ANALYSIS OF THE DIFFERENTIAL PROTECTION FUNCTION ACCURACY IN THE UNIT REF 542PLUS

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ABSTRACT

The differential protections present basic protection to protect power transformers, motors, generators, blocks power transformer-generator, bus bars and important lines. Differential protection has to operate in very short time to faults in the protection zone, but it must not operate to faults outside. Control and protection unit REF 542plus is used to protect in medium voltage systems. Unit REF 542plus has a lot of protection functions even the differential protection function. This paper deals with measuring of accuracy of the differential protection function algorithm in the unit REF 542plus applied to protect power transformer because in this case are the highest requirements (vector group adaptation, difference between nominal primary current and nominal secondary current, etc.) It was measured the minimum setting values of the characteristic of the differential protection. Differential current was generated by the amplitude simulation of incoming and outgoing current. At the end is evaluated accuracy of the algorithm.

1 INTRODUCTION

The differential protection is a current comparison scheme for the protection of a component with two ends, like e.g. two windings power transformer, therefore the incoming and outgoing currents through the component to be protected are compared with each other. If no fault exists in the protection zone, the incoming current and the outgoing current must be identical. Therefore the difference between those currents, the differential current, can be used as criteria for fault detection. Consequently the protection zone of the differential protection is limited by the place where the current transformers or current sensors are installed. To perform the current comparison, it is necessary to correct the amplitude of the current. In the modern differential protection the amplitude correction adaptation is done by software. In the case of power transformer protection for example, the current measurement quantities on the primary and the secondary side must be corrected by taking the different CT nominal values into account. Also the adaptation of the vector group between the primary and the secondary side including the compensation of the zero sequence component of the current must be considered.

2 DIFFERENTIAL PROTECTION IN REF 542PLUS

The differential protection function has the following properties:

- Differential protection of two windings power transformer
- Amplitude and vector group adaptation is done by software
- Zero sequence current compensation
- Three fold tripping characteristic
- Inrush stabilization by the 2^{nd} and 5^{th} harmonics
- Stabilization during through faults also in case of CT saturation
- Processing of Buchholz – Signals

2.1 TRIPPING CHARACTERISTIC

The tripping characteristic of the transformer differential protection function is a threefold characteristic.

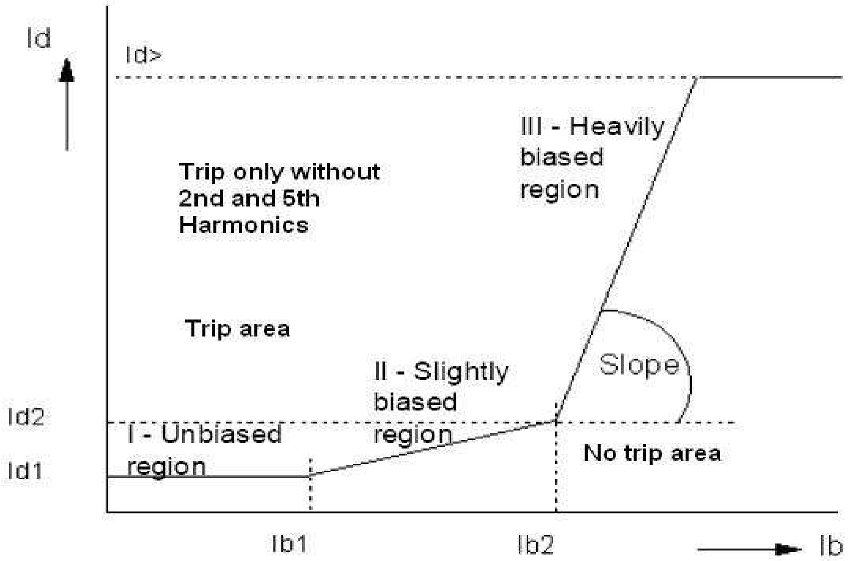

Fig. 1: *Tripping characteristic of the differential protection function in REF 542plus*

The tripping characteristic is drawn on p.u. basis after normalization of I_1 and I_2 currents on the primary or secondary nominal power transformer current (Primary, Secondary nominal current). Therefore I_d and I_b currents are expressed in p.u. as multiples of the Rated power transformer current I_r (p.u.). The bias currents I_b are defined as the average values (in p.u.) between primary and secondary currents obtained after transformation ratio compensation and vector group adaptation. Due to the measurement error of the current quantities on both sides of the object to be protected, a small differential current I_d will occur during normal operation condition. The first fold of the characteristic curve is given by the settable threshold value of the differential current (Threshold current) and the bias current limit (Unbiased region limit). The second fold of the characteristic curve is defined by the threshold value of the differential current (Slightly biased region threshold) and the bias current limit (Slightly biased region limit). Afterwards a line with a selectable slope (Heavily biased slope) continues the characteristic. In case of the occurrence of a high differential current, a direct tripping can also be generated by the threshold value (Trip by $I_{d>}$) as the third fold of the tripping characteristic. The setting value should be selected in such a way, that no tripping could happen during the energizing of the power transformer.

$$I_b = \frac{\left|\overline{I_1} + \overline{I_2}\right|}{2} \tag{1}$$

$$I_d = \left|\overline{I_1} - \overline{I_2}\right| \tag{2}$$

3 DESCRIPTION OF THE MEASUREMENT

For the testing of tripping characteristic was used Relay test system Freja 300 by Programma – Analog inputs: 3 phase AC 3x15 A with the guaranteed inaccuracy (±0,01% of range) + (±0,3 % of reading).

3.1 SETTING VALUES

For the testing was used an imaginary power transformer:

S_n=20 MVA, Yy0, U_p=22 kV, U_s=6 kV; I_p=525 A, I_s=1925 A;

CT_1 Primary side: 500/1, CT_2 Secondary side: 2000/1

Transformer group	0	Threshold current I_{d1}	0,1
Transformer Earthing	No/No	Unbiased region limit I_{b1}	0,5
Primary nominal current I_p	525 A	Slightly biased region threshold I_{d2}	0,2
Secondary nominal current I_s	1925 A	Slightly biased region limit I_{b2}	1,00
Second harmonics blocking	Not used	Heavily biased slope	0,40
Fifth harmonics blocking	Not used	Trip by $I_{d>}$	5,00

Tab. 1: *Setting values*

4 RESULTS OF THE MEASUREMENT

The differential protection function was tested in 34 points of all parts of the characteristic. Tested points are shown in fig. 1. For testing were used minimum setting values. Especially were tested the first and the second parts of the characteristics – Unbiased region and Slightly biased region, you can see them in fig. 2.

I_1	I_2	I_d	I_b	t (ms)	I_1	I_2	I_d	I_b	t (ms)
0,103	0,000	0,103	0,052	58	1,554	1,200	0,354	1,377	43
0,202	0,100	0,102	0,151	59	1,856	1,400	0,456	1,628	44
0,402	0,300	0,102	0,351	58	2,758	2,000	0,758	2,379	41
0,504	0,400	0,104	0,452	57	3,510	2,500	1,010	3,005	40
0,534	0,430	0,104	0,482	57	4,261	3,000	1,261	3,631	42

0,544	0,440	0,104	0,492	58	5,763	4,000	1,763	4,882	40
0,554	0,450	0,104	0,502	57	7,000	4,822	2,178	5,911	40
0,576	0,470	0,106	0,523	59	8,500	5,821	2,679	7,161	40
0,601	0,490	0,111	0,546	56	10,000	6,818	3,182	8,409	40
0,700	0,570	0,130	0,635	54	12,000	8,149	3,851	10,075	39
0,799	0,650	0,149	0,725	53	13,000	8,814	4,186	10,907	40
0,900	0,734	0,166	0,817	54	14,000	9,479	4,521	11,740	39
1,000	0,815	0,185	0,908	52	14,783	10,000	4,783	12,392	40
1,049	0,855	0,194	0,952	52	15,428	10,430	4,998	12,929	40
1,100	0,897	0,203	0,999	51	15,606	10,580	5,026	13,093	37
1,220	0,977	0,243	1,099	45	16,026	11,000	5,026	13,513	37
1,328	1,050	0,278	1,189	46	16,228	11,200	5,028	13,714	36

Tab. 2: *Tested points of the differential protection characteristics*

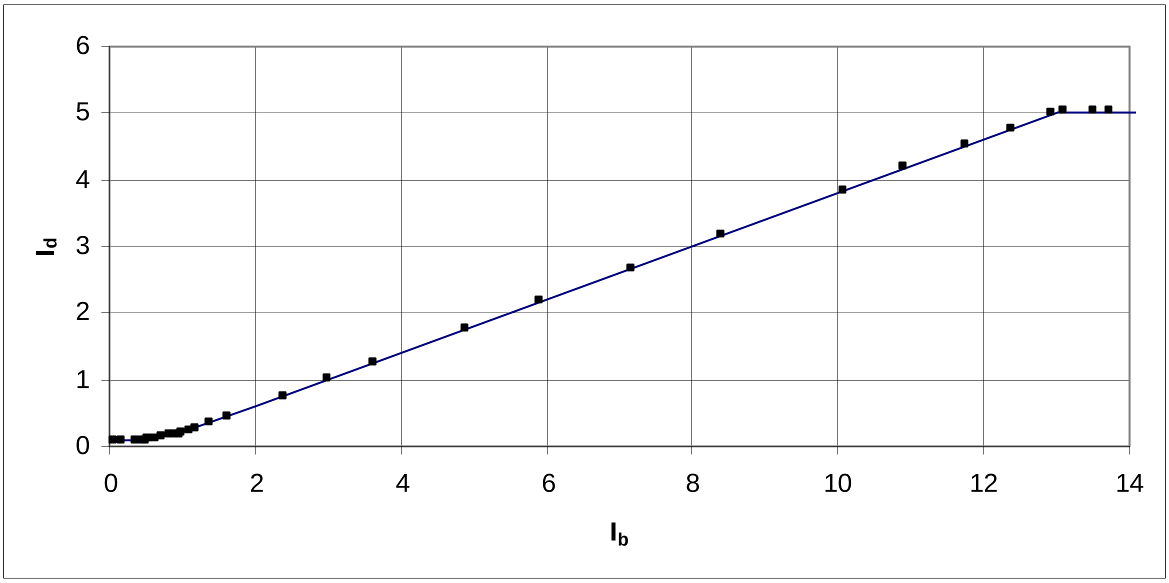

Fig. 2: *The theoretical characteristic of the differential protection and tested points*

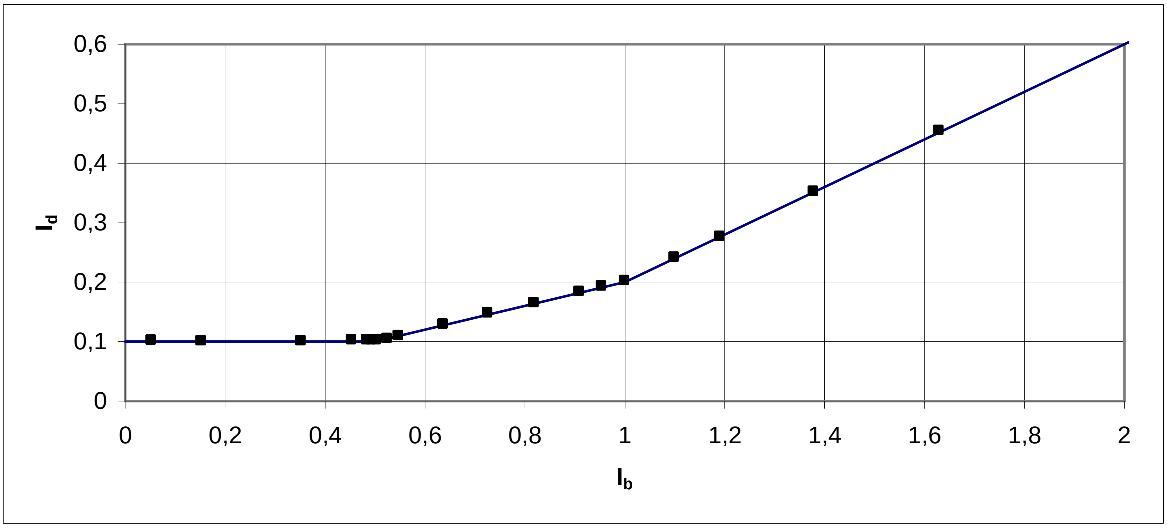

Fig. 3: *Magnification of the first and the second part of characteristic*

I_d meas.	I_b	I_d teor.	Difference	I_d meas.	I_b	I_d teor.	Difference
0,103	0,052	0,100	0,003	0,354	1,377	0,351	0,003
0,102	0,151	0,100	0,002	0,456	1,628	0,451	0,005
0,102	0,351	0,100	0,002	0,758	2,379	0,752	0,006
0,104	0,452	0,100	0,004	1,010	3,005	1,002	0,008
0,104	0,482	0,100	0,004	1,261	3,631	1,252	0,009
0,104	0,492	0,100	0,004	1,763	4,882	1,753	0,010
0,104	0,502	0,100	0,004	2,178	5,911	2,164	0,014
0,106	0,523	0,105	0,001	2,679	7,161	2,664	0,015
0,111	0,546	0,109	0,002	3,182	8,409	3,164	0,018
0,13	0,635	0,127	0,003	3,851	10,075	3,830	0,021
0,149	0,725	0,145	0,004	4,186	10,907	4,163	0,023
0,166	0,817	0,163	0,003	4,521	11,740	4,496	0,025
0,185	0,908	0,182	0,004	4,783	12,392	4,757	0,026
0,194	0,952	0,190	0,004	4,998	12,929	4,972	0,026
0,203	0,999	0,200	0,003	5,026	13,093	5,000	0,026
0,243	1,099	0,239	0,004	5,026	13,513	5,000	0,026
0,278	1,189	0,276	0,002	5,028	13,714	5,000	0,028

Tab. 3: *Differences between the measured and the theoretical values*

Unbiased region $I_b \in \langle 0; 0,5 \rangle \Rightarrow I_{d\ teor.} = 0,1$

Slightly biased region $I_b \in \langle 0,5; 1 \rangle \Rightarrow I_{d\ teor.} = 0,2 \cdot I_b$

Heavily biased region $I_b \in \langle 1; 13 \rangle \Rightarrow I_{d\ teor.} = 0,4 \cdot I_b - 0,2$

$I_{d>}$ stage $I_b \in \langle 13; \infty) \Rightarrow I_{d\ teor.} = 5$

5 CONCLUSION

The measurment discuss about accuracy of the differential protection algorithm in the unit REF 542plus. The analog input channels of REF 542plus have the guaranteed class 0,5 of the range and the tester Freja 300 has the guaranteed inaccuracy (±0,01 % of range) + (±0,3 % of reading). In the first part of the characteristic (Unbiased region) was average difference between the theoretical and the measured value 0,003 p.u. In the second part (Slightly biased region) was average difference 0,003 p.u. In the third part (Heavily biased region) was average difference 0,013 p.u. and in the fourth part ($I_{d>}$ stage) was average difference 0,027 p.u. In the first and the second parts are inaccuracies extremely low and in the third and the fourth parts are inaccuracies low. All differences are on the limit of inaccuracy of the tester Freja 300 and of the REF 542plus analog inputs. Very interesting were the tripping times. In the first part was the average tripping time 57,8 ms; in the second part was 54,2 ms; in the third part was 41,3 ms and in the fourth part was 36,7 ms. These tripping times are on the boundary of the characteristic, with higher differential currents are tripping times lower.

REFERENCES

[1] Manuals and technical documentation of REF 542plus