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An Investigation of Circuit Breaker Switching Transients for Shunt Reactor

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ABSTRACT

Reactor banks play an important role in mitigating the voltage rise, otherwise known as Ferranti rise, which is characteristic to long lightly loaded transmission lines having high capacitive charging current .The energizing and de-energizing of the reactor bank introduces high frequency transient that might stress the insulation of the switching equipment leading to equipment failure. The different phenomenon associated with reactor bank energization and de-energization addresses the issue of circuit breaker application when interrupting low inductive currents from an engineering stand point. In order to study the various transients occurring during the switching of reactor bank in normal switching and switching of reactor bank during fault condition, I thought of publishing the paper in which the topic relates to occurrence of restrikes in circuit breaker. The reason for the occurrence of restrikes in circuit breakers is also to be studied. The simulation model and result of the implemented system are also analyzed. Several parameters affecting this phenomenon, such as arcing time, switching transient over voltages and dielectric co-ordination of interrupter are also to be studied in this dissertation work.

Keywords: Voltage Rise, Overvoltage's, Transients, Restrikes, Shunt Reactors

I. INTRODUCTION

Modern sf6 puffer circuit breakers have been designed with far fewer interrupters per pole than previous generations of sf6 circuit breakers. This has meant than modern circuit breakers have to contend with far higher voltage stress in the dielectric recovery region than previous types. Switching of shunt reactors is recognized as a duty that causes a very high rate of rise of transient recovery voltage across the circuit breaker contacts. Failures due to restrikes or re-ignition are becoming more of concern as it is difficult to detect re-strike occurrence. Failures can be catastrophic and they can affect the availability, reliability, safety and cost of the system which can greatly affect the utilities. Condition monitoring of circuit breakers is thus important in order to ensure safe operation and reliability of circuit breakers. To date, no specific technique has been developed to detect restrike. Currently shutdowns are requiring to physically connecting monitoring equipment to measure switching transients and restrikes.

Shunt reactors are commonly employed in sub-station as a cost effective way of reducing the voltage rise, during conditions of low load. When the transmission line is loaded below the surge impedances load, the line experiences a voltage rise due to the line's shunt capacitance drawing charging current through the series inductance. Shunt reactors are switched into the circuit to compensate this effect. In other words, when load is low and power source of EHV line is at considerably long distance from sub-station, due to Ferranti effect receiving end voltage is greater than sending end voltage as line conductors act as capacitors. High receiving end voltage can cause insulation failure of the substation equipment. Therefore, shunt reactors are introduced in substation bus which draws reactive power and loading on line increases causing drop of voltage.

II. Need for Study

Due to the deregulation of electricity markets, reliability, stability and availability of power systems must be improved in order to increase the competitiveness of electricity markets. In order to improve such aspects, power systems should be operated with minimal abnormal conditions and those conditions must be cleared as soon as possible. Therefore, HV circuit breakers, designed to interrupt faulted conditions, have played an important role in power systems over 100 years since the first introduction of oil circuit-breakers. It is believed that designing general HV circuit-breakers to fit all purposes is cost effective and easy to maintain. However, it is found that there are many over-designed HV circuit-breakers installed in the networks during the past 30 years. Although the technology of an interrupting medium used in HV circuit-breakers has not been considerably changed since the introduction of SF6 circuit-breakers in 1960s, the development and studies in other areas, such as, materials, structures, arc models, monitoring, maintenance techniques and asset management are still continued. The comparison represented that single-pressure SF6 circuit breakers have less major failure rate than older technology circuit breakers. Nevertheless, the minor failure rate of single-pressure SF6 circuit breakers is higher than older-technology circuit breakers. At present, HV circuit-breakers are basically designed to fit in the networks for any applications; for instance, capacitance switching, line closing, shunt reactor switching, transformer switching and generator protection. Hence, it becomes necessary to study the various effects on circuit breaker while switching reactor bank. Hence, it is very challenging for engineers to improve the maintenance programs while keeping the maintenance costs at an acceptable level. This is among the most discussed issues in the asset management area, since maintenance costs are considered as the large part of the operation costs.

Two questions were identified to guide the study:

- To study the behaviour of circuit breaker during inductive load switching.
- To study the behaviors of circuit breaker during inductive load switching including switching during fault/tripping by developing soft computing model.

III. METHODOLOGY

Switching of reactive equipment such as shunt reactors is known to produce overvoltage transients that may cause insulation breakdown lead to power system failure. The reactive equipment is connected to power system via circuit breakers this similar for equipment like overhead lines, transformers and generators. When circuit breaker operates, parts of power system are either connected or disconnected to each other. This can be either closing or opening operation of circuit breakers. Thus, switching of reactor banks causes over voltages and over currents which may lead to circuit breaker failure. So, it becomes necessary to study the behavior of circuit breaker for inductive load switching during normal as well as during faulty condition in order to save the power system from complete failure. HV circuit-breakers are among the most important equipment in power systems. They are designed to use as interrupting devices both in normal operation and during faults. It is expected that HV circuit-breakers must be operated in any applications without problems. Moreover, it is expected that they must be ready to be operated at anytime, even after a long period of non-operating time. The main functions of HV circuit-breakers can be categorized into four functions. Switching-off operating currents, switching on operating currents, short-circuit current interruption, secure open and closed position. Insulation: The electric insulation of HV circuit-breakers is provided by a combination of gaseous, liquid and solid dielectric materials. The failure of insulation can lead to severe damage such as flashover between phases, to ground or across the opening poles resulting in major repair or replacement. In order to prevent such failures, the insulation must be maintained and monitored. Current carrying: The current carrying parts are significant components that assure the flowing of current in the closed position. Switching: During operation of HV circuit-breakers, they are subject to electrical, thermal and mechanical stresses. It is required that they should be able to make and break large amount of power without causing failures. Operating mechanism: The operating mechanism is a part used to move contacts from open to closed position or inversely. Control and auxiliary functions: Control and auxiliary components are the parts controlled by 110-220 volts d. c. Arc interruption**:** The arc interruption can be carried out by cooling the arc, increasing the length and splitting it into a number of arcs in series. The methodology proposed for this dissertation work is given as below: It is proposed to consider 132KV level sub-station as a model sub-station having 132KV bus and feeding source to this bus is near about 150Km away from the bus. Line feeding to this bus is having current carrying capacity of 500Amps and accordingly the line conductor size (02) is chosen. But, sub-station is having very low load connected to its bus, say near about 4 MW only, and in this case due to capacitance of conductor, receiving end voltage of the substations bus tending to rise beyond 145Kv.This type of conditions are to be simulated in soft model and switching of reactor of 10MVAR is to be done with the help of soft model. Thereafter, when load condition changed to normal load and voltage drop down having no need of shunt reactor, this condition is also to be simulated and then reactor is to be switched off. In both condition switching on and off with the soft model, various parameters are to be studied. Breaker is considered to be of normal standard specifications and switching parameters are to be studied to draw a conclusion to establish that specifications of a circuit breaker are adequate /inadequate for switching the10MVAR reactor

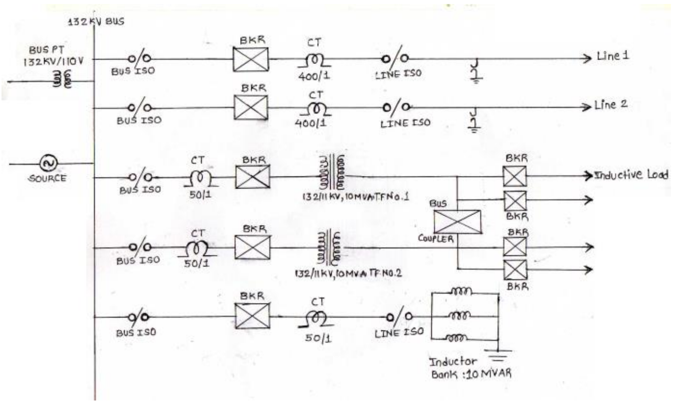

Figure 1. Single line diagram of proposed 132/11kv model substation

It is proposed to consider 132KV level sub-station as a model sub-station having 132KV bus and feeding source to this bus is near about 150Km away from the bus. Line feeding to this bus is having current carrying capacity of 500Amps and accordingly the line conductor size (02) is chosen. But, sub-station is having very low load connected to its bus, say near about 4 MW only, and in this case due to capacitance of conductor, receiving end voltage of the substations bus tending to rise beyond 145Kv.This type of conditions are to be simulated in soft model and switching of reactor of 10MVAR is to be done with the help of soft model. Thereafter, when load condition changed to normal load and voltage drop down having no need of shunt reactor, this condition is also to be simulated and then reactor is to be switched off.

- Normal Voltage—145KV (max)
- Normal Current—1600Amps
- Lightning impulse withstand voltage—650KV
- Short circuit breaking current—31.5 Amps/second
- Line charging breaking current –50 Amps
- Operating sequence— 0.035- C0 - 3min - C0
- First pole to clear factor—1.3
- Power frequency withstand voltage –275kv
- DC component—51%
- Making capacity—80Kamps

IV. Simulation model

A simulation model of work topology is presented over here. Simulation model comprises of various blocks as 3 phase source, 3 phase VI measurement block, 3 phase transformer, Distributed parameter, 3 phase breaker, 3 phase fault, Reactive load. It comprises of two models to show the effect of switching of reactive load on circuit breaker during normal as well as faulty condition. During normal condition, the transmission lines are first switched off at the line side resulting in no-load transmission lines. At this moment, only a charging current flow in the transmission lines and it charges the capacitance of the transmission lines. After that, the circuit-breaker at the sending end is called upon to switch off. The circuit-breaker is then stressed by the voltage rise at the supply side and the oscillation at the line side. The recovery voltage across the circuit-breaker varies from 2.0 to 3.0 p. u. Interruption of no-load cables is similar to interruption of no-load transmission lines which belongs to the case of capacitive current interruption. But during normal switching and switching during fault there are switching surges which may burst the circuit breaker as shown in below model. It comprises of control unit which will automatically disconnect the faulty portion without harming the whole power system. The logic unit mainly comprises of timer circuit which will automatically disconnect the entire circuit during faulty condition.

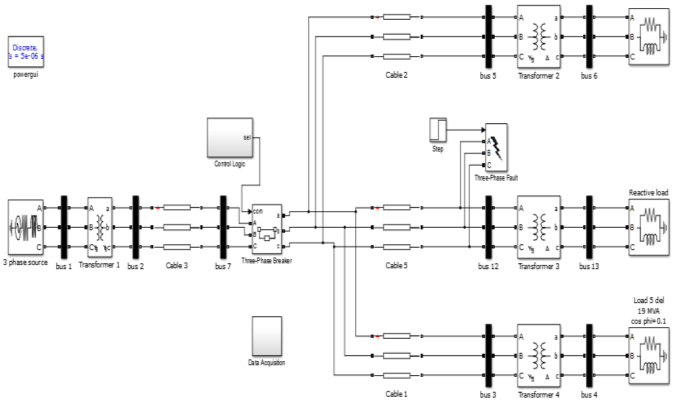

Figure 2. Model with logic unit

V. Result and Discussions

The simulation study of the proposed system is conducted by MATLAB. It is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Table 1. System Parameters

Description	Parameters	Real Value
Rated capacity	P	10MVAR
Rated Voltage	V	132KV
Rated frequency	F	50Hz
Breaker resistance	Rb	0.001ohm
Snubber Resistance	Rs	10^5 ohm
Fault Resistance	Rf	0.001ohm

During normal condition while switching inductive load breaker gets burst shown by period up to 0.2 sec at bus no. 1. Condition remains same at all the buses it means at bus 7 and bus 12.During faulty condition at bus 7 as the fault occurs, there is over current and after that circuit breaker disconnects the reactor bank thus protecting the power system .

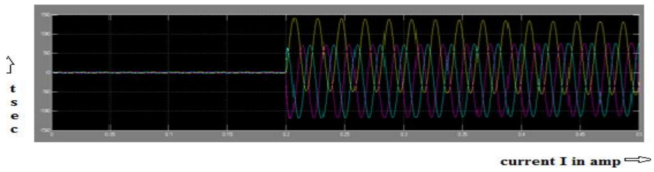

Figure 3. Waveform during normal switching

The Timer block generates a signal changing at specified transition times. Use this block to generate a logical signal (0 or 1 amplitudes) and control the opening and closing times of power switches like the Breaker block and the Ideal Switch block. You can also use this block to generate a signal whose amplitude changes by steps at specified transition times. It comprises of control unit which will automatically disconnect the faulty portion without harming the whole power system. The logic unit mainly comprises of timer circuit which will automatically disconnect the entire circuit during faulty condition.

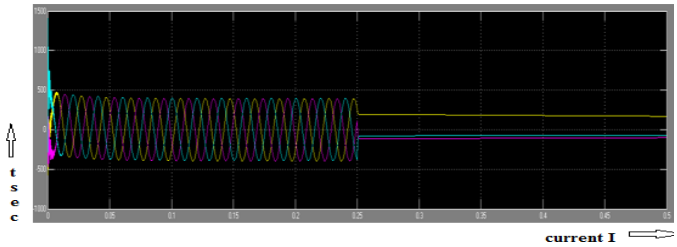

Figure 4. Waveform during faulty switching

VI. Conclusion

When special purpose switching devices are available for harsh switching duties, such as shunt reactor switching, they will often be a better fit to the application than general purpose devices. Over the years, circuit breakers and circuit switchers have been adapted for routine shunt reactor switching. Because of constraints in recent Matlab also only two switching transients are studied and in both the cases breaker found failed during switching of reactor bank. However, breaker fail during reactor switching because dc component and first pole to clear factor could not be studied, which are the major transients. Because of constraints in recent Matlab also only two switching transients are studied and in both the cases breaker found failed during switching of reactor bank. However, breaker failure during reactor switching because of dc component and first pole to clear factor could not be studied, which are the major transients and which requires sophisticated software like EMTP.After studying these two transients in detail the technique for avoiding breaker failure during reactor bank switching can be developed.

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