Technical Bulletin

NO. 749

TOPIC: COMPUTER ANALYSIS OF MEASURING HEAD LOCATIONS IN BUS SYSTEMS.

File TEC749c

INTRODUCTION: When you purchase a DC Current Metering System from DynAmp, you get more than just hardware. You also get results in the form of high accuracy and reliability. The expertise that brings these results to you was gained over 35 years of experience of DC Current Metering Systems. An example of a computer analysis of the location of a Measuring Head is included in this technical bulletin. The purpose of this technical bulletin is to provide you with the answers to the questions listed below.

Why is a bus analysis worth doing?
What does DynAmp, LLC offer?
What questions does the bus analysis answer?
What data is required to perform the bus analysis?
How is the data used in the program?
How is a typical analysis performed?

WHY IS THE BUS ANALYSIS WORTH DOING? This is a technique allowing DynAmp to guarantee to the customer that the equipment chosen for the application will have satisfactory operating conditions, enabling a long, accurate and useful life. Although the DynAmp DC Current Measuring Systems are designed to be accurate, stable, and reliable, they may be badly used by installing the Measuring Head(s) in unnecessarily high stress locations. Some problems are closely related to local overheating problems that reduce the life of the system. Bus currents external to the measuring head cause magnetic fields that can sometimes cause some types of DC Current Metering Systems to exhibit zero offsets and error at low current levels. There are some general guidelines to be considered when mounting the Measuring Head(s) within the bus system which are discussed in DynAmp Technical Bulletin No. 748. <u>However, it must be pointed out that the Technical Bulletin No.748 general guidelines should be applied only when a detailed analysis of the bus system is not available.</u> It is better to let DynAmp review the proposed location and guarantee the performance.

WHAT DOES DYNAMP OFFER? To assure you that a new DC Current System ordered will function properly in your application, DynAmp will perform a detailed computer analysis of the purposed location of the Measuring Head(s) within your bus system at no charge. DynAmp is the only manufacturer of this type or similar types of DC Current Metering Systems that offers this unique service.

The function of the detailed computer analysis is to determine the effects of the various magnetic fields acting on the Measuring Head(s) in their proposed locations within your bus system. The results of the analysis may indicate that the proposed locations of the Measuring Head(s) are acceptable. On the other hand, the results of the analysis may predict that local overheating in one channel due to load unbalance between channels, or error in low current measurements due to zero offsets. In such cases, DynAmp will propose alternate locations of the Measuring Head(s) within your bus system, if possible. Alternate equipment might also be proposed in some cases.

WHAT QUESTIONS DOES THE BUS ANALYSIS ANSWER?
The evaluation of the detailed computer analysis will provide the answer to the following questions.

1. Will the specified LEM system function with the Measuring Head(s) geometrically centered in the proposed location within your bus system? If not, at which location and under what geometric conditions will the system function properly?

2. If there is no readily determined location that will prove satisfactory in all respects, what compromise is necessary? In some few cases, locations must be selected where non-linearities resulting from zero-offset and/or overloading occurs. Non-linearities may occur in the measurement system when the magnetic field from a nearby bus is dominant over the field from the measured bus. The non-linearity occurs when the measured bus currents are very low and a nearby bus current is high. Non-linearity due to overloading may occur at normal (or higher) current levels, in a "compromise" location. In either case, DynAmp can advise the customer that the conditions exist, estimate their magnitudes and recommend the steps necessary to compensate for them. It is far easier, quicker and less expensive to move the heavy sensors in the computer rather than employ manpower on site during a busy start-up procedure.

WHAT DATA IS REQUIRED TO PERFORM THE BUS ANALYSIS?

The computer requires certain data inputs to perform the detailed analysis. To this end, the customer must supply the specific information requested below.

> ***NOTE: All technical information and documentation received by DynAmp, LLC from the customer, will be held in the strictest confidence.***

1. Provide dimension plan and elevation views of all bus work within a 10-meter (33 ft.) radius of each proposed Measuring Head location. Dimensions may be in any conventional unit (usually feet or meters); the same unit must be used throughout. All drawing submitted must be legible.

   a) Show the prime locations for the Measuring Head(s).

   b) Show the alternate locations for the Measuring Head(s).

   c) Indicate the direction and normal magnitude of the current in each bus. Drawing current direction arrows on bus layout prints will be helpful.

   d) Indicate the anticipated maximum current through each bus.

   e) Show the distances between the various buses.

   f) Show the cross-sectional dimensions of each bus passing through a Measuring Head.

   g) Show any structural details that might mechanically interfere with the installation or positioning of any measuring head.

   h) (If Applicable) For multiple rectifier systems feeding a common bus:

   i) (Normal Operation) State the maximum number of rectifiers in use during normal operation, the normal and maximum current level for each, and the time in minutes that each can be operated at maximum level.

2. For Abnormal or Emergency Operation, state the minimum number of rectifiers that can remain in sustained operation, the normal and maximum current level for each, and the time in minutes that each can be operated at maximum level.

3. Provide a schematic diagram of the proposed DynAmp current output circuit.

   a. Show all burden resistance, including interconnecting lead resistance.

   b. State the trip point of overcurrent device if one is used.

HOW IS THE DATA USED? The bus paths and current directions are established for a specific analysis project. The X, Y, and Z coordinates of the end points of each straight line segment of the bus is determined from the scaled plan and elevation views. This data, along with the value of current carried by each segment of the bus, is used to produce a Summary of Coordinates Table for the bus. Current direction is defined as flowing conventionally from the beginning coordinate to the end coordinate of a given segment of bus. Similarly, the coordinates for the center points of each Measuring Head are determined. This data is entered into the computer and processed as follows using a 30 kA, LKP model for example:

1. In the computer model of a 30kA Measuring Head, each of the four sides of the Measuring Head is divided into 12 equal segments. The magnetic field at the center point of each segment is computed for each bus. The component of the resulting field in the core direction is multiplied by 1/12th the core length, then the products are summed. The result is the predicted ampere loading on each channel due to each bus in the system. This data is tabulated by the computer as BUS, Channel (1), Channel (2), Channel (3), and Channel (4). The results are summed for each channel and immediately checked to see if the loading on any of the four channels exceeds the maximum limit of 9750-Ampere turns.

2. Since the computer program is in reality an implementation of Ampere's Law, the sum of the currents in the four channels equals the primary bus current enclosed by the Measuring Head. The sum is identified by the computer as HEAD AMPS TOTAL, and is typically well within 1% of the measured bus current. These small, insignificant errors are due to data approximations and arithmetic rounding.

Generally, the first computer run is performed with the measuring Head(s) geometrically centered on the bus in the proposed prime location. If each channel loading is within the specified limit (e.g., 9750 amperes maximum, per channel for a 30 kA measuring head), no further analysis is required. However, if a channel exceeds the specified limit, the next step is to reposition the Measuring Head center slightly displaced from the bus geometric center, so that the heavily loaded channel is farther from the bus and the lightly loaded channel is closer to the bus. This can be accomplished by:

   1. Moving the Measuring Head up, down, to the left, and/or to the right

   2. Rotating the Measuring Head clockwise or counter clockwise

   3. Tilting the Measuring Head up, down, to the left, and/or to the right

If the current in one channel still exceeds the specified limit, the alternate location for the Measuring Head must be considered. This location is usually found by moving the Measuring Head axially along the bus, generally away from a bus section that is making a large contribution to the total channel load. If the current in one channel is still excessive, the position in steps discussed above are repeated. In all cases, relocating or repositioning of the Measuring Head from geometric center is accomplished by entering new location coordinates of the Measuring Head into the computer.

In the event that no satisfactory location is found the customer is contacted and discussions are initiated regarding the most probable and viable alternate solutions. In more extreme cases, these alternates might include upgrading the equipment chosen or modifying the bus design.

HOW IS A TYPICAL ANALYSIS PERFORMED?

Figure 1 shows the layout and dimensions of two identical, adjacent bus systems, and the initially proposed ("prime") locations of the measuring heads. In this example, nominal bus current in each system is 29 kA and DynAmp's selected model LKP-30 measuring systems are rated at 30 kA . Bus segments to be considered are numbered 1 through 16. Since a total closed current path should be considered the rectifier's internal paths are approximated by buses 8 and 16 and the load is approximated by buses 5 and 13. An initial XYZ coordinate point is then selected where, for convenience, all points in the system are positive with respect to the initial point. Again, due to the program, the initial point is given a value other than zero, for all axes.

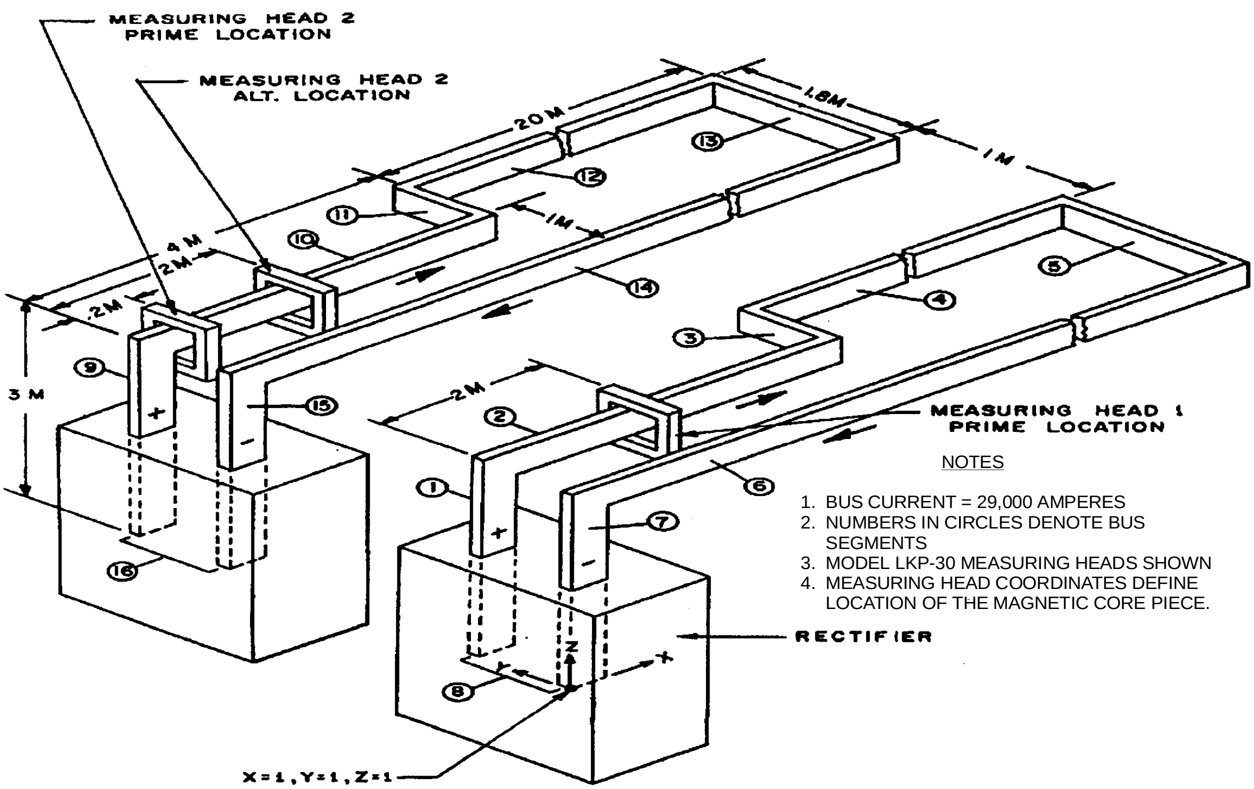

Figure 1. Typical bus diagram & dimensions required for analysis

The "Bus Analysis Coordinates" form shows how the coordinates data is obtained from the bus diagram, and tabulated for use. The analyst first enters the coordinates for all buses into the table. This entry is only made once, regardless of the number of heads and location to be analyzed. Figure 2 below shows the table of bus coordinates corresponding to the previously shown pair of rectifiers.

Bus Number	x1	y1	z1	x2	y2	z2	Current
1	1000	2000	1000	1000	2000	4000	29000
2	1000	2000	4000	5000	2000	4000	29000
3	5000	2000	4000	5000	2800	4000	29000
4	5000	2800	4000	25000	2800	4000	29000
5	25000	2800	4000	25000	1000	4000	29000
6	25000	1000	4000	1000	1000	4000	29000
7	1000	1000	4000	1000	1000	1000	29000
8	1000	1000	1000	1000	2000	1000	29000
9	1000	4800	1000	1000	4800	4000	29000
10	1000	4800	4000	5000	4800	4000	29000
11	5000	4800	4000	5000	5600	4000	29000
12	5000	5600	4000	25000	5600	4000	29000
13	25000	5600	4000	25000	3800	4000	29000
14	25000	3800	4000	1000	3800	4000	29000
15	1000	3800	4000	1000	3800	1000	29000
16	1000	3800	1000	1000	4800	1000	29000

Figure 2. Bus Bar End Point Coordinates

Figure 3 shows the entry/response printout for the analysis of MH2 in the prime location shown in figure 1. Following entry of MH2 corner coordinates, the computer outputs the current in each Measuring Head channel (or "leg") contributed by each section of the bus. As seen in the analysis summary below, channel 4 (leg 4) is **overloaded** (i.e., greater than 9750amperes) and hence the location of MH2 is unsatisfactory. As seen in figure 1, this channel (or leg) is very near bus 9 that is contributing a high level of current.

DYNAMP TYPE: LKP-30 UNITS: Millimeters

CENTER OF HEAD MH2 In Initial Location Choice: X= 1200 Y= 4800 Z= 4000
HEAD PLACEMENT: Y-Z PLANE
HEAD ROTATION: X axis = 0 Y axis = 0 Z axis = 0

HEAD CHANNEL COORDINATES

	X	Y	Z
CHAN 1	1200.00	4568.00	3768.00
CHAN 2	1200.00	4568.00	4232.00
CHAN 3	1200.00	5032.00	4232.00
CHAN 4	1200.00	5032.00	3768.00

HEAD AMPS CALCULATION RESULTS

BUS #	CHAN 1	CHAN 2	CHAN 3	CHAN 4
1	0	-18	0	22
2	-37	28	299	28
3	-39	0	33	0
4	-55	7	64	7
5	3	0	-3	0
6	313	-18	-275	-18
7	0	9	0	-10
8	3	0	-2	0
9	0	-1136	0	6774
10	5833	5833	5833	5833
11	-57	0	59	0
12	35	8	-20	8
13	3	0	-3	0
14	1690	-297	-995	-297
15	0	157	0	-254
16	8	0	-7	0

CHANNEL AMPS TOTAL:	7361	4571	4981	**12092**
MAX AMPS/CHANNEL ALLOWABLE:	9750	9750	9750	9750
PERCENT LOADING:	75.5%	46.9%	51.1%	**124.0**%
HEAD AMPS TOTAL:	-29005.9			

Figure 3. Analysis of MH2 in prime location

The obvious solution in this case is to move MH2 axially along bus 10, away from bus 9, to the ALT location shown in figure 1. This was done and Figure 4 shows the printout for the ALT location analysis of MH2. The resulting totals for the current in each channel are all below the 9750-ampere design limit, and this position is satisfactory.

DYNAMP TYPE: LKP-30 UNITS: Millimeters

CENTER OF HEAD MH2 in Alternate Location: X= 3000 Y= 4800 Z= 4000
HEAD PLACEMENT: Y-Z PLANE
HEAD ROTATION: X axis = 0 Y axis = 0 Z axis = 0

HEAD CHANNEL COORDINATES

	X	Y	Z
CHAN 1	3000.00	4568.00	3768.00
CHAN 2	3000.00	4568.00	4232.00
CHAN 3	3000.00	5032.00	4232.00
CHAN 4	3000.00	5032.00	3768.00

HEAD AMPS CALCULATION RESULTS

BUS #	CHAN 1	CHAN 2	CHAN 3	CHAN 4
1	0	-112	0	126
2	-511	37	3988	37
3	-68	0	48	0
4	-150	18	157	18
5	4	0	-4	0
6	442	-25	379	-25
7	0	64	0	-69
8	20	0	-17	0
9	0	-392	0	493
10	7190	7190	7190	7190
11	-183	0	207	0
12	114	27	-71	27
13	4	0	-4	0
14	2615	-469	-1588	-469
15	0	308	0	-377
16	45	0	-43	0

CHANNEL AMPS TOTAL

9524	6646	5884	6951

MAX AMPS/CHANNEL ALLOWABLE

9750	9750	9750	9750

PERCENT LOADING

97.7	68.2	60.4	71.3

HEAD AMPS TOTAL
29005.5

Figure 4. Analysis of MH2 in alternate location

ZERO OFFSET ANALYSIS

A zero offset can occur when unidirectional systems are used and there are other, nearby active bus currents while the current through the measuring head is zero (e.g. rectifier and buses associated with it re shut down for repair). In a 4 channel system it is usual to find 2 channels turned on by the external magnetic fields and 2 channels to be turned off. The zero offset will be approximately equal to the sum of the turned-on channels.

To determine the amount of zero offset that can be expected in the measuring system for a given bus, the current in that bus is set at zero. The adjacent bus system is than considered to be carrying its normal current. Since the current in each bus segment is entered along with it's coordinates, the process must be repeated. Figure 5 shows the zero offset analysis for MH1, with the current in buses 1 through 8 at 0 amperes, and in 9 through 16 at 29000kA. Note that the "Head Amps TOTAL sum to zero amps. However, since the LEM model LKP-30 being used can only compensate for current in the positive direction, the negative currents in Channel (1) and (4) will not be subtracted from the current meter reading, and the zero offset will be the positive current total in Channels (2) and (3), or 554 amperes. In a bi-directional measurement system, such as LKB-30, the "negative" channels would add and there would be no zero offset. If there is a zero offset then the program can also be used to predict the current level above which the system is operating with normal system accuracy. More information on zero offsets can be found in Technical Bulletin #9908.

HEAD AMPS INFORMATION

BUS #	CHAN 1	CHAN 2	CHAN 3	CHAN 4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	-112	0	126
10	388	37	-511	37
11	-28	0	38	0
12	46	10	-152	10
13	4	0	-4	0
14	-890	-133	1209	-133
15	0	202	0	-238
16	25	0	-30	0
CHANNEL AMPS TOTAL				
	-355	3	551	-199
MAX AMPS/CHANNEL ALLOWABLE				
	9750	9750	9750	9750
PERCENT LOADING				
	3.6	0.0	5.6	2.0
HEAD AMPS TOTAL				
	0.0			

Figure 5. Zero offset analysis for Measuring Head #1

SUMMARY

The computer analysis provides an extremely useful tool for previewing and avoiding application problems in a proposed location and for correcting head location problems in existing bus system. The analysis can also be used as a basis for selecting the DynAmp model best suited for the bus system and for easily predicting performance in alternative locations. This is very useful in the increasingly difficult magnetic environments found in modern complex bus systems that are compressed in order to maximize long term economic process performance.