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Railway Catenary Insulation UV Inspection Reliability Enhancement

Reliability assurance of electrified railway catenary alongside with significant shortage of useful life of its principal elements depends to a greater extent on selection and implementation of technical servicing and repair strategy. The considerable role here is played by mobile inspection systems used for diagnostics of catenary, including technical condition assessment of insulation with a help of UV radiation [1]. Operating experience suggests the use of UV inspection systems based on bispectral cameras such as DayCorII provides the possibility to decrease insulation overlapping several times [2]. This helps substantially cut down labor, time and costs connected with maintenance and repair of electrified railway catenary insulation.

The experience connected with operation of mobile railway car based UV inspection systems shows that the main aspect of their efficiency - insulation technical condition assessment reliability - is still not high enough. This is connected for a variety of reasons having methodological, hardware, managerial and engineering nature.

UV Inspection Technique Reliability and Sensitivity

Reliability is understood as probability of inspection results to conform with real (actual) technical condition of facility [3]. This implies two errors. Error of the first kind (α) is when properly operating insulator is taken as malfunctioning (spurious defect) and the second kind error (β), when malfunctioning insulator is taken as properly operating (defect skipping). From the viewpoint of powerline reliability the most dangerous is the second kind error, which in extreme case may lead to overlapping of insulation with all the ensuing drastic consequences. However even less developed defect that is accompanied with surface partial discharge or corona, leads to electrolytic corrosion and gradual breakdown of insulation elements due to creation of nitric acid in the presence of water vapor in air. Furthermore, the presence of an electrical discharge and corona leads to power losses, generates radio frequency interference (RFI) and lowers the quality of radio communications.

The catenary insulation maintenance experience suggests that the absence of surface partial discharge or corona is one of indicators of normal condition of insulation and its manifestation, on the opposite, talks of the availability of defects or contamination of insulation.

2

227215
12
170
129
41
0
50
100
150
200
250

Number of defects

2007 2008

TOTAL Walkover Test car

Fig. 1 Number of defective insulators revealed by UV system in 2007 and 2008 at Gorky Railway Co.

Shortcomings of currently existing mobile UV systems based on DayCorII and test car cameras are connected with β errors (defect insulation skipping), and can be illustrated by the graphic chart given in Fig. 1. According to the data from Gorky Railway Co. test car inspections in 2007 revealed only 12 out of 227 defects or a total of 5.3%, and in 2008 41 defects out of 170 or 24.1%, correspondingly.

Remaining defect insulators were revealed during walkovers using standalone UV cameras.

This may be explained by objective and subjective reasons. The first group of reasons may be associated with the following: insulation viewing from a test car is performed only from one angle (rearmost side of insulators is not inspected); absence of possibility to use the UV events integration mode and signal enhancement (camera operation with decreased frequency: 0.5; 1; 1.25 sec), in connection with a test car movement at over 60-80 km/h. Subjective reasons that reduce reliability of UV inspection of insulation may include the following:

- insufficient sensitivity of DayCorII camera;

● small field-of-view angles that do not allow simultaneous observation of suspension as well as
cantilever, clamp insulation and parallel overhead lines (DPR);
● absence of possibility to immediate and adaptive fine adjustment of camera depending on external
viewing conditions;
● lack of direct digital interface;
● use of outdated software, etc.

Actual service tests of the UV system performed in 2006 have demonstrated [1], that out of 53
catenary insulation defects revealed by UV system based on DayCorII camera, contact measurements
have confirmed 52 defects or 98%. However in practice this means that only the first kind
error (α) was experimentally assessed - probability of fictitious failures. It comprised about 2%. In
order to reveal the second kind error (β) - defects skipping, it would imply in practice to check over
1,000 insulators in the field of view of UV inspection system using contact methods at the extended
catenary section. In connection with associated significant labor, time and costs this was not done
during the experiment.

The principal characteristic defining the quality of UV inspection system is its sensitivity. It is
defined by the minimal fluence of ultraviolet light E_{min} surface partial discharge or corona, which is
captured by the camera detector. For DayCorII camera it comprises $E_{min} = 3 \times 10^{-18}$ W/cm^2 when observing
insulation from the distance of 8 meters. The assessment of technical condition of insulation
and taking a decision about technical servicing and repair is done based on presence or absence of
surface partial discharge or corona. The higher the fluence of radiation and the greater the magnitude
it exceeds the minimal threshold E_{min}, the higher the probability of taking a correct decision
about technical servicing and repair of insulation and the higher is UV inspection reliability.

In order to determine the UV system sensitivity E_{min} impact on UV inspection reliability - D it is
necessary to accept it as the probability of taking a correct decision about technical condition of insulation
following inspection results. The inspection reliability is within the range: $0 \le D \le 1$ and is defined

by the sum of first and second kind errors

$D \approx 1 - (\alpha + \beta)$

Alternatively, reliability depends on the probability of finding of test parameter E in the field of admissible values:

$D \approx P(E > E_{min})$

where $P(E > E_{min})$ is the probability of finding of test parameter E in the field of tolerance limits; E, E_{min} are correspondingly the current value of fluence of ultraviolet light and the camera detector sensitivity.

In this connection E_{min} the detector sensitivity shall be lower than the threshold value, when surface partial discharge or corona is taking place. In this vein for porcelain insulation the threshold value E_{min} is defined by the minimal electric field intensity comprising 25-30 kV/cm. The test parameter E is a random value since environmental loads and intrinsic factors bear random character.

In accordance with the central limit theorem of the theory of probability, the normal probability law of parameter distribution and corresponding environmental loads are accepted. The probability of finding of normally distributed random value E within tolerance limits [3] is defined using the following expression:

P (E>E_{min}) = z dz

ZH

1 exp(2) ∫

↕

+

□

or

$P(E > E_{min}) = 0{,}5[1 - F(Z_H)]$

where F is Laplace's function. The indicated value of test parameter Z_H for the lower limit of tolerance is defined using the following expression:

$Z_H = (E_{min} - E_{cp}) / (\sqrt{2}\,\sigma_E)$

where E_{ave}, σ_E are correspondingly the current average value and the assessment of root-meansquare deviation (fluctuation) of radiation energy E. The Laplace's function value is tabulated and increasing from 0 to 1 as Z is changing from 0 to + . However, when Z=0.5 the value F (Z) $\approx$ 0.52; when Z=1 it approximately equals to 0.84; when Z=2 it comprises 0.995, and when Z=3 it practically equals to one, i.e. F (Z) $\approx$ 1.

The analysis of Laplace's function and the expression (5) shows that the probability of finding
of random value E within tolerance limits is as higher as the wider is the interval boundary (E_{ave} - E_{min})
and the lower is dispersion $_{2E}$
$\int$. In practice the radiation energy intensity E is characterized by the indirect value -UV light spot area S_{UV} on the LCD screen of camera. The practice of UV inspection of
catenary insulation shows that root-mean-square deviations S_{UV} are roughly constant and comprise
30-35%. Using the fixed value σ_E the probability of entering the unilateral interval (E_{ave} - E_{min}) of random
value E is as higher as E_{min} is lower (higher sensitivity of UV camera) and as higher as the current
average radiation energy E_{ave}.
(1)
(2)
(3)
(4)
(5)
4
The camera detector sensitivity E_{min} is the most important feature defining the interval value
(E_{ave} - E_{min}), and, consequently, the reliability of UV diagnostics D. The UV range of the electromagnetic
spectrum lies to the left of the visible wavelength between 400-200 nm. Fig. 2 shows the spectral
irradiance of corona and solar energy [4]. The latter is shown scaled 1,000 times and is
highlighted in blue. The corona irradiance spectrum coincides with the electromagnetic irradiance of
atmospheric nitrogen at its ionization. This process mechanism is shown in [1] and, in particular, may
occur as a consequence of presence of defect or contamination of insulation. As it follows from Fig.
2, the corona spectrum has two strongly pronounced superior limits falling at 340 and 360 nm.
Along with this, solar energy irradiance in these ranges is also high.
Fig. 2 Spectral irradiance of corona and solar energy
In order to have possibility to inspect an insulator in daylight modern electrooptical UV imagers
use the range 240-280 nm corresponding to what is known as Uvc range. The irradiance of sun in
this range is almost completely absorbed by atmospheric ozone molecules that enable observation

of insulation without any hindrances. In practice in order to isolate the said spectral range the special optical filter is installed before the camera UV detector (Fig. 3).

Fig. 3 Simplified schematics of bispectral UV camera: visible channel on top; UV channel on bottom; solar blind filter is circled in red

The UV detector in its turn is calculated and manufactured in such a manner as to ensure the greater spectral sensitivity exactly within the range of 240-280 nm. In this connection the maximal

sensitivity corresponds to 260 nm. Fig. 4 presents the exemplary spectral density diagram of distributed energy captured by UV detector of bispectral UV camera [4]. The energy value is shown in relative view from 0 to 1.

Fig. 4 Spectral density of energy distribution E captured by the UV camera detector according to length of wave L, μm

The simultaneous analysis of diagrams in Figs. 2 & 4 shows that the influence of solar irradiation is minimal in the camera operating range of 240-280 nm. However, the corona UV irradiation intensity is sufficiently small, particularly in comparison with that in the range from 320 to 360 nm, where the corona irradiation intensity is several times greater than in the 240-280 nm range.

At the same time, the diagram in Fig. 4 shows that the camera detector at the wavelength from 280 to 320 nm (what is known as expanded UV range of UVb spectrum) has lower, but nevertheless, well defined sensitivity. Assessment results show that with due consideration of multiple increase of corona intensity in this range, the useful signal from the camera UV detector can be amplified approximately 2-3 times as compared with the signal obtained when observing insulation in approved operating range of 240-280 nm [4]. In this connection in order to eliminate the influence of solar irradiation UV inspection shall be carried out in conditions of evening and morning twilight, and also at night using LED flashlight operating in visible range, at the wavelength of over 400 nm. In order to implement the proposed method of UV channel sensitivity increase it is necessary to make provision for automatic toggling (removal from UV channel) of the solar blind filter (see Fig. 3). Considering the fact that catenary inspections from test car, including IR inspections of hardware, assessment of contact wire position, stagger magnitude, etc., are conducted at day as well as at night, then an extension to day timeframe for UV inspection of catenary insulation seems quite logical and expedient.

The interrelation between the sensitivity E_{min} and reliability of UV inspection D may possibly be examined on numerical example. This is done by taking reference conditions for calculation of D that are specific for insulation defect at an early stage of its development. The UV detector sensitivity value is given by $E_{min} = 3 \times 10^{-18}$ W/cm^2 that corresponds to parameters of DayCorII camera manufactured by Ofil company (Israel) when viewing insulation from the distance of 8 m [1]. Let’s take the average irradiance energy E_{ave} at 10% higher than E_{min} that corresponds to operation the camera at the limit of its sensitivity. The root-mean-square deviation of energy using statistical data and operating experience shall be taken as σ_E =35%. Using expressions (4) and (5) we will get the following:

$$D = 0,5\left[1 - F\left(\frac{3 - 3,3}{3,3 \cdot 0,35\sqrt{2}}\right)\right] = 0,5[1 - F(-0,84)] = 0,605 \qquad (6)$$

In practice this means that out of 100 defective insulators in the field of view of UV inspection system most likely only 60 will be revealed. Obviously it is insufficient for maintenance of catenary insulation.

Assuming that all other things being equal, the camera sensitivity will be E_{min} =1,5 × 10^{-18} W/cm^2, i.e. it will increase twofold. Then we will get:

$D=0,5[1-F(-1,105)]=0,945$

By this means, given initial conditions, the detector sensitivity twofold increase from $E_{min} = 3 \times 10^{-18}$ to E_{min} =1,5 × 10^{-18} W/cm^2 elevates reliability of insulation UV diagnostics from 60,5% to 94,5%. In other words, 94 out of 100 defects will be revealed, i.e. overwhelming majority. From expression (1) it proceeds, that with the increase of reliability D resultant diagnostic errors are decreased

including the most dangerous for operation of catenary insulation – errors of the second kind
(β) – defect skipping, ultimately connected with insulation overlapping.
The proposed approach to assessment of reliability and enhancement of UV inspection sensitivity
contribute towards the efficiency of mobile catenary insulation diagnostics and leveling the
quantitative disbalance between defects revealed using a test car and walkovers.

Last Generation of Multispectral Electrooptical Imagers

The article referred to in [2] have reviewed principal directions for upgrading of catenary insulation
UV diagnostic system currently operated by OJSC ≪Russian Railways≫. During the last 1.5-2
years the world market of NDT/NDE instruments have seen the cutting edge mobile bi- and multispectral
UV imagers like CoroCAM and MultiCAM manufactured by CSIR-UVIRCO (RSA). Their principal
difference from the earlier generation of UV cameras like DayCorII made by Ofil (Israel) resides in
increased sensitivity, wider field of view angles, availability of advanced digital communication ports,
independence of digital recording of data from visible and audio channels. Lowered weight and overall
dimensions, low power consumption and ergonomics provide possibility to use CSIR-UVIRCO
imagers for diagnostics of catenary insulation using test car and walkovers.
Fig. 5 below shows the external view of bispectral UV camera CoraCAM504. Table 1 lists its
principal features. For comparison purposes this table shows principal features of DayCorII UV
imager. The exterior appearance of CoroCAM504 resembles a portable video camcorder. The comparative
analysis of specifications demonstrates that implementation of previously outlined sensitivity
enhancement method in CoroCAM504 gives it threefold increase in contrast to DayCorII: from
3×10^{-18} to 1×10^{-18} W/cm^2 in night mode operation. In this connection there are good reasons to
believe that reliability of diagnostics may be increased by 1.5-2 times, especially when revealing incipient
defects of insulation and operation of camera at the limit of its sensitivity. CoroCAM504 has
the field of view angle of 8×6°, expanded by 60% as contrasted with DayCorII.

Fig. 5 External view of bispectral UV camera CoraCAM504: a - front view; b - rear view

a b

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This significantly enhances the efficiency of UV system owing to increase in number of simultaneously observed insulators from the effective range of 8 m during single run of test car. Coro-CAM504 has digital interfaces USB2.0, RS232, RS485 in contrast to DayCorII, which has only analog interface. This provides the possibility to increase data throughput, eliminate the analog to digital converter (ADC) from the system, and remotely control the camera from PC for its immediate and adaptive fine adjustment depending on external viewing conditions. In addition to camera installation on test car CoroCAM504 can be independently operated for inspection of catenary insulation by walkovers. The camera has built-in digital recorder of UV, video and audio data, provides the possibility to optically zoom UV channel image.

Comparative Specifications of Bispectral UV Cameras: CoroCAM504, DayCorII, CoraCAM6D and UVolley

Specifications CoroCAM504 DayCorII CoroCAM 6D UVolley

Maximal sensitivity
at the distance of 8 m:
daytime (with solar blind filter)
night (without filter)

3×10^{-18} W/cm^2

1×10^{-18} W/cm^2

3×10^{-18} W/cm^2

N/A

3×10^{-18} W/cm^2

–

3×10^{-17} W/cm^2

–

Signal integration mode
(averaging and amplification)
available N/A

Autofocus, auto exposure available N/A

Field of view angle, degrees 8 × 6 5 × 3,75 8 × 6

Digital interface
(including remote control
possibility)

USB
RS232
RS485
N/A
N/A

N/A
USB
RS232
(remote control
optional)
N/A
N/A
N/A
Video output PAL/NTSC N/A
Audio output available N/A available N/A
Built-in digital recorder available N/A available N/A
Optical zoom:
Visible channel
UV channel
25×
available
18×
N/A
10×
available
N/A
N/A
Power supply:
AC adapter 220/7.2 V
rechargeable battery
continuous work time, hours
available
built-in Li-ion
2.5
available
external Ni-Cad
1.0
available
built-in Li-ion
2
available
4 ＡＡ batteries
0.5
Weight, kg 2.3 7.7 1.4 1.3
Overall dimensions, mm 302 × 165 × 125 275 × 175 × 180 220 × 160 × 80 280 × 100 × 70
Failsafety:
failure number / camera number
failure quota, %
1/46
2.2%
3/16
19%

These functions are not available in DayCorII camera. CoroCAM504 is more than 3 times lighter than
DayCorII. The portable Li-ion rechargeable battery installed in CoroCAM504 does not require individual
pouch with vest to carry clumsy and cumbersome Ni-Cad battery like that installed in Day-

CorII. One of the most important features of UV cameras is their failsafety and unfailing performance. The six-year operating experience of DayCorII at OJSC ≪Russian Railways≫ have shown that out of 16 purchased cameras 3 (operated at Gorky, Krasnoyarsk and Irkutsk railway companies) have failures requiring significant factory repair. Estimate of probability of failure-free operation comprises about 80% that is obviously insufficient to ensure operational integrity of catenary. Coro-CAM504 out of 46 serial units has only one minor defect, which was eliminated on the spot. Estimate of probability of its failure-free operation is significantly higher and comprises 97%. To a great

extent it is explained by the CoroCAM504 newest hardware components and cutting edge manufacturing technologies.

In spite of possibility of CoraCAM504 use to inspect catenary insulation in test car as well as in walkovers CSIR-UVIRCO offers the portable CoroCAM6D camera for stand-alone use. The camera external view is given in Fig. 6. CoroCAM6D is more convenient and ergonomical for manual operation, has foldable color LCD. The previously given table lists all its principal features. The mentioned table also includes comparative specifications of UVolley camera manufactured by Ofil company.

The comparative analysis of table data shows that the sensitivity of CoroCAM6D is 10 times (by an order of magnitude greater) higher than UVolley: 3×10^{-18} and 3×10^{-17} W/cm^2, correspondingly. It can be explained by the fact that CoraCAM6D has UV channel and detector similar in their characteristics and design to CoroCAM504 with somewhat simplified additional functions. UVolley camera has quite another design and characteristics of visible channel and UV detector, in contrast to Day-CorII, since weight and dimensions of the latter did not allow to put together the previously developed design into the new portable body. The tenfold decrease of UVolley sensitivity has limited its use to finding only developed defects of insulation of high-voltage transmission lines above 110 kV and it practically does not reveal defects in 27.5 kV catenary insulation.

Fig. 6 External view of portable bispectral UV camera CoraCAM6D: a - front view; b - rear view

The prime advantage of insulation UV inspection method by catenary walkovers as contrasted with riding inspections on test car, is the possibility to use the mode of UV signal integration (amplification and averaging) by means of its integration by UV shooting frames. In contrast to the real time operation mode with the rate of 24 fps, the camera in integration mode can work with rates like 0.5; 1.0 or 5/4 fps. As this takes place, the UV spot from surface partial discharge or corona on defective insulator indicated on LCD screen is repeatedly zoomed. While working with UV camera in standalone mode insulation defects are revealed only visually by operator, then the UV spot area size is the most important diagnostic indicator defining the UV camera resolution. Fig. 7 presents bispectral images (imposition of UV and visible images) of string with 3 insulators PF70. In the first as well as in second case the camera amplification gain is maximal (G140). Fig. 7a shows that the integration mode is toggled off (LI0S). Insulation defect is not observed. Fig. 7b shows the same amplification gain of camera (G140), the integration mode is toggled on and equals 1 s (LI1S), signal is integrated from 24 frames. The middle insulator of string distinctly manifestates UV corona in the area of defect in cement chock of insulator core.

a b

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Fig. 7 Actual illustration of integration mode operation: a - integration mode is toggled off (LI0S) and defect is not visible; b - integration mode is toggled on (LI1S), the middle insulator manifestates UV corona due to defect in cement chock of insulator core

The comparative analysis of table data shows that UVolley, in contrast to CoroCAM6D, does not have the integration mode function. In addition to low sensitivity of UVolley, more decreased LCD screen resolution of 320 × 240 pixels and its size of 3.5”, as contrasted with 640 × 480 pixels and 5.7” color LCD of CoroCAM6D, the advantage of camera manufactured by CSIR-UVIRCO becomes absolutely evident. The extensive array of digital interfaces, availability of built-in digital data recorder, optical image zooming and continuous work time make CoroCAM6D camera particularly

attractive. Primarily the camera is necessary for electrical power supply sections of railroads for large-scale UV inspections of 27.5 kV catenary insulation that cannot be observed from test car, and also for inspection of insulators of transformer and traction substations, 110 and 220 kV overhead power transmission lines.
Apart from the UV method, catenary insulation diagnostics can be performed using IR inspection [3]. Insulation resistance change, availability of leakage currents due to structural defects and contamination of insulation, lead to heating and temperature drop of individual insulator caps in string. Particularly this is true for DC catenaries, where leakage currents are several times as much as in AC catenaries. In many instances, however, temperature difference is rather small and comparable with sensitivity limit of even the most modern IR cameras.
Simultaneous implementation of UV and IR diagnostic techniques for catenary insulation has essential advantages especially when revealing defects at an early stage of development. Manifestation of surface partial discharge or corona, and also temperature differences bear random nature.
Utilization of diagnostic signals in UV and IR spectrum ranges, their correlation analysis and establishing the complex criterion of technical condition – all that contribute to increase of sensitivity and reliability of catenary insulation diagnostics. It is specifically relevant for 3.3 kV DC catenary insulation, where electric field intensity is substantially low, than for 27.5 kV AC catenary, and conditions of UV irradiation occurrence due to insulation defect are much worse. Heating of DC catenary insulators under otherwise equal conditions, is substantially higher, than for AC catenary.
Hardware implementation of both UV and IR diagnostic techniques for catenary insulation with visual assessment of its condition becomes possible with appearance on the market of multispectral MultiCAM imager manufactured by CSIR-UVIRCO from RSA. The camera external view is given in Fig. 8.

a b

Fig. 8 External view of multispectral MultiCAM camera

Unlike bispectral UV cameras, MultiCAM has 2 lenses. The top lens is made of germanium, and is purposed for viewing in IR range, the bottom lens is made of quartz for visual channel of UV and visible range. The weight and overall dimensions of MultiCAM are similar to bispectral CoroCAM504 UV imager. The characteristics of UV and visual channels are almost identical to corresponding characteristics of CoroCAM504. The IR channel of MultiCAM operates within the range of 8-12 μm, the sensitivity of microbolometer array of IR detector comprises 0.05° C, resolution is 320 × 240 pixels, and frequency is 30 Hz.

All three channels are optically coupled with high precision and have field of view angles 8×6° .

Digitized images in UV, IR, and visible ranges can be overlaid on each other in various combinations.

The camera operates from the built-in Li-Ion rechargeable battery during 60 min without charging.

The operating temperature range of MultiCAM is within the range from -15° C to +50° C. High sensitivity, advanced digital interface, built-in digital recorder of UV, IR, video and audio data, low weight and dimensions, low power consumption - all that provides with possibility to use MultiCAM for inspection of catenary insulation from test car as well as to use it for walkovers. Figs. 9, a & b give the example of multispectral inspection of 3.5 kV DC catenary insulation, which was carried out in November of 2010 in RSA. The defect of suspension porcelain insulator on IR image (Fig. 9,b) is highlighted with specific overheating (shown in yellow). In UV range strongly pronounced corona is observed, that is shown in red. The shooting of catenary in visible as well as UV and IR ranges was done from various angles. The visual inspection of insulator revealed its heavy contamination with specific traces of electrochemical corrosion in the area of cement chock of insulator core as a consequence of UV corona and creation of nitric acid. The practical demonstration of multispectral MultiCAM camera application allows to count on its successful implementation for 3.3 kV DC catenary insulation diagnostics, and also for comprehensive multispectral inspections of 27.5 kV AC catenary insulation from test car as well as during walkovers.

Fig. 8. Images showing results of 3.5 kV DC catenary insulation inspection using MultiCAM (ЮАР):
a - visual image; b - overlay of two images of defective insulator in UV and IR spectrum ranges
(UV corona image is shown in red, IR heating is shown in yellow)
a b
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Conclusions and Outlook
1. The operating experience of UV system for inspection of catenary insulation shows that the
bulk of insulation defects are revealed by means of catenary walkovers. Test car inspections account
for about 25% of the whole number of revealed defective insulators. One of the fundamental reasons
of insufficient reliability of mobile diagnostics is low sensitivity of UV system in the absence of
possibility to use the diagnostic signal integration mode during movement of test car.
2. One of the ways to enhance the reliability of UV diagnostic system installed on test car and
to lower the number of skipped defects is to expand viewable spectral range from 240-280 nm to
240-320 nm. Multiple increase of the system sensitivity in this case is reached through increase of
useful signal on the camera UV detector in connection with objective growth of radiation fluence
intensity from surface partial discharge and corona in expanded UV range of UVb spectrum. Engineering
implementation of this approach resides in automatic switching off of solar blind filter from
the UV camera visible channel. Diagnostic inspections shall be carried out in conditions of evening
and morning twilight, and also at night using LED flashlight operating in visible range, at the wavelength
of over 400 nm.
3. The hardware support of expanded spectral range is implemented in CoroCAM504 UV imager
manufactured by CSIR-UVIRCO. Its sensitivity in night mode comprises $E_{min} = 1,0 \times 10^{-18}$ W/cm ^{2}, and
it is 3 times as high as the sensitivity of DayCorII. This feature significantly increases the reliability of
UV diagnostics of catenary insulation, particularly from mobile carrier like test car. CoroCAM504 has
built-in lens with expanded field of view angles 8 × 6°. This allows to significantly enhance the efficiency
of UV inspections owing to increase in number of simultaneously observed insulators from the

effective range of 8-10 m. The camera has advanced digital interface including RS485 for its remote control from PC, built-in digital recorder of UV, video and audio data. CoroCAM504 is highly reliable, energy-efficient and ergonomical. The camera features fully comply with all the requirements to UV inspection system upgrade [2].

4. Inspections of insulators of transformer and traction substations, overhead power transmission lines that do not appear in the field of view during test car rides are done during walkovers. The most practical solution here is to use portable CoroCAM6D camera. It has the same basic features of CoroCAM504 and somewhat simplified interface. Contrary to UVolley camera made by Ofil, Coro-CAM6D has greater sensitivity, optical zoom, signal integration options, audio recoding function, 4 times greater independency in power supply. All these make CoroCAM6D the most preferable for common use in diagnostics of railroad power supply network. In addition to that, the camera has relatively low price substantially depending on serial procurement scale.

5. Multispectral MultiCAM camera incorporates UV, IR and visible digital channels. The features of MultiCAM currently make it potentially the only possible mobile instrument for diagnostic of 3.3 kV DC catenary insulation. The practical demonstration of its capabilities is shown by the example of inspection of suspension porcelain insulator of 3.5 kV DC catenary in the RSA. The increase of number of high speed railroad lines with DC catenaries in the network of OJSC ≪Russian Railways≫ gives ground to consider the use of MultiCAM for insulation diagnostics particularly topical.

6. Contrary to DayCorII and UVolley cameras, cameras like CoroCAM and MultiCAM have extensive array of digital interfaces that allow taking the UV diagnostic system to a new software and algorithmic level. This provides the possibility to eliminate the analog to digital converter (ADC) from the system, to increase operation speed and reliability of automatic UV measurement data processing software. This limits participation of operator in manual time-consuming and lengthy processing workflow of considerable volume of diagnostic data.

7. Implementation of the proposed technique with application of reviewed UV diagnostic devices
will contribute to further enhancement of reliability and efficiency of operation of electrical
equipment insulation in power supplying facilities of OJSC ≪Russian Railways≫.
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