Master Thesis

Fast current limiting circuit breakers for railway feeding applications

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Objective

The thesis is dedicated to estimate the benefits of VARC breaker by implementing it in a railway feeding application.

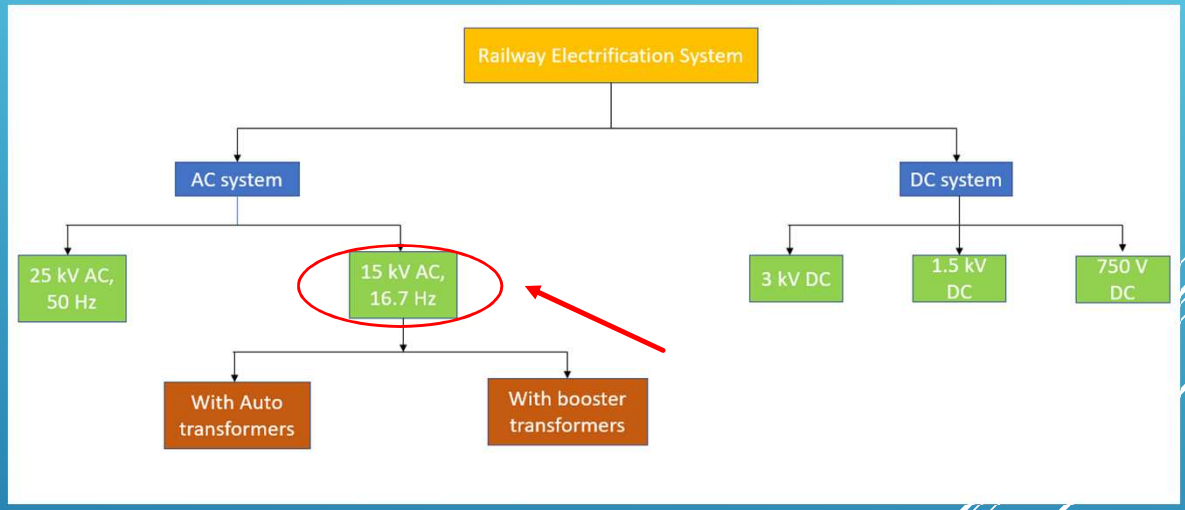
The study is carried out with consideration of the following:

- To be able to have a fast bypass time.
- To find out the optimal energy required by the varistor (MOV).
- And subsequently, dimensioning of the whole breaker.

Railway electrification system

The electrification systems are classified based on the following parameters:

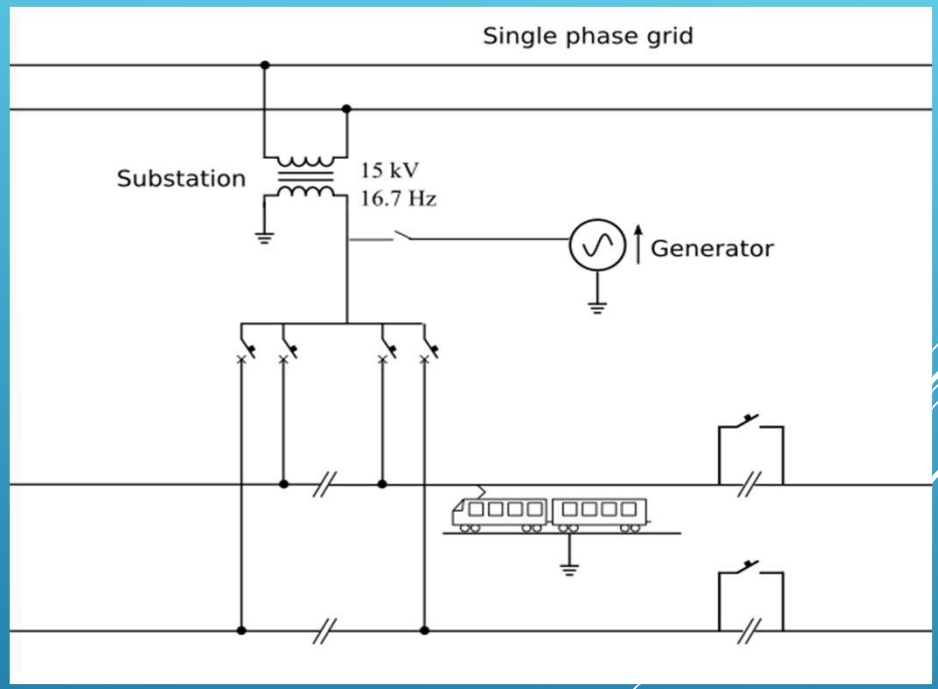
- Voltage
- Current
  - Direct current (DC)
  - Alternating current (AC)
- Contact system
  - Overhead line (Catenary)



15 kV AC, 16 2/3 Hz system

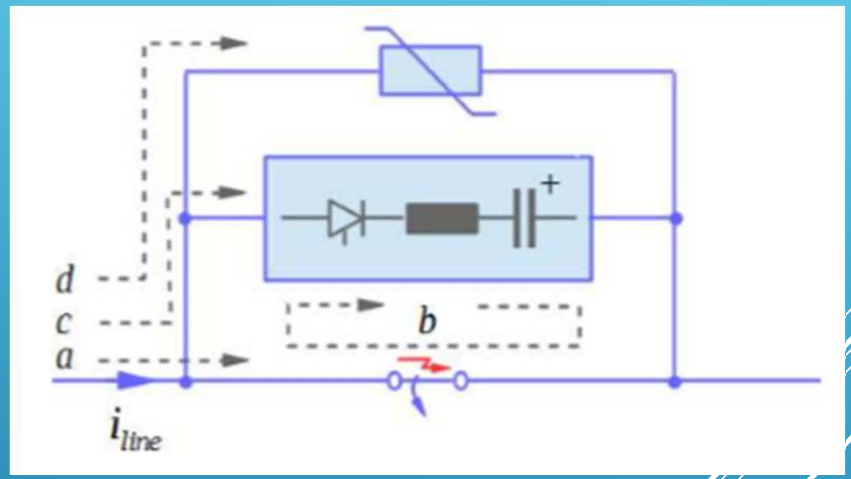
The 15 kV, 16 2/3 Hz railway electrification system has enabled high power transmission with the lower frequency and reducing the traction motor losses which were made available at the dawn of the 20th century.
Sweden, Germany, Austria, Switzerland and Norway has being adopting this standard since the beginning.
Under this system there are two ways in which the power (that is fed to the traction system) is taken from the main grid.

- Centralized: Has a separate single-phase power distribution grid for railway powered with 16 2/3 Hz. The voltage can be either 110 kV or 132 kV on the main grid.
- Decentralized: power is taken directly from the three-phase grid (110 kV with 50 Hz), converted into low frequency (of 16 2/3 Hz) single phase and fed to the catenaries



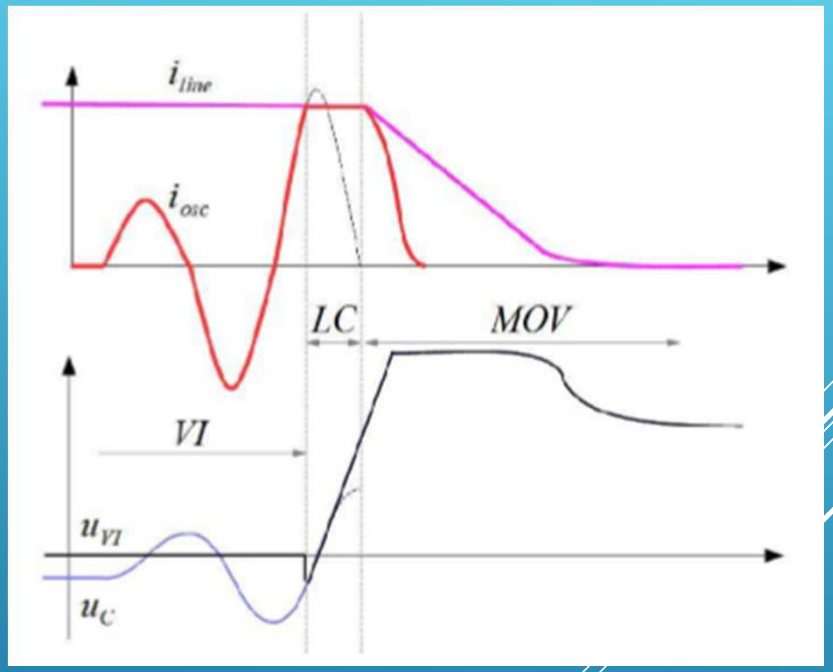
VSC assisted Resonant Current Circuit Breaker

- The MOV in series with the line utilizes an auxiliary circuit to force the current to cross zero while its contacts are separating.
- The line current normally flows in the main branch (a).
- An arc (indicated in the figure) continues to carry the line current between the contacts. While the arcing between the contacts is on-going some arrangement in an auxiliary circuit is commanded to create a circulating current (b) which opposes the current in the arc, forcing it to zero
- Typically, the protective voltage is 1.3-1.5 times the rated system voltage



Interruption Process

- The line current passes through in steady state. The breaking operation is initialized by a command to the mechanical actuator to start separating the contacts in the VI. The current continues to flow through an arc between the contacts when they part. This time interval is denoted “VI” .
- The line current is conducted by the resonant circuit during the time denoted by “LC” .
- As the MOV protective voltage is reached the current is transferred to the MOV.
- As the MOV protective voltage exceeds the network voltage driving the line current the latter decreases and approaches zero. This terminates the current breaking operation.



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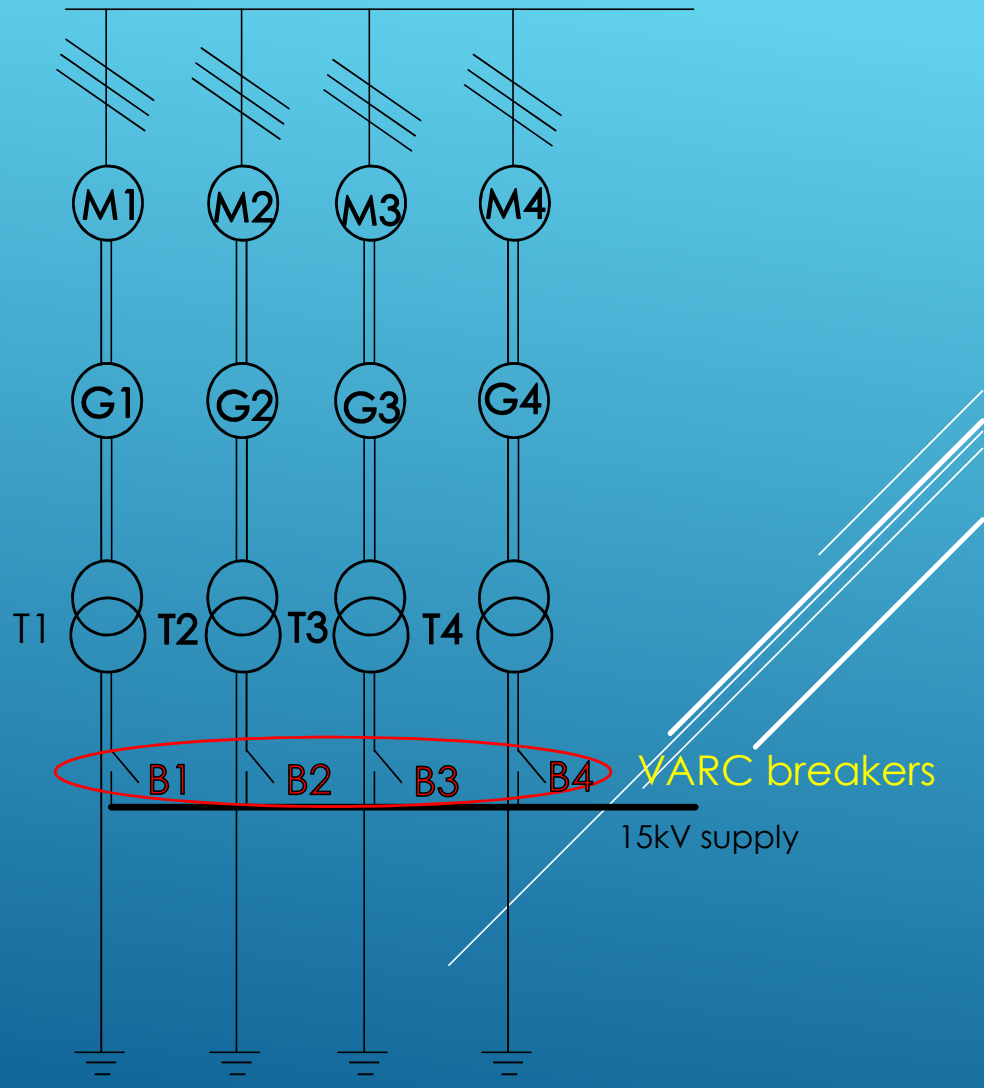
- The time to achieve a sufficient gap between the mechanical contacts in the VI is at least one millisecond.

- The semiconductors, on the other hand, easily can be operated at a frequency of 10 kHz or higher. Therefore, the semiconductors can easily make many interventions during the time needed to execute the necessary separation of the mechanical contacts.

Implementation in Railway feeding

- The performance of the VARC breaker is carried out by placing them near the multiple rotary converters.
- The maximum continuous power of the synchronous generator is 10 MVA.
- With the introduction of more converters, it is apt and sensible to place the breaker before the 15kV supply.
- Depending on the short circuit current , the total energy absorbed in the varistor (present in the VARC breaker) is found.
- The numerical value of the energy will decide on the dimension of the breaker for this particular application.



Results

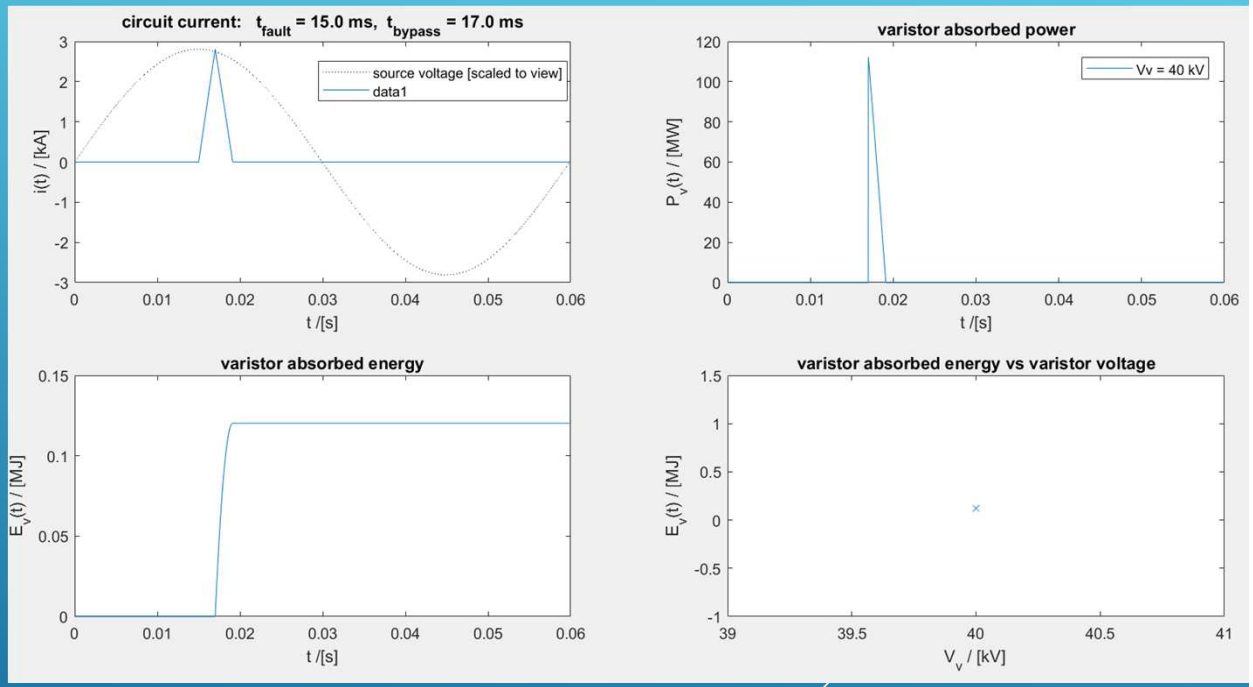
- A simple model was used to see;
  - The bypass time of the VARC breaker
  - The energy absorbed by the MOV during the same fault time.

- The 14.14 kA current was interrupted against a recovery voltage of 40 kV.

- The current was successfully commutated to the energy absorption branch within 2.1ms after the trip order was given to the circuit breaker. This was achieved thanks to the ultra-fast main interrupter which is operated with the Thomson-coil actuator.

- The MOV absorbs 120 kilo joules of energy.

- Also, as you can see in the figure the fault occurs right at the peak of the half cycle.



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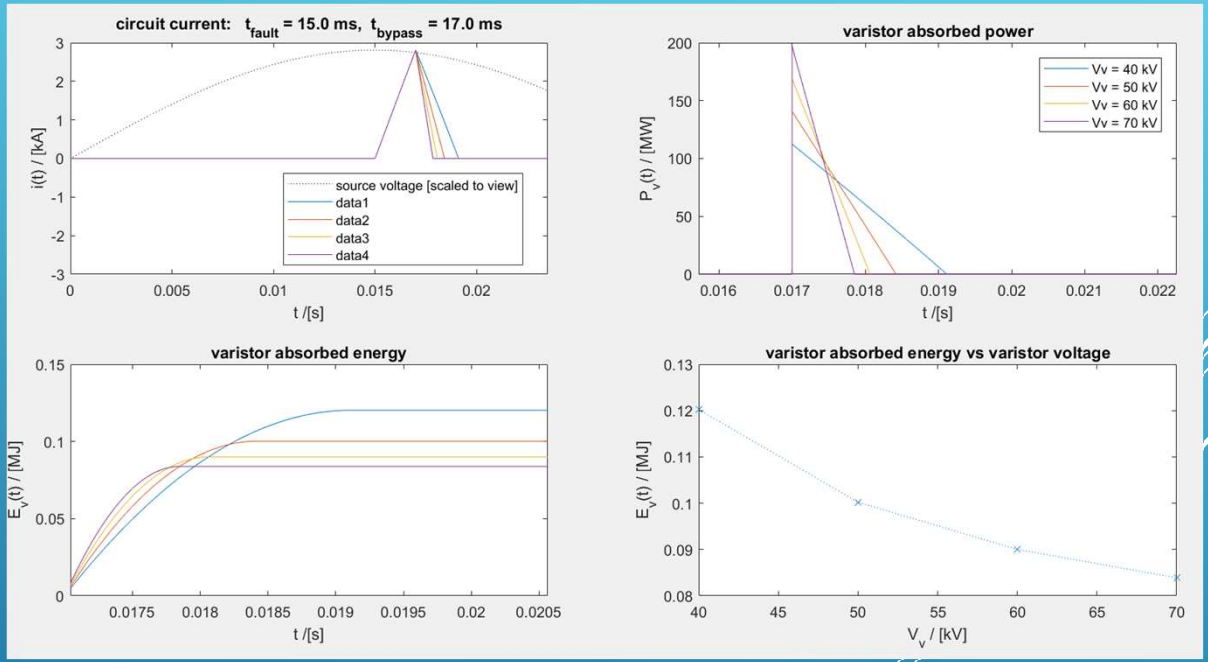
- With the increase in the varistor voltage the energy absorbed by the MOV decreases.
- The bypass time decreases as the varistor voltage increases.



Work ahead

- Implement the breaker model in the real railway feeding system.
- Study and compare the fault time occurrence (at the beginning of the half cycle and at the middle (peak) of the half cycle
- Look into the effects of harmonics from the transients.

Thank You!