DynAmp

Technical Bulletin

NO. 9902

TOPIC : OVERCURRENT RELAYS LOCATED IN AC MAINS CIRCUITS OF DynAmp HIGH CURRENT METERING SYSTEMS

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INTRODUCTION

In addition to high accuracy measurement of dc bus current, some DynAmp customers wanted an associated overcurrent measurement for protection purposes. To accomplish this, some customers installed overcurrent relays in the ac mains feed circuit of DynAmp's high current metering systems to operate when a severe overcurrent condition occurs. This approach is based on the knowledge that during severe overcurrent conditions the measurement system draws significantly more current from the mains. Documentation of the characteristic relationship between measured current and mains current draw for various models was meager, informal, and possibly derived from a single unit of a particular model. This technical bulletin explores the problems of the consistency of the mains ac current to measured bus current ratio and announces a stand against this practice.

It is important to emphasize that, while the ratio of the mains ac to primary bus dc may change, this does not affect the accuracy of the dc measurement. The flux nulling circuit design keeps the dc indication extremely accurate despite variations in the environmental conditions. The feedback current and dc voltage signals ratio to the actual dc primary bus current is accurate to within 0.1% for the LKP and LKB measurement systems.

In the past, when customers wanted to associate Inverse Time Relay (ITR) or Over Current Relays (OCR) relays with metering systems, the best available devices were driven by ac current. A number of customers successfully installed ITR or OCR relays as series connected devices in the ac mains feeding the CXM and FM families of products. It was known that the "constant" of proportionality of the ac mains current was affected by variations in a number of environmental conditions. Some data was made available to characterize variables such as mains voltage and burden but other sources of variation were ignored. The lack of accuracy in these installations was more tolerable when the OCR trip threshold was set at levels were far above normal operating levels.

THEORY OF OPERATION

The most accurate method of measuring very high direct current uses the closed loop control, flux nulling technique, as sensed by Hall devices, in a closed path around the bus current. These measurement systems react to primary magnetic flux due to the current being measured by forcing a compensation current through feedback coils, producing an opposing magnetic flux that cancels out the primary flux. Some of these measurement systems use phase-fired thyristors, otherwise known as Silicon Controlled Rectifiers or SCRs, to maintain an exact balance of feedback current. When more current is needed or the resistance in the feedback loop increases, the firing angle of the SCR is advanced to achieve the flux balance. The energy needed to drive the feedback current is drawn from the mains.

Actually, the SCRs are turned on only for a short period in each ac cycle. During the period when the SCRs are turned off, the feedback current continues to flow through the highly inductive feedback coils via a "free-wheeling" diode in the circuit. To maintain the flux null balance, SCRs are turned on to supply the energy that is dissipated in the system components. Furthermore, the mains current waveshape is not sinusoidal, appearing basically as a set of bi-directional rectangular pulses with both the height and width increasing as the primary bus level increases. In part, because the mains energy use is to balance out the energy dissipated, there are a number of environmental factors that cause variations in the ratio of ac mains current to dc bus current.

SOURCES OF VARIATION IN THE AC/DC RATIO

It is important to understand that many factors, which do not impact dc measurement accuracy, cause variations in the proportionality ac/dc ratio from one unit to the next. A customer does not want to custom adjust each relay to match the characteristics of the particular serial numbered unit involved. The relays should be interchangeable and able to be set at the same threshold indications.

Here are a number of identified causes of variations in the ac/dc ratio:

A. Resistance shift of the feedback coils with temperature

The resistance of the copper feedback coils changes about 0.4% per degree Centigrade. Even self-heating causes a shift in the mains current draw of the 17FM of about 2% from cold to hot operating conditions. From the theory explanation above, even at a constant bus current, it is obvious that this increased resistance will increase the energy dissipation in the feedback current path and consequently alter the ac/dc ratio. As a particular unit installation site ambient temperature varies, there is additional change in the ac/dc ratio.

B. Manufacturing variations in coils

There can be variations in the room temperature coil resistance from one coil to the next and also from one batch of coils to another. The variation maybe caused by the wire diameter, materials or even the tightness with which the coil is wound. This can cause a variation from one measurement system to another.

C. Burden in the output current loop of the system

Resistance added into the output "measurement" current loop is called burden. Adding to the burden are additional shunts for the individual measurement system or for totalizing purposes, located either locally or remotely, and all the current loop wiring. From the theory of operation it follows that a change in burden causes a change in the input current. At first thought, it is expected that the burden in an installed system is constant, however, over the years, there are may be changes in the burden as new devices are added. Consequently, it is possible that a technical person could add or remove a shunt and will be unaware that this changes the OCR trip threshold. It is a concern in the 17FM there was +2.5% variation of mains current draw for +1.25 Ohms burden (10 Volts at 40 kA).

D. AC Mains voltage variation

If the bus current and other environmental conditions all stay the same, it is expected that the energy dissipated in the measurement system will stay the same. The energy supplied from the mains is the product of the mains voltage and the mains current. Consequently, in the event the ac mains voltage increases, we can expect the ac mains current to decrease. In the 17FM, there was a -2.5% shift for +10 volts of mains voltage. However, a second effect, due to the magnetizing currents of any transformers, also occurs with line voltage rise and this effect has a positive coefficient with rising mains voltage. Consequently, this cancels some of the power product effect.

E. Magnetizing current levels of any downstream isolation transformers

A major contributor to variation in the proportionality characteristic from one unit to another is related to any included isolation transformer. Responding to customer's comments, DynAmp's LKP and CM7000 product series were designed to use isolation transformers with a higher VA rating, operating with lower loading, to allow cooler transformer operation. The magnetizing current in transformers is a function of the transformer construction, copper winding resistance, the amount of iron in the transformer, the type of iron, and slight variations in the core laminations. At low operation levels, the magnetizing current can be a large percentage of the total current drawn by the transformer. As the operation level approaches full load, the magnetizing current becomes smaller compared to the total current load. In some cases, particularly where the unit's normal operating point is well below the system's maximum rating, the isolation transformers chosen for use in the LKP Series may operate at 20% or less of their full load rating. In this range, the magnetizing current is significant and will vary widely from transformer to transformer. Depending on the transformer design, the magnetizing current may be quite sensitive to the mains voltage. Therefore, particularly for LKP and CM7000 systems, the primary main current draw will vary from one unit to the next. In a study of 12 units of model LKP-45, operating at 26 kA, it was found that the highest and lowest unit ac mains current varied +/-0.61 amps from the average of 4.83 Amps. Most of the variation was attributed to differences in the magnetizing current. In these cases, the variation extremes amounted to +/-20% of the average. It is noted that the LKP-5000, CM-5000 and CXM systems are supplied without the large isolation transformers. The only transformers in these models draw very low magnetizing currents.

F. Electrical Centering, External Magnetic Fields and Off-Center mounting

The flux balancing method of measuring the dc current has practical challenges caused by great variations in the local magnetic field around the closed integration path surrounding the dc bus. The technique DynAmp uses to make the overall system work well is to break the closed path into independent segments, which are called "channels". Each channel may operate at different primary bus flux and, consequently, different feedback current level to provide proper balance for the local magnetic condition. One channel may be operating at 0.5 Amps while another is at 0.75 Amps. However, there is a limit to the drive voltage available. At the extreme levels of overcurrent operation, it is important to be sure there is adequate channel drive voltage available to achieve a local magnetic null. At ever-increasingly severe primary bus overcurrent levels, first one and then another channel will arrive at the limit of available drive voltage. Consequently, in severe overcurrent conditions, a specific channel may not be able to contribute any more to the total feedback current and, above that level, the system will progressively go further into error. By "electrically centering" the measuring head on the bus, the customer is assured of the maximum possible linear operating range for the heaviest driven channel. More information on this topic can be found in Technical Bulletin 9908.

G. Dependence upon the dc measurement system unit to be working properly.

Obviously, it is necessary for all the components and power supply to be properly operating for the ac/dc ratio to be correct. Also, when one loses mains power to the metering system, this overcurrent protective function is also lost.

DynAmp RECOMMENDATIONS REGARDING USING OVERCURRENT RELAYS

Over the years, there have been additional significant changes besides the transformer selection. The size of the rectifier current has stepped up to require higher rated measurement systems. Now there are other OCR devices available that do not need to be located in the mains current circuit. Practically, customers want to use relays set at the same trip point from one unit to the next. Probably most importantly, many of today's installations are designed for operation that demands the OCR trip threshold set closer to the normal operating point and installers want consistency to within a few percent.

As a result of all these considerations, **DynAmp recommends against the use of overcurrent relays in the mains feed circuits.**

Concerning LKP meter units, particularly in new installations of standard LKP equipment, the proportionality of the mains current to the dc measured by these systems varies too much from unit to unit and due to causes other than the measured dc current. On one extreme, this can result in inadequate protection and on the other extreme is the problem of unnecessary overcurrent relay actuation, tripping the process off-line. Neither of these results is acceptable.

It is recommended that existing installations which use this practice be checked for acceptability and the possibility of relocation of any such relays be given serious consideration.

Concerning installations where new LKP-8000 or LKP-5000 meter units are to replace older model meter units, overcurrent relays may have been installed long ago and the customer may not be aware the upgrade to LKP may significantly shift the trip threshold setting of individual units. For these installations, the overcurrent relay function should be moved out of the mains circuit.

Summary

Wherever overcurrent relays are installed in DynAmp ac mains supply circuits, there is wide variability in uncontrolled factors that significantly affect the ratio of the mains ac current to the primary bus current. Consequently, it is recommended to abandon the practice of operating overcurrent relays in the mains circuits of DynAmp measurement systems.