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Switching Surge Study on High Voltage Efficient Motor

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Abstract*—Steep fronted transients such as switching surges can cause severe stress on motor turn insulation. The introduction of vacuum switchgear has caused particular concern since multiple surges can be generated in each switching operation. This project is aimed at determining the actual surge environment in typical power plants as well as the capability of modern turn insulation to withstand these surges. Switching surge measured on the motor were significantly below the withstand strength of most utility motors. In normal motor switching operations, the rise times and magnitudes of surge are similar for air magnetic and vacuum breakers. Switching overvoltage originate at the terminal of circuit breaker. The limiting of surge provide the some protective device like capacitance, capacitance-resistance,ZnO-varistor at the motor terminal. Using Matlab software, simulation and modeling is made to compare and decides the best device with its location for the protection of High voltage motor.

Keywords— Switching Surges, Transients, High Voltage Motors, ZnO-Varistor, Shielding Ends of XLPE cable

I. INTRODUCTION

Electric impulse strength of high-voltage motor winding is of great interest to users and manufactures because it is usually impractical to insulate against the worst surges that may occur in service life. The subject of overvoltage generated by switching devices has received much attention in recent year, particular attention being directed to the production of switching overvoltage in motor circuits.

The surges are usually caused by circuit breaker operations or faults on the supply circuit. The use of new improved materials, devices and the desire to produce cost effective competitive product has resulted in greater exposure of the motor to high amplitude steep fronted surges. Because of their reliability, compact size, low maintenance needs and longer life, vacuum switchgear is almost universally used. However, they produce repetitive, high amplitude steep fronted surges during closing as well as opening operations. Voltage transients are produced by circuit breakers during contact opening as well as contact closing. Air magnetic breakers produce a fast rise time surge during closing only, whereas the vacuum breaker produces steep fronted surges during opening as well as closing. Thus, for a single event of opening or closing the vacuum breaker produces multiple surges and therefore stresses the insulation more than other switching devices. Further, multiple re-ignitions cause each successive surge to be at a level higher than the previous one.

II. SURGE PROTECTION

Surge protection devices may be divided into two categories; firstly those that protect against surge voltage magnitude and secondly those that modify transient voltage rate of rise. The first category includes all types of surge arresters from conventional gapped station class arresters with low protective levels, to intermediate and Distribution class arresters having high protective levels. The new technology component in this area is the ZnO-Varistor, which has much better V-I characteristics than does the SiC used in a conventional arrester. ZnO-Varistor may be gapless or they may have either series or parallel gaps. Several manufacturers throughout the world have developed ZnO suppressors specifically to be applied with vacuum switchgear. A ZnO suppressor is basically similar to a ZnO-Varistor. It is usually (but not always) gapless and is generally a lighter duty unit having some-what lower energy absorption capability than that of a ZnO-Varistor

The second category of surge protectors includes surge capacitors, C-R suppressors and series reactors. In accordance with industry practices and standards surge capacitors should be located at the load and as close to the load terminals as possible. This minimizes series inductance effects, which reduce the effective surge impedance of the load circuit. All of these factors are important in reducing the probability of degradation of solid insulation, which could result from the non-uniform distribution of fast transient voltages in machine windings.

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III. SYSTEM DEVELOPEMENT

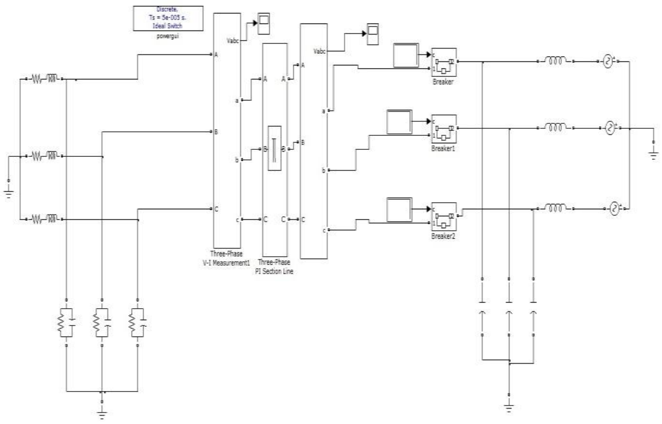

Fig 1: CIGRE circuit for Simulation without Protection

Matlab simulation is a field of study, which allows one to analyze and examine a complicated or nonlinear model or process. A quantitative evaluation of switching surges in high-voltage motor systems has been carried out under different operating conditions using the matlab.

(A) Test Circuit Simulation

The circuit represents three-phase induction motor under standstill rotor condition. The power-frequency impedance is represented by the linear inductance L and resistance R for each phase. The natural frequency and damping of the circuit are adjusted by means of capacitances Cp to earth.

(B) Characteristics of Supply Circuit

In our circuit, we have used a simple R-L series three phase voltage source. There are three types of source control modes Fixed, External and Auto. We have used fixed control for our system.

(C) Modeling of Circuit Breaker

The interaction between the circuit breaker and the motor circuit is represented by simulating the breaker. During interruption of starting current the circuit breaker duty is characterized by a high current and a low power factor. Also, since the interrupted current is high, the chopping current can attain high values. The circuit breaker is modeled in Matlab by a resistor, which has either a very-low resistance value or a very-high resistance value depending on whether closing or opening is to be simulated.

(D) Induction Motor Modeling

The equivalent circuits of high-voltage motor as shown in Figure 1 suggested by CIGRE represent the three-phase induction motor under block-rotor condition. Damping at higher frequencies due to increased losses in copper and iron is accounted for by adding the parallel resistor Rp. Distributed turn-to-turn capacitance and turn-to-ground capacitance contribute to wave-like propagation of transients through the machine. The capacitance of the winding is assumed to be lumped at machine terminal. Cp assumes two discrete values for two different starting current values. The load circuit represents a three phase load. The motor substitute circuit is connected to the circuit breaker.

(E) Modeling of Protective Devices

The protective devices used during simulation studies are surge capacitors, R-C suppressors and ZnO-Varistors. These devices are helpful in limiting the peak/ slope of the waveform of switching surges and thus provide protection for turn to turn and ground insulation of the motor. We have dealt with various cases as listed below. The analysis has been done by studying the results obtained by using the protective devices on both the motor and source side. The various cases under study are both for 3.3 kV and 6.6 kV systems.

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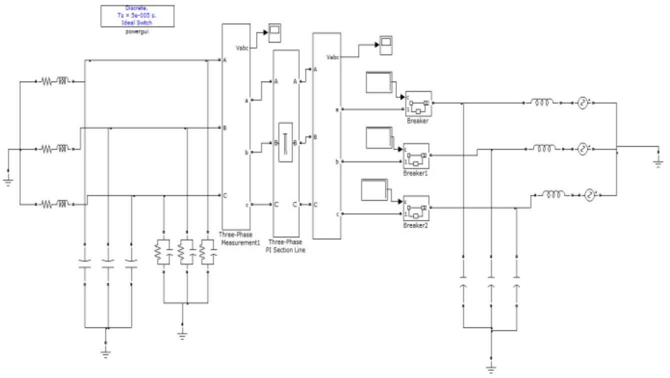

Fig 2: CIGRE used for Simulation with Capacitor as a Protective Device

a) Without Protection
b) With Capacitor of capacity 0.1 µF at motor end
c) With Capacitor of capacity 0.5 µF at breaker end
d) With RC at motor end (R=100 Ω & C= 0.05 µF)
e) With RC at breaker end (R=100 Ω & C= 0.05 µF)
f) With Surge Arrester at motor end
g) With Surge Arrester at breaker end
h) With Surge Arrester and Capacitor in parallel at motor end
i) With Surge Arrester and Capacitor in series at motor end

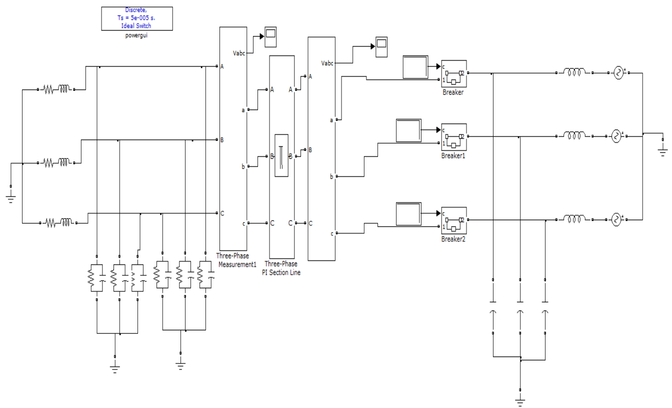

Fig 3: CIGRE used for Simulation with RC as a Protective Device

IV. SIMULATION RESULT

The over voltages are measured at motor as well as breaker terminals. Comparative study of various circuits using different schemes of protection has been shown in tabular form.

The digital simulation results of over voltage at load terminals with surge capacitors at motor terminals show that there is a substantial increase in the rise time of the surges. This leads to a more uniform distribution of surges in the windings, thus reducing the stresses imposed on the motor turn insulation. Similarly, the effect of R-C suppressor placed at motor terminals offer an additional advantage, *i.e*. oscillations.

The highly non-linear characteristic of surge arrestor leads to a reduced magnitude of switching surges generated with surge arrestor placed at motor terminals. Damping in the oscillations is also introduced to a large extent. The combination of surge arrestor and capacitor in parallel proves to be the best to reduce the magnitude of the surge.

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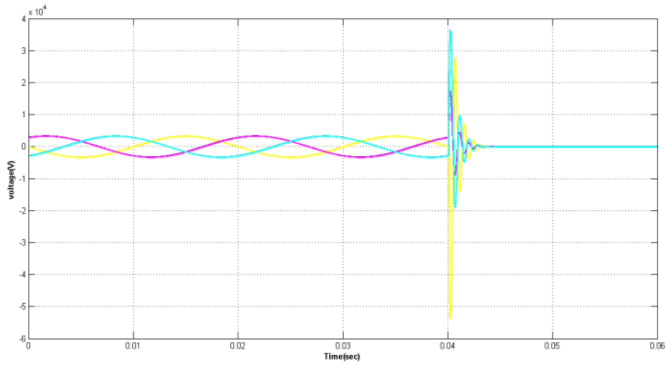

Fig 4: Voltage at Motor End without Protection

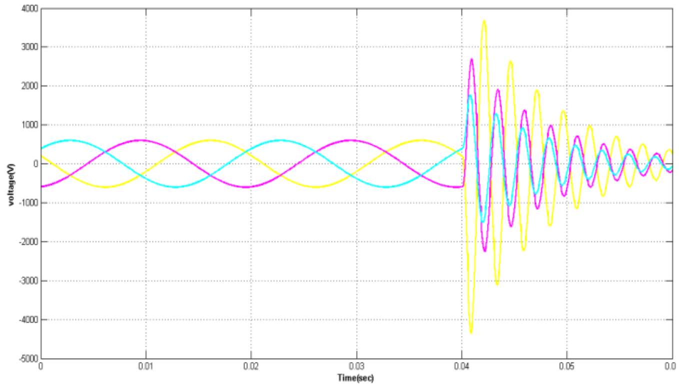

Fig 5: Voltage at Breaker End without Protection

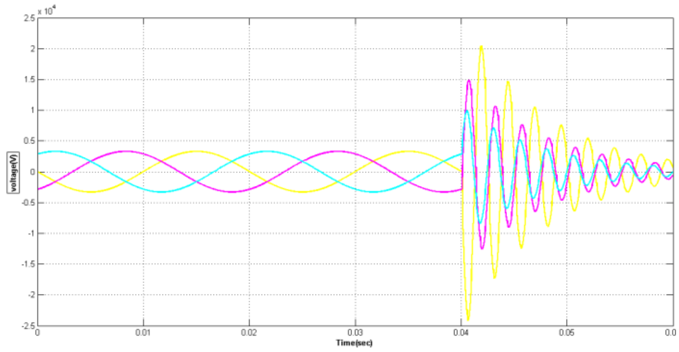

Fig 6: Voltage at Motor End with Capacitor as a Protective Device

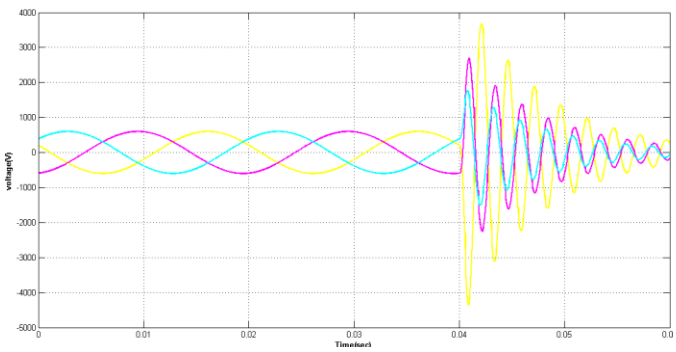

Fig 7: Voltage at Breaker End with Capacitor as a Protective Device

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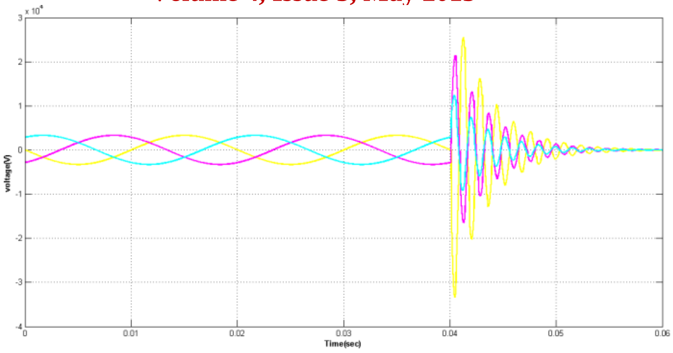

Fig 8: Voltage at Motor End with RC as a Protective Device

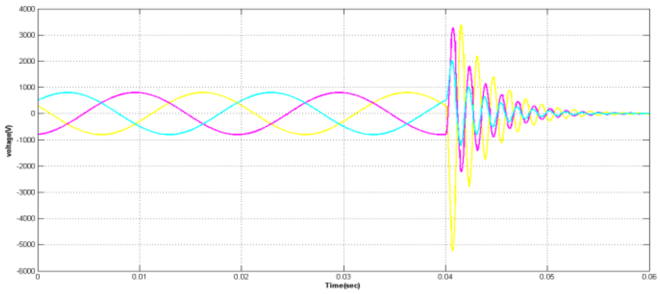

Fig 9: Voltage at Breaker End with RC as a Protective Device

Surges in kV Due to Switching operation of Circuit Breaker (System voltage 3.3 kV)					
Mode	phase	Surge at breaker end		Surge at Motor end	
		Magnitude in kV	Rise Time in µs	Magnitude in kV	Rise Time in µs
Without protection	A B C	36.39 23.6 -53.66	40.3 40.15 40.3	12.22 6.64 -17.87	40.45 40.25 40.45
With C	A B C	14.81 9.944 -23.96	40.75 40.6 40.65	14.81 9.944 -23.96	40.75 40.6 40.65
With RC	A B C	21.36 12.01 -32.87	40.5 40.5 40.45	21.36 12.01 -32.87	40.5 40.5 40.45
With surge arrester	A B C	24.58 11.65 -2.930	46.09 44.85 41.49	24.58 11.65 -2.930	46.09 44.85 41.49

V. CONCLUSIONS

CIGRE circuit for the starting of High voltage motor gives the less transient because the value of capacitance use in CIGRE model is more. As a result switching surge gives less stressed on the turn to turn and ground insulation winding of High voltage motor.

The operating mode of the motor at the time of switching was found to be the most significant factor governing the severity of overvoltages generated. When switching off a starting induction motor, very high Overvoltages can occur. Also, the shorter the cable connecting to the motor to the breaker, the more severe the overvoltages generated. On the other hand, the presence of the power factor correction capacitors precludes the production of serious overvoltages. The effects of the short circuit ratio, grounding practices of the cable sheath, length of the cable connecting the motor to the power factor correction capacitors and the rating of the power factor correction capacitors on the overvoltages severity were found to have less impact.

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The performance of different protection measures was evaluated. It was found that connection of Capacitor or combination of capacitor and resistance can be effective in reducing the overvoltages at the terminals of connected equipment providing the cable lengths are not excessive. Even with short lead lengths, the fast-front overvoltages generated by the breaker can result in a protective level higher than the clamping voltage of the capacitor at the terminals of the equipment.

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