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VCU Current Chopping Effects on MV Motor

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***Abstract*— As Power system Analysis has been developed protection of motors can be studied in detail with respect to the Switching Transients over voltage due to Current Chopping caused by VCU operation and its impact on the medium voltage motor winding insulation and mitigating such transients over voltages by introducing the different techniques.**

***Keywords*— Vacuum contactor unit (VCU), Current Chopping, MV Motors, Surge Suppressor, Surge Arrestor**

I. INTRODUCTION

Implementation of MV motors for pumpstation in the industries such as Oil & gas, Petrochemical, Water treatment etc. are in common practice for many decades with DOL starter with standard protections against Overload, Overcurrent, earth fault etc. However, the protection against the switch transient over voltage is not the common practice in the past. The Purpose of this paper is to explain about the impact of switch transient over voltages on the Insulation of motor winding caused due to the current chopping of Vacuum contactor unit.

II. UNDERSTANDING OF MOTOR WINDING INSULATION LEVEL

Motor Winding insulation level for Steep front impulse voltage with stand (Peak) has been well defined in the IEC 60034-15 Table-1 and this will be primary guidance for Basic Switching Level (BSL) for medium voltage motors.

Table 1 – Impulse voltage withstand levels for sample form-wound coils used in a.c. rotating machines

Rated voltage	Rated lightning-impulse voltage withstand (peak) (see Notes 1 and 2)	Rated steep-front-impulse voltage withstand (peak) (see Notes 3 and 4)
U_N	U_P	U'_P
kV	kV	kV
2,3	14	9
3	17	11
3,3	18	12
4	21	14
6	29	19
6,6	31	20
10	45	29
11	49	32
13,2	58	38
13,8	60	39
15	65	42

NOTE 1 The levels in Column 2 are based on a standard lightning impulse having a front time of 1,2 µs ± 30 %, a time-to-half-value of 50 µs ± 20 % and a peak value of the impulse voltage U_p ±3 % as specified in IEC 60060-1.

NOTE 2 The levels in Column 2 are obtained by using the formula: $U_P = 4\ U_N + 5$ kV.

NOTE 3 The levels in Column 3 are based on an impulse having a front time of 0,2 ± 0,1 µs up to 35 kV. Above 35 kV, the front time is 0,2 µs with a tolerance of +0,3 µs/–0,1 µs.

NOTE 4 The levels in Column 3 are obtained by application of the formula: $U'_P = 0,65\ U_P$.

NOTE 5 The levels in Column 3 have been deemed appropriate for stresses related to circuit breaker operation that could occur in service. They may not be adequate for special operating conditions (e.g. interrupted start or direct connection to overhead lines). In such cases the windings should either be designed to withstand other impulse levels or be protected in an appropriate way.

In General, the Switching over voltage due to VCU chopping current shall not be higher than the values higher than the guidelines value mentioned in the IEC 60034-15 for Impulse voltage with stand (Peak)

There are another two criteria which use to checked during such VCU Current Chopping Study as mentioned below.

1. Motor side rate of rise time to peak impulse voltage.
2. No of Re-Strikes at the motor terminal end.

The above mentioned both parameters don't have the clear guidelines with respect to international standards, however the philosophy is Longer the rate of rise and lesser the number of re-strikes the detrimental effects on the motor winding is considerably lesser.

However, in general practice the front time i.e., rate of rise to peak impulse voltage less than 10µs is consider as safe for medium voltage motors.

In extreme cases it can even reach a low of 0.2µs and become capable of causing severe damage to the Motor windings.

When such a surge penetrates medium voltage motor winding, most of its stress may appear mainly across the first coil of the motor winding and Voltage stress across the fist coil alone can be as high as 70-90% of total transient voltage across a motor winding having the front time of 0.2µs.

Working Group 13.02 of study committee 13 and Slamecka has produced curves to illustrate the TRVs appearing across the entrance coil for different front times for different lengths of conductor of the first coil.

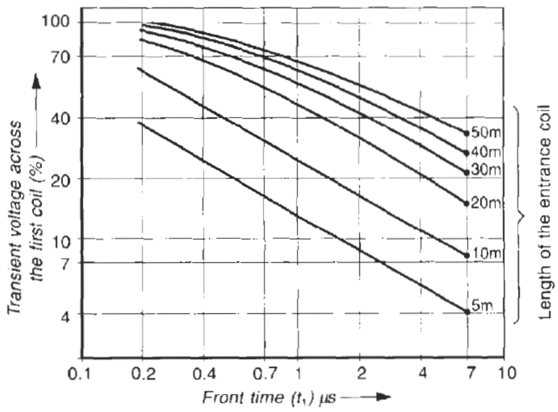

Figure 17.14 A transient voltage stress across the first (entrance) coil of an induction motor as a function of front time (t_1) and length of entrance coil 'l' (from Slamecka, 1983)

III. UNDERSTANDING OF VCU CURRENT CHOPPING

Chopping Current is a phenomenon observed in Vacuum Contactor units used in medium voltage MCC/Switchgears for

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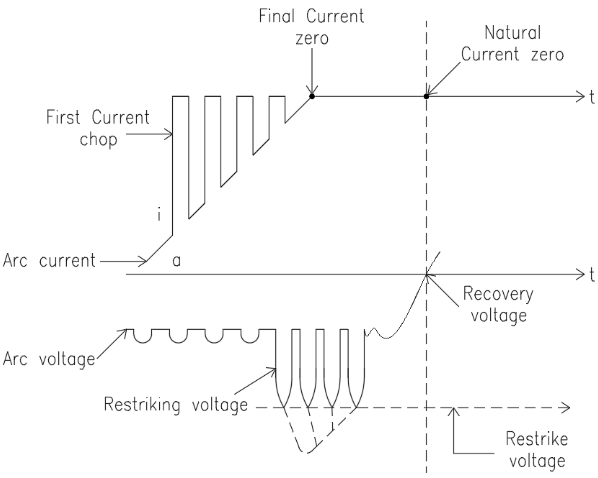
feeding the Motors at the voltage level of 3.3kV, 4.16kV, 6.6kV etc.

Current chopping in VCU is defined as a phenomenon in which current is forcibly interrupted before the natural current zero and this leads to the detrimental effects on the motor winding.



While interrupting highly inductive current, like the no-load current of the transformer or motor, the rapid deionization of contact space and blast effect may cause current interruption before its natural zero. Such an interruption of current before its natural zero is termed as "Current chopping". Even though the instantaneous value of current being interrupted may be less than the normal current rating of the contactor, it is quite dangerous from the point of view of overvoltages which may result in the system

Let,

L = Inductance of the system

C = Capacitance of the system

i =Instantaneous value of arc current

V = Instantaneous value of capacitor voltage (which appears across the breaker when it opens)

The electromagnetic energy stored in the system at the instant before interruption is [$\frac{1}{2} * L * i^2$] As soon as the current is interrupted the value of i becomes zero. But, the electromagnetic energy stored in the system [$\frac{1}{2} * L * i^2$] cannot become zero instantaneously and so it is converted into electrostatic energy [$\frac{1}{2} * C * V^2$] as the system has some capacitance.

According to the principle of energy conversion we have,

$\frac{1}{2} * L * i^2 = \frac{1}{2} * C * V^2$

$V = i * \sqrt{(L/C)}$

This value of V is called as Arc Voltage. If this voltage is very high when compared with the gap withstanding voltage, then the gap breakdowns and so "the arc restrikes. Again the current is chopped (interrupted) because of high quenching force and so, restriking occurs. This process repeats until the current is suppressed finally without any restrike and this occurs near current zero.

Most of the major manufacturers of MV Switchgear/Vaccum contactors offer the chopping current from 0.5A to 3A.

IV. CONCLUSION

In Recent days most of the Engineering Design Organizations, Power system Consultants, Companies & plants belongs to oil and gas industries are addressing this issue of Switching Overvoltage impacting the motor winding because as this industry demands the high reliable system.

Even though Certain Guidelines are provided in IEEE standards such as IEC 60071, IEC 60034-15, IEEE 3004.8, IEEE C37.96 and IEEE C62.21 etc. However, these standards don't recommend any standard practice nor addresses the current industrial problem with Practical solutions.

This Switching Over Voltage shall be studied in detail with the modern power system Analysis software to come with different techniques which can be effectively implemented in the industries