Application of Surge Arrester on Vacuum Circuit Breaker

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***Abstract*—A vacuum circuit breaker switching in installations supplying shunt reactor can cause overvoltage transients. These phenomena has been occurred in some distribution network especially in the network which require the application of shunt reactor to compensate voltage amplification due to very low current flow through the transmission lines. This transient problem is generally associated to the high-frequency overvoltage produced by the re-strikes and pre-strikes during the opening or closing of a switching device. The problem is occurred in all circuit breakers type, especially in vacuum circuit breaker (VCB). This paper intends to present a study case of this phenomenon. In this case, failures of a vacuum circuit breaker during shunt reactor bank switching in distribution network have been observed. There has been some evidence that the failures of vacuum circuit breaker have been occurred due to re-striking during reactor switching. Therefore the simulation and experimental investigation were conducted and the results were presented. The simulation was conducted to simulate the transient overvoltage when the switching occurred. Then the results of simulation were compared with experimental investigation in laboratory. The experimental set-up was made to reproduce similar switching re-strikes and fast transients overvoltage as it could be experienced when disconnecting a shunt reactor from the distribution network. Later the simulation was repeated using surge arrester to suppress the transient overvoltage. The surge arrester was also implemented in the experimental set-up. The result from simulation and experimental investigation were compared. Finally the surge arrester was implemented in the distribution network where the vacuum circuit breaker failure had occurred.**

I. Introduction

20 kV 10 MVAR shunt reactor has been installed in one of substation in Sumatera interconnection system. It is used to compensate the capacitive load of 150 kV transmission line during light load. The shunt reactor is directly grounded and connected to the system on 20 kV substation bus bar using vacuum circuit breaker (VCB). It has been observed that there have been five failures of VCB during its switching operation for one year service. All of the VCB that has been used is identical. The resulting failure of VCB can be seen in fig. 1.

By evaluating the damage of the VCB and its behavior during disconnecting low current, it is predicted that the high transition voltage has exceed the dielectric strength of VCB tube. This overvoltage is caused by high current chopping and re-ignition overvoltage.

For further evaluation of this failure, experiment is conducted in laboratory to observe the arc condition using 24 kV 630 A 12,5 kA-1s VCB recloser. To get the relationship between transition voltage with arc and load current, the experiment is conducted using 20 A inductive current. Re-ignition observation is done by determining transient recovery voltage (TRV) and rate of rise of recovery voltage (RRRV) using ATP-EMTP simulation of shunt reactor operation. Helmer circuit is used to simulate re-ignition with switch model type 13 Transient Analysis of Control System (TACS) switch which is programmed according to [1].

Fig. 1. Result of VCB failure

The experiment and simulation of Metal Oxide Varistor (MOV) implementation to solve this problem are also conducted. MOV performance simulation is conducted in load terminal (shunt reactor) and across contact gap, whereas the disconnecting laboratory experiment is conducted only in load terminal. The MOV type that is used in the experiment is ordinary 18 kV 5 kA distribution lightning arrester.

II. Laboratory Experiment

Experiment is conducted in laboratory with experiment setup of disconnecting low load current can be seen in fig. 2. The experiment result of disconnecting 20 A inductive loads without MOV can be seen in fig. 3. From the current curve, it is observed that since arc is unstable, the current chopping is relatively far away from zero which exhibits itself in the form of a negatively damped current oscillation superimposed on the load current. Re-ignition occurred in phase T which has short arc duration among other phase. After the current reach zero point, TRV increase and oscillates with high frequency. RRRV is more than 0,5 kV/s however TRV maximum value can not

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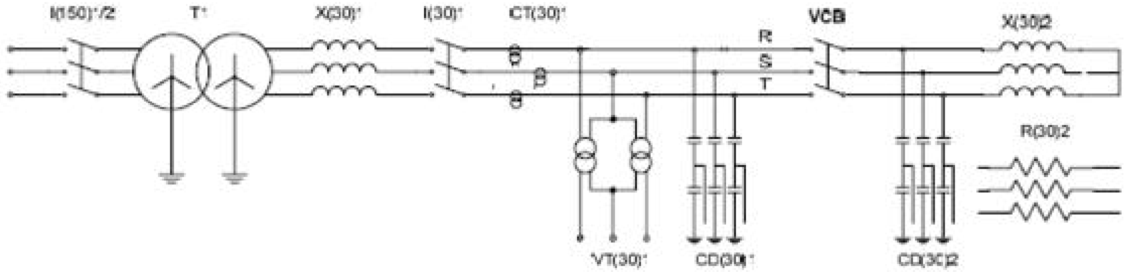
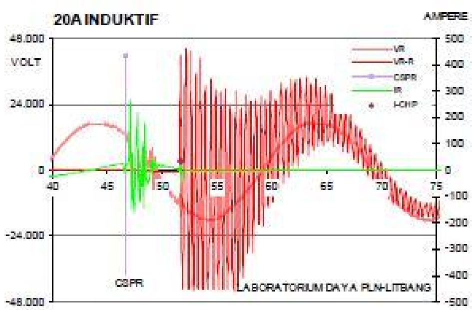
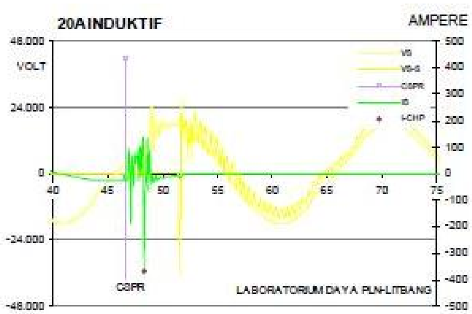


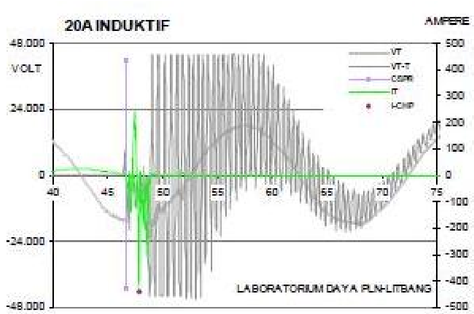
Fig. 2. Experiment setup of disconnecting low load current



(a) Phase R

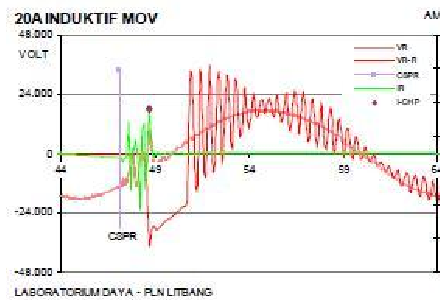


(b) Phase S

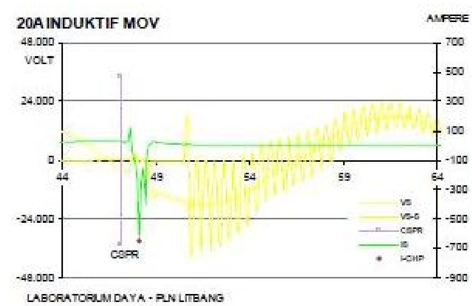


(c) Phase T

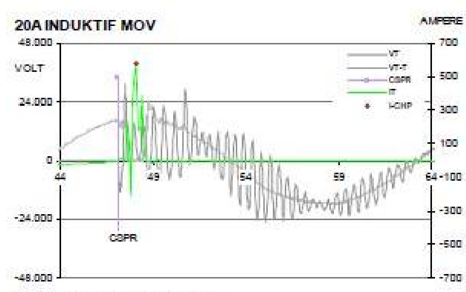
Fig. 3. Oscillogram of disconnecting 20 A inductive load without MOV



(a) Phase R



(b) Phase S

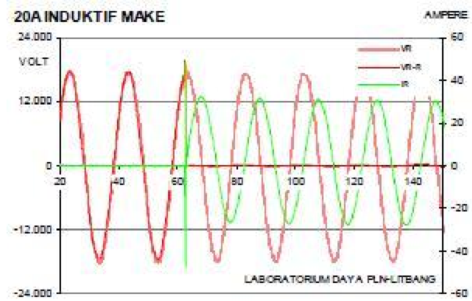


(c) Phase T

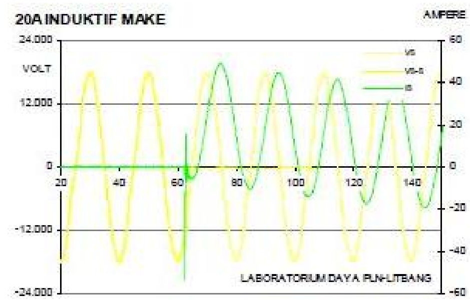
Fig. 4. Oscillogram of disconnecting 20 A inductive load with MOV

be seen since it exceed the measurement equipment capability. Nevertheless TRV and RRRV value of phase T exceed the limit which is determined by IEC 60056.

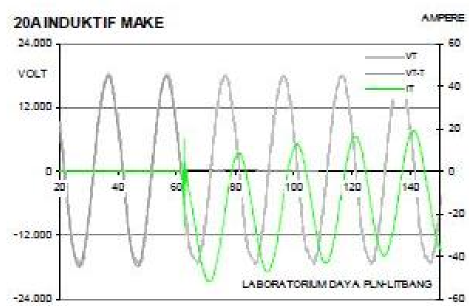
The experiment result of disconnecting 20 A inductive loads with MOV can be seen in fig. 4. MOV is installed on the load side or on the shunt reactor terminal. From the oscillogram, the overvoltage is not seen in phase T which is the first phase to be opened and phase R. The highest TRV from all phases is 39,3 kV and RRRV is 0,36 kV/s which is still under the



(a) Phase R



(b) Phase S



(c) Phase T

Fig. 5. Oscillogram of energizing 20 A inductive load

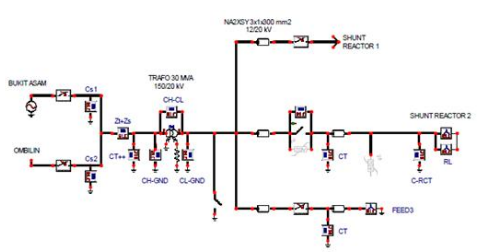
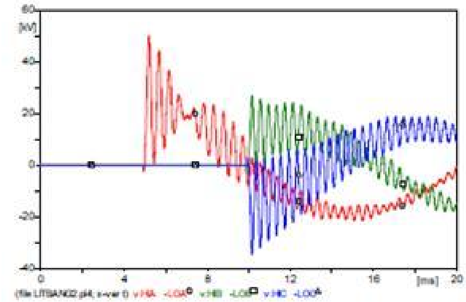


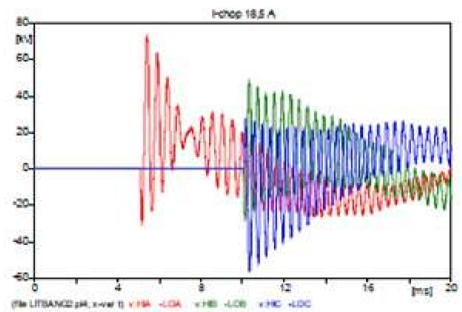
Fig. 6. Simulation circuit

limit of IEC 60056.

The next experiment is conducted to simulate switching in a low inductive load. From the result of experiment in fig. 5, it can be seen that there is no extreme overvoltage across contact gap or load terminal.



(a) Chopping Current 4,5 A



(b) Chopping Current 18,5 A

Fig. 7. Simulation curve of disconnecting shunt reactor

III. SIMULATION

The simulation is conducted using ATP-AMTP and the simulation circuit can be seen in fig. 6. From simulation curve of disconnecting shunt reactor which is shown in fig. 7, it can be observed that the highest TRV of all phase is 50,1 kV which is exceed the maximum value for VCB TRV (41 kV) according to IEC 60056 (CB for general use). RRRV is 0,24 kV/s which is still under IEC 60056 requirement (0,47 kV/s).

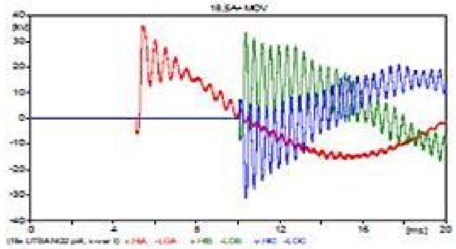
Further simulation is conducted using MOV to suppress overvoltage and the result can be seen in fig. 8. When MOV is installed in shunt reactor terminal (K1) TRV can be limited into 36,3 kV with RRRV 0,29 kV/s which is below IEC 60056 standard. Moreover when MOV is installed across contact gap (K2), TRV become 19,63 kV.

Another simulation is conducted to simulate re-ignition occurrence during disconnecting shunt reactor using Helmer circuit [2]. The resulting curve of circuit without MOV and circuit with MOV in K1 or K2 can be seen in fig. 9. It can be observed that MOV can reduce the magnitude of resulting overvoltage but it can not remove the re-ignition.

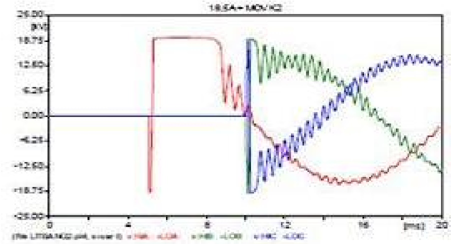
IV. CONCLUSION

VCB failure in this study case is caused by overvoltage which is occurred during disconnecting shunt reactor. The overvoltages which are generated are chopping overvoltages and re-ignition overvoltages.

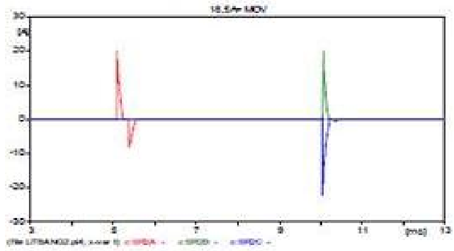
MOV (Lightning arrester) can be used to suppress the resulting overvoltages of disconnecting shunt reactor. MOV can be installed across contact gap or shunt reactor terminal with satisfactory result. Furthermore although MOV can reduce the



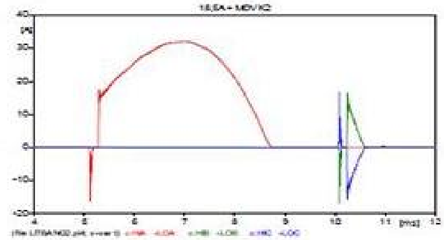
(a) TRV in K1



(b) TRV in K2



(c) Current in K1



(d) Current in K2

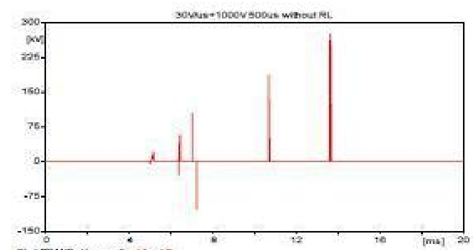
Fig. 8. TRV Curve and Current curve with MOV

magnitude of resulting overvoltage but it can not remove the re-ignition.

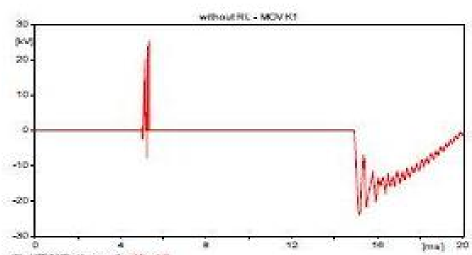
REFERENCES

[1] "High voltage alternating current circuit breakers, inductive load switching," IEC, 2 1233, 1993.

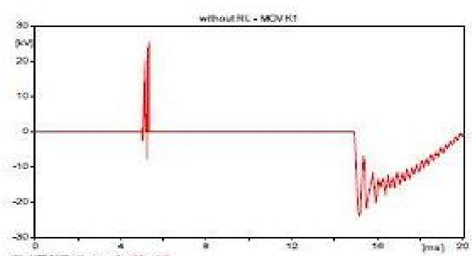
[2] P. Slade, "Growth of vacuum interrupter application in distribution switchgear," in *Trends in Distribution Switchgear: 400V-145kV for Utilities and Private Networks, 1998. Fifth International Conference on (Conf. Publ. No. 459)*, nov 1998, pp. 155 –160.



(a) Without MOV



(b) With MOV in K1



(c) With MOV in K2

Fig. 9. Disconnecting curve of VCB