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Evaluation of the Performance of Different Relays under Magnetizing Inrush Current.

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EVALUATION OF THE PERFORMANCE OF DIFFERENTIAL RELAYS UNDER MAGNETIZING INRUSH CURRENT

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Abstract

Harmonic restraint differential relays are popular in practice for transformer protection. Under magnetic inrush current, these relays should not operate since the harmonic restraint discriminates between this current and short-circuit current according to the harmonic analysis of the two waves. This analysis is carried-out for different operating and design parameters of the protected transformer. The resulted data is used to evaluate some practical differential relays with harmonic restraint. A new idea for a restraining feature of differential relay is introduced.

1.0 INTODUCTION

The magnetising inrush current (m.i.c.) is a transient phenomenon which is occasionally observed when the transformer is switched-on. This current may reach very high values in primary side of the transformer only. Consequently, the differential relay may consider this phenomenon as an internal short-circuit and un-necessary trips the transformer from the supply.

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To avoid such false or un-necessary tripping, the differential relay must discriminate between m.i.c. and internal short circuit current. This discrimination is based on the harmonic analysis of the two current wave-shapes.

2.0 HARMONIC ANALYSIS

A comprehensive harmonic analysis of m.i.c. is explained by the authors in a seperate paper (1). The analysis is carried-out for numerous design parameters and operating conditions of the transformer under protection. Numerical samples of this harmonic analysis is given in the attached Table.

The wave of the internal short-circuit current is, mainly, a sine-wave plus a d.c. decaying wave. Hewever due to saturation, in transformers. the sine-wave may be distorted and second harmonic component may be produced but will be of low value compared to that of magnetising inrush current.

3.0 EVALUATION OF SOME METHODS OF BLOCKING DIFFERENTIAL RELAY AGAINST MAGNETISING INRUSH CURRENT

A popular method of blocking differential relays against magnetising inrush current is to filter-out the harmonics from the differential current, rectify them and add them to the percentage restraint of the relay. There are different features of harmonic restraint that are applied in practice, and some of these features will be evaluated according to the harmonic analysis given in the shown Table.

(a) Fig. (1) illustrates the basic circuit of harmonic restraint relay (2,3,4) . Harmonic restraint is obtained from tuned circuit X_c, X_1 which permitts only current of

B_S	B_R	$\frac{R}{X}$	Harmonic components of the first cycle of M.I.C. in percentage of the fundamental.							
			Fundamental	D.C.	2 nd	3 rd	4 th	5 th	6 th	7 th
$1.4\ B_m$	$0.8\ B_m$	0.09	100	78.1062	45.449	7.4565	3.1559	7.2545	2.345	0.3035
		0.12	100	77.4040	47.016	8.6431	3.5525	7.6097	1.3850	0.3021
		0.09	100	81.7	37.6517	2.8707	5.4556	2.5543	0.2417	0.9000
$1.2\ B_m$	$0.8\ B_m$	0.12	100	81.2	39.129	3.7990	5.6177	6.0897	2.0637	1.3925
		0.09	100	93.4858	10.3165	5.7334	4.6868	4.2854	1.6858	2.0055
	B_m	0.12	100	90.4568	11.9194	5.0911	4.6318	3.3228	1.4107	1.881
B_m	$0.8\ B_m$	0.09	100	87.8450	28.2548	2.3167	5.2468	4.5654	1.1165	1.3976
		0.12	100	87.4791	30.7135	2.7299	8.6518	5.3402	1.2958	1.1531
	Zero	0.09	100	60.4150	52.0297	16.9692	11.8872	5.5949	2.6961	1.857
		0.12	100	60.0238	55.0961	16.1034	0.5985	2.2742	5.6228	3.4318
	-0.8_m	0.09	100	51.5723	90.2145	75.8585	56.8509	41.8078	29.0009	25.4416
		0.12	100	51.6396	90.43	76.1537	59.2159	41.2178	19.2556	14.0846
		10	100	50.6039	96.322	90.460	82.7289	73.5867	64.7739	53.3314

B_S: saturation flux density, B_R : residual flux density
B_m : maximum flux density.

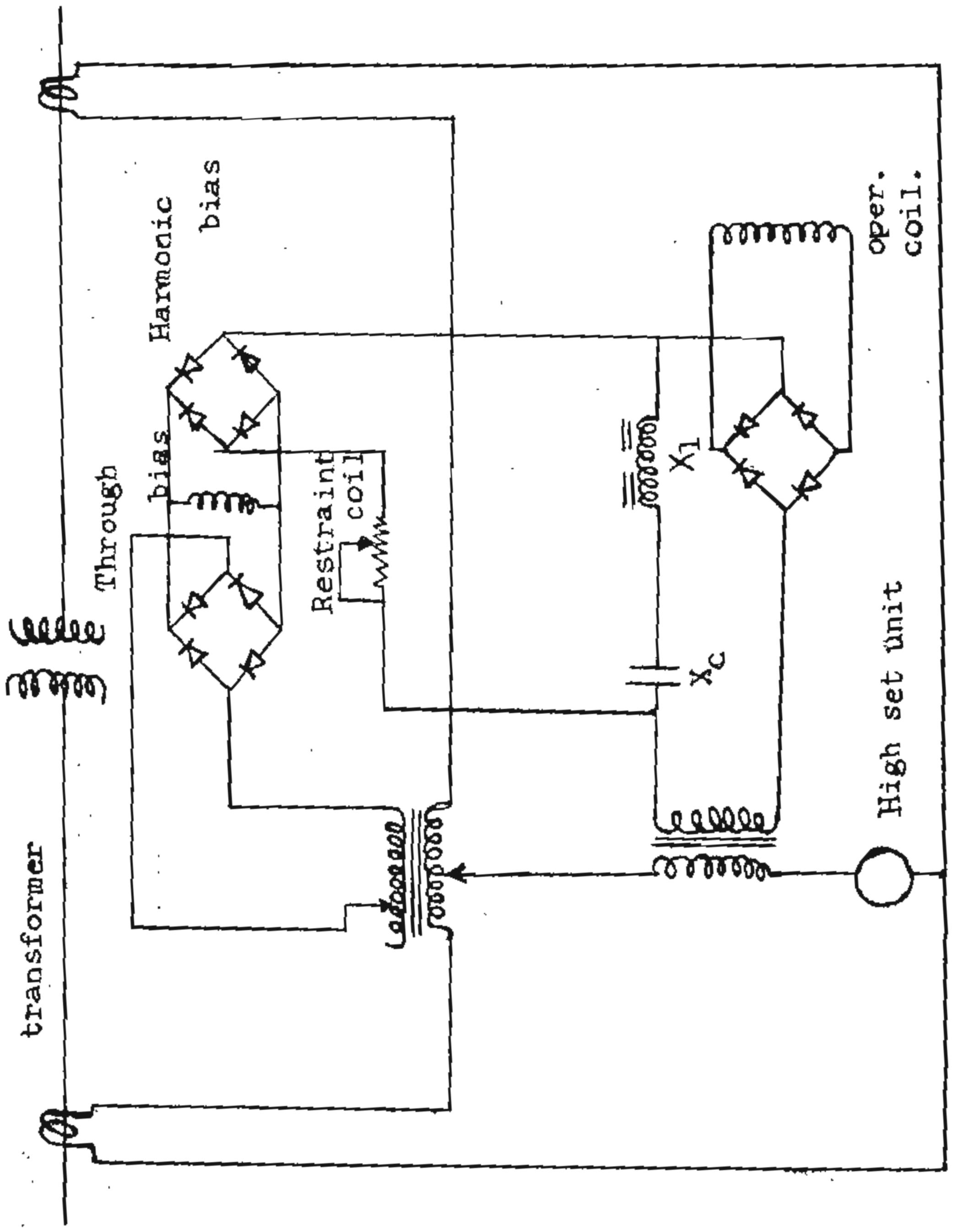

Fig. (1) Basic Circuit of harmonic restraint relay.

fundamental frequency to enter the operating circuit, d.c. and harmonic being diverted into the harmonic restraining coil. The relay is adjusted so that it will not operate when the second harmonic component in the differential current-wave exceeds 15% of the fundamental current. This means that if the second harmonic component in the differential current is less than 15% , the relay will consider this case as a short-ciruit and it will trip. However. from the given Table, the second harmonic component of m.i.c. may be as low as 10 % , and this relay may trip un-necessarily

(b) Fig (2) (a) shows a restraining feature which is applied to relays widely applied in practice (5). The circuit supplying the operating coil of the relay is a series tuned circuit, tuned to pass currents of fundamental power system frequency, and to offer high impedance to currents of other frequencies. The circuit supplying the restraining coil of the relay is a parallel tuned circuit, tuned to offer high impedance to currents of power system frequency and to offer less impedance to currents of the higher harmonic frequencies. In some cases,from the Table, where the wave of the differential current has very low harmonic components, the relay will have no restraint , which is also the case for the restraint feature based on second harmonic restraint.

(c) Fig. (2) (b) gives a construction of harmonic restraint relay. A filter or rectifier circuit, connected to isolate the d.c. or harmonic components and deliver them to a a restraining winding on the relay, will effectively prevent false operation during m.i.c. The series tuned circuit is tuned to resonance at fundamental frequeney. The parallel tuned circuit is tuned to anti-resonance at fundamental frequency. By using the harmonic restraint circuits, the

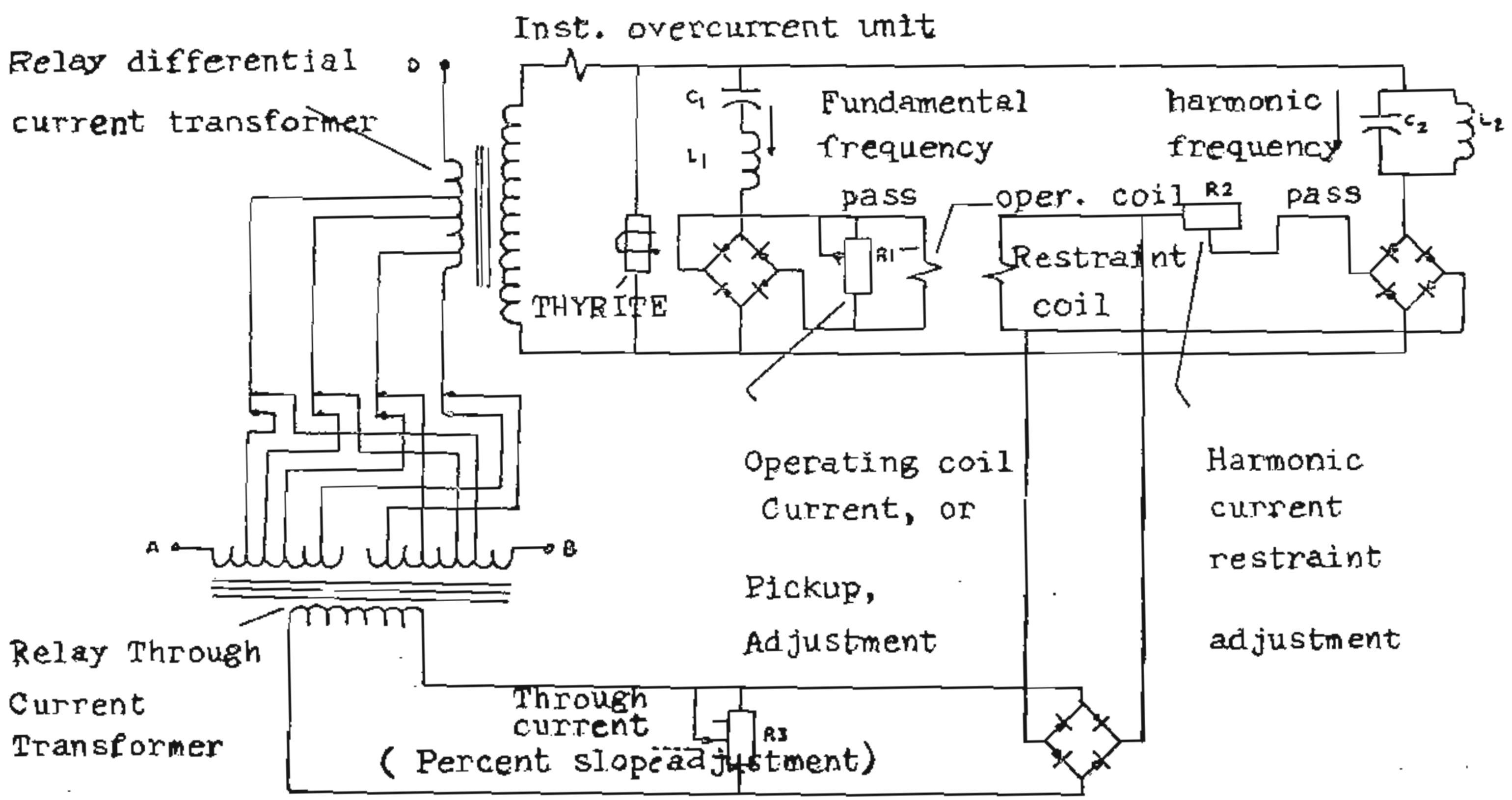

Fig. (2) A schematic internal circuit diagram of a per- centage differential relay with harmonic restraint for 2-winding transformer protection.

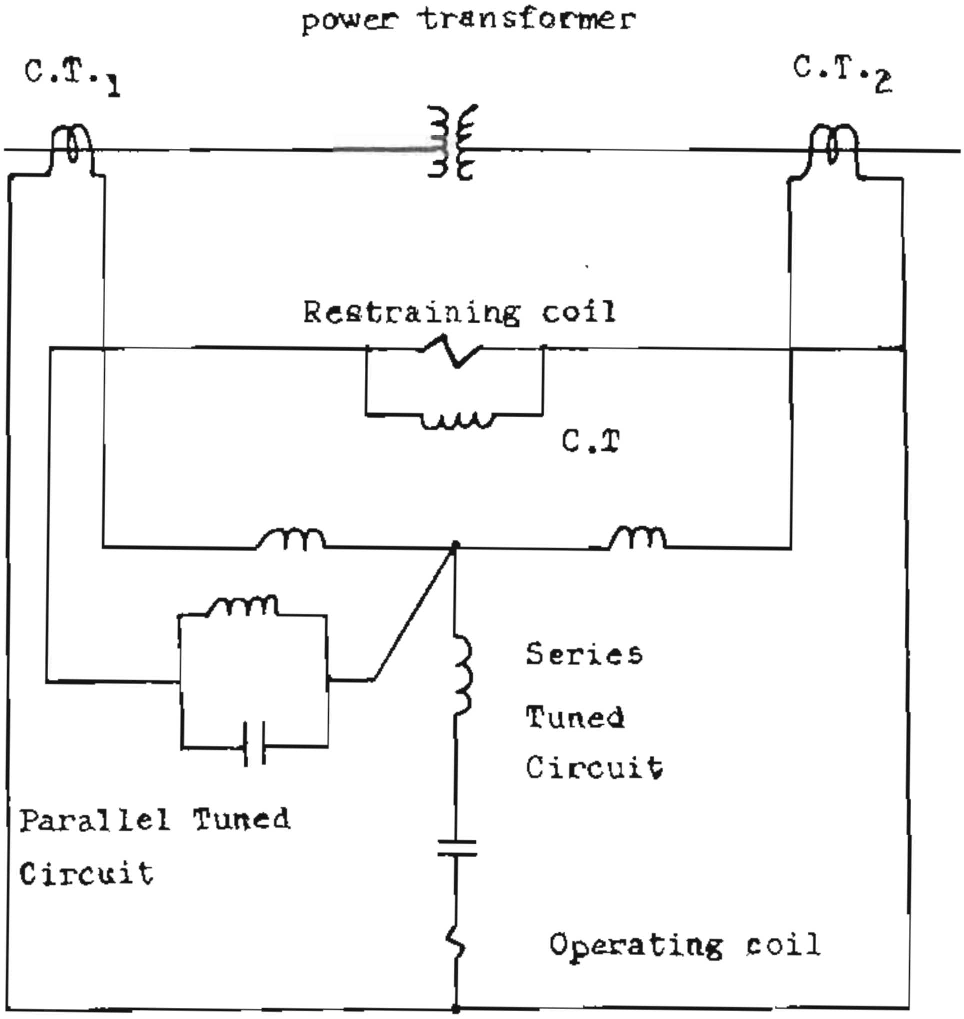

Fig. (2) b Percentage differential relay with harmonic restraint relay is prevented from operation during m.i.c. This harmonic restraint feature may result in non-trip situation on an internal fault condition of considerable harmonic in the current delivered to the relay, These harmonics may be present in the fault current itself, due to are of the fault or due to saturation current transformers. Also, if the fault exists at the time the transformer is energised, harmonics in m.i.c. may prevent it from operation. Moreover, when the wave of m.i.c. has very high peak and a very wide base, the percentage of the second harmonic will be very low, and the relay may consider this case as an internal short-circuit,

(d) Fig. (3) illustrates a d.c. biased scheme. This schem is a convenient way of obtaining percentage bias on through faults by rectifying the through current and using it to control linearly the output from a.c. primary winding carrying the differential current the same phase. The output from this transductor goes to the second one which controls a tripping relay. The d.c. component of m.i.c. has been used as auto-bias to the relay in the same transductor element. When m.i.c, is symmetrical and dees not contain a d.c. component, the relay is made stable by cross-feed bias from the d.c, component of m.i.c. in another phase. For this purpose another transductor element has been incorporated. For a small d.c. component, which is likely to happen according to the given Table, the relay may not operate properly.

4.0 PROPOSED NEW IDEA FOP COMBINED SECOND HARMONIC AND D.C. RESTRAINT FEATURES

Harmonic restraint features discussed in section (3), have limitations for certain transformer design and operating conditions. These conditions result in lew percentages of second harmonic and d.c. components in magnetising inrush current.

From the harmonic analysis tabulated in the given Table, it is noticed that, when the second harmonic component of magnetising inrush current is of low value, the corresponding d.c. component is of high value.

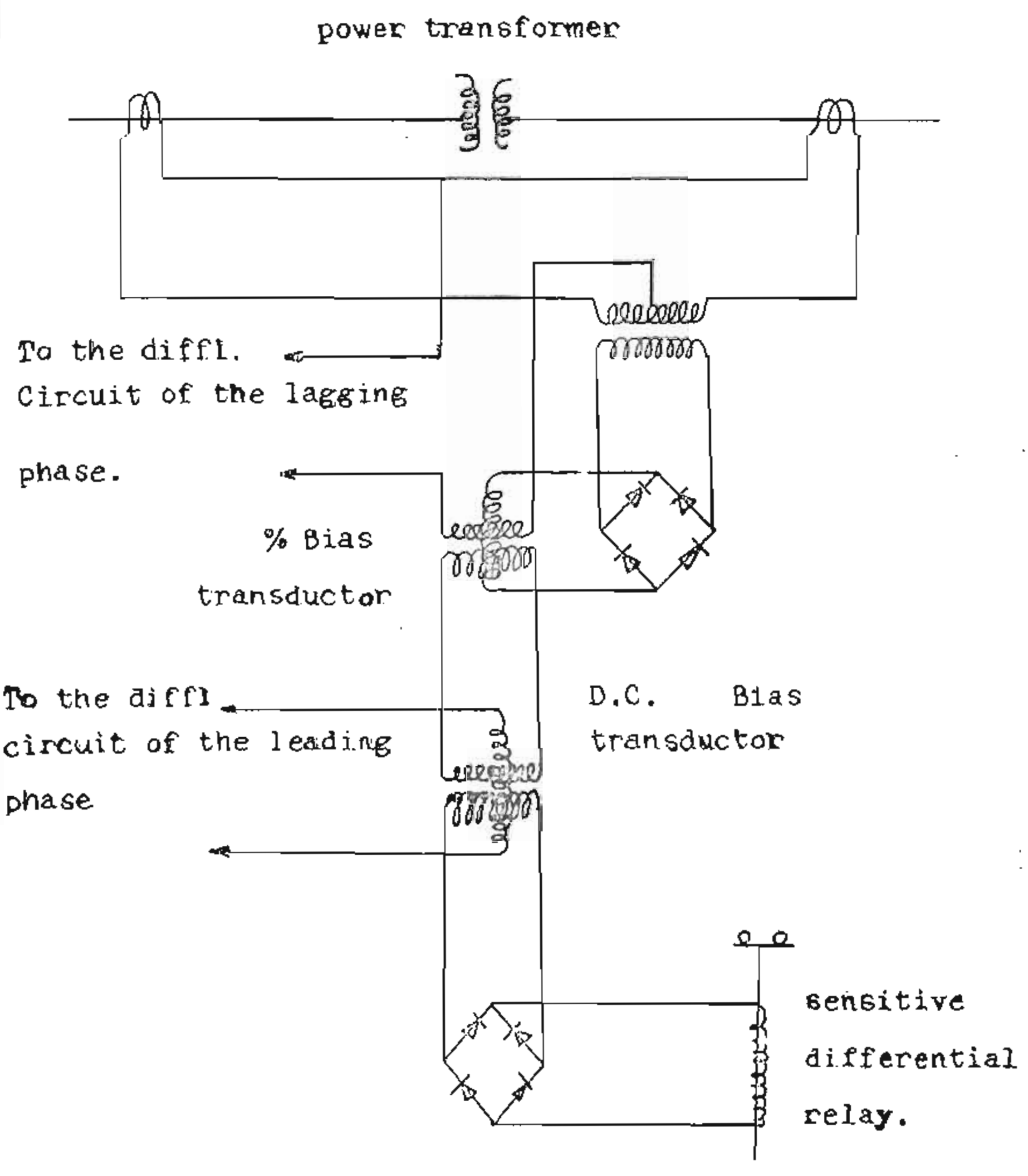

Fig. (3) Percentage biased and d.c. component biased transductor relay for transformer protection.

Consequently, the new idea is to propose a restraint feature based on both second harmonic and d.c. components. In so doing, if the magnitude of the second harmonic component is not sufficient to discriminate between magnetising inrush current and internal short circuit current, discrimination may be obtained based on the corresponding d.c. component. The proposed idea is shown in Fig. (4).

5. 0 CONCLUSIONS

The harmonic contents in the wave of magnetising inrush current depend on the different operating conditions of the transformer under protection, and also on its design parameters. Therefore, differential relays with harmonic restraint needs careful evaluation if accurate data on harmonic contents in magnetising inrush current is available. The evaluation carried-out in the present paper show that un-necessary tripping might happen due to magnetising inrush current. A new idea for a restraint feature is introduced to avoid un-necessary tripping.

6. REFERENCES

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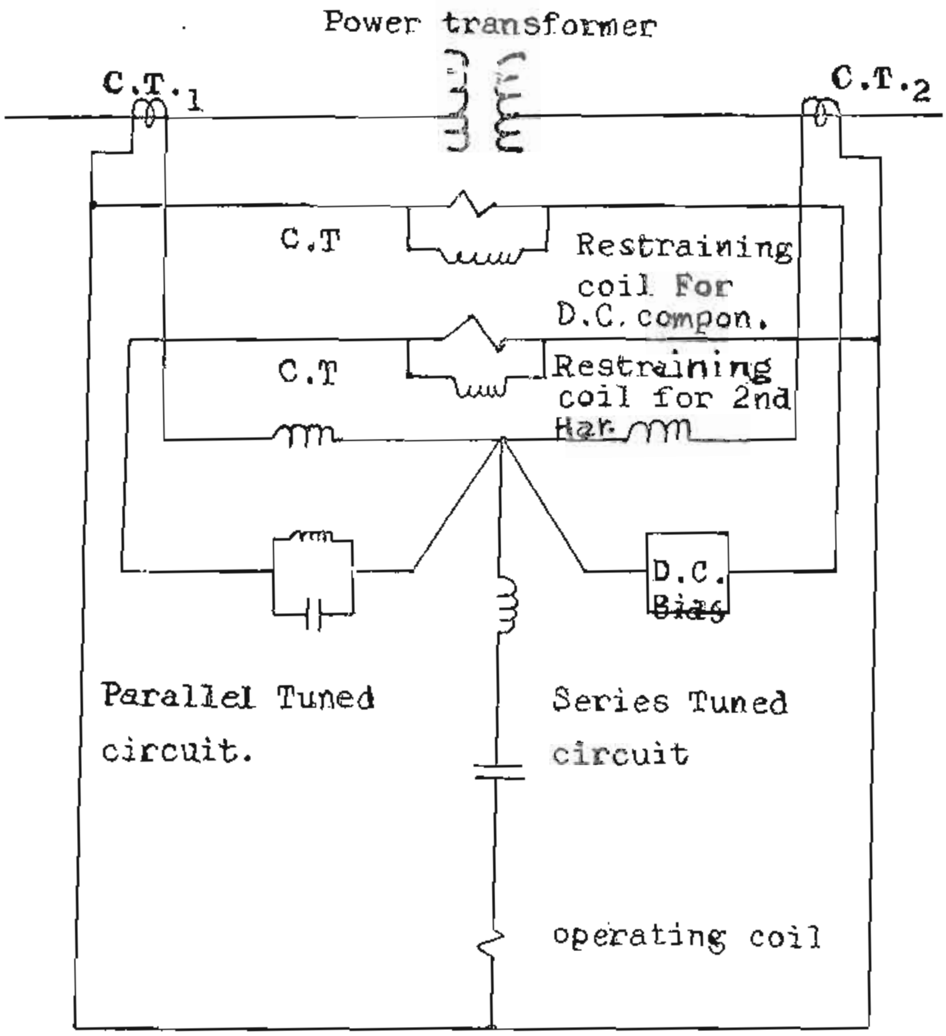

Fig. (4) Percentage differential relay with harmonic - restraint and D.C. Bias.

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