Fast Fault Detection Challenge for Alienation Coefficient Based Bus Fault Discriminator

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Monir Hossain
PhD Candidate

Dr. Ittiphong Leevongwat
Associate Professor

Dr. Parviz Rastgoufard
Professor

Dept. of Electrical a Engineering
University of New Orleans

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PROBLEM STATEMENT

- *One of the key challenges for bus differential protection is to prevent mis-operation due to CT saturation during close-in external faults.*
- *Various techniques have been used to supervise traditional bus differential characteristics in order to solve this challenge:*

- ***Logical follow-up to block trip during CT saturation***
- ***It blocks internal faults if CT saturates!***
- ***Directional supervision***
- ***It blocks high impedance internal faults as load current continue to flow!***
- ***Supervision based on change of system parameters (differential current, restraint current)***
- ***Mis-trip during fast CT saturation!***

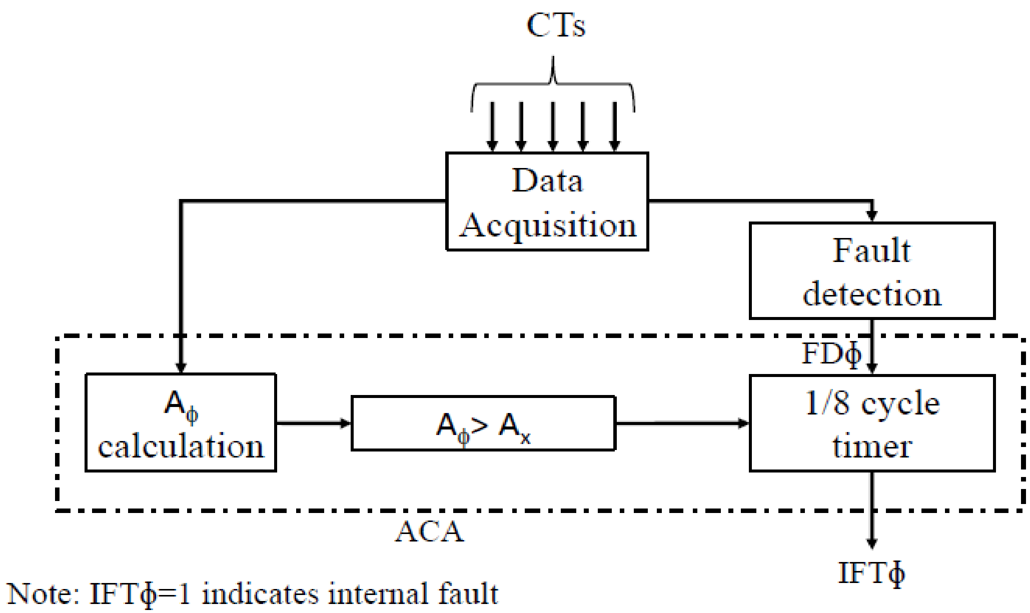
PROBLEM STATEMENT

- ***ACA: Use of alienation coefficient of two current signals from two-terminal equivalent busbar configuration to discriminate internal and external faults.***

- ***Delayed detection of fault inception results mis-trip during external faults.***

- ***This paper presents:***
    - ***The performance evaluation of ACA for currently used fault detection technique.***
    - ***An alternative fault detection technique.***
    - ***Performance validation for modified fault discriminator.***

Fault Discrimination by Alienation Coefficient



$$r_\Phi = \left(\sum_{n=1}^{m} i_{\Phi E1} i_{\Phi E2} - (1/m)\sum_{n=1}^{m} i_{\Phi E1} \sum_{n=1}^{m} i_{\Phi E2}\right) / \sqrt{\left(\left(\sum_{n=1}^{m} i_{\Phi E1}^2 - (1/m)\left(\sum_{n=1}^{m} i_{\Phi E1}\right)^2\right)\left(\sum_{n=1}^{m} i_{\Phi E2}^2 - (1/m)\left(\sum_{n=1}^{m} i_{\Phi E2}\right)^2\right)\right)}$$

$$A_\Phi = 1 - (r_\Phi)^2$$

- A_ϕ *becomes high instantaneously with the inception of internal fault.*
- A_ϕ *becomes high after 1/8 cycle of fault inception in case of external faults.*

Important: Detection of fault (fault inception) instantaneously if possible

Issues Identified with Present Method

What?
- *Fault discriminator responds incorrectly by detecting external fault as internal fault*

Why?
- *Delayed fault detection*

When?
- *Fast CT saturation during external faults*

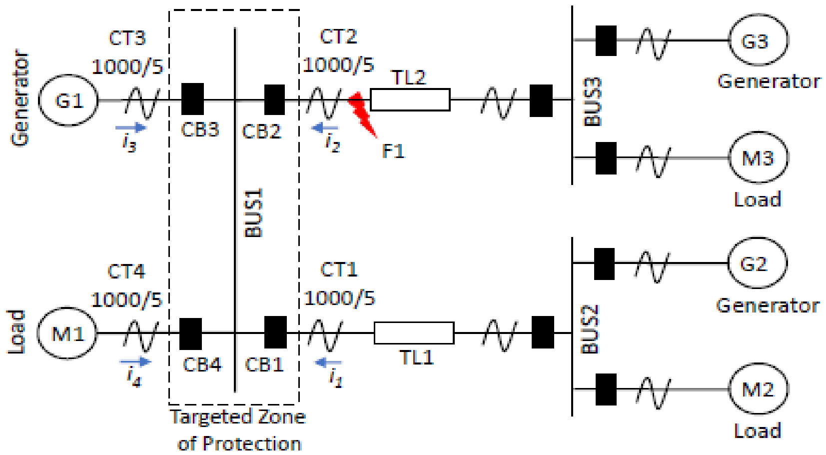
How?
- *Time difference between fault detection and starting of CT saturation becomes less than 1/8 cycle*

Fault detection:

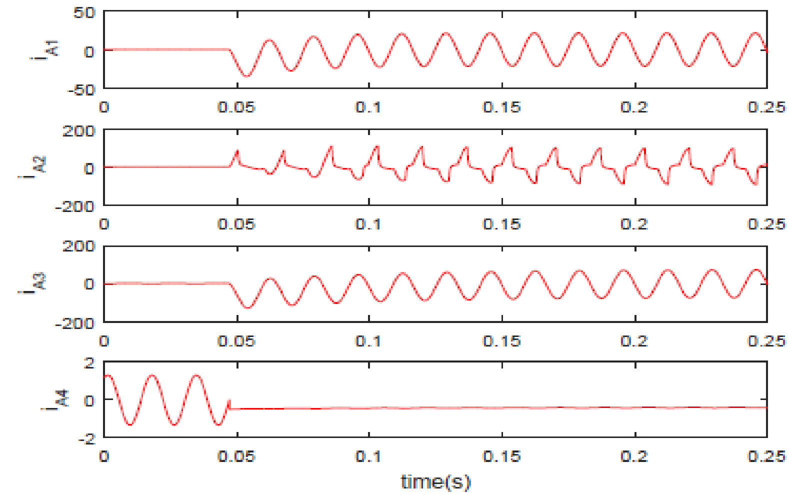
$$I_{\Phi t} = \frac{1}{2}\sum_{k=1}^{n} I_{\Phi k}$$

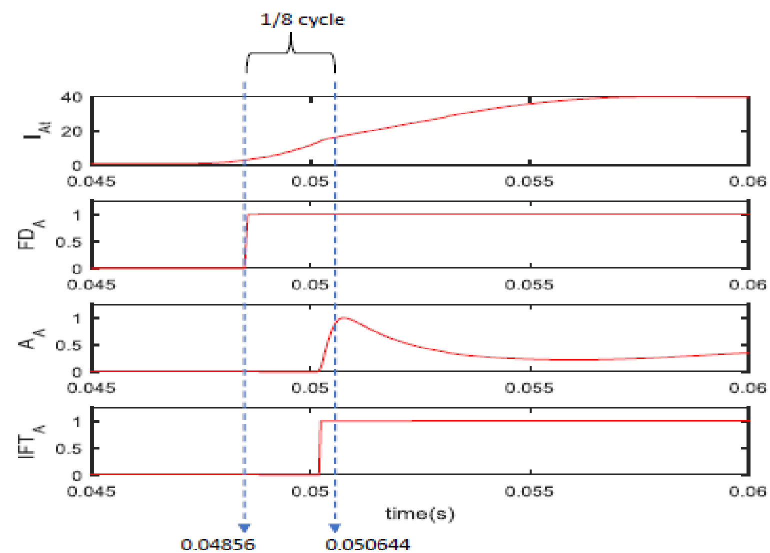
Fault: If $\Delta I_{\phi t} > 0.2 I_n$

Issues Identified with Present Method



I_n is considered 2000A.





Issues Identified with Present Method

PERFORMANCE ANALYSIS WITH EXISTING FAULT DETECTOR

Fault	Location	R_f (Ω)			Time (ms)		Response of discriminator
			T1	T2	T3	T3 - T2	
AG	F1	0.1	47	48.56	50.23	1.67	**Internal fault**
AG	F1	5	47	48.64	50.56	1.92	**Internal fault**
AG	F1	10	47	48.73	50.98	2.25	External fault
AG	F1	0.1	49	50.15	51.77	1.62	**Internal fault**
AG	F1	5	49	50.23	52.10	1.87	**Internal fault**
AG	F1	10	49	50.31	52.52	2.21	External fault
ABG	F1	0.1	47	48.73	50.48	1.75	**Internal fault**
ABG	F1	5	47	48.81	50.77	1.96	**Internal fault**
ABG	F1	10	47	48.90	51.23	2.23	External fault
ABG	F1	0.1	49	50.23	51.90	1.67	**Internal fault**
ABG	F1	5	49	50.31	52.19	1.88	**Internal fault**
ABG	F1	10	49	50.40	52.60	2.20	External fault

Proposed Fault Detection Method

In steady-state:

$$i_{\Phi k}(t) = \sqrt{2} I_{\Phi km} \cos(\omega t + \theta_k)$$

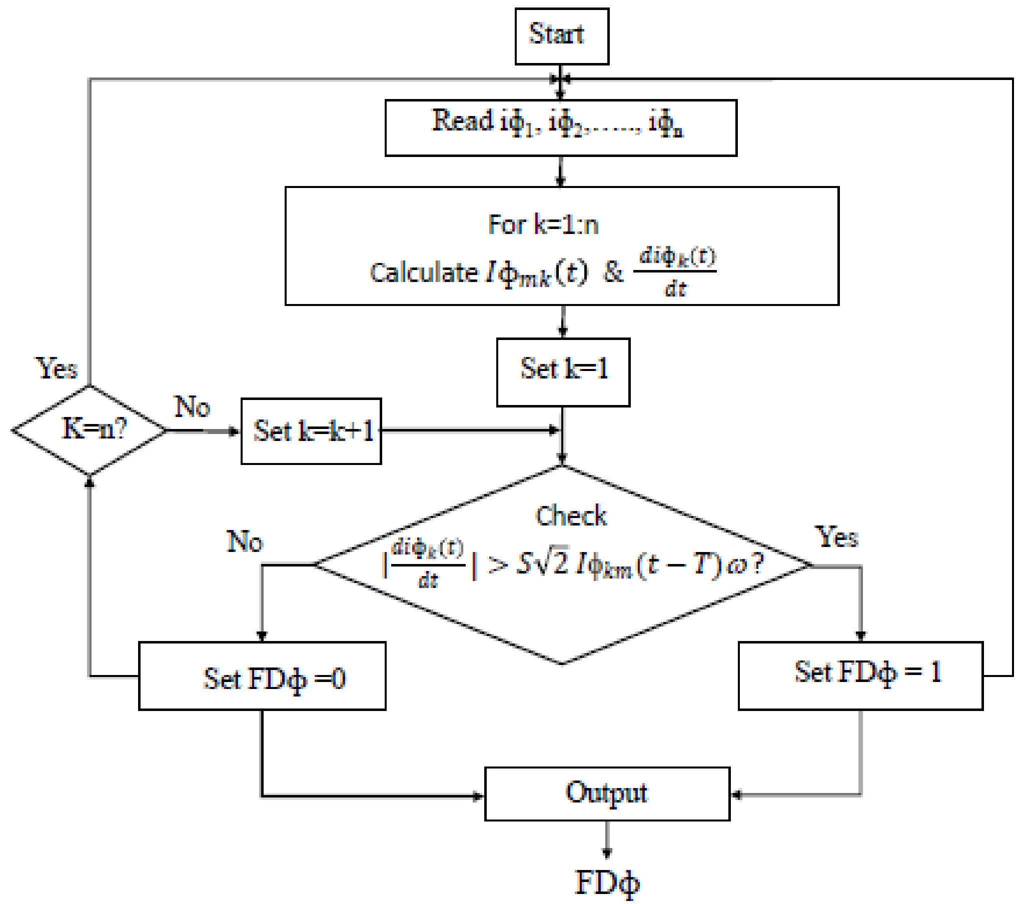
$$\left|\frac{di_{\Phi k}(t)}{dt}\right| = \sqrt{2}\omega I_{\Phi km} |\sin(\omega t + \theta_k)|$$

$$|\sin(\omega t + \theta_k)|_{max} = 1.$$

$$\left|\frac{di_{\Phi k}(t)}{dt}\right|_{max} = \sqrt{2}\omega I_{\Phi km}$$

$$I_{\Phi km}(t) = I_{\Phi km}(t - T)$$

$$\left|\frac{di_{\Phi k}(t)}{dt}\right|_{max} = \sqrt{2}\omega I_{\Phi km}(t - T)$$



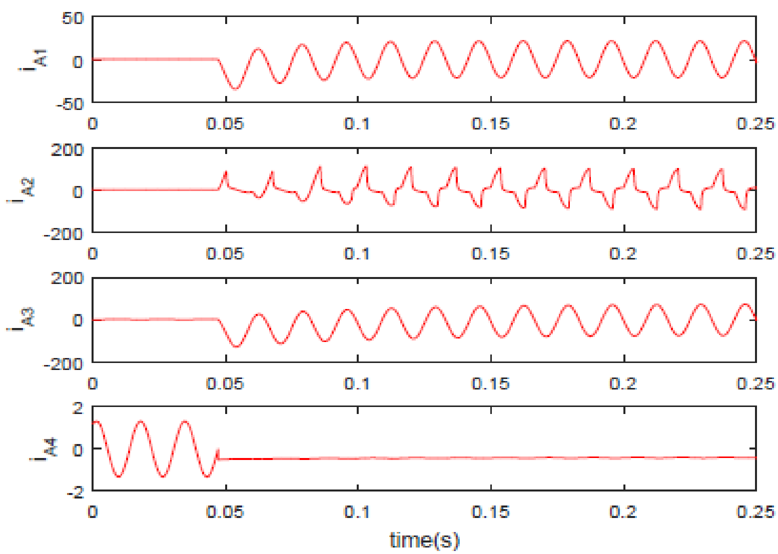
In transient (fault):

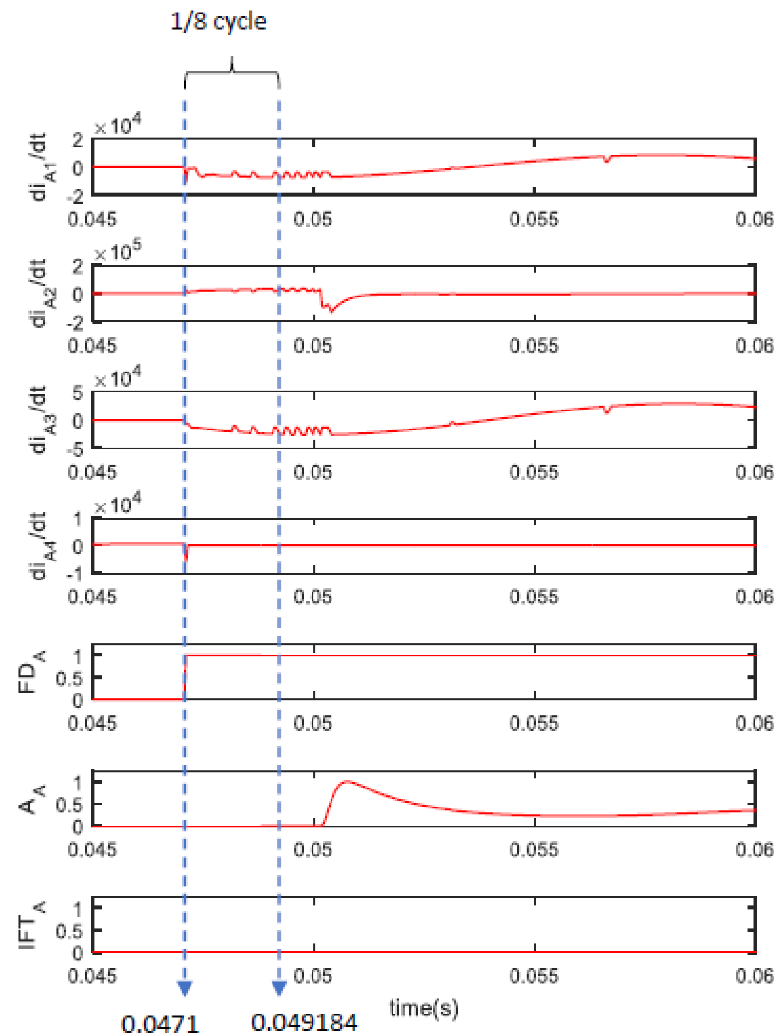
$$\left|\frac{di_{\Phi k}(t)}{dt}\right| >> \sqrt{2}\omega I_{\Phi km}(t - T)$$

OR

$\left|\frac{di_{\Phi k}(t)}{dt}\right| > S\sqrt{2}\omega I_{\Phi km}(t - T)$, S is a marginal constant

Performance Validation





Performance Validation

PERFORMANCE ANALYSIS WITH PROPOSED FAULT DETECTOR

Fault	Location	R_f (Ω)	Time (ms)				Response of discriminator
			T1	T2	T3	T3 - T2	
AG	F1	0.1	47	47.10	50.23	3.13	External fault
AG	F1	5	47	47.10	50.56	3.46	External fault
AG	F1	10	47	47.10	50.98	3.88	External fault
AG	F1	0.1	49	49.11	51.77	2.66	External fault
AG	F1	5	49	49.11	52.10	2.99	External fault
AG	F1	10	49	49.11	52.52	3.41	External fault
ABG	F1	0.1	47	47.10	50.48	3.38	External fault
ABG	F1	5	47	47.10	50.77	3.67	External fault
ABG	F1	10	47	47.10	51.23	4.13	External fault
ABG	F1	0.1	49	49.11	51.90	2.79	External fault
ABG	F1	5	49	49.11	52.19	3.08	External fault
ABG	F1	10	49	49.11	52.60	3.49	External fault

Concluding Remarks

- *This paper examines the performance of alienation coefficient-based bus fault discriminator including existing fault detector by simulation study.*
- *The study suggests that existing fault detector can introduce mis-operation during external faults due to delayed fault detection.*
- *An alternative fault detection method is proposed based on the first derivative of instantaneous terminal current to overcome the aforesaid problem.*
- *The performance of the proposed fault detector is validated by simulation study.*
- *The results of the study indicate that the proposed method is able to detect fault inception almost instantaneously which addresses the risk of mis-operation of alienation coefficient-based bus fault discriminator.*

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THANK YOU! ☺