

一种基于数字化采样计算电力系统频率的方法

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【摘要】 本文介绍一种利用采样电力系统母线上电压来计算频率及频率变化率。讨论了减小误差的方法,此方法用在微机线路保护中,减少了一路电平检测输入量。

【关键词】 低周减载 频率 滑差 微机线路保护

引言

在电力系统稳态运行中,系统频率应保持在 50Hz。当系统频率降低,将给电力系统工作带来危害。我国目前广泛地采用低周减载装置,当系统功率缺额时,将断开一部分次要负荷,恢复有功功率平衡,使系统频率恢复到一定值,以保证系统稳定运行和重要负荷的正常工作。传统的低周减载装置采用将电压信号接至电平检测器中,测量电平检测器电平翻转的方法来计算频率,此种方法通过提高测量周期的精度来提高测量精度。而采用数字化采样计算频率,可以减少一路输入电平检测,充分利用采样值,在微机线路保护中很方便地增加低周减载功能。

1 频率的计算

采样电压信号为一正弦电压,假设电压采样期间,电压保持不变,系统频率也不迅速改变,系统电压信号采样值可写作:

$$U(n) = U_m \sin 2\pi f (T_0 + nT_s)$$

选用两组系统 $\{h_1(n)\}$ 、 $\{h_2(n)\}$, 分别用这两组系数计算出一个 $U(n)$ 的线性组合值

$$S_1 = \sum_{n=1}^N h_1(n)U(n)$$

$$S_2 = \sum_{n=1}^N h_2(n)U(n)$$

式中 N 的大小及 $h_1(n)$ 、 $h_2(n)$ 的值与采样率有关,当采样率为 200Hz 时, $N = 7$

$$\{h_1(n)\} = -1, 0, 1, 0, 1, 0, -1$$

$$\{h_2(n)\} = 0, -1, 0, 2, 0, -1, 0$$

当采样率大于 200Hz 时 $\{h_1(n)\}$ 与 $\{h_2(n)\}$ 中非零值和其对应的时间间隔不变,只是增加了零的个数。

$$\begin{aligned} S_1 &= -U_m \sin 2\pi f (T_0 - 3KT_s) + U_m \sin 2\pi f (T_0 - KT_s) + U_m \sin 2\pi f (T_0 + KT_s) - \\ &\quad U_m \sin 2\pi f (T_0 + 3KT_s) \\ &= 2U_m \sin (2\pi f T_0) (\cos 2\pi f KT_s - \cos 6\pi f KT_s) \\ &= 2U_m \sin (2\pi f T_0) [2\cos 2\pi f KT_s - \cos 6\pi f KT_s + \cos 2\pi f KT_s] \\ &= 2U_m \sin (2\pi f T_0) (2\cos 2\pi f KT_s - 2\cos 4\pi f KT_s \cos 2\pi f KT_s) \\ &= 2U_m \sin (2\pi f T_0) \times 2(1 - \cos 4\pi f KT_s) \cos 2\pi f KT_s \\ S_2 &= -U_m \sin 2\pi f (T_0 - 2KT_s) + 2U_m \sin 2\pi f T_0 - U_m \sin 2\pi f (T_0 + 2KT_s) \\ &= 2U_m \sin (2\pi f T_0) (1 - \cos 4\pi f KT_s) \end{aligned}$$

$$\text{则: } \frac{S_1}{S_2} = \frac{U_m \sin(2\pi f T_0) \cdot 2\cos 2\pi f K T_s}{U_m \sin(2\pi f T_0)} = 2\cos 2\pi f K T_s \quad (1)$$

$$f = \frac{1}{2\pi K T_s} \arccos \frac{S_1}{2S_2} \quad (2)$$

对 50Hz 的系统 $K T_s = 5\text{ms}$, 对式 2 在零点附近展成幂级数

$$f = \frac{1}{2\pi K T_s} \left[\frac{\pi}{2} - \frac{S_1}{2S_2} - \frac{1}{6} \left(\frac{S_1}{2S_2} \right)^3 - \frac{1}{40} \left(\frac{S_1}{2S_2} \right)^5 \dots \right]$$

截去高次项得

$$f = 50 - \frac{1}{4\pi K T_s} \times \frac{S_1}{S_2}$$

经过量化可得频率的基本公式

$$f_j = 50 - 16(S_1/S_2) \quad (3)$$

在微机线路保护中, 采样每周 12 点, 采样率为 600Hz, 取 $N = 24$

$$\{h_1(n)\} = -1, -1, -1, -1, -1, -1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, -1, -1, -1,$$

$$-1, -1, -1$$

$$\{h_2(n)\} = 0, 0, 0, -1, -1, -1, -1, -1, -1, -1, 2, 2, 2, 2, 2, -1, -1, -1, -1,$$

$$-1, -1, 0, 0, 0$$

利用此算法的误差

$$Er = f - f_j = f - 50 + 32\cos(2\pi f K T_s)$$

在 44 ~ 56Hz 范围内变化时最大计算误差小于 0.012Hz

2 影响计算频率精度的原因

从推导出公式 3 可知

$$f_j = 50 - 16 \times \frac{S_1}{S_2}$$

$$\frac{S_1}{S_2} = \frac{2U_m \sin(2\pi f T_0) (\cos 2\pi f K T_s - \cos 6\pi f K T_s)}{2U_m \sin(2\pi f T_0) (1 - \cos 4\pi f K T_s)}$$

在推导出公式 3 时把 $U_m \sin(2\pi f T_0)$ 约去。而在计算时需要把 S_1 、 S_2 分别算出, 再相除。可见影响计算精度为二个因素:

1) U_m 稳定不变

2) 采样 $U(t)$ 的初始角 $2\pi f T_0$

U_m 随系统电压波动而改变, 在建立模型时我们已假设系统电压保持不变。而实际运行中 U_m 会随系统电压波动, 但变化不大。但这个因素也会影响到计算精度。

若采样初始角为零度, 即 $2\pi f T_0 = 0$

或初始角很小 $\sin 2\pi f T_0$ 很小

则 $\frac{S_1}{S_2}$ 的计算误差将很大。

实际使用时, 增加一组系数 $\{h_3(n)\}$ 、 $\{h_4(n)\}$,

$\{h_3(n)\}$ 、 $\{h_4(n)\}$ 与 $\{h_1(n)\}$ 、 $\{h_2(n)\}$ 相差 90°

$$\text{使得 } \frac{S_3}{S_4} = \frac{U_m \cos(2\pi f T_0) \times 2\cos 2\pi f K T_s}{U_m \cos(2\pi f T_0)} = 2\cos 2\pi f K T_s \quad (4)$$

$\frac{S_3}{S_4}$ 在 $2\pi f T_0 = 90^\circ$ 附近计算出误差较大

综合式 1 和 4 取 $\max\{S_2, S_4\}$, 取相应的 S_1, S_3

$$\text{即 } f_j = 50 - \frac{1}{16} \frac{\text{相应 } S_1 \cdot S_3}{\max\{S_2 \cdot S_4\}} \quad (5)$$

利用式 5 可以克服式 1 在 $2\pi f T_0$ 在零附近, 计算出 S_2 很小, $\frac{S_1}{S_2}$ 引起很大的计算误差。

另外用下面方法也可减小 $2\pi f T_0$ 在零点附近引起的很大计算误差, 因为需要用到开方运算, 微处理器计算不方便, 不宜采用式 6

$$\frac{S_1^2 + S_3^2}{S_2^2 + S_4^2} = 4\cos^2 2\pi f K T_s \quad \sqrt{\frac{S_1^2 + S_3^2}{S_2^2 + S_4^2}} = 2\cos 2\pi f K T_s$$

$$f_j = 50 - \frac{1}{16} \cdot \sqrt{\frac{S_1^2 + S_3^2}{S_2^2 + S_4^2}} \quad (6)$$

3 滑差的计算

滑差的计算通过计算两点频率及这两点频率变化的时间, 如电压频率在 ΔT 的时限内由 f_1 变化到 f_2 , 就可以如下式子求得频率变化率——滑差的平均值:

$$\frac{df}{dt} = \frac{1}{\Delta T} (f_2 - f_1) \quad (\text{Hz/s})$$

在时间间隔 ΔT 内, 必须计算 f_1 及 f_2 , 若时间间隔很短, 即 ΔT 越小, $\frac{df}{dt}$ 计算误差越大。在实际测试中, f_2 取 49.5Hz, f_1 取 49Hz, 若 $\frac{df}{dt}$ 取 10Hz/s, 误差达 $\pm 20\%$, 若 $\frac{df}{dt}$ 取 5Hz/s, 误差小于 $\pm 10\%$ 。

4 结束语

本文讨论了利用采样计算电力系统频率的方法, 此方法用在微机保护中增加低周减载功能有二个优点:

- 1) 减少一路电平检测回路
- 2) 充分利用数字化采集量

但是与常规的频率继电器, 采用电平检测回路测周法相比也有它的缺点:

- 1) 受电压变化影响
- 2) 误差稍大

测周法的频率测量误差可达到小于 0.005Hz , 而利用采样值计算误差可达 0.012Hz 。

在专门的频率继电器中采用测周法, 提高测量精度, 是很好的解决办法。但在微机保护中, 充分利用采样值来增加低周减载功能, 满足用户需要, 本文讨论的方法亦不失为一种很好的解决办法。

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- 2 以最小绝对值近似法为根据的频率继电器保护算法. 继电器译丛, 1991. 3

RELAY

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The Main Protection Scheme of Internal Short Circuit for Generator Transformer Bank of Three Gorges Hydroelectric Power Station Wang Weijian, Liu Junhong (5)

Based on the theoretical analysis and test research of the main protections for Long Yang Xia station and Er Tan station, the main protection schemes of Three Gorges station are put forward in this paper. The first main protection for generator is the unit transverse differential relay with high sensitivity, the second main protection is the incomplete differential relay. For transformer, the differential relay with the restraint of scalar product of fault component may be used as the first main protection, and the incomplete differential relay for generator-transformer is the second main protection. The differential relay of transformer is restrained by harmonic of square sum of three phase current.

Key words: Three Gorges Station Generator-Transformer bank Internal short circuit Main protection

Sectional Algorithm for Open-Conductor Plus Short Circuit Fault in Protective Relay Setting Calculation

..... Cao Guochen, Tan Xingquan (8)

This paper presents a sectional algorithm for open-conductor plus short circuit fault in protective relay setting calculation. The algorithm has the following characteristics:

- 1) Storage requirements can be reduced
- 2) The nodal impedance matrices of each original sequence subsystems do not need to be modified
- 3) Any type of simple fault can be solved as a special issue of open-conductor plus short circuit fault

Key Words: Protective relays Setting calculation Sectional algorithm

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Key words: Adaptive reclose Random analysis

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Key Words: Distance protection Swing blocking condition

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Key words: Microprocessor-based protection Data collection system PWM Triangle wave generator

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via using this method on microprocessor-based line protection

Key words: Reducing load as underfrequency Frequency Rate of frequency variation Microprocessor-based line protection

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Key words: Traction load Feeder protection Harmonic restraint

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Disturbance produces during electromagnetic energy conducting and radiating. Maintaining electromagnetic compatibility (EMC) is an important project in international standardization.

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