AUTOMATED DC SUBSTATION SHORT-CURRENT EVALUATION

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Summary Technical praxis has no easy-to-use standardized method for a DC short-current evaluation. For a correct rating of rectifying blocks (diodes) and input and output current-carrying cables is need to know short-current parameters. The current flow in the substation is derived by commutation of rectifying blocks, which define current of transformers and DC part. For evaluating exists a semi empiric formula, that has a delimited relevance to small power range up to 50 kWatts of output power. New way of evaluation of short current is based on simulation of simplified substation model using the capabilities of DYNAST simulation program, or other dynamic equation solver based on numerical method, like Matlab.

1. INTRODUCTION

The rectifier of converter substation is nonlinear system. With magnitude of the DC current sink is shifted shape of current demanded out of AC net. In normal operating mode is current taken from AC net closely cutting out from a half-period of current waveform. At the short are the sharp transition changed to slow transition, until case, where current demanded by substation from net, in principle sinusoidal. It's a case of short directly in the substation, or in the immediate proximity of substation. In this case is short-current magnitude approximately equal to the value of short-circuited current AC part behind the transformer.

For a rating in design process of substation components is need to know concrete values of short circuit time, maximum current and 20 ms effective current, or Joule's integral I^2t of a substation particular components.

Because the substations have in principle similar wiring diagram, there is suggesting automating whole process by the help of computer program, which will derive benefit of numerical simulating program as internal solver. The designer enters necessary parameters, like as net parameters, parameters of transformer, rectifying blocks and the AC line parameters. System put together simulation formulas and performs a solution and interpretation of results. For simulation is not necessary knowledge of wiles of a numerical method, that is used for a simulation.

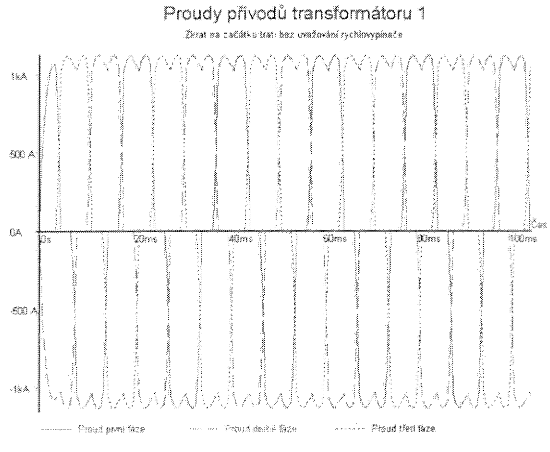

Fig. 1 : Normal substation run

2. THE MODEL

The model is most important section for a simulation. Model of substation is rising from real schematics. Simplification ratio is growing out to maximal error 5 % at short without a cut-off of DC circuit breaker (CB). This error ratio allows solve a magnetization inductivity of transformer by estimation out of transformer power and allows to use simple diode approximation by fractional line too. If analysis of circuit with switch-off with high speed DC circuit breaker is performed, the simulation is more complicated. Large diffusion of values of arc voltage curve at cutting-off process doesn't allow adjust quite accurately model parameters. The manufacturer describes only maximal over voltage that can arise in switch-off process. This parameter is in principle overestimated, to prevent failure of insulation co-ordination in circuit of converter substation. That is a reason, why is more suitable to use a switch-off voltage estimation from a design of an extinguishing chamber.

3. HIGH-SPEED DC CIRCUIT BREAKER

For a CB with a metal splitter plates chamber (deion plates) is possible to estimate the value of arc voltage according to number of arcing chamber metal plates. Voltage per one-plate amounts according to shape and material of plate roughly 16-18 volts in a large range of current.

For chambers with non-conducting barrier we have no reference with manual or measured data. Value of arc voltage is given by the arc length in chamber and depends on the material of barrier that is vaporized in contact with hot plasma.

Generally, we can suppose, that a cut-off voltage at contactors of CB within the range aprox. 1.2-1.5 times nominal voltage of CB.

By reason of following inaccuracy, it is impossible to calculate analysis accurately. The toleration of analysis with a switch-off CB process is in divide ± 20 %.

4. FUSES

If is available a current waveform in a given place of circuit, it is possible to derive behavior of fuse, that is in this place inserted, from a Joule's Integral (I^2t).

Shorts over 10-times of nominal current of substation are switched-off in process of time shorter than 40ms. Cut-off state of fuse is possible decide from an I^2t value of a fuse. The fuse began switch-off, if fuse strip obtain a thaw I^2t. I^2t thaw in fuses for a semiconductor protection is aprox. in range $I^2t_t \in \langle 0{,}45;0{,}5\rangle$ of I^2t total.

At cutting-off process without cut-off of CB is possible to resolve between 3 cases of fuse behavior decided from I^2t parameter.

- Fuse will cut-off rise of current. Thaw I^2t is reached before the first quarter of current period. Fuse stops of rising of a current.
- Fuse will switch-off. Thaw I^2t is reached in time between 5 ms and 20 ms of short. Fuse switch off.
- It is impossible to decide about fuse behavior by the value I^2t. Fuse cut-off is necessary to decide pursuant to fuse characteristics.

At short with a switch-off CB, it is possible except three previous next two possible cases outage of fuse.

- Fuse wills not outage. The CB switch off sooner beyond fuse obtain thaw I^2t.
- Fuse will be smelted. Fusing conductor has absorbed the energy, needed for thaw a wire, but cut-off current will be switched off by another way. The metal of fuse will not be totally absorbed and recombined by plasma in extinctive siliceous sand. In the fuse will be created a semiconductive channel, which will further conduct a current. This state is very dangerous. After commissioning substation into the normal run fuse will generate a lot of heat and can cause the burn in a substation.

5. MODEL VALIDATION

Records of theoretical analysis are compared with the measured records for verification. From measured records are composed parameters of circuit in short. Example and correction of theoretically model is shown at fig 2.

5.1. Substation DPmP Barrandov

Given parameters:

Transformer : 2×850 kVA u_k=6%

Diodes: R_{dd} = 0,12 mΩ

Resistance to track began: 7,2 mΩ

Time response: 5 ms.

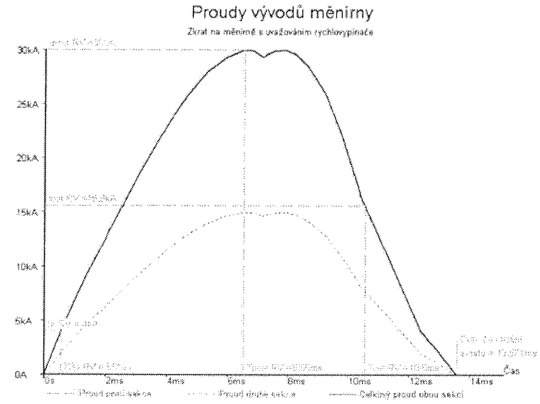

Fig. 2. Theoretically evaluated short -current waveform

Nominal Voltage of CB: 1000V

Estimated parameters of CB:

Mechanical time of CB: 6 ms

Time of arc voltage growth: 4 ms

Arc voltage: 1200 V.

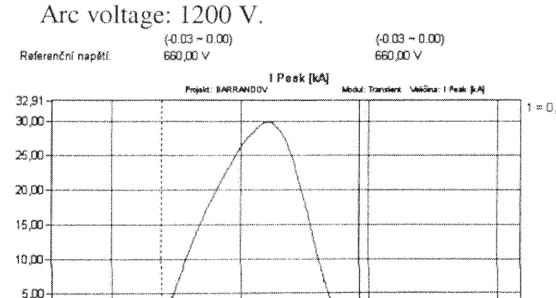

Fig. 3. Measured short-current waveform

5. 2. Substation DPmP Hlubočepy

Parameters of substation : the same as in the Barrandov's substation. Point of short is 150 meters from a track input. Resistance of DC part: 35 mOhms, time response 10 ms.

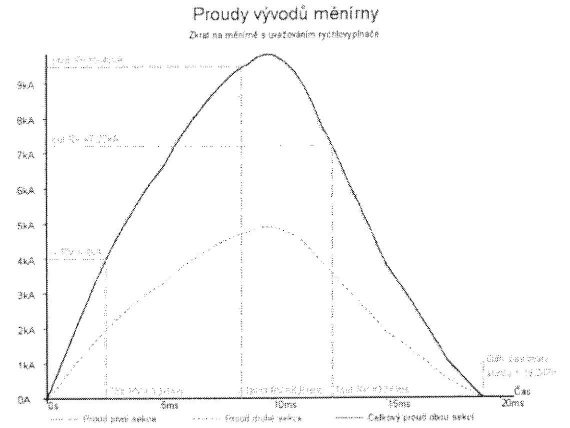

Fig. 4. Theoretically evaluated current waveform in substation Hlubočepy

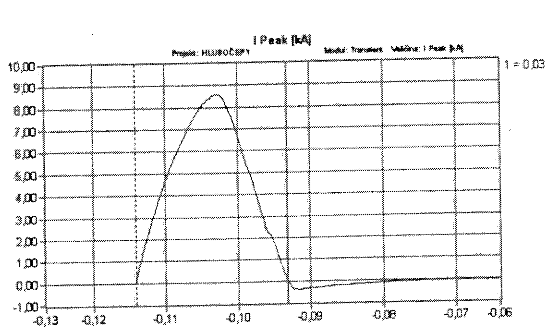

Fig. 5. Measured record of short-current test in substation Hlubočepy

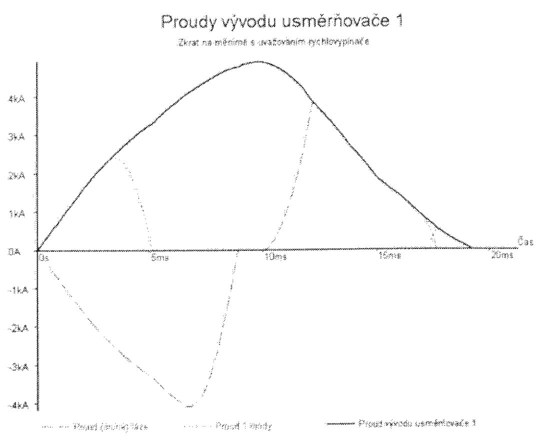

Fig. 6. Theoretically evaluated short-current of one section in substation Hlubočepy

6. DISCUSSION

In conjunction with a designating company it was created a computer program, which perform whole suit from an equation formation, analysis and evaluation automatically, that way to use in design profession, include an output in numerical format and graphs. Whole process of analysis from setting of parameters into the program to the obtaining records is abbreviated to less than 1 minute.

In present time be in process finishing of a few substation, that will be proof by short-circuit test. Records of this measure will be evaluated and will serve to the next precising of valuation of substation model, fuses and High Speed Circuit Breakers.

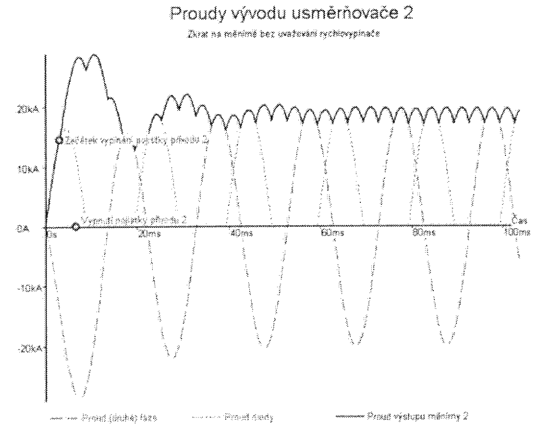

Fig. 7. Short without a cut-off of CB

7. CONCLUSION

Analysis method of short-circuit current by the help of simulating substitutive circuit can be very suitable tools for a design and education in the sphere of heavy current electrotechnics.

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