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THE PHYSICS OF POWER INTERRUPTION. A USER'S VIEW

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INTRODUCTION

The National Grid Company pIc (NGC) owns and operates the high voltage electricity transmission system in England and Wales and transmission links with Scotland and France. At present, NGC owns of the order of 700 circuit breakers at 400kV, 660 at 275kV and 690 at 132kV. As a user of high power circuit breakers, NGC has an interest in the physics of power intenuption in order to maintain an awareness of operational implications on the use of circuit breakers in the system and to be an informed buyer.

Key words: Physics, Interruption, Transmission, Circuit Breakers

CIRCUIT BREAKER PERFORMANCE

One aspect of power interruption is the need for circuit breakers. which an: designed to handle fault currents of several tens of kiloamperes. to interrupt small reactive currents of several amperes and be able to withstand the subsequent seven: dielectric stress without damage. Such applications arise when switching shunt reactors and de-energising unloaded transmission circuits. The user will want to ensure that a circuit breaker is adequate for its duty and will continue to operate correctly under all circumstances. He will need adequate specifications and tcst procedures and will wish to have his needs represented in international standards. However in the above applications, and particularly in the case of shunt reactor switching. the performance of a circuit breaker in a laboratory test circuit is not sufficient to guarantee its performance in service. The arc and the associated circuit interact with each other through current chopping, recovery voltages, reignitions and so forth. Furthermore, the behaviour of the arc is not necessarily predictable.

To better understand the problems associated with low current reactive switching. arc behaviour is being studied at the University of Liverpool in a co-funded investigation with the Engineering and Physical Sciences Research Council (EPSRC)(1). while NGC is performing studies to model the associated circuit and its response. Measurements of switching waveforms in service are an essential part of the research program and an: used by NGC in addition to the relevant type tests to confirm satisfactory performance in situ when a circuit breaker is put into service.

The arangement used for measuring switching waveforms of GIS circuit breakers is shown in Figure 1. The sensors used for voltage measurement an: purpose-built capacitive couplers, where these are installed. and partial discharge capacitive couplers elsewhere. The coupler output is connected to a digital storage oscilloscope via a passive probe for buffering and a fibre optic light link for isolation.

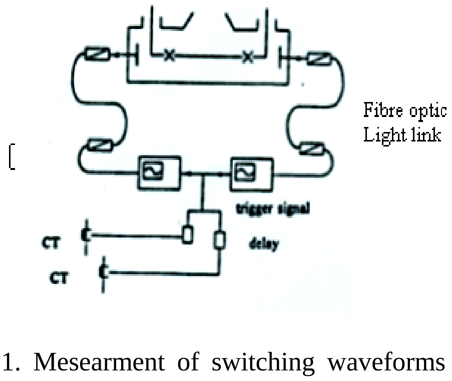

Figure 1. Mesearment of switching waveforms for GIS circuit breaker

Two oscilloscopes provide 2MB of acquisition memory on each of four channels, allowing 40ms of waveform to be captured with a sampling rate of 50 MS s.' or lOOms of waveform with a sampling rate of 20 ms 5" for all three phases on both sides of the circuit breaker. Where the faster sampling rate is used, the overall bandwidth for the measuring system extends to the

15MHz limit of the light links. The measurement system Is intended to allow both the power frequency information and high frequency events to be captured.

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The typical result of Figure 2 shows the load side voltage on one phase during an open (or break) operation on a 400 kV shunt reactor circuit. The waveform shows a reignition followed by a successful interruption half a cycle later. The reignition overvoltage is also shown in expanded form. The user will wish to evaluate whether such ovcrvoltages place an unacceptable stress on the shunt reactor.

Wave form showing reignition followed by successful interuption, timebase = 10 ms per division.
Expansion of reignition overvoltage, timebase = 1µs per division

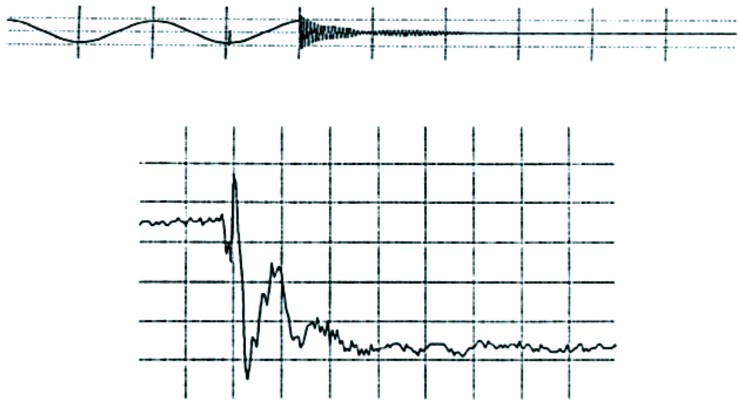

Figure 2 Voltage waveform during open operation on 400kV shunt reactor

For measuring the switching "wave forms of open terminal circuit breakers, NGC has procured a set of capacitive dividers from Re)TOlle Switchgear. Each divider consists of a small GIS chamber equipped with two capacitive couplers and is connected to the system via a gas to air bushing. The response of the capacitive dividers was evaluated in tests at the Clothier Laboratory. The coupler output was compared to the signal obtained using an elecric field probe located below the busbar adjacent to the divider under test. The response was shown to be sufficiently fast to record the falling edge of a lightning impulse chopped by a rod-rod gap in air.

CIRCUIT BREAKER DEVELOPMENTS

Switchgear users continually demand smaller, simpler and cheaper equipment with reduced life cycle costs, while maintaining specified performance. The consequent evolution in circuit breaker technology over the years has been characterised by a number of step changes as different arc interruption techniques have been introduced and developed in turn. At present. through the application of powerful experimental and analytical tools, manufacturers of transmission switchgear
are pursuing developments and refinements of SF, puffer systems with the development of the self blast or auto puffer interrupter. These developments have enabled the use of lower powered and hence cheaper mechanisms. It is of interest to the switchgear user to consider what new technique may form the basis of the next generation of circuit breaker for use at transmission voltage levels in order to stimulate the next step change and anticipate possible adverse system effects.

In recent years, a number of manufacturers have produced circuit breakers for use at distribution voltage levels which are based on electromagnetic arc control, such as the rotary arc interrupter, where the arc is driven through the gas by the Lorentz force to provide forced convection cooling. Application of this technique to transmission voltage levels would lead to a significant reduction in operating energy requirements, allowing simplification of the drive mechanism. Other potential advantages would be improved interruption performance and greater interrupter life and reliability. A feasibility study performed by the University of Liverpool for The National Grid Company pic concluded that electromagnetic arc interruption was feasible for transmission applications provided a suiuble interrupter geometry could be found. Work is continuing at Liverpool under EPSRC funding (2).

CONCLUSIONS

As a user of circuit breakers in a high voltage electricity transmission system, NGC is maintaining an interest in the physics of power interruption through effort in house and under contract. Measurement techniques have been developed and are being used to study the performance of circuit breakers in service, revealing information on the interruption process and its interaction with the associated system. TIle information gained will be used to refine user requirements for future devices.

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