

Advanced Tuning Methods in PEPSE[®], Demonstrated by Application to a Design Mode Nuclear Reheater

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ABSTRACT

This paper presents advanced methods that can be used effectively to solve difficult analysis tasks that otherwise sometimes do not converge in PEPSE. The analyses of interest here involve the use of controls to calculate a component's tuning factor. Design mode nuclear reheater tuning is a useful example for discussion of difficulties that may occur and for demonstration of alternative methods to overcome the difficulties.

Some analysis applications using PEPSE are challenging to both the program and to the modeler. Commonly many design mode calculations require tuning in order to obtain a match between calculations and measured or design-predicted performance at a known condition. Once a tuning factor has been obtained, it is available subsequently for analyses of general conditions. For example tuning of a heat transfer factor in a design mode nuclear reheater component may be used to match the performance that is claimed on a vendor's specification sheet. Once found/tuned, this factor is applied as a characteristic of the reheater for later analysis tasks.

The specific advanced methods discussed are the control, with significant use of optional inputs, the control block, the sensitivity study feature, and the optimization feature.

Introduction

Many PEPSE modelers are experienced in the use of controls for specialized and custom calculations. For example a control could be used in an established model to compute the main steam pressure needed by a steam turbine to generate a target amount of electric power. In the vast majority of cases, the use of controls for these calculations is routine. However, some analysis cases present extra challenges for PEPSE. For a successful solution, you may need to try advanced methods.

These kinds of special challenges can arise in a number of different types of system analyses, such as in tuning input variables for a design mode nuclear reheater to match known behavior, in tuning for heat transfer results in a design mode fossil boiler model, in tuning calculations in a combined cycle model, and others.

How a Control Works

In a normal/basic application of PEPSE, we specify the required inputs for the model, and the program uses these inputs to “march” through the model, calculating outputs. We could call the results, y , and we could call the inputs x . We specify the x 's; PEPSE calculates the y 's for us. The result value of y depends on the input value of x .

In some applications the result, y , may be known, but the input, x , is not known, and we want to use PEPSE to obtain x for us. It would be relatively straightforward for us to guess a value of x and to run a PEPSE case to see what y would be produced and then to do a second run using a different guessed x . This running of cases could be repeated over and over again by trial and error until our guessed input, x , was “the right one”. Plotting the results of this trial and error process might help to reduce the number of guesses that were needed to give us the desired y (thus x).

The mechanism of a control contains the essence of the use of a plot of y versus x . The curve is generated by incrementing the x value from iterate to iterate and observing the changes that occur in y . The slope of the curve is used in order to move to a new guessed x for an ensuing iterate, and so forth, until the result value y is tolerably close to the desired/target value.

In concept y is a function of x . The calculation method used in the control assumes that changes of other x 's, inputs, in the model have no effect to alter y . Even though this is rarely strictly true, the assumption of a single y depending on a single x is good enough to solve the vast majority of problems faced by controls.

Again, to give meaning to these ideas by a specific example, consider that we may have a verified/validated model of a turbine cycle and that the input data are complete and that the calculated electric generation is 650 MW. The input data include a specified value of main steam pressure, among others. Suppose it is desired to find out the main steam pressure that is needed in order to change the output to 640 MW. Many details are involved (in

passing, it is emphasized that Special Option Number 1 is needed in order to obtain reliable results), but the focus here is on controls. In order to run this analysis, a control can be specified wherein the x variable is main steam pressure (an input variable) and the y variable is electric generation (a result variable). The pressure that is specified in input is used as a first guess in the control, and the control adjusts this value as iterations proceed in order to match the calculated y value with its target value.

The Kinds of Challenges

Most commonly, evidence of challenges in the use of controls is seen in a PEPSE analysis case that does not converge, giving instead an “abnormal termination”, or in an analysis that terminates with a “fail” message.

The causes of computational difficulties for controls are not always known explicitly. Furthermore, the causes can be difficult to track down. Some causes that are known may be:

1. There may be a computational delay (requiring several iterates to settle out) between the incrementing of the x variable and the y variable of the control.
2. There may be no functional relationship between the x and the y variables.
3. Convergence may proceed slowly, requiring an unusually large number of iterates.
4. The increment of the x variable according to the control’s algorithm may be large, such that the x variable is driven out of reasonable or physically possible range. The numerical assumption underlying the algorithm is that perturbations are “small”.
5. PEPSE has been programmed with many fixups that take over when variables go out of range. Many of these fixups are distinct and separate from the control feature itself. When these occur, the cause and effect relationship between x and y becomes disconnected. This disconnect is unknown to the control’s algorithm. The control cannot do its job without good information.
6. A large number of controls in a model may cause jitter/noise in the numerical solution, thus preventing convergence.
7. When there are multiple controls in a model, there is substantial chance that the y variables in the controls are interdependent on all of the x variables in the controls. Interdependence of this nature violates the underlying assumption of the controls’ algorithm. Sometimes addition of a control block to the control can yield a successful result.

Example Illustration – Nuclear HP Reheater

Tuning the heat transfer calculations in a design mode nuclear reheater component poses a challenging application of a control. The main causes are numbers 5 and 7 above.

The figure below shows a submodel containing an HP stage of an MSR. The submodel includes the reheater component, along with the needed sources to furnish cycle steam and heating steam and the sinks needed to receive the outflows from the reheater.

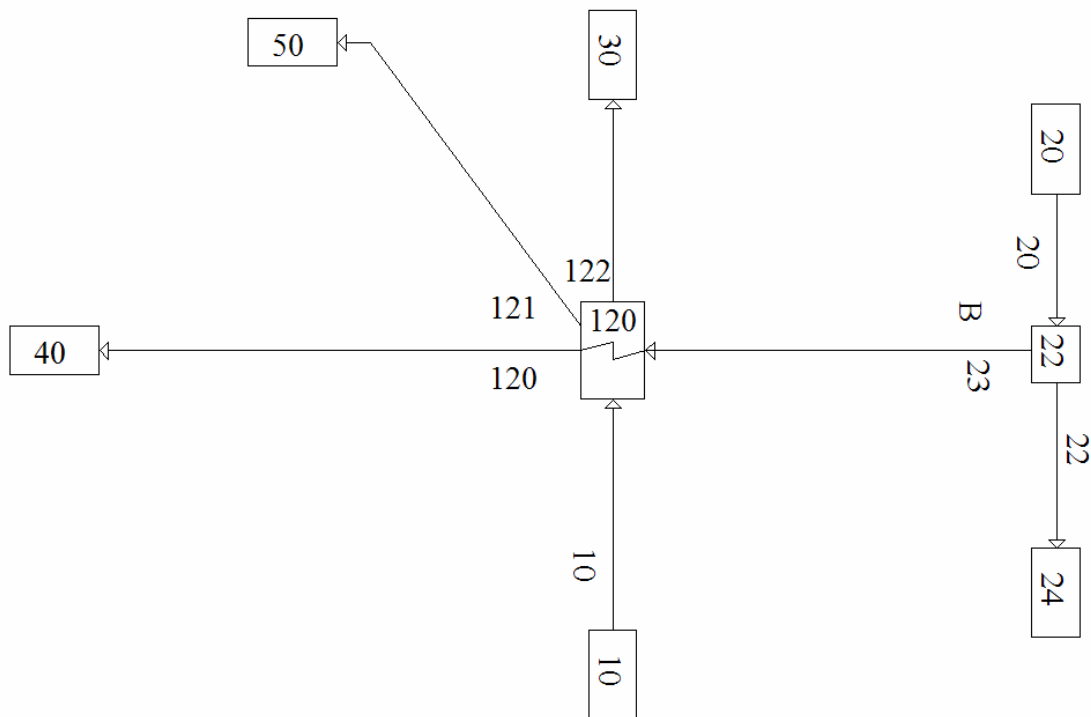


Figure 1 Nuclear HP Reheater Submodel

In the submodel, demand splitter 22 supplies the heating steam to the reheater and source 10 supplies the cycle steam. Sink 30 receives the heated cycle steam. Sink 40 receives the condensed heating flow extracted after the second tube pass of the tube-side flow. Sink 50 receives the condensed heating flow (plus any “excess” or “scavenging” steam) that exits the fourth tube pass of the reheater.

This reheater is defined by design mode 6 input data. In this tubing arrangement, shown in Figure 2, the cycle steam enters at the bottom and flows upward through the shell side of

the reheater. The cycle steam flows over the second, third, fourth, and first tubing passes of the heating steam's flow, in that order.

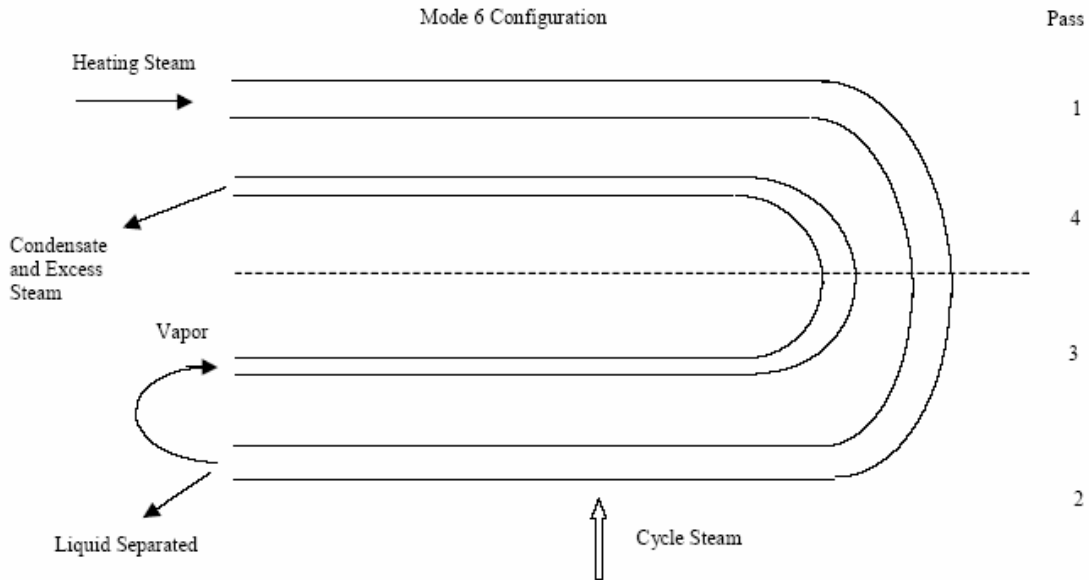


Figure 2 Flow Path of Cycle Steam Over the Four Tube Passes

The objective in the use of the submodel is to match the computed performance with the MSR vendor's performance summary. This involves tuning heat transfer coefficients. The inputs to the model include the incoming conditions and flows and the details of the reheater's internal geometry and material, and so forth.

Table A of Appendix A shows the .job file of the basic model. While the inputs were developed by responses to forms in the graphics program, the easiest way to show all of the inputs here is via the .job file. The table is a comprehensive presentation of all of the data entered for this basic model. In order to interpret the inputs, see the PEPSE input manual, Ref 1.

Future use of this model is intended to predict the reheater's performance under varying operating conditions. To satisfy this intent, we ground the design mode model in the best information available. In most cases, this is the vendor's detailed structural and thermal specification provided with the reheater. The structural description and the inlet conditions are specified in PEPSE as inputs. The model is run, and the results are compared with the vendor's performance summary. Generally, the calculated results do not match the vendor's summary. Tools for tuning the calculations are called upon then.

In the example here, there are two heat transfer coefficient multipliers used for this tuning. As inputs to PEPSE, these are x variables, from the perspective of controls. The first

multiplier applies to the first and second passes, and the second applies to the third and fourth passes.

Using the Basic Control Method of Solution

Controls are defined, using the HTTIR1 and HTTIR3 tuning factors in order to obtain a match with vendor claims. These are multiplying factors that are taken times the internally calculated heat transfer coefficients for the first and third passes, respectively. Note that HTTIR2 is set to HTTIR1, and HTTIR4 is set to HTTIR3 via operations. In the controls, the targets are result variables, the vapor flow rates on the tube side exiting the second and fourth passes of the reheater.

Table B of Appendix B shows the additions to the basic .job file for using these features in the model. While the inputs were developed by responses to forms in the graphics program, the easiest way to show all of the inputs here is via the .job file. The table is a comprehensive presentation of the special features data entered for this basic model. In order to interpret the inputs, see the PEPSE input manual, Ref 1.

It is VERY important to realize that, for this tuning analysis, the demand reference input, IHXDEM, is set to zero. This means that the flow of heating steam from demand splitter 22 will remain fixed at the value specified as the “initial guess” for splitter 22. This assures that the final results of tuning apply to the exact incoming steam flow as stated by the vendor.

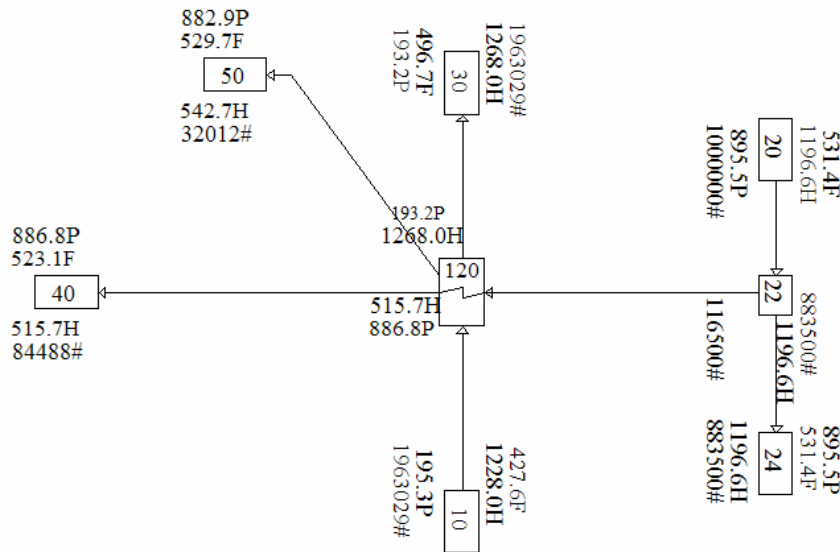
Several “optional” inputs have been entered for the controls. Without these inputs, the run of the model does not converge. This combination of optional inputs evolved by a trial and error process, one step at a time. It is probable that alternative combinations of optional inputs would work as well, or perhaps better than the one shown here.

The rationale for the choices in these options is as follows:

1. On Control #1, IBGCON, the initial exercise of the control is iterate 10, compared to the default of 5. Starting at 10, instead of 5, gives the basic model a chance to settle down before being disturbed by the effect of controls.
2. On Control #1, INRCON, the interval of the control is 5, compared to the default of 1. Choosing 5 has the benefit of giving time for the effects of changing the x variable (HTTIR1) in this control to reach a stable condition throughout the model. This selection addresses item 1 in the list of challenges in a previous section.
3. On Control #1, RELAXC is 0.75. This input is a factor used to multiply/adjust the increment of x when the control calculation is done. The default value is 1.0. The motive is to reduce the size of the increments that would otherwise occur, improving the probability of well-behaved numerics.

4. On Control #1, the limits XCLO and XCHI, equal to $-2.$ and -0.01 are used to prevent the value of x from straying outside of reasonable bounds. Recall that x is a factor that multiplies the internal heat transfer coefficient; so, it should be of the order of 1.0. These inputs are motivated by item 4 of the list of challenges above.
5. Notable in Control #2 is the use of a difference between two PEPSE variables, OPVB,12 and OPVB,11 as a composite y variable. These OPVB's are defined/calculated in Operations 11 and 12. They are the calculated 4th pass tube-side exit vapor flow rate and the desired 4th pass tube-side exit vapor flow rate. When the control has succeeded in driving the difference to zero, the two are equal, the desired result.
6. On Control #2 other optional input data are specified, similar to those for Control #1. Take note that the interval, INRCON, for this control is 20. This selection is a tactic to address item 7 in the list of challenges given in a previous section. By waiting 20 iterates between adjacent applications of Control #2, the chance of Control #1's settling down is improved, and the chance of the model's convergence is improved.

When the model is run using the controls as discussed above, the model converges in 288 iterates. This large number of iterates is mainly a consequence of the interdependence of the two controls and the large intervals that were chosen in order to overcome the dependencies in the calculations. Figure 3 below shows results on the PEPSE schematic from this successful run.



NRHHP(SET 2)-HP reheater (DESIGN MODE 6) all refs specd, cntrl method

Special Output				
Heating steam flow rate	WW	23	116500	LBM/HR
Excess heating steam flow rate	OPVB	11	893.01	OPVB
PASS 1,2 HTCM	HTTIR1	120	-0.804638	NO-UNITS
PASS 3,4 HTCM	HTTIR3	120	-0.899105	NO-UNITS
PASS 2 VAPOR OUT	WTVO2	120	32011.7	LBM/HR
PASS 4 VAPOR OUT	WTVO4	120	893.01	LBM/HR
Specd Excess Steam Frac	TUXSFR	120	0.0106	NO-UNITS
Calc'd Ref Excess Steam Frac	TXSREF	120	0.00766383	NO-UNITS
Calc'd XS steam (result)	OPVB	15	0.00766536	OPVB

Figure 3 Results of Analysis Using Basic Controls

The successful combination of options discussed above was preceded by many unsuccessful trials using other combinations. The use of alternative methods of analysis is worth trying, in hopes of finding one that produces successful results routinely.

Using the Control Block Method

The second method of analysis uses a control block, a very easy tool to use. A control block is an overlay on the basic control method with the intent of accounting for interdependencies between the two controls, that is addressed by item 7 in the list of challenges in the previous section.

While the control block feature is a powerful tool that has provided many successful analyses for many models since its inception, attempts to use the control block feature here were not successful. None of the optional tools associated with control blocks were tried. The root cause of the trouble is unknown, but the results files have included warning

messages indicating that the cause is probably item 5 in the list of challenges in the previous section.

Continued effort might overcome the root cause of the trouble, as in the previous applications of optional inputs for simple controls, but other methods, below, may prove more productive and more consistently successful.

Using the Sensitivity Study Feature Method

The strong interdependencies between the two controls in this model, and in general in models with tuning of design mode nuclear reheaters, pose a difficult analysis task, as has been shown in uses of the preceding methods of analyses. Elimination of one of the controls in the model has a high probability of improved convergence behavior.

To eliminate a control, it is necessary to find some other way of obtaining the result that the control would otherwise obtain. Developing a map of the variables in the disabled control offers this opportunity. The sensitivity study feature is useful for developing this map. The idea behind this method is that one control is easier to converge than two and that the task of the second control can be worked by a systematic trial and error search.

The sensitivity study feature runs a stack of cases over a range of the independent (input) variable x and presents results of specified y variables from each case. See Ref 1 for discussion of the sensitivity study feature. Also, view the input forms for this “Special Feature” in the graphics interface program.

To apply this feature as a method in the present example, we retain the first control and disable the second control of the base model. Next, we specify the sensitivity study feature, defining the range of x , HTTIR3, to include the value where we think the answer lies. The sensitivity study feature allows us to specify a list of y variables that are to be printed in columns beside the x variable’s column of values. The choice of the y list here includes the quantity that was formerly included as the y in Control #2.

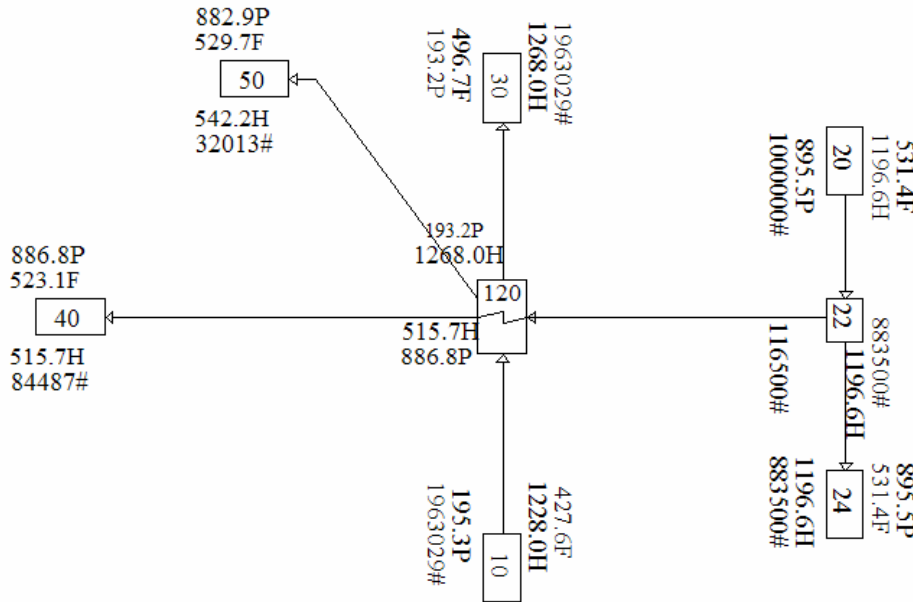
Note that, since Control #1 has been retained, each new case that is analyzed in the sensitivity study produces a successful value of HTTIR1 that is consistent with the HTTIR3 value that was used for that case. Thus, once the case that gives the desired HTTIR3 result is found, it automatically also has the “correct” value of HTTIR1.

Once the sensitivity run is complete, it is easy to open the .out file, scroll to the summary table for the sensitivity feature near the end of the file, and survey the columns to locate the calculated y value corresponding most closely to the desired y variable. This will also correspond most closely to the required x value. If we want to obtain an even closer answer, it is easy to make a new run, where the input specifications of the sensitivity feature are narrowed in the range of the x variable, based on the evidence in the just-completed .out file, and run a new sensitivity study. This cyclic application can be

repeated as many times as needed to get as close as desired to the exact tuning factor, HTTIR3.

See Appendix C for an excerpt from the .job file of the input data that apply specifically for the sensitivity study method.

Table 1 and Figure 4 below show the result that was attained at the first cycle of the procedure outlined above.



SENSITIVITY STUDY CASE 11 - HTTIR3(120)=-9.000E-01

Special Output

Heating steam flow rate	WW	23	116500	LBM/HR
Excess heating steam flow rate	OPVB	11	871.44	OPVB
PASS 1,2 HTCM	HTTIR1	120	-0.804771	NO-UNITS
PASS 3,4 HTCM	HTTIR3	120	-0.9	NO-UNITS
PASS 2 VAPOR OUT	WTVO2	120	32012.6	LBM/HR
PASS 4 VAPOR OUT	WTVO4	120	871.44	LBM/HR
Spec'd Excess Steam Frac	TUXSFR	120	0.0106	NO-UNITS
Calcd Ref Excess Steam Frac	TXSREF	120	0.00766383	NO-UNITS
Calc'd XS steam (result)	OPVB	15	0.00748013	OPVB

Figure 4 Results from Sensitivity Study Method at the Point Nearest the Desired Answer

Table 1 Summary of Results Taken From .out File From the First Run Using the Sensitivity Study Feature

V69/GT (67 STEAM TABLES) OF 19 MAY 04 DATE 05/20/04.

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SENSITIVITY STUDY CASE 31 - HTTIR3(120)=-7.000E-01

** SAVE CASE **

COMPRESSED TABLE OF SENSITIVITY STUDY RESULTS

X = HTTIR3 120, NO-UNITS , P4 Wvap SNSTVT to HT Mult #3
 Y(1) = OPVB 15, OPVB , Calc'd XS Steam Frac (result)
 Y(2) = TXSREF 120, NO-UNITS , Target XS Steam Frac
 Y(3) = OPVB 13, OPVB , Offset of vapor flow from desired

HTTIR3	120	OPVB	15	TXSREF	120	OPVB	13
-1.00000E+00	0.00000E+00	7.66383E-03	2.35188E+03				
-9.90000E-01	0.00000E+00	7.66383E-03	2.13032E+03				
-9.80000E-01	0.00000E+00	7.66383E-03	1.90748E+03				
-9.70000E-01	0.00000E+00	7.66383E-03	1.68283E+03				
-9.60000E-01	0.00000E+00	7.66383E-03	1.45606E+03				
-9.50000E-01	0.00000E+00	7.66383E-03	1.22738E+03				
-9.40000E-01	0.00000E+00	7.66383E-03	9.96716E+02				
-9.30000E-01	1.15112E-03	7.66383E-03	7.58731E+02				
-9.20000E-01	3.24557E-03	7.66383E-03	5.14727E+02				
-9.10000E-01	5.35578E-03	7.66383E-03	2.68889E+02				
-9.00000E-01	7.48013E-03	7.66383E-03	2.14016E+01				
-8.90000E-01	9.61883E-03	7.66383E-03	-2.27757E+02				
-8.80000E-01	1.17710E-02	7.66383E-03	-4.78488E+02				
-8.70000E-01	1.39397E-02	7.66383E-03	-7.31142E+02				
-8.60000E-01	1.61226E-02	7.66383E-03	-9.85442E+02				
-8.50000E-01	1.83201E-02	7.66383E-03	-1.24146E+03				
-8.40000E-01	2.05320E-02	7.66383E-03	-1.49914E+03				
-8.30000E-01	2.27586E-02	7.66383E-03	-1.75854E+03				
-8.20000E-01	2.50024E-02	7.66383E-03	-2.01994E+03				
-8.10000E-01	2.72619E-02	7.66383E-03	-2.28318E+03				
-8.00000E-01	2.95347E-02	7.66383E-03	-2.54796E+03				
-7.90000E-01	3.18240E-02	7.66383E-03	-2.81465E+03				
-7.80000E-01	3.41284E-02	7.66383E-03	-3.08312E+03				
-7.70000E-01	3.64499E-02	7.66383E-03	-3.35358E+03				
-7.60000E-01	3.87864E-02	7.66383E-03	-3.62578E+03				
-7.50000E-01	4.11402E-02	7.66383E-03	-3.90000E+03				
-7.40000E-01	4.35095E-02	7.66383E-03	-4.17602E+03				
-7.30000E-01	4.58840E-02	7.66383E-03	-4.45265E+03				
-7.20000E-01	4.82734E-02	7.66383E-03	-4.73101E+03				
-7.10000E-01	5.06825E-02	7.66383E-03	-5.01168E+03				
-7.00000E-01	5.31069E-02	7.66383E-03	-5.29412E+03				

The variables in the table are:

1. OPVB,13 is the offset of the calculated fourth pass steam flow from the target value of the fourth pass steam flow. This is the same quantity that was used in the original Control #1. The desired value of HTTIR3 will occur at the point in the table where OPVB,13 changes sign.
2. OPVB,15 is the calculated vapor flow rate at the exit of the fourth pass as a fraction of the incoming heating steam. This could be considered the excess steam fraction.
3. TXSREF,120 is the target vapor flow rate at the exit of the fourth pass as a fraction of the incoming heating steam. This is obtained from the “reference” input data, taken from the vendor’s specification sheet. The desired value of HTTIR3 will occur at the point when OPVB,15 equals TXSREF,120, one and the same HTTIR3 as that found by item 1 immediately above.

Surveying the tabulated results shows the change of sign of OPVB,13 occurring near HTTIR3 of -0.9 . Comparison of this result with the result from the basic control method above shows good agreement. The agreement can be improved by refining the x range in the sensitivity study and repeating the run.

While this sensitivity study method may not be very elegant, it has a substantial advantage over the basic control method. The sensitivity study method is easy to understand, and it provides a predictably convergent process.

At this point, we have a method (the basic control) that gives the desired tuning in a single run and a second method (sensitivity study) that requires several runs, but gives the answer more reliably.

Using the Optimization Feature Method

The optimization feature finds the minimum of a y function, versus a set of x variables. See Ref 1 for discussion of this topic. Also, view the input forms for this “Special Feature” in the graphics interface program.

This capability can be applied to replace the second control as long as meaningful y and x’s can be chosen. In the preceding section, the sensitivity study feature was used to take the place of the second control, that had been interfering with convergence. We used a visual method, studying the output from the sensitivity study’s run of a sequence of cases, to find the value of HTTIR3 where the OPVB, 13 reached a value of zero. OPVB, 13 is the difference between desired and the calculated value of the fourth-pass exit vapor flow rate. If a new variable, OPVB, 14, is formed as the absolute value of OPVB, 13, its minimum value is zero. The location of this minimum gives us the answer that we want to find. In this case, the optimization feature can be used instead of the more labor-intensive

sensitivity study method of the previous section. OPVB, 14 can be specified for use by the optimization feature as the y function for minimization. Variable HTTIR3 is declared as the x variable (no additional x's are involved here). The optimization feature adjusts HTTIR3 to find the minimum, which makes the calculated vapor fraction equal the desired vapor fraction!

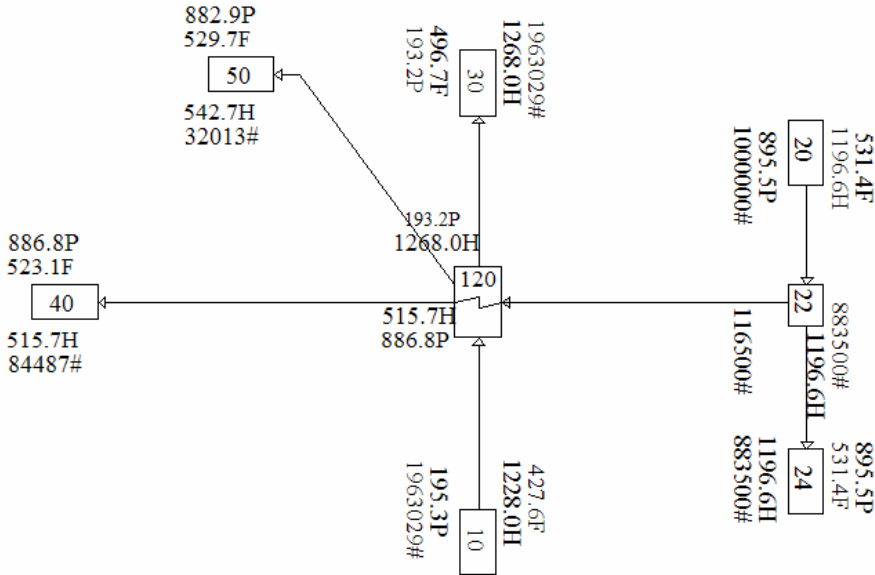
In the optimization feature, finding the minimum happens by using a programmed search algorithm. In the language of optimization, the dependent variable y is called the “objective function”, and the inputs for the feature permit defining the y any way that you choose. You can choose one or more x independent variables. It is necessary that y be a function of the x's. Normally the x's are input independent variables, for which you would normally specify values. The feature obtains the answer by running a large number of cases over ranges of the several x variables until it finds the minimum y. This process is similar to that of the sensitivity study feature, with the added sophistication of inclusion of a method to “home in” on the minimum of the y function. Therefore, this method has the possibility of finding the answer to our task in a single run.

In this application, as in the sensitivity study method, the first control in the model is retained, and the second control is disabled, replaced by the optimization feature. The feature is used to locate the value of HTTIR3 that gives the desired result, i.e. the minimum y. The value of the objective function, y, for use in the optimization is calculated by operations. It is the offset of the calculated fourth pass exit vapor flow rate from the target value of this vapor flow rate. When this offset is zero (the minimum of y), the answer is obtained.

See Appendix D for an excerpt from the .job file of the input data that apply specifically for the optimization feature's method.

Figure 5 and Table 2 below show the .out file's optimization study results.

Figure 5 Results from Optimization Feature Method



FINAL OPTIMIZATION CASE, CYCLE 3, CONVERGED. 15TH CASE, THIS CYCLE

Special Output

Heating steam flow rate	WW	23	116500	LBM/HR
Excess heating steam flow rate	OPVB	11	893.27	OPVB
PASS 1,2 HTCM	HTTIR1	120	-0.804622	NO-UNITS
PASS 3,4 HTCM	HTTIR3	120	-0.899131	NO-UNITS
PASS 2 VAPOR OUT	WTVO2	120	32013.0	LBM/HR
PASS 4 VAPOR OUT	WTVO4	120	893.27	LBM/HR
Spec'd Excess Steam Frac	TUXSFR	120	0.0106	NO-UNITS
Calcd Ref Excess Steam Frac	TXSREF	120	0.00766383	NO-UNITS
Calc'd XS steam (result)	OPVB	15	0.00766755	OPVB

Table 2 Results from optimization feature

OPTIMIZATION CALCULATION RESULTS

NRHHP (SET 4)-Opt'z'n tool replaces Control 2
05/25/04

VALUE	DESCRIPTION	UNITS
	Y OBJECTIVE FUNCTION OPTIMIZED:	
4.322E-01	OPVB (14), DELTA FROM DESIRED EXCESS STEAM	OPVB
	X INDEPENDENT VARIABLES:	
-8.991E-01	HTTIR3(120), 3RD, 4TH PASS HTC	NO-UNITS

As seen in Figure 5 and Table 2, the results from the optimization feature are in excellent agreement with those from the control method of solution.

Summary

Tuning PEPSE's design mode calculations to match target performance parameters can sometimes be difficult. This report has discussed and demonstrated four different methods for solving such problems. As a means of showing an application, the methods have been applied to the task of tuning the heat transfer calculations in a design mode nuclear reheater. Many other modeling tasks could use the same types of techniques as shown here for this specific model.

The four methods discussed have been the control method, where optional tools have been employed to help the controls to converge. The second method uses a control block to account for interdependence among the controls. The method is a strong computational tool, but it did not succeed in the present example model. Most likely, during marching through the model, fixups were happening in some physical parameters that had drifted out of range. When fixups happen, they can confuse the control block's calculations. In spite of this lack of success, control blocks can be very beneficial in cases where controls will not converge. The third method uses a sensitivity study to replace the control that we chose to disable. This method is robust. It gives good results. For the general analysis case, a typical application requires several runs in order to reach satisfactory accuracy in its answer. The fourth method uses the optimization feature as a replacement for the second control. It converges to the correct answer in a single run. Definition of the optimization feature may require sophisticated understanding and setup.

While the sensitivity study and the optimization feature have performed well here to give a good answer, they also have their limitations. As used, they have replaced a single control. If experience in running a model shows that there are more than one troublesome control, some additional feature would be needed to obtain the answer. Such applications could

motivate additional trials using the control block feature. Alternatively, a more complex objective function for the optimization feature may enable using optimization to take the place of several controls.

References

1. Minner, et al, User Input Description, PEPSE Manual Volume I, 2004, Idaho Falls, Idaho, 2004.

Appendix A

This appendix shows the input data, extracted from the .job file, for the basic design mode nuclear reheater submodel of Figure 1. This listing was created by entry of the component-by-component descriptions on the forms of the graphics interface program and then by running the basic model.

Table A Input data, .job file, for basic reheater model

```
010001 80 PRINT
010101 0.0
*
*
*       DATE: Tuesday, May 25, 2004
*       TIME: 10:22 AM
*       MODEL: NRHHP.MDL
*       JOB FILE: C:\UGM04\NRHHP.job
*
=C:\UGM04\NRHHP(SET 1)-HP reheater (DESIGN MODE 6) NO DMD REF, NO REFS
*
*****
*   GENERIC INPUT DATA
*****
*
*   ITRMAX
012000 999 0.0 0.0 0.0 0.0 0.0 0 0.0
*
*   PC DISPLAY VARIABLES
080001 HTTIR1 120 WTVO2 120
080002 TT 122 HTTIR3 120
080003 OPVB 11 WTVO4 120
*
*****
*   STREAMS
*****
*
*
501210 120 T4 50 I
501220 120 D 30 I
500200 20 U 22 I
500220 22 U 24 I
500100 10 U 120 S
500230 22 B 120 T
501200 120 T 40 I
*
*****
*   COMPONENTS
*****
*
*   Reheater A, First Stage-DESIGN MODE 6, NO DMD REF
701200 22 0 6 25.
701201 0.0 0.0505 0.00818 0.0 0.0
701205 2 285. 0.64 0.57 37.33 0.9375 0.9375 29. 11.4
701206 106. 1. 0.0 0.0 0.0 0.0 0.0 4 0.0 1
701207 0.0106 0.00082 0.0 0.0 0.1 0.0 16757.7 0.0 0.0 0.0 0.0
```

```

+ -0.5
701208  0.0  0.0  -0.5  0.0  0.0  0.0  0.0  -0.6  0.0  0.0  -0.6
701209  0  0  0  0.0  0.0  0.0  0.0  0.75  0.1  75000.  200000.
711201  0  0.0
701202
*
* Condensate from reheater bundle, 4th tubing pass
700500  30
700502  0
*
* Condensate from reheater bundle
700400  30
700402  0
*
* Cycle steam, heated by reheater bundle
700300  30
700302  0
*
* Dump receiver for extra heating steam
700240  30
700242  0
*
* Heating steam to reheater bundle
700200  31  531.38  895.5  1000000.  0.0  0.0  0
700202  0  0  0
*
* Cycle steam to reheater
700100  31  427.6  195.29  1963029.  0.0  0.0  0
700102  0  0  0
*
* Demand splitter for heating steam
700220  60  0.0  116500.  0.0  0  0.0
700221  0
*
*****
*   SPECIAL FEATURES
*****
*
890010 "Heating steam flow rate"
890011 WW  23  0.0  U
*
890020 "Excess heating steam flow rate"
890021 OPVB  11  0.0  U
*
890030 "PASS 1,2 HTCM"
890031 HTTIR1  120  0.0  U
*
890040 "PASS 3,4 HTCM"
890041 HTTIR3  120  0.0  U
*
890050 "PASS 2 VAPOR OUT"
890051 WTVO2  120  0.0  U
*
890060 "PASS 4 VAPOR OUT"
890061 WTVO4  120  0.0  U
*
890070 "Specd Excess Steam Frac"

```

```

890071 TUXSFR 120 0.0 U
*
890080 "Calcd Ref Excess Steam Frac"
890081 TXSREF 120 0.0 U
*
890090 "Calc'd XS steam (result)"
890091 OPVB 15 0.0 U
*
* OUTPUT GLOBAL SUPPRESSION CARD
020000 PRINT PRINT NOPRNT
020002 NOPRNT * Geometry Configuration of Model
020004 NOPRNT * Stream Properties
020005 NOPRNT * Comparison of Component Port Test Data With Stream
Properties
020015 NOPRNT * Detailed Mixer Performance Output
020016 NOPRNT * Detailed Splitter Performance Output
020021 NOPRNT * Second Law of Thermodynamics Performance - Components
020022 NOPRNT * Second Law of Thermodynamics Performance - Streams
020023 NOPRNT * Second Law of Thermodynamics Performance - System
020024 NOPRNT * Material Descriptions Used in the Model
020025 NOPRNT * First Law of Thermodynamics Performance - Envelope
020030 NOPRNT * Warning Table of Stream Closures
020032 NOPRNT * Input Schedule Number N Table of Values
020033 NOPRNT * Variable Sets Which Reference Schedules
020034 NOPRNT * Controls Input
020037 NOPRNT * Definitions of Special Operations Specified
020059 NOPRNT * Stream Transport Properties
020078 NOPRNT * Nonzero Operational Variables
*
* CYCLE FLAGS
010200 0 0 0 5 1 0 0.0 0.0 0 0 0 0 0 0 0
010000 ENGLISH ENGLISH
*
*
* END NOTES
*SET 2- SPECIFY DELTA P FOR DESIGN MODE
* ALSO SPECIFY REFERENCE VALUES (VENDOR) FOR P, SUBCOOLING, ETC
* THESE LINES ARE NEEDED BECAUSE THE V68 DESIGN MODE FORMS PROVIDE
* NO WAY TO SPECIFY THE REHEATER PRESSURE DROPS
*
701201 0.0 0.01406 0.0107 0.0 0.0
*
* TEST NEW SPECS OF REFERENCE (VENDOR DESIGN) INPUTS
*
* PPSIRF PPSORF PPTIRF PPTOP2 PPTOP4 TTLOP2 TTLOP4 WTLOP4
711202 195.29 193.2 895.5 886.81 882.91 523.07 523.66 30774.
+ 1235. 116500. 32011.
* WTVOP4 WHTNG WTVOP2
*

```

Appendix B

This appendix shows the input data, extracted from the .job file, that apply to use of the control feature, with optional inputs specified. The data here were extracted from the .job file, for the design mode nuclear reheater submodel. This listing was created by entry of the input data on the forms of the graphics interface program and then by running the model.

Table B Inputs of Controls and Operations for the Control Method

```
*
*****
* SPECIAL FEATURES
*****
*
* Control FIRST (+2ND) PASS HT COEF MULT FOR 2ND STM OUT
840100 HTTIR1 120 32011. 0.0001 1. WTVO2 120 1. 0
840105 5 0
840106 10
840107 0.75
840109 -2. -0.01
*
* Control THIRD (+4TH) PASS HT COEF MULT FOR XS STM
840200 HTTIR3 120 0.0 1. 1. OPVB 12 -1. OPVB 11
840205 20 0
840206 10
840207 0.75
840209 -2. -0.01
*
* SET 2ND PASS HT TR COEF MULT TO FIRST PASS VALUE
880010 HTTIR1 120 EQL HTTIR2 120
*
* SET 4TH PASS HT TR COEF MULT TO THIRD PASS VALUE
880020 HTTIR3 120 EQL HTTIR4 120
*
* CALC VAPOR FLOW FROM PASS 4
880110 XX 121 MUL WW 121 OPVB 11
*
* CALC DESIRED EXCESS STEAM AT 4TH PASS OUTLET
880120 TXSREF 120 MUL WW 23 OPVB 12
*
* DELTA EXCESS STEAM FROM DESIRED VALUE
880130 OPVB 12 SUB OPVB 11 OPVB 13
*
* ABSOLUTE OF DEVIATION
880140 ONE 0 ABS OPVB 13 OPVB 14
*
* Calc'd XS steam (result)
880150 WTVO4 120 DIV WW 23 OPVB 15
*
*
```

Appendix C

This appendix shows the portion of the input data that applies specifically to the sensitivity study feature. The data here were extracted from the .job file, for the design mode nuclear reheater submodel. This listing was created by entry of the input data on the forms of the graphics interface program and then by running the model.

Table C Inputs for sensitivity study feature

```
*
* SENSITIVITY STUDY
930000 1 NOPRNT 0 0 0.0
*
930001 "P4 Wvap SNSTVT to HT Mult #3"
930002 HTTIR3 120 -1. -0.7 31
*
930011 "Calc'd XS Steam Frac (result)"
930012 OPVB 15
*
930021 "Target XS Steam Frac"
930022 TXSREF 120
*
930031 "Offset of vapor flow from desired"
930032 OPVB 13
```

Appendix D

This appendix shows the portion of the input data that applies specifically to the optimization feature. The data here were extracted from the .job file, for the design mode nuclear reheater submodel. This listing was created by entry of the input data on the forms of the graphics interface program and then by running the model.

Table D Input data for the optimization feature

```
*
* OPTIMIZATION
940000 3 100 NOPRNT 0 0 0
940001 "DELTA FROM DESIRED EXCESS STEAM"
940002 OPVB 14 0 -1.
*
940011 "3RD, 4TH PASS HTCM"
940012 HTTIR3 120 -0.7 -0.6
940013 0.0 0.0
*
```