Analyses of the Probability of Expose to Dangerous Voltage During Manipulations in the HV Substations

Mito G. Zlatanoski[1] and Atanas M. Iliev[2]

Abstract: **Probability of expose to dangerous voltage in HV substations is very important for precise risk level from fatal electric shocks estimation. In this paper is shown a method for probability calculation which is applied on some practical examples: substations 110/X kV in Skopje, Macedonia. Some results obtained from observation concerning manipulation are also presented.**

Keywords: **HV Substation, Manipulation, Dangerous voltage, manipulation**

1. INTRODUCTION

The risk from accidents from fatal electric shocks is very significant, quantitative indicator for the level of human's exposure to the dangerous in substations. It's defined as a total probability a person to be injured from fatal electric shock in electric substation during one year. We distinguish:

- Risk from accident in a substations with automatic switch off of the faults, where time duration depends on relay protection settings.
- Risk from accident in a substations without automatic switch off of the faults (unlimited duration of the electric shocks).

There are a number of papers which deal with this problem from theoretical point of view. In the past very thorough models for the risk of electrocution associated with the towers of transmission lines [2] and substation [3] have been developed by applying Monte Carlo simulation and analytical approaches. A detailed model for prediction of potentially critical faults for high voltage substations as well as probabilistic model for the shock impact on the electrocuted person have been suggested [4] based on experimental data, analyzed and interpreted according the IEC [5]. In all of these aforementioned approaches, only a general and rough guess is made for the presence and behavior of the persons within the potentially critical area around electric power installations.

In this paper are shown results from investigation undertaken for more precise determination of the probability of the human exposing to the dangerous during manipulation in HV substations. The data have been collected by intensive observation in many high voltage substations 110/X, in the Republic of Macedonia [1].

[1)]Mito G. Zlatanoski is with Faculty of Electrical Engineering, Karpos b.b. P.O. Box 574, 1000 Skopje, Macedonia, E-mail mitzar@cerera.etf.ukim.edu.mk

[2)]Atanas M. Iliev is with Faculty of Electrical Engineering, Karpos b.b. P.O. Box 574, 1000 Skopje, Macedonia, E-mail: ailiev@ieee.org.

II. EXPOSURE TO DANGEROUS VOLTAGE DURING MANIPULATIONS

In a process of exploitation of the high voltage substations, very often, there are real needs people to entrance in the substations area. Thus, the people who are involved in the process of exploitation are exposed to the dangerous touch and step voltages.

Depending on the activities that people performed in the substation area, the entrance may be undertaken from different reasons, such as:

- Making visual inspection of the installed electrical equipment,
- Realizing manipulation with the equipment,
- Maintenance of the equipment,
- Repairing,
- Testing the functionality of the equipment,
- Measurement e.t.c.

All of those activities are performed by well-educated people, composed from engineers and technicians. They belong to competent team, well informed about all the danger that may occur in high voltage substation surroundings.

The numerous entrances in the high voltage substations are noticed by non-competent people like mechanics, craftsmen, or by students or pupils during theirs common visit in educational purposes. These types of events are unpredictable and undefined and they can be taken in account only if the exact evidence for a long time of period, for particular substation exists.

Personal entrances in the high voltage substation depend on the degree of automation of the elements installed in the substitution, as well as on correct operation of the circuit breakers and disconnectors. In the case of the manual operation with the equipment, the number of the entrances in the area of the substation is much bigger and depends on the number of operation that must be realized.

The time of presence in the potentially danger usually depends on the place where the disconnectors are installed. It's very important for a worker to know the shortest way to the disconnector in order to realise the manipulation.

Also it's very important to mention that the person who should realise manipulation with the commutation equipment, every time has a touch, and he is exposed to risk. The duration of the presence and the duration of the touch depend on the skills and efficiency of the workers. These parameters could be well estimated, with high degree of accuracy, from practical experience.

Today, the high voltage substations are full automated and all switching operations are realised by remote control. Manual switching operations are performed only in accidental cases. Thus, the attendance of the personal in the substation is

insignificant. The duration of this attendance could be calculated if the probability for disfunction of the disconnectors (unsuccessful switch off and switch on operation) and the mean time of one manipulation are known.
The number of manual manipulation with particular disconnectors in high voltage substation could be identified from evidence of switch off and switch on operation from a long time of period. The location of the isolators for all isolators (with or without blades) in each particular substation is well known. In addition, it's well known that the trajectory which the workers have been used to come to the place where the disconnectors are installed, every time is almost the same.

Consequently, the time needed for transition of the particular trajectory may be easily estimated. Thus, the total time of presence in substation area consists of:

- Arriving time,
- Time for realisation of manipulation (time with touches), and
- Time for back, which is equal with time of arriving.

This process could be modelled by the following equation:

$$t_{\Sigma} = 2t_p + t_d \tag{1}$$

where:

t_{Σ} - total time

t_p - time for arriving to particular disconnector,

t_d - time duration of the undertaken manipulation,

Mean time of presence in substation area during the manual manipulation, in particular HV substation is:

$$\overline{t_m} = \frac{\sum_{i=1}^{r} n_i t_i}{n_m} \tag{2}$$

where:

r – number of disconnectors,

n_i -expected number of manipulation with the i-th disconnector from time of one year,

t_i - time duration of the manipulation with the i-th disconnector,

n_m - total number of the expected manipulation with all disconnectors in the particular substation from time interval of one year.

The total time of the supervisor personnel presence in high voltage substation for one year is:

$$T_m = \overline{t_m} \cdot n_m \tag{3}$$

Probability of exposure (λ_m) to the dangerous step voltage of the supervisor personnel is:

$$\lambda_m = \frac{T_m}{T} \tag{4}$$

where is:

T_m - total time of the presence in the dangerous zone of the HV substation,

T - duration of the analyzed period (one year).

The probability of expose (λ_{md}) to the dangerous step voltage of the supervisor personnel could be calculated by the following formula:

$$\lambda_m = \frac{T_{md}}{T_m} \tag{5}$$

where is:

T_{md} - total time of touch during manipulations for one year $(T_{md} = n_m \overline{t_{md}})$,

T_m - total time of the presence in the dangerous zone of the substation during manipulation,

t_{md} - mean time of a touch during one manipulation

In this investigation, we consider, according to our experience and data from literature, that mean time of touch for one manipulation is 5-8 s

III. Analyses of the probability of the expose to dangerous in substations 110/x in Macedonia

In order to collect relevant data, the authors have been realised a number of observations in many high voltage substations 110/x in the Republic of Macedonia. In these investigations the following parameters were measured:

- Time duration of the movements of the personnel,
- Number of the touches, and
- Time duration of the touches.

In this paper, with the proposed methodology is performed calculation of the parameters of probability of expose on fatal electric shock during manipulation, classified by functions and elements. The results from calculations are shown in Table I and Table II.

TABLE I
RESULTS OBTAINED FROM OBSERVATION DURING TOUCHES REALISED THROUGH MANIPULATIONS IN SUBSTATIONS 110/X KV

		n_d	t_d(s)	t_{d1}(s)
1.	Switching off of the disconnectors in connection bay	4	27	6.75
2.	Switching on and switching off operation in transformer bay	7	39	5.57
3.	Switching off of the line isolator	4	32	8.00
4.	Checking of the circuit breaker closing	5	25	6.00
5.	Checking of the isolator closing	6	46	7.66

where:

n_d - number of realised touches;

t_d - time of touches during manipulation by element;

t_{di} - time of one touch;

TABLE II
RESULTS OBTAINED FROM OBSERVATION DURING WORK ON SPECIFIED ELEMENT IN SUBSTATIONS 110/X KV

	Element	n_d	t_p(s)	t_d(s)
1.	Isolator	34.20	4248	367
2.	Circuit breaker	24.63	3852	173
3.	Current transformer	25.05	6674	160
4.	Voltage transformer	11.67	2516	52
5.	Lighting arrester	5.49	1209	24

where:

n_d - mean number of realised touches during work on a particular element (for all three poles)

t_d - mean time of touches during work on specified element (for all three poles)

t_p - mean time needed for work on the specified element (for all three poles).

The values shown in Table I and Table II are obtained from measurement realised in a long period of time. We have to outline that the results will be more precise if the number of investigated substations is bigger.

Our opinion is that the presented results give real image of the condition of the worker taking into account the manner and the mentality of the technical team established for maintaining of the high voltage substation in the Republic of Macedonia.

Furthermore, the risk level is calculated associated to touch and step voltage during manipulation and maintenance.

Thus, the risk level inside HV substation from touch voltage is: $7{,}60 \cdot 10^{-11}$ for manipulation and $8{,}09 \cdot 10^{-11}$ for maintenance work. The total risk level from step voltage (both manipulation and maintenance work) is estimated to $1{,}13 \cdot 10^{-14}$.

IV. CONCLUSION

In this paper, a method for calculation of the probability of expose on danger during manipulation in HV substation is presented. The method is based on collecting real data by observation of the real HV substation in Macedonia.

In order to obtain more precise results of the relevant parameters, the procedure of measurement and collecting date must continue. Moreover, including bigger number of substations in the process of observation will be very useful for providing more confidential records.

The results from this investigation are very useful for assessment of the risk of fatal electric shocks in high voltage substations. Such results could be also helpful for an adequate evaluation of the related safety standards and current engineering practice.

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