

UR Family UR Relays Percent Differential Element Testing Application Note

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This document outlines testing of the UR relays Percent Differential element and results. Although content below is shown for the B90 relay for illustration purposes, it's fully applicable to all UR platform percent differential relays, B30, B90, G30, G60, M60, T35 and T60 having the same algorithm.

Introduction

The B90 Low Impedance Bus Differential System is part of the GE Universal Relay (UR) product family.

The B90 provides protection and metering for busbars with up to 24 feeders. It provides multi-zone differential protection with both restrained (percent, biased) and unrestrained (unbiased, instantaneous) functions incorporated, together with the phase comparison operating principle. Low and high breakpoints are connected together with a cubic spline function to provide a smooth transition between slope 1 and slope 2. If testing of points along this region is required, use the 87T Characteristics.xlsx spreadsheet.



Figure 1: Biased operating characteristics



The differential signal is composed of the sum of individual feeder currents.

$$I_{DIF} = \left| I_1 + I_2 + \dots + I_n \right|$$

The restraint quantity is chosen to be the maximum of the individual feeder currents.

$$I_{RES} = \max\left(\left|I_1\right|, \left|I_2\right|, ..., \left|I_n\right|\right)$$

The biased operation has two FlexLogic operands, BUS 1 BIASED PKP and BUS 1 BIASED OP. The pickup (PKP) operand responds to the characteristic shape. The operate (OP) operand responds to the characteristic shape AND the directional principle or the characteristic shape and NO saturation detected.

Figure 2: Biased pickup and operate



The differential and restraint quantities can be plotted on the biased operating characteristic curve. Since the relay also uses the directional principle, the biased trip may not occur when the two points intercept the curve. To test the curve, assign the FlexLogic BUS 1 BIASED PKP operand to an output that is used for sense on the test set.

The directional principle responds to the relative direction of the fault currents; therefore, no reference signal is required. The directional principle declares that

• If at least one fault current flows in the same direction, compared with the sum of the remaining

currents, the fault is internal, or

• If at least one fault current flows in an opposite direction compared with the sum of the remaining currents, the fault is external

The current is determined to be a fault current if the magnitude is greater than an adaptable threshold based on the restraint current and the number of feeders in the bus. The current is considered if its magnitude is greater than K * I_{rest} or 2 times the CT rating. For bus zones with two feeders K = 0.2, for bus zones with three to six feeders K = 0.8 / (N - 1). For bus zones with more than six feeders K = 0.16. This is important when testing the directional principle supervision.

Setup

The example in this document tests a B90 with six zones each with a 2000:5 CT on each CT input. The following settings are used.

📟 Bus Differential // Office: A-To	p: Settings: Grou 🗖 🔳 💌								
Save Restore	Default Reset VIEW A								
PARAMETER	BUS ZONE 1 DIFFERENTIAL								
Operating Characteristc Graph	View								
Function	Enabled								
Pickup	0.200 pu								
Low Slope	25 %								
Low Bpnt	2.00 pu								
High Slope	50 %								
High Bpnt	8.00 pu								
High Set	8.00 pu								
Seal-In	0.400 s								
Supervision	ON								
Trip	OFF								
Block	OFF								
Target	Latched 🗸								
Events	Enabled								
A-Top Settings: Grouped Elemen	ts: Group 1 Screen ID: 187::								

Figure 3: Bus differential settings

The View button (shown in red outline) at the top of the settings opens a live view of the element.



Figure 4: Bus differential characteristic view

Zoom into regions of the graph by clicking and holding the left mouse button on the graph and expanding the window.



Figure 5: Zoomed-in bus differential characteristic view

Set the trip output or spare output wired to test set sense to BUS 1 BIASED PKP to test the shape of the dual slope characteristic.

📟 Contact Outputs // Office: A-T	op: Settings: Inputs 🗖 🔳 론	-
🕞 Save 🔛 Restore	Default Reset VIEW A	Ц <i>т</i>
SETTING	PARAMETER	~
[H1] Contact Output 1 ID	Cont Op 1	
[H1] Contact Output 1 Operate	BUS 1 BIASED PKP 🔍	
[H1] Contact Output 1 Seal-In	OFF	
[H1] Contact Output 1 Events	Enabled	

Figure 6: Output contact setting pickup

NOTICE

The current inputs have a continuous rating of 4 x Inom. Do not exceed 4 x Inom current continuously during testing, else damage to the relay occurs.

The characteristic accuracy is $\pm 3\%$ of the maximum circuit current or $\pm 2\%$ of rated, whichever is greater.

Pickup test

The pickup is set at 0.2 pu, which makes the operate current 0.2 * 5 = 1 A. The per unit value is based on the largest CT primary rating. In this case, because all the CTs are 2000:5, the pickup is 0.2 * 2000 on the primary or 0.2 * 5 on the secondary.

To test the pickup value, use a pulsed linear ramp test starting with two equal currents 180° apart. Then increase or decrease one of the currents until the test set receives a sense.

- 1. Set the initial values to 2 A on each source, one set to 0° and the other set to 180°. This results in zero differential current.
- 2. Set the pulse duration to 50 ms with a wait time of 50 ms.
- 3. Set the delta current to -0.01 A with a current limit of 0 A.
- 4. Select current source 2 as your action source.
- 5. Start the test.

Figure 7: Pickup test pulsed ramp setup

Pulsed Linear Ramp, Current (IB)																				ProTesT Equivalent: PRAM	PI
Pulsed Linear Ramp, Current (IB)				E	<mark>st Points</mark> ixpected 1.000 A	Actual ¥		G -	Eurrent	F D E E E E On Sense	E S	iense	A B C D E F G Fault de	st Parame Name Offse Offset Initis Pulse ± Delt Cur etails Fault type Voltage	tters t Current t Duration Wat Current Current Current Non Current Current	Value 2.000 A 1.000 s 2.000 A 0.050 s -0.010 A 0.000 A e 0 V				Pro I es I Equivalent: PRAM	PI
										"											
	Action Sta	te Sumn	nary						C	ontrol Panel	Sens	se Seti	tings								
	Source Name	s DC	CT/VT R	itio	Connections Hi Lo	Amplitude		Actio Phase	n 1	Frequency		Cha	annel ID	Label	Connection	ons	S	ense Condit	tion		
	VA		1	*		0.0 V		0.0	•	60.000 Hz	S1	LN1	×	LN1			1	0->1	~		
	VB		1	*		0.0 V		0.0 %	•	60.000 Hz				inse Deby	0.000 c	,	l				
	VC		1	*		0.0 V		0.0	•	60.000 Hz				Durakas	0.000 -	•					
	IA		1	*		2.00 A	~	0.0 9	•	60.000 Hz			Disu cound u	e ouration	0.000 s	•					
	IB		1	*		Action	~	180.0	•	60.000 Hz			Play sound v	operates							
	IC		1	*		0.00 A	*	0.0 %	•	60.000 Hz	Jum	pers									

View the test points live on the Operating Characteristic Graph View. The restraint current is the maximum, 1 A in this case, which is 0.4 pu. The red X starts at (0.4,0) and rises to the differential characteristic.



Figure 8: Pickup test view

Figure 9: Pickup test result

Test Points	Test Points														
Expe	Expected Measured Results Tolerance A														
Ор	Ourrent	Ор	Ourrent	Δ		Minus	Plus	Severity	Timers						
Value 🗸	1.000 A	Ор	0.950 A	-0.050 A	1	0.100 A	0.100 A	Error 🗸							
						Tolerar	псе Туре	Absolute 🗸							

Accuracy is ±2% of 5 A, or 0.100 A.

Slope 1 test

Slope 1 can be checked in a similar way because the restraint quantity is less than the continuous amp limit of the relay.

The settings have a 25% slope with a low breakpoint of 2 pu. Choosing a restraint of 1.5 pu results in a (required differential current of $1.5 \times 0.25 = 0.375$ pu. The current on source 2 must then be $(1.5 - 0.375) \times 5 = 5.63$ A.

To test slope 1, use a pulsed linear ramp test starting with equal currents 180° apart. Increase or decrease one of the currents until the test set receives a sense.

1. Set the initial values to 7.5 A on each source, one set to 0° and the other set to 180°.

- 2. Set the pulse duration to 50 ms with a wait time of 50 ms.
- 3. Set the delta current to -0.01 A with a current limit of 0 A.
- 4. Select current source 2 as your action source.
- 5. Start the test.

Figure 10: Slope 1 test pulsed ramp setup



Figure 11: Slope 1 test view



Figure	12: Slo	pe 1	test r	esults

Test Points	Test Points														
Expected Measured Results Tolerance A															
Ор	Current	Ор	Current	Δ		Minus	Plus	Severity	Timers						
Value 🗸	5.630 A	Ор	5.610 A	-0.020 A	≺	0.225 A	0.225 A	Error 🗸							
						Tolerar	псе Туре	Absolute 🗸							

Accuracy is ±3% of 7.5 A, or 0.225 A.

Slope 2 test

Slope 2 begins at breakpoint 2, which is set at 8.0 pu and the slope is 50%. Since 8.0 pu is above the 4.0 pu continuous rating of the input, a test cannot hold the restraint current at 40 A. Test set source limitations also can come into play, requiring the user to parallel sources to get the higher magnitude currents.

For slope 2, the restraint quantity needs to be 8 pu or 40 A. The test requires using two paralleled sources each set at half of the test value. The differential current needs to be 50%, so Source 2 = 8 (1 - 0.5) * 5 = 20 A.

To test slope 2, use a pulsed linear ramp with three sources. Fix one source at 180° and the other two at 0°, then increase their magnitudes until the test set receives a sense.

- 1. Parallel sources 1 and 3 going into the relay.
- 2. Set the initial values to 10 A on sources 1 and 3, set to 0°, and source 2 set to 20 A and 180°.
- 3. Set the pulse duration to 50 ms with a wait time of 50 ms.
- 4. Set the delta current to 0.1 A with a current limit of 25 A.
- 5. Select current sources 1 and 3 as your action sources.
- 6. Start the test.

Figure 13: Slope 2 pulsed ramp setup

									•									
Pulsed Linear Ramp, Current (IA,	IC)																ProTesT Equiv	alent: PRAMPI
				Tect	Pointc			Curre	nt				Test Parame	eters				
				Test	rounts		_	G		F	F		Name	e Valu	e			
				Exp	ected	Actual	•			F T	D	A	Offse	et Current 10.000	A			
				20.	000 A	*		с		D		В	Offse	t Duration 1.000	s			
												C	Initi	ial Current 10.000	A			
												D	Pulse	e Duration 0.050	s			
									1 2	E	E	E		Wait 0.050	s			
									Time	+	0	F	± Deł	ta Current 0.500	A			
									В		56	G	Cur	rrent Limit 25.000	A			
								Note: P	ulse ends on	Sense		Faul	t details					
													Fault type	None	\sim			
													Voltage	0.00 V				
	Action Sta	e Sumi	mary						Cont	rol Panel	Sens	e Settings						
	Source	s		C	onnections			Action										
	Name	DC	CI/VI Ra	H	Lo	Amplitude		Phase	F	requency		Channel ID	Label	Connections	Sense Condit	ion		
	VA		1	*		0.0 V		0.0 °	60	.000 Hz	51	LN1 🗸	LN1		/_ 0->1	~		
	VB		1	*		0.0 V		0.0 °	60	.000 Hz			Sense Delay	0.000 c	1			
	VC		1	*		0.0 V		0.0 °	60	.000 Hz			Durat Duraking	0.000 -				
	IA		1	*		Action	~	0.0 °	60	.000 Hz		Diay sou	nd when relay	0.000 s				
	IB		1	*		20.00 A	~	180.0 °	60	.000 Hz			operates					
	IC		1	×		Action	×	0.0 0	60	1.000 HZ	Jump	ers						



Figure 14: Slope 2 test view

Figure 15: Slope 2 test results

Test Poin	Test Points														
Ð	Expected Measured Results Tolerance Aux														
Ор	Current	Ор	Current Δ			Minus	Plus	Severity	Timers						
Value 🗸	20.000 A	Ор	20.100 A	0.100 A	<	0.600 A	0.600 A	Error 🗸							
						Tolerar	ісе Туре	Absolute 🗸	0						

Accuracy is ±3% of -0 A, or -1.20 A, but because we have current from two sources it is half, or 0.600 A.

Directional principle check

Now that the characteristic has been verified, the trip operation can be verified quickly by injecting currents that meet the operate conditions.

First, change the output operate being used for test set sense to BUS 1 BIASED OP.

Figure 16: Output contact setting OP

Contact Outputs // Office: A-T	īop: Settings: Inputs 📼 💷 💌]
Save Restore	Default Reset VIEW AL	n
SETTING	PARAMETER	-
[H1] Contact Output 1 ID	Cont Op 1	
[H1] Contact Output 1 Operate	BUS 1 BIASED OP	
[H1] Contact Output 1 Seal-In	OFF	
[H1] Contact Output 1 Events	Enabled	

If a restraint value of 15 A or 3 pu is chosen, because there are six feeders in this relay's bus zone, K = 0.16 so source 2 current is 15 * 0.16 = 2.4 A. Use the pulsed ramp test for this.



In firmware released after April 2021, the B90 uses an extra protection security enhancement that requires the relay to detect an actual fault disturbance to operate. The fault detection algorithm uses a rate of change of current algorithm to distinguish a fault from non-fault conditions.

- 1. Set the initial values to 15 A on source 1, set to 0°, and the other set to 180°.
- 2. Set the pulse duration to 50 ms with a wait time of 50 ms.
- 3. Set the delta current to -0.05 A with a current limit of 0 A.
- 4. Select current source 2 as your action source with an initial value of 5A.
- 5. Start the test.

Figure 17: Directional principle check settings



The relay operates when the source 2 current gets to 2.4 A.



Figure 18: Directional principle test view



Test Points	5											
Exp	ected		Measured R	tesults		Tolerance						
Ор	Ourrent	Current	Δ		Minus	Plus	Severity	Timers				
Value 🗸	2.400 A	Ор	2.400 A	0.000 A	<	0.450 A	0.450 A	Error 🗸				
						Tolerar	псе Туре	Absolute 🗸				

Accuracy is ±3% of 15 A, or 0.450 A.

For further assistance

For product support, contact the information and call center as follows:

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