THE PECULIARITIES OF INTERRUPTION OF THE MEDIUM VOLTAGE MOTORS BY VCB WITH CuCr CONTACTS.

Alexey M. Chaly, Alevtina T. Chalaya, Victor N. Poluyanov, Irina N. Poluyanova,

Tavrida Electric Ltd, P.O. Box 26, 335045 SEVASTOPOL - 45, Crimea

Abstract - Monte-Carlo simulating technique and appropriate software has been developed to analyze switching overvoltages occurring at interruption of 6 and 10 kV motors by VCB with CuCr contacts. VCB parameters have been determined experimentally.
A comparison has been provided between VCB switching behaviour at interruption of 6 and 10kV motors.
Voltage escalation has been shown to be the most important process for 6kV motors with respect to switching overvoltages generation.
In contrast to 6kV motors three phase virtual current chopping predominates for 10kV motors.
It has been deducted that for the majority of the real field applications VCB with the most popular contact material (CuCr base) can create dangerous overvoltages.
Switching surge analysis conducted with the aid of Alternative Transients Program (ATP) proved metal oxide surge arrester connected in parallel to VCB contacts to be the most effective way to suppress phase to ground overvoltages.
Turn-to-turn overvoltages induced at interruption of medium voltage motors by VCB with described protection have also been studied.
These overvoltages have been compared with turn-to-turn overvoltages induced by «ideal» breaker that does not interrupt high frequency current at all.
Our analysis revealed that maximum turn-to-turn overvoltages induced by VCB with adequate protection do not exceed overvoltages induced by the «ideal» circuit breaker (ICB) for more then 15% and are lower then similar overvoltages induced by conventional breakers in the same conditions (oil, air, magnetic).

Introduction

It is well known that Monte-Carlo simulation technique is an effective method for theoretical investigations of overvoltages associated with VCB [1-7].
A description of the computer programs developed by the authors for simulating overvoltages when VCB interrupts motors is given in papers[4,5]. These programs allow us to analyze overvoltages during interruption of any feeders with motors in any regimes (unloaded motors, rated and starting regimes) if statistical characteristics of the VCB (chopping current (CC), dielectric strength rise and high frequency current interruption capability) are known.
These calculations have a quite practical use - to decide whether protective means are required.
In recent years ZnO surge arresters (SA) proved to be the most universal means to protect against switching surge but one can not accept the appearance of a steep front wave on the motor's winding.
In this paper the peculiarities of interruption of the medium voltage motors 6-10 kV are analyzed and the turn-to-turn overvoltages generated by VCB protected by SA are estimated.

1. INTERRUPTION OF 6-10KV MOTORS BY VCB

When a medium voltage motor (MVM) is switched off by VCB (with dielectric strength rise about 10÷50kV/ms) there are two mechanisms of the overvoltage generation depending on the motor duty:
- for unloaded motor and motor carrying nominal load, overvoltages are basically determined by «natural» CC. These overvoltages are not generally followed up by reignitions because of the small recovery voltage resulting from deduction of the induced EMF from source voltage;
- for starting motors, the dominant reasons for overvoltages are voltage escalation (VE) and virtual current chopping (VCC).

The research of the overvoltages has been executed for typical commercial MVM 6-10kV 200,1000 and 3150kW. The statistical parameters of VCB are given in [5], 4.2 p.u. safe level of overvoltages is taken [7].

1.1 Interruption of unloaded and carrying nominal load motors

To analyze overvoltages during the interruption of unloaded and carrying nominal load motors the computer simulating models described in [6] have been used.
In Fig.1 the typical oscillograms of the currents and voltages at the motors winding are shown.
Figs 2 and 3 present dependencies of the maximum (1%) overvoltages on the cable lengths when CC occurs in the first and in two remained poles for MVM 200kW 6kV.
Fig.4 presents the similar dependency for unloaded 200kW 10kV.

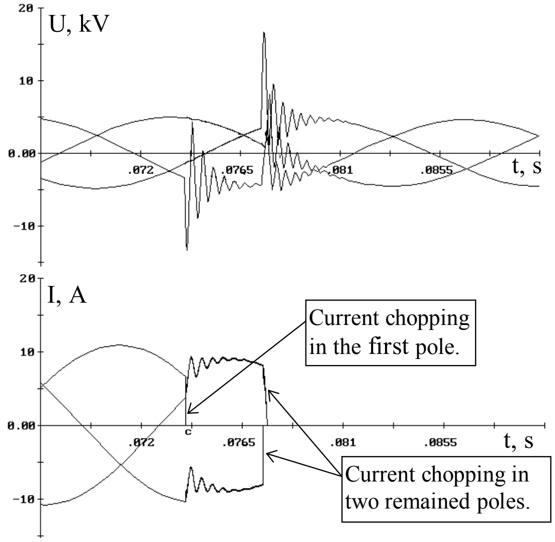

Fig.1

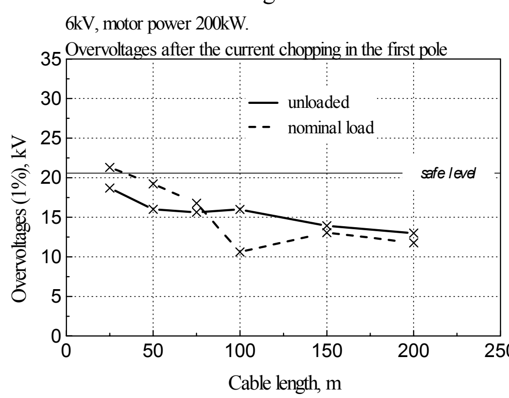

Fig.2

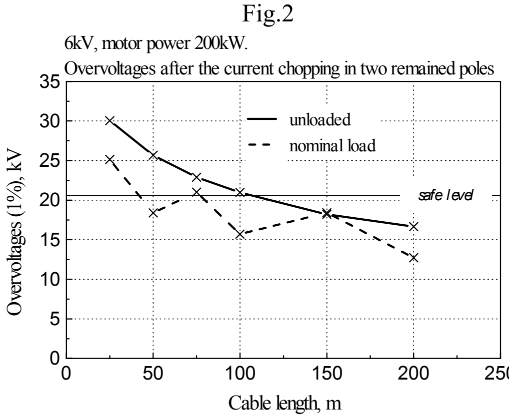

Fig.3

Fig.5 presents dependencies of the maximum overvoltages after the chopping in two remaining phases for unloaded 200, 1000 and 3150kW 6kV.

It is easy to see that interruptions of 1000 and 3150kW MVM in all regimes will not result in dangerous overvoltages.

Because the most dangerous interrupting duty (See Fig.2-4) has been chosen for comparison in Fig.5 other interrupted duties for 1000, 3150kW motors can also be considered as unhazardous.

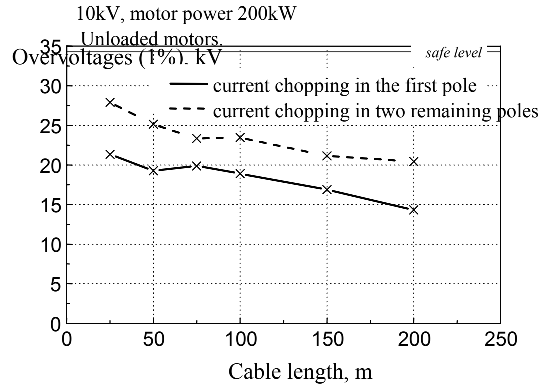

Fig.4

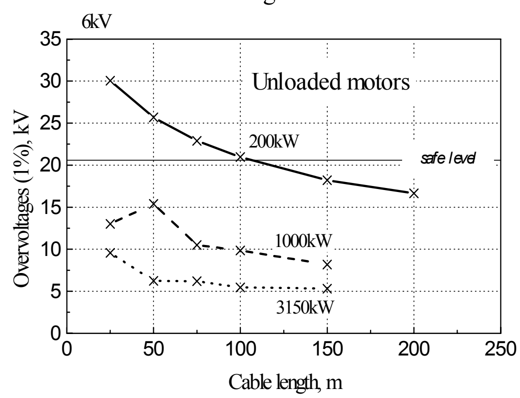

Fig.5

1.2 Interruption of starting motors

To analyze overvoltages during interruption of starting motors the simulating model [4] has been used.

The condition of the VCC appearance has been checked using the approach proposed in [8].

In Fig.6 and 7 the dependencies between max overvoltages (1%) and cable length are presented for motors 6-10kV 200,1000 and 3150kW.

The circuit parameters that can result in VCC are marked with thick lines below.

It is important to note that overvoltages in such cases can be in excess of those exposed in Fig.6 and 7.

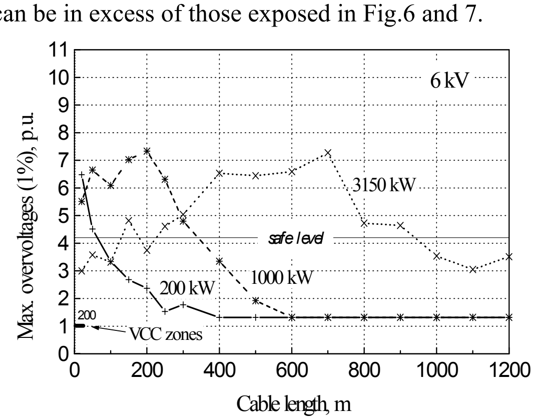

Fig.6

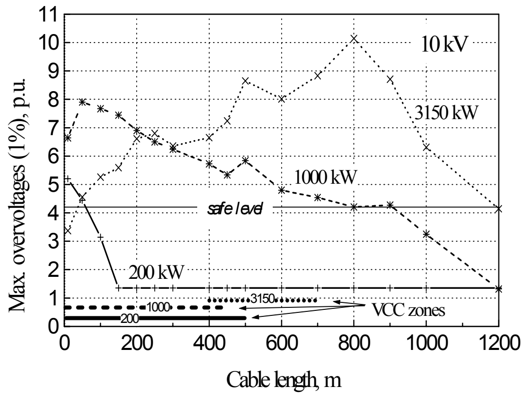

Fig.7

1.3 Safe operation regions for MVM interrupted by VCB

All calculations presented in the previous sections have been generalized in «safe operation» regions showed in Fig.8. If the feeder's parameters belong to the white regions, the probability of dangerous overvoltage appearance is less than 1% and overvoltage protective means may be considered unnecessary.

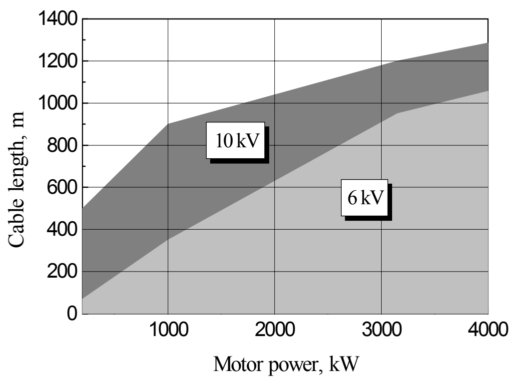

Fig.8

It follows from Fig.8 in the majority of practical cases surge suppression is required.

2. PROTECTION BY ZnO SA

In recent years ZnO SA became widely applied for protection against switching surges.
Fig.9 and 10 show typical oscillograms of the phase to ground voltages when the starting motor equipped with SA is interrupted by VCB: Fig.9 - SA is installed in parallel to winding, Fig.10 - in parallel to the VCB contacts.

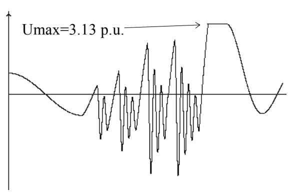

Fig.9

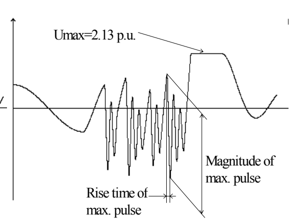

Fig.10

The installation of SA limits the number of breakdowns and reduces the probability of the VCC appearance. The SA connected in parallel to contact allows to accept the VCC appearance et al. and to suppress generated overvoltages to the safe level.

3. ESTIMATION OF THE DANGER OT THE TURN-TO-TURN OVERVOLTAGES

The use of the SA as a protective device does not prevent the appearance of a steep front wave at the motors winding.
Generally accepted safe limits of pulse withstand ability of rotating machines are given in [7].
The calculations of the maximum turn-to-turn overvoltages were executed with the aid of ATP stray model of the motor winding.
Maximum impulse (1%) stresses on the turn to turn insulation have been calculated for ICB (having no HF interrupting capacity) and VCB with surge arresters installed in parallel to contacts. Fig.11-16 provide comparison of the calculated stresses with IEEE safe level.

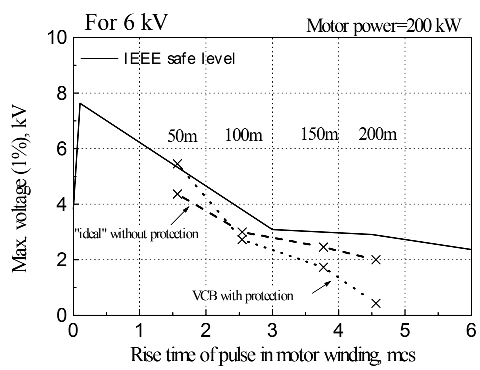

Fig.11

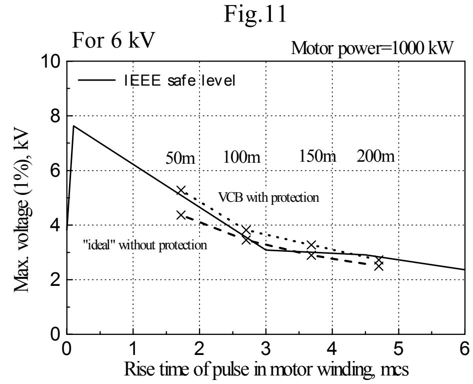

Fig.12

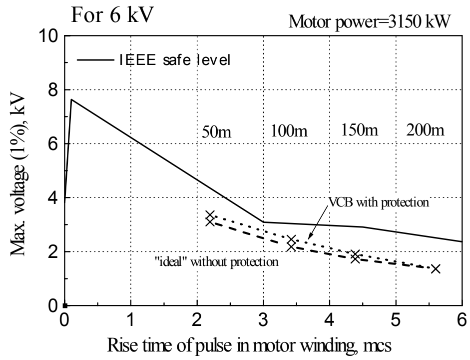

Fig.13

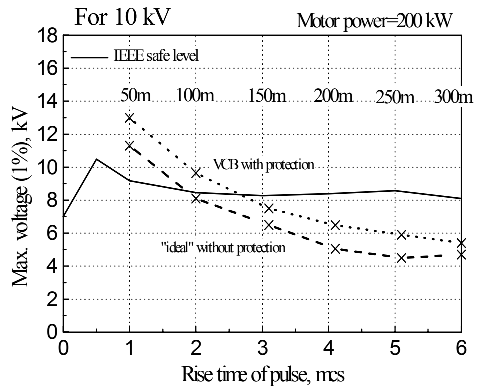

Fig.14

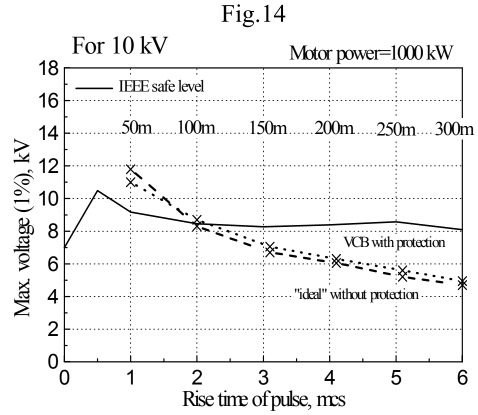

Fig.15

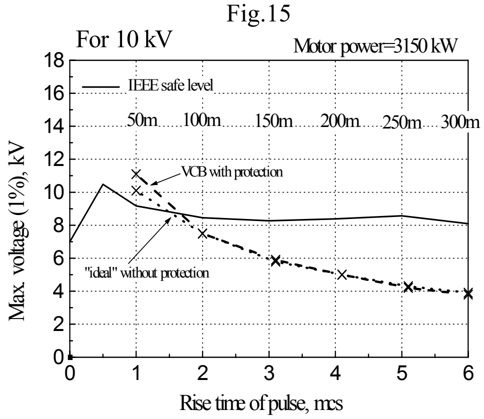

Fig.16

4. Summary

The most dangerous overvoltages at interruption of MVM may appear at interruption of starting motors due to VE and VCC. In the majority of practical cases application of SA is required. SA connected in parallel to VCB contacts provides effective suppression of the phase to ground overvoltages.
Turn-to-turn overvoltages are also reduced because VE stops earlier. These overvoltages may be higher or lower than those for «ideal» circuit breaker depending on the circuit conditions.
Maximum turn-to-turn overvoltages induced during 6kV motors interruptions by VCB with arresters do not exceed the IEEE level for more than 10% and never exceed SIGRE level.
For 10kV motors both VCB and ICB may create turn-to-turn overvoltages in excess of IEEE safe level.
For real commercial CB (oil, air, magnetic) currently used for motor control one could expect even higher turn-to-turn stresses (because none of them can be considered as «ideal» CB). Nevertheless these CB are widely used for motor control without significant trouble for motor turn-to-turn insulation. The later allows us to recommend the application of VCB (with built in surge arrester parallel to main contact) for motor control instead of existing equipment. One can expect no increase of an insulation failure.

REFERENCES

[1] J.F. Perkins, D. Blasavanich, ″Vacuum switchgear application study with reference to switching surge protection″, IEEE Trans. on Industry Applications, Vol. 1A-19, № 5, 1983.P.879-887.

[2] N. Veno et al., ″Simulation of overvoltage generation in the Inductive current interruption by vacuum interrupters″, IEEE Trans. Power Appar. And Syst., Vol. PAS-103, №3, 1984, P.498-505.

[3] Y. Kosmac, P. Zunko, ″A statistical vacuum circuit breaker model for simulation of transient overvoltages″, IEEE Trans. On Power Delivery, Vol. 10, No. 1, Jan. 1995, p.294-300.

[4] A.M. Chaly, A.T. Chalaya, ″The influence of a vacuum circuit breaker and circuit parameters on switching overvoltages generated during interruption of starting motors″, 17th Int. Symposium On Discharge and Electric Insulation in Vacuum, Berkeley, US., 1996. P.244-248.

[5] A.M. Chaly, A.T. Chalaya, ″A computer simulation of transformer magnetizing current interruption by a vacuum circuit breaker″, 17th Int. Symposium On Discharge and Electric Insulation in Vacuum, Berkeley, US, 1996. P.249-253.

[6]. A.M. Chaly et al., ″The features of 0.4kV motor interruption by a vacuum contactor with different contact materials″, 18th Int. Symposium On

Discharge and Electric Insulation in Vacuum, Eindhoven, Netherlands, 1998
[7] R.P.P Smeets, ″Switching surges associated with vacuum interrupters in motor circuits″, KEMA High-Voltage Laboratories, 1996, p.7-16.
[8] J. Panek, K.G. Fehrle, ″Overvoltage phenomena associated with virtual current chopping in three phase circuits″, IEEE Trans. Power Appar. And Syst.,. Vol. PAS-94, 1974, P.1317-1324.