Customized Data Validation in PSS®E

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Introduction
PSS®E users maintain huge amounts of data for power system static analysis and dynamic simulation. High data quality is important to yield accurate calculation results in PSS®E. Numerous data checking and validation schemes are embedded in PSS®E to make sure that power system data are reasonable, consistent and error free. However, some types of data (e.g., RATEA, RATEB, RATEC) are defined by users; they are not checked and validated in PSS®E in the way some users prefer (e.g., RATEC≥RATEB≥RATEA if RATEA is normal limit, RATEB is the 30-minute limit and RATEC is the 10-minute limit). It is the users’ responsibility to ensure their data accuracy. For large power systems, it is burdensome and error-prone to check and validate data manually. A more efficient way is required.

To solve this problem, PSS®E provides a command line interface and Python APIs to users. Python scripts can be developed by users to check and validate data automatically. This article presents an example of Python scripting used for data checking and validation.

Customized Data Validation Applied to Transformer Phase Shift Angles

To simplify, only data validation of the transformer phase shift angles is demonstrated. ANG1 in a two-winding transformer is the phase shift angle (in degrees) from winding 1 to winding 2. ANG1 is positive if winding 1 bus voltage leads winding 2 bus voltage. ANG1, ANG2 and ANG3 in three-winding transformers are phase shift angles (in degrees) to the star point from winding 1, 2 and 3 respectively, where ANG1 is positive if winding 1 bus voltage leads star point voltage; the signs of ANG2 and ANG3 are similarly defined.

Phase shift angles result from different transformer winding connections (Y/Δ, Δ/Y and Y/Y) and from phase shifters. In power systems, winding Y and Δ connections generally result in phase shifts of 0°, ±30°, ±150° or 180°. These phase shifts must be compatible, that is, if there are two transformers in a loop and one transformer has a 30° phase shift, another one must have a -30° phase shift so that there is no loop power flow caused by the two transformer phase shifts. This compatibility must be met by both two-winding and three-winding transformers in all possible loops.

In PSS®E, ANG1, ANG2 and ANG3 combine both the phase shift resulting from winding connections and the phase shift resulting from phase shifters. Without extra information, it is impossible to have a generic way to validate the compatibility of transformer phase shifts. For example, ANG1 = -29° for a two-winding transformer could mean either Y/Y-0 plus -29° phase shift resulting from a phase shifter or Y/Δ-11 plus 1° phase shift resulting from a phase shifter. This ambiguity cannot be solved unless more information is provided by the user. Therefore, customized data validation is necessary.

Transformer phase shift angle validation starts from the swing bus, to which a 0° phase angle is assigned. Figure 1 shows the flow chart for the validation process:
Build mapping dictionary \textit{TransDict} for transformers with phase shifter and transformers with ambiguous angle shift. This dictionary maps each transformer with phase shifter to their winding phase shift angles resulting from winding connections.

Add swing bus with 0° phase angle to lists \textit{BusesToProcess} and \textit{BusesProcessed}.

For each bus in \textit{BusesToProcess}:

For each neighboring bus connected through transmission lines, two-winding transformers and three-winding transformers:

Assign phase angles to neighboring buses according to connecting equipment:
1. If it is a line, no phase shift
2. If it is a transformer (two- or three-winding) and is in \textit{TransDict}, determine the phase shift from dictionary \textit{TransDict}
3. If it is a regular two-winding transformer, determine phase shift by ANG1
4. If it is a regular three-winding transformer, determine phase shift by ANG1, ANG2 and ANG3

Is the neighboring bus in \textit{BusesProcessed}?  

Is phase shift angle compatible?  

Add the neighboring bus into lists \textit{BusesProcessed} and \textit{BusesToProcess}.

End loop: For each neighboring bus connected through transmission lines, two-winding transformers and three-winding transformers.

End loop: For each bus in \textit{BusesToProcess}.

Stop.

Figure 1 - Transformer Phase Shift Angle Validation Flow Chart
The building of mapping dictionary TransDict depicted in Figure 1 is completed by the creation of an auxiliary Python script BuildXfrAngleShiftDictionary.py which actually builds two sub-dictionaries; one for two-winding transformers, and one for three-winding transformers. Figure 2 shows an example of the script file:

![Sample BuildXfrAngleShiftDictionary.py](image)

The above Python script needs to be created by each user for their system. Another Python script CreateTransformerAngleShiftDictionaryScript.py needs to be developed to help to create the preliminary BuildXfrAngleShiftDictionary.py, which then should be edited by users to match their system.

The transformer phase shift angle validation process assumes that all on-line buses can be traced by transmission lines, two-winding transformers and three-winding transformers. If this is not the case (e.g., a system with a DC line connecting two subsystems with different frequencies), some special logic should be implemented so that all on-line buses can be traced. During the processing, the status of equipment is considered as well.

**Test Results**

For the next step in our example, a Python script file ValidateTransformerShiftAngles.py is developed to implement the transformer phase shift angle validation. Two real systems are used in our example; system 1 and system 2. The version of PSS®E used is 32. Figure 3 shows the validation results for system 1; Figures 4 and 5 show the results for system 2.
Figure 3 - Transformer Phase Shift Angle Validation Success – System 1 Results

Transformer angle shift integrity check begins!

Number of conflicts = 0

Total checked buses = 9058

Total on-line buses = 9058

Figure 4 - Transformer Phase Shift Angle Validation Failure – System 2 Results

Transmission line 62176 62162 bus 62162 has angle conflict: 30.000000  0.000000

Bus 62162 has angle 30.0 and was traced through the following transformers:

- 30000  30527  1 from  30000 to  30527 with  0.0 degree
- 30245  30005  31796  1 from  30245 to  30005 with  0.0 degree
- 60240  60235  60238  1 from  60240 to  60235 with  0.0 degree
- 65665  65670  65685  2 from  65665 to  65670 with  0.0 degree
- 65860  65850  1 from  65850 to  65860 with  30.0 degree
- 62005  62115  1 from  62005 to  62115 with  0.0 degree

Bus 62162 now has angle 0.0 and is traced through the following transformers:

- 30000  30527  1 from  30000 to  30527 with  0.0 degree
- 30245  30005  31796  1 from  30245 to  30005 with  0.0 degree
- 60240  60235  60238  1 from  60240 to  60235 with  0.0 degree
- 60190  60185  60188  1 from  60190 to  60185 with  0.0 degree
- 62071  62118  1 from  62071 to  62118 with  0.0 degree

Number of conflicts = 30

Total checked buses = 15112

Total on-line buses = 15112
Figure 3 shows that system 1 has no transformer angle shift error. Figure 4 shows that system 2, however, has transformer phase shift angle errors. For each error, the conflict information is displayed. After data corrections are made by the user, system 2 passes the transformer phase shift angle validation, as shown in Figure 5.

**Conclusion**

PSS®E provides the capability for users to validate data. This type of customized data validation is very useful in those cases where there is no generic data validation. The example test results above show that customized data validation is feasible and helpful.