Protective Measures against Hazardous Contact Voltage – Course: Basic Skills and Knowledge of Electrical Engineering. Methodical Guide for Instructors

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Methodische Anleitung für den Lehrenden
"Schutzmaßnahmen gegen zu hohe Berührungsspannung"

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1. Aims and Contents of Practical Vocational Training in the Field of "Protective Measures against Hazardous Contact Voltage"

At the end of the training in these lessons the trainees must have reached the following objectives:

– The trainees have acquired the necessary knowledge and skills in the field of protective measures against hazardous contact voltage.

– The trainees are able to make practical use of the respective protective measures when working at electrical plants.

– The trainees are able to check the protective measures installed.

– The trainees observe the regulations on industrial health and safety.

In order to reach the required goals, the instructor must impart the following contents:

Knowledge

– Necessity of taking protective measures against hazardous contact voltage.

– Subdivision of the protective measures against hazardous contact voltage.

– Criteria of the individual protective measures.

Skills

– Putting into practice of protective measures at devices or electrical plants.

– Checking of the protective measures installed.

2. Organizational Preparation

In order to guarantee that the instructions and exercises go off smoothly, the training should be well organized.

This comprises the following steps:

2.1. Preparation of the Instruction about Industrial Health and Safety

Before starting the exercises, a brief instruction should be given about the proper use and handling of the working means and how to avoid accidents.

As a proof of these instructions on industrial health and safety standards it is recommended to keep a book in which all instructions on accident–free working and proper use and handling of working means are entered in brief outlines.

The trainees confirm by signature that they were taught.

The following hints should be included:

– Every work in and at electrical plants has to be carried out in dead condition.

– The dead condition has to be checked with the help of testing instruments.

– Make sure that the plant is not reconnected by other people.

– If test work is necessary in alive plants, there must be one supervisor to look after the person carrying out the work.

– All works in connection with protective measures have to be carried out especially carefully.

– How to act after accidents caused by electric current.

Perhaps further hints on industrial health and safety are to be given according to the local requirements

2.2. Preparation of the Teaching Aids

For theoretical instruction, the trainees should have a writing place. Recommendable is a room equipped with blackboard, desks and electric connection.

If instruction takes place in the workshop or at the workshop place, clean pads should be put on the working tables for the trainees to put their papers on and take notes.

For demonstration purposes, a working place with the following equipment should be prepared:

On the necessity of taking protective measures:

Devices and parts of plants showing

– natural ageing
– destruction due to inexpert use
– premature ageing caused by the influence of moisture, chemical gas, vapours etc.

Illustrations showing people who had accidents caused by lacking or not functioning protective measures.

On potential equalization:

Here, the thing to do would be on the spot to show plants and parts of plants which require the measure of potential equalization or where potential equalization has already been created.

On the individual protective measures:

- Visual aids from which the mode of functioning can be seen.
- Equipment and accessories required to put the individual protective measures into practice.
- Also here, it would be convenient to show the respective plants on the spot.

The "Trainees' Handbook of Lessons" – protective measures against hazardous contact voltage has to be destributed according to the number of trainees.

Tables and switching diagrams are drawn on the blackboard before the lesson begins.

2.3. Preparation of the Working Means

As a theoretical basis of the exercises to be carried out, the "Instruction Examples for Practical Vocational Training/Protective Measures against Hazardous Contact Voltage" are to be distributed according to the number of trainees.

The material required for the exercises has to be prepared and laid out ready in sufficient quantity and/or number according to the instructions given in the "Instruction Examples...".

Each trainee must have his own place to work and exercise.

2.4. Time Planning

Starting from the total number of teaching hours, the times for the individual sections of this lesson should be planned separately.

Time planning is recommendable for the following sections of training:

- For the introduction into each respective working technique in the form of an instruction.
- For necessary demonstration.
- For task–related instructions in preparation of the exercises.
- For the carrying out of the exercises.
- For recapitulations and tests.

In addition, the following factors should be taken into consideration:

- The education level of the trainees.
- The training conditions.
- The future job of the trainees.
- The degree of difficulty of the respective section of training.

In each section of training, main emphasis should be put on the aquisition of abilities and skills by practical exercise.

If – in spite of good planning – it commes to waiting periods for the trainees, these should be filled by appropriate tasks such as the preparation of materials for exercises.

3. Recommendations for Practical Vocational Training in the Working Techinques of "Protective Measures against Hazardous Contact Voltage"

The following sections give suggestions as to how the instructions, demonstrations, exercises and checks can

be organized.

3.1. Introductory Instructions, Demonstrations and Exercises

The respective instructions on each working technique can be held in a teaching room. During these instructions, make sure that the trainees write down additional remarks or answers in the "Trainees' Handbook of Lessons". The "Trainees' Handbook of Lessons" is structured correspondingly to the introductory instruction. The main points have to be imparted. A precondition for learning the working techniques in the field of "protective measures against hazardous contact voltage" is that the trainees are able to lay cables, to install and connect devices and to carry out testing and measuring work. In imparting the above mentioned knowledge, therefore, these working techinques have to be refered to in the form of a repetition.

The "protective measures against hazardous contact voltage" should be imparted by making intensive of use all available teaching aids as well as practical experience on the spot.

Necessity of taking protective measures against hazardous contact voltage

In order to make the trainees aware of the necessity of taking protective measures against hazardous contact voltage, their attention should be drawn especially to the protection of human life, health and labour as a basic human concern. It presents itself in this context to point to the harmful effects of electric current on human organism.

In support, the representation of the sensation measurements with passing of alternating current may be used which is contained in the complex material "How to Act after Accidents Caused by Electric

Current". Also it can be dealt with known electricity−caused accidents due to inexpert installation or defective protective measures. With the help of examples, the trainees should be made aware of the importance of working carefully, reliably and free of faults.

It should also be mentioned that the manufacturer of electrical devices, motors, cables etc. is obliged to insulate them for the respective working voltage.

Protection of man has priority over functioning of any electrical device!

Potential equalization

Here, the instructor together with the trainees should repeat the factors which may lead to the destruction of the insulation. Furthermore, the trainees must realize that by insulation defects voltages may be transferred to metallic parts that do not belong to the service circuit. Also it must be made clear that the thus created potentials between the metallic parts are dangerous for man. Starting from this, it is explained to the trainees how potential equalization and zero potential are created.

Therefore the knowledge of the zero potential the trainees have already acquired should be used. It is of paramount importance to draw the attention to the point that counting devices and plastic parts (non−conducting materials) in pipe systems have to be bridged.

The potential equalization must not be interrupted by the removal of certain parts.

Protective measures against hazardous contact voltage

Here, it is started from the fact that in electrical plants – except test and pilot plants – protective measures against hazardous contact voltage are required.

It is also important to explain to the trainees the division of the protective measures in two groups as well as the possibilities of further subdivision.

The fault−current circuit (Fig. 3 of the Trainees' Handbook...) should be explained in detail to the trainees with the help of a blackboard drawing or projected diagram, because the fault−current circuit is the basis of the understanding of the individual protective measures.

Protective insulation

In explaining this protective measure, special emphasis should be put on the following points:

– forms
– fields of application
– testing.

The criteria have to be mentioned and demonstrated by appropriate examples.

For the chapter of testing, the complex material of "Testing of Electrical Plants" may be used. Do not forget to point out that defects of the protective insulation must not be repaired by provisional mending.

Defects are repaired only by replacing the original parts.

Protective low voltage

Point out to the trainees that this is the most effective and safe protective measure. Its application is limited, though. This results from the reduced rated voltage and the involved operating currents which – with equal transferred power – are approximately 5 to 10 times greater than, for instance, with 220 V alternating voltage. For the trainees it is important to understand from this that for the low voltage plant and the service equipment required essentially greater conductor cross sections are necessary.

Protective low voltage plants are operated only up to approximately 4 kW.

Then, the criteria, required devices and fields of application are explained.

Plants of this kind, if available, should be demonstrated. Also give demonstration of inspection and measurement. If possible, the trainees should practise this at the plants shown to them.

Protective isolation

Before explaining the main points of this protective measure, repeat the therm "galvanic isolation" together with the trainees.

Input and secondary end of the devices that create the protective isolation must be connected with each other only through the magnetic flux. There must be no current–conducting connection.

After this, the fields of application are deduced. Underline why not fault current cant flow with the protective isolation because of "non–earthing". Explain to the trainees what measures enable the operation of more than one electrical device with this protective measure. (Potential equalization leads and common base.)

Lacking potential equalization leads and the existence of two faults at different conductors of the supply line may lead to a dangerous contact voltage.

Protective conductor system

Here, the criteria and conditions of this protective measure should be dealt with first. Then, the mode of action is explained, which may be repeated by some trainees. The fields of application should be determined together with the trainees. Point out the high degree of safety of this protective measure. As the reason of this mention the great extent of this measure.

Also, demonstrate the testing of this protective measure. Demonstration should be followed by the trainees exercising the testing.

Protective earthing

The mode of action of the measure of protective earthing is explained for both possibilities:

– closing of the fault–current circuit by the ground and
– closing of the fault–current circuit through the water pipe system.

For this purpose, prepare appropriate diagrams on the blackboard. Then, explain the criteria of the measure of protective earthling and demonstrate one calculation of the protective earthling resistance for the two possibilities, each.

When explaining the fields of application of the measure of protective earthling, make sure that the trainees understand that this measure has some disadvantages, though. When coming to the testing of the protective measure, explain to the trainees, that at first the earthling resistance has to be calculated and then checked by measuring.

Connection to neutral

This protective measure can be elaborated together with the trainees on the basis of Fig. 11 of the "Trainees' Handbook of Lessons".

In doing so, the difference to the measure of protective earthling must become clear.

Most of the criteria of this protective measure, tool, can be found out together with the trainees with the help of the illustration. The rest of the criteria is explained by the instructor.

Then, the fields of application and the testing of this measure are dealt with.

In the context of this protective measure, put the main emphasis on the explanation of the following points:

– If the conductors are very long, the resistance has to be kept as low as possible. (This is achieved by earthling the neutral conductor at the network ends).

– The neutral conductor must not be fused or separately switched.

– This protective measure becomes inefficient, if too strong fuses are used.

– In the case of fracture of the conductor before the plant, all casings of the devices that are switched on carry the full mains voltage in the absence of potential equalization.

Fault–voltage protective system

To explain the mode of action of this protective measure, a blackboard diagram for projection may be prepared, too.

Fig. 12 of the "Trainees' Handbook of Lessons" would also be suitable. It is also important to show a foult–voltage protective switch and demonstrate its mode of action.

This is followed by the explanation of the criteria and application of this protective measure.

In doing so, put special emphasis on the following points:

– The resistance of the auxiliary earthling must not exceed a certain maximum admissible value.

– The cross section of the protective conductor must not be less than a definite value.

– Testing of the serviceability.

– Measuring the resistance of the auxiliary earthling. (Therefore, use the Fig. 13 of the "Trainees' Handbook of Lessons". It is suitable to support the explanation of the measuring circuit.)

Fault–current protective system

For explaining the mode of action start from the fact that with normal operation the sum of all conductor currents including the neutral conductor amounts to zero.

(Unequal intensity in the external conductors is of no importance in this respect!)

Only if a fault current flows, the total of these currents is unequal to zero and the protective system comes into action.

While afterwards the criteria and application of this protective measure are elaborated with the trainees, it is absolutely necessary to calculate an example of the resistance of the protective earthling system.

Whit this protective measure, too, the functioning of the protective system has to be demonstrated and then practised by the trainees.

Put special emphasis on the following points:

– Fault–current protective switches are manufactured, for instance, with rated fault–current intensities of 15 mA, 30 mA, 80 mA, 100 mA, 200 mA, 300 mA and 500 mA.

– The fault–current protective system can be combined with the connection to neutral.

– Switches are manufactured for rated current intensities up to 80 A. (Beyond this limit, they are used in combination with transducer cores, trip coils and contactors.)

– The fault–current protective system needs a good insulation value. (Otherwise, currents caused by insulation damages lead to the switching off.)

– The fault–current protective system may also be used in three–phase systems without earthed net point.

Isolating fault–current protective system

In explaining this protective measure, start from the fact that its mode of functioning is similar to that of the fault–current protective system.

In contrast to the fault–current protective system, this system is operated with the help of an isolating transformer the neutral point of the secondary side of the transformer being earthed over a coil.

In elaborating the criteria of this protective measure, special value should be attached to the breaking fault current, the resistance of the protective earthling and the insulation resistance between conductor and protective conductor as well as to the capacity between conductor and earthling.

The functional testing has to be demonstrated especially carefully because, for this purpose, the input end of the isolating transformer has to be disconnected from the supply system.

It is not allowed to work at the alive system, except for certain special conditions and observing all required protective measures.

3.2. Recommendations for Working with the Instruction Examples for Practical Vocational Training

In the instruction examples, the sequence of operations including a diagram is to be found. Furthermore, they contain a list of the materials, working tools, testing and measuring tools, auxiliary means as well as basic knowledge required for each instruction example. Appropriate comments are made to the sequence of operations in order to provide the trainees with all the information they need to fulfill their tasks orderly and taking into consideration the respective protective measures. When organizing the work with the instruction examples, the following hint should be heeded:

– The trainees shall carry out the tasks of the instruction examples by themselves.

This enables the instructor to watch the work of each trainee, to correct it and to assess them justly.

3.3. Examples for Recapitulation and Tests

For consolidating and testing the knowledge and skills acquired, questions are composed in this section.

To each question the respective answer is given.

Questions contained in the "Trainees' Handbook of Lessons" are marked with the letter "A".

1. What is the aim and purpose of protective measures?
(Protection of human life, health and ability to work)

2. Why is it necessary to take protective measures even if cables, electrical devices and plants are sufficiently insulated?
"A" (Natural ageing, destruction due to inexpert use, premature ageing by climatic influences and chemical effects may lead to dielectric breakdowns that make conductive parts alive.)

3. Why must the potential equalization not be broken when certain parts are removed?
(Because in this case a potential may be created which, when bridged by the body, may cause a mortal current flow.)

4. How can a potential equalization to zero potential be achieved?
"A" (When all metallic parts, such as water pipes, gas mains, central heating, metallic sheathings of cables and other metal constructions, are connected with one another and with the ground in a conductive way.)

5. What line cross–sections should be used for potential equalization?
"A" (10 mm^2 copper, 25 mm^2 aluminium, 50 mm^2 steel.)

6. Where is the protective insulation preferabely used?
"A" (household appliances/except thermal appliances, cosmetic and massage as well as do–it–yourself equipment.)

7. Where is the protective low voltage used?
"A" (Electrical toys, cosmetic and massage appliances without protective insulation, inspection lamps and electrical tools for boiler and large pipe systems, vibrating devices.)

8. Where is the protective isolation used?
"A" (In all plants and pans of plants in which especially great danger may be evoked by contact with large metallic constructions, furthermore, for operating physiotherapeutical equipment for medical purposes as well as for shaving sockets in washrooms of passenger trains.)

9. Where is the protective conductor system used?
"A" (In factories where the failure of one machine leads to a disturbance of the entire manufacturing process; with electrical plants in operating theatres; in miming.)

10. What value must the test resistance of a protective conductor system have with a mains voltage of 220 V?
"A" (5.5 kiloohms)

11. Where is the protective earthling used?
"A" (Mainly in all nets which cannot be connected to neutral.)

12. Why can the protective earthling give a limited protection only?
(Because the earth transistor resistance – due to climatic influences – is subject to fluctuation; because the required earthling resistances are difficult to achieve; because the single–pole switching–off of three–phase current consumers may cause defects at these consumers.)

13. Where is the connection to neutral used?
"A" (In all nets with sufficiently earthed neutral conductor/zero conductor; because of the simple and cheap application in all fields of electric current.)

14. Why does the protective measure of "connection to neutral" become inefficient if a too strong fuse is connected before?

(The defective external conductor does not switch off quickly enough so that the fault voltage remains at the defective equipment.)

15. Where is the fault−voltage protective system used?
(In order plants, where it has not yet been replaced by the fault−current protective system. By fault−voltage protective switches, neutral conductors can be controlled.)

16. Where is the fault−current protective system used?
"A" (It can be installed in all electrical plants with three−phase or alternating current and can be combined with the protective measure of "connection to neutral".)

17. Where is the isolating fault−current protective system used?
"A" (Mainly in ship building.)