# ETAP Workshop Notes

**Unit Generator Step Up Transformer Tap Optimization**

## Unit Generator Step Up Transformer Tap Optimization

### Theoretical concepts

The ETAP transformer tap optimization module is to optimize the tap setting of a step up generator unit transformer tap changer based on ANSI/IEEE Standard C57.116 1989. This module is used to determine the optimal transformer tap (turns ratio) so that the transformer is capable of delivering/exporting the maximum Mvar output OR importing maximum reactive power within generator PQ capability under various grid source operating voltage variations without generator operating outside its allowable terminal voltage range.

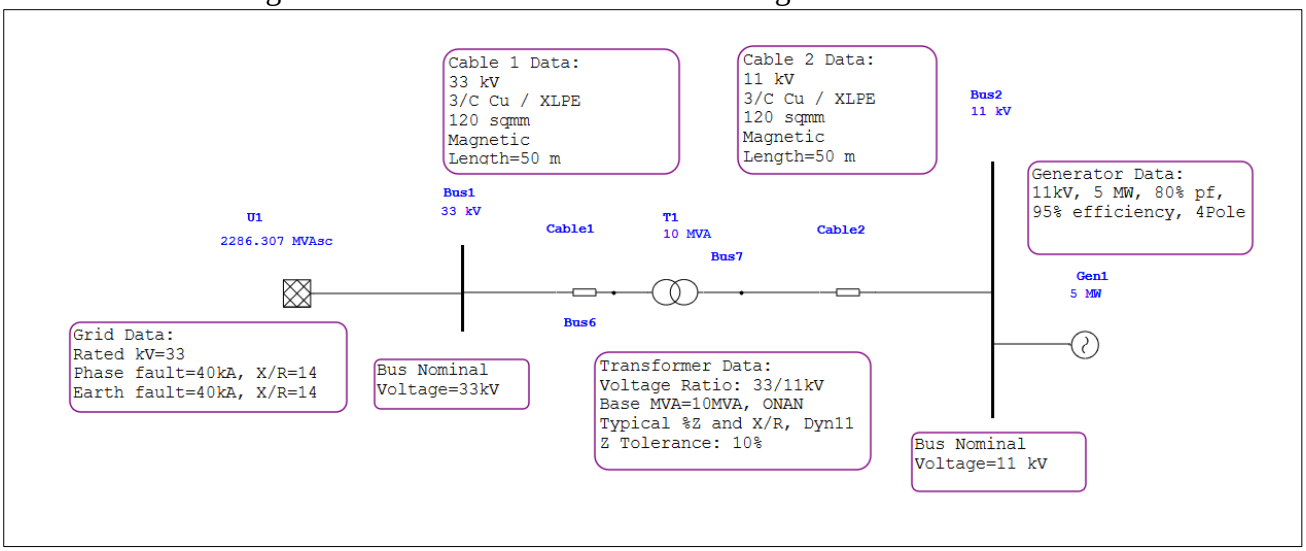
For the selected or optimised tap setting the module run results are presented in graphical form showing the reactive power export or import under a range of plus/minus grid voltage for various generator terminal voltages ranging from its permissible maximum and minimum terminal voltage range.

This chapter describes the interfaces, input, and output data necessary to run the transformer tap optimization module. Other associated operations including data update, plotting, and printing will also be explained, along with a brief view of the related standard. The calculation method and the data required for the transformer tap optimization calculation will be outlined as well.

### Purpose and Description

The transformer tap optimization calculation optimizes a unit transformer tap, or equivalently, its turn ratio, to ensure that the generator unit voltage remains within its upper and lower variation range (typically 95% to 105%), while producing its full MW and Mvar export or import capability under the grid source system voltage variation.

This exercise involves creating the below shown SLD and entering the corresponding data. The detail modelling of the SLD is shown in the below image.



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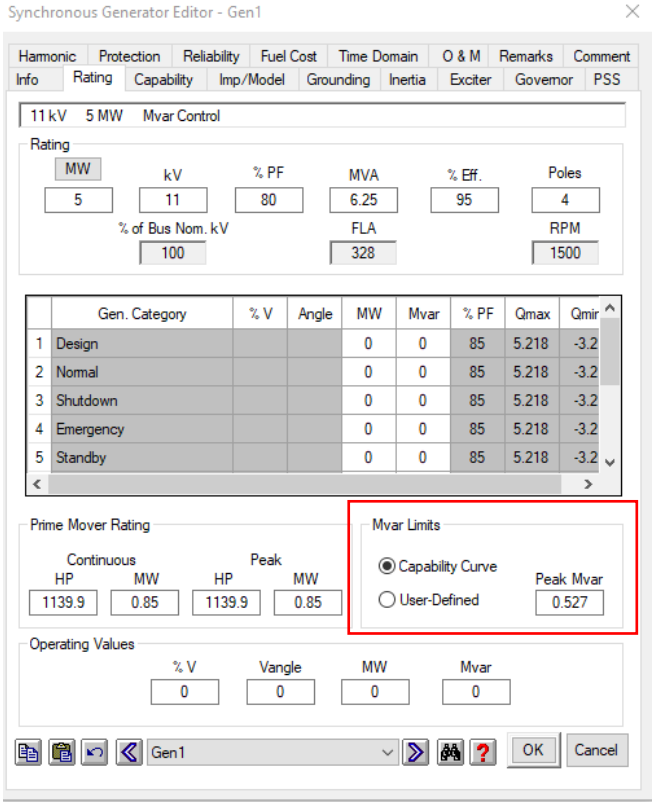
***Note:***

***1. While preparing SLD the unit generator step up transformer should be aligned or rotated in such a manner that its primary winding side is connected to the grid.***

***2. The generator auxiliary load is ignored in this exercise.***

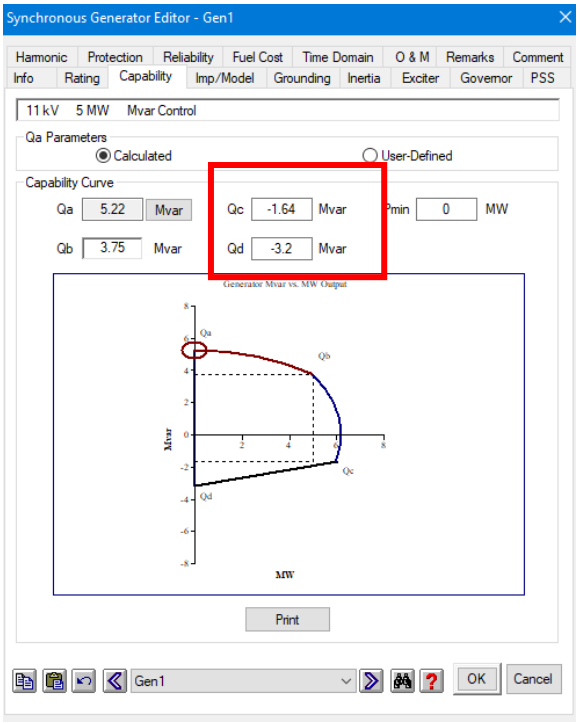
1. Create the above shown SLD and entered the above input data into the ETAP.

2. While modelling the generator note that, generator is in MVAR control mode. and the MVAR limits is based on Capability curve.




3. For the generator, the PQ capability curve should be obtained from the vendor. In this exercise the PQ curve consider is shown below image:

## Unit Generator Step Up Transformer Tap Optimization




The negative MVAR limit is found by below formulae after allowing for 10-20% safety margin to prevent generator operation at its theoretical stability limit (The –ve MVAR represents the MVAR input to generator operating at leading power factor):

MVAR_Gen (import)= Gen MVA * SCR *0.8 = Gen MVA * 0.8 / xd (pu)

Where SCR= Short Circuit Ratio = 1 / xd (pu)

For Generator MVA of 6.25 and generator Xd of 1.55 pu as in this example the MVAR import which was not plotted in PQ diagram by etap can be manually entered as below: Qd = -3.2 MVAR and Qc = -1.64 MVAR (considered as 95% leading power factor limit at full generator MW export) into the capability page of generator.

4. To access the transformer tap optimization calculation, go to the tap page of the 2-winding transformer editor. Check the unit transformer for generator check box and the tap optimization button will appear on the right of this page. Select a generator from the pull-down list, then click on the button to launch the transformer tap optimization editor.

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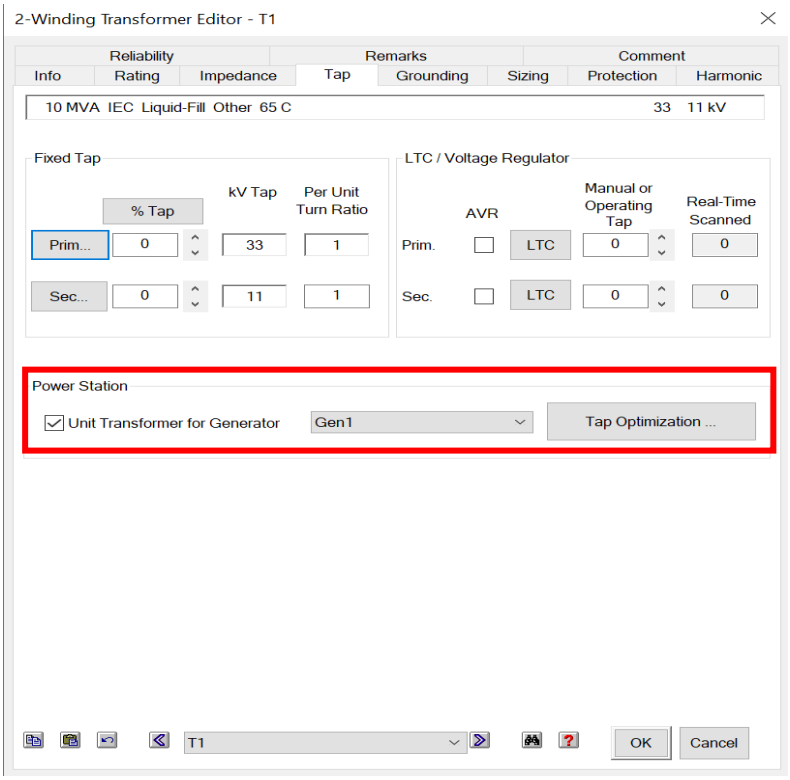
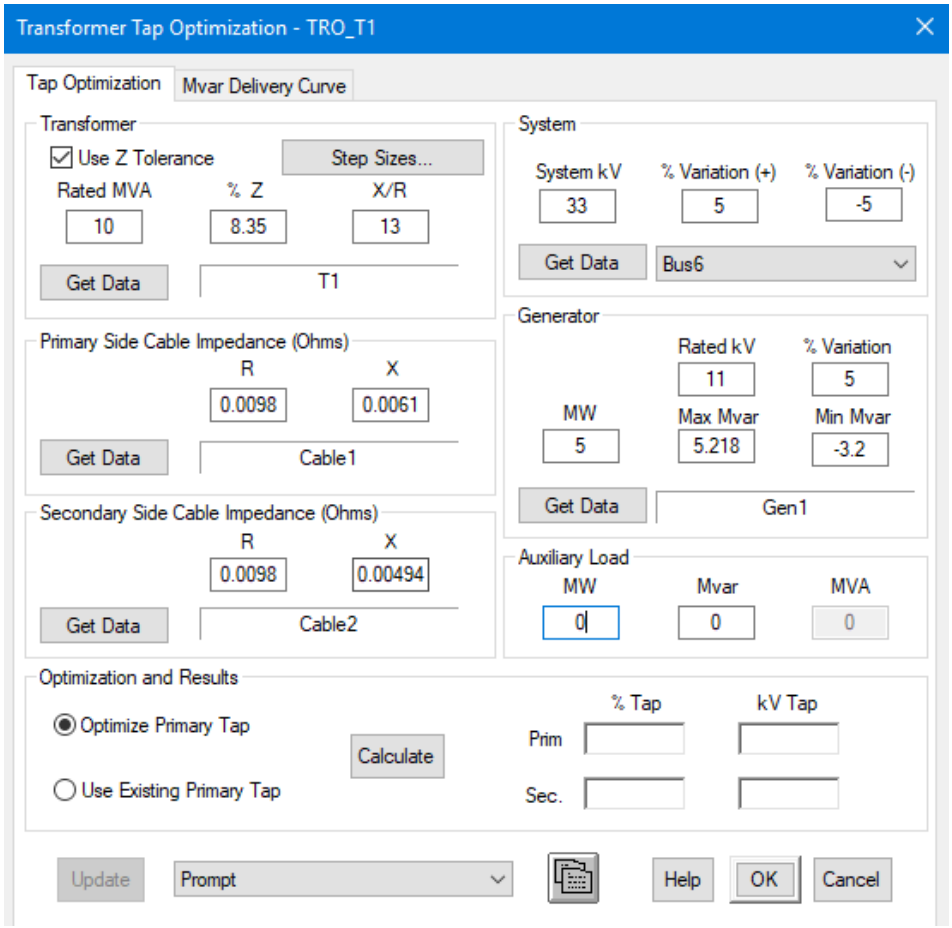



5. Click on tap optimization. The transformer tap optimization editor has 2 pages:
   1.Tap optimization page
   2.Mvar delivery curve page

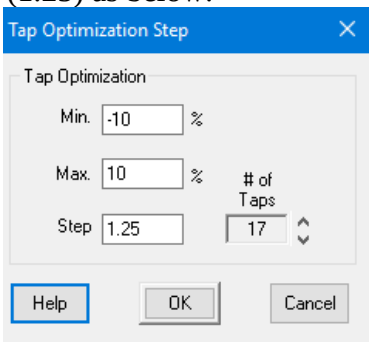
6. In the tap optimization page, select get data for all the components.
   i.e. for transformer, system, primary and secondary cables and generator.
   Also enter the MW rating of generator as 5 MW.

7. Make sure that '**Use Z tolerance**' option for transformer is checked.

## Unit Generator Step Up Transformer Tap Optimization

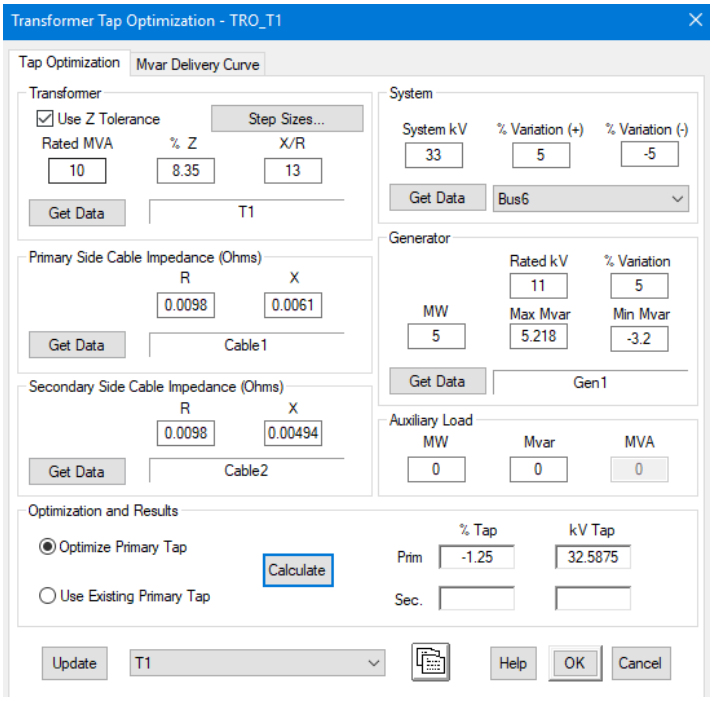



8. In the step size option for transformer, enter the minimum & maximum tap settings (± 10% ) with step size (1.25) as below:




9. After finishing of all the inputs, click on '***calculate'*** option available at the bottom of the page.

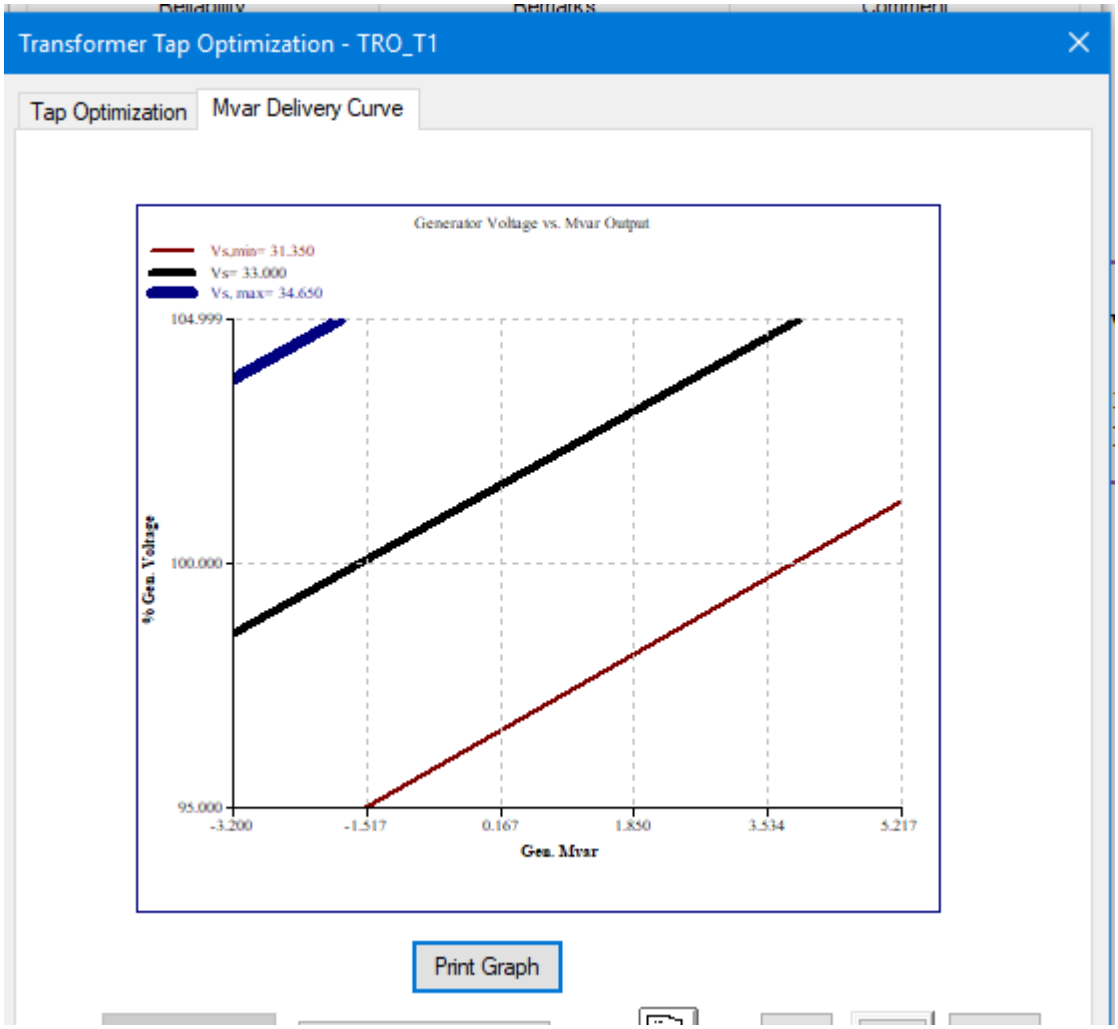
## Unit Generator Step Up Transformer Tap Optimization




10. Now based on the input data ETAP will calculate the optimal size of the transformer tap.
11. Note that the estimated optimal size for tap is -1.25%.
12. Click on Mvar Delivery Curve Page. It displays the results of the Transformer Tap Optimization calculation in a graphical format.

    The plot depicts generator voltage vs. the generator reactive power output. This format is also called the generator reactive power (Mvar) delivery capability, because it shows the generator reactive power output range at the calculated transformer tap and system operating voltages. The plot below contains three delivery curves at three different system-operating voltages. The first voltage is the actual system rated voltage while the other two plots are based on the voltage variation (max and min) specified in the editor.

## Unit Generator Step Up Transformer Tap Optimization

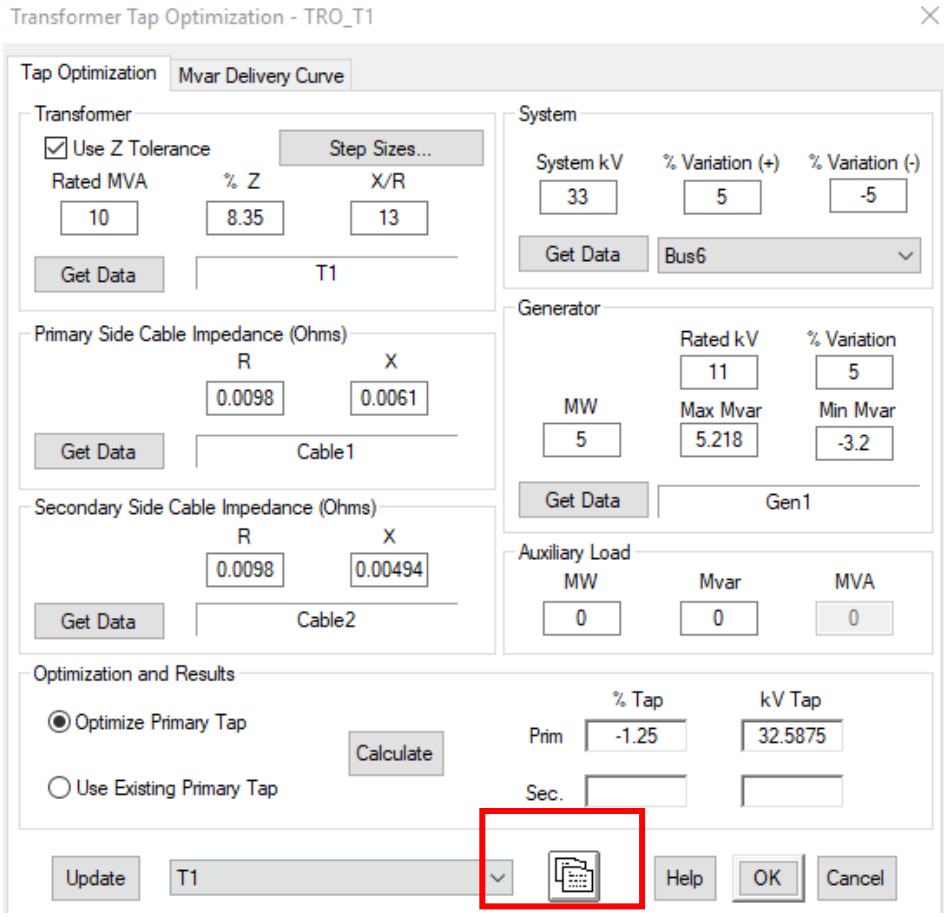



**Note:**

The graph is not accurate if the generator transformer rated voltage and the bus nominal voltage are not same.
However, the results in the report are correct. The same will be rectified and updated here also.

13. To check the report for optimal tap position, click on the report manager (available on bottom of page tap optimization). Go to the result tab and select the result in pdf format.

## Unit Generator Step Up Transformer Tap Optimization




14. The Report will be generated as follows:

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## Unit Generator Step Up Transformer Tap Optimization

**Calculation Method:** Primary Tap Optimization

| | % Tap | kV Tap |
|---|---|---|
| **Optimal Tap Position:** | -1.25 | 32.588 |

**System Power Flow**
**at the Optimal Transformer Ratio**

| System Voltage | | Generator Voltage | | Generator Output | | | Transformer Output | | | Transformer Input | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kV | % | kV | % | MW | Mvar | % PF | MW | Mvar | % PF | MW | Mvar | % PF |
| 31.350 | 95.00 | 10.450 | 95.00 | 5.000 | -1.540 | 95.57 | 4.976 | -1.819 | 93.92 | 5.000 | -1.540 | 95.57 |
| | | 11.000 | 100.00 | 5.000 | 3.798 | 79.63 | 4.969 | 3.436 | 82.25 | 5.000 | 3.798 | 79.63 |
| | | 11.137 | 101.25 | 5.000 | 5.218 | 69.19 | 4.960 | 4.749 | 72.23 | 5.000 | 5.218 | 69.19 |
| 32.175 | 97.50 | 10.554 | 95.95 | 5.000 | -3.200 | 84.23 | 4.970 | -3.552 | 81.35 | 5.000 | -3.200 | 84.23 |
| | | 11.000 | 100.00 | 5.000 | 1.056 | 97.84 | 4.979 | 0.816 | 98.69 | 5.000 | 1.056 | 97.84 |
| | | 11.403 | 103.67 | 5.000 | 5.218 | 69.19 | 4.961 | 4.771 | 72.08 | 5.000 | 5.218 | 69.19 |
| 33.000 | 100.00 | 10.842 | 98.56 | 5.000 | -3.200 | 84.23 | 4.971 | -3.534 | 81.50 | 5.000 | -3.200 | 84.23 |
| | | 11.000 | 100.00 | 5.000 | -1.686 | 94.75 | 4.978 | -1.943 | 93.16 | 5.000 | -1.686 | 94.75 |
| | | 11.550 | 105.00 | 5.000 | 3.922 | 78.68 | 4.971 | 3.585 | 81.11 | 5.000 | 3.922 | 78.68 |
| 33.825 | 102.50 | 11.128 | 101.17 | 5.000 | -3.200 | 84.23 | 4.973 | -3.517 | 81.64 | 5.000 | -3.200 | 84.23 |
| | | 11.128 | 101.17 | 5.000 | -3.200 | 84.23 | 4.973 | -3.517 | 81.65 | 5.000 | -3.200 | 84.23 |
| | | 11.550 | 105.00 | 5.000 | 1.042 | 97.90 | 4.981 | 0.824 | 98.66 | 5.000 | 1.042 | 97.90 |
| 34.650 | 105.00 | 11.415 | 103.77 | 5.000 | -3.200 | 84.23 | 4.974 | -3.501 | 81.77 | 5.000 | -3.200 | 84.23 |
| | | 11.415 | 103.77 | 5.000 | -3.200 | 84.23 | 4.974 | -3.501 | 81.77 | 5.000 | -3.200 | 84.23 |
| | | 11.550 | 105.00 | 5.000 | -1.838 | 93.86 | 4.980 | -2.075 | 92.31 | 5.000 | -1.838 | 93.86 |