Eskom	Standard	Technology

Title: **APOLLO – SONGO HVDC ASYMMETRICAL HYBRID FOR POWER LINE CARRIERS**

Unique Identifier:	**240-146313203**
Alternative Reference Number:	**<n/a>**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**1**
Total Pages:	**11**
Next Review Date:	**August 2024**
Disclosure Classification:	**Controlled Disclosure**

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Date: 22/07/2019	Date: 23/7/2019	Date: 25/7/2019

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Date: 23 July 2019

PCM Reference: **240-53458797**

SCOT Study Committee Number/Name: **Telecommunications**

Content

Figures

Executive Summary

There are two HVDC power lines that extend from Apollo located near Pretoria in South Africa to Songo located near Cahora Bassa in Mozambique. The HVDC power from Cahora Bassa is transferred to Apollo via the two HVDC power lines and is converted to AC power and linked to the Eskom national power grid via the Apollo inverter station.

The Apollo – Songo HVDC line is approximately 1414 km with a single PLC repeater station at Pietersburg. The section of the HVDC line length from Pietersburg to Songo is approximately 1146 km making this one of the longest PLC links in the world. As a result, there are certain non-standard PLC link requirements to allow for the PLCs to operate on this condition.

The specification details the asymmetrical hybrid requirements for the Apollo – Songo PLC links.

1. Introduction

The Apollo – Songo HVDC system is rated for dispatching 1920MW generated by the Cahora Bassa Power Station in Mozambique to Eskom's grid in South Africa. The power transfer is achieved through two HVDC power lines from Songo (6 km from Cahora Bassa) to Apollo (at Pretoria) which have a length of 1414 km.

The Apollo – Songo HVDC line is approximately 1414 km with a single PLC repeater station at Pietersburg. The section of the HVDC line length from Pietersburg to Songo is approximately 1146 km making this one of the longest PLC links in the world.

The asymmetrical hybrid was designed for use on the Apollo –Songo HVDC PLC link to accommodate the long distance.

2. Supporting clauses

2.1 Scope

The document details the requirements for the asymmetrical hybrid.

2.1.1 Purpose

The document is required as the PLC requirements for the Apollo-Songo HVDC PLC link requires additional equipment to reduce the PLC link losses to manage the long line distance.

2.1.2 Applicability

This document shall be applicable to Eskom Transmission.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] 240-106920490, Specification for Power Line Carrier & Integrated Teleprotection Equipment.

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
ASH	Asymmetrical Hybrid
PEP	Peak Envelope Power

2.5 Roles and responsibilities

Not applicable.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

This specification is based on the symmetrical hybrid section in Eskom document, 240-106920490.

3. General

The main purpose of the hybrids is to split and combine the power line carrier signals onto the power line through the coupling equipment.

For the Apollo – Songo PLC system, the PLC signals need to be split between the phase conductor and the insulated earth conductor. The phase conductor and the insulated earth conductor are coupled through Coupling Capacitors and LMEs. Each LME has their own co-axial cable which would terminate into the asymmetrical hybrid (ASH) in the PLC cabinet.

For the Apollo-Songo PLC system, the signal split and recombination is not equal. The ratio of the split in the signal is 76% to the insulated earth conductor and 24% to the phase conductor. The reason for the asymmetrical split is to reduce the losses caused by the specific line design (includes the tower and conductor configuration (modal propagation)).

3.1 Equipment design

a) The primary and secondary windings shall have impedance taps of 75Ω. The primary windings shall be balanced and free from earth.

b) The ASH shall split/combine the PLC signal in the following combination:

1) Secondary part of Hybrid Transformer shall split the signal with a 76% of the signal ratio – connected to the LME on the Insulated Earth Conductor.

2) Secondary part of Hybrid Transformer shall split the signal with a 24% of the signal ratio – connected to the LME on the Phase Conductor.

Figure 1 displays the ASH and the signal splitter/combiner required. The transformer and components are only proposed values and the supplier can provide their own design as long as it provides the 76%/24% split as detailed above.

c) Each asymmetrical hybrid (ASH) shall be supplied with a non-inductive 50 W dummy load resistors, resistance detailed in figure 1, to enable the asymmetrical hybrid to function in either of the following modes:

1) Power splitting unit

Where the resistor prevents a short-circuit on the one secondary winding from short circuiting the complete hybrid.

2) Isolating hybrid

Where the resistor provides maximum isolation between the two secondary windings when the primary winding is terminated in its nominal impedance.

d) To comply with mode (i), the resistors shall have a minimum rating of 50W r.m.s. to handle the power dissipation when one line matching equipment earthing switch is closed. To meet the requirements of mode (ii), the load resistor shall be essentially resistive over the carrier frequency band.

e) The ASH shall have a maximum insertion loss of 0,5dB between primary and secondary windings, and a minimum return loss between secondary windings (trans-hybrid loss) of 30dB, when the primary winding is terminated in its nominal impedance, at any frequency in the carrier frequency range of 40kHz to 500kHz.

f) The ASH shall have a 1min power frequency withstand insulation of 2kV between primary and secondary windings and a 5kV, 1.2/50μs, 0.5J impulse withstand insulation between primary and secondary windings and earth.

g) The polarity of the secondary terminals relative to the primary terminals shall be clearly marked on the equipment or equipment drawings, so that the correct connections for phase-to-phase coupling can be easily determined.

h) The primary and secondary terminals shall be clearly marked to identify the terminals for:

1) The PLC

2) The LME to the insulated earth conductor (76% signal ratio)

3) The LME to the phase conductor (24% signal ratio)

i) The asymmetrical hybrid shall have a minimum PEP rating of 400W with intermodulation products at least 80dB down on the PEP level.

j) The asymmetrical hybrid shall have a minimum Continuous Wave rating of 100W.

k) The co-axial plugs shall be of the PL159 crimp type suitable for RG11A/U cable, e.g. “Suhner” type 11 UHF-0-7-19c/022, or similar.

l) All carrier combiners shall be tested for insertion loss and phasing of the signals to the individual Line Matching Equipment (LMEs) as specified in Eskom’s order document.

m) The carrier combiner shall be supplied complete by the supplier, with all the components shown on Figures 1 and 2 and shall include the engravings, co-axial plugs and sockets, hybrids, dummy load resistors and surge arrestors.

n) The carrier combiner wiring, terminals, etc. shall be to Eskom’s approval and details must be furnished at the time of tendering.

o) The carrier combiners shall be fitted at the rear of the carrier cabinet, in a position so as not to interfere with the cabinet terminal blocks in the cabinets specified in Eskom’s order document. The proposed dimensions are listed below. If the dimensions are greater than specified below, then Eskom shall evaluate and confirm if the dimensions are acceptable or not.

i. Length: 38cm

ii. Width: 28cm

iii. Height: 10cm

3.2 Routine Tests

a) The polarity of the secondary terminals relative to the primary terminals shall be checked to ascertain that all terminals are correctly marked in conformance with the equipment drawings.

b) The insertion loss between primary and secondary windings shall be measured at a nominal frequency of 100kHz.

c) The return loss between secondary’s (trans-hybrid loss) shall be measured at a nominal frequency of 100kHz with the primary winding terminated in its nominal impedance.

3.3 Type Tests

a) Insulation Tests

The symmetrical hybrid insulation shall be tested by means of a 2kV one minute power frequency withstand test voltage and a 5kV 1,2/50 μs 0,5 joule impulse withstand test voltage, between the primary and secondary windings and earth, as well as between the secondary and primary windings and earth.

b) Insertion loss test

The insertion loss between the primary and secondary windings, over the specified carrier frequency band, shall be measured when the windings are terminated in the nominal impedances specified.

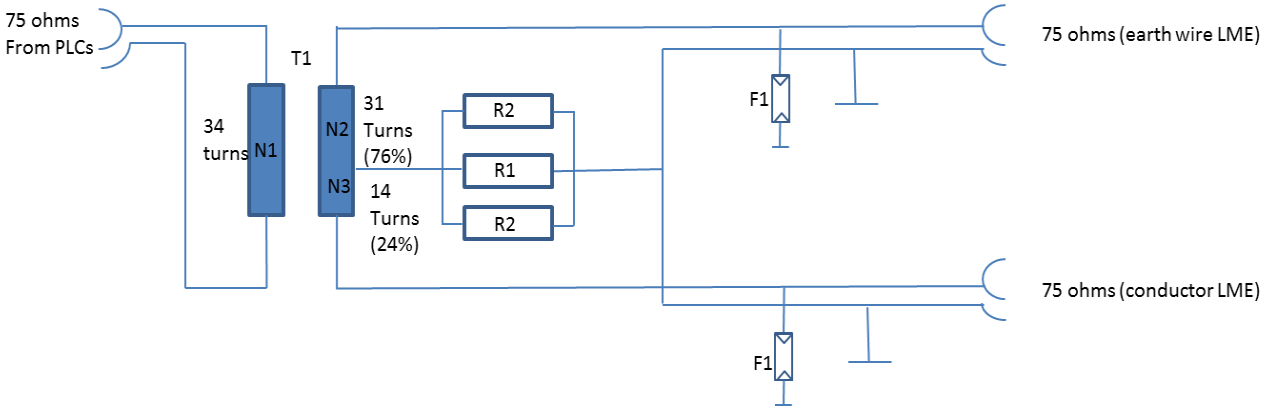
c) Trans-hybrid loss test

Trans-hybrid loss between the secondary windings (i.e. from secondary winding to secondary winding), over the specified carrier frequency band, shall be measured when the primary winding is terminated in the specified nominal impedance.

d) Intermodulation tests

The PEP versus Intermodulation distortion shall be measured over the specified carrier frequency band as detailed in 12.3 of IEC 60481.

As alternative the manufacturer's calculations of PEP rating and intermodulation distortion over the specified frequency range will be accepted.



T1 – Hybrid Transformer
N1 – Primary part of Hybrid Transformer with 34 turns
N2 – Secondary part of Hybrid Transformer with 31 turns (76% of signal-ratio)
N3 – Secondary part of Hybrid Transformer with 14 turns (24% of signal-ratio)
R1 – Non-inductive 50 W resistor, resistance of 150 ohms
R2 – Non-inductive 50 W resistor, resistance of 100 ohms
F1 – 350 V Gas Arrester (Surge Arrester)

Figure 1: Electrical diagram of the Asymmetrical Hybrid for the Apollo – Songo HVDC PLC System

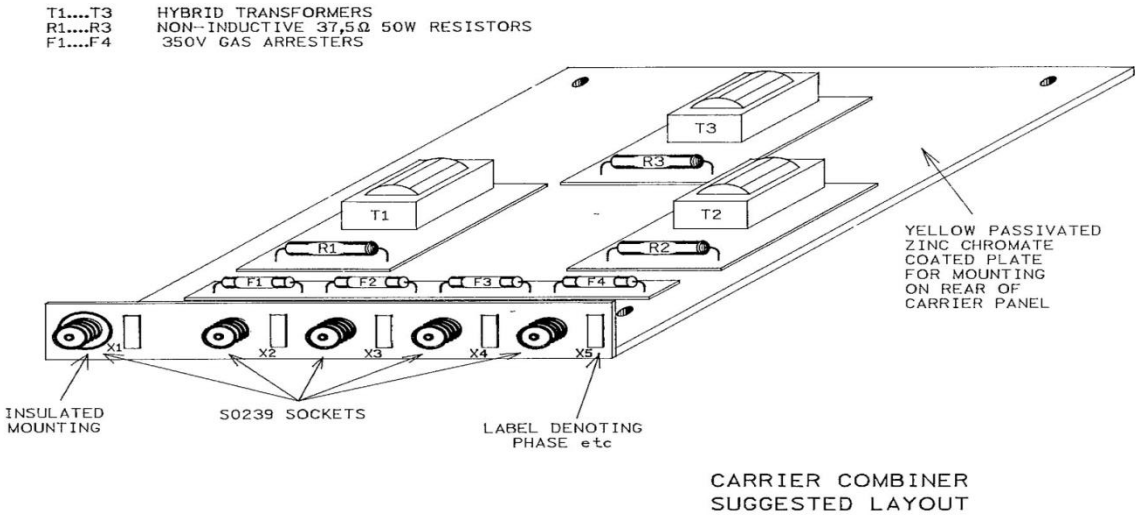


Figure 2: Layout diagram of the Asymmetrical Hybrid

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Lenah Mothata	Senior Manager – Grids
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5. Revisions

Date	Rev	Compiler	Remarks
Aug 2019	1	T. Gosai	Original document and business requirement

6. Development team

The following people were involved in the development of this document:

- T. Gosai
- A. Pereira

7. Acknowledgements

Not applicable.

Annex A – Technical Schedules A/B

ITEM	DESCRIPTION				COLUMN A PARTICULARS OF ESKOM'S REQUIREMENTS	COLUMN B GUARANTEED TECHNICAL PARTICULARS OF EQUIPMENT OFFERED	REMARKS
ASH	1.	Symmetrical Hybrid					
		(i)	Manufacturer				
		(ii)	Manufacturer's type reference				
		(iii)	Winding construction				
		(iv)	Impedance ratio:				
3.1.a)		a)	Connections to LME unbalanced ohms		75		
			Impedance taps provided if any ohms		Specify		
3.1a)		b)	Connection to carrier equipment balanced ohms		75		
3.1.e)		(v)	Frequency pass band	kHz	Specify		
3.1e)		(vi)	Maximum insertion loss of transformer over pass band	dB	0,5		
3.1i)		(vii)	Rated PEP handling with inter-modulation products at least 80 dB below rated PEP				
		(a)	At 50 kHz minimum	Watts	Specify		
		(b)	At 100 kHz minimum	Watts	Specify		
		(c)	At 250 kHz minimum	Watts	400		
		(d)	At 500 kHz minimum	Watts	400		
3.1j)		(viii)	Rated RMS power handling capacity	Watts	100		

ITEM	DESCRIPTION				COLUMN A PARTICULARS OF ESKOM'S REQUIREMENTS	COLUMN B GUARANTEED TECHNICAL PARTICULARS OF EQUIPMENT OFFERED	REMARKS
3.3		(ix)	Type Test Reports				
			Are the following reports available and provide the location of the reports in the tender documentation:		Yes/No and specify location in tender documentation		
3.3a)			Insulation tests				
3.3b)			Insertion loss test				
3.3c)			Trans-hybrid loss test				
3.3d)			Intermodulation tests				
3.2		(x)	Routine Tests				
			Are the following reports available and provide the location of the reports in the tender documentation:		Yes/No and specify location in tender documentation		
3.2a)			Polarity test				
3.2b)			Insertion loss				
3.2c)			Return loss				
(3.1c)	2.	Dummy Load					
		(i)	Resistive value	Ohms	37,5		
		(ii)	Inductance value	H	0		
		(iii)	Minimum power rating	W rms	50		
3.1k)	3.	(i)	Combiner fitted with UHF sockets type S0239 and crimp plugs type PL259		YES		
		(ii)	Input socket to SSBs isolated from earth		YES		
		(iii)	Outputs sockets earthed		YES		

ITEM	DESCRIPTION				COLUMN A PARTICULARS OF ESKOM'S REQUIREMENTS	COLUMN B GUARANTEED TECHNICAL PARTICULARS OF EQUIPMENT OFFERED	REMARKS
	4.	(i)	Output sockets fitted with gas discharge tubes		YES		
		(ii)	Striking Voltage	V	350		
	5.	(i)	Number of asymmetrical hybrids		1		
		(ii)	Number of dummy load resistors		Specify		
	6.	Number of Input / Output Co-Ax Sockets			3		
Figure 2.	7.	Suitable for fitting in the carrier cabinet for all PLC ratings.			YES		