X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

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Overcurrent protection of active distribution networks: A comparative review

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Image taken from: https://www.pngwing.com/es/free-png-ybhlm.

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2. Integration of Distributed Energy Resources (DER).

3. Transition to Active Distribution Networks (ADN)

Images taken from: https://www.pngwing.com/es/free-png-ybhlm.

II. Conventional approach for overcurrent relay coordination

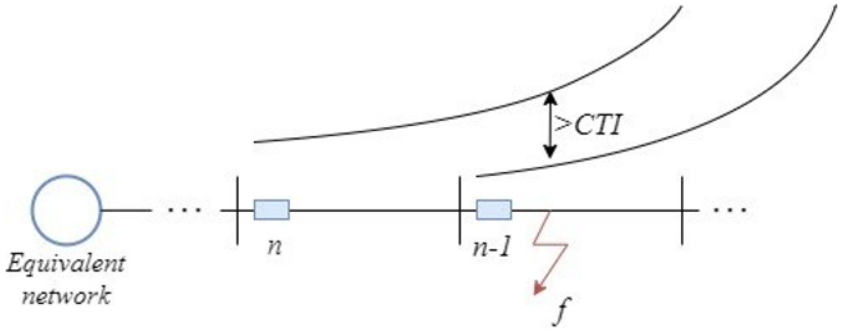

Fig 1. Coordinated 51 relays.

$$
\begin{cases}
t_{R_n} \geq t_{L_{n-1}} + CTI_{52_{n-1}} \\
t_{network} \geq t_{L_N} + CTI_{52_N}
\end{cases}
$$

The operation time is defined by the according to the IEC 255 standard.

$$
t_{op} = \frac{A}{M^P - 1} TDS \qquad M = \frac{I_F}{I_p}
$$

III. Adaptive approach for overcurrent relay coordination

1. Sequence currents based adaptive protection approach for DNs with DER

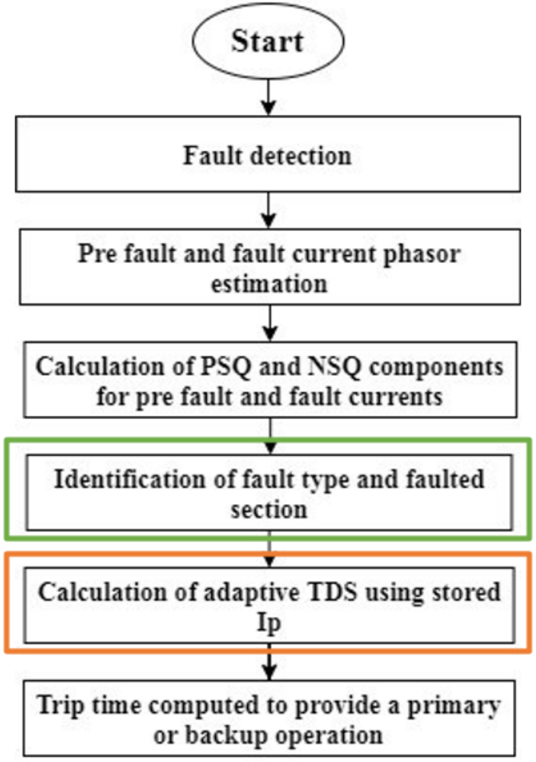

Fig 2. Flow chart of the adaptive approach I.

Positive sequence componet

$$t^{c}_{p\_ij} = \frac{0.14}{\left((I^{c}_{1Fij}/I^{c}_{pj})\right)^{0.02} - 1} TDS^{c}_{pj}$$

Negative sequence componet

$$t^{c}_{b\_ij} = \frac{0.14}{\left((I^{c}_{2Fij}/I^{c}_{bj})\right)^{0.02} - 1} TDS^{c}_{bj}$$

The relay computes the adaptive-TDS when a fault has occurred

$$TDS_{new} = \frac{(M)^{P}_{new} - 1}{(M)^{P}_{old} - 1} TDS_{old}$$

2. Superimposed Adaptive Sequence Current Based Microgrid Protection: A New Technique

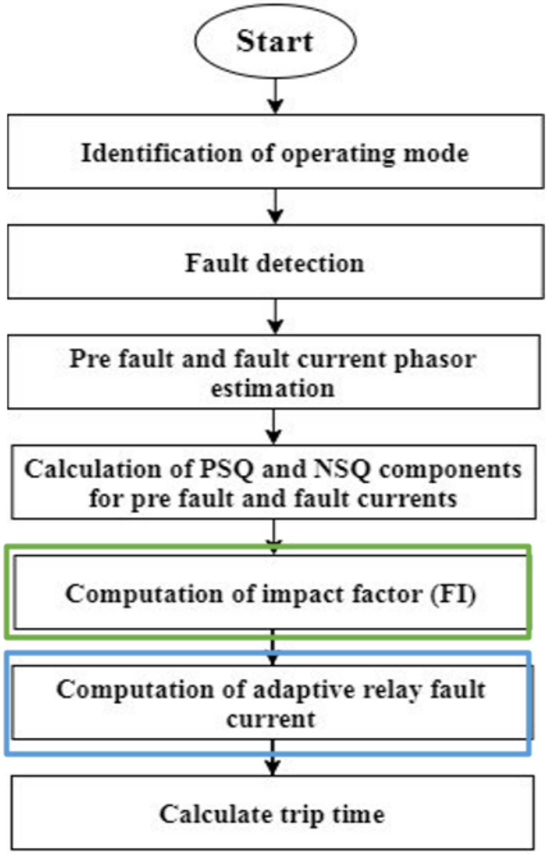

Fig 3. Flow chart of the adaptive approach II.

Impact factor (FI) based on the operation of the microgrid.

$$FI = \frac{|\Delta I_{1F}|}{|1 - I_{1F}||1 - \Delta I_{1F}||I_{1pre}|} \qquad FI = \frac{|\Delta I_{1F}| - |I_{1pre}|}{|\Delta I_{1F}|}$$

Adaptive fault current.

$$I_{F_{ad}} = (I_{1F} + I_{2F})(FI)$$

Depending on the change of the operating mode, the authors propose the calculation of an new TDS.

$$TDS_{new} = \frac{(M)_{old}^{P} - 1}{(M)_{new}^{P} - 1} TDS_{old}$$

3. Dynamic adaptive protection for distribution systems in Grid-Connected and Island Modes

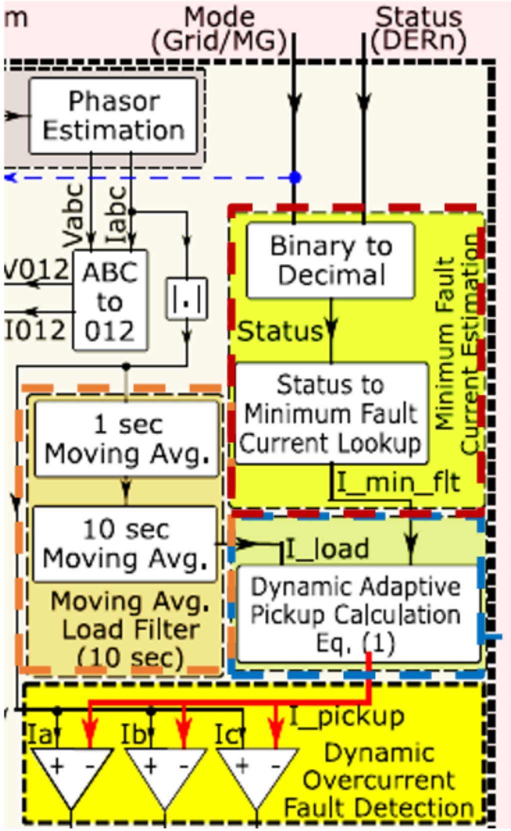

Fig 4. Overview of the adaptive approach III.

The paper is focused on the estimation of an Dynamic Adaptive Pickup current $(I_{p_{ad}})$

$$I_{p_{ad}} = a\, I_{mov_{10s}} + b\left(I_{F_{DERs}} - a\, I_{mov_{10s}}\right)$$

- $I_{mov_{10s}}$ is a 10-second moving average window filter.
- $I_{F_{DERs}}$ is the minimum fault current estimation.

Image taken from: Dynamic Adaptive Protection for Distribution Systems in Grid-Connected and Islanded Modes.

4. An adaptive directional current protection scheme for distribution network with DERs

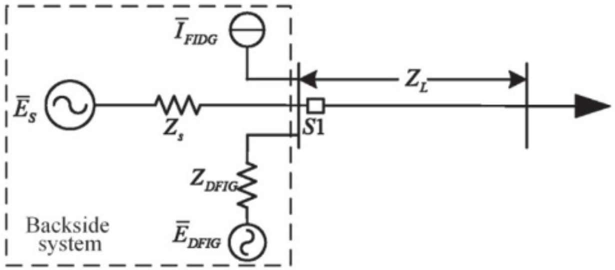

Fig 5. Equivalent circuit of simple ADN

The system at the backside of the protection could be replaced with a equivalent after fault occurred.

The setting formula

$$I_{p\,ad} = \frac{K_{rel} K_d \overline{E}_e}{Z_e + Z_L}$$

When the fault location $\alpha\langle\beta$

$$I_{p\,ad} = \frac{\sqrt{3}}{2}\left|\frac{\overline{E}_e}{Z_e + \alpha Z_L}\right| > \frac{\sqrt{3}}{2}\left|\frac{\overline{E}_e}{Z_e + \beta Z_L}\right|$$

When the fault location $\alpha\rangle\beta$

$$I_{p\,ad} = \frac{\sqrt{3}}{2}\left|\frac{\overline{E}_e}{Z_e + \alpha Z_L}\right| < \frac{\sqrt{3}}{2}\left|\frac{\overline{E}_e}{Z_e + \beta Z_L}\right|$$

Image taken from: An adaptive directional current protection scheme for distribution network with DG integration based on fault steady-state component

IV. Results

Test system

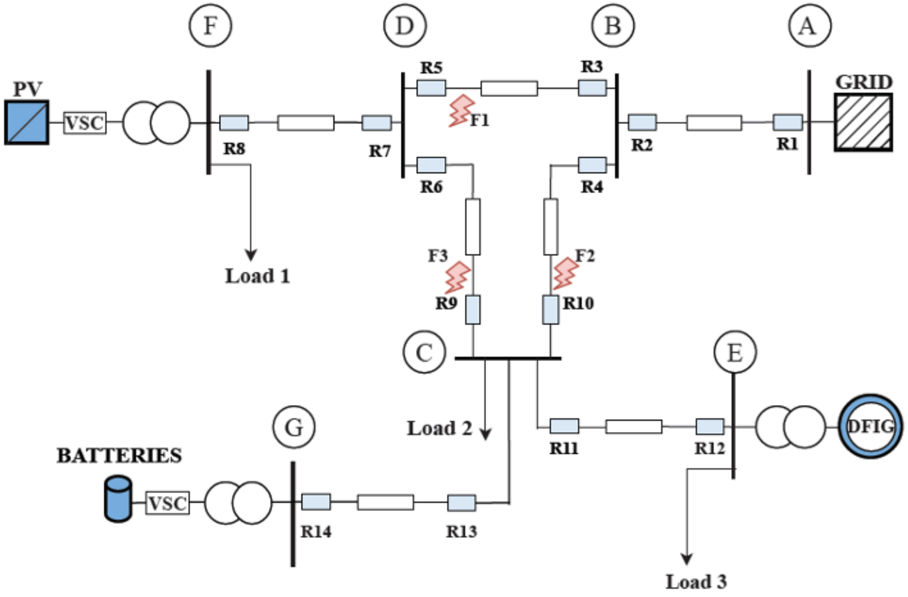

Fig 6. ADN used as test system.

Mode I: all sources are on.
Mode II: only the DFIG based DER is on.
Mode III: only the PV-based DER is on.

IV. Results

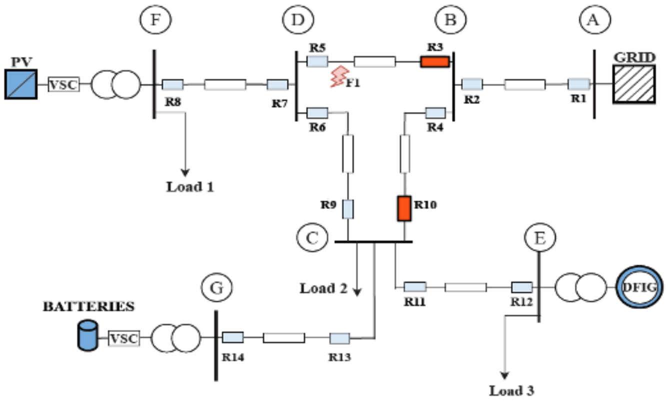

Fig 7. Primary and back-up relay for F1.

Mode I: all sources are on.
Mode II: only the DFIG based DER is on.
Mode III: only the PV-based DER is on.

Test Results - Conventional Approach

	Relay		Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.296	0.441	0.145	0.315	0.121	-0.194	0.317	0.119	-0.198

Test Results - Adaptive Approach I

	Relay		Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.296	0.441	0.145	0.276	0.421	0.145	0.296	0.452	0.156

Test Results - Adaptive Approach II

	Relay		Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.297	0.407	0.110	0.297	0.411	0.114	0.323	0.457	0.134

IV. Results

Test Results - Conventional Approach											
Relay			Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.296	0.441	0.145	0.315	0.121	-0.194	0.317	0.119	-0.198

Test Results - Adaptive Approach I											
Relay			Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.296	0.441	0.145	0.276	0.421	0.145	0.296	0.452	0.156

Test Results - Adaptive Approach II											
Relay			Mode I			Mode II			Mode III		
Fault	PR	BR	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt	t_{PR}	t_{BR}	Δt
F1	3	10	0.297	0.407	0.110	0.297	0.411	0.114	0.323	0.457	0.134

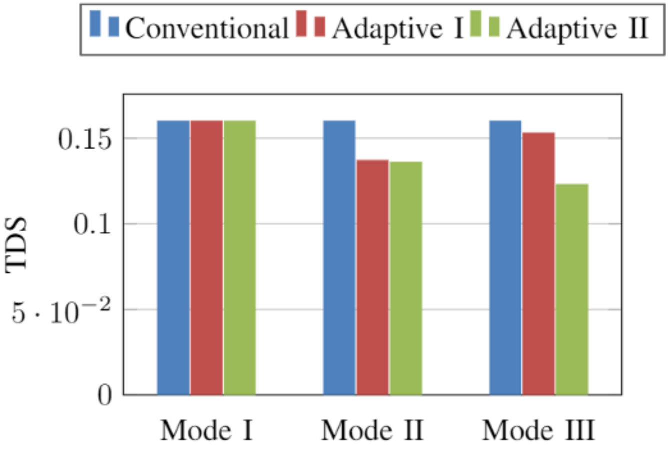

Fig 7. Relay R3's TDS for each mode operation.

IV. Results

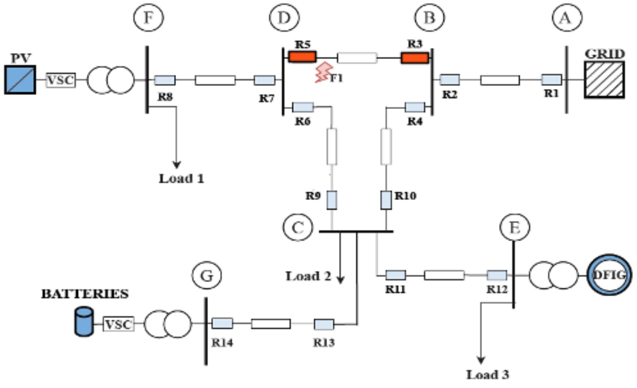

Fig 8. Primary relay for F1.

Mode I: all sources are on.
Mode II: only the DFIG based DER is on.
Mode III: only the PV-based DER is on.

Test Results - Adaptive Approach III

Fault	Relay PR	Mode I I_{pad}	Mode I I_F	Mode I Trip	Mode II I_{pad}	Mode II I_F	Mode II Trip	Mode III I_{pad}	Mode III I_F	Mode III Trip
F1	5	33	854	Yes	43	636	Yes	40	669	Yes
	3	30	707	Yes	40	574	Yes	26	560	Yes

Test Results - Adaptive Approach IV

Fault	Relay PR	Mode I I_{pad}	Mode I I_F	Mode I Trip	Mode II I_{pad}	Mode II I_F	Mode II Trip	Mode III I_{pad}	Mode III I_F	Mode III Trip
F1	5	941	1255	Yes	910	1214	Yes	931	1241	Yes
	3	1356	1808	Yes	1343	1791	Yes	1340	1787	Yes

VI. Conclusions

- An ADN has different operating modes and the conventional approach does not guarantee overcurrent relay coordination.
- Adaptive approaches I and II can provide a solution to coordination with the calculation of TDS and Ip for each operation mode. However, these schemes use adaptive parameters estimated using the fault voltages and currents.
- The approach III requires communication infrastructure, making the proposed scheme expensive and vulnerable to cyber-attacks.
- Approach IV presents an adequate performance without communication infrastructure but has a long time to detect the fault.

VII. Questions

Image taken from: https://www.pngwing.com/es/free-png-ybhlm.