用 C167的捕获比较单元实现频率滑差控制

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摘要: 传统的低周减载保护中的频率滑差闭锁元件常用一段时间内的频率变化平均值计算得出,但该方法将使得保护的速动性降低。针对这一问题,以西门子的 C167单片机为硬件平台,在阐述了其频率测量的原理后,采用图表结合的方法,提出一种新型的频率滑差计算方案。该方案利用 C167的捕获比较单元的捕获中断,采用频率实时跟踪的方法来实现频率滑差的控制,使得滑差闭锁与低频判据达到同步,大大缩短了保护的固有动作时间,在实际应用中取得了较好的效果。

关键词: 频率滑差; C167; CCU; 捕获中断; 固有时间

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0 引言

目前各家的微机线路保护装置中基本都配置有低周减载保护,以实现分散式的低频切负荷功能,使得系统在有功发生缺额时能尽快地过渡到新的稳定状态。为了防止短路故障或负荷反馈造成频率骤降而使低周减载保护误动作,设置了频率滑差闭锁元件,当所测的频率滑差大于滑差闭锁定值时,闭锁低周减载保护,这样就增强了保护的可靠性。对于频率滑差的计算,一种传统的做法就是每隔 0.1 s计算一次频率差 Δf,得出滑差 $df/dt=\Delta f/0.1$。但这种方法势必增加保护的固有动作时间(不能低于 0.1 s),使保护无法满足快速性的要求。本文提出了采用中断跟踪的方法,不仅使滑差计算准确,而且也满足了保护的速动性的要求。

1 频率测量原理

本文阐述的方法所采用的硬件平台为西门子公司的 C167单片机,利用 C167的捕获比较单元 CCU(Capture & Compare Unit)实现频率的测量。CCU可以捕获其输入引脚上的信号跳变,产生中断。同时,CCU本身具有一个 16位定时器,可以在中断中将信号跳变的时刻记录下来。这样,对于一个正弦波输入信号,可以在波形两次相邻的下降过零处触发 CCU的捕获中断,记录两次的时刻 t_1、t_2,则 $T=t_2-t_1$就是输入信号的周期,而信号频率 $f=1/T$。实际应用中,常常要把正弦信号调制成方波信号,整个捕获过程如图 1所示。硬件的实现部分如图 2所示,首先,输入的正弦信号 Fin经低通滤波环节(LF353)滤除高频成分,再经比较器 LF311调制成等频的方波信号,最后经光电隔离 TLP521-1,形成 CCU所需的管脚电平 Fout。CCU实时监视 Fout,在其下降沿产生捕获中断,记录对应的时刻。作者设置 CCU本身的定时器每 800 ns记数一次,设两次相邻捕获中断中记录的时刻数分别为 N_1 和 N_2,则 $T=(N_2-N_1)\times800\times10^{-9}$ s。

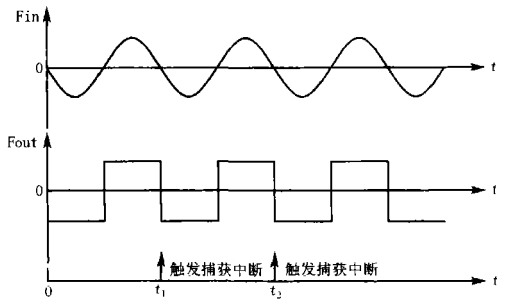

图 1 CCU捕获中断测频时序图

Fig 1 Time sequence of frequency measurement of CCU

2 频率滑差控制的实现

为了便于频率滑差的计算,设置了滑差计算的启动频率定值 f_{st},该值应略低于额定频率而高于低频定值 f_{op}。当在 CCU的捕获中断中测得的频率 f_1 低于 f_{st}时,程序开始在每次的 CCU中断中累积时间,直到频率 f_2 低于 f_{op}。设此时累积的时间为 t_Σ,则可计算出频率滑差为 $df/dt=(f_2-f_1)/t_\Sigma$。当然,在此过程中,若频率又恢复到 f_{st}之上时,则整个滑差控制过程实现复归。程序框图见图 3。

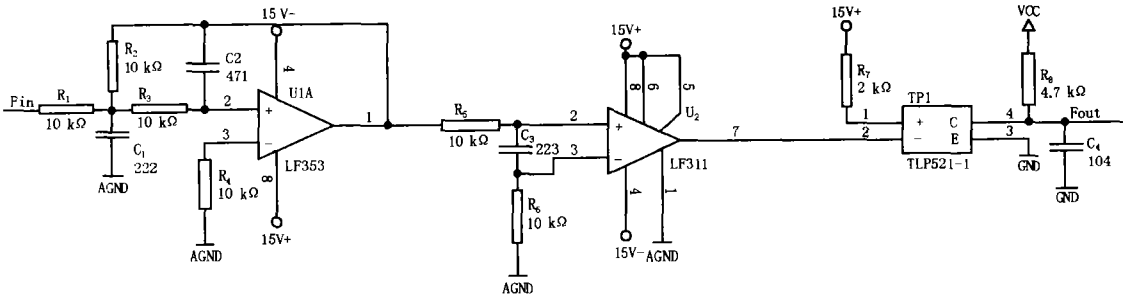

图 2　CCU 测频的硬件原理图

Fig 2　Principle of frequency measurement

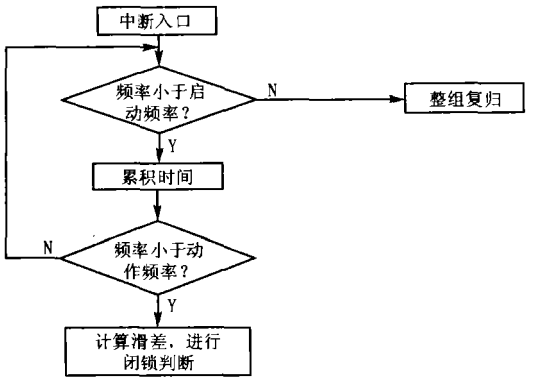

图 3　CCU 中断服务程序逻辑框图

Fig 3　Logic frame of interrups service program

由于这种方法是在信号的每个周期内对频率进行实时跟踪,当频率低于 f_{op} 时,即可将频率滑差计算得出,与低频判据同步,在提高了滑差计算精度的同时使得保护的固有动作时间大大缩短,实测的固有动作时间平均不大于 50 ms。表 1给出了频率滑差的实验测试数据,从中可以看出,频率滑差的测试误差不大于 0.2 Hz/s。

表 1　频率滑差实验测试数据

Tab. 1　Testing data on slope of frequency

滑差定值 /Hz·s^{-1}	0.5	1.0	5.5	8.5	10.0
实测滑差	0.49	1.02	5.5	8.55	10.2

在应用本方法时,有以下几点需要注意:

1) 为了减小中断服务程序的计算量,频率比较实际是按周期比较进行的(每次中断计算出的是信号周期),即"频率小于定值"等效成"周期大于定值对应的周期",仅在最后算滑差时采用频率。

2) C167为定点数制,为提高精度,作者采用了8位定点小数。

3) 在累积时间时要有预防 t 溢出的异常处理措施。

3　结论

本文提出的频率滑差控制的方法是在 C167平台下实现的,实际对于其他的硬件平台也完全可以实现移植,其核心就是采用硬件测频,在测频中断服务程序中实现频率的跟踪、时间的累积,最终计算出频率滑差。该算法实时性强,计算精度高,在实际应用中取得了较好的效果。

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Realizing control of frequency slope by CCU in C167

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Research on power system real-time simulation

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Abstract: Real-time simulation has proved to be an effective tool for research, test, plan, operation and security situation assess of power systems. Real-time simulation of power systems technology development experienced physical simulation, digital physical mixed simulation and digital simulation throughout the three stages. This paper introduces the general definition, development and present situation of power system real-time simulation and highlightens the real-time characteristics of this technology. Meanwhile, it illustrates the theory basis, the algorithms involved and implement methods of real-time simulation technology, compares and summaries three simulation technologies to the power system real-time simulation. Because they have their own advantages and disadvantages, they need to be employed selectively in practical application. Digital physical mixed simulation technology in the simulation applications has more advantages and is emphasized. Finally, the scheme of solving the problem of power system real-time simulation technology is put forward.

Key words: power system; digital simulation; real-time simulation; hybrid real-time simulation

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Abstract: The slope of frequency is a very important closedown element to the protection of low frequency shedding. The traditional method of realizing the element is to calculate the average value of the variation of the frequency during some time. But it lowers the natural delay of the protection. This paper aims at solving this shortcoming. Based on the plat of C167, it explains the theory that C167 is employed to measure the frequency, then gives a method that traces the frequency of the signal in the capture interrupt of the capture & compare unit (CCU) which belongs to C167. The method makes the slope of frequency keep synchronized with the criterion of low frequency, and reduces the natural delay of protection.

Key words: slope of frequency; C167; CCU; interrupt of CCU; natural delay