APPENDIX I MARKING \( \delta_{MPU} - \delta_{KBG} = 120^\circ \) AND \( \delta_{MPU} - \delta_{KBG} = 240^\circ \) ON THE SWING LOCUS

This appendix shows how the network condition \( \delta_{MPU} - \delta_{KBG} = 120^\circ \) and \( \delta_{MPU} - \delta_{KBG} = 240^\circ \) are marked on the impedance locus the swing traces. The case considered is the swing locus the detailed network model traces.

\( \delta_{POOL} = \delta_{MPU} - \delta_{KBG} \) is the power angle that develops between \( E_{MPU}^* \) and \( E_{KBG}^* \).

I.1 MARKING \( \delta_{MPU} - \delta_{KBG} = 120^\circ \) AND \( \delta_{MPU} - \delta_{KBG} = 240^\circ \) ON THE SWING LOCUS THE DETAILED NETWORK MODEL TRACES

Figure I.1 and figure I.2 show the per unit impedance seen at the Hydra busbar of the detailed network model obtained for the case when \( \delta_{MPU} - \delta_{KBG} = 120^\circ \) and when \( \delta_{MPU} - \delta_{KBG} = 240^\circ \). The MVA base used is 100 MVA.

To change the per unit impedance to be an impedance measured in ohms the per unit impedance is multiplied with the base impedance. When using a 100 MVA base the base impedance, \( Z_B \), computed for a 400 kV network is:

\[
Z_B = \frac{V_B^2}{S_B} = \frac{[400]^2}{100} = 1600
\] (I.1)
FIGURE I.1 The per unit impedance seen at Hydra when $\delta_{MPU} - \delta_{KBG} = 120^\circ$

FIGURE I.2 The per unit impedance seen at Hydra when $\delta_{MPU} - \delta_{KBG} = 240^\circ$
Table I.1 lists the impedances seen at Hydra. All the impedances listed are in ohms.

Positive current is defined to be the current flowing from Mpumalanga to the Western-Cape. Hence, the sign shown in figure I.1 and in figure I.2 for the impedance seen when “LOOKING TO BETA” should be changed.

**Table I.1 Impedance seen at Hydra**

<table>
<thead>
<tr>
<th>FORWARD DIRECTION OF DISTANCE RELAY</th>
<th>SEEN IMPEDANCE [Ohm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\delta_{MPU} - \delta_{KBG} = 120^\circ$</td>
</tr>
<tr>
<td>Looking towards Mpumalanga</td>
<td>$49.12 - j6.72$</td>
</tr>
<tr>
<td>Looking towards Koeberg</td>
<td>$88.96 + j14.72$</td>
</tr>
</tbody>
</table>

**FIGURE I.3** Impedance locus traced by the detailed network model obtained for the case where the out-of-step relay is located at Hydra and the forward direction of the relay is towards Mpumalanga.

Figure I.3 shows the impedance locus the swing traces when the out-of-step relay is located at Hydra and the forward direction of the relay is towards Mpumalanga.
FIGURE I.4 Procedure used to mark the network condition $\delta_{MPU} - \delta_{KRG} = 120^\circ$

and $\delta_{MPU} - \delta_{KRG} = 240^\circ$ on the impedance locus shown in figure I.3

FIGURE I.5 Impedance locus traced by the detailed network model obtained for the case where the out-of-step relay is located at Hydra and the forward direction of the relay is towards Koeberg
Figure I.4 illustrates how the network condition $\delta_{MPU} - \delta_{KGB} = 120^\circ$ and $\delta_{MPU} - \delta_{KGB} = 240^\circ$ are marked on the swing locus shown in figure I.3. The impedances marked in figure I.4 are listed in table I.1.

Figure I.5 shows the impedance locus the swing traces when the out-of-step relay is located at Hydra and the forward direction of the relay is towards Koeberg.

Figure I.6 illustrates how the network condition $\delta_{MPU} - \delta_{KGB} = 120^\circ$ and $\delta_{MPU} - \delta_{KGB} = 240^\circ$ on the impedance locus shown in figure I.5.

Figure I.6 illustrates how the network condition $\delta_{MPU} - \delta_{KGB} = 120^\circ$ and $\delta_{MPU} - \delta_{KGB} = 240^\circ$ are marked on the swing locus shown in figure I.5. The impedances marked in figure I.6 are listed in table I.1.