The R2200 - Portable Device for Partial Discharge Measurement and Analysis in High Voltage Equipment Insulation

DIMRUS Ltd.
www.dimrus.ru

The R2200 Device is for Effective Partial Discharge (PD) Measurement in High Voltage (HV) Equipment Insulation

The R2200 device is for partial discharge measurement in the insulation of different types of electrical equipment, such as transformers, cables, high-voltage electric machines, etc.

Such diagnostics can be carried out during operation for the current insulation condition evaluation, as well as during for acceptance tests of the high voltage equipment.

The R2200 is supplied with the set of sensors and calibration equipment. This is usually enough for practical PD measurement in most cases.

The R2200 device can be fed from the mains supply as well as from the inbuilt accumulators; it is in strong metal enclosure, which makes the sphere of its use wider, especially in the field condition.

The Delivery Set of the 9 Channel PD Measuring R2200 Device

The portable R2200 device for PD measurement is supplied in the strong rollaboard, which makes the device convenient for transportation.

The standard delivery set includes the R2200 device, the set of PD sensors, the calibration generator, the set of connection cables and the set of documentation.

There is also the CD with the software for the PC communication and data storage.

If the PD measurement conditions are supposed to be unusual, some specific sensor can be optionally added to the delivery set, such as HV coupling capacitors, PD sensors for transformers, surface current sensors and electromagnetic antennas. The sensor can be custom-made.

The Set of Facilities Which Make the R2200 Measuring Device Almost Universal

The standard delivery set of the R2200 device is enough for PD measurements in most cases.

All the sensors and the GKI-2 calibration generator supplied together with the device are produced by «DIMRUS».

The sensors supplied together with the R2200 device have protecting insulation against up to 1000 volt, so they have to be mounted at the earthed circuits or the circuits of low potentials. For measuring under high potential some specially tested sensors, supplied optionally, should be used.

The primary sensors are connected to the device with the 6 meter coaxial cable. Optionally the cable can be as long as 50 meters.

The R2200 Specifications

№	Parameter	Value
1	The number of PD measurement channels	9
2	The frequency range of the measured PDs	0,5 – 15,0 MHz
3	The dynamic range of the measured PDs	70 dB
4	PD pulse measurement synchronization	Inside - outside
5	Display resolution, pixel	480 * 640
6	PC interface	USB
7	Operation temperature range	-20 +40 C
8	The time of operation from the built-in accumulator, hour	5
9	The device weight (without sensors), kg	3,5
10	The transportation case (rollaboard) dimensions, mm	520*430*220
11	The device weight with the transportation case, kg	21,5

The device and the software can be realized optionally in Russian, English or Chinese.

The Methodological Documentation Supplied with R2200

The R2200 is supplied together with the whole set the documentation, this is enough for effective PD measurement.

The documentation includes:

- The set of the certificates for the device, the sensors and the calibration generator.

- The user manual for the device and the PC software printed.

- For the work to be more convenient there is the context-dependent help function realized in the device. The function is activated at pressing «Help» key in the device.

- The monograph «Partial Discharge Measurement in High Voltage Equipment Insulation» by Valery Rusov. In the monograph the basic methodical and problems arising during the diagnostics of the HV equipment of basic types are discussed.

The R2200 – is Compact but Powerful Portable Device with the Set of Unique Functions

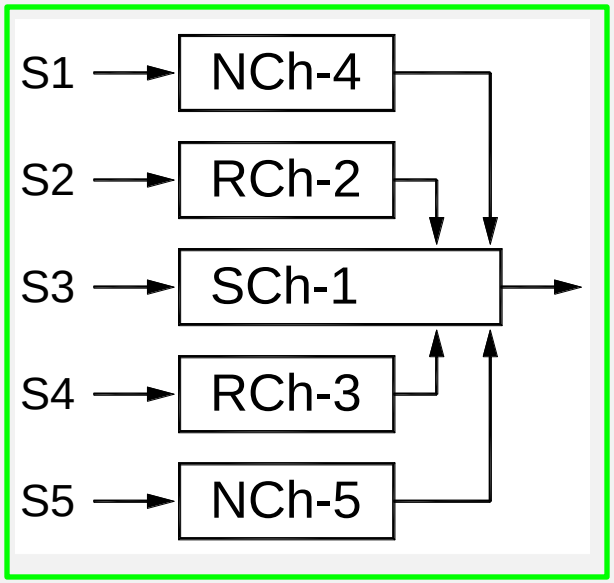
The R2200 measuring device has been developed on the base of the modern high-speed microprocessor and has wide computational power, colored display and membrane keypad.

The 9 input channels allow to carry out the PD measurements at the most complicated HV equipment. For the measurements' results to be more reliable the device has a whole set of HV noise rejection facilities.

For the PD measurements to be more informative there are several ways of synchronization of the measurements to the supply net phase.

The parameters of the PD measurements can be specified on site or beforehand and loaded into the device from PC. You can load as many configurations as you need. It allows to realize routing technology of PD measurements.

The Principal Scheme of the R2200 Device for PD Measurements in Insulation



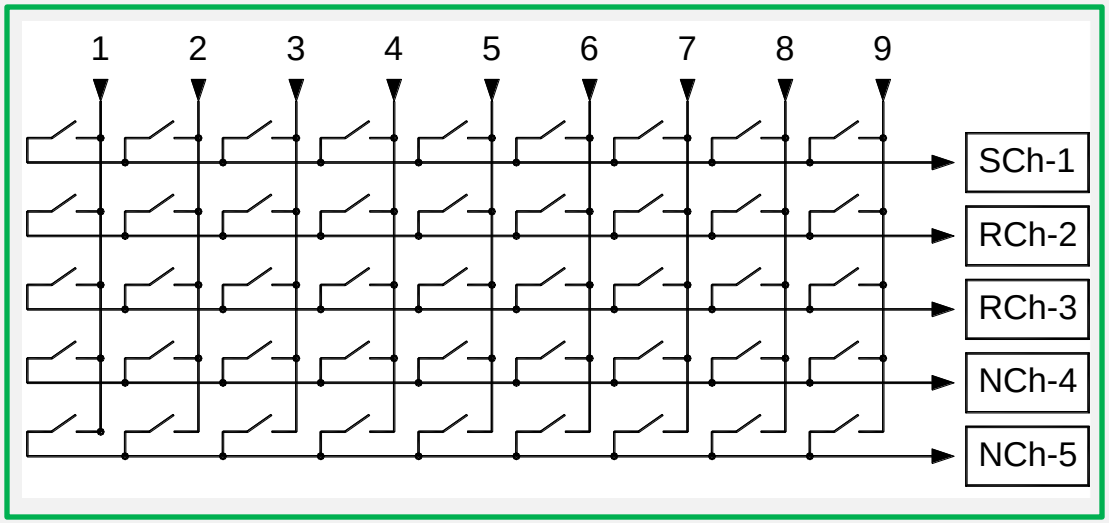
The R2200 device simultaneously measures high frequency pulses coming from 5 primary channels:

- «SCh-1» - the main, signal channel for PD measurement.
- «RCh-2» and «RCh-3» - the reference channels for time and phase analysis.
- «NCh-4» and «NCh-5» - the noise channels for amplitude rejection of high frequency noises.

PD measurement is always done through channel «1». The other four channels are supporting. They are for internal and external noise rejection.

Synchronic PD measurement from 5 channels allows to effectively reject external noise pulses on the hardware level in real time mode.

Software Controlled Configuration of the Measurement Scheme During PD Measurement by the R2200



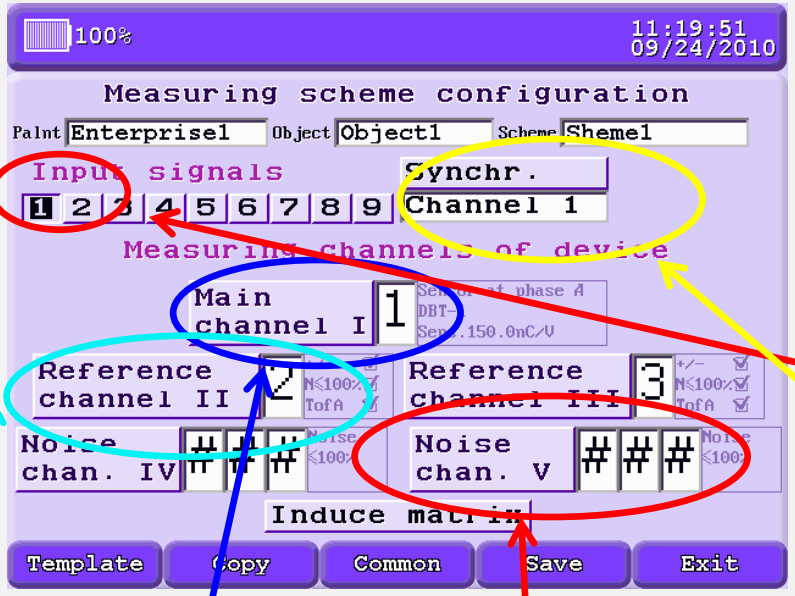
The electronic matrix switch built into the device allows the 9 PD sensors to be effectively connected to the 5 measurement channels according to the operator's choice.

The current state of electronic matrix switch, including the position of the primary sensors at the equipment and their connection to the 5 measurement channels, is called the scheme configuration of PD measurement in HV equipment.

The measurement scheme configuration also includes the sensitivity of each PD sensor, specified during calibration, with the allowance for the fading in the controlled object.

The absolute and relative values of the inner measurements thresholds are also the important configuration parameters, witch influence the PD measurement precision.

The Operative R2200 Measurement Configuration Forming in the Field Condition



The operator of R2200 device can form and save the measurement configuration for all the input measurement channels.

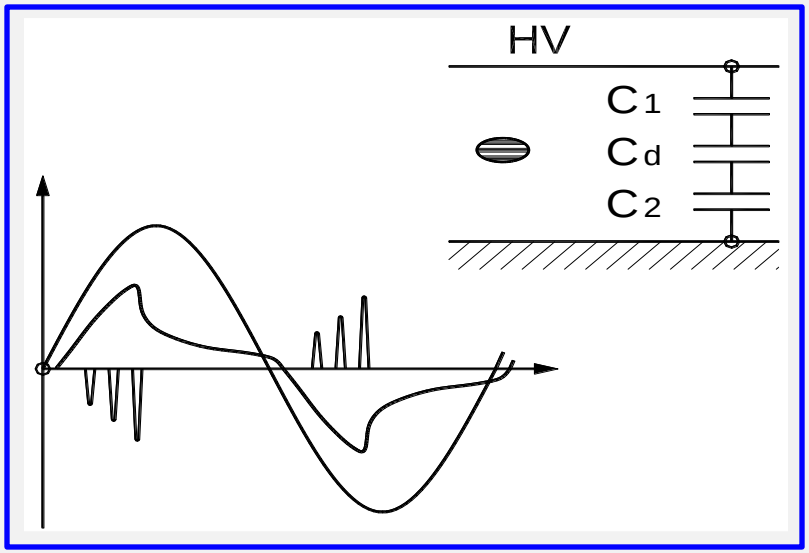
For that the following parameters should be specified in turn:

- The number of the input channel for which the configuration is being formed.
- The way of the measurement synchronization to the supply voltage.
- The number of the input channel for the basic PD measurement in the controlled equipment.
- The number of the reference channel to which the basic channel will be compared in polarity and the time of the pulse arrival.
- The noise channel for the amplitude comparison. The noise channel summator can collect the signals from up to three sensors.

In one configuration all the 9 input signals can be used. It is the most complicated configuration of the device.

2. PD in the HV Equipment: Cause of Arising. Primary Measurement Sensors

The Causes of PD Arising in HV Equipment Insulation



PDs are the first sign of the insulation defect development for most of the HV equipment. Over some time the PDs will develop into spark discharges and arch discharges, which cause breakdowns.

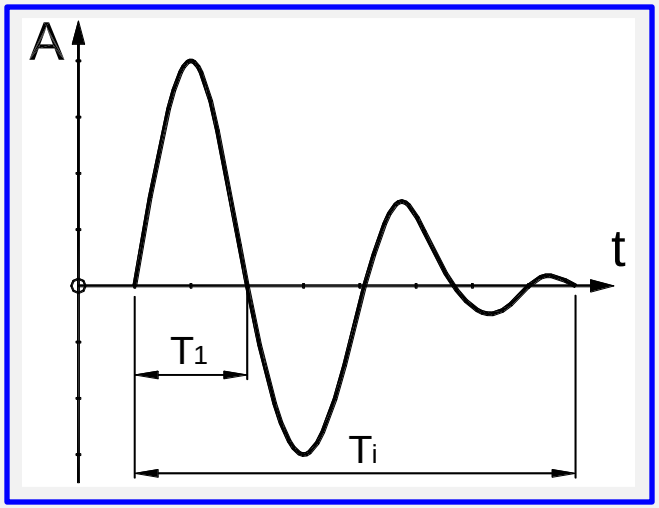
PD usually appear in holes and the zones of insulation where there are some defects, such as – foreign inclusions, gas bubbles, and moisture.

At the place where the voltage, applied to the defect zone, grows up, one or several PDs arise, which causes the redistribution of potentials in the whole of the insulation.

If the defect is situated closer to the outer surface of the insulation, that is to the higher potential, then there are more PDs at the positive half-wave of the supply voltage and less at the negative one.

If the defect is situated closer to the «earth» potential, then, on the contrary, there will be more PDs at the negative half-wave of the supply voltage.

Time and Frequency Parameters of the PD Pulse in the HV Equipment Insulation



The rising edge of the PD pulse in the defect zone is usually very steep. It lasts for a couple of nanoseconds or even parts of a nanosecond.

This «primary PD pulse» causes resonant oscillation around the defect zone. The frequency of the resonant oscillations depends on the environment.

As the pulse is moving away from the place of the PD arising the oscillations involve more and more insulation and equipment, which have their own resonant characteristics. As a result in the output signal of the measurement sensor there are the oscillations differing much in frequency.

The smaller is the insulation defect zone – the steeper is the rising edge of the PD pulse and the higher is the PD pulse frequency.

PD Measurement in Different Frequency Rangers.

PD measurement can be done with the sensors of three types, differing in operating frequency:

- Low frequency sensors (LF), for frequencies of up to hundreds of kHz. These are acoustic and acoustic-emission sensors.

- High frequency sensor (HF), for frequencies of up to tens of MHz. These are the transformer sensors, coupling capacitors and the sensors of the surface high voltage currents spreading.

- Ultrahigh frequency sensors (UHF), for frequency of up to several GHz. These are various electromagnetic antennas.

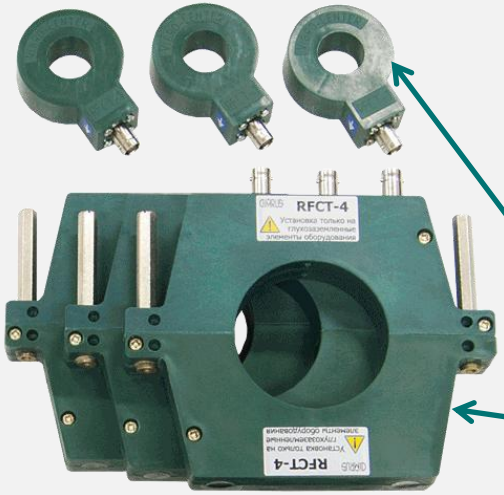
R2200 device measures PDs in insulation in the high frequency range - HF. This frequency range has been chosen for several reasons:

- Only in this frequency range the correct measurement circuit calibration together with the measurement object is possible.

- HF sensors and devices are relatively cheap and are easily mounted at earth circuits.

- In HF range the maximum quantity of PDs from different types of defects can be measured, which is impossible in other frequency rangers.

RFCT Sensors for PD Measurement in Insulation in HF Range



For PD measurement in HF range relatively cheap sensors are used.

The standard version of R2200 is supplied with 4 types of RFCT (Radio Frequency Current Transformer) sensors, they are:

- RFCT-1 – ring HF current transformer, 3 pieces.

- RFCT-4 – split-core ring HF current transformer for mounting at the conductors and buses of jump lead without the primary chains dismantling, 3 pieces.

- RFCT-5 – HF clump meter for operative PD measurement in earth conductors.

- DRTD-3 – HF transformers for PD measurements in the circuits of Pt 100 resistance thermometers.

GKI-2 - the Test Generator for R2200 Measurement Circuits Calibration

The specific feature of PD measurement in HV equipment insulation is the influence of the object itself on the pulse dumping on the way from the place of its arising to the primary sensor.

During usual electric measurements there is no such influence, for example while measuring voltage in electric circuits.

PD measurement has something in common with electric current measurement in closed circuit, but there is an important difference: we do not know the inner resistance of the PD source, which can differ much from one object to another.

In order to find out the unknown inner resistance, it is necessary to use the calibration pulses and watch the reaction of the controlled object to the test pulse. Thus knowing the response of the object to the pulse of definite parameters it is always possible to «restore» the primary PD pulse on the base of the object response to it.

For that purpose there is the GKI-2 calibration generator included into the standard delivery set of the R2200, which injects test pulses into the controlled object.

Coupling Capacitors for Contact PD Measurement in HV Circuits - Optional Function

For some special PD measurements in HV equipment insulation there could be additional set of three coupling capacitors optionally included into the R2200 delivery set. The coupling capacitors are for the rated voltage of 12 or 24 kV and the frequency of 50 Hz.

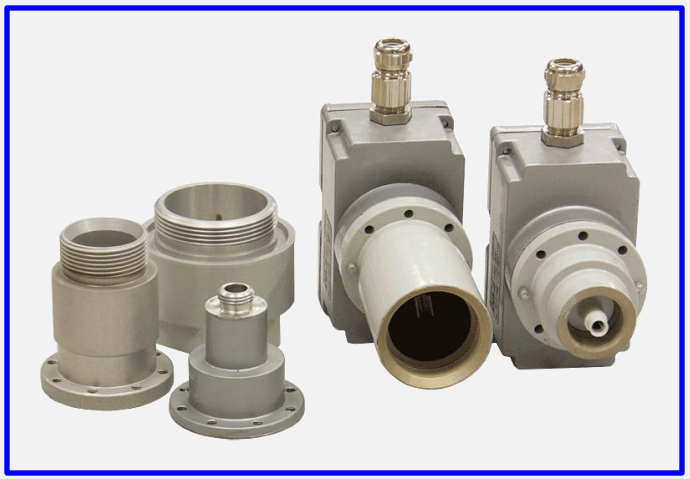
Such coupling capacitors are made on special technology and have mica insulation, which guarantee the parameter stability and the long life time.

The advantage of the coupling capacitors is that they can be connected to the full rated voltage of the objects, which provides high sensibility in PD measurement.

As a rule, the coupling capacitors are used in two cases:

- For PD measurement in the insulation of stator winding of HV electric machines.
- For PD measurement in switchgear buses and bus ducts.

DB-2 Sensors for PD Measurements in the Power Transformer Bushings - Optional Function



For PD measurement in the HV equipment insulation it is necessary to use the set of DB-2 sensors mounted at the test taps of the transformer bushings.

This is because in practice there are lots of different bushings with different test tap designs, produced by different firms.

The complete universal set of DB-2 sensors, which can be used with the bushings of any design and any producer, include 2 modifications of the sensor and 6 modifications of adapter rings, which provides the reliable fixing of the sensor at the bushings, and also the set of connection coaxial cables.

The set of DB-2 sensors supplied together with R2200 is for temporary mounting at the transformer, for PD measurement in transformer insulation and HV bushings.

PFR System for Remote Synchronization of PD Measurement Processes Through Radio Channel - Optional Function

During PD measurement in the HV equipment insulation it is very important to synchronize the measurement process to the supply net sinusoid phase. Only in this case it is possible to diagnose the defect type and its progress correctly.

In practice the synchronization can be complicated, because of the device remoteness from the supply net, necessary for synchronization. It in especially difficult when RFCT sensors are used, because they don't transfer the power-line frequency current.

In this case the measurement process is synchronized to the supply net by use of some special reference signal passed through the radio channel. The PFR-1 reference signal transmitter is set at the place where the supply voltage is present, at the distance of 100 meters from the place of measurement. The similar device in receive mode is connected to R2200 device.

2. The Hardware and Software of the R2200 Device for HV Noise Rejection

The R2200 – is the Optimum Combination of Hardware and Software for Noise Rejection During PD Measurement

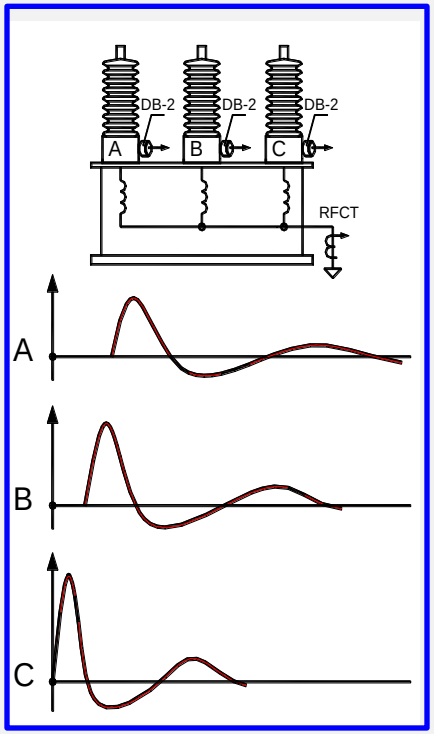
Noise rejection is the basic task during PD measurement in HV equipment insulation. Noise rejection is very important because the parameters of the informative PD pulses are very close to the parameters of noise pulses. There are lots of noises in the HV nets and often it is impossible to separate them from informative pulses.

Noise rejection can be done in two ways: by hardware and by software, while measuring and while processing the saved pulses. At first sight both the methods seem alike, but each of them has its own specific features, faults and merits.

In the R2200 device the optimum combination of the two methods of noise rejection is used. The techniques of the noise pulse blocking are used to the maximum extent. This makes algorithmic filtration and analysis of the measured PD pulses much easier.

It is very important that the operator can adjust the HV pulse sorting and choose the set of specialized noise rejection algorithms by himself.

Synchronized Multichannel PD Measurement is the Possibility to Get the Best Noise Rejection



PD pulses arise in insulation in very short time and they spread in the insulation and in the equipment itself with the speeds close to the speed of light.

PD impulse «flies» the distance of one meter inside the cable or some other equipment in 4-5 nanoseconds. Because of that you have to compare the signals form different sensors with time resolution of up to nanoseconds. This degree of precision is impossible when using standard techniques (ADC) .

The very high time resolution necessary for comparing of several pulses is achieved in R2200 thanks to the use of synchronic registration of HV pulses from several channels and the use of high-speed solutions.

The use of such solutions allows the time resolution of the measurement scheme to be as small as 2 nanoseconds.

Amplitude Comparison of Pulses From Several Sensors is the Possibility to Exclude the Cross Talk in the Equipment

*	Ua	Ub	Uc	Un
Ua	1,0	0,8	0,6	0,7
Ub	0,8	1,0	0,8	0,5
Uc	0,6	0,8	1,0	0,5
Un	0,7	0,5	0,5	1,0

The example with the power transformer mentioned above illustrates that the PD pulse arising in one transformer phase will be measured by sensors in other phases but with smaller amplitude.

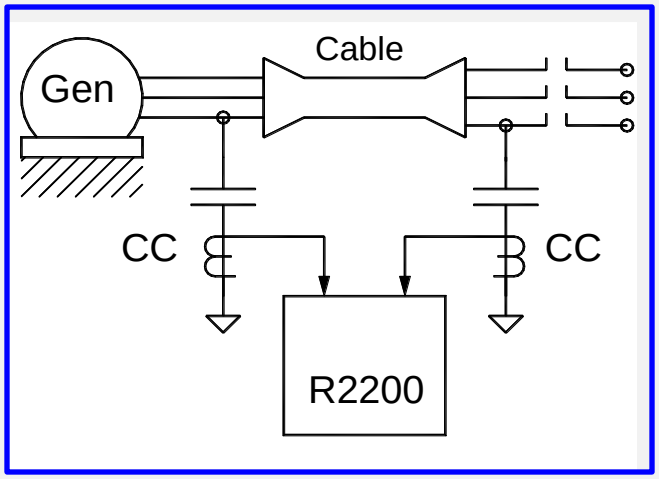
The rule of such inner noise rejection is simple – if the amplitudes of signals in some other phase are bigger than that of the measured phase, then the PD has arisen not in the measured phase.

There are some special hardware and software means in the R2200 device that reject the influence of such «inner» noises.

- When calibrating the measurement scheme before PD measurement the operator can «fill in» the cells of cross matrix, illustrating the influence of the transformer phases to each other. The values of the cross matrix cells are calculated automatically.

- The values of the transformer phases cross influence can be used during PD measurement as the relative values of the signal amplitude.

Noise Rejection by the «Time of Arrival» method



When a pulse close in parameters to a PD pulse is measured, for example, in generator stator winding, there is always the question: whether the pulse has arisen inside the generator winding or has come to the generator from the outside through the connection cable.

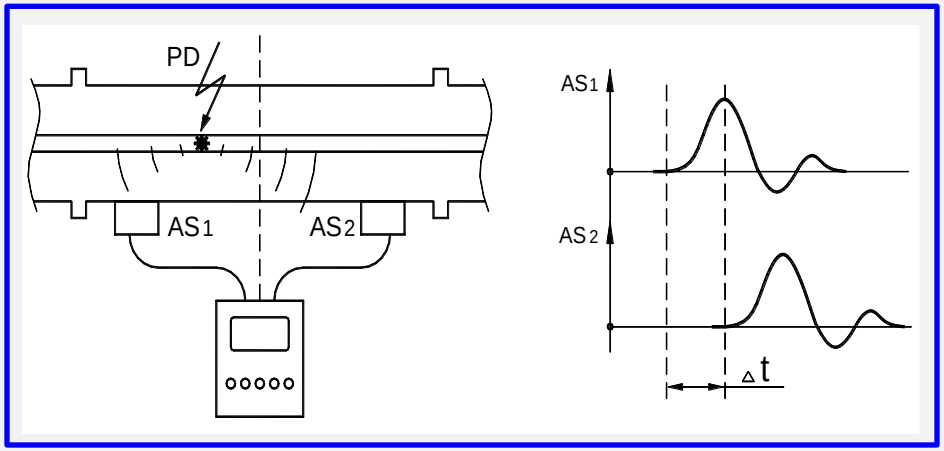
The answer to this question radically changes the conclusion about the insulation condition.

To answer this question the «time of arrival» method is used most often. This method is based on the analysis of the time of arrival of the signals from two sensors to the device.

If the pulse from the sensor which is set closer to the generator was the first to come to the device then the pulse is sure to arise in the generator stator winding. If the first to come to the device was the pulse from the second sensor then the pulse is a noise pulse and it has nothing to do with the stator winding insulation.

For R2200 the distance of not less than 1 meter is enough for the device to give the correct data.

The PD Pulse Generation Place Location by Analyzing the Time of Arrival to Two Sensors

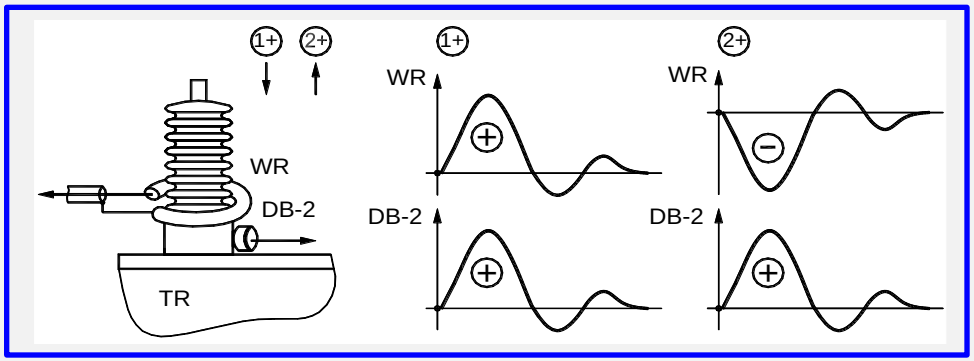


With R2200 it is possible to locate the PD generation place even if the defect zone is situated between two PD sensors.

The device can evaluate the time lag between PD pulse arrival to each sensor from the place of its generation. If the defect is situated strictly between the two sensors then the pulse will come to both the sensors simultaneously. If the pulse comes quicker to one of the sensors then the defect zone is situated closer to it.

The time delay Δt is proportional to the double time of the pulse fly from the defect zone to the centerline between the two sensors. If the defect is much close to «1» sensor, then the Δt time shift will be equal to the time of the pulse fly from one sensor to the other. By this parameter you can calculate the precise value of the electromagnetic wave speed inside the object.

Noise Rejection by Comparing the Polarities of Pulses from Sensors of Different Types



If the noise level in the monitored object is high, like in power transformer where the influence of corona discharges is considerable, you can use sensors of different types to decrease the noise influence.

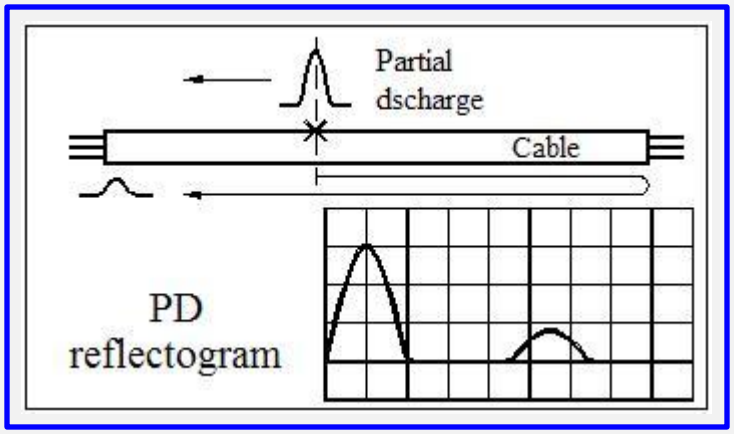
There is the situation when 2 sensors - Rogowskiy WR coil and DB-2 (or RFCT) sensor - are installed on one test tap of transformer bushing.

The polarity of the output signal of the DB-2 sensor depends on the high frequency pulse polarity only, no matter whether the pulse goes into the transformer of out of it.

The output signal of Rogowskiy coil is connected to pulse polarity and the direction of its movement through the bushing.

Comparing the polarities of the two pulses allows to define the direction of the pulse movement. If it goes "out of the transformer", then it is a PD, if it goes "into the transformer", then it's a noise pulse.

The Location of the PD Pulses by the «Time of Arrival» of Direct and Reflected Pulses



By PD pulses you can reveal the presence of defects in the insulation and locate of defect zone place in power cable.

The method of such location has a lot in common with using of reflectogram, but it operates in on-line mode.

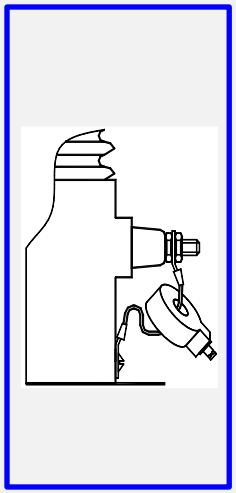
PD pulse with the amplitude that allows to measure the reflected signal from the opposite end of the cable line is used as the probe pulse.

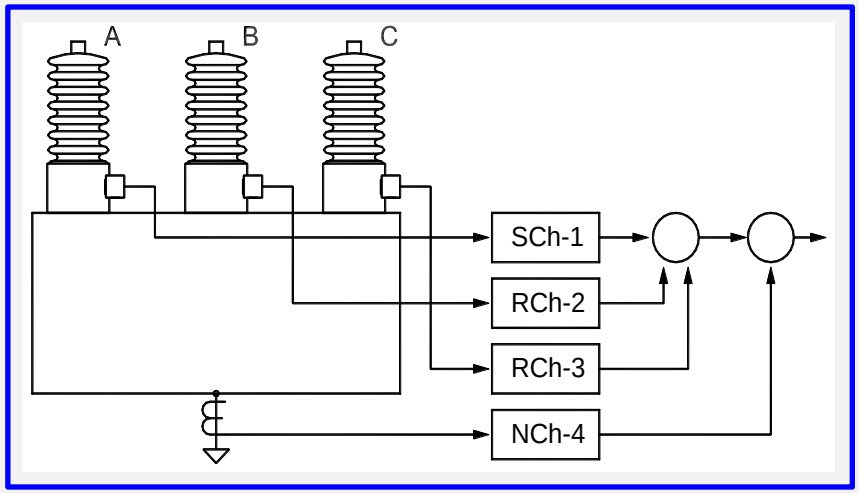
The location is based on the method of the evaluation of the difference in the time of arrival of "direct" and "reflected" pulses from PD to the device. This time definitely define the place of the defect zone in the cable.

The R2200 device has automated function of reflectogram measurement and analysis. If the device finds any PD in cable, it is possible to measure and store the arrival graph of all the pulses during the time enough for the pulses to pass the monitored cable length twice.

3. Practical Examples of Using the R2200 Device for PD Measurement in High-Voltage Equipment of Different Types

PD Measurement in High-Voltage Power Transformer by the R2200 Device





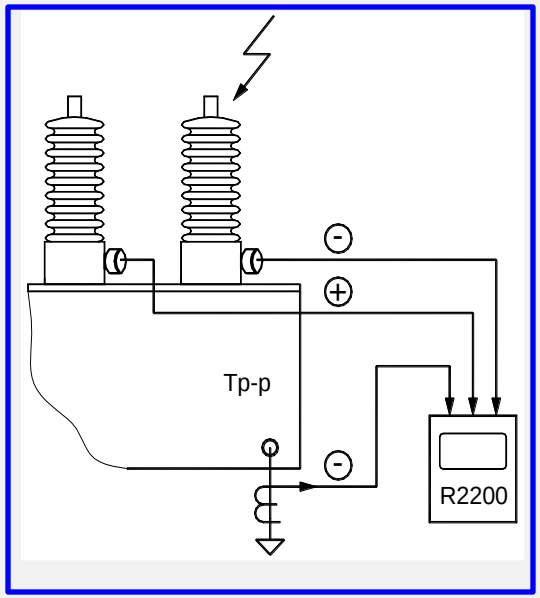
The left figure shows the way of temporary installation of RFCT-1 sensors on the test tap of the measuring transformer. The test tap is safely grounded and the PD sensor is installed on the grounded conductor.

4 sensors are installed on the monitored transformer: 3 sensors are installed on the test taps and 1 sensor is installed on the high-voltage winding neutral, or on magnetic core ground conductor, or on the general ground of transformer tank.

4 measuring channels of the R2200 device – one main signal channel, two reference channels and one noise channel - are used during PD measurements in every transformer phase.

The measuring configuration of the device in this mode is shown in the figure. The use of the 4 channels allows to reject the noises which pass from phase to phase inside the tank and to reject the external corona discharge pulses.

The Method of Corona Discharges Rejection During PD Measurement in Power Transformer



Corona discharge pulses rejection is made according to the polarity of signals measured at the test taps of transformer phase bushings.

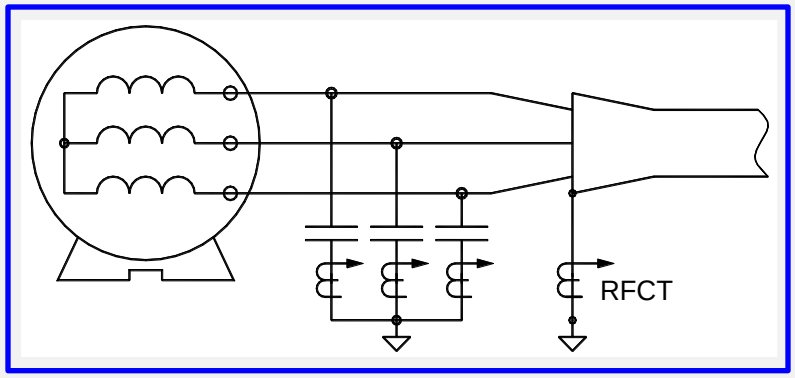
During PD measurement at any transformer phase the polarities of the pulses measured from all the three sensors installed on the bushings are synchronically compared.

If all the three pulses from phase sensors has the same polarity, then this is a PD pulse.

If the signals first "peaks" are of different polarities – then it is the corona discharge pulse that has been measured, thus it is some external noise which is rejected by the R2200 device itself.

Thus even on the hardware level of the R2200 device there is very efficient differentiation of the pulses, which allows to separate the pulses arising inside of the transformer and the external pulses.

PD Measurement in Stator Winding of High-Voltage Generator and Electric Motor



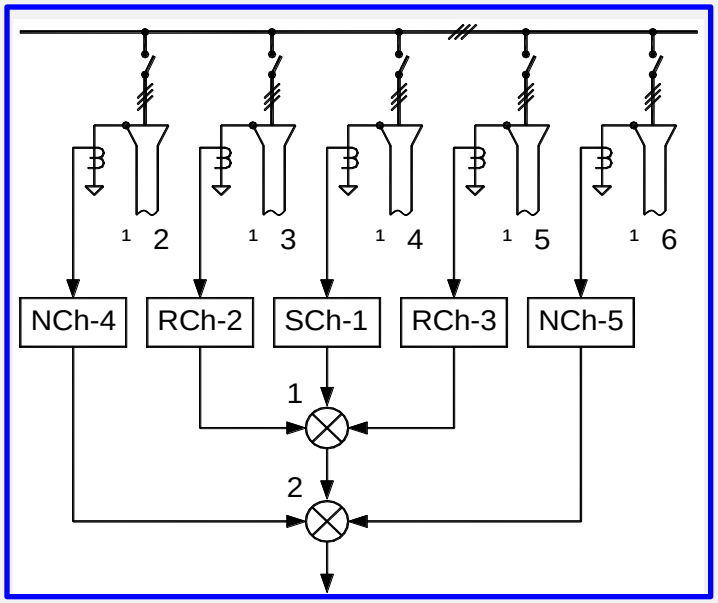
The stator winding insulation condition is most often monitored through PD level and distribution in high-voltage electrical machines. One variant of primary sensors installation is in the figure.

4 PD sensors are also used in this case, but the general configuration of the measuring circuit is different. Only amplitude sorting of pulses is used between the phases of stator winding.

The sensor which is installed on grounded shield of electric motor supple cable is used in the device for pulses «time of arrival» sorting. Thanks to that you can efficiently reject any external noises which come into stator winding from the outside through connection cable.

Coupling capacitors are very effective for stator winding insulation condition monitoring by PD and periodical measurements, when coupling capacitors are installed stationary. They are not convenient for one-time PD measurements as they are difficult to install.

PD Measurement in Group of Power Cables by the R2200 Device



It is difficult to measure PD in cables when several cables are connected to one bus of switchgear.

In this case the mutual pulses pickup between the cables is so big, that it is difficult to find the defect cable.

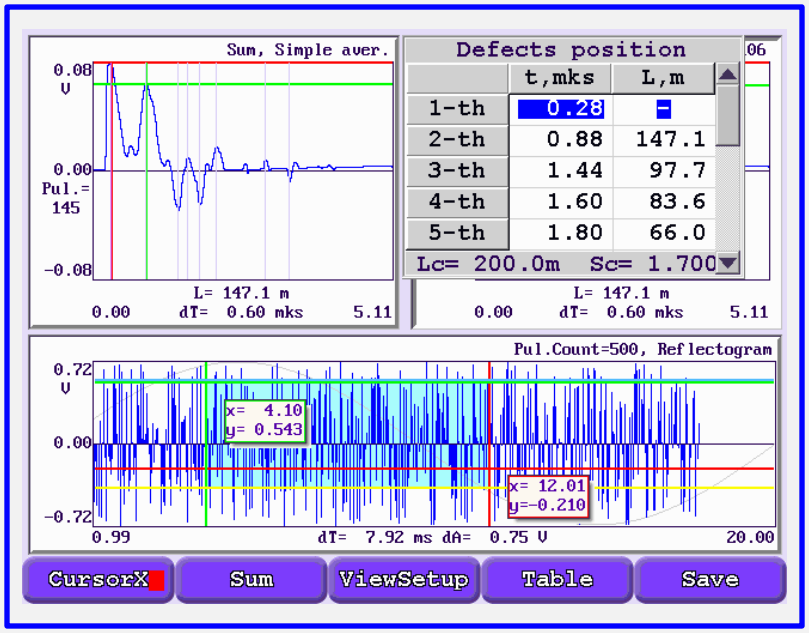
Using the R2200 device in this case is very efficiently, because even its hardware has the necessary means for separating of high-frequency pulses from the objects situated close to each other.

The picture illustrates the measuring circuit configuration when all the 5 measuring channels of the R2200 device are used for PD measurement in one cable (cable № 4). The following means for noise rejection are used in this device configuration:

- «Time of arrival» method in cables 3 and 5.
- Signals amplitude rejection method in cables 2, 3, 5 and 6.

The additional use of the algorithmic methods of noise rejection allows to almost exclude the influence of the induced pulses.

The Defect Location in Cable by the R2200 Device



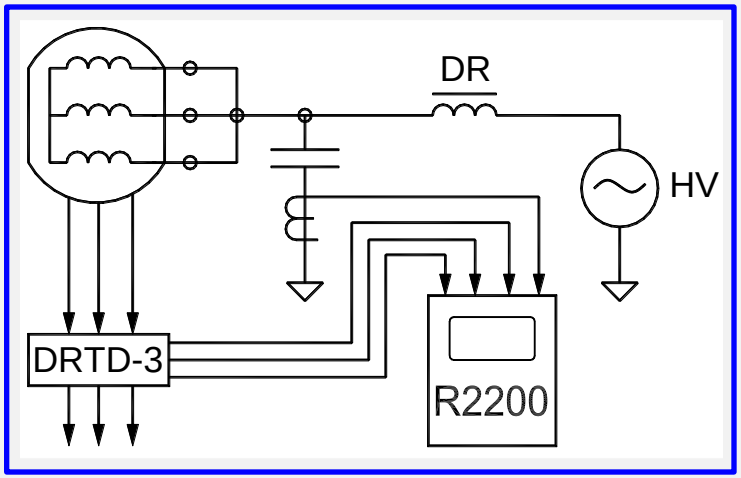
The defect origin place location in cable insulation can be done by the R2200 device simultaneously with PD measurement in the insulation of cable assembly. The device capabilities in this mode are shown in the copy of device screen.

The time distribution of all the measured pulses from one cable is shown in the lower part of screen.

The operator can choose the alike pulses, which refer to one and the same defect, from all the pulses measured by the device. The averaged reflectogram of defect origin place location can be made using the chosen pulses.

There is defect computational table of reflectogram in the top right hand corner of the screen. The coordinates of defect are the function of 2 parameters: time delay of pulses arrival and the distance from the opposite end of monitored cable.

PD Measurement on Testing Stands by the R2200 Device



The R2200 device can be used in testing stands for detection of high-voltage insulation condition after the equipment production or repair.

In the figure there is the example of the PD measurement in electric motor stator on PD stand.

The main difference from measurements in operating equipment is that one and the same voltage from one high-voltage source is applied to all the three stator windings. One DRTD-3 sensor and one coupling capacitors are use as PD sensors in this scheme.

The minimal level of measured PDs depends on the level of external noises, that are impossible to reject by the device hardware and software means. For measuring the PDs of the minimal level, in pC, it is necessary to carefully screen the object being measured, for example, to put it in cell of Faraday and use «PD-Free» testing voltage source.

4. The Evaluation of High-Voltage Equipment Insulation Condition on the Basis of PD Measurements

About the Choice of the PD Parameters Used for the Insulation Condition Evaluation

Different parameters are used for the assessment of the intensity, energy and repeatability of PD pulses. More often the following is used:

- the value of apparent PD, measured in pC.
- the PD pulse amplitude, measured on sensor output in mV.
- the quantity of PD pulses in insulation, brought to one sinusoid of supplied voltage.
- the quantity of PD pulses in insulation, to five sinusoids of supplied voltage.
- the energy of all the measured PDs.
- the power of all the measured PDs.

All these PD parameters, as well as some secondary parameters at Users choice are assessed in the R2200 device.

There is some small difference between some repeating parameters. It is because different specialists give different description of PD. We tried to make the device «friendly» to all Users, each of them can choose the parameters he or she needs.

Methods of Insulation Condition Evaluation by Measured and Calculated PD Parameters

There are several methods of equipment insulation condition assessment by PD.

The first is the insulation condition evaluation by amplitude PD parameters:

- Insulation condition evaluation by the amplitude of maximal PD pulses.
- Insulation condition evaluation by the amplitude of the repeating PD pulses only.
- Insulation condition evaluation by positive trend in changing of any PD parameters.

The second is the evaluation by PD energetic parameters:

- Insulation condition evaluation by PD energy.
- Insulation condition evaluation by PD power.

The third is the evaluation by parameters of defects in the insulation:

- Equipment insulation condition evaluation by risk level of defects revealed by PD analysis in insulation.
- Insulation condition evaluation by the progress level of the revealed dangerous defects. This is the most difficult method of insulation condition evaluation.

Insulation Condition Evaluation by Measured PD Level

The insulation condition evaluation of HV equipment by measured PD level seems simple at first sight. But in practice it is the most difficult way of evaluation, influenced by many unconnected parameters.

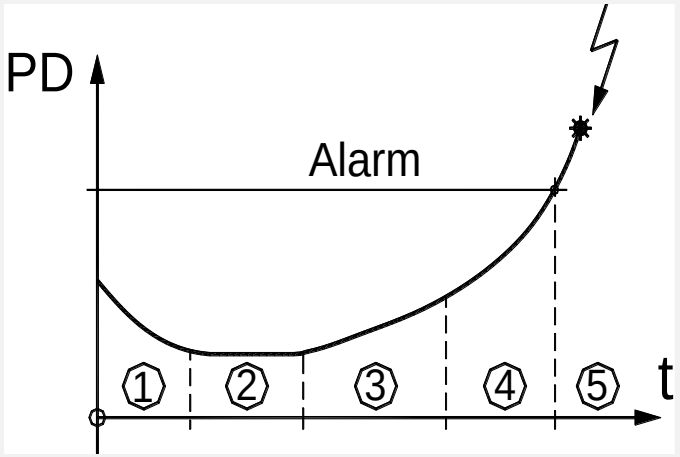
First of all, the insulation parameters are different. Even in one type of HV equipment produced by one manufacture, the basic PD level and condition thresholds can differ in several times.

Secondly, operating the equipment with different insulation types makes impossible the use of some generalized condition thresholds.

Thirdly, the insulation condition thresholds depend on the operating time of every equipment unit, on the operating conditions, temperature loads, etc.

Thus, sometimes the insulation condition of some devices could be similar, though the PD level in those devises could differ in ten times. That is why only an experienced diagnostician should carry out the PD measurement correctly.

The Presence of Increasing Trend in PD Parameters is the Sign of a Developing Defect in the Insulation



It is more correct to evaluate the condition of the equipment by the presence of time trend, showing the increase of PD level in the insulation.

If PD level increases 3-5 times during one year, then some dangerous defects are developing in the insulation.

There are 5 specific zones in time graph of PD level changing in the insulation:

1 – Zone of equipment run-in when PD level can even decrease.

2 – Zone of normal "zero-defect" insulation operation.

3 – Zone of arising and slow developing of defects in the insulation.

4 – Zone of accelerated "self-development" of defects.

5 – Zone of pre-accident insulation condition which ends by breakdown.

The time length of every zone depends on many parameters of equipment and operation conditions. It can be evaluated more precisely if PD measurements are carried out periodically.

Diagnostics of Defect Type and Place is the Most Important Task of Insulation Condition Analysis

Even if you have evaluated the PD level in the insulation correctly, there is always the main question: is the present defect dangerous for equipment operation or not?

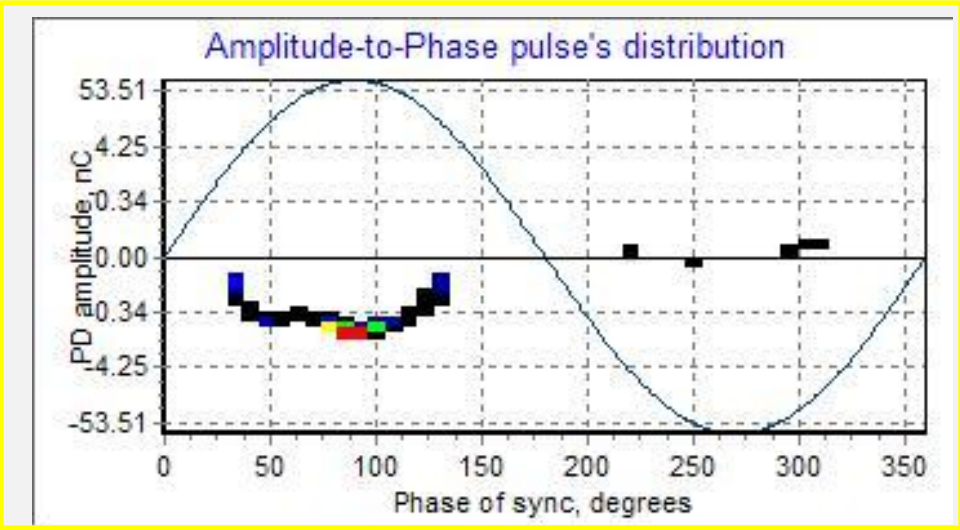
High PD level doesn't always mean failure condition. It is not the PD level, that is dangerous, but the type of the defect, that has caused the PDs. The place of the defect origin is extremely important!

For example, PDs often arise in core or in magnetic shunts of transformer equipment. Even if the level of such PDs is high, they have almost no influence on transformer operation reliability.

On the contrary, PDs of much lower level in transformer bushings can cause quick transformer failure.

The R2200 device has the functions for PD pulses measurement and functions for operative diagnostics of defect types "on site" as well. R2200 is the only device with build-in expert system PD-Expert, which allows to reveal the insulation defect type and place in automatic mode.

PRPD – Amplitude-Phase-Frequency PD Pulses Distribution



Amplitude-phase-frequency PD pulses distribution analysis is very important.

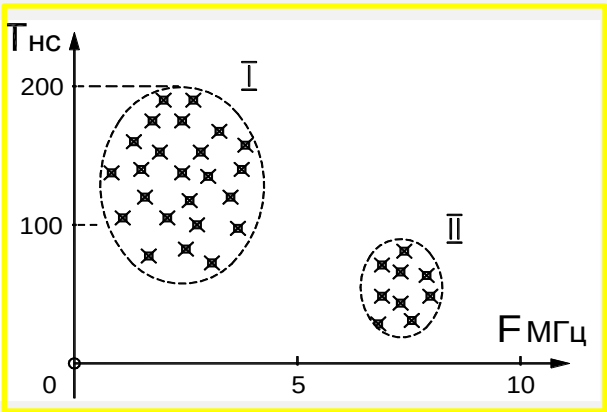
In literature it is called PRPD (Phase Resolved Partial Discharge).

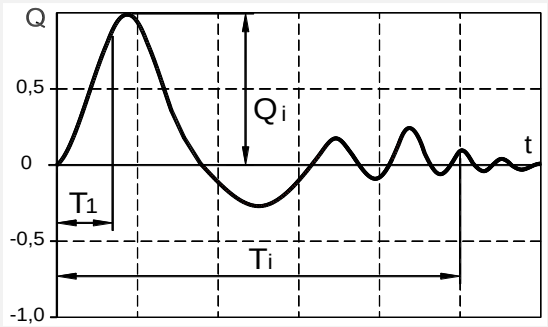
As this pulse distribution is synchronized to the sinusoid of supplied voltage, so this form of PD distribution is almost directly connected to the type of the insulation defect. That's why PRPD distribution is often called the «graph shape» of the defect type in the equipment insulation.

In the R2200 measuring device the PRPD distribution is displayed after each PD pulse measurement.

An experienced practical diagnostician can easily detect the type of insulation defect by PRPD distribution with high accuracy.

Time – Frequency Distribution of PD Pulses on TFM Plate – is the Method of Several Defects Division





The diagnostics on the basis of frequency features of every pulse is very important.

The R2200 device and PD-Expert software can analyze of frequency features of PD pulses by using time-frequency distribution.

In literature such distribution is called TFM – plate (Time Frequency Map).

The main parameters of TFM are:

- The frequency of first pulse in PD signal.
- The total duration of PD pulse detected at 5% level from amplitude.

It is possible to divide all the measured PD pulses into groups by TFM plate. The difference features of the groups are:

- The pulses arisen from different types of defects in the insulation.
- The pulses arisen from similar types of defects but in different zones of monitored equipment insulation.

5. Automated Diagnostic Expert System «PD-Expert» is the Build-in Function of the R2200

Purpose and Main Features of Expert Diagnostic System PD-Expert of the R2200 Device

The automated expert diagnostic system PD-Expert of the R2200 device is used for operative diagnostics of defects in the insulation of the monitored equipment.

The PD-Expert system solves 2 important tasks:

- the system allows reducing labor content of diagnostic works and forming reports for advanced diagnosticians.

- the PD-Expert system has the function of teaching program, which allows to reduce the number of first-level mistakes for a diagnostician of low experience, just a beginner in PD analysis.

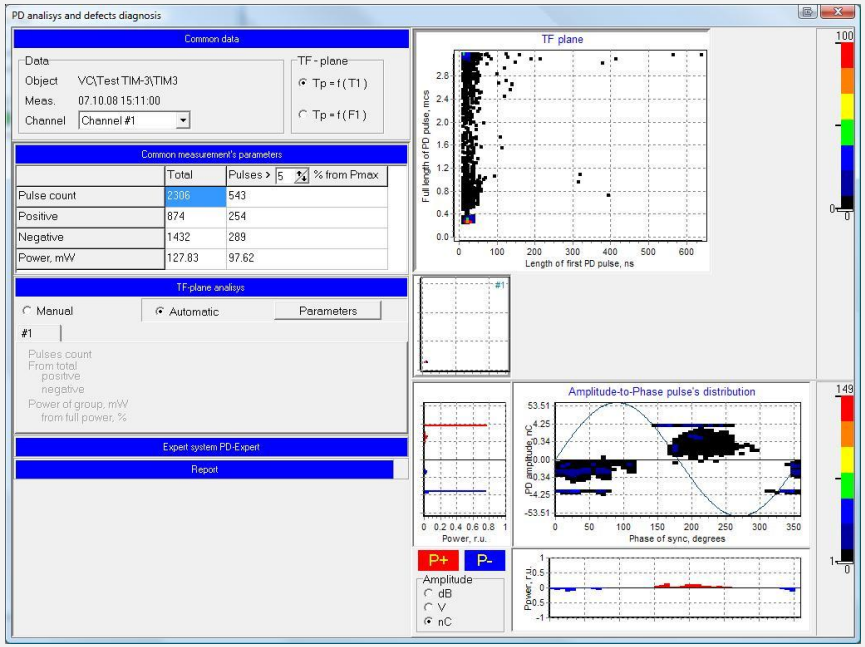
The unique features of expert system PD-Expert are:

- Realization of the system on two levels – as the R2200 device firmware (it gives a possibility for operative diagnostics) and in PC (for measurement database storage).

- Openness and adaptability of the build-in insulation defect diagnostic algorithms.

An advanced specialist always has the possibility to adjust the diagnostic rules to the features of concrete equipment. If necessary he can create his own diagnostic rules which are more effective in practice.

Measuring Data Processing Algorithm in PD-Expert Expert Diagnostic System



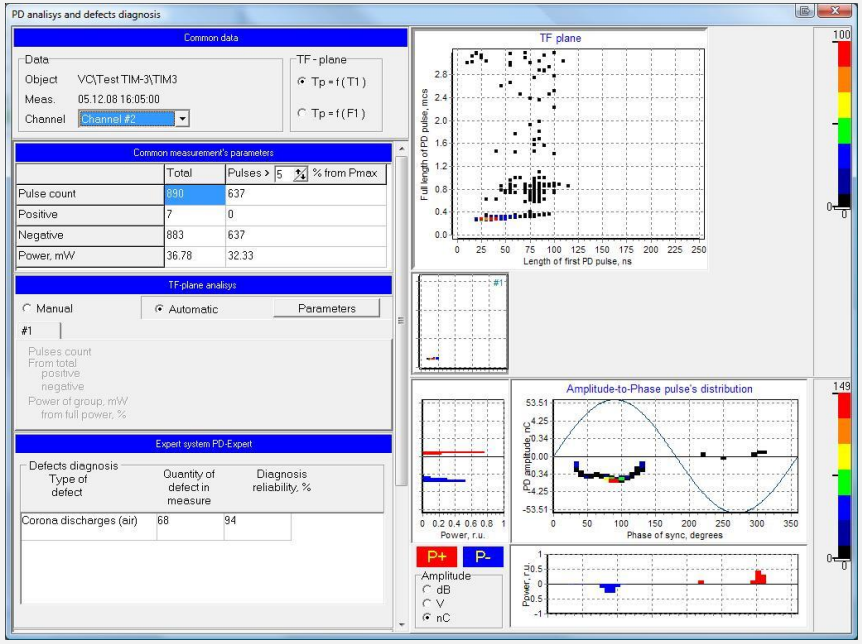
The PD-Expert software distributes all the PD pulses from one measurement at TFM plate and automatically forms the groups of identical pulses coming from different defects.

Such distribution allows to filter out the accidental pulses with untypical frequency parameters.

The PRPD distribution, which is compared to the "graph shapes" of insulation defects in program memory, is analyzed separately for each group of pulses from measurement on TFM plate. If the measured pulses coincide to it, then the pulses of this group refer to the given defect type, with reliability evaluation.

The diagnostic report about insulation defects is automatically formed by PD-Expert after the measurement is finished.

Using Algorithm Means of PD-Expert for PD and External Noises Division



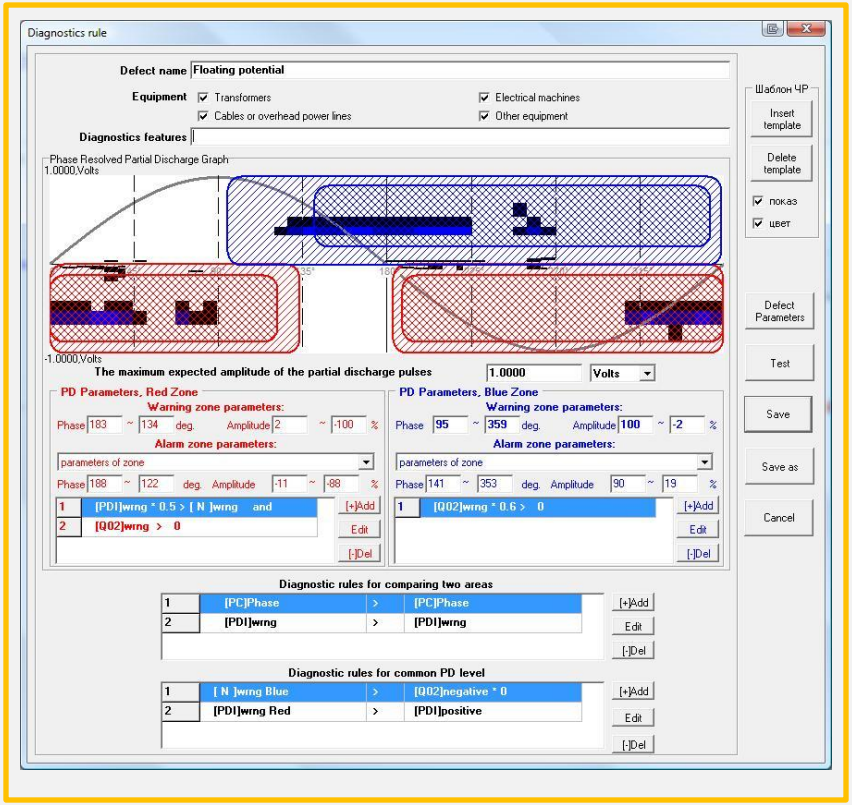
The figure illustrates that all the PD pulses are united into three groups on the TFM plate.

Only the lowest and biggest group of PD pulses corresponds to shapes of defect in the program memory. There isn't graph analogues for the two other groups of pulses, so they are the two types of external noises.

You can see from the PRPD distribution of the informative group in the down right-hand corner of the screen that these pulses are usual corona discharges.

Thus, all the high-frequency pulses measured in this example are noise pulses. These pulses are not caused by the insulation defects, and the insulation condition is good.

Means of Forming the Shapes of Defects and Diagnostic Rules for Program User



The copy of PD-Expert screen from PC in the figure shows that the User can create and correct his own diagnostic rules.

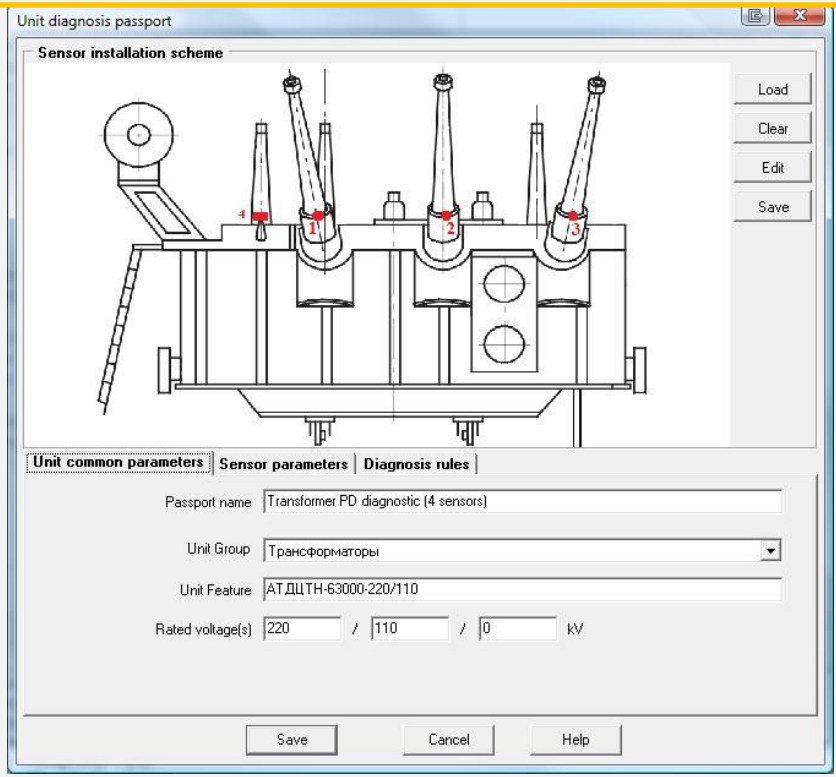
A rule can be created by the User «from scratch», or on the basis of an available rule, or on the basis of a real PD measurement in the equipment insulation.

You can distinguish 2 zones of pulses in every phase zone. These zones correspond to different levels the rules reliability.

The open possibility for the diagnostics rules correction is very valuable for an advanced diagnostician: it helps in work and allows to teach other Users, to pass the knowledge to them.

The diagnostic rules can be sent through net to other Users of the R2200 device if it is necessary.

«Diagnostic Passport» of High-Voltage Equipment is the Basis for Automated Diagnostics



The library of diagnostic rules in PD-Expert program is universal. For using some rule, add it to «diagnostic passport» of monitored equipment.

The «diagnostic passport» of equipment includes the following information:

- The places of sensors installation.
- The type and sensitivity of sensors.
- The diagnostic rules to be used.

The «diagnostic passport» is created by User and stored in the device memory. It is the algorithm program for PD-Expert system, when evaluating the insulation condition of the monitored equipment.

The accuracy of diagnostics results depended on the correctness of the «diagnostic passport».

Using the PD-Expert Expert System in the R2200 Device During Measurements

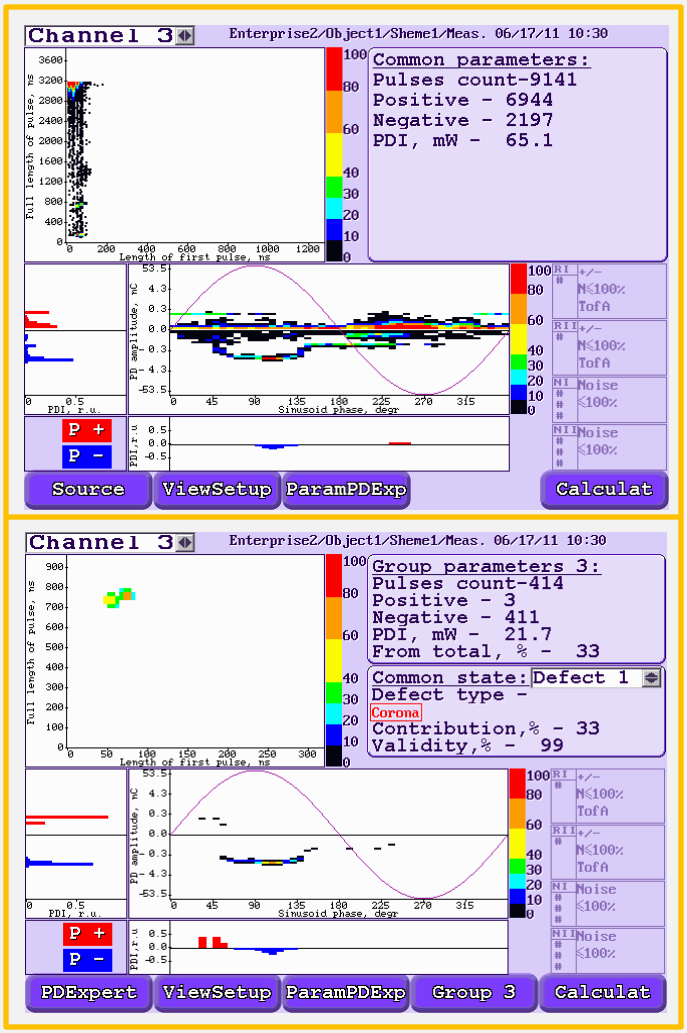
The main “place” of expert system PD-Expert operation is PC. Here the User can do all the works for creation of diagnostic rules and passports, their correction, and carry out the diagnostics itself.

The PD-Expert system is also implemented in the R2200 device software, but not to the full scale. The main reason for that is not the limited power of the device microprocessor, as it is powerful enough to run the full version of the expert system. The main reason for the limitation is the limited controls, which is the feature of any portable devices. With such controls it is impossible, for example, to create diagnostic rules.

That’s why all the diagnostic rules and passports are created on PC and are loaded into the R2200 portable device, if necessary. Then there is no limits for using them.

You can analyze the high-frequency measurement “on site”, using the necessary diagnostic rules and passports of different modifications. You can get and view the ready reports, which is very convenient.

The R2200 Device + System PD-Expert is Maximal Possibility for Noise Rejection



The R2200 device hardware ability of noise rejection + the algorithm ability of the PD-Expert = system = the unique possibility to external and induced noise rejection.

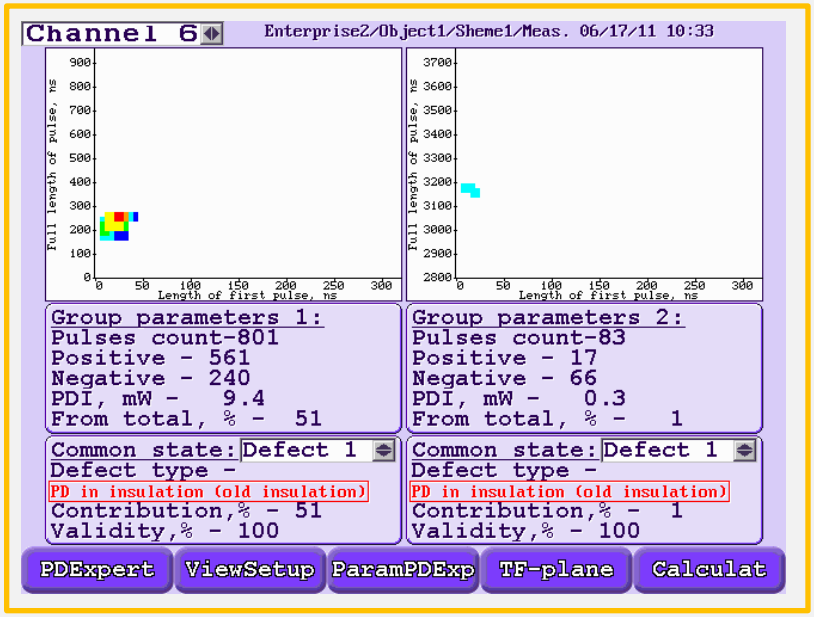
The figure illustrates the device ability for noise rejection. During measurement the following quantity of pulses have been measured:

- About 32 thousand of high-frequency pulses of different origin were measured by the device without using hardware and algorithm means of noise rejection.

- About 9 thousands pulses were stored in the device memory after switching on hardware of noise rejection.

- Only 414 informative pulses remained in the measurement after the data had been processed by the PD-Expert system.

The PD-Expert System is the Means to Separating Two Similar Defects from Different Insulation Zones



The PD-Expert system allows to separate not only different defects, but also the similar defects, which have arisen in different insulation zones of the monitored equipment.

There is the copy of the R2200 device screen in the picture, which shows the results of PD measurement analysis. The program has found two similar defects arisen in different places.

The first diagnostic defect is more developed, there is power about 50 mW; the power of the second is 1,6 mW. Thanks to the use of TFM plate, it is possible to separate the defects with the power differing more than 30 times.

In both the cases the program defines the type of defect as «PD in insulation (old insulation)». The second defect is closer to the measuring sensor, because the frequency of first pulse is higher and the full time of the whole pulse is less.

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