Eskom	Standard	Technology

Title. **PLC SYSTEM COUPLING DEVICE MAINTENANCE**

Unique Identifier. **240-122859919**

Alternative Reference Number. **TPC41-84**

Area of Applicability. **Engineering**

Next Review Date. **STABILISED**

COE Acceptance

Richard McCurrach

PTM&C Senior Manager

Date: 13/1/2017

DBOUS Acceptance

Vinod Singh

DBOUS Manager

Date: 16/1/17

This document is **STABILISED**. The technical content in this document is not expected to change because the document covers. *(Tick applicable motivation)*

1	A specific plant, project or solution	
2	A mature and stable technical area/technology	✓
3	Established and accepted practices	
Notes.	Section **3.5 Roles and Responsibilities.** "TPL41-75" should read "TST41-75" Section **3.5 Roles and Responsibilities** The second sentence should read. "For maintenance periods, the requirements of 240-54894702 Maintenance Standard for Power Line Carrier (PLC), associated Transmission Line Coupling Equipment and Teleprotection Equipment, shall apply "	
	This document is stabilized until such time that a task manual is compiled to supersede it.	

PCM Reference: **240-41836800**

SCOT Study Committee Number/Name: **Power Delivery Maintenance**

Eskom Transmission	**Procedure**	**Document Classification : PUBLIC**

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COMPILED BY	FUNCTIONAL RESP.	AUTHORIZED BY
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DATE: 4/04/2008	DATE: 9/4/2008	DATE: 21/4/08

Content

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1. Introduction

This procedure deals specifically with the intrusive maintenance of Power Line Carrier System coupling devices, namely coaxial cable, Line Matching Equipment and Carrier Combiners.

The Coupling Equipment discussed in this document is used for isolating and coupling Power Line Carrier signals, and is usually found in Transmission and Distribution substation yards and also in Power Station HV yards, and are connected to the High Voltage power line**.**

2. Document Content

2.1 REQUIREMENTS

Test equipment:

- S.L.M.S., preferably with tracking oscillator e.g. W&G SPM3/PS3, SPM31, SPM33, PSM137 etc., alternatively with separate, synchronisable oscillator such as the W&G PS3
- Impedance, Return loss Measuring test set/ attachment e.g. W&G SFZ1.
- Variable dummy load/ test unit for LME Insertion loss.
- 75Ω 1W resistors for termination of CCUs
- Multimeter e.g. “Fluke”.
- Equipment specific test cords, extender cards, dummy loads.

2.2. DEFINITION OF MEASUREMENT UNITS

The importance of using the correct measuring techniques and units cannot be over- emphasised in the process of performing intrusive maintenance on Power Line Carrier Coupling Devices. The following units require definition:

dB The ratio of two powers, typically that at the output of a device/ component compared to that at the input to express the gain or loss in a component or system.

$XdB = 10 \log_{10} (P_{out}/P_{in})$

dBm The absolute power level of a signal (Px) expressed in relation to a signal with a power level of 1 mW.

level in dBm $= 10 \log_{10}(P_x/1 \text{ mW})$

(1mW into 600 Ω produces a voltage of 0.775V and = 0dbm)

dBu/dBv The dBu (ABB/BBC) or dBv (Telettra) is used by some manufacturers for ease of measurement when doing high impedance measurements on their systems. When levels are indicated in dBu/dBv all readings are done on the 600Ω, high input impedance, scale even at 150 Ω and 75 Ω measuring points. This eliminates the need to constantly change impedance settings or inputs and reduces the possibility of human error.
Caution must be taken that dBv referred to in relation to equipment of European origin is not confused with the American (radio) standard where dBv is referred to 1V

dBu/dBv = $20 \log_{10}$(V/ 0.775 volts) where V is the voltage being measured

ONLY at 600Ω measurement points dBu/dBv = dBm

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To convert dBu/dBv to dBm a correction factor can be used.
At 600Ω 1mW = 0dBm = 0.775V = 0dBu/dBv
At 150Ω 1mW = 0dBm = 0.387V = -6dBu/dBv (add 6dB to dBu/dBv to convert to dBm)
At 75 Ω 1mW = 0dBm = 0.274V = -9dBu/dBv (add 9dB to dBu/dBv to convert to dBm)

In the context of this document, only the units dB, dBm and dBu will be used.

2.3 ACTIONS

Warning:

Intrusive maintenance on PLC coupling devices can only be performed if the associated HV line is dead and has been visibly earthed by the relevant Authorised Person. This warning is particularly important when testing the LMEs, as this will require the connection between the LME and CVT/CC to be opened. This latter operation must NEVER be done if the line is alive.

2.3.1 Coaxial Cable

These cables interconnect the CCU (or directly from the PLC transceiver if only single phase coupling is used) installed in one of the PLC terminal cabinets in the Telecommunications Room to the LMEs outside in the HV yard. After a visual inspection to ascertain that no apparent mechanical damage is present, each cable (two in the case of phase-to-phase coupling, three for three phase coupling schemes) must be individually measured for end-to-end attenuation.

2.3.2 Measurement of Coaxial Cable Insertion Loss

1. Calibrate the Level Meter in selective mode.

2. Disconnect the cable from the CCU at the one end (or carrier 2w point if single phase coupling is used) and from the LME at the other.

3. Set up the test arrangement as indicated in Fig. 1, The terminating resistor installed on the one end of the cable must have the value of 75Ω, for all standard Eskom installations.

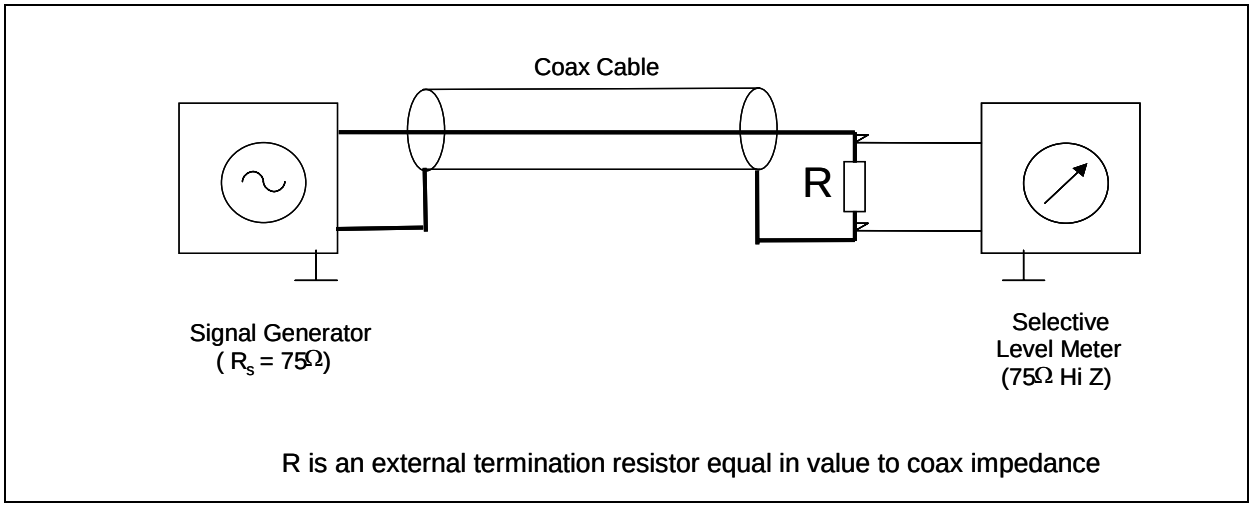

Fig. 1 Measurement of coax insertion loss

4. Set output level of oscillator to 0dBm at a frequency of 500kHz, with R_s= 75Ω.

5. Note level on Selective Level Meter, -XdBm say. (level Meter set to measure 75Ω Hi Z)

6. Cable loss is then XdB.

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7. Note result on measurement sheet and compare with typical loss of standard coaxial cable which is 0.47dB/100m at a frequency of 500 kHz.

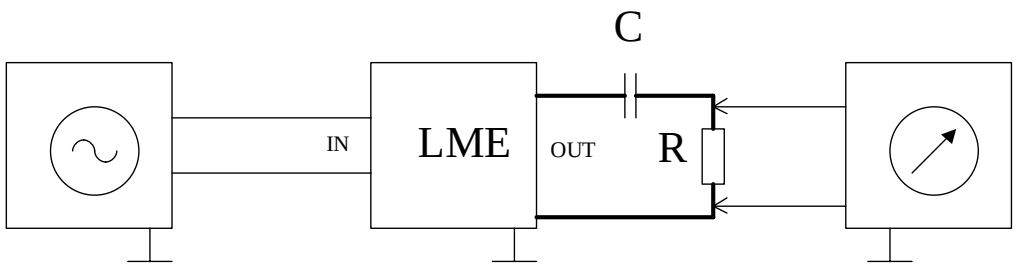
8. Restore all coaxial cable connections

2.3.3 Line Matching Equipment

The correct operation of LMEs is ascertained by the measurement of both the insertion loss and return loss performance. These measurements must be done after a visual inspection to see that no obvious electrical, physical or mechanical damage has occurred and that the enclosure is free from water or insect ingress. The measurements must be made directly at the input of the LME in the HV yard, after disconnecting the coax cable coming from the terminal equipment in the Telecommunications room.

2.3.4 Measurement of LME Insertion Loss

1. Calibrate Level Meter in Selective mode
2. Connect equipment as indicated in Fig. 2, selecting the external discrete components C and R, which are connected directly to the output of the LME in place of the usual HV coupling capacitor, as appropriate for the specific installation. The value of capacitor C must be chosen to correspond to that of the coupling capacitor/capacitor voltage transformer installed, while resistor R is made equal to the characteristic impedance of the line - 240Ω for a bundled conductor line, and 320Ω if the line has only a single conductor per phase. Typically, C=4400pF for a 400kV line installation. For exact connection details of the various LME types refer to the drawings in Appendix 1.
3. Set output level of oscillator to 0dBm with the source impedance (Rs) equal to the nominal input impedance of the LME (usually 75Ω). The frequency selected should be within the LME coupling band.
4. Measure the output across R with the selective level meter set for a 600Ω high impedance measurement (RI ≥ 5kΩ). Suppose the level measured is XdBu.



C equal to value of coupling capacitor, typically 4400pF at 400kV
R equal to value of line impedance, typically 240Ω for bundled conductor

Note : LME set for 75Ω input impedance

Fig. 2 Measurement of LME Insertion Loss

5. Insertion loss (AldB) is given by:

A_l = XdBu – Correction Factor,

Where Correction Factor (CF) = $10\log_{10}(R/600)$

Ie if R=240Ω, CF = $10\log_{10}(240/600)$ = -4dB

So in this case A_l = (X **+ 4**)dB

Note: in the LME pass-band, typical Insertion Loss should be of the order of 1dB.

6. Repeat measurements for the frequencies indicated in the result sheet (ANNEX 3)

2.3.5 Measurement of LME Return Loss

The basic principle involved in the measurement of LME Return Loss performance is outlined in Fig. 3, which indicates that some form of Return Loss Bridge is used in conjunction with a signal generator and a selective level meter, and that the input impedance presented by the LME is compared to the nominal resistance R_{Nom} connected to one arm of the bridge. The LME itself must be terminated by components C and R in a similar manner discussed for the LME Insertion Loss measurement. In other words, capacitor C must have a value equal to that of the associated coupling capacitor/capacitor voltage transformer, and R equal to the nominal line impedance: 240Ω for bundled conductor, 320Ω for a single conductor phase configuration.

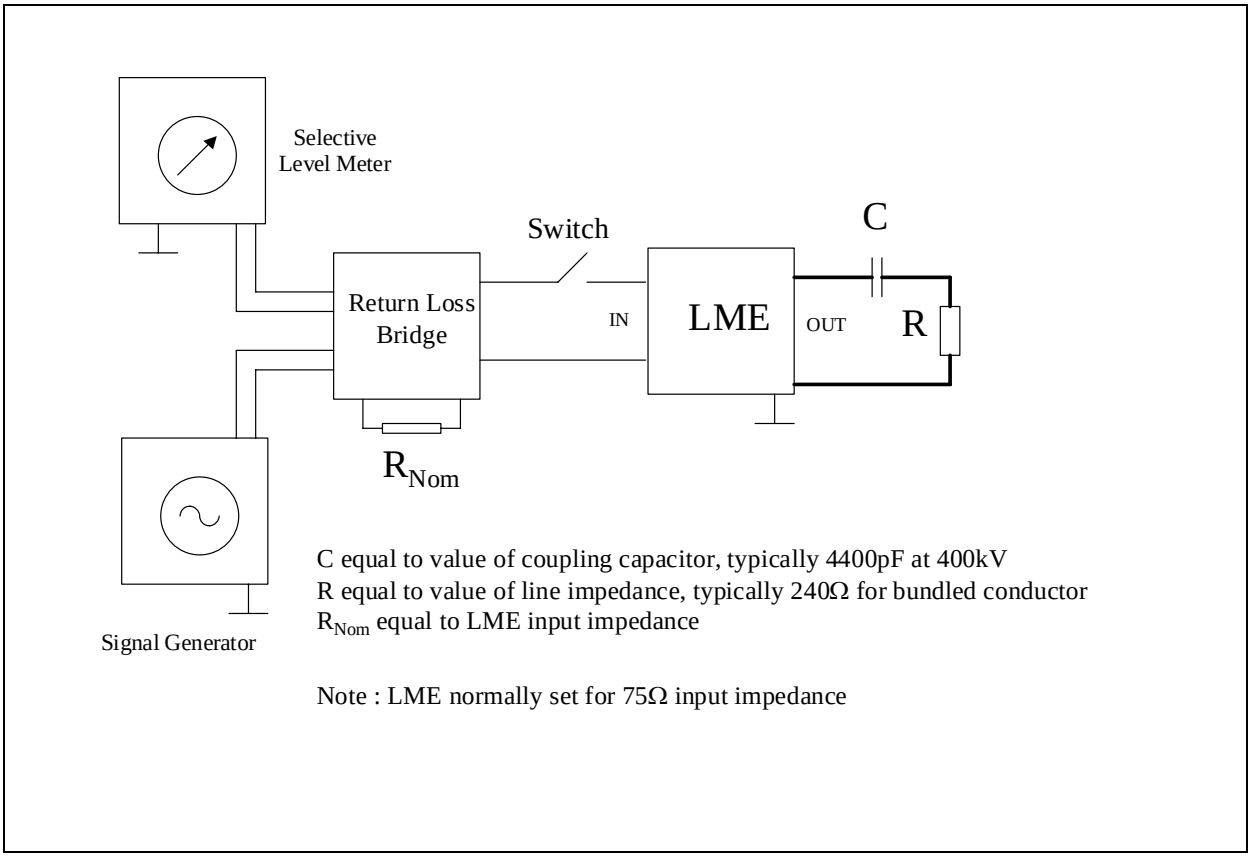


Fig. 3 Measurement of LME Return Loss (Generic arrangement)

Measurement using the W&G SFZ-1 Bridge attachment.

1. Calibrate level meter in selective mode.

2. Set up the equipment as shown in Fig. 3, paying particular attention to the connection to station earth. For exact connection details of the various LME types refer to the drawings in ANNEX 1.

3. Either disconnect the cable between the SFZ-1 bridge and the load, or ensure switch “S” is in the open position.

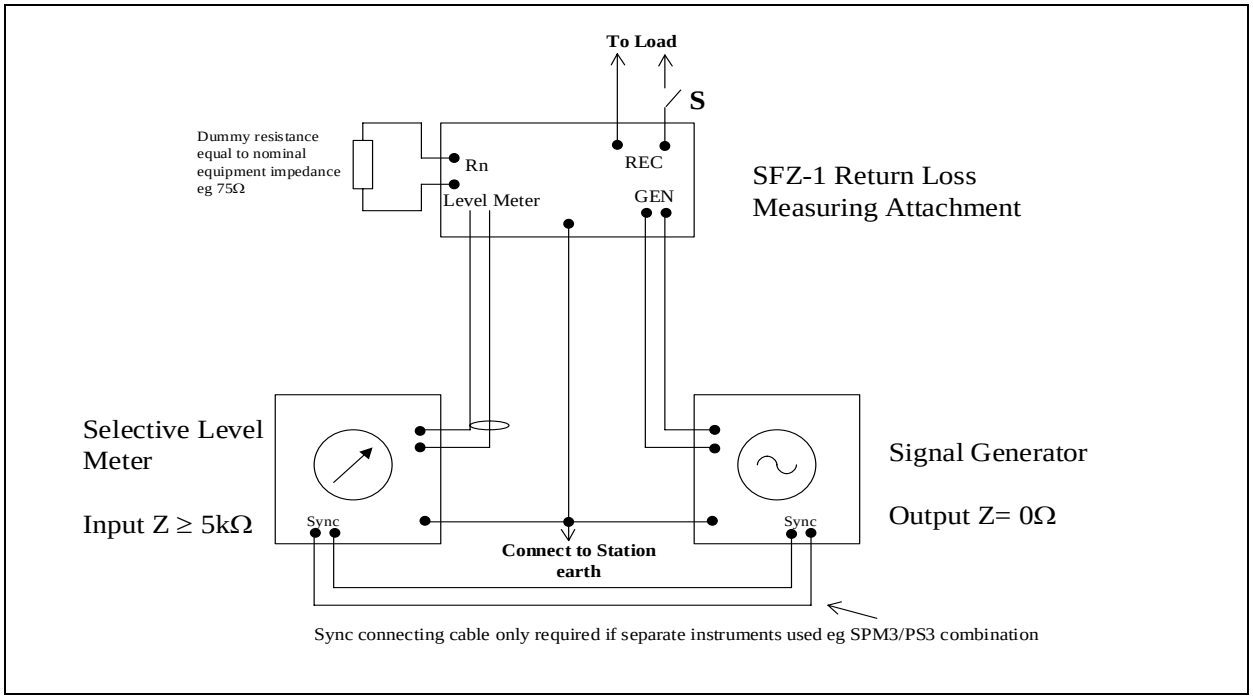


Fig. 4 Measurement of LME Return Loss with W & G SFZ-1 Bridge

4. Adjust signal generator output, with R_s=0, to approximately +9dBm at some frequency within the LME pass band. This should give 0dBm (desirable, but not always possible) on the level meter. The level meter should be set to 600Ω high impedance, selective mode, and both the level meter and signal generator must be set to run in synchronism. The level indicated on the meter is now the zero reference point for the Return Loss measurement.

5. Reconnect the load to the Return Loss Bridge or close switch “S”.

6. Note the deflection observed on the selective level meter. Suppose this now indicates –10dBm. This means that the Return Loss, A_r, presented by the LME and dummy capacitor ”C”, and line “R” is 10dB.

7. Repeat for various frequencies across the coupling band of the LME and fill in the results sheet (ANNEX 3)

When an SFZ-1 Bridge is not available, the improvisation techniques described in Appendix 2 can be used just as successfully to allow accurate Return Loss measurements to be made
The measured values of Return Loss, within the LME pass-band, should always be better than 12dB. If the measured figure is lower that than desired, further investigation is required after checking for any deviation from the standard strapping arrangements prescribed in the relevant Instruction Manual.

2.3.6 Carrier Combining Units

The correct operation of carrier combiners must be ascertained by measuring the insertion loss produced by the device, as well as checking the phasing of the output signals.

There are two basic types of CCU in use on Eskom's PLC systems at Transmission level, namely the CCU-1 for phase-to-phase coupling, and the CCU-3 which provides for three phase (Mode 1) coupling. The former version is by far the most common in practice.

2.3.7 Measurement of Insertion Loss and phasing of carrier combiners

Type CCU-1

1. Calibrate the Level Meter in selective mode.

2. Disconnect all the cables from the CCU and terminate all the output ports as described below.

3. Set up the test arrangement as indicated in Fig. 5. The terminating resistors installed on all the output connections of the CCU cable must have the value of 75Ω, for all standard Eskom installations. For exact connection details of the CCU-1 unit refer to ANNEX 1.

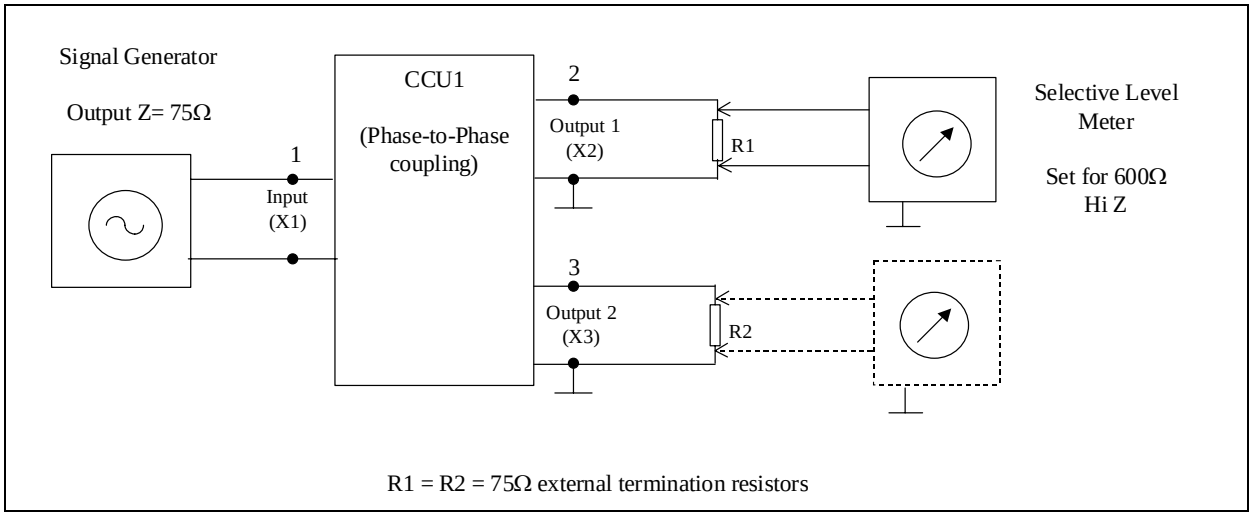


Fig. 5 Measurement of Insertion Loss and Phasing of CCU-1 unit

4. Set the oscillator for an output of 0dBm at a frequency of 100kHz, with the output impedance (R_s) of 75Ω.

5. Measure, in turn, across R1, R2 and from point 2 to point 3. The selective level meter must be set for 600Ω, high impedance measurement.

6. Compare the measured results with those in the table 1. Any deviation more than 0.5dB indicates an irregularity, and must be investigated. The measurement from Point 2 to Point 3 is critical for establishing that the phasing is correct. Readings obtained must be recorded in the result sheet (ANNEX 3).

Table 1

Measurement	Desired Level (dBu)
Across R1	-12
Across R2	-12
Point 2 to Point 3	-6

Type CCU-3

1. Calibrate the Level Meter in selective mode.

2. Disconnect all the cables from the CCU and terminate all the output ports as described below.

3. Set up the test arrangement as indicated in Fig. 6, The terminating resistors installed on all the output connections of the CCU cable must have the value of 75Ω, for all standard Eskom installations. For exact connection details of the CCU-3 unit refer to ANNEX 1.

4. Set the oscillator for an output of 0dBm at a frequency of 100kHz, with the output impedance (R_s) of 75Ω.

5. Measure, in turn, across R1, R2, R3, from point 2 to point 3, point 2 to point 4 and from point 3 to point. The selective level meter must be set for 600Ω, high impedance measurement.

6. Compare the measured results with those in the table 2. Any deviation more than 0.5dB indicates an irregularity, and must be investigated. The measurements from Point 2 to Point 3, Point 2 to Point 4 and from Point 3 to Point 4 are critical for establishing that the phasing is correct. Readings obtained must be recorded in the result sheet (ANNEX 3).

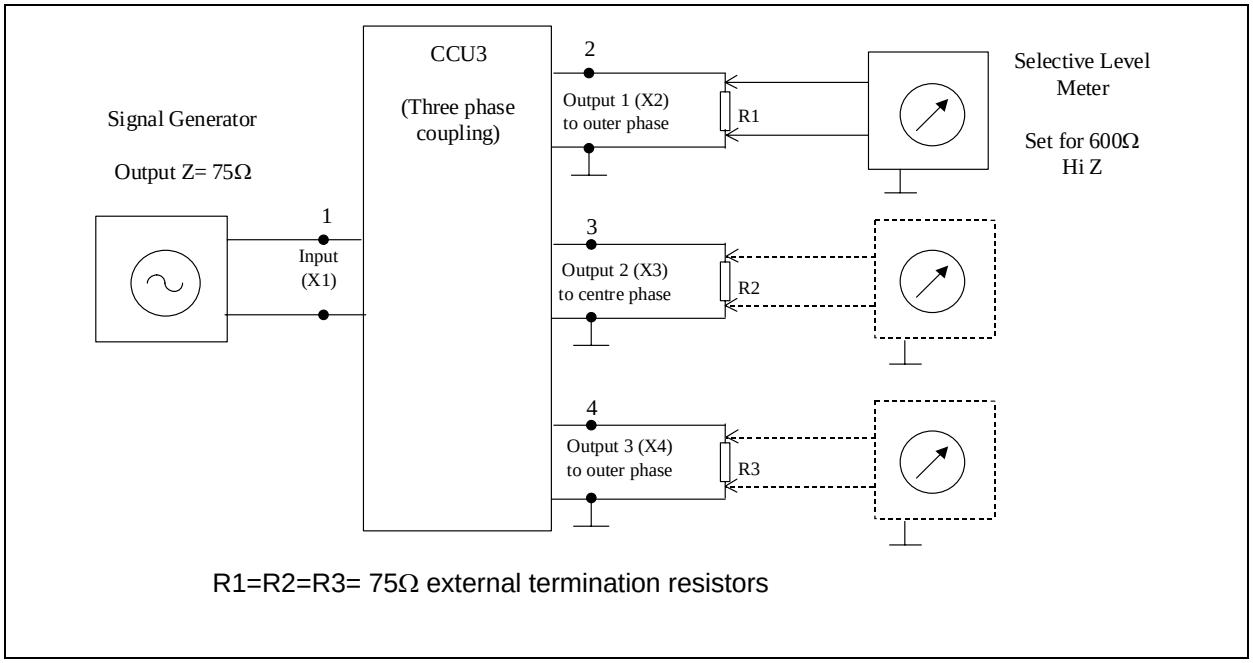


Fig. 6 Measurement of Insertion Loss and Phasing of CCU-3 unit

Table 2

Measurement	Desired Level (dBu)
Across R1	-15.0
Across R2	-12.0
Across R3	-15.0
Point 2 to Point 3	-7.4
Point 2 to Point 4	-9.0
Point 3 to Point 4	-22.7

2.4 DOCUMENTATION

Copies of measurement results/records must be distributed as follows:
- Local Maintenance Manager and/ or maintenance records
- Grid Secondary Plant Manager
- Maintenance Manager, Power Telecommunications,
- Site Copy

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3. Supporting Clauses

3.1 Scope

3.1.1 Purpose

To provide a procedure for the intrusive maintenance required periodically on the coupling devices forming an integral part of all Power Line Carrier Systems.

3.1.2 Applicability

This procedure is applicable to all personnel responsible for the maintenance of any coupling device installed on any of Transmission's Power Line Carrier Systems.

3.2 Normative/Informative References

The references listed below contain provisions that, through reference in the text, constitute provisions of this procedure or may contain additional information that may be required in some circumstances. The latest revisions of the references should be used.

ORHVS	Operating Regulations for high voltage systems
SLDG 9-1	Design Guide for Power Line Carrier Coupling Systems
TPC41-532	Power Line Carriers And Associated Teleprotection Systems: Commissioning And Major Maintenance Procedure
TPC41-132	PLC System Periodic On-Load testing
TPL41-75	Maintenance intervals of Power Line Carrier integrated teleprotection equipment and associated transmission line coupling equipment
TPC41-75	Maintenance Intervals of Power Line Carrier, Integrated Teleprotection Equipment and associated Transmission Line Coupling Equipment

3.2.1 Informative

Operating Instructions for Elektrisk Bureau Line Matching Equipment
Operating Instructions for ABB Line Matching Equipment type MCD80
Operating Instructions for ABB Type ETI21/101 Power Line Carrier terminals

3.3 Definitions

ORHVS:	ESKOM's Operating Regulations for High Voltage Systems.
Responsible employee (person):	An employee (person) who has been authorised in writing to be responsible for ensuring that the work on electrical apparatus covered by the Operating Regulations for High Voltage Systems can be carried out safely.

The definitions in ORHVS are applicable to this Procedure.

3.4 Abbreviations

3.4.1	CC	Coupling Capacitor
3.4.2	CCU	Carrier Combining Unit
3.4.3	CVT	Capacitor Voltage Transformer
3.4.4	HF	High Frequency
3.4.5	HV	High Voltage
3.4.6	LME	Line Matching Equipment
3.4.7	LT	Line Trap
3.4.8	ORHVS	Operating Procedures for High Voltage Systems
3.4.9	PLC	Power Line Carrier
3.4.10	SLMS	Selective Level Measuring Set
3.4.11	Tx	Transmit (Transmitter)
3.4.12	TU	Tuning Unit
3.4.13	PPE	Personal Protective Equipment

3.5 Roles and Responsibilities

It will be the responsibility of the various Grid Secondary Plant Managers to ensure that regular maintenance is performed, by competent personnel, on all Power Line Carrier coupling devices installed on all of Transmission's Power Line Carrier Systems in their area. The maintenance period is specified in the Power Line Carrier System Maintenance Policy Document TPL41-75.

SAFETY

There are definite hazards inherent in working in an HV environment and strict observance of regulations, an alert and responsible attitude and common sense is required if staff are to work safely.

All work to be done in the HV yard shall be in strict accordance with "Operating Regulations For High Voltage Systems" (ORHVS), and under control of a Responsible Employee as defined in ORHVS. The provisions of ORHVS will take precedence over any other reference to working procedures contained in this document.

Persons working in the HV yard shall use appropriate Personal Protective equipment (PPE) e.g. safety belts/harnesses, hard hats, shoes etc. as required.

Refer to the sections of the ORHVS pertaining to earthing and safety.

3.6 Implementation Date

The implementation date is July 2006.

3.7 Process for monitoring

As per Policies and Standards detailed in clause 3.8.

3.8 Related/Supporting Documents

TPL41-125	Secondary Plant Refurbishment Policy
TPL41-425	Maintenance Management Policy and Strategy

4. Authorization

This document has been seen and accepted by:	
Name	**Designation**
PI Lubbe	Senior Technologist, Power Telecomms
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IS Worthington	Sec. Plant Manager, S Grid
JO Pieterse	Sec. Plant Manager, NW Grid
K Govender	Sec. Plant Manager, E Grid
N Sipunzi	Sec. Plant Manager, W Grid
P Grobler	Sec. Plant Manager, NE Grid
C Ramgovind	Sec. Plant Manager, Central Grid

5. Revisions

Date	**Rev.**	**Remarks**
January 2006	0	New number (TPC0049)and new format
		Replaces document TRMPVADQ0
July 2006	0	New Reference Number
		Corrections to Supporting Clauses
		Re-arrange position of Annexes

6. Development team

DC Smith

PI Lubbe

ANNEX 1 – Equipment Drawings

Elektrisk Bureau LME

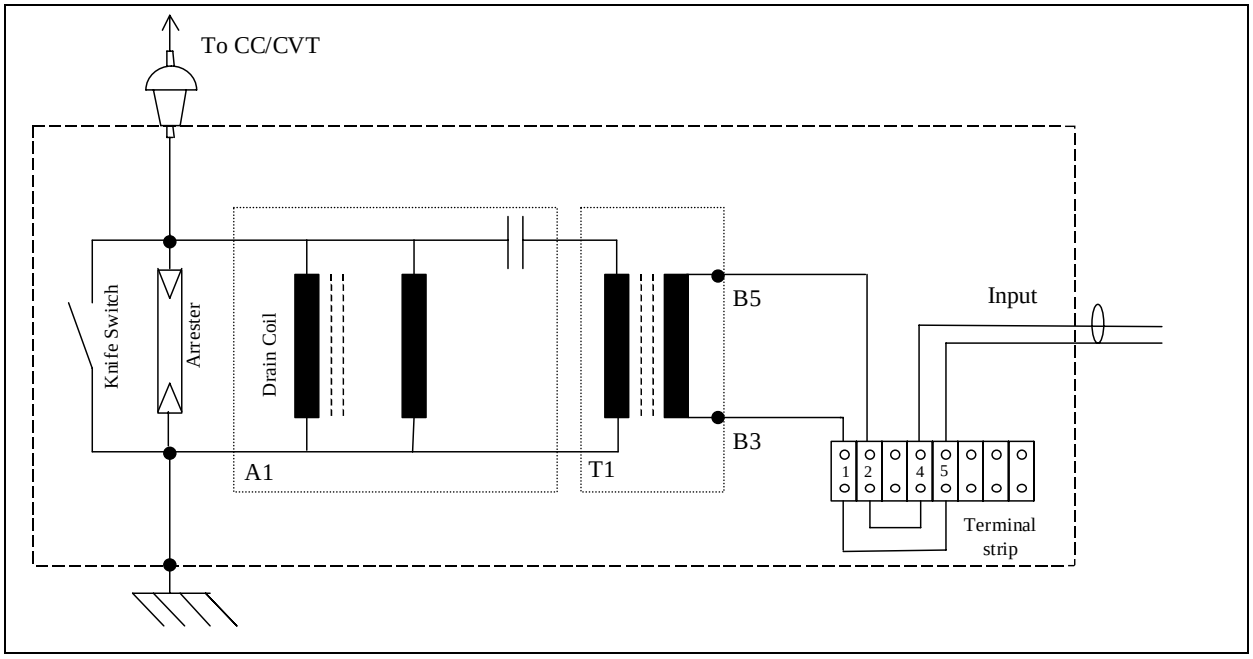


ABB HIGH PASS LME (Type A9BS)

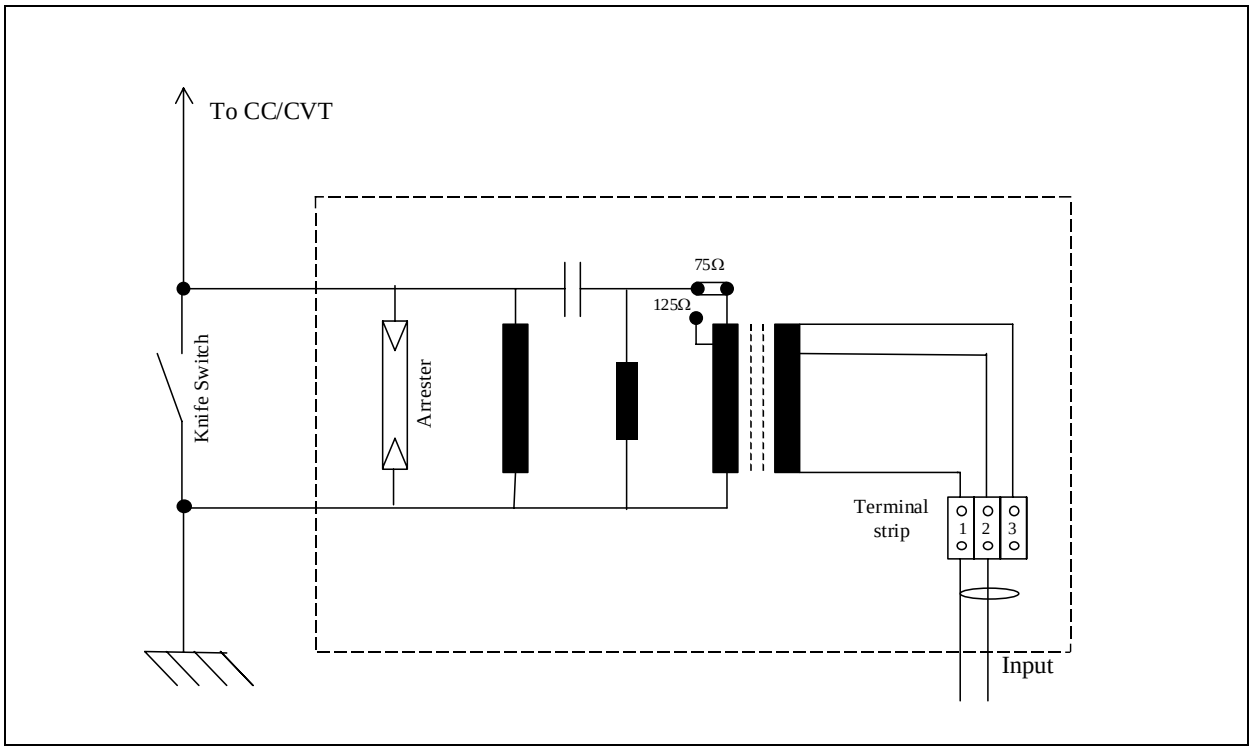
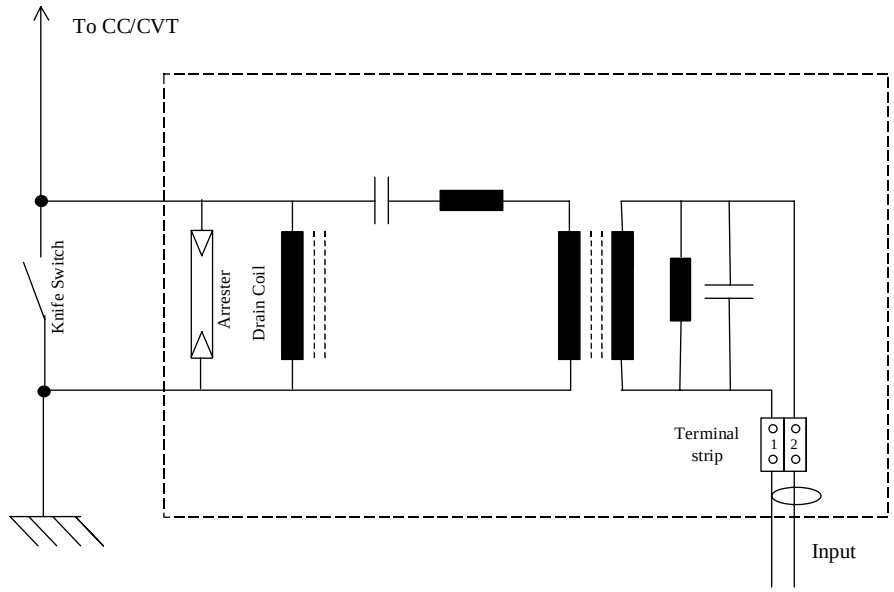
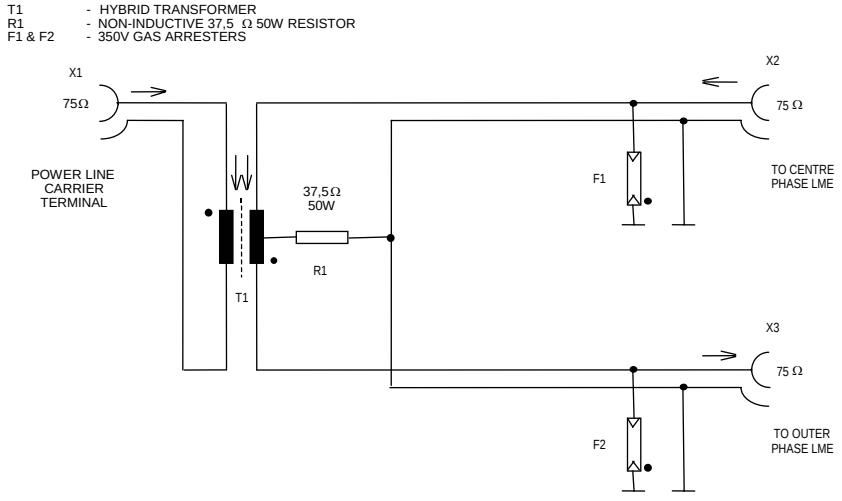


ABB BAND-PASS LME (Type A9BP)

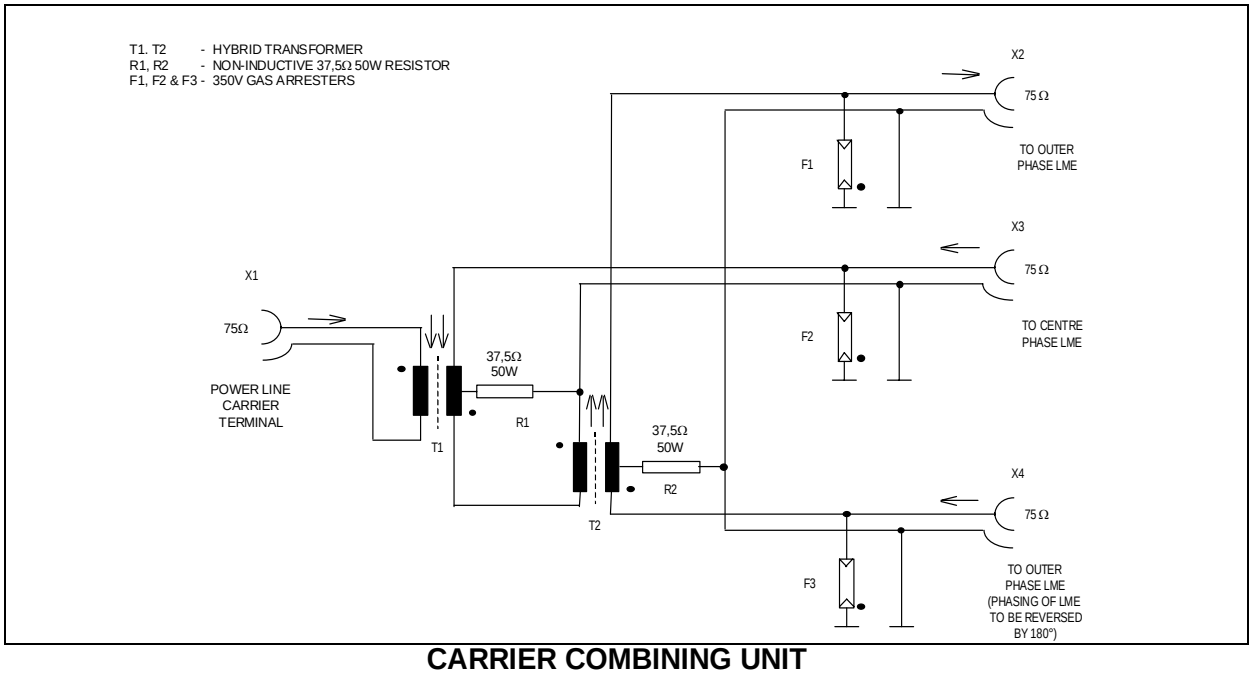


CCU-1



CARRIER COMBINING UNIT
TYPE CCU 1 - PHASE TO PHASE COUPLING

CCU-3



CARRIER COMBINING UNIT
TYPE CCU 3 - THREE PHASE COUPLING

ANNEX 2 - Alternative Techniques for the Measurement of LME Return Loss

Measurement using the Elektrisk Bureau (EB) type R800473/2 transformer

1. When the SFZ-1 attachment is not available, a suitable substitute can be made by utilising the R800473/2 combination transformer manufactured by Elektrisk Bureau. The transformer can be obtained by stripping an EB Type "Z" LME or de-commissioned coax switching panel.

2. The procedure to be followed is as described for the SFZ-1 bridge, with the exception that the equipment is set up as shown in Fig. 1. As before, "S" is opened to calibrate the "0dB" Return Loss point, and then closed for the actual measurement.

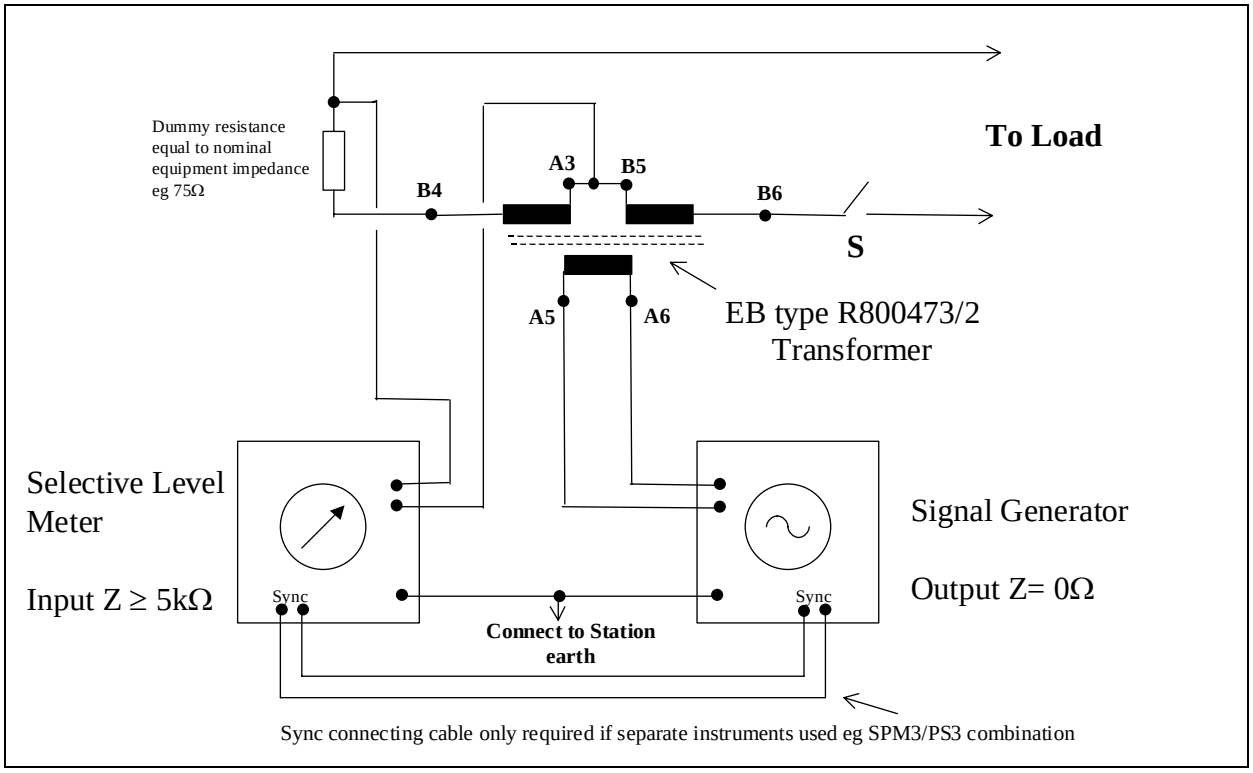


Fig 1. Measurement of Return Loss using transformer from EB LME

Measurement using the A1AC hybrid from ABB

1. When the SFZ-1 attachment is not available, a suitable substitute can be made by utilising the A1AC hybrid manufactured by ABB. An A1AC module can be obtained from any version of the Carrier Combiner Units (CCU-1…CCU-3) supplied to Eskom by ABB over the last few years.

2. The procedure to be followed is as described for the SFZ-1 bridge, with the exception that the equipment is set up as shown in Fig. 5. As before, "S" is opened to calibrate the "0dB" Return Loss point, and then closed for the actual measurement. It is important to note that link "X1" must be removed, and resistors R1…R3, short-circuited by an external jumper as shown before calibration or measurement can proceed.

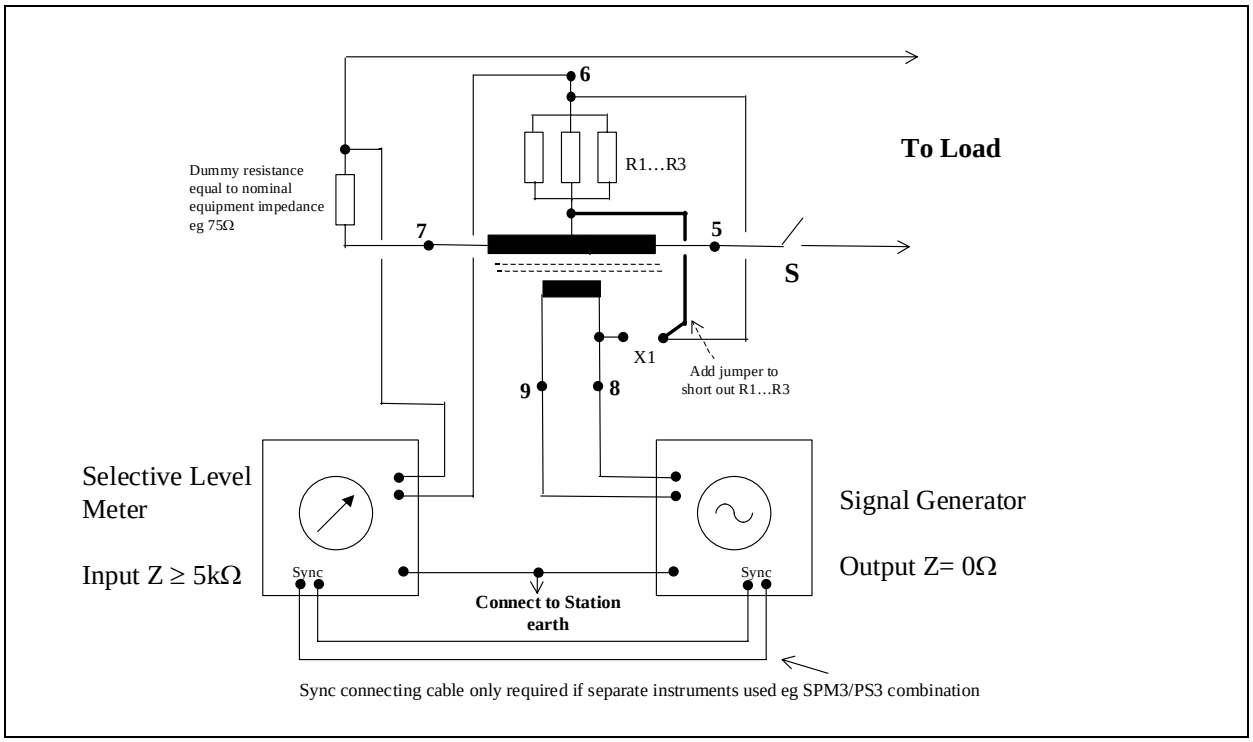


Fig 2. Measurement of Return Loss using A1AC hybrid from ABB

Measurement by Resistor Bridge Technique

1. For this technique, three resistors equal in value to the nominal equipment impedance are required.

2. For measurement of Return Loss relative to 75Ω nominal impedance, the circuit must be set up as shown in Fig. 3. It is important to note that the Selective Level Meter must be set for a 75Ω terminated reading, while the Signal Generator must be set for a source impedance of 75Ω.

3. To calibrate the system, open switch “S” and set the generator output level for a 0dBm reading on the level meter.

4. To measure return loss, close “S” and note the decrease in the reading on the level meter – this gives the value of Return Loss directly in dB.

5. Repeat for various frequencies across the coupling band of the LME

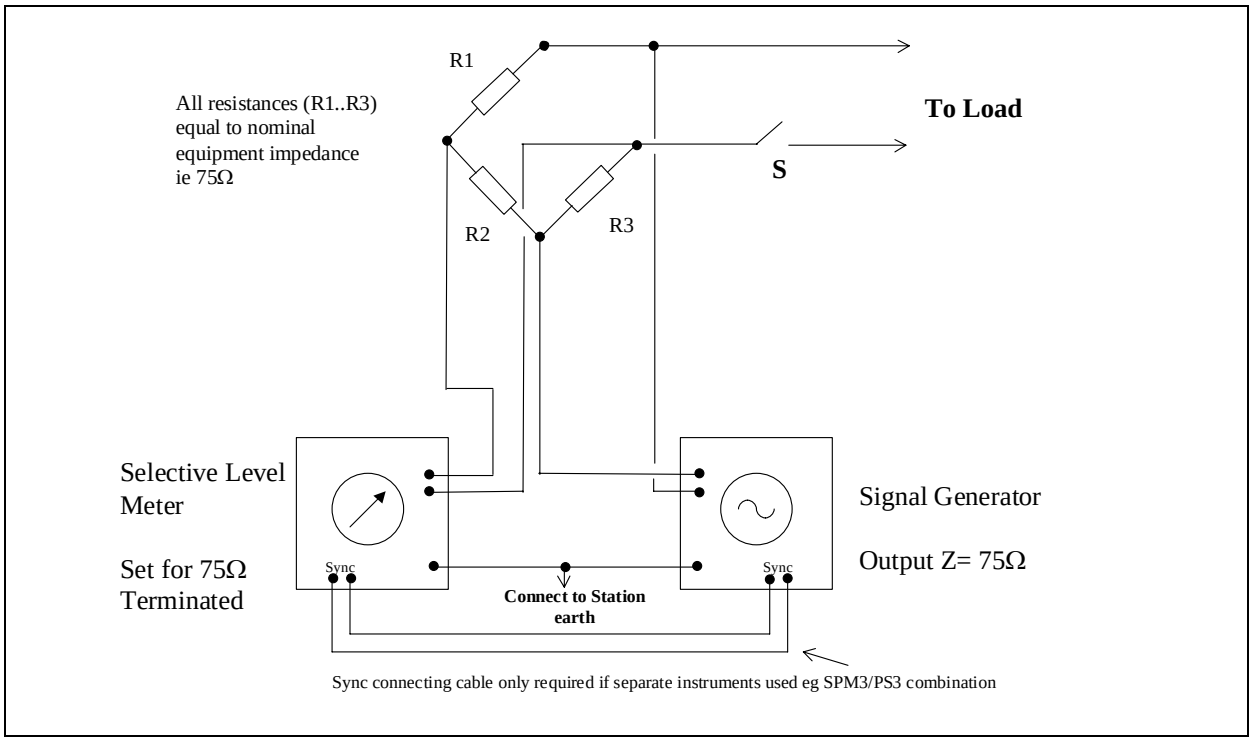


Fig 3. Measurement of Return Loss using Resistance Bridge

ANNEX 3 - TEST SHEETS

SHEET 1 – Tests on Coaxial Cable

Station: _____ **Distant Station:** _____

Feeder Number: _____ Line Number & Voltage: ___ , _____kV

Estimated cable length: _____m (X)

	R ϕ	**W ϕ**	**B ϕ**
Cable Number			
Measured loss At 500kHz	dB	dB	dB
Expected Loss ((X x 0.5)/100)dB	dB	dB	dB
Colour of cable sheath (black or grey)			
Signs of physical damage? (yes/no)			
If “Yes” give details			
Condition of Coax Connector & termination of cable			

Date of test: _____

Tested By: _____ _____
Print Name Signature

SHEET 2 – Tests on LMEs

Station: _____ **Distant Station:** _____

Feeder Number: _____ Line Number & Voltage: ___ , _____kV

LME Type: EB / ABB (A9BS) / ABB (A9BP) / Other: _____
(Circle type, if "Other" specify)

Values of dummy line components used: **C**=_____nF, **R**= _____Ω

	Rϕ			**Wϕ**			**Bϕ**		
Freq. (kHz)	Reading on meter (dB)	Insertion Loss (dB)	Return Loss (dB)	Reading on meter (dB)	Insertion Loss (dB)	Return Loss (dB)	Reading on meter (dB)	Insertion Loss (dB)	Return Loss (dB)
50									
100									
150									
200									
250									
300									
350									
400									
450									
500									

Date of test: _____

Tested By: _____ _____
Print Name Signature

SHEET 3 – Tests on Carrier Combiners

Station: _____ **Distant Station:** _____

Feeder Number: _____ *Line Number & Voltage:* ___ , _____*kV*

Type CCU-1

Measurement	Desired Level (dBu)	Measured Level (dBu)
Across R1	-12	
Across R2	-12	
Point 2 to Point 3	-6	

Type CCU-3

Measurement	Desired Level (dBu)	Measured Level (dBu)
Across R1	-15.0	
Across R2	-12.0	
Across R3	-15.0	
Point 2 to Point 3	-7.4	
Point 2 to Point 4	-9.0	
Point 3 to Point 4	-22.7	

Date of test: _____

Tested By : _____ _____
Print Name Signature