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Unexpected Inrush Current During Generator Energization at Hindalco Mahan Plant before Synchronization

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Abstract: ***In a power plant, the Generator and Generator Transformer are among the most critical and high-value electrical assets. Any unexpected behaviour during their operation or commissioning can raise serious concerns and potential operational risks.***
Annual overhauling and energising a transformer are regular work in a power plant. An investigation was conducted to identify the root cause of the inrush current and to explore the means to mitigate the problem. The result suggest the use of demagnetising process to be followed DC test conducted on transformer.
Keywords: Transformer Inrush Current, DC test

I. INTRODUCTION

At Hindalco Mahan Plant, Unit #1 was brought back online following a Capital Overhauling. During the startup sequence, excitation was switched ON, and all parameters appeared normal initially.
However, as the Generator terminal voltage approached 15.75 kV, an unexpected reading of 1400 A appeared on the amperemeter (Refer to Fig-1). This sudden current draw surprised the desk operator, especially since both the Generator Breaker and Unit Auxiliary Transformer (UAT) Breaker were open at the time Fig.2.
The current lasted only a few seconds before returning to zero. No tripping, fault indication, smoke, or abnormal sounds were observed. All CT and PT connections were checked and found to be in proper condition.
While the unit eventually synchronized successfully, the source of the transient current remained unclear — raising questions among the operating and maintenance teams.

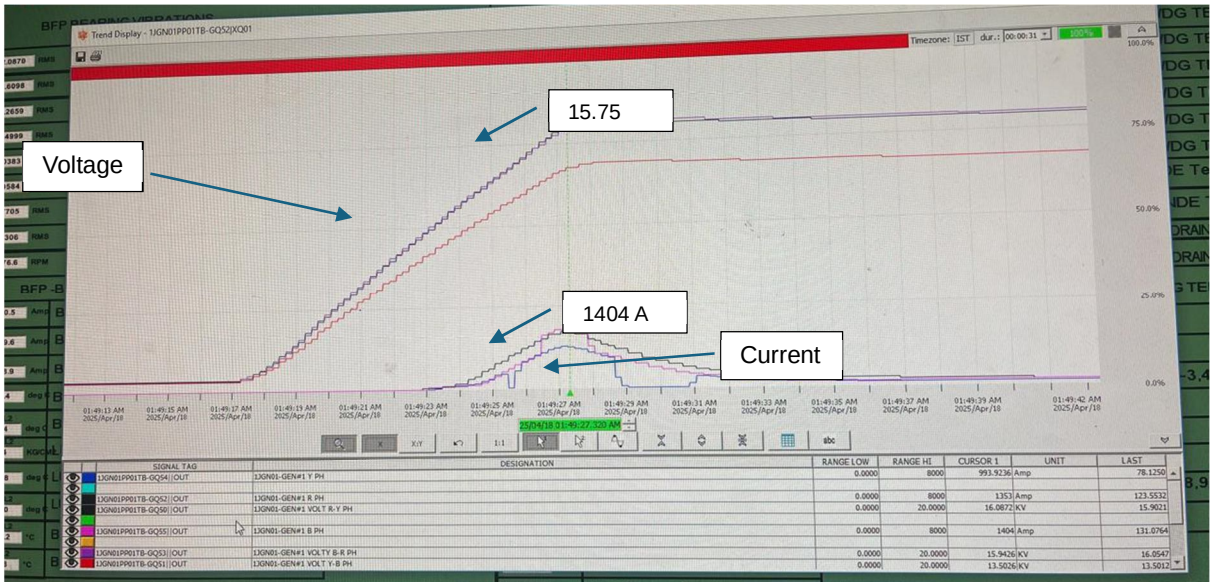


Fig-1

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II. SYSTEM CONFIGURATION

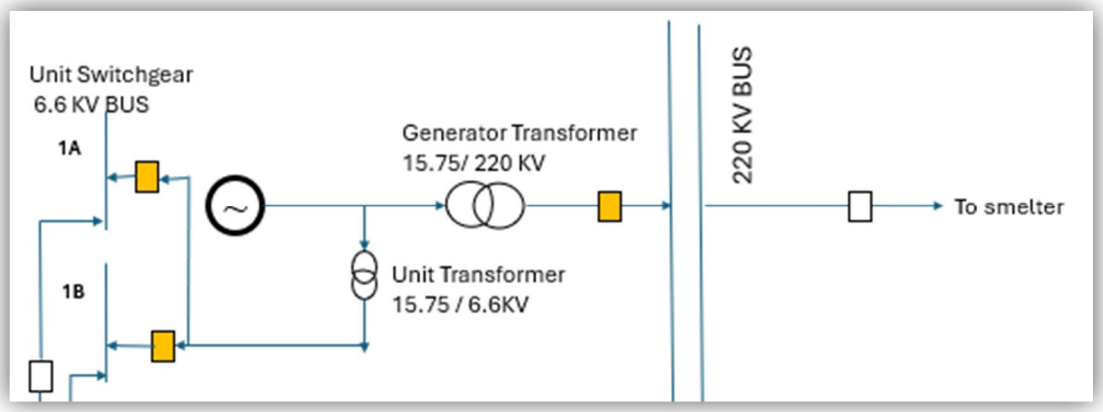


Fig.2

There had different aspects or causal factor, as follows: -

1) It might be Lightening Arrestor (LA)because Porcelain type old LA was replaced with New Polymer type LA during the Capital Overhauling. It was unlikely as LA did not conduct at nominal system Voltage and High current discharged for few microseconds, but here current passed for 4-5 seconds.

2) It might be Current Transformer (CT) terminal block got damaged due to looseness, but all Terminal were inspected -found tight and in good condition.

3) It might be the SF6 based Generator Circuit Breaker (GCB) whose pole might conduct. It was unlikely event as Current Transformer before the GCB did not record any current.

4) It might be the Generator transformer drawing this current as the charging inrush current. It was not as voltage was gradually ramped up (Fig-1), not a typical step-energization eliminating this thought.

5) It might be the Generator transformer and Unit Auxiliary Transformer drawing this current as magnetizing current because core might get demagnetized during the Capital overhauling as they were under shutdown for long period of overhauling.

6) After discussing with several experts of Power plant, it was ascertained that it was Generator Transformer. But how? Why was this phenomenon observed for the first time in Mahan?

Since Unit #1 underwent its first Capital Overhauling, the Generator Transformer was opened for internal inspection, and a series of diagnostic tests were performed as part of standard maintenance.
This raised the question:

Did the internal inspection or system grounding cause the unusual current behaviour?
After thorough evaluation, it was determined that neither the internal inspection nor grounding was responsible.
Instead, the root cause was linked to the DC tests conducted during the overhaul — specifically Insulation Resistance (IR) and Polarization Index (PI) tests.

So, how did DC testing lead to this behaviour?
When you apply DC voltage to transformer windings (like during insulation resistance or polarization index testing), a direct current can flow through the winding insulation. This can create a unidirectional magnetic field in the core, which can magnetize it. Since there's no alternating current to cancel out the flux over time, residual magnetism remains in the core after the test.

This residual flux can lead to:

- Inrush currents when the transformer is energized.
- Incorrect readings in other tests (like sweep frequency response or even TTR).
- Audible noise or increased losses.

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Typical Inrush Current Range

- Magnitude and Duration: Usually lasts for 1 to 3 seconds, depending on transformer size and system impedance.
- Factors influencing inrush:
  - Residual flux in the core
  - Instant of energization (relative to the voltage waveform)
  - System source impedance
  - Transformer design (core type, winding resistance, etc.)

Why residual magnetism matters:
If the core was left with residual magnetism after DC testing, and it's energized at the wrong point in the voltage cycle, the resulting flux can exceed core saturation. That's when you get huge inrush currents.
This can:

- Trip protection relays (incorrectly)
- Stress circuit breakers
- Cause mechanical stress on windings

Upon review, it was found that IR and PI tests had been conducted on both the Generator Transformer and Unit Auxiliary Transformer just before the final box-up. These DC-based tests resulted in residual magnetism being retained in the transformer cores.
As a result, when the Generator terminal voltage approached 15.75 kV, the Generator Transformer began drawing current in order to re-establish magnetic balance, as the core flux reversed direction with every AC cycle. This was observed as an unexpected inrush current during energization.

Root Cause of unexpected high current before synchronisation

- Residual flux in the core altered the magnetic conditions during energization.
- The transformer was not demagnetized after the DC tests.
- This residual flux, when combined with supply voltage, caused core saturation → high inrush current

This incident highlights why modern transformer testing equipment—such as winding resistance measurement kits—often includes a built-in demagnetization function after DC testing.
To avoid such issues:

- DC tests must not be the final step before closing and charging the transformer.
- A demagnetization cycle should always be performed after any DC test and before energization.

Lessons Learned

1. Always perform demagnetization after any DC-based test like IR or PI on large transformers
2. Ensure demagnetization is not skipped before final box-up of equipment
3. Use test kits with built-in demagnetization cycles for winding resistance measurements
4. Include this step as a mandatory part of test and commissioning protocols

III. CONCLUSION

This case underscores how a well-known physical phenomenon — core residual magnetism — can create puzzling and seemingly abnormal behaviour if not anticipated.
As the generator voltage approached 15.75 kV:

1) The core experienced flux reversal with every cycle
2) Transformer drew magnetizing inrush current to balance the residual flux
3) Current appeared on the amperemeter, despite no load being connecte
4) Once flux normalized, current dropped back to zero

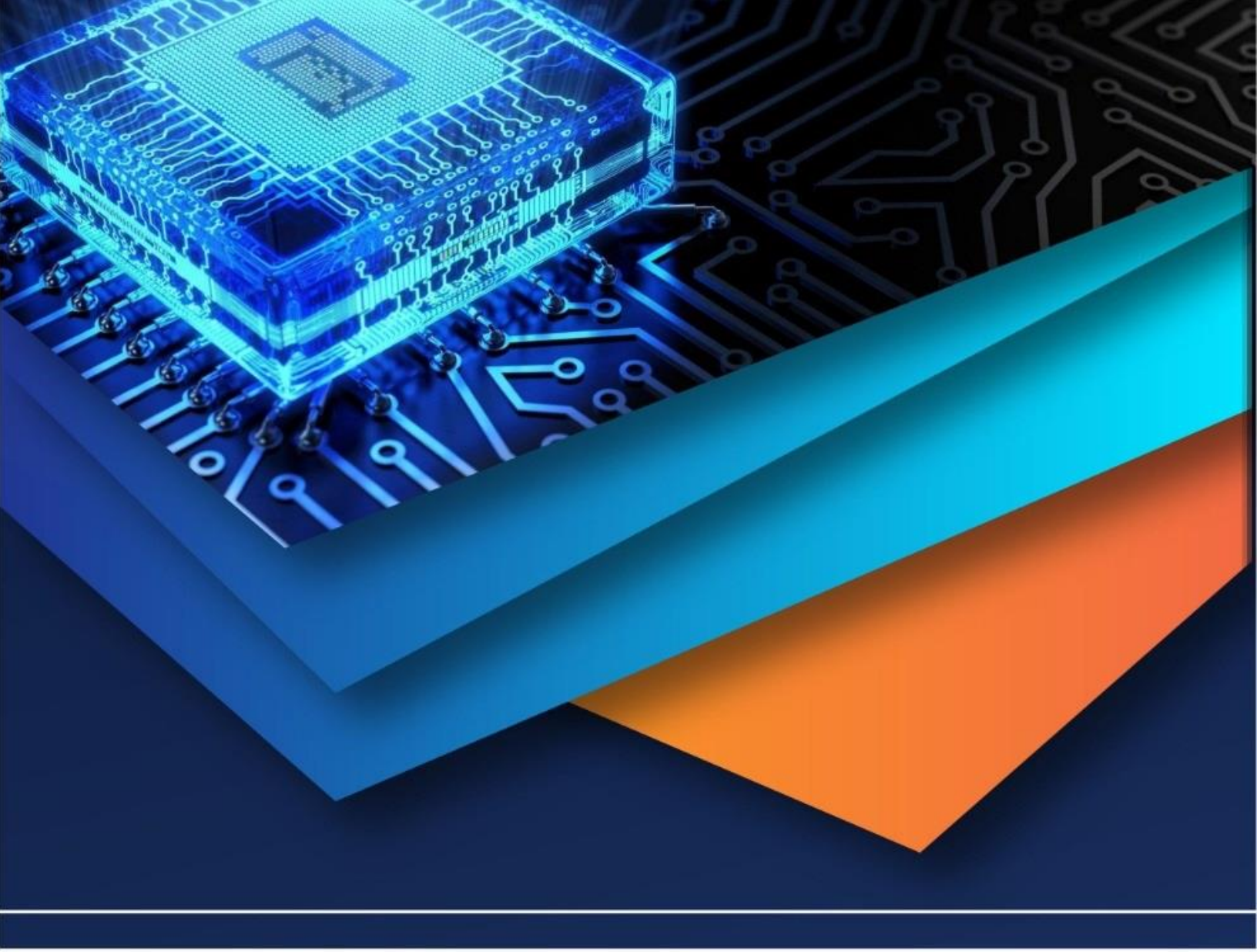
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