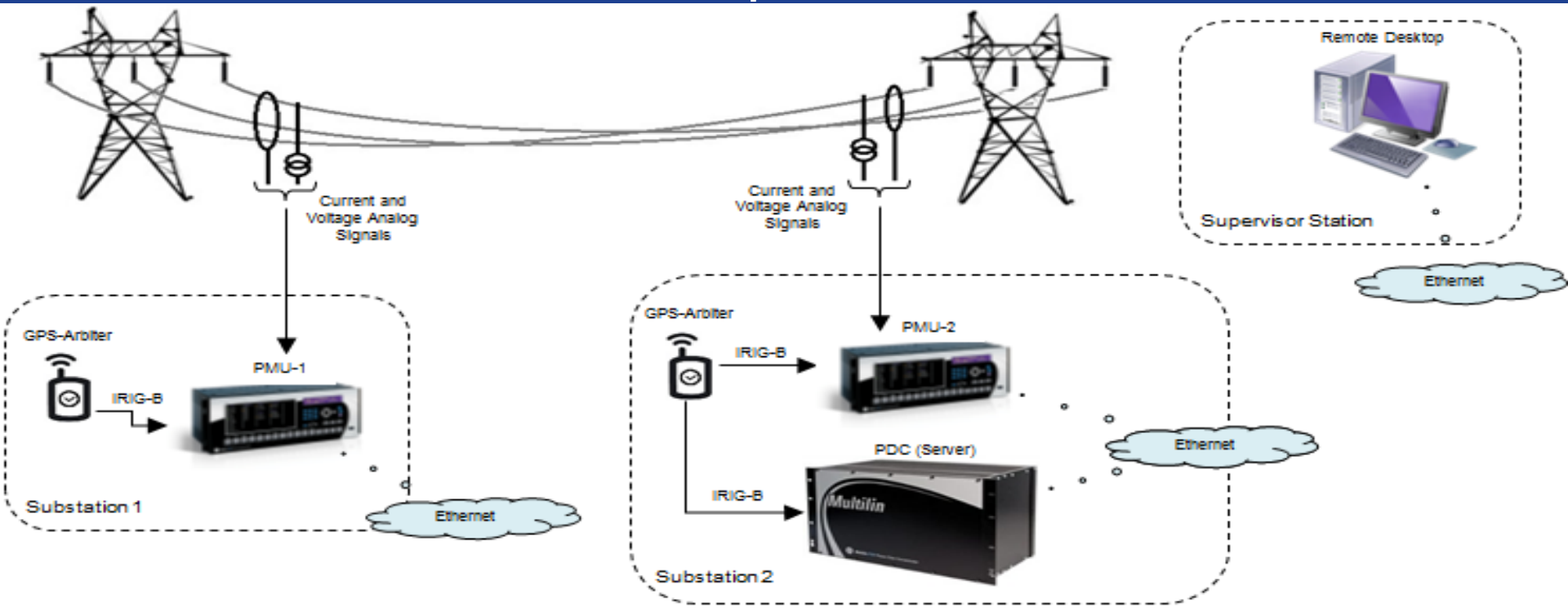


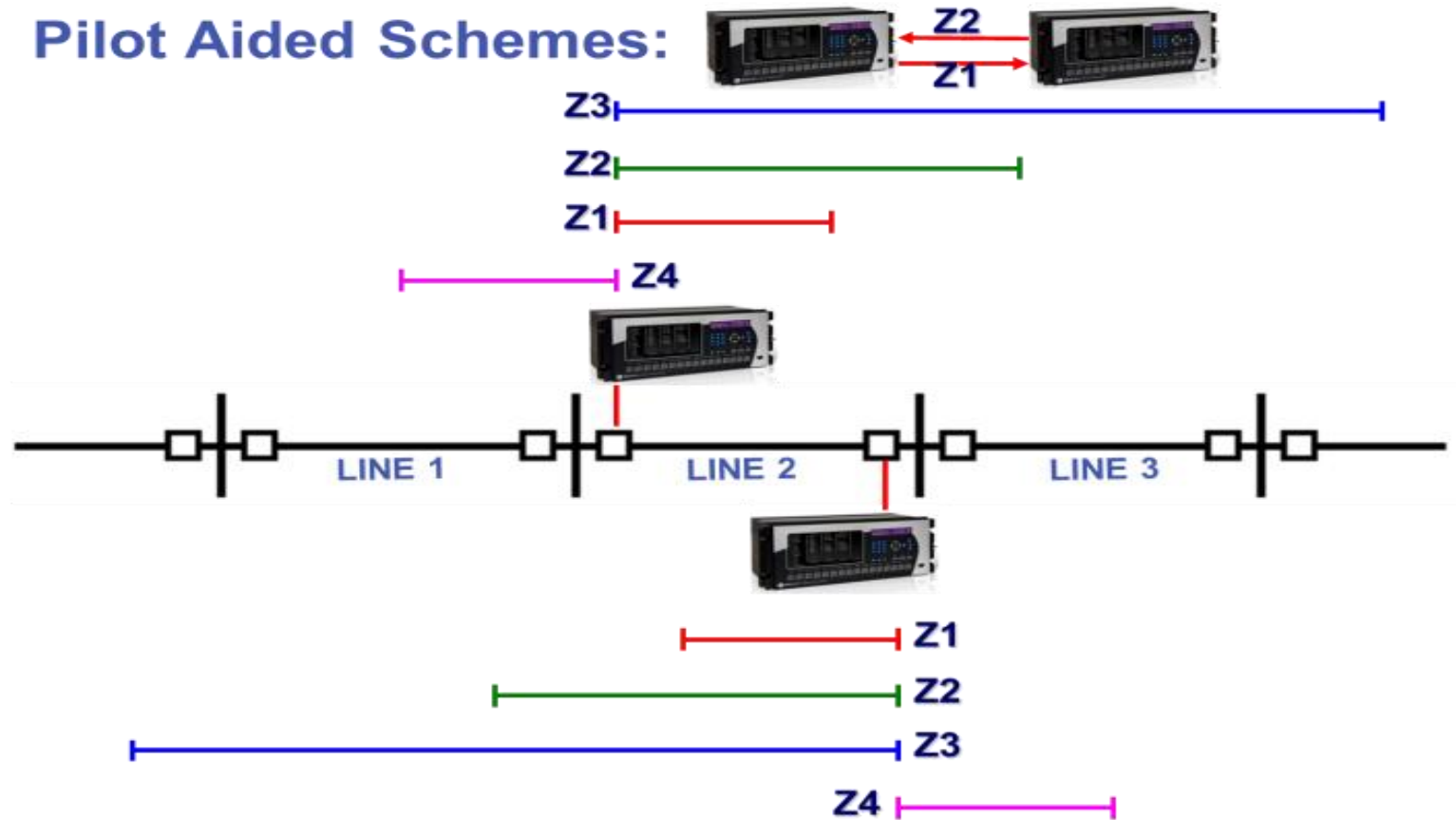
Selective Backup Protection for AC HV and EHV Transmission Lines

Jorge Cardenas
GE Digital Energy
Spain

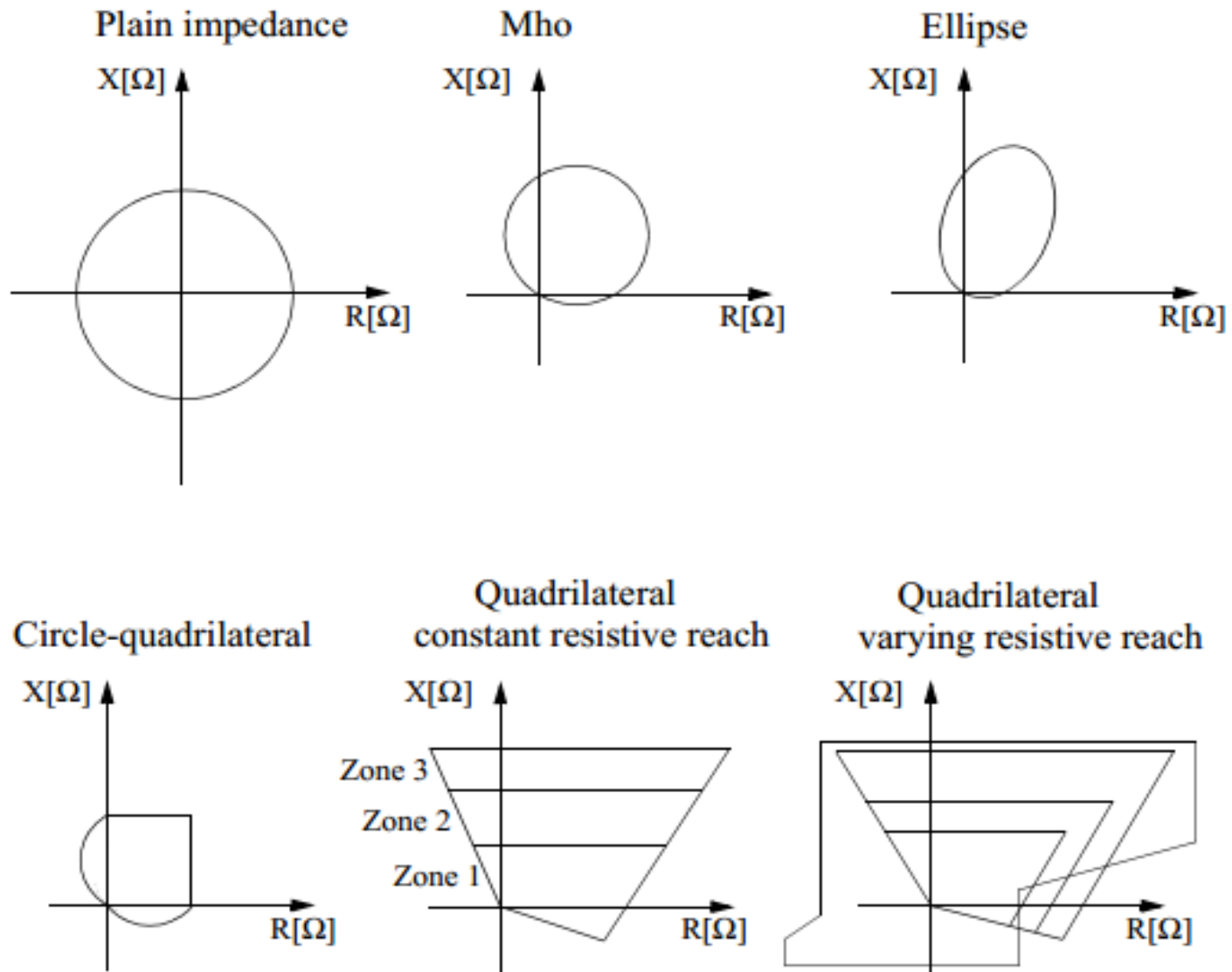


ACTUAL DISTANCE PROTECTION SCHEME

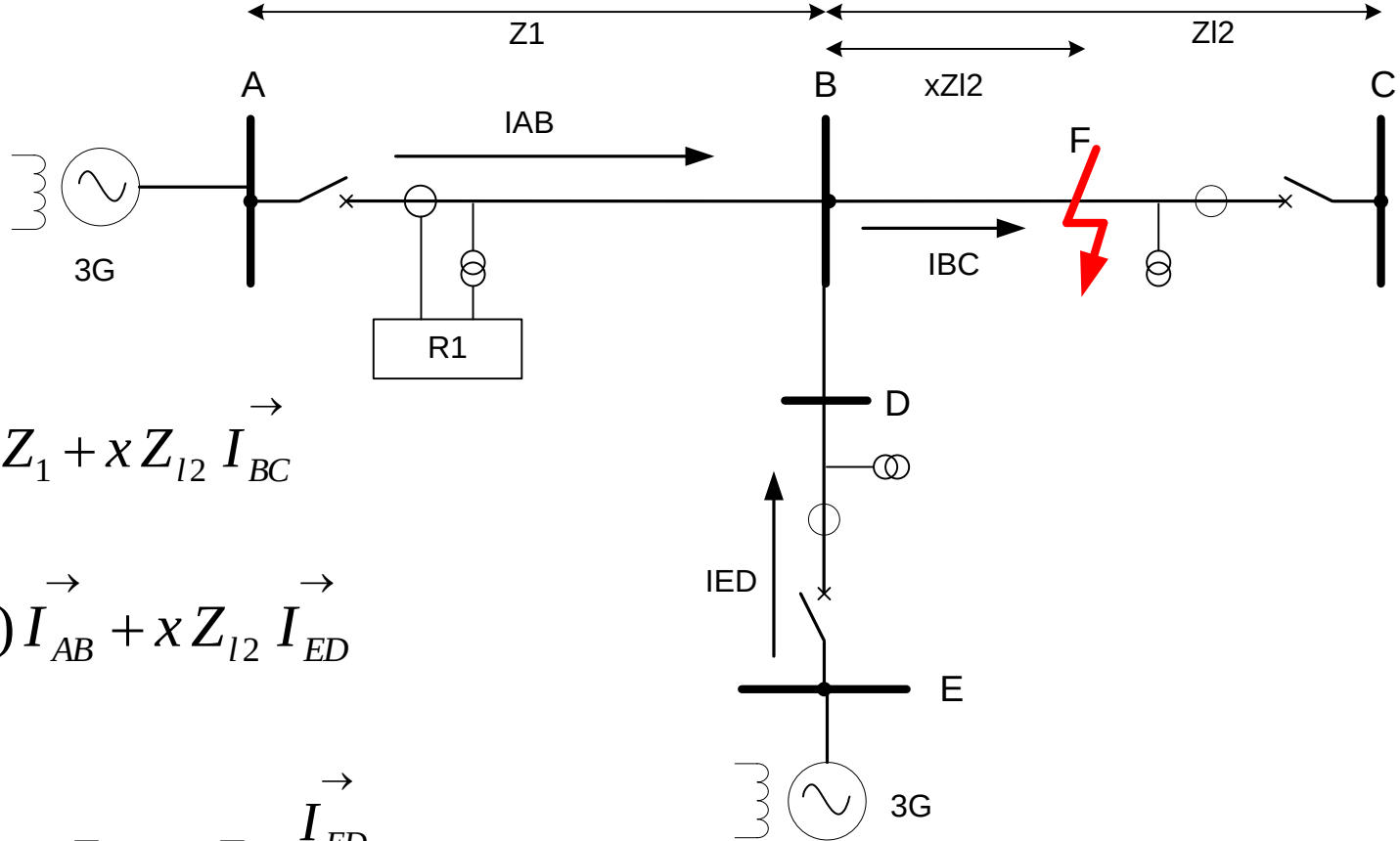
Pilot Aided Schemes:



RELAY CHARACTERISTICS

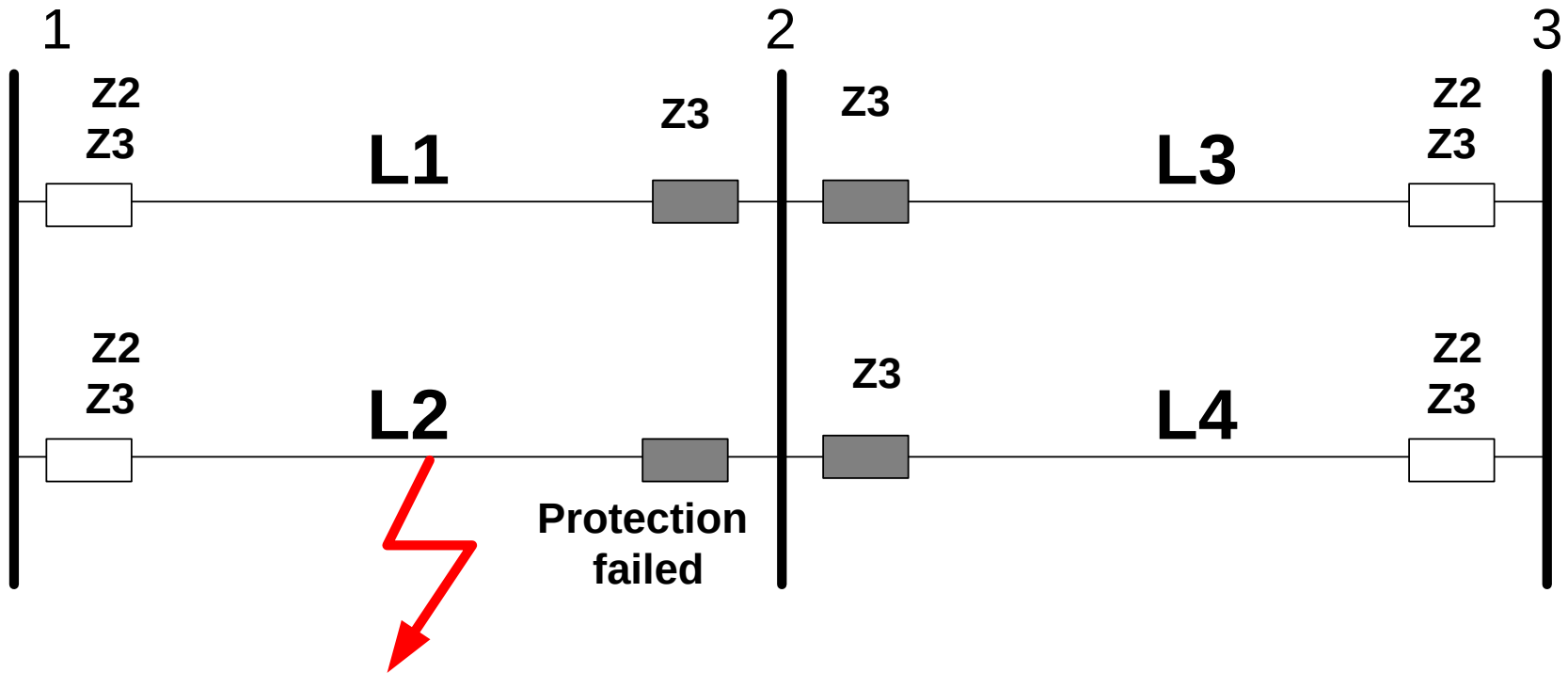


LIMITATIONS OF DISTANCE MEASURING CRITERIA

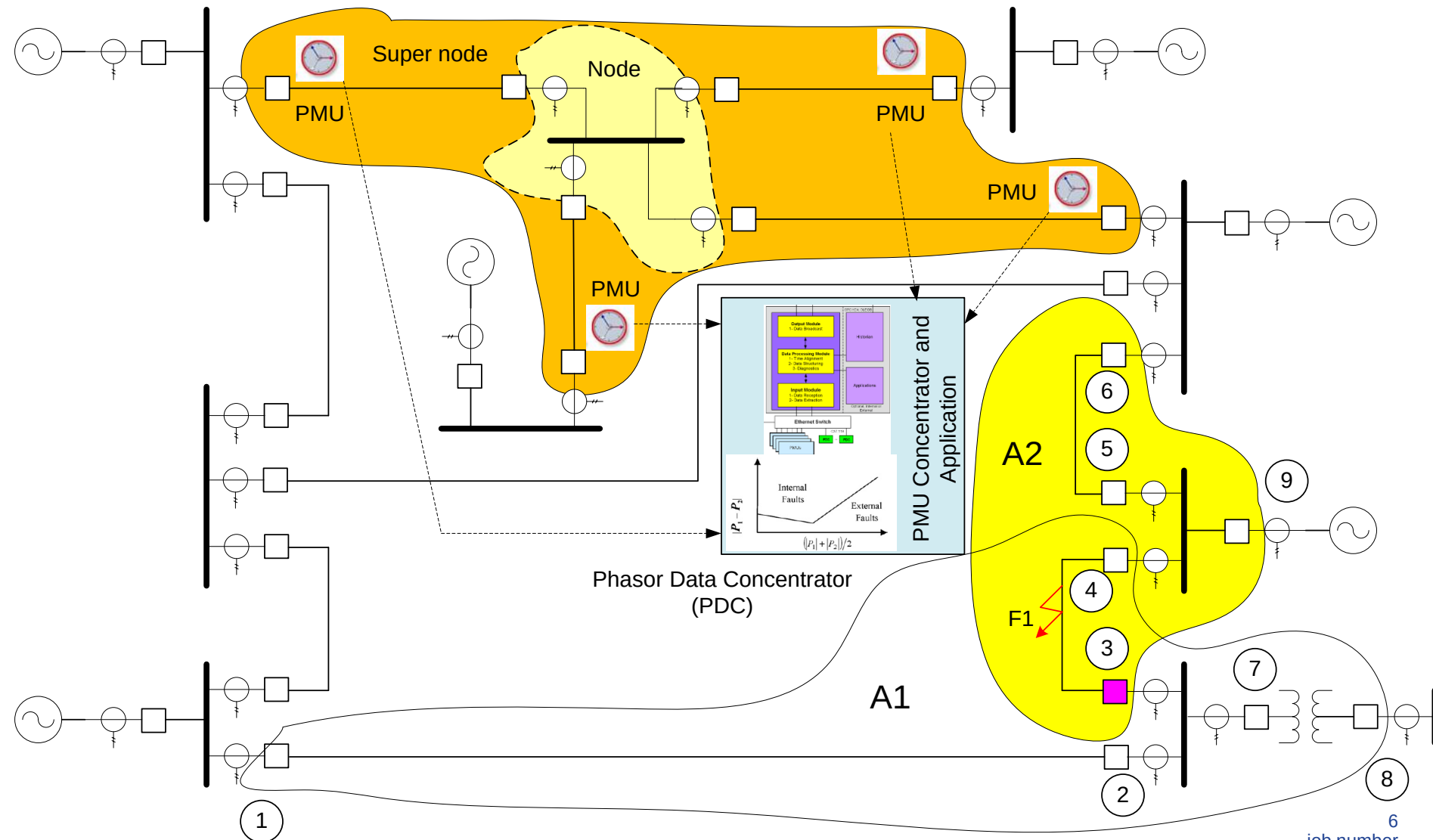


$$\begin{aligned} V_{R1} &= \vec{I}_{AB} Z_1 + x Z_{l2} \vec{I}_{BC} \\ &= (Z_1 + x Z_{l2}) \vec{I}_{AB} + x Z_{l2} \vec{I}_{ED} \\ \frac{V_{R1}}{\vec{I}_{AB}} &= Z_1 + x Z_{l2} + x Z_{l2} \frac{\vec{I}_{ED}}{\vec{I}_{AB}} \end{aligned}$$

PROTECTION FAILURE



NEW VISION OF BACKUP PROTECTION



NEW LINE PROTECTION CRITERIA

- Primary protection (as usual, distance, line differential) as the first defence line.
- First Backup selective protection: Differential (Active Power) time delayed with PMU (200 to 300 ms could be sufficient). Other criteria as current differential or directional also could be used. Active Power is preferred because it is inherent non-affected by Line Charging, Inrush current from transformers. Differential criteria works well with none, or reduced infeed during faults as in case with non-renewable (wind and solar) energy sources. This is the second defence line.
- Second Backup Protection: As usual, BF, Zone 3, Overcurrent, etc. (disabled while First Backup is active and automatic enabled if First Backup is non-active or failed). Alternative second (no deterministic) defence line.

NEW ALGORITHM

$$P_{\text{Diff}} = |\underline{P}_{1,1} + \underline{P}_{1,2} + \dots + \underline{P}_{1,n}|/n$$
$$P_{\text{Rest}} = \text{Max}(|\underline{P}_{1,1}|, |\underline{P}_{1,2}|, \dots, |\underline{P}_{1,n}|)$$

where:

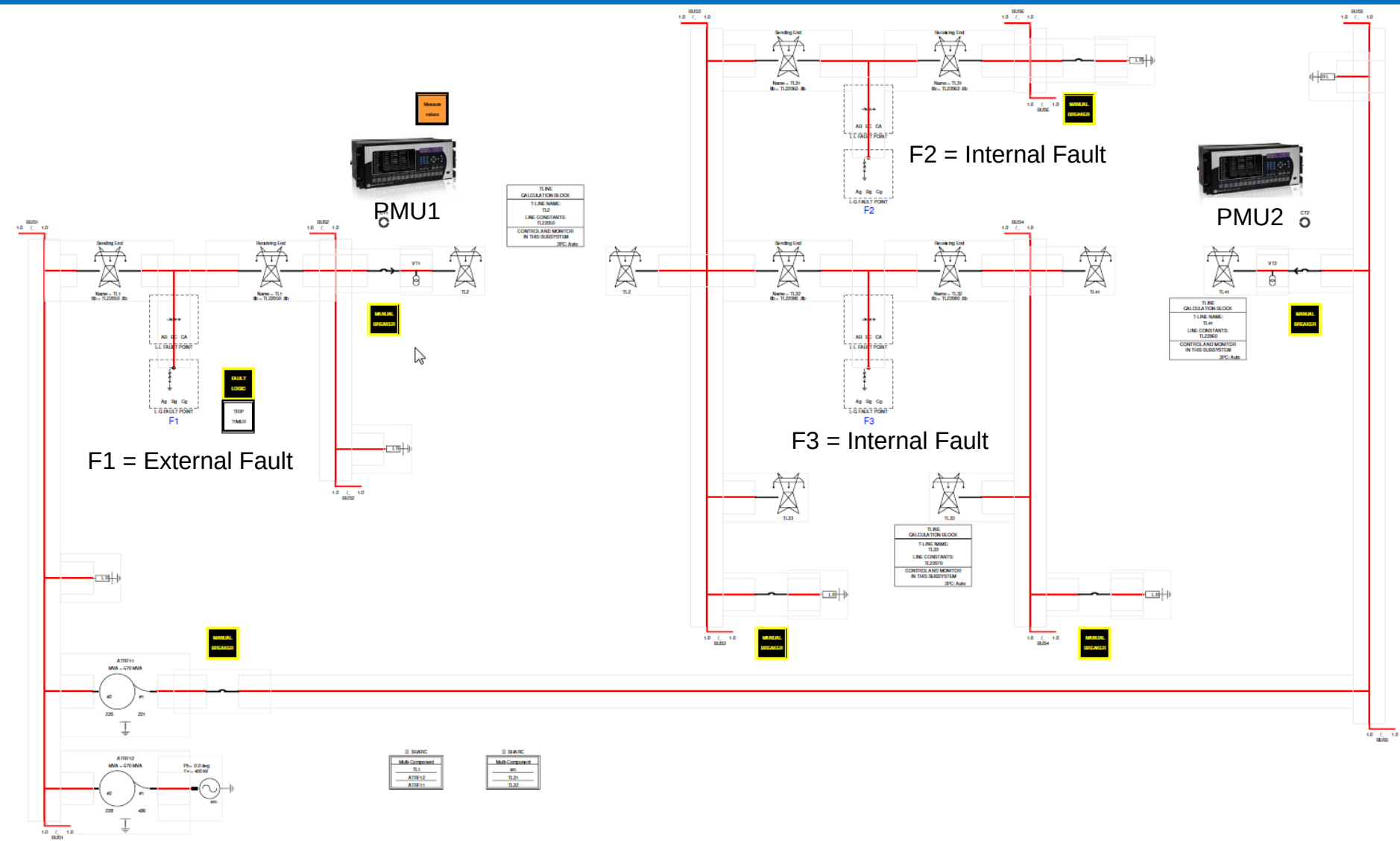
$\underline{P}_1$ – Positive-sequence power in per unit

calculated as: $\underline{P}_1 = \underline{U}_1 \cdot \underline{I}_1^*$

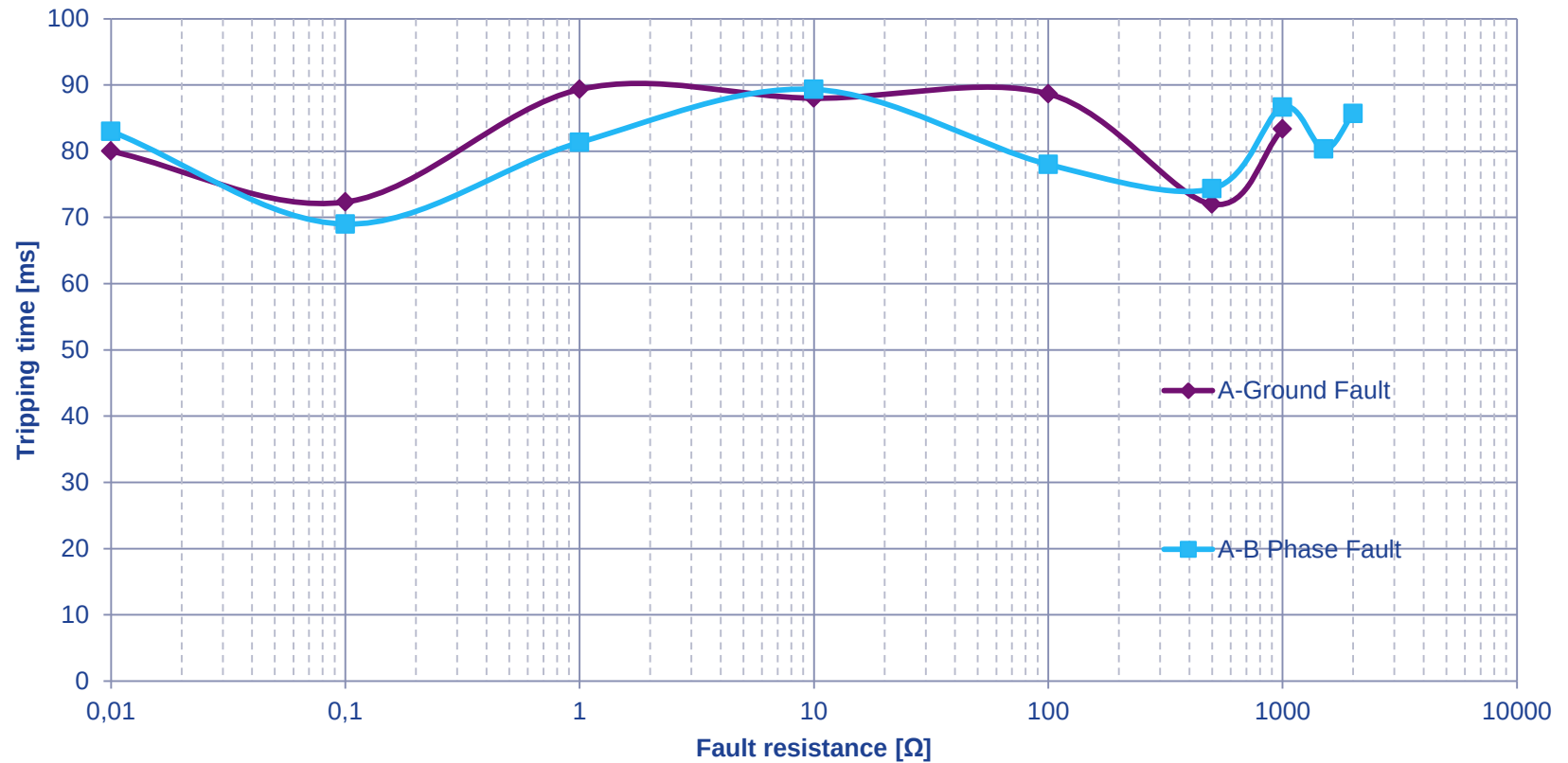
n – n -th PMU of the super node

The above algorithm was combined with a power directional algorithm to discriminate internal from internal faults.

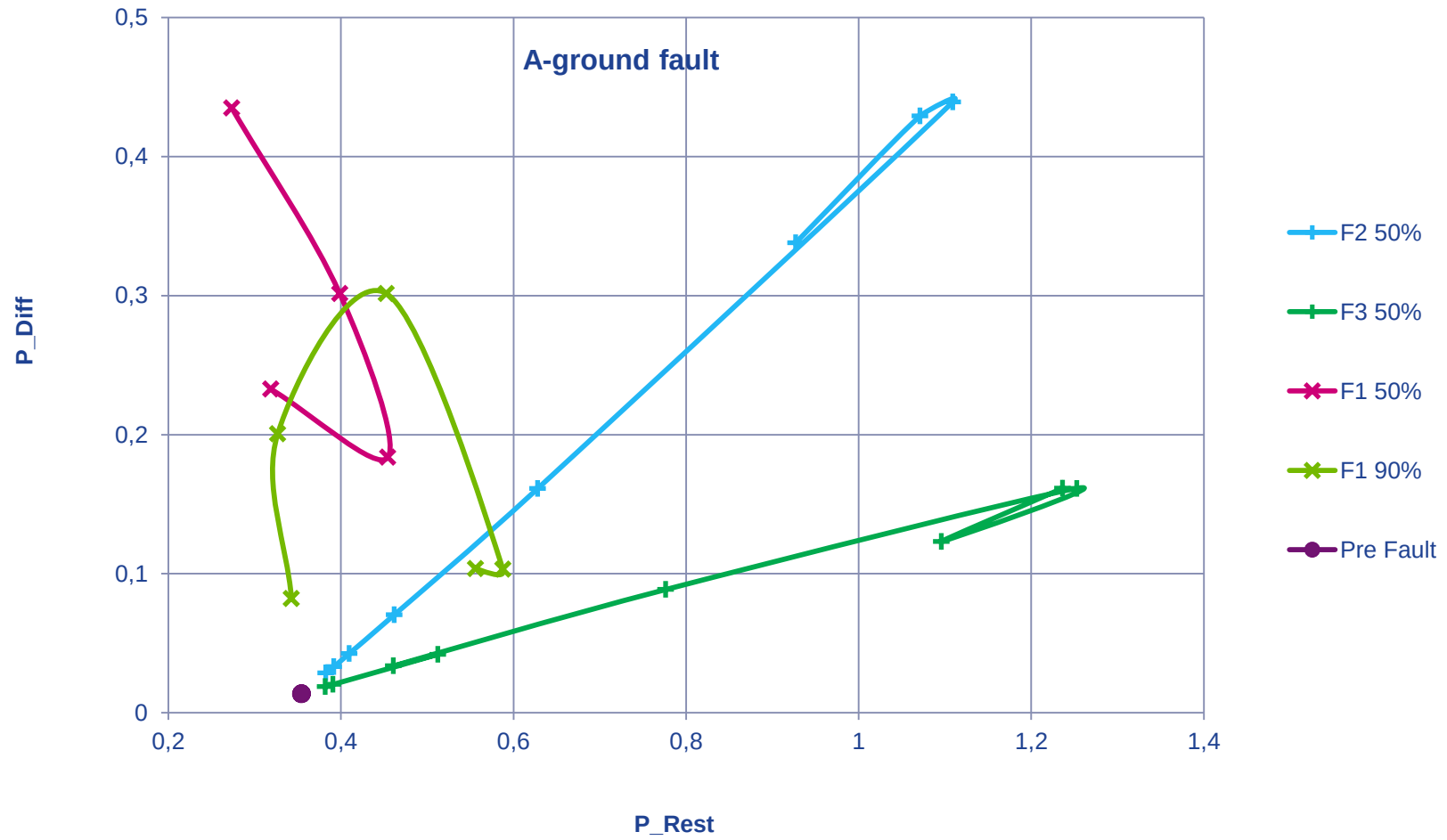
RTFS MODEL IN SIMULATIONS



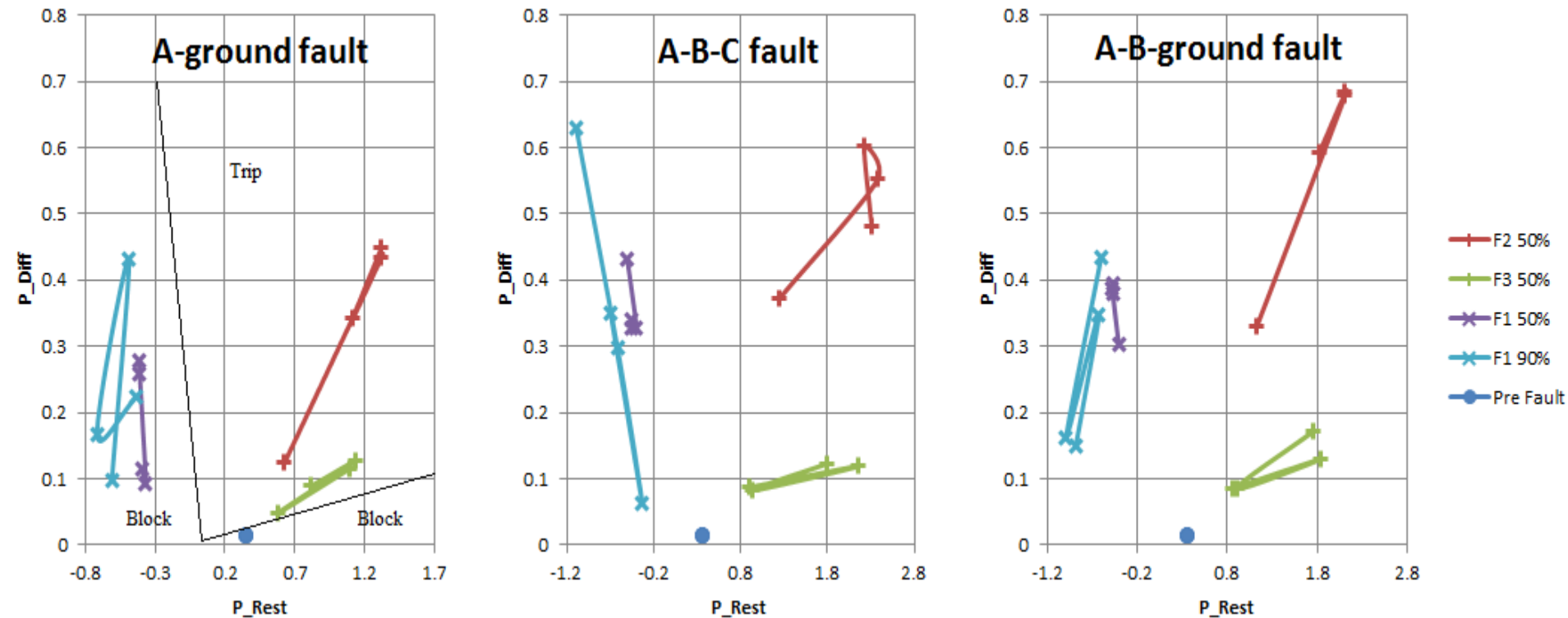
OPERATING TIME W/O DELAY



RESPONSE WITH ONLY DIFFERENTIAL ALGORITHM



RESPONSE WITH DIFFERENTIAL AND DIRECTIONAL ALGORITHM



CONCLUSIONS

- Power Differential Algorithm combined with power directional criteria give a very good response a correct fault discrimination with any kind of faults.
- Test were made using only two PMU's sending information at 50 values per second. Operating time is much smaller than typical delay for Zone 3. For coordination, additional time may be required.
- Research is at early stage, but with promising results. Further work will be needed to define the final structure of the most suitable algorithm and also tests on other more “standard” network models.