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Fault detection based on ROCOV in a multi-terminal HVDC grid

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Protection of a meshed VSC-HVDC grid is a challenge due to the behaviour of DC current and voltage signals during fault conditions. Protection systems must operate in a very short time range. Since fault detection should be very fast, local measurement based algorithms are mostly used; communication based algorithms lack the needed speed as a result of the communication time delay. This way, a ROCOV algorithm is proposed in this paper. This algorithm is analysed for different fault conditions.

RATE OF CHANGE OF VOLTAGE ALGORITHM

ROCOV characteristics

- Local-measurement based.
- Voltage derivative based.
- Under normal operation conditions, the voltage is constant.
  - The ROCOV value is ideally zero.
- Under fault conditions, the voltage drops sharply.
  - The ROCOV value takes a non-zero value.
- The ROCOV value is negative due to the voltage collapse.
- Comparison with a selected threshold for better selectivity.
- Very fast fault detection.

Fault detection: ROCOV $<$ Threshold

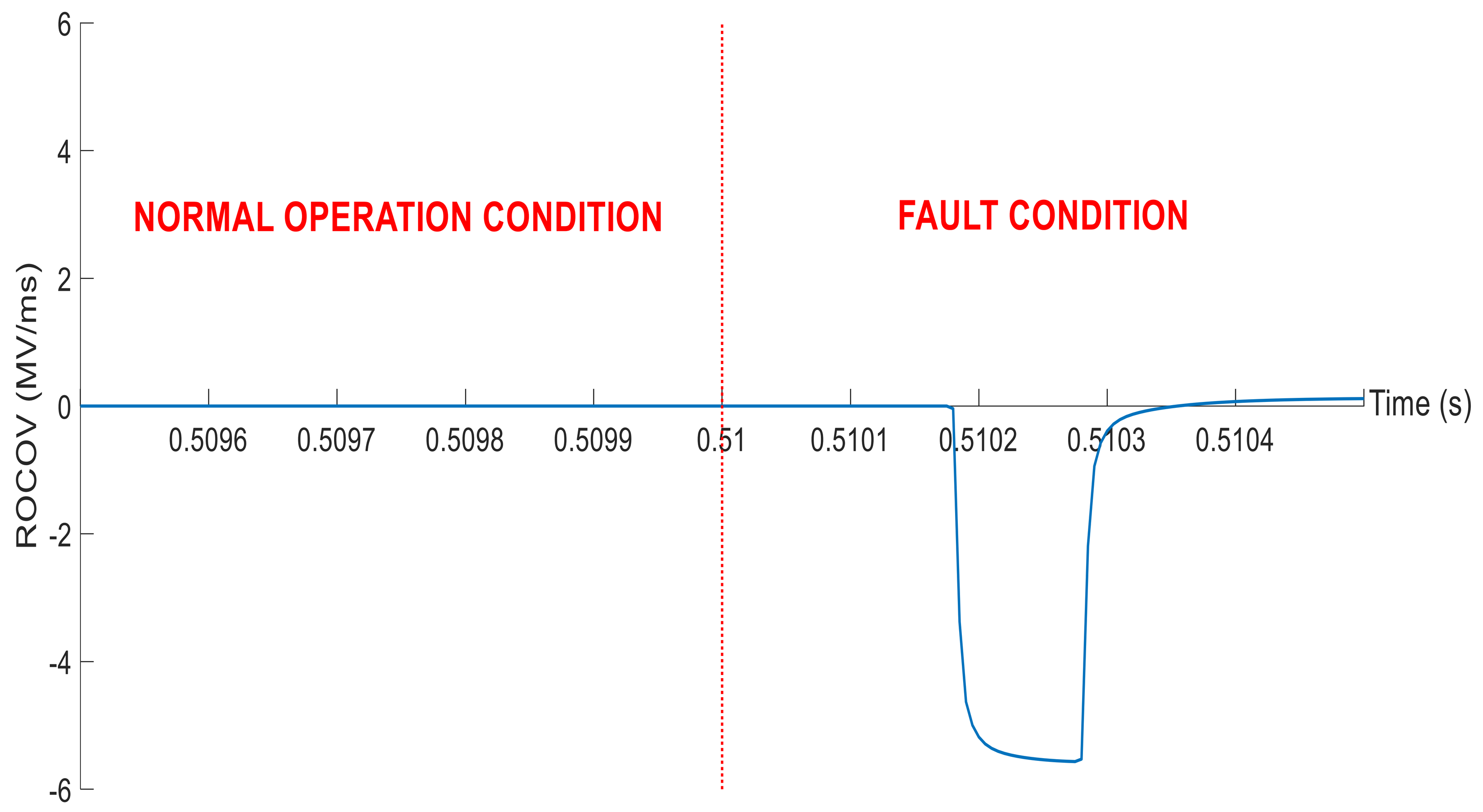

Fig 1.- ROCOV variation between normal operation and fault condition.

Study Case

- ROCOV performance analysis.
- 4-terminal MMC-based HVDC grid.
  - Links 12 and 34 – 100 km.
  - Links 13 and 14 – 200 km.
  - Link 34 – 150 km.
- Full-selective fault-clearing strategy.
  - Circuit breakers in series with 0,1 H limiting inductors are located at both ends of each link.
- Different fault conditions were simulated.
  - Pole-to-pole faults.
  - Positive-pole-to-ground faults.
  - Negative-pole-to-ground faults.
  - Different fault locations.
  - Different fault impedances – up to 200 Ω.

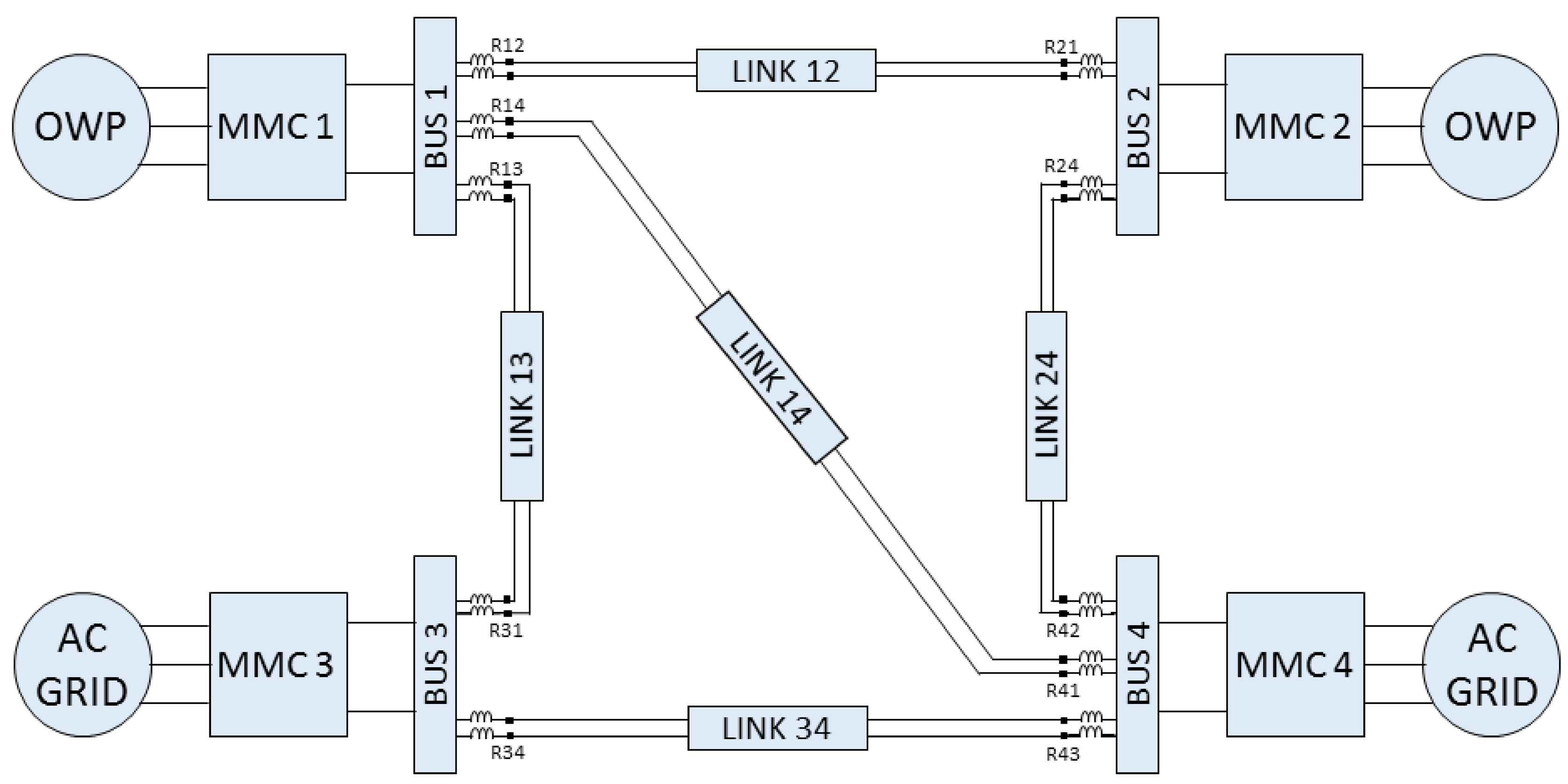

Fig 2.- 4-terminal MMC-based HVDC grid modelled in PSCAD.

Results: The ROCOV algorithm detected every simulated fault conditions, regardless the fault type, location and impedance. Remote fault conditions were detected in approximately 1 ms while near fault conditions were detected in a few hundreds of microseconds. The fault detection time hardly varies between low impedance and high impedance fault conditions.

CONCLUSIONS

Nowadays, HVDC transmission alternative is getting more relevance. However, due to the fast increase of the current and the sharp collapse of the voltage during fault conditions, fast detection algorithms and HVDC circuit breaker must be developed.

This paper proposes a protection system for multi-terminal grids based on a full-selective fault clearing strategy using hybrid HVDC CBs located at both ends of each link in series with 0.1 H inductive reactors. A local method is used for fault detection based on the rate of change of voltage. The performance of this algorithm is tested through simulations in PSCAD software. Different fault conditions varying the fault distance and resistance on different links were simulated. The ROCOV algorithms presented a reliable and selective performance to all the conditions simulated; even fault conditions up to 200 Ω were properly detected. The ROCOV operation time is from a few ten of microseconds for close faults to around 1 millisecond for remote faults.

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