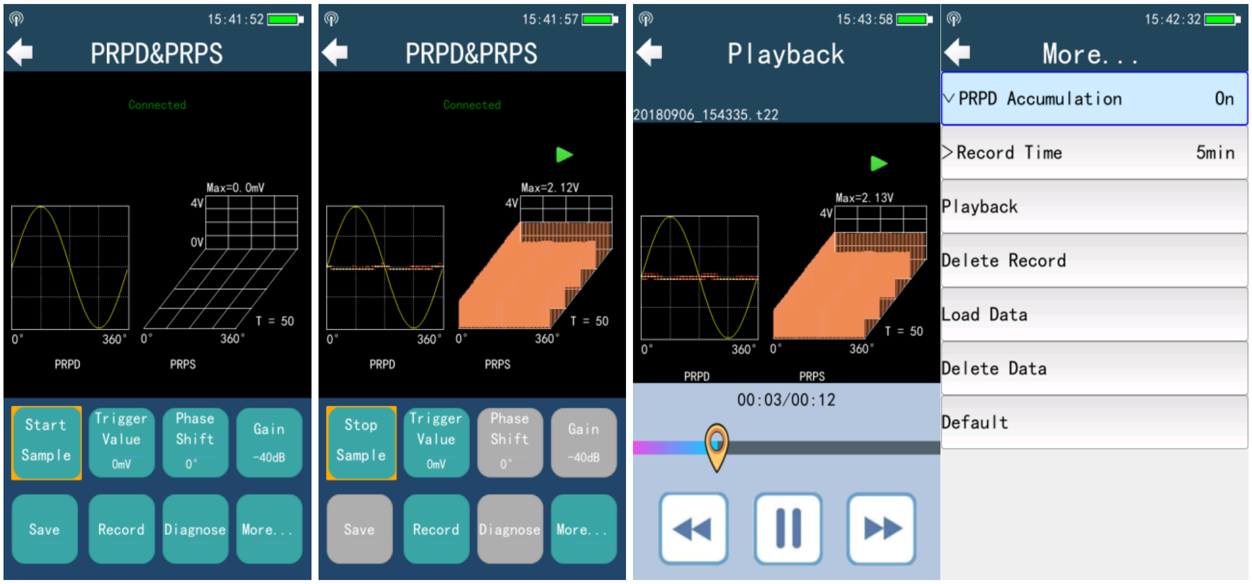


Figure 4.26. PRPD & PRPS Review for CA Module

Parameter Settings:

At the bottom of the **PRPD&PRPS** screen, the following options are listed:

- ***Start/Stop Sample***: Take a sample measurement of HFCT signal readings.
- ***Trigger Value***: Set the trigger value to a value from 0 to 50 millivolts.
- ***Phase Shift***: Set the phase shift value from 0 to 360 degrees.
- ***Gain***: Set the gain value to a value of 0, -20, -40, or -60 decibels.
- ***Save***: Save the current screen values to a file.
- ***Record***: Record the current PRPD and PRPS sample data.
- ***Diagnostic***: Perform initial diagnostics on the current sample data.
- ***PRPD Accumulation***: Select to turn this option ON or OFF during data sampling.
- ***Record Time***: Screen recording time can be set as 1 minute, 2 minutes, 3 minutes, 4 minutes and 5 minutes.
- ***Playback***: Load the recording file save in local memory space for playback.
- ***Delete Record***: Delete the recorded file saved to the main unit.
- ***Load Data***: Select saved data, read and display.

- ***Delete Data***: Delete the directory or file of waveform data selected.
- ***Default***: Press **OK** button on the device to set the parameters to the system default setting.

4.11. Infrared Testing

Infrared testing and OLPD testing have been important over time but independent for condition-based maintenance programs of power equipment. Substation operators have been conducting the two routine testing methods separately for many years. The PMDT's new innovative PDStar now makes it possible to test PD and IR together in one single tool, which brings a more productive, efficient, and cost-effective online testing and maintenance program for customers.

The thermal imaging camera is convenient to use by simply attaching the Thermal Imaging Camera to the PDStar main unit. It has 320x256 native high resolution 4.3" HD LCD touch screen and can detect any abnormal heating and defects effectively. Images can be edited on the PDStar main unit directly. Tap the screen or buttons to quickly access temperature measurement tools, parameters, image modes, and more. The user can also measure the temperature of one specific point or area.

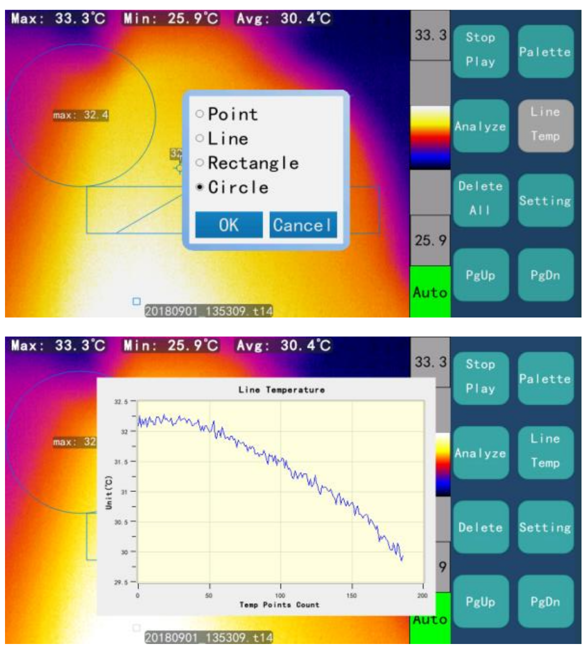


Figure 4.27. Infrared Testing

Parameter Settings:

At the right of the **Infrared** screen, the following options are listed:

- ***Start/Stop Play***: Start and pause the infrared readings.
- ***Palette***: Select between the iron red and rainbow palette settings.
- ***Analyze***: Perform analysis on the current infrared readings using the point, line, rectangle, or circle settings.
- ***Line Temp***: Display line temperature graph for the current infrared readings.
- ***Delete***: Delete the currently saved reading(s).
- ***Setting***: Set values for the emissivity, distance, air temperature, reflective temperature, and relative humidity.
- ***Page Up***: Scroll the page up.
- ***Page Down***: Scroll the page down.

4.12. RFID Tool

The PDStar provides an innovative PD asset management solution via RFID tagging based on the Internet of Things. With the RFID Patrol program, the OLPD testing procedure is standardized; thus, PD testing efficiency is greatly improved, data flow and accuracy are ensured, and your power assets are better managed.

The RFID tags can be affixed to your power assets and store the power equipment information such as asset name, asset ID number, substation name, and provides prompts for the appropriate tests for that asset. Each test is recorded with a unique test ID number and date/time stamp to ensure reliability, consistency, and credibility. Following the routine patrol procedure to perform field testing will vastly improve the testing efficiency. Use the PDStar to write to a new RFID tag or use the PDStar to scan an existing RFID tag and it will obtain the asset's information automatically. All the test data will then be imbedded with the asset's information after the scan is complete. This allows the system to automatically identify and link the data to each specific asset.

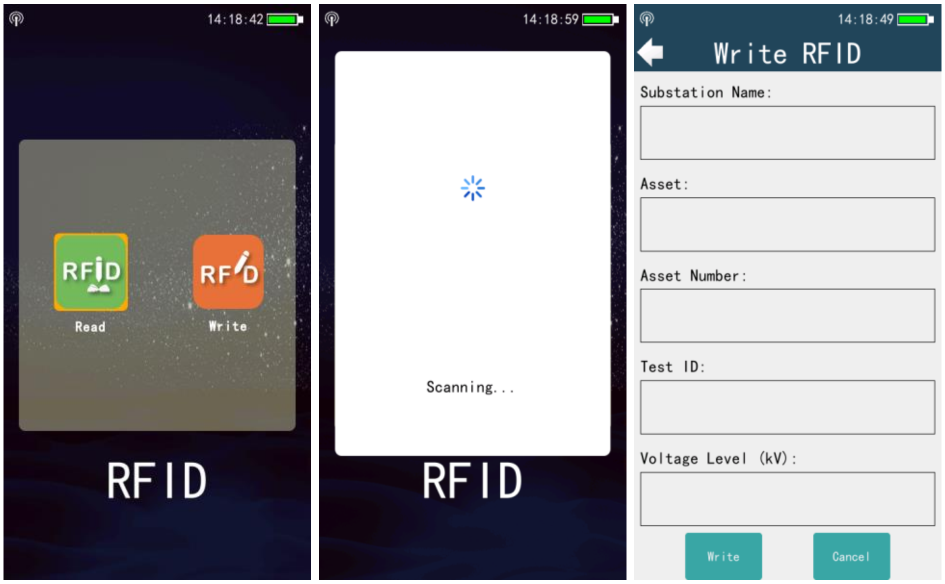


Figure 4.28. RFID options

RFID Tool achieves accurate management of the asset's ID, physical status, and test point information. It standardizes the field OLPD testing procedure and retains the PD test data accurately, consistently, and comparably. It also eliminates the need to write down all the asset information and test data with the paperless OLPD testing realized with PMDT's innovative RFID patrol function.

4.13. Peripheral Matching/Pairing

The main unit can operate with the UHF Signal Processor, HFCT Signal Processor signal, Ultrasonic/AE Signal Processor, current and external power synchronizer. Peripheral matching steps are usually performed at the factory; however, users can manually perform these as well by

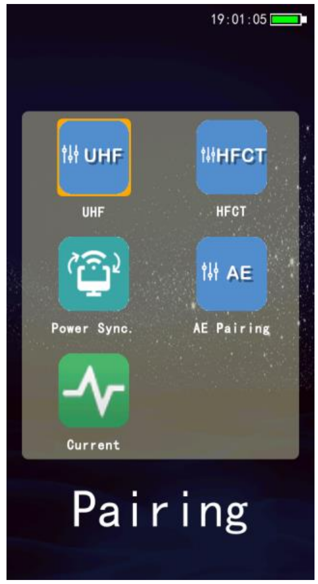


Figure 4.29. Pairing Main Screen

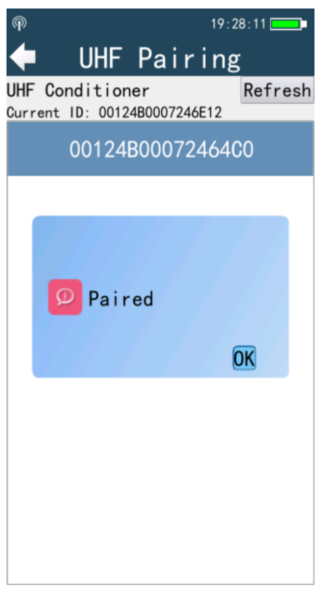


Figure 4.30. Successful Matching with UHF Processor

AE/HFCT/Current/External Power synchronization device peripheral matching with the main unit share the same procedure as the matching process with UHF Processor.

4.14. Audio

Select **Audio** in the main menu and select the appropriate option on the device to enter the Audio interface. There are three modes of operation under Audio: **Record**, **Play**, and **Delete**.

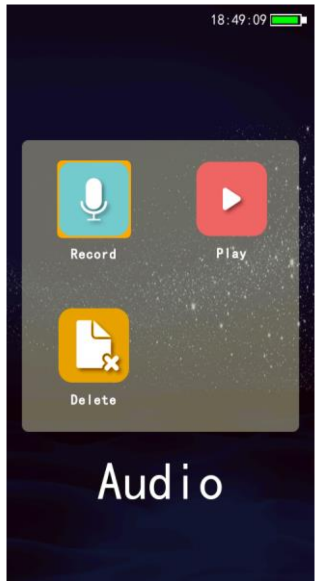


Figure 4.31. Audio Options

4.14.1. Record

Audio functions allow the user to select **Record** and follow the button prompts at the bottom of the screen to successfully record and save audio files. Once the recording has started, the user can either pause the recording or stop the recording in order to save the recording automatically.

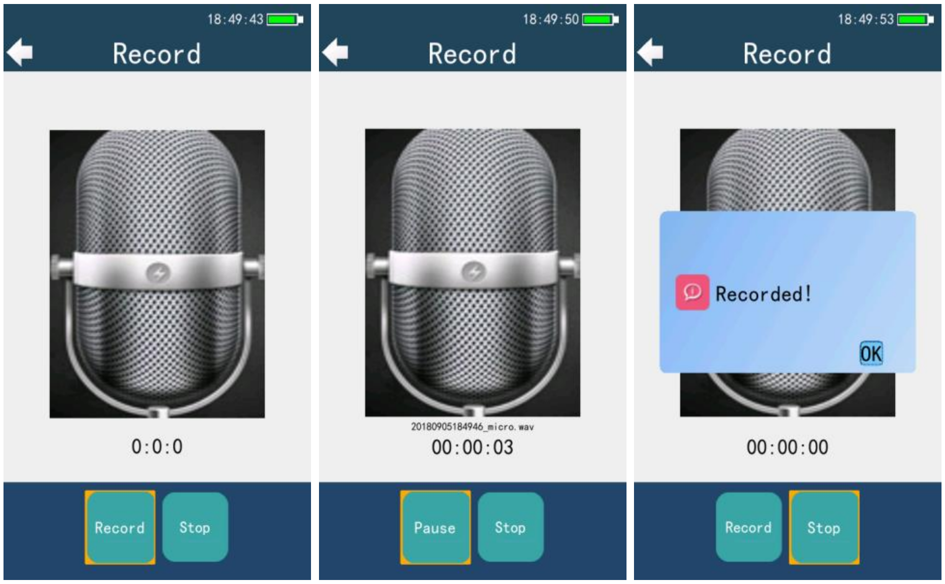


Figure 4.32. Record Options

4.14.2. Play

Audio functions allow the user to select **Play** and follow the button prompts at the bottom of the screen to successfully play saved audio files. Once the recording has started playing, the user can either pause the recording or adjust the volume of the recording. Use the navigation buttons to select a file in a particular folder.

Figure 4.33. Play Options

4.14.3. Delete

Audio functions allow the user to select **Delete** and follow the button prompts at the bottom of the screen to successfully delete saved audio files. Once the recording has started playing, the user can either pause the recording or adjust the volume of the recording. Use the navigation buttons to select a file in a particular folder.

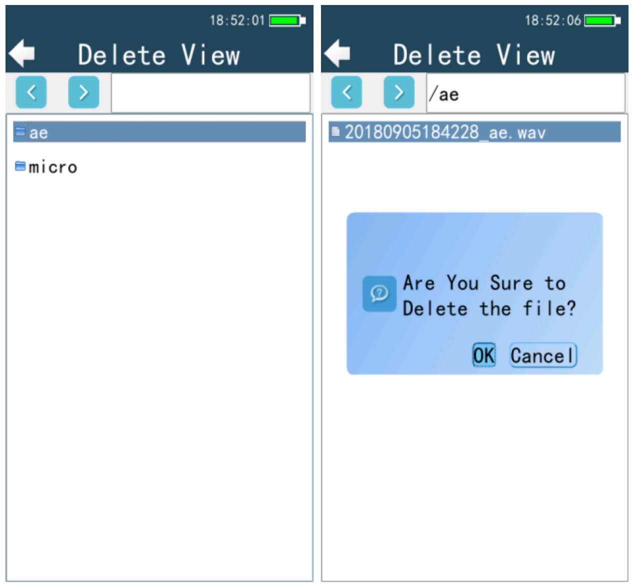


Figure 4.34. Delete Options

4.15. System Settings

Select **Settings** from Main Menu, then select the appropriate option to complete the selection and enter the appropriate interface.

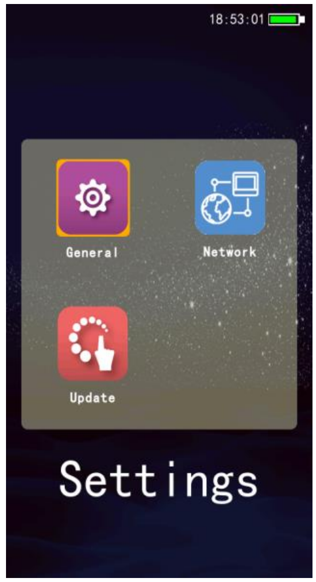


Figure 4.35. System Settings Options

4.15.1. General Settings

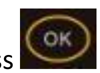
In **Settings**, select **General** to access the general settings of the main unit and press  button on the device to enter the corresponding interface. Press  and  buttons on the device to select from various settings and change the setting.

Figure 4.36. General Settings Options

4.15.2. Brightness

Select **Brightness** from the **General Settings** and press **OK** button to enter the corresponding interface. The current selection is the one first highlighted when entering this setting, press the **Left** and **Right** button to select from three different settings to determine the desired brightness for the screen. Press **OK** button to confirm.

Figure 4.37. Brightness Settings Options

4.15.3. Grid Frequency

Select **Grid Frequency** from the **General Settings** and press **OK** button to enter the corresponding interface. The current selection is the one first highlighted when entering this setting, press the **Left** and **Right** button to select the power grid frequency for your test site. ***50*** or ***60 Hz*** is supported by the main unit. Press **OK** button to confirm.

Figure 4.38. Grid Frequency Options

4.15.4. USB Mode

Select **USB Mode** from the **General Settings** and press **OK** button to enter the corresponding interface. The current selection is the one first highlighted when entering this setting, press the **Left** and **Right** button to select the desired USB mode for the main unit. A ***Media*** or ***Storage*** option is supported by the main unit. Press **OK** button to confirm.

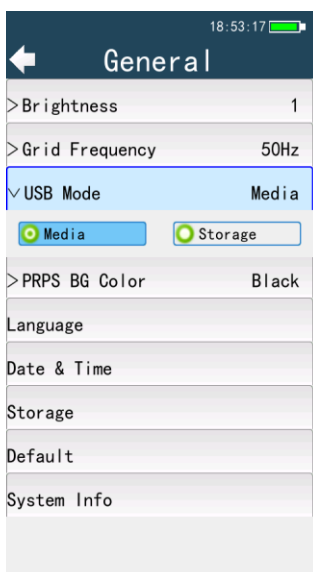


Figure 4.39. USB Options

4.15.5. Automatic Shutdown

Select **Auto Shutdown Time** from the **General Settings** and press **OK** button to enter the corresponding interface. The main unit can be set to automatically shut down after a certain amount of idle time. The time range that can be set is from 0 to 30 minutes. Press **OK** to confirm the selection.

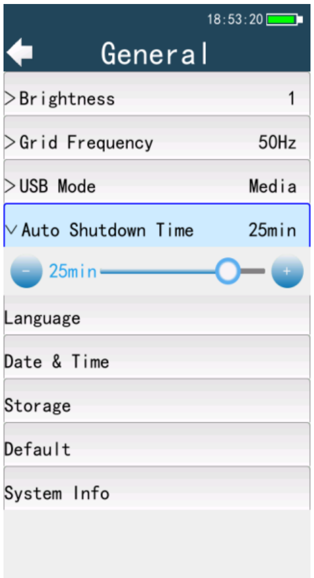


Figure 4.40. Automatic Shutdown Setting

4.15.6. PRPS Background Color

Select **PRPS BG Color** from the **General Settings** and press **OK** button to enter the corresponding interface. The background color of the main unit can be set to a black or white screen. Press **OK** to confirm the selection.

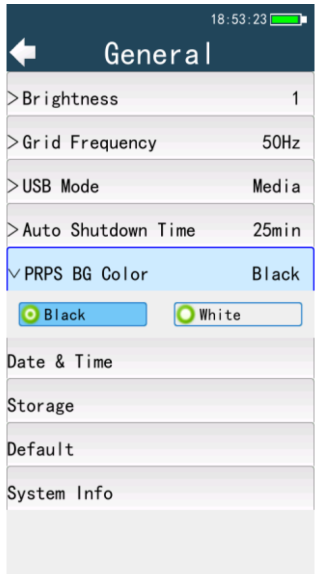


Figure 4.41. PRPS Background Color Settings

4.15.7. Language

Select **Language** from the **General Settings** and press **OK** button to enter the corresponding interface. The language selections include Chinese simplified and traditional as well as English. Use the **UP** and **Down** buttons to select the desired language. Press **OK** to confirm the selection.

Figure 4.42. Language Setting Options

4.15.8. Date & Time

Select **Date & Time** from the **General Settings** and press **OK** button to enter the corresponding interface. Use the **UP** and **Down** buttons to select the desired date and time. Press **OK** to confirm the selection.

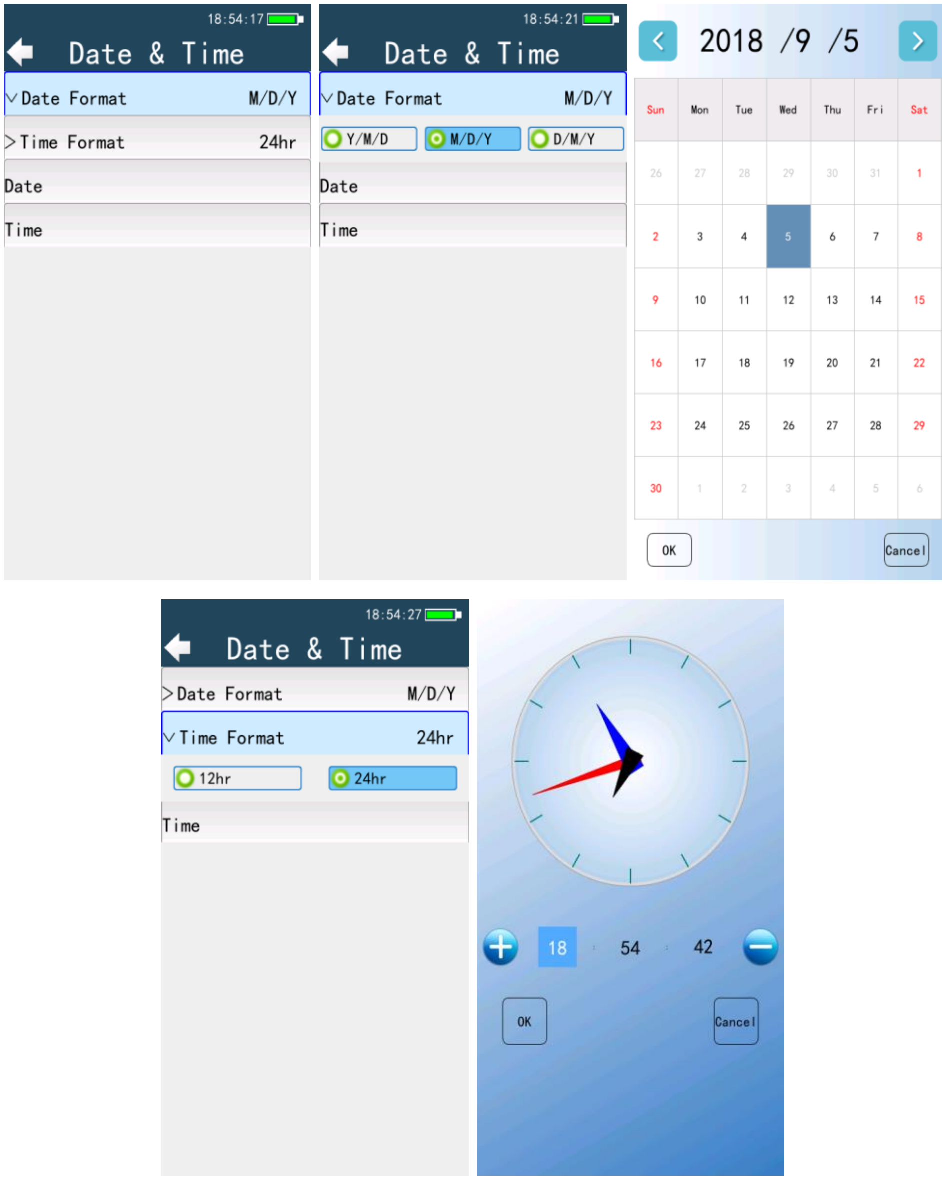


Figure 4.43. Date & Time Setting Options

4.15.9. Storage

Select **Storage** from the **General Settings** and press **OK** button to enter the corresponding interface. The current storage amounts for shared and used storage are displayed along with the amount of available storage. Select Format Storage and confirm to reformat the storage amounts. Press **OK** to confirm the selection.

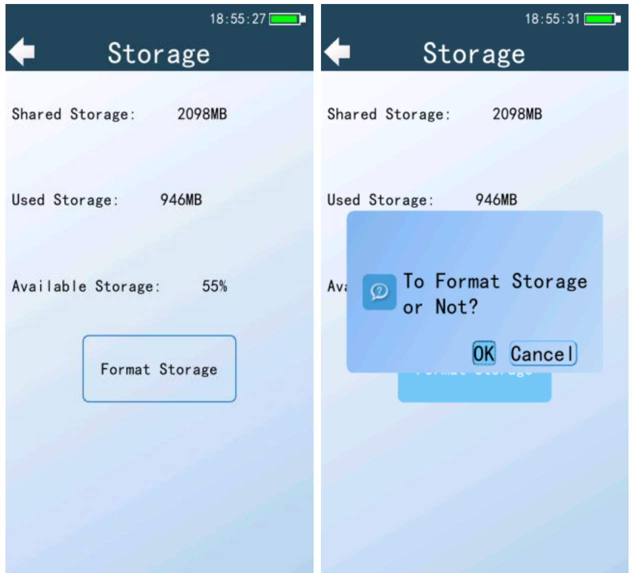


Figure 4.44. Storage Setting Options

4.15.10. Default

Select **Default** from the **General Settings** and press **OK** button to enter the corresponding interface. Confirm the selection of restoring the main unit to its default settings. Press **OK** to confirm the selection.

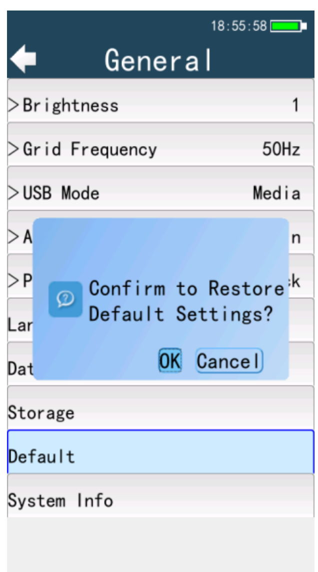


Figure 4.45. Default Settings Option

4.15.11. System Info

Select **System Info** from the **General Settings** and press **OK** button to enter the corresponding interface. This option displays the model type, serial number of the main unit, and current version. Press **ESC** to return to previous screen.

Figure 4.46. System Info

4.15.12. Network

Select **Network** from the **General Settings** and press **OK** button to enter the corresponding interface. Use the **UP** and **Down** buttons to select the desired setting for turning the hotspot and 4G communication on or off as well selecting a network to connect to the available Wi-Fi service. Press **OK** to confirm selections.

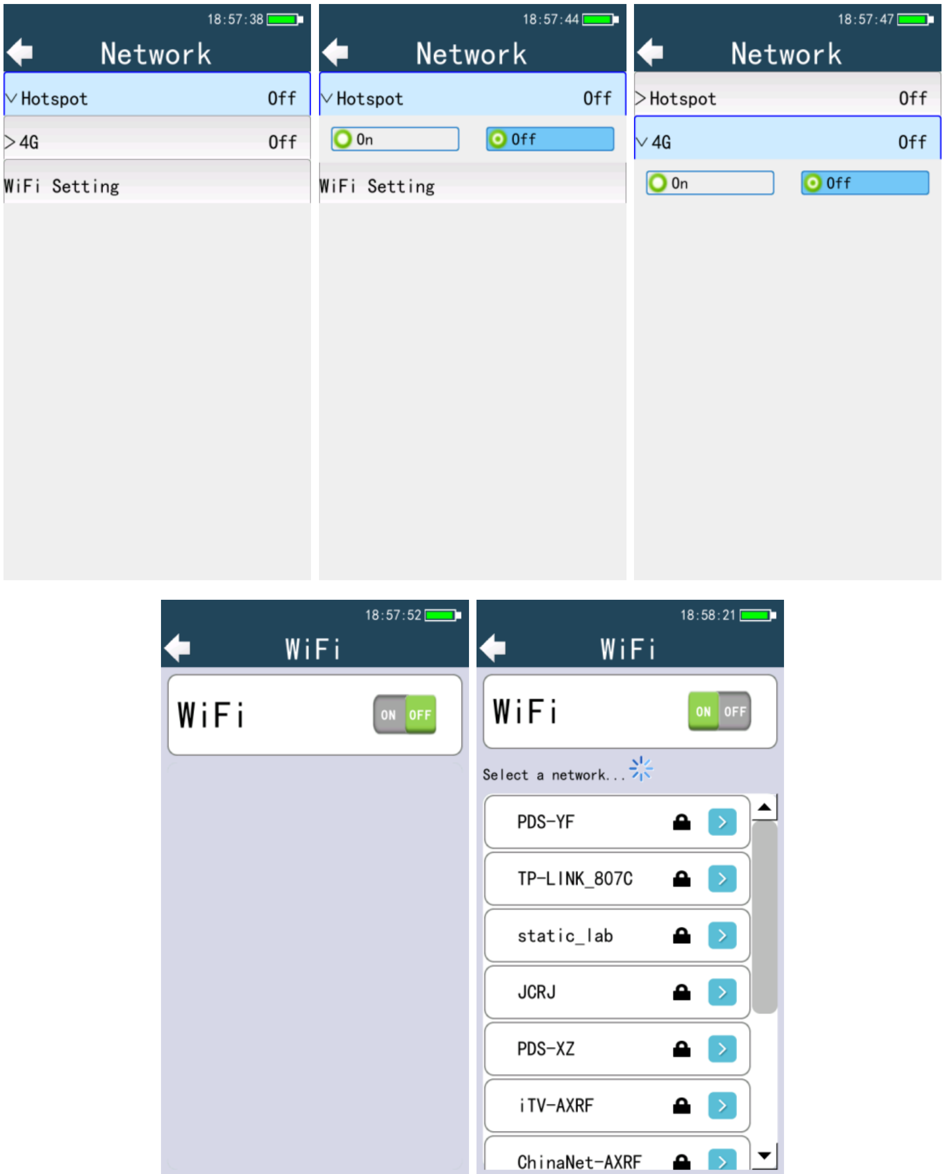


Figure 4.47. Network Settings Options

4.15.13. Update

In order to update the firmware, select **Settings** from the Main Menu, and then turn on the WiFi settings by selecting **Network** then **WiFi Setting** in order to connect to a WiFi network. Next, check and/or input the cloud settings in **Remote Setting**. This option allows the user to update the IP address and port number. **Remote Upgrade** then allows for the ***Download*** and ***Install*** of the update of the current software version for the device.

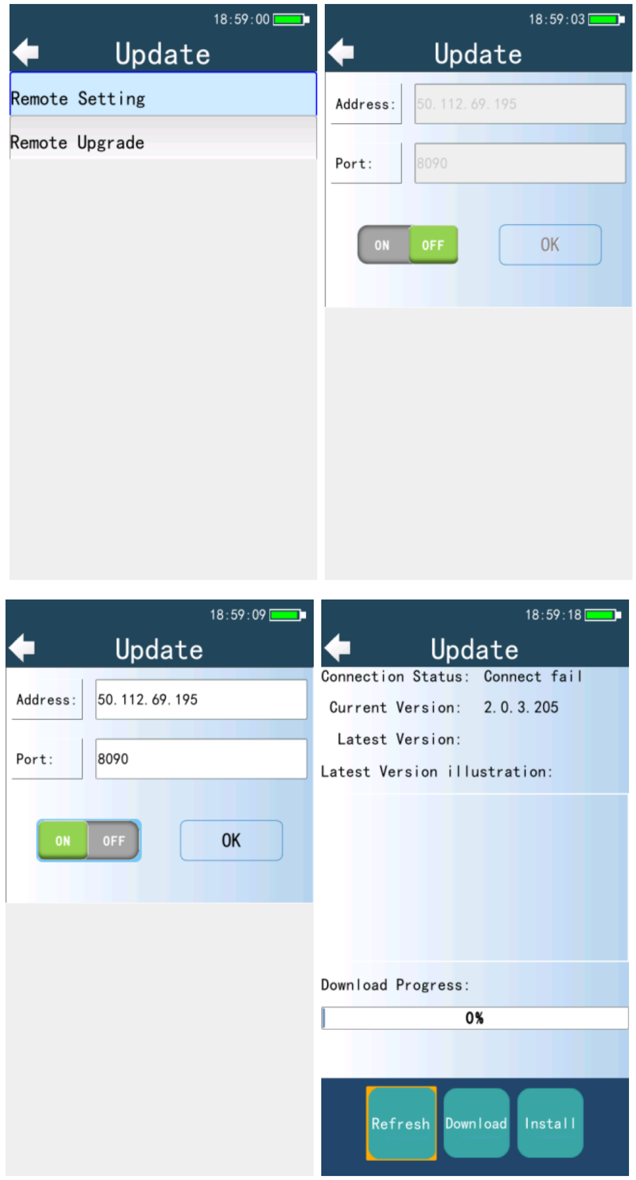


Figure 4.48. Update Settings Options

5. Field Testing Operations and Data Analysis

5.1. MV Switchgear Online PD Field Testing and Data Analysis

5.1.1. MV Switchgear TEV Field Testing

Figure 5.1. TEV Testing

- Induced TEV signals serve as a great indicator of PD activity in metal-clad switchgear.

- The TEV Sensor is built into the PDStar. It is located on the right side of the top face of the PDStar.

- Place the TEV sensor flush onto metal surface of the switchgear. Test in the following places:
    i. Front Center
    ii. Front Bottom
    iii. Back Top
    iv. Back Center
    v. Back Bottom

5.1.2. MV Switchgear Ultrasonic Testing

Figure 5.2. Ultrasonic Testing

- PD activity which is at or near the surface of an insulator will produce an ultrasonic and sometimes audible emission.
- The Ultrasonic sensor is built into the PDStar. It is located on the top left side of the PDStar.
- It is very important that users always use headphones when conducting any type of Ultrasonic or Acoustic sensor testing.
- Track the sensor around the seams, gaps, windows or any other non-metal surface of the switchgear in order to obtain optimal results.

*Note: Ultrasonic Extension Wand - can be used as an extension of the built-in Ultrasonic Sensor for testing objects out of ones reach.

1. Plug the extension wand into the bottom face of the PDStar
2. Use the provided headphones
3. Track the sensor around the seams, gaps, windows or any other non-metal surface of the switchgear in order to obtain optimal results

5.1.3. MV Switchgear UHF Testing

Figure 5.3. UHF Testing

Connect the signal processor to the sensor via the N-type/BNC-type connectors and ensure that the signal processor is powered on.

Place the UHF sensor on the window pane of the switchgear so that the UHF signal can be detected.

You can also place the UHF sensor on the seams or gaps between two switchgear cabinets since the UHF signals can’t be detected through metal surfaces.

- *If abnormal UHF signals are detected,*

Turn the gain ON and OFF - to amplify the signal with it ON and receive only the original signal with it OFF

Amplifying the signal yields a larger detection range and more sensitive reading
N-type and BNC-type connectors are used to connect the main unit to the signal antenna box in order to make the UHF sensor functional.

Always start with the gain ON to detect and cover the smaller signals
Switch the gain OFF to check whether the signal is from the detection location or another area and also detect the actual magnitude of the signal without amplification

- ***Bandwidth***: ALL, HIGH, LOW

No.	PD Type	UHF Signal Characteristic	Filter Setting
1	Internal Insulation Discharge (Void Discharge)	Focus on higher portion, usually higher than 800MHz	High Pass If noise signal is strong
2	Floating Electrode Discharge	Wider range, mostly around low frequency	Low Pass If noise signal is strong
3	Corona Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
4	Surface Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
5	Particle Discharge	Low frequency	Low Pass if noise signal is strong (AE testing is the more ideal method)

ALWAYS start with the bandwidth set to ALL to ensure no signals are missed.

Move the sensor around and change the direction of the sensor => trying to compare the signal magnitudes from different locations.

5.2. Transformer Online PD Field Testing and Data Analysis

5.2.1. Transformer HFCT Testing

Figure 5.4. HFCT Testing

- Connect the signal processor with the sensor via the N-type/BNC-type connectors and ensure that the signal processor is powered on.
- Open clamp on sensor and carefully place the sensor around the cable, testing only one cable at a time. Close and fasten clamp, then gently allow the sensor to rest on the cable or ground.
- Abnormal HFCT signals can be detected by the PDStar through the neutral, surge arrester, and tank ground cables.
- This test is performed using the HFCT sensor.

- Compare these signals to the HFCT signals collecting through the testing of the ground cables on the adjacent assets.
  - Compare the PD pattern and type of each signal
  - Compare the magnitude of each signal
- Compare these HFCT signals with other testing methods (UHF, AE)

  - *If HFCT signal is abnormal and UHF is abnormal*,
  - HFCT and UHF emanate from the same source => EXTERNAL DISCHARGE
  - Come from different sources => compare magnitudes to make sure of location

    - Transformer AE Testing

Figure 5.5. AE Contact Sensor Testing

Sensor Location: Use vacuum grease and magnetic holder to attach the sensor to the tank where there is a test point every one meter apart.

Data Analysis: vibration and noise => very common (from fans or electric force)

How to tell the difference between vibration/noise and PD?

1.Listen to sound through earphones

2.Compare waveforms and phase spectrums

❖ *If abnormal AE signals are detected*, then find the location with the strongest magnitude and compare with the HFCT signal.

5.2.3. Transformer UHF Testing

Figure 5.6. UHF Testing

- Connect the signal processor with the sensor via the N-type/BNC-type connectors and ensure that the signal processor is powered on.

- Make sure the Gain position is ON when beginning the test

  - Position the UHF sensor to:

A. Scan for possible PD signals in bushings
B. Scan for possible PD signals inside of transformer
C. Scan for possible PD signals in surrounding assets

❖ *If abnormal UHF signals are detected,*

- Turn the gain ON and OFF – with the gain ON, locate all the signals present; with the gain OFF, locate only the signals with the highest magnitude.

- N-type and BNC-type connectors are used to connect the main unit to the signal processor in order to make the UHF sensor functional.
- Always start with the gain ON to detect and cover the smaller signals.
- Switch the gain OFF to check whether the signal is from the detection location or another area and also detect the actual magnitude of the signal without amplification.

❖ ***Bandwidth***: ALL, HIGH, LOW

No.	PD Type	UHF Signal Characteristic	Filter Setting
1	Internal Insulation Discharge (Void Discharge)	Focus on higher portion, usually higher than 800MHz	High Pass If noise signal is strong
2	Floating Electrode Discharge	Wider range, mostly around low frequency	Low Pass If noise signal is strong
3	Corona Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
4	Surface Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
5	Particle Discharge	Low frequency	Low Pass if noise signal is strong (AE testing is the more ideal method)

ALWAYS start with the bandwidth set to ALL to ensure no signals are missed.

Move the sensor around and change the direction of the sensor => trying to compare the signal magnitudes from different locations

5.2.4. Transformer Ultrasonic Testing (Parabolic Dish)

Figure 5.7. Ultrasonic Testing

- ❖ Most useful for detecting corona and surface discharge, as well as some floating electrode discharge (when due to loosen bolt connections, etc.)
- ❖ Corona shows only one cycle per period, and surface tracking shows two simultaneous cycles, separated by 180 degrees

- ❖ *If abnormal Ultrasonic signals are detected,*

- Listen for distinctive PD sound with earphones
- Find approximate location with laser point

Use combinational analysis when multiple-type signals are found:

Compare the following signal combinations:

- HFCT – AE
- HFCT – UHF
- HFCT – Ultrasonic
- AE - UHF

5.3. GIS Online PD Field Testing and Data Analysis

5.3.1. GIS UHF Field Testing

Figure 5.8. UHF Testing

- Connect the signal processor to the sensor via the N-type/BNC-type connectors and ensure that the signal processor is powered on.

- Place the UHF sensor onto the Basin Insulated to detect signals
    - This sensor cannot detect signals through metal enclosures

❖ *If abnormal signals are detected,*

- Turn the gain ON and OFF - to amplify the signal with it ON and receive only the original signal with it OFF
- Amplifying the signal yields a larger detection range and more sensitive reading
- Always start with the gain ON to detect and cover the smaller signals
- Switch the gain OFF to check whether the signal is from the detection location or another area and also detect the actual magnitude of the signal without amplification

❖ ***Bandwidth***: ALL, HIGH, LOW

No.	PD Type	UHF Signal Characteristic	Filter Setting
1	Internal Insulation Discharge (Void Discharge)	Focus on higher portion, usually higher than 800MHz	High Pass If noise signal is strong
2	Floating Electrode Discharge	Wider range, mostly around low frequency	Low Pass If noise signal is strong
3	Corona Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
4	Surface Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
5	Particle Discharge	Low frequency	Low Pass if noise signal is strong (AE testing is the more ideal method)

- ALWAYS start with the bandwidth set to ALL to ensure no signals are missed.

- Move the sensor around and change the direction of the sensor => trying to compare the signal magnitudes from different locations

5.3.2. GIS AE Contact Field Testing

Figure 5.9. AE Testing

- Sensor Location: Apply a dab of vacuum grease onto the sensor and attach the sensor to the tank with test points being spaced 1 – 1.5 meters apart.

- Data Analysis: vibration and noise => very common (from fans or electric force)
    - How to tell the difference between vibration/noise and PD?
        1. Listen to sound through earphones
        2. Compare waveforms and phase spectrums

5.3.3. GIS AE Contact Field Testing

Figure 5.10. AE Contact Testing

- Connect the signal processor with the sensor via the N-type/BNC-type connectors and ensure that the signal processor is powered on.

- Open clamp on sensor and carefully place the sensor around the cable, testing only on cable at a time. Close and fasten the clamp, then gently allow the sensor to rest on the cable or ground.

- Abnormal HFCT signals can be detected by the PDStar through the neutral, surge arrester, and tank ground cables.

- Compare these signals to the HFC signals collecting through the testing of the ground cables on the adjacent assets.

    - Compare the PD pattern and type of each signal
    - Compare the magnitude of each signal
- Compare these HFCT signals with other testing methods (UHF, AE)

- *If HFCT signal is abnormal and UHF is abnormal*,
  - HFCT and UHF emanate from the same source => EXTERNAL DISCHARGE
  - Come from different sources => compare magnitudes to make sure of location

5.4. Cable Online PD Field Testing and Data Analysis

5.4.1. Cable HFCT Field Testing

Figure 5.11. HFCT Testing

- Find the cable terminations of the circuits in the manhole, open the HFCT Sensor clamp, place it around the cable terminations, lock the clamp and observe your data on the PDStar. All cable terminations in the manhole should be tested thoroughly.
- If any abnormal signals are found, compare these signals to the HFCT signals collected through the testing of the cable terminations on the adjacent assets.
  - Compare the PD pattern and type of each signal
  - Compare the magnitude of each signal
- Compare these HFCT signals with other testing methods (UHF, AE)

- *If HFCT signals is abnormal and UHF is abnormal,*
  - Adjust the gain (0 dB, -20dB, -40dB, -60dB) and compare the signals
  - HFCT and UHF emanate from the same source => EXTERNAL DISCHARGE
  - HFCT and UHF come from different sources => compare magnitudes to ensure location of PD

5.4.2. Cable AE Field Testing

- This test is performed by using the AE Contact sensor.
- Sensor Location: Use the vacuum grease to attach the sensor to the area to be tested.

Figure 5.12. AE Contact Testing

- Test each phase for the circuit and compare data.
- Data Analysis: Vibration and noise are very common (from surrounding equipment, outdoor noise, people talking, etc.)
  - If abnormal AE signals are detected, find the location/phase with the strongest magnitude and compare with the HFCT signal.

5.4.3. Cable UHF Field Testing

Figure 5.13. UHF Testing

- *If abnormal UHF signals are detected,*
  - Turn the gain ON and OFF - to amplify the signal with it ON and receive only the original signal with it OFF
  - Amplifying the signal yields a larger detection range and more sensitive reading
  - N-type and BNC-type connectors are used to connect the main unit to the signal antenna box in order to make the UHF sensor functional.
  - Always start with the gain ON to detect and cover the smaller signals
  - Switch the gain OFF to check whether the signal is from the detection location or another area and also detect the actual magnitude of the signal without amplification

❖ ***Bandwidth***: ALL, HIGH, LOW

No.	**PD Type**	**UHF Signal Characteristic**	**Filter Setting**
1	Internal Insulation Discharge (Void Discharge)	Focus on higher portion, usually higher than 800MHz	High Pass If noise signal is strong
2	Floating Electrode Discharge	Wider range, mostly around low frequency	Low Pass If noise signal is strong
3	Corona Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
4	Surface Discharge	Lower than 300MHz	All Pass (Ultrasonic testing is the more ideal method)
5	Particle Discharge	Low frequency	Low Pass if noise signal is strong

- ALWAYS start with the bandwidth set to ALL to ensure no signals are missed.
- Move the sensor around and change the direction of the sensor => trying to compare the signal magnitudes from different locations

5.5. Other Equipment Field Testing and Data Analysis

Field testing can also be performed on external areas throughout the substation switchyard and should also be performed to test background noises to ensure the overall testing quality of all data obtained during field testing.

5.6. Precautions to Be Taken During Testing Process

- Transformer substation Partial discharge test is prohibited to operate high-voltage equipment when testing. For operation, you should promptly notify the testers to stop the test and evacuate.

- Adopt the measure of taking off the wireless communication equipment when testing for a partial discharge signal indoor to reduce noise from affecting results.

- In online testing of partial discharge, noise should be thoroughly eliminated before making any judgments concerning the abnormal signal found. Taking into consideration the amplitude of the signal, size, waveform, and other factors to comprehensively determine whether the signal has partial discharge characteristics.

- Under normal circumstances, turning off lights in the vicinity of the test and then testing is not recommended considering safety issues. Only when the area is well-lit can we consider taking the test while having the lights, in the vicinity of the test, off. But in the case of finding an abnormal signal, we should test signals of lights on and off to eliminate the possibility of the signal being noise.

- When test signals are abnormal, we should check whether there is other equipment causing noise around the switchgear, such as the meter screen, air conditioning, fans, etc. When necessary, it might be wise to turn off any such equipment, if that is an option, to eliminate the noise.

- Determine whether the device is working properly before going out to test, especially checking to make sure battery has sufficient charge. Discovery of problems with the device and then impact that might have on the test after arriving at the site should be avoided.

- Partial discharge test equipment should be verified and calibrated regularly to maintain accuracy of test data.

5.7. Abnormal Signal Diagnostic Procedures and Precautions

- Exclude Noise: Noise in the test may come from all directions. The source may be present inside or outside the electrical equipment. Before starting the test, exclude the presence of noise as much as possible, such as shut off fluorescent lamps and cellphones. Nevertheless, there is still some noise in the on-site environment.

- Record data and give a preliminary conclusion: After filtering measurements taken, if abnormal signal still persists, we need to record data from the current testing point, give a preliminary conclusion, and then detect the adjacent location.

- Attempt to locate: If abnormal signals are not located near the adjacent location, the user can determine that the signal is located internally, and that can be determined directly. If the signal can be found nearby, the signal needs to be positioned as much as possible. Discharge location is an important aspect of health of the equipment. We can probably set the source of the signal by 3D modeling method or means of other instruments. If at the external, we may be able to determine if the noise is from other electrical parts; and if at the inside, the abnormality diagnostic can be made.

- Give the judgment by comparing spectrums: Testers can compare the measured spectrum with typical discharge patterns to determine the type of its partial discharge.
- Save data: Accuracy of partial discharge type recognition depends on the accumulation of experience and data. After the test results and inspection results are determined, waveform and spectral data should be retained as a future basis for identifying the type of partial discharge.

6. System Parameters

Detection Bandwidth	TEV	3MHz ~ 100MHz
	Acoustic	Contact AE sensor: 20kHz ~ 300kHz Ultrasonic sensor: central frequency 40kHz
	UHF	300MHz ~ 1.5GHz
	HFCT	500kHz ~ 50MHZ
Test Range	TEV	0 ~ 60dB
	Ultrasound	-10 ~ 70dB
	UHF	0 ~ 70dB
	HFCT	0 ~ 80dB
Accuracy		1dB
Resolution		1dB
Environment	Temperature	32℉ ~131 ℉ / 0℃ ~ 55℃
	Humidity	0 ~ 90%, RH non-condensing
Display		High definition color TFT LCD
Shell		Plastic protective cover
Appearance	Size	7.3 "x 4.3" x 1.4 "/ 185 x 110 x 35mm
	Weight	1.3lb /0.59kg
Connector	Charging and Data Connector	Mini-USB
	Headphone Connector	3.5 mm audio connector
Charger		Input 85 ~ 264V AC,50Hz/60Hz, output: 5V DC 1A

Power supply	Built-in rechargeable Li-Ion battery, the battery voltage is low or automatically off when the operation is inactive.

7. Maintenance

Keeping the instrument clean and dry is very important. The instrument was not designed to be waterproof. Do not store the instrument in a humid environment. Do not exceed the temperature limit use. Don’t shock and impact instrument excessively. Do not over-squeeze the instrument. Do not open the instrument and its accessories. If you have any questions about the features and operations of the equipment, consult the manufacturer or dealer. Instrument can be wiped clean with a damp cloth. If seriously contaminated, it can be cleaned with foam detergent. Take care and do not let the liquid flow into the instrument when cleaning. The instrument must be wiped with a soft cloth. Be careful not to scratch the surface of the instrument, especially a liquid crystal display.

8. Warranty

Warranty period of this equipment is twelve months after the date of delivering. The Contact AE sensor warranty period is three months after the date of delivering. During quality assurance, if equipment that is provided has existing quality issues, PMDT, the manufacturer, will repair or replace the device free of charge.

Equipment is required to be returned to a certain location for service or repair. Damage caused by improper maintenance, mishandling, improper usage, or taking apart the instrument without permission will result in this warranty becoming null and void and therefore the equipment will not be repaired or replaced unless certain fees are applied and paid.

Attention:

The operation manual above is the manual of all PDStar functions. Since the PDStar that you have selected to buy may not come with all the configurations enabled based on the "Kit" purchased, so some functions listed above may not be available in the PDStar you purchased.

PMDT Company's development strategy is to research and develop the products continuously and keep enhancing the products performance. We have made a very great effort to ensure the accuracy of the descriptions in the above manual. However, there might still be some small inevitable differences between the details of the manual above and the actual product.

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