Improved Fault Phase Selection Scheme for Lines Terminated by Inverter Based Resources

IEEE PES Power & Energy Society® GENERAL MEETING 2023 IEEE

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Fault Phase Selection Problem for Inverter Based Resources (IBRs)

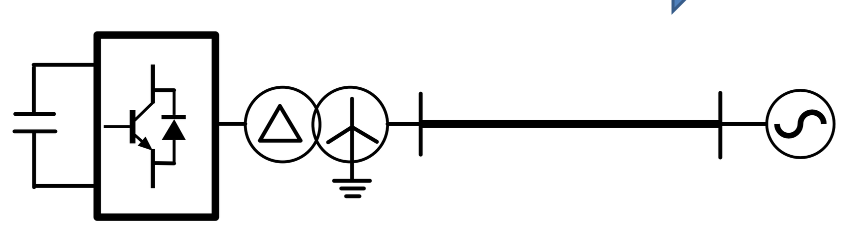
The Phase Selector for Power System

- ➢ Distinguish fault types when faults occurs.
- Provides information to other protective devices and assists relays in cutting out.
- Support fault location and automatic reclosing.

Limitations of Classic Selection Methods:

- ➢ Traditional current-based phasor schemes.
- Incorrect selection results for line with IBRs.
- Uncertain results due to small negative sequence current.
- ➢ Existing voltage-based phasor schemes.
- Need additional assumptions (such as specific system) or availability of extra data.

The integration of IBRs



Make full use of measurement data

The Impact of IBRs:

- The system connected to the IBR are non-homogeneous. Due to the sequence impedance of IBRs is determined by the control strategy.
- Some strategies of IBR restrain negative sequence current during the asymmetric fault.

Proposed method

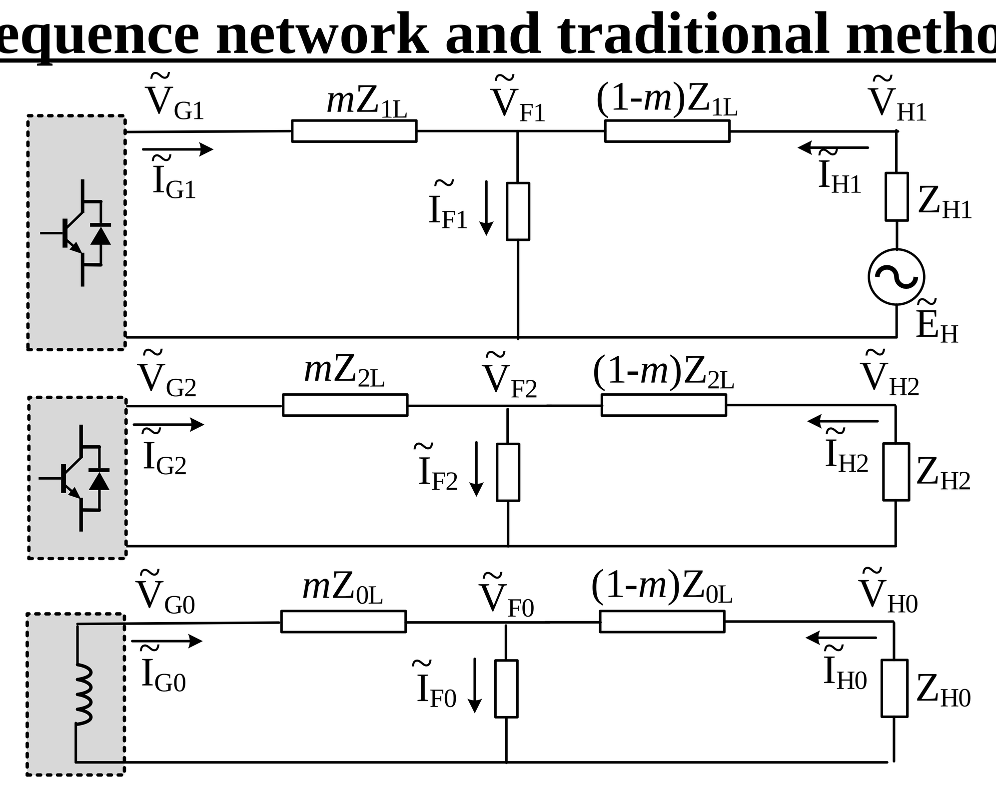
- Compound proportion criterion.
- Use both voltage and current information.

Advantages

- High accuracy for system with IBRs connected to local terminal.
- Work under different control strategies and grid codes.
- Based on phasor, easy to implement and reliable.

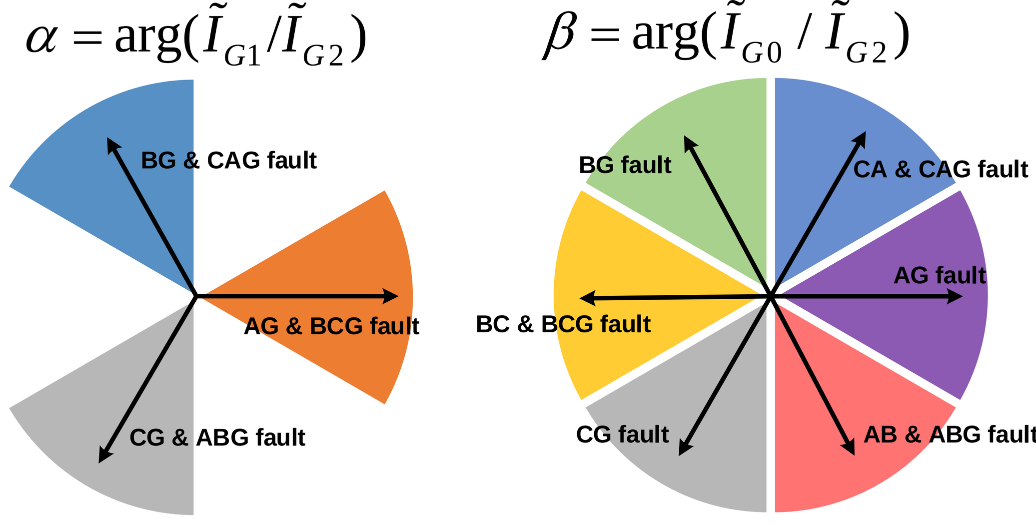
Proposed Composite Criterion and Fault Phase Selector Design

Sequence network and traditional method



- The criterion of **traditional method** is to use local terminal currents criterion:

$\alpha = \arg(\tilde{I}_{G1}/\tilde{I}_{G2})$ $\beta = \arg(\tilde{I}_{G0}/\tilde{I}_{G2})$



Angle range of traditional method, left: α, right: β

- It is not valid for line with IBRs.

Proposed method

There is still a equation of fault current. e.g. in A-G fault $\tilde{I}_{F1} = \tilde{I}_{F2} = \tilde{I}_{F0}$ holds.
The fault current can be expressed as:

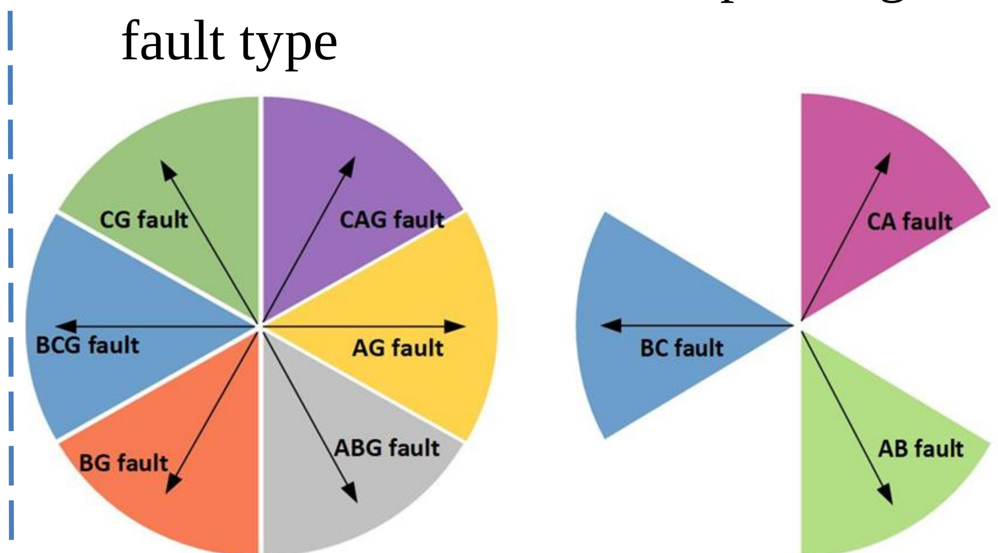
$$\tilde{I}_{F1} = \frac{-\Delta\tilde{V}_{G1} + \Delta\tilde{I}_{G1}(Z_{1L} + Z_{H1})}{(1-m)Z_{1L} + Z_{H1}}$$

$$\tilde{I}_{F2} = \frac{-\tilde{V}_{G2} + \tilde{I}_{G2}(Z_{2L} + Z_{H2})}{(1-m)Z_{2L} + Z_{H2}}$$

Thus the proposed criterion is defined as:

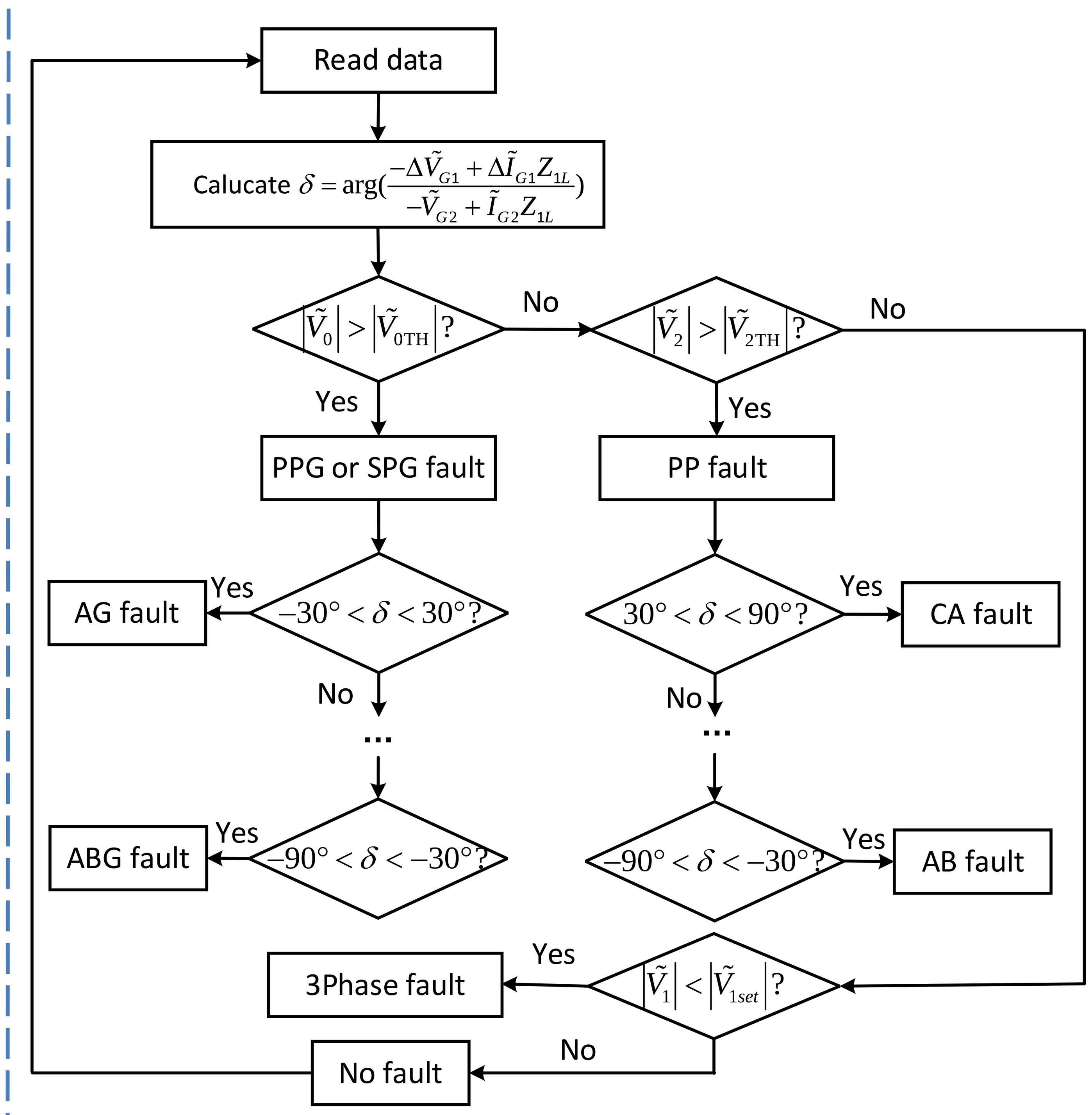
$$\delta = \arg\left(\frac{-\Delta\tilde{V}_{G1} + \Delta\tilde{I}_{G1}(Z_{1L} + Z_{H1})}{-\tilde{V}_{G2} + \tilde{I}_{G2}(Z_{1L} + Z_{H2})}\right)$$

- Requires only local measurement
- Different value for corresponding fault type



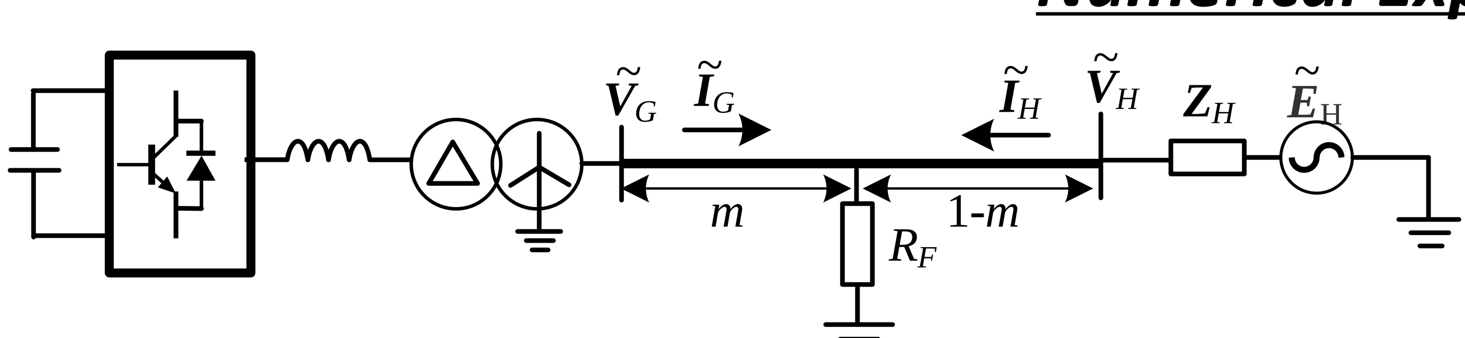
Fault type zones of proposed method
left: PPG or SPG faults, right: PP faults

Proposed phase selector scheme



Flow chart of proposed method

Numerical Experiments and Conclusion



- 110 KV, 50Hz, 3-phase AC system, 50km transmission line
- Local bus is connected to a PV plant, Remote bus is dominated by SG.
- The inverter of PV uses P-Q control, utilize multiple control strategies.

➢ Three fault phase selection methods are compared

- The **Traditional method** (current proportion method)
- The **existing improved method** (voltage proportion criterion)
- The **proposed method** (compound proportion criterion)

➢ Two typical control modes are applied to verify adaptability

- **Inject neg-seq current for European grid codes**
- **Restrain neg-seq current for China grid codes** (similar to NA)

Tables I and Tables II shows the results under different control modes

Table I. Phase selection results with neg-seq current injection

Fault type	m	Fault Resist.	δ	Prop. method	Trad. method	Exist. method
AG	10%	1Ω	-2.7°	√	×(ABG)	√
		100Ω	-4.7°	√	×(ABG)	×(N.A.)
	50%	1Ω	-3.5°	√	×(N.A.)	√
		100Ω	-3.6°	√	×(ABG)	×(N.A.)
	90%	1Ω	-3.7°	√	×(N.A.)	√
		100Ω	-0.2°	√	×(ABG)	×(N.A.)
BCG	10%	1Ω	-172.9°	√	×(CG)	√
		15Ω	-157.0°	√	×(CG)	√
	50%	1Ω	-179.1°	√	×(CG)	√
		15Ω	-177.8°	√	×(CG)	×(N.A.)
	90%	1Ω	179.9°	√	×(CG)	√
		15Ω	177.6°	√	×(CG)	×(N/A)
BC	10%	1Ω	177.3°	√	√	×(N.A.)
	50%	1Ω	177.6°	√	√	×(N.A.)
	90%	1Ω	178.0°	√	√	×(N.A.)

Table II. Phase selection results without neg-seq current injection

Fault type	m	Fault Resist.	δ	Prop. method	Trad. method	Exist. method
AG	10%	1Ω	-1.3°	√	×(N.A.)	√
		100Ω	0.5°	√	×(N.A.)	√
	50%	1Ω	-1.2°	√	×(N.A.)	√
		100Ω	0.5°	√	×(N.A.)	×(N.A.)
	90%	1Ω	-1.2°	√	×(N.A.)	√
		100Ω	-0.8°	√	×(N.A.)	×(N.A.)
BCG	10%	1Ω	174.6°	√	×(N.A.)	√
		15Ω	177.2°	√	×(N.A.)	×(N.A.)
	50%	1Ω	177.6°	√	×(N.A.)	√
		15Ω	177.5°	√	×(N.A.)	×(N.A.)
	90%	1Ω	178.0°	√	×(N.A.)	√
		15Ω	176.4°	√	×(N.A.)	×(N.A.)
BC	10%	1Ω	178.0°	√	×	√
	50%	1Ω	178.1°	√	×	√
	90%	1Ω	178.3°	√	×	√

Conclusion

- The traditional current method can not identify the fault type due to the output characteristics of IBRs, especially special neg-seq current.
- Existing improved method can not identify the fault type correctly in some high resistance cases.
- The proposed method accurately identify various fault types with different fault resistances and IBR control schemes.