SIMPLE SOLUTIONS FOR IMPROVING LIFE OF BREAKERS USED IN TRANSMISSION AND DISTRIBUTION SYSTEMS

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INTRODUCTION

The Transmission and Distribution systems over a period of time have grown complex as well as have become highly demanding. Due to large proliferation and also mix up of linear and non-linear loads, the systems are continuously stretched to switching on and off of passive and active control devices, such as capacitor banks (APFC or TSC or TCR), or harmonic filter banks for correction of reactive power / power factor and / or load current harmonics. These economical methods have been further improved to direct on line correction with the use of STATCOM(N) / Active Filters / Unified power controllers etc. The most important aspects of a power system (T&D) are to (i) deliver quality power without interruption, (ii), use the switchgear and associated components within rated capacities, (iii) limit the voltage current transients within limits so that life of all connected components and system improves, (iv) apply all necessary protections to achieve improved life and reduce stresses on the connected equipment(s), and (v) retain its objective of simplicity in operation, highest possible reliability, almost nil maintenance, and highly economical.

It may appear that such a vast coverage of various associated aspects and objective(s) may be difficult to achieve. This paper perhaps is an attempt to get into possibly a new outlook or at least look at what can be done in such a situation. The paper first deals with reduction of voltage in stresses on protective breakers when applied in an MV substation and then analyses how to reduce transient voltages / currents in a relevant capacitor switching system.

The first and second aspects covered are basically improvement in operational reliability of protective breakers. The fallouts also are discussed. The aspects represent how simple the approaches should be to achieve some of the earlier listed objectives for the power system and should form a direction for much needed application research through simple approaches and innovativeness.

REDUCING STRESSES FOR BREAKERS CONTROLLING SHUNT REACTORS IN SUBSTATION

Figure 1(a) gives an example of a three-phase breaker in a 36 kV substation (a case study conducted for one of the electricity boards of Turkey) controlling 3500 kVAr shunt reactors in the substation meant

<u>for keeping supply voltages within limits, especially when load is thrown off or it gets reduced suddenly.</u> This is a model assembled in Matlab and run with Simulink platform. Figure 1(b) gives the shunt reactors of 3500 kVAr as represented by subsystem 3 in fig. 1(a). Figure 1(c) gives R-C snubber circuit connected at the breaker input and output side of the breaker as represented by subsystem 1 and 2 in fig. 1(a).

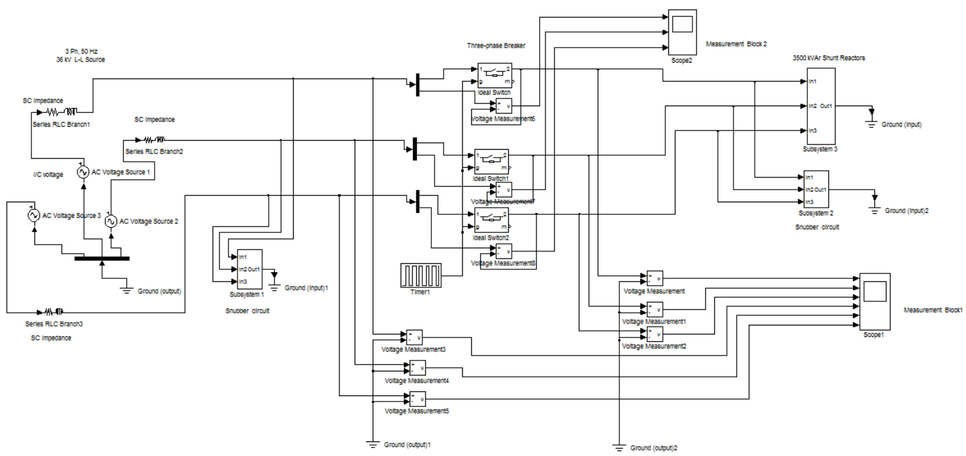

Figure 1: Matlab model for the 36 kV substation reactors and breaker

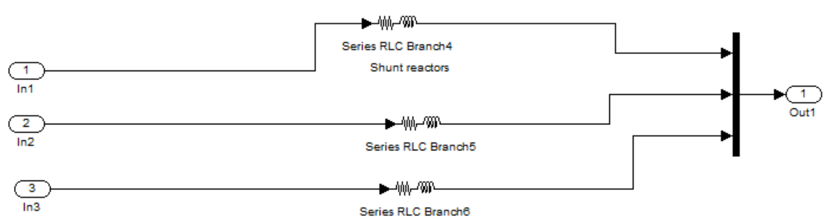

Figure 1(b): Shunt reactors of 3500 kVAr (subsystem 3)

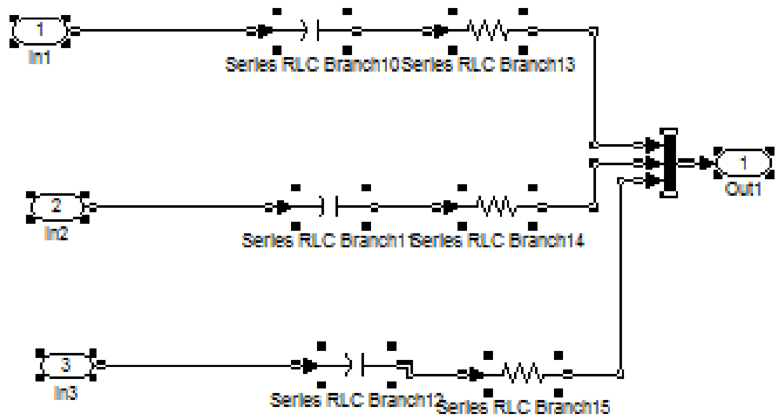

Figure 1(c): Snubber circuit (subsystem 1 and 2)

Figure 2(a) to 2(d) give the voltage stresses seen by the breaker (at its input terminals, at its output terminals and also across its poles) "without connecting the snubber circuits" as shown in subsystem 1 and 2. Note that the as the peak voltage stresses seen are quite high in MV range, the nominal sinusoidal phase voltage of 20785 V (=36000/√3) is not visible in all the figs 2(a) to (d).

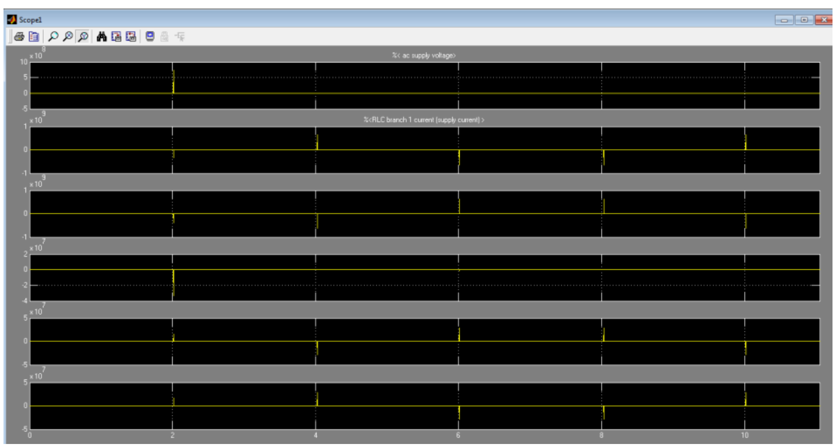

Figure 2 (a): Voltage stresses for the breaker poles (output to neutral and input to neutral)

Channel 1, 2, and 3: Voltage between "output side" of the breaker poles and neutral

Channel 4, 5, and 6: Voltage between "input side" of the breaker poles and neutral

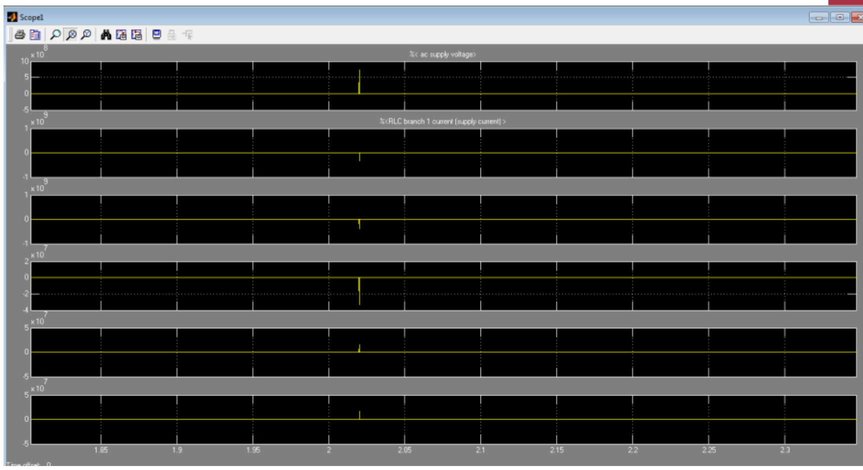

Figure 2 (b): Voltage stresses for the breaker poles (output to neutral and input to neutral), expanded view of fig. 2(a)

Channel 1, 2, and 3: Voltage between "output side" of the breaker poles and neutral (maximum stress touches nearly 730 MV)

Channel 4, 5, and 6: Voltage between "input side" of the breaker poles and neutral (maximum stress touches nearly 30 MV)

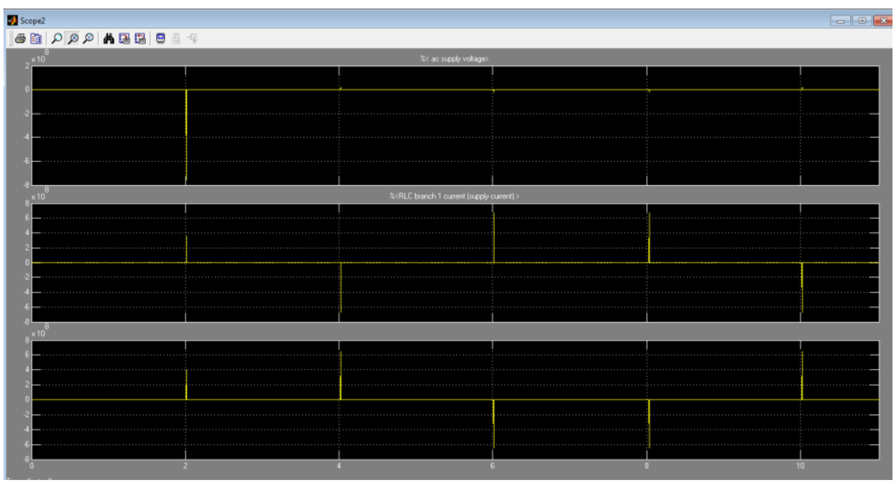

Figure 2 (c): Voltage stresses across the breaker poles

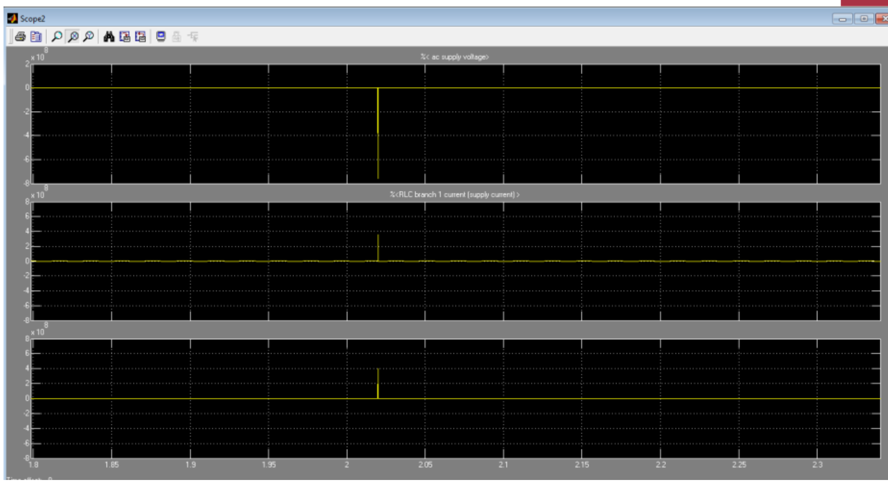

Figure 2 (d): Voltage stresses across the breaker poles, <u>expanded view of fig. 2(c) (maximum stress touches nearly 770 MV)</u>

Figure 3(a) and (b) give the voltage stresses seen by the breaker (at its input terminals, at its output terminals and also across its poles) “with connecting the snubber circuits” as shown in subsystem 1 and 2.

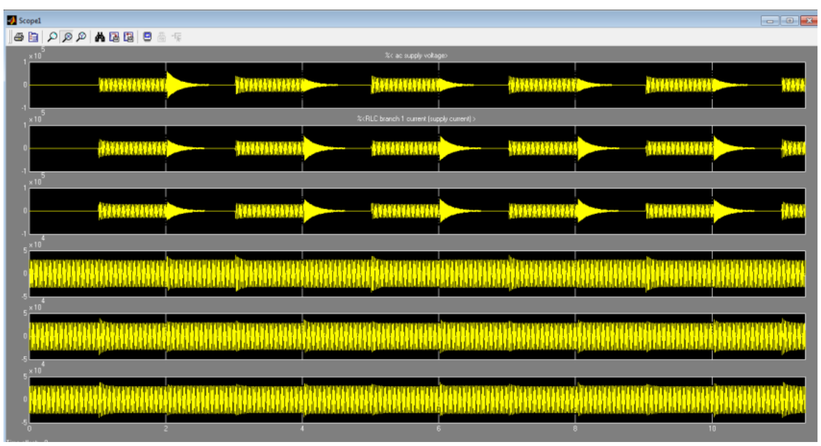

Figure 3 (a): Voltage stresses for the breaker poles (output to neutral and input to neutral)

Channel 1, 2, and 3: Voltage between output side of the breaker poles and neutral (maximum stress touches nearly 57 kV)

Channel 4, 5, and 6: Voltage between input side of the breaker poles and neutral (maximum stress touches nearly 39 kV)

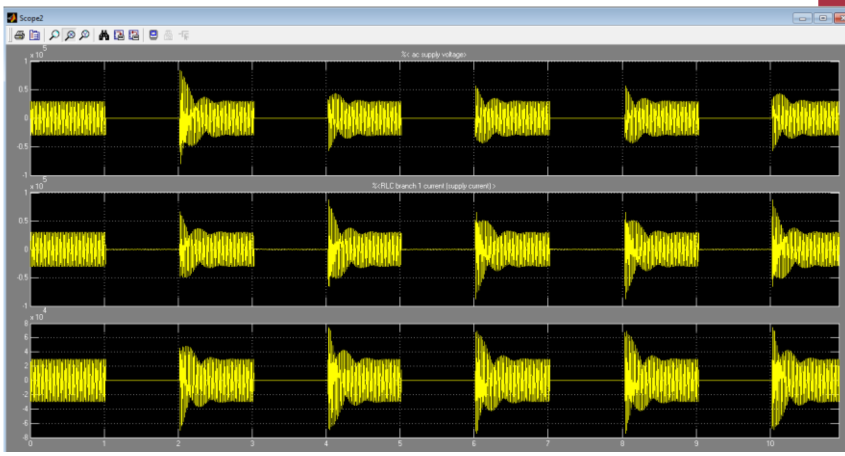

Figure 3 (b): Voltage stresses across the breaker poles (maximum stress touches 84 kV)

The results are also compared in Table -1.

Table -1 (Breaker pole voltages)

Peak Voltage	Without any R-C snubber	With R-C snubbers connected between input and output side of breaker poles to neutral
Voltage across breaker input terminals and neutral	30 MV	39 kV
Voltage across breaker output terminals and neutral	730 MV	57 kV
Voltage across breaker poles	770 MV	84 kV

The MV impulses are for short duration (few µsecs). However, it indicates that the breaker can fail after some time because of sustained shots or impulses of such magnitude. A simple R-C reduces removes these impulses, reduces the pole voltages to safe level, protects the breaker, and improves its electrical working life. The R-C values are dependent on the incoming voltage, the short circuit capacity of the network, and the kVAr / MVAr of shunt reactors and can be properly decided based on system simulation with Matlab / Simulink platform. The principle can be extended any power system where either breaker or contactor switching is involved. It also improves operational reliability of the connected equipment.

REDUCING STRESSES FOR BREAKERS APPLIED FOR CAPACITOR SWITCHINGS

It is now assumed that 36 kV supply system is feeding a balanced linear load approximately 5800 kVA at 0.8 power factor and a compensating capacitor bank of 3500 kVAr using a switching breaker. The shunt reactors are not considered here. The load active power is approximately 4670 kW. The model given in fig. 1 remains same except that the subsystem 3 which earlier consisted of shunt reactors of 3500 kVAr is now replaced by capacitor bank of 3500 kVAr and a load of 5800 kVA at 0.8 power factor. Further, the 0.2% reactors are used for inrush current limiting and a resistor of 24 Ω is used in parallel with the inrush current limiting reactors.

Figure 4 gives voltage between input as well as output of the breaker poles to neutral. Figure 5 gives the voltage across the breaker poles. The maximum voltage between breaker contact input to neutral, breaker contact output to neutral and across the breaker contact are 48 kV, 50 kV, and 58 kV respectively. This shows the impulses for the breaker pole voltage are reduced as have been seen earlier in Table -1. This as explained earlier should help improving electrical life of the breaker.

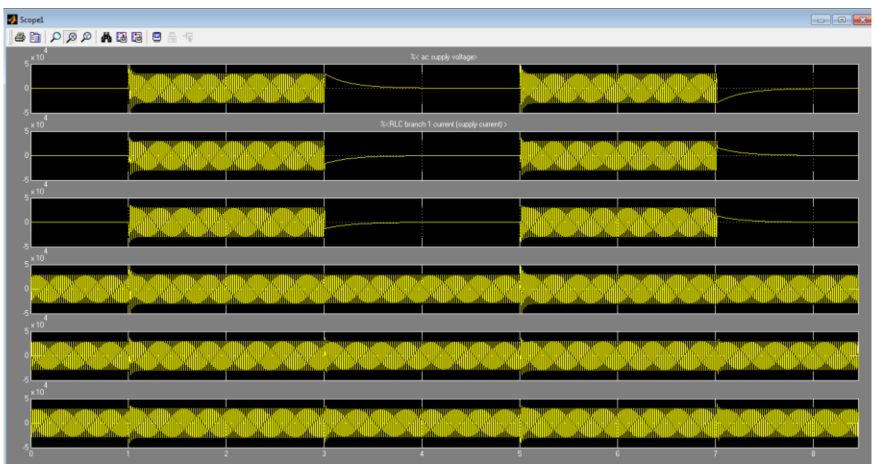

Figure 4: Voltage stresses for the breaker poles (output to neutral and input to neutral)

Channel 1, 2, and 3: Voltage between output side of the breaker poles and neutral (maximum stress touches nearly 50 kV)

Channel 4, 5, and 6: Voltage between input side of the breaker poles and neutral (maximum stress touches nearly 48 kV)

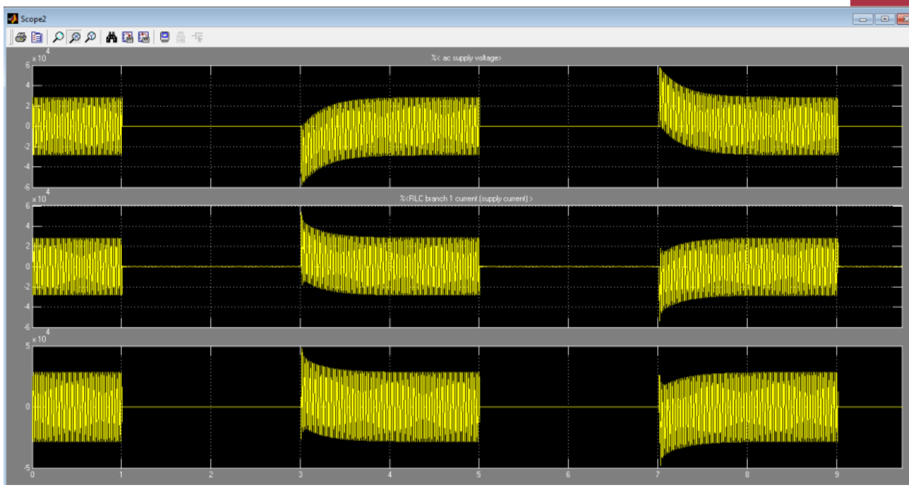

Figure 5: Voltage stresses across the breaker poles (maximum stress touches 58 kV)

Refer fig. 6 now. As seen from this figure 6, the capacitor voltages are not exceeding 50 kV when the breaker turns on. It also shows the transient currents are not more than twice the stable filter currents.

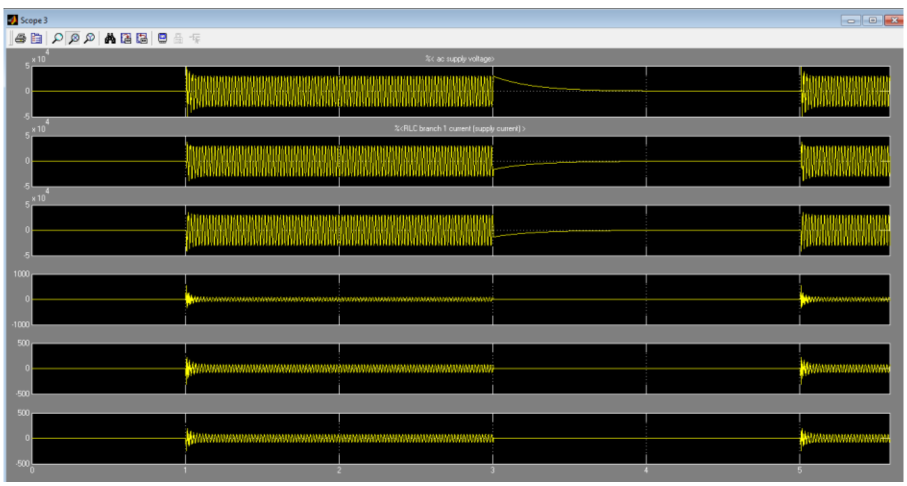

Figure 6: Voltages across the filter capacitors (channels 1, 2, and 3) and filter input currents (channels 4, 5, and 6)

Figures 7 and 8 compare the voltages across the 0.2% inrush current limiting reactors “without and with” the 24 Ω resistors in parallel with the inrush current reactors, respectively.

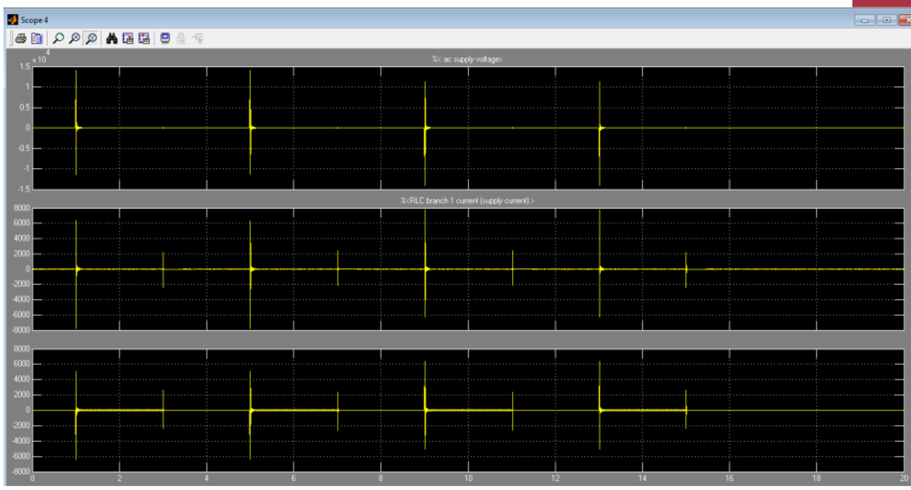

Figure 7: Voltages across the 0.2% inrush current reactors "without" the parallel resistor of 24 Ω

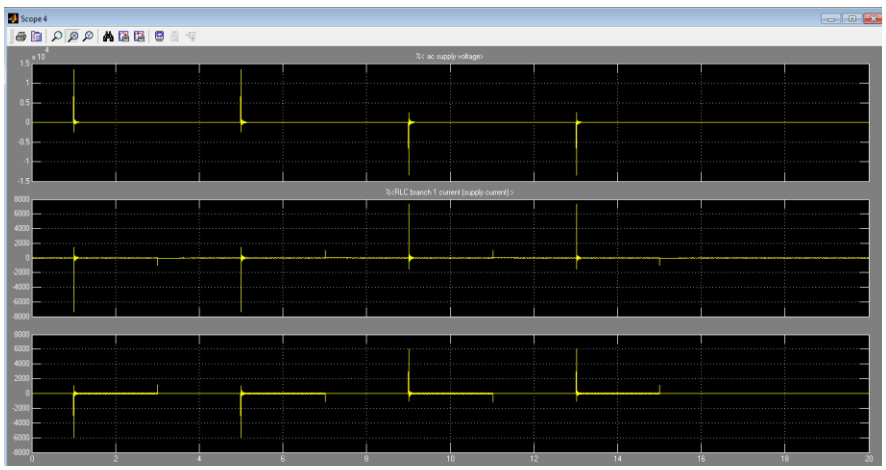

Figure 8: Voltages across the 0.2% inrush current reactors "with" the parallel resistor of 24 Ω

It is clear from figs. 7 and 8 that the voltages during turn on are similar as expected. However, the turn off voltages have gone down by almost 50% (±2000 V to 1000V) also reducing the dv/dt considerably across the reactors. This should help improve the life of the filter reactors and capacitors.

The R-C values for the snubbers are to be decided as explained earlier. The value of resistor R_f to be connected across (in parallel with) the filter reactor is as given below.

$$R_f = 2 * \pi * f * L * 30 \qquad \text{Equation (1)}$$

Where f is the supply frequency in Hz (50 Hz for India) and L is the inductance in Henry of the reactor. If there are current harmonics present in the system, a multiplication factor of "n" is essential, where "n" is the maximum lower order current harmonic expected in the system.

It should be noted that the parallel resistor R_f allows the filter inductor current to freewheel in it when the filter is disconnected from the system. This reduces arcing in breaker / contactor contacts virtually bringing down the dissipated energy close to zero, thus improving life of contacts.

CONCLUSION

The paper deals with simple methods to improve life of switching breakers / contactors used in power systems for power distribution or for control of switching reactors and capacitor banks. The suppressor network (snubber R-C) connected from input of poles to neutral or from output of poles to neutral allows considerable reduction of voltage impulses / stresses (MV to kV range) for the contacts. Further, parallel resistors used across filter inductances help in reducing arc energy dissipated across contacts. Similar methods need to be developed using simple strategies to improve health of every power system network to make the systems operationally healthier.