SF_6 Puffer Circuit Breaker Modelling

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1. Basic Introduction

- Circuit breaker as the main protective device in a power transmission network
- Able to clear load and fault currents without causing damaging overvoltages
- Sophisticated arc control mechanism required
- Types: oil, air, vacuum, SF_6

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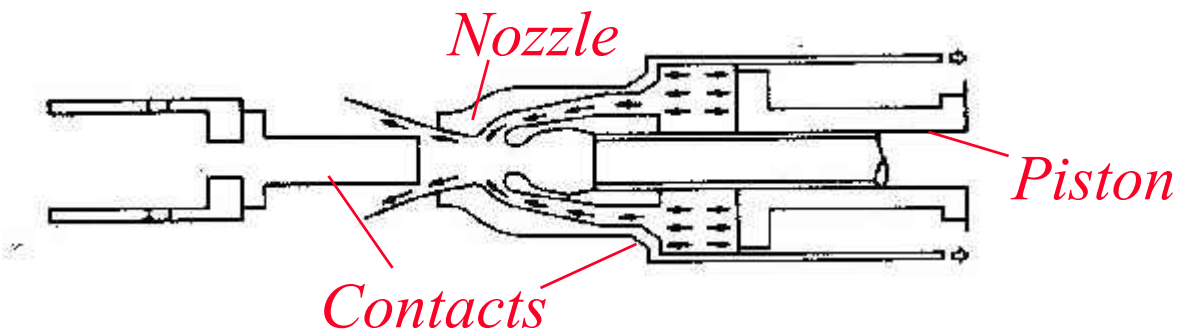
SF_6 Puffer Circuit Breaker

- Emerging technology: SF_6 gas as both an arc interrupting and a dielectric medium



- Puffer action: Pressurisation to produce sufficient flow by piston movement for arc extinction
- Interrupting capability and performance are difficult to predict

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Circuit Breaker Arc

- C.B performances depend on arc behaviours
- Electrical discharge with high temperature gases inside its column across the contact gap
- Conductivity changes from a reliable insulator to an excellent conductor at high temperature
- Arc controlling: arc resistance to be increased rapidly to force current down to zero

2. Objectives

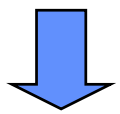
- To obtain an equivalent circuit model of circuit breaker structure
- To understand and to model arc plasma behaviour within the interrupter structure
- To investigate circuit breaker performance in connected power transmission network

Stage 1

FDTD and lumped circuit modelling of circuit breaker

Stage 2

Arc modelling



Stage 3

Lumped power network modelling

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3. Modelling

Numerical method: Finite Difference Time Domain (FDTD)

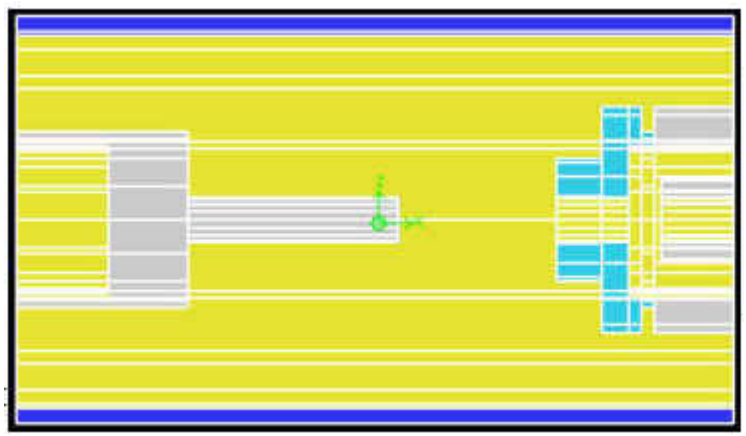
A fully-opened puffer circuit breaker

Metal

PTFE

Ceramic

SF_6



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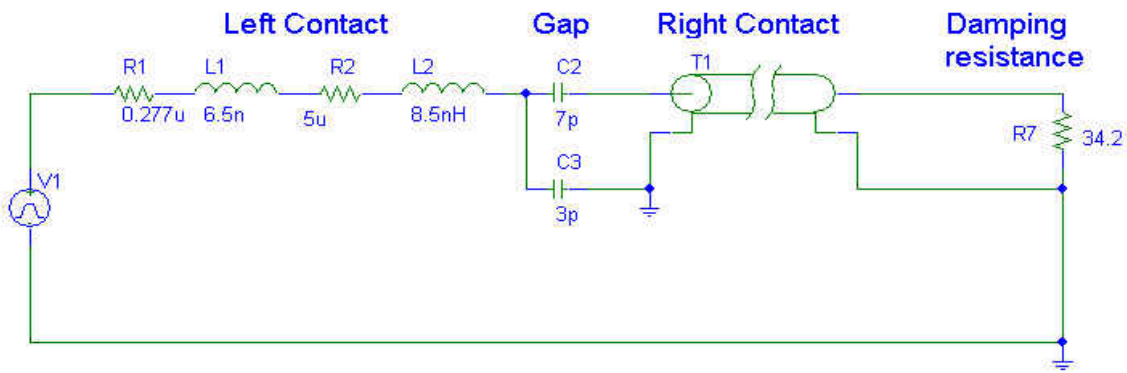
Lumped Circuit Modelling

- A fully justified equivalent circuit model of circuit breaker has been obtained based on FDTD simulation.



- Gap capacitance of 7pF and 3pF for the fully opened case

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Arc Modelling

- Used to simulate the circuit breaker behaviour
- Arc characteristics are obtained by solving non-linear differential equations
- Arc model to represent the thermal and dielectric recovery characteristic
- Capture the essence of real puffer operation (e.g gas pressure, thermal power loss, cooling rate)

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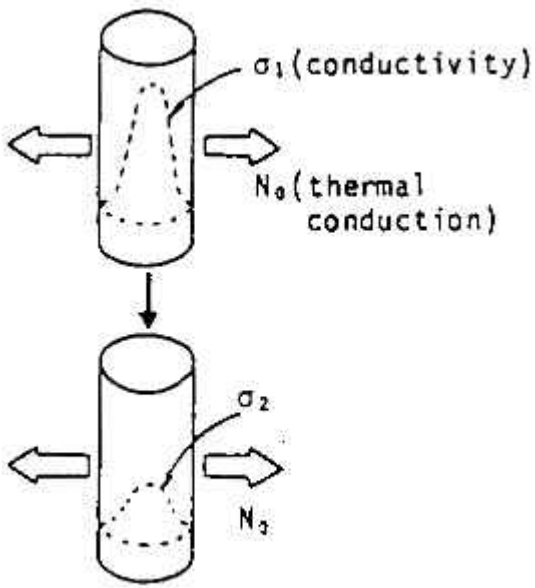
An example



Modified Mayr's model:

$$\frac{1}{G}\frac{dG}{dt}=\frac{1}{\tau}\left(\frac{V.I}{P(P_0+C_I|I|)}-1\right)$$

--Energy balance between thermal power loss and power input in the arc channel

--Neglecting the complex physical processes

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Lumped Power Network Modelling

REQUIREMENTS: Correct representation of power system

a) Network source
b) Transmission lines or cables
c) Circuit breaker model
d) Arc model
e) Load (e.g capacitor bank, reactor)

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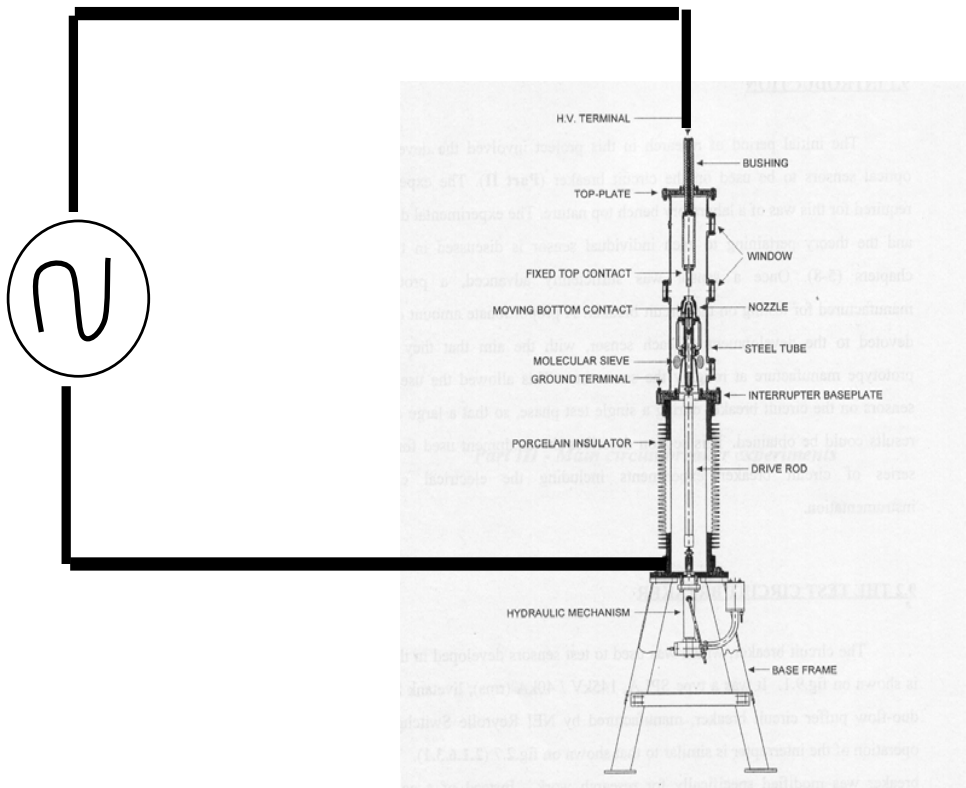
Test configuration in laboratory

20m power cable

Capacitor bank 35mF and tuned coil 216uH with rated voltage of 6.3kV



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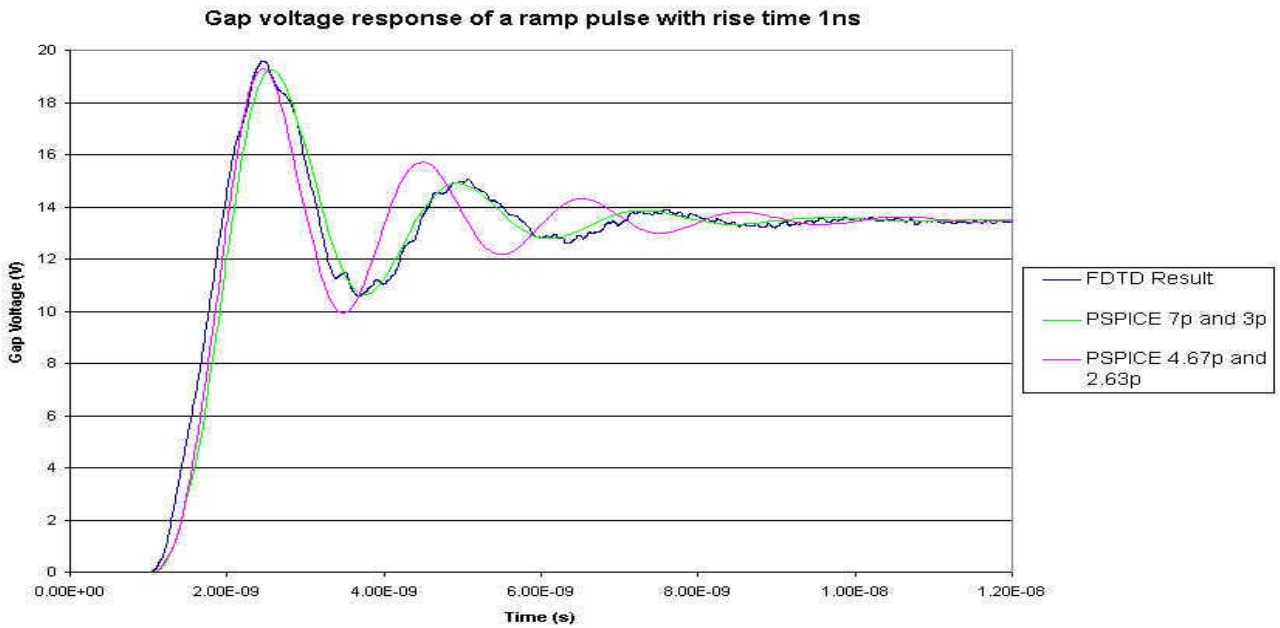
4. Some results

- Good agreement of results between FDTD and PSPICE models



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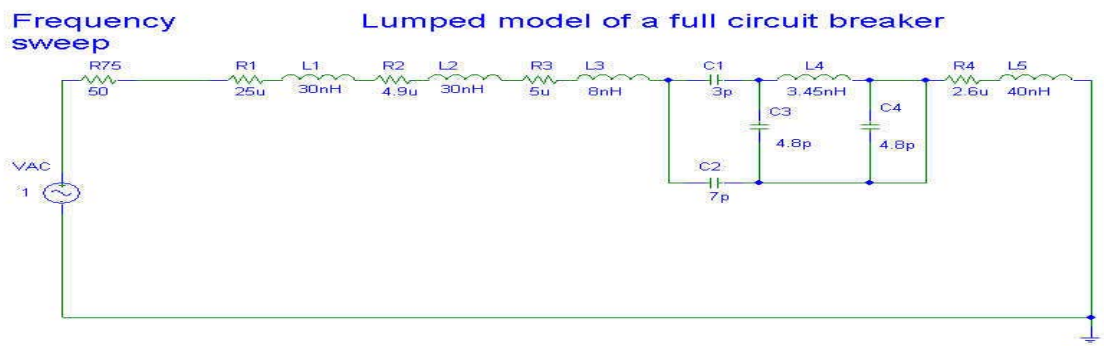
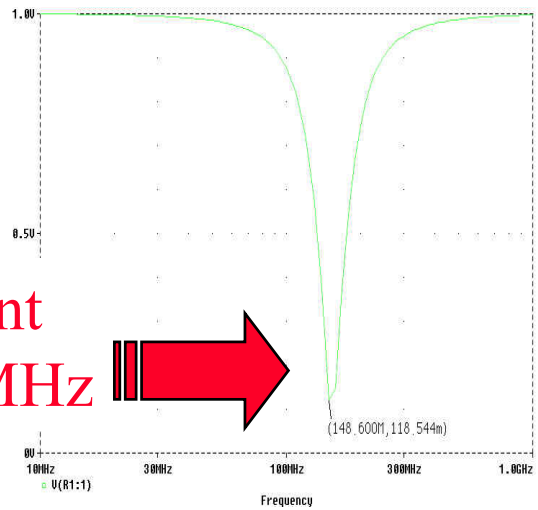
- Frequency response of a full circuit breaker model





Resonant at 148MHz

Theoretical analysis:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$f_r = \frac{1}{2\pi\sqrt{111.45nH \times 10\,pF}}$$

$$f_r = 143\,MHz$$

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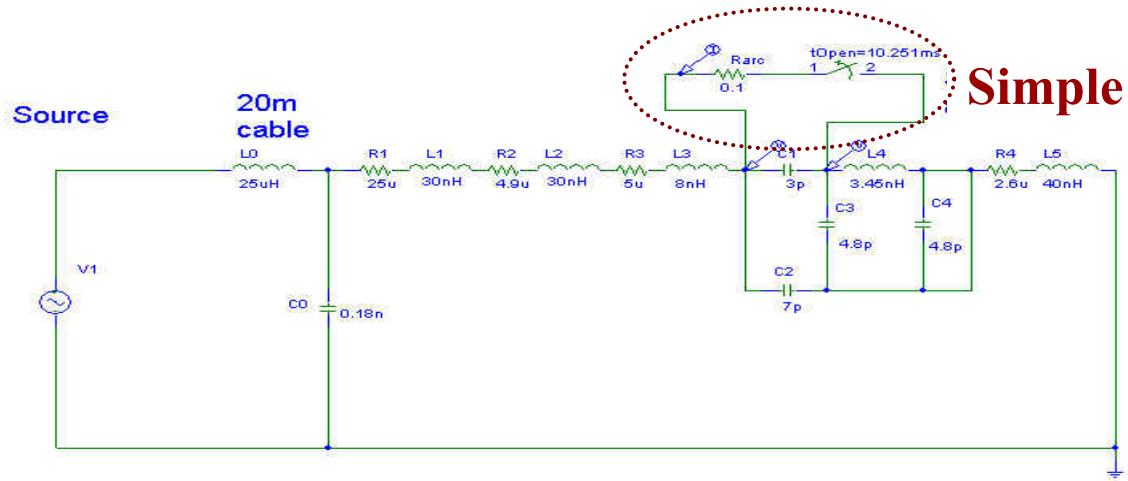
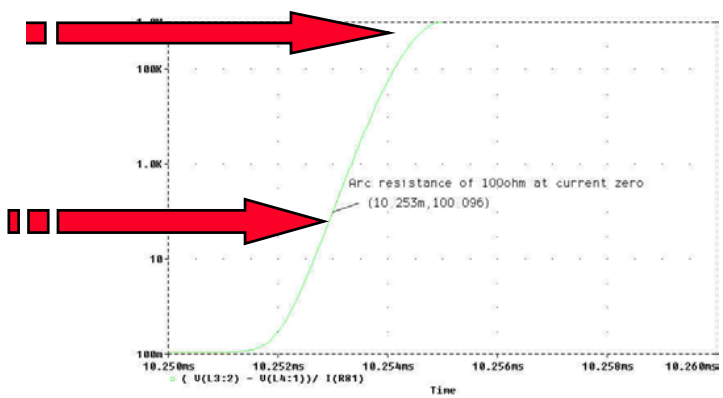
- Case study: Interruption of high current arc



Simple arc model

Arc resistance of 1MΩ after current zero

Arc resistance of 100Ω at current zero



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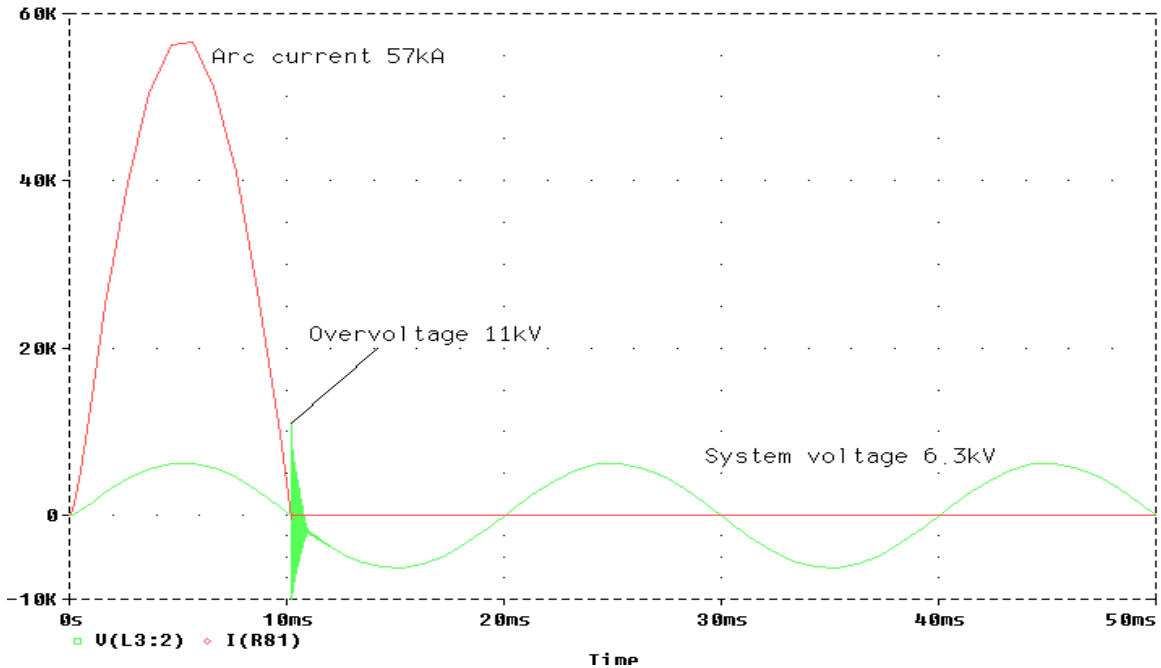
System response in the event of arc extinction



- High current arc of 57kA is interrupted at current zero
- Maximum overvoltage of 11kV is generated

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5. Conclusions and Future Plan

- This modelling work will contribute towards building a lumped network model for assessing circuit breaker performance.
- Besides DC and LF analysis, high frequency circuit breaker model is to be developed.
- A best suitable arc model is needed to correctly represent SF_6 circuit breaker (ATP software in use).
- Possible live test measurements for comparison with simulation results.

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