SIMULATION OF SHUNT CAPACITOR SWITCHING TRANSIENT

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Keywords

Capacitor banks, circuit breaker, capacitive coupler, controlled switching, current interruption, high voltage, over-voltages, switching, transients, voltage allergen.

Abstract

Energization of capacitor banks and shunt reactors has been recognized as a possible source of malfunctions due to the known effect of Switching Transient. Switching transient can produce unwanted high currents with different frequencies that can harm the system in different ways.Modern controlled switching techniques have been developed to reduce switching unwanted effects. Theses modern techniques are based on the fact that if switching operation takes place at a point-on-wave, then it can minimize effectively the effect of switching transient. Theoretically, the controlled switching techniques shall eliminate the switching transients totally. However, current statistics and researches show that the characteristics of the controller and the circuit-breaker itself can affect the success of this method. Therefore, basic understanding of all transients produces during switching process shall be studied taking into consideration all possible parameters and effects. Therefore it was necessary to use the modern computational techniques to solve to a high fidelity nonlinear mathematical model for the transient effect. In this work we used the numerical method applied by ATP software to investigate the transient effect on the quality and quantity of system. Investigations for the cases of Energization inrush, Back to back switching, Outrush Transient, Voltage Magnification and Transient Recovery Voltages was done. The important results are the fact that the transient can be modelled including all parameters and components in such a way that the effect of transient can be minimum. The pivotal identification properties of the transients definitely can be used to improve design characteristics and controlling parameters.

ABSTRAK

Pengkuasaan kapasitor bank dan reaktor selari telah diiktiraf sebagai sumber yang berkemungkinan akan menyebabkan kerosakan berdasarkan kesan yang di ketahui iaitu Pensuisan Sementara (Switching Transient). Pensuisan Sementara ini akan menghasilkan arus tinggi yang tidak diingini dengan frekuensi yang berbeza-beza yang akan membahayakan sistem dalam pelbagai cara. Teknik moden pensuisan terkawal telah di wujudkan untuk mengurangkan kesan pensuisan atau pertukaran yang tidak dinigini. Teknik baharu ini adalah berdasarkan fakta bahawa jika operasi pensuisan berlaku pada gelombang yang betul, maka ia boleh mengurangkan dengan berkesan kesan beralih sementara ini. Secara teorinya, teknik pensuisan terkawal ini seharusnya menghapuskan sepenuhnya peralihan sementara ini. Walau bagaimanapun, statistik semasa dan kajian-kajian menunjukkan bahawa ciri-ciri pengawal dan pemutus litar itu sendiri boleh mempengaruhi kejayaan kaedah ini. Oleh itu, pemahaman asas kesemua perkara berkenaan sementara yang berlaku dalam tempoh masa yang pendek haruslah dikaji dengan mengambil kira parameter munasabah dan kesan-kesannya. Oleh itu, adalah perlu untuk menggunakan teknik-teknik moden untuk menyelesaikan model matematik linear kesetiaan yang tinggi untuk kesan yang sementara. Dalam bidang ini, kita menggunakan kaedah berangka yang diaplikasikan oleh perisian ATP untuk mengkaji kesan sementara kepada kualiti dan kuantiti sistem. Siasatan bagi kes-kes Energization Inrush (Pengkuasaan Rempuh Masuk), Back to back Switching (Penukaran Balik ke Belakang), Outrush Transient (Rempuh Keluar Sementara), Pembesaran Voltan dan Pemulihan Voltan Sementara telah dilakukan. Keputusan yang penting adalah hakikat bahawa kesan sementara yang boleh dimodelkan termasuklah

semua parameter dan komponen melalui apa-apa cara supaya kesan sementara boleh menjadi minimum. Ciri-ciri pengenalpastian penting daripada kesan-kesan sementara sudah tentu boleh digunakan untuk meningkatkan ciri-ciri reka bentuk dan parameter kawalan.

CHAPTER ONE

INTRODUCTION

1.1 Background.

Increased emphasis on energy conservation and reduction of purchased electric power bills have resulted in an increased awareness of the importance of capacitors on industrial systems. Larger banks of capacitors are being considered for installation and many questions relating to the application must be answered. Most of the commonly encountered factors relating to equipment selection, location on the system, protection, and switching criteria are reviewed (Miller, 1976). So that the increasing use of interruption in power distribution systems for a variety of switching conditions have provided considerable operating experience and generally their performance has been good. Also as it known that Shunt capacitors are capacitors which are placed across an electric power line or electric appliance to provide a voltage increase or to improve the power factor of the circuit. The most important function of using shunt capacitor banks that they develop the quality of the electrical source and the effectiveness operation of the power system. As it knows shunt capacitors are capacitors which are placed across an electric power line or electric appliance to provide a voltage increase or to improve the power factor of the circuit.

The elements protection of shunt capacitor bank usually contains protecting from internal bank faults which often occur inside the capacitor unit, and protecting the bank from system disturbances (Erven *et al,* 1985). Protection orders start with a

shutdown of the bank, and in case of faults inside the bank that may lead to disastrous failures in section.

Circuit breakers CB called SF6 have been designed with less interrupter per pole than earlier generations of SF6 circuit breakers. This has meant that recent circuit breakers must contend with very high voltage stress in the dielectric recovery region than prior classes (IEEE Std C37.012, 2005). The increased stress has affected dielectric re-ignition of some classes of circuit breaker on capacitor switching (CS) duties. In this context, recent standards have been established that necessitate a big number of experiments and provide a categorization of circuit breakers based on their probability of re-striking for capacitor switching (IEC62271-100, 2001). Switching of shunt capacitor bank is identified a very high proportion of high transient recovery voltage across circuit breaker. With the continuing evolution in capacitor bank; re-strike free process of circuit breaker is not fail safe for the traumatic capacitor and inductive switching responsibilities. Situations that a very lower re-strike possibility as the best potential performance for circuit breaker on capacitor bank switching responsibilities (IEEE Std C37.012, 2005).

Given guide on the application of alternative current high voltage circuit breaker forcapacitor bank switching respectively. Safeguards are also taken through the designed stage by selection suitable breaker responsibilities, carrying out system study and evaluate method to reduce over voltages transients. Controlled switching to reduce switching transients appears to be the favored ways selected by utility, observed procedures these fault from modern circuit breaker through capacitor bank switching (Bachiller *et al,* 1994). Also there is last faults from circuit breakers has been due to re-striking through reactor switching, capacitive switching where re-

strikes does not cause instant faults. Although they progressively degrade the nozzles over times lead to cataclysmic faults. (Spencer *et al,* 1998) proposed that the high frequency reigniting current through interrupted causes parasitic arcing in the circuit breaker nozzle. These phenomenon leads to gradually deterioration of the nozzles that may be eventually puncture the nozzles materials, consequence in the faults of the interrupted. Faults due to re-strikes, reigniting are becoming more concerned as it is hard to detect re-strikes incidence. The faults cases can be disastrous and affected the available practicalities protective and value in the system which can be greatly affect the utility through substituting from reactive tools. (Moore, 2004) has proved the practicalities from gauging time between poles closing in circuit breaker through capacitor switching responsibilities of measuring of emission radio wave. In this thesis research is implemented to selecting whether it is likely to outspread Moore method to investigate switching transient through circuit breakers. Methods for monitoring the sizes and numbers from re-strike which happening through reactor switching by this or analogous techniques have been discovered.

1.2 Research Conducted.

This research investigates switching transient through the switching of three phases circuit breaker. It will be used an experiment of transient phenomena which occurring in circuit breaker and the shunt capacitors. It also includes a review of information, analytical and techniques that were researched and implemented for the calculation of the transient duties of shunt capacitor components. At the case of switching operation occurring at breaker and energizing transients of the capacitor banks.

1.3 Problem Statement.

Voltage transients produced by switching operations are governed through the characteristics of the circuit breaker performing the switching operation, as well be the circuit breaker that is of greatest concern is probably its chopping level current. Since research on contact materials has been progressing the problem of over voltage attributable to current chopping has been practically solved, therefore expanding the switching devices application range (Eugene *et al,* 1969 & Panekj *et al,* 1975).

Capacitor banks have long be used to provide voltage support, provide reactive power compensation and to correct power factor on utility distribution systems, (Reid *et al,* 1984) they are provided to reduce power and energy losses, preserve best voltage principles for load buses and mend power system. Capacitor banks are connected either directly to the high voltage bus or to the tertiary winding of the main transformer. Switching off capacitor banks provides a convenient means of controlling transmission system voltages. They are normally distributed throughout the transmission system so as to minimize losses and voltage drops. Due to their widespread applications, capacitor switching transients are the most common transient events on the power system.

Unfortunately, most utilities have limited resources to know these problems and connect them with capacitor switching operations at electric circuits, so that the issue is connected with the supply of capacitors in system, which is essentially through effectiveness of capacitors in the electric system. As well as a huge variety of research work has been done on capacitor switching

in the past. All the approaches are different from each other by the way of their formulating the problem and the solution method employed. Many studies have been done to trying to develop the effectively capacitors since they are widely used as parts of electrical circuits in many common electrical devices. For example, (Van, 2001) studied of the optimum location, size, and timing of capacitor banks on feeders with uniformly distributed loads, may be distribution randomly for the variable loads and to evaluate the reduction at costs of active, transients caused by switching of high voltage, and failures of shunt capacitors during service operations received significant attention in recent years via numerous technical papers and guides from the power community. As I mentioned that the studies of capacitors differ from each other, such as (Grebe T.E, 1996) reported that problems with switching of small capacitive and inductive currents can be solved by applying controlled switching. For normal conditions, controlled switching reduces voltage and current transients.

Hence, the analytical method using (ATP) will be done to find out if there are any effects of faults occurring through the operation of shunt capacitor bank, and to investigate different operational cases of the capacitor switching aiming at finding the best technique can be used to limit the effect of capacitor switching transients. It mainly focuses on determining the current and voltage transients. It also describes a review of transient phenomena associated with shunt capacitor bank.

1.4 Research Scope.

This research studies the changes which occur on high voltage and high current during shunt capacitor bank switching transient at different times and calculating the best and the worst case in high magnitude of current and high frequency, at the same time the case when occur of fast distribution.

1.5 Objectives of the Research.

This study will be conducted to achieve the following objectives:

i. To calculate transient voltages and currents during shunt capacitor banks switching operations.

ii. To study the effect of faults occurring through the operation of shunt capacitor bank.

iii. To analyze transient of capacitor banks switching using simulation software (ATP).

1.6 Thesis Outlines.

The chapter content is divided into five chapters. Following this introductory chapter, chapter two describes the literature review of previous studies and review of background information on transient switching of circuit breaker and shunt capacitor bank at five cases in electric power system.

Chapter three describes the methodologies of study that will include the analysis of transient phenomena occurring in circuit breaker in the simulation of shunt capacitors bank. It also includes a review of information about analytical techniques that were researched and implemented for the calculation of the transient

duties of shunt capacitor components. At the case of switching operation occurring at breaker and energizing transients of the capacitor banks.

Chapter four discusses results of descriptive analysis of the transient during circuit breaker switching and capacitor bank, will then present the result and discussion. Chapter five will be dealing with the conclusions and recommendation for future research.

CHAPTER TWO

LITERATURE REVIW

2.1 Introduction

In an electrical power system, passive reactive power compensation is provided by shunt capacitors. Shunt capacitors are used for lagging power factor circuits, so the effect is to provide reactive power support that maintains the voltage limits in the system. This chapter presents a literature review of findings pertinent to this research. Shunt capacitor bank have been used in electric power distribution systems for over 60 years. Historically, they have been applied to correct power factors and regulate voltages. In the 1950s, shunt capacitor banks began to be installed on electric power transmission systems to increase the overall system efficiency and, to some extent, improve transient stability. More recently, fast mechanically switched or thyristor switched capacitor banks have also been used in transmission systems to dampen system oscillations .As well as Shunt capacitor banks are used to improve the quality of the electrical supply and the efficient operation of the power system. Studies show that a flat voltage profile on the system can significantly reduce line losses. Shunt capacitor bank are relatively inexpensive and can be easily installed anywhere on the network (Reid *et al,* 1976).

2.2 Review of Current Interruption in Circuit Breakers.

The principal objectives from an interposing stratagem for instance Shunt capacitor bank is to detach the circuit in the point at which it is laid. When closing the circuit breaker ought to convey continued rated current. The dielectric to ground is strained through the power frequency voltage; any transient over voltages when open the insulation between the connections is strained through the voltage, developing through the open connection. Through, the transition time of close to open and conversely, a scope of dynamic circumstances arise. Such as through a change of close to open and the current should be outage to accomplish electrical isolation. Disconnected of current usually happens at a current zero of the sinusoidal wavelength and a voltage known, for example the transient recovery voltage seems through the open connections from the circuit breaker. The ability of circuit breaker to interrupt the current is contingent on exterior circuit parameters, insulation recovery and connections separated in the time of current zero interrupter designed, the interrupter situations for example ordinary load, reactive switching or fault current. The ratio of elevation, the peak value of the transient recovery voltage has an important impact on circuit breaker performance. Wavelengths of model circuit disruption series are given in Figure 2.1 for a failure on the carry lateral substation from the circuit breaker. Circuit disruption series are given in Figure 2.1 for a failure on the carry lateral substation from the circuit breaker. (Bachiller *et al,* 1994)

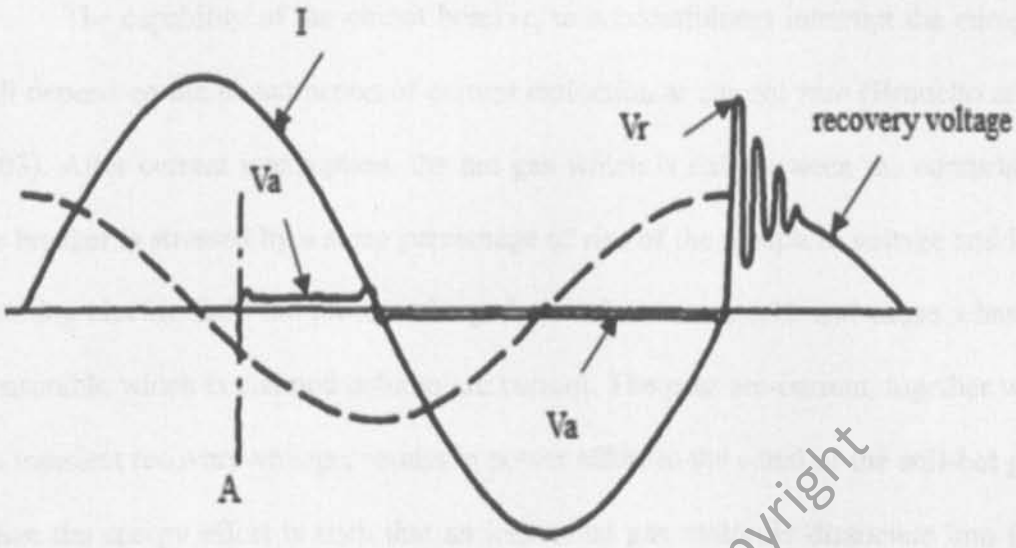

Figure 2.1 Circuit Interruptions (Bachiller *et al,* 1994).

The circuit breaker communicates discrete in the point and causes are curve, drawn between the contacts and these curves have a resistance which generates a small voltage dropping (VA).The curve and lasts until the current (I), drops into a level also small to retain it. This happens such as the current pass during zero, at this level the curve extinguishes and the transient recovery voltage TRV appears during the circuit breaker connections. Succeeding interruption is attained if the insulator strength between the connections as they separated increase at a larger average than that of the transient recovery voltage. In addition, the breakdown strength from the aperture between the connections should surpass the peak value from the transient recovery voltage. If not the curve will be recreate, and current interruption may happen in resultant zero. When the current severed, the voltage between the connections changes of almost zero the curve voltage in the immediately value from the power frequency voltage. These changes cannot take place immediately, a resulting skip happens. The voltage methods it steady states values through a transient oscillating with a frequency that is determined through the values from the circuit inductance and capacitors.

The capability of the circuit breaker, to successfulness interrupt the currents will depend on the phenomenon of current extinction at current zero (Brunello *et al,* 2003). After current interruption, the hot gas which is still between the contacts of the breaker is stressed by a steep percentage of rise of the recapture voltage and in a resulting electric field the present charged particles start to drift and cause a hardly measurable which is claimed column arc current. The post arc-current, together with the transient recovery voltage, results in power effort in the canal of the still-hot gas. When the energy effort is such that an individual gas molecule dissociate into free electrons and heavier positive ions, the plasma state is created again and current interruption has failed. This is called a thermal breakdown. Thermal breakdown normally occur within microsecond in a region known as thermal recovery phase. When the current interruption is successful, the hot-gas channel cools down and the post arc current disappears. However, if the dielectric strength of the gap between the breaker contacts is not sufficient to withstand the transient recovery voltage, a dielectric failure can occur. Dielectric failure normally occurs within milliseconds in a region known as dielectric recovery phase.

2.3 Power System Frequency Characteristics.

An accurate knowledge of the power system's frequency characteristics is needed to design filters to mitigate harmonics and to investigate system resonances. The installation of shunt capacitor bank changes the power system's frequency characteristics. With the advent of power electronic devices and the operation of the power system closer to its limits, the extent of harmonics in the power system has increased. At the same time, the use by consumers of devices sensitive to harmonic currents and voltages has increased. Examples of devices that may