

利用磁特性鉴别变压器励磁涌流时磁化曲线的求取方法

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【摘要】 本文为适应利用磁通特性鉴别变压器励磁涌流的需要, 提出了一种求取变压器磁化曲线的新方法—逼近函数优选法。实算表明, 利用此算法求取的磁化曲线精确度高, 其误差在 1% 之内, 能够满足变压器差动保护的要求。

【关键词】 电力变压器 磁化曲线 励磁涌流

引言

目前利用磁通特性鉴别变压器励磁涌流的方案都需要利用变压器的基本磁化曲线^[1], 如何精确地求取变压器的基本磁化曲线是此类方案能否实用的一个最关键的问题。

对于铁芯磁化曲线的求取, 前人已作了许多研究, 提出了一些算法, 如遗传算法^[2]、尤拉算法^[3]、样条函数法^[4]等。这些算法多用来计算电流互感器铁芯的磁化曲线。本文在大量实验数据的基础上提出了求取变压器基本磁化曲线的方法—逼近函数优选法。

1 原理分析

函数逼近法可以采用最小二乘原理、线性回归拟合原理、非线性回归拟合原理, 根据不同的拟合原理可以选取不同的逼近函数。

如果采用最小二乘原理拟合曲线, 则其逼近函数可选为多项式 1:

$$H = a_0 + a_1 * B_1 + a_2 * B_2 + a_3 * B_3 + \dots a_m * B_m \quad (1)$$

由实验数据可得 n 个离散点:

$$B_1, B_2, B_3, \dots, B_n$$

$$H_1, H_2, H_3, \dots, H_n$$

根据多项函数求极值原理可以得 $a_0, a_1, a_2 \dots a_m$, 然后将这些系数代入多项式 1 中, 即可得磁化曲线的逼近函数。

如果采用线性回归原理或非线性回归原理拟合曲线, 根据实验所得的变压器磁化曲线的实际形状, 可选用以下几种形式的逼近函数:

$$y = a + bx \quad (2)$$

$$y = a + b \log(x) \quad (3)$$

$$y = \frac{x}{a + bx} \quad (4)$$

$$y = e^{a + b \log x} \quad (5)$$

选好逼近函数后, 通过相应的变量代换, 就

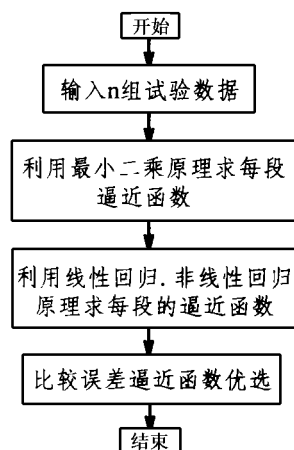


图 1

可以利用一元线性回归分析的方法进行参数估计、显著性较验,最后通过变量反代换即可求得磁化曲线的逼近函数。

前人已研究的算法,一般把磁化曲线分为几段,选取不同的逼近函数进行拟合。由于只采用单一原理进行拟合,这样算出的磁化曲线误差较大,有时高达 5%,其精度不能满足变压器保护的要求。为了保证拟合精度,笔者采用自适应原理把变压器的磁化曲线分成三段,每段均采用不同的逼近函数、不同的原理进行拟合,最后通过比较误差优选出各段的逼近函数。通过实验数据表明,采用该逼近函数优选法求出的磁化曲线误差在 1% 以内,其精度能够满足变压器保护的要求。

本计算程序采用 FORTRAN 语言编写,其计算框图见图 1。

2 实例计算

下表为一变压器磁化曲线的实验数据:

表 1 50Hz, 0.5 毫米, D_{23} 磁化曲线

B (T)	0	0 01	0 02	0 03	0 04	0 05	0 06	0 07	0 08	0 09
0 4	1 38	1 40	1 42	1 44	1 46	1 48	1 50	1 52	1 54	1 56
0 5	1 58	1 60	1 62	1 64	1 66	1 69	1 71	1 74	1 76	1 78
0 6	1 81	1 84	1 86	1 89	1 91	1 94	1 97	2 00	2 03	2 06
0 7	2 10	2 13	2 16	2 20	2 24	2 28	2 32	2 36	2 49	2 45
0 8	2 50	2 55	2 60	2 65	2 70	2 76	2 81	2 87	2 93	2 99
0 9	3 06	3 13	3 19	3 26	3 33	3 41	3 49	3 57	3 65	3 74
1 0	3 83	3 92	4 01	4 11	4 22	4 33	4 44	4 56	4 67	4 80
1 1	4 93	5 07	5 21	5 36	5 52	5 68	5 84	6 00	6 16	6 33
1 2	6 52	6 72	6 94	7 16	7 38	7 62	7 86	8 10	8 36	8 62
1 3	8 90	9 20	9 50	9 80	10 1	10 5	10 9	11 3	11 7	12 1
1 4	12 6	13 1	13 6	14 2	14 8	15 5	16 3	17 1	18 1	19 1
1 5	20 1	21 2	22 4	23 7	25 0	26 7	28 5	30 4	32 6	35 1
1 6	37 8	40 7	43 7	46 8	50 0	53 4	56 8	60 4	64 0	67 8
1 7	72 0	76 4	80 8	85 4	90 2	95 0	100	105	110	116
1 8	122	128	134	140	146	152	158	165	172	180

注: (1) 表中查出的磁场强度单位为安 / 厘米

(2) 1 特(T) = 1 韦 / 米²

把表 1 中的数据代入程序进行计算,采用最小二乘原理对三段进行拟合,拟合出三段曲线的逼近函数为:

$$\text{第一段: } B = 0.555115 + 0.879203 * H - 0.13398 * H * H \quad (6)$$

$$\text{第二段: } B = 0.568874 + 0.131133 * H - 5.21509 * e(-3) * H * H \quad (7)$$

$$\text{第三段: } B = 1.34555 + 7.76598e(-3) * H - 3.6409e(-5) * H * H \quad (8)$$

如采用回归原理进行拟合,根据回归显著性检验,可得出三段曲线的逼近函数分别为:

$$\text{第一段: } B = 0.222948 + 0.620459 * \text{LOG}(H) \quad (9)$$

$$\text{第二段: } B = H / (0.593235 * H + 1.55998) \quad (10)$$

$$\text{第三段: } B = 0.998935 + 0.165583 * \text{LOG}(H) \quad (11)$$

由计算可知,利用最小二乘原理拟合的逼近函数中,第一段曲线拟合得较精确,误差在 1% 之内,而第二段、第三段的误差却较大,最大误差达 4%,这与文献^[1]的分析结果是一致的。恰恰相反,利用回归原理拟合出的三段磁化曲线,第一段曲线的误差较大,最大误差可达 5%,第二段、第三段误差均小于 1%。

经过优选,最后可得到各段磁化曲线的逼近函数:

$$\text{第一段: } B = 0.555115 + 0.879203 * H - 0.13398 * H * H \quad (12)$$

$$\text{第二段: } B = H / (0.593235 * H + 1.5598) \quad (13)$$

$$\text{第三段: } B = 0.998935 + 0.165583 * \text{LOG}(H) \quad (14)$$

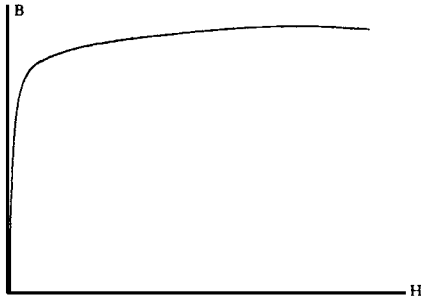


图2

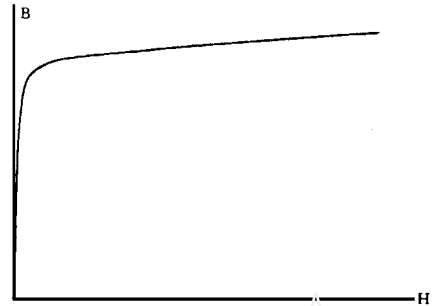


图3

图2是仅用最小二乘原理求出的磁化曲线,图3是仅用回归原理求出的磁化曲线,图4是根据逼近函数优选法求出的磁化曲线。我们通过观察即可知哪种算法的精确度较高。

3 结论

利用函数优选法求取变压器磁化曲线,不仅便于频繁计数,满足变压器保护中需要不断查询磁化曲线的要求,而且便于求取初值磁导率 μ_0 ,此算法有助于提高利用磁特性鉴别变压器励磁涌流方案的实用性。

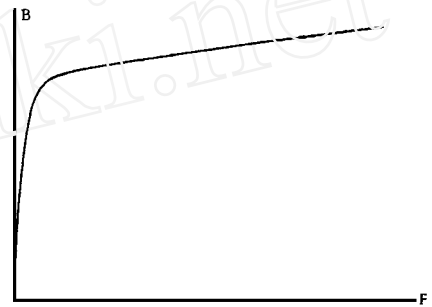


图4

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..... Wu Yekai, Zou Dongxin (4)

The influence of distributed Capacitance of UHV distant transmission line to current differential protection is analyzed and the corresponding capacitance current compensation scheme is presented in this paper. The scheme is simple and practical, not only increasing security during short-circuit beyond protected zone but also improving sensitivity at fault within the protected zone

Key words: Distributed capacitance Current differential protection Capacitance current compensation

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..... Pan Zhencun et al (9)

A new concept of whole line fault high speed clearing protection is introduced according to the structure of urban distribution power system and requirement of power supplying. Feasibility study on this protection is carried out. A practical implement scheme of this protection, which measures the electrical signal on both sides of the protected line is presented

Key words: Distribution power system Line protection High speed relay Feasibility

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Key words: Open circuit fault Bus- impedance matrix Line with zero- sequence mutual impedance

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..... Zhang Yan et al (16)

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Key words: Power transformer Magnetization curve Energization inrush

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Key words: Redundancy Fault- tolerant Substation Microcomputer supervisory control

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..... Jin Ming (22)

A new method to realize the digital impedance relay based on microcomputer is described in this paper. The new method utilizes ANN (artificial neural network) and is available for all kinds of relay characteristics which are used in power system. Some examples are used to test the new algorithm and the results show the algorithm performs well

Key words: ANN Impedance relay Distance protection

Microcomputer Based Single Phase Earthed Protection of Generator stator Winding of Secondary Harmonic Mould

..... Yan Zhuosheng et al (26)

A single phase earthed protection of generator stator winding is presented in this paper. It is realized by de-