

Automated Total Transfer Capability (TTC) Computations

Thermal Limits

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Outline of Presentation

- Overview of Objectives
- TTC Calculator: How it looks and what it does
- TTC Calculator: Design Features
- More details of supporting .aux files
- Near Future Plans

Overview of Objectives

Existing TTC calculation process

- Day Ahead Market (DAM): Thermal limits are calculated for five interfaces subject to N-2 contingencies (CTG)
- CTGs: Line + Line (2ndLine); Generator + Line (2ndGen)
- Variety of EMS tools including Contingency Analysis, Power Flow, linearized Interface Limit Calculation

Drawbacks

- Process takes up to 10-12 hours/one person each day
- Inconsistency of results day-to-day and person-to-person
- Significant amount of manual work
- “Last minute” changes difficult to apply

Requirements to new process for DAM

- Dramatic increase of efficiency and robustness
- Day-to-day consistency of process/results. Eliminate dependence of results on person performing calculations
- Maximal automation and short learning curve to run process
- Ability to consider a variety of scenarios for each interface
- Ability to adopt new process for Real Time operation and other markets (FTR, FCM)

PowerWorld: Pros for new TTC process

- ISO New England has the best implementation in industry achieving EMS model and PowerWorld synchronization
- Excellent flexibility and functionality of Power World as a research and engineering tool
- Fast and efficient work of Power World, Inc. staff to implement desirable to ISO-NE changes in software
- Availability of process automation tool - SimAuto
- Industry proven reputation of Power World (BPA, TVA, Entergy, etc)

PowerWorld: Cons to overcome in new process

- Complicated tool
 - A lot of parameters to be adjusted for proper ATC run
 - Long learning curve for a new user
- Vulnerability of data/settings from the unassuming user

TTC Calculator: How it looks and what it does

Step by Step Calculation process

Step 1: Prepare power flow case in EMS environment and convert it into .aux format

Step 2: Select pre-defined type of computations (All Interfaces, Single Interface, Single Scenario)

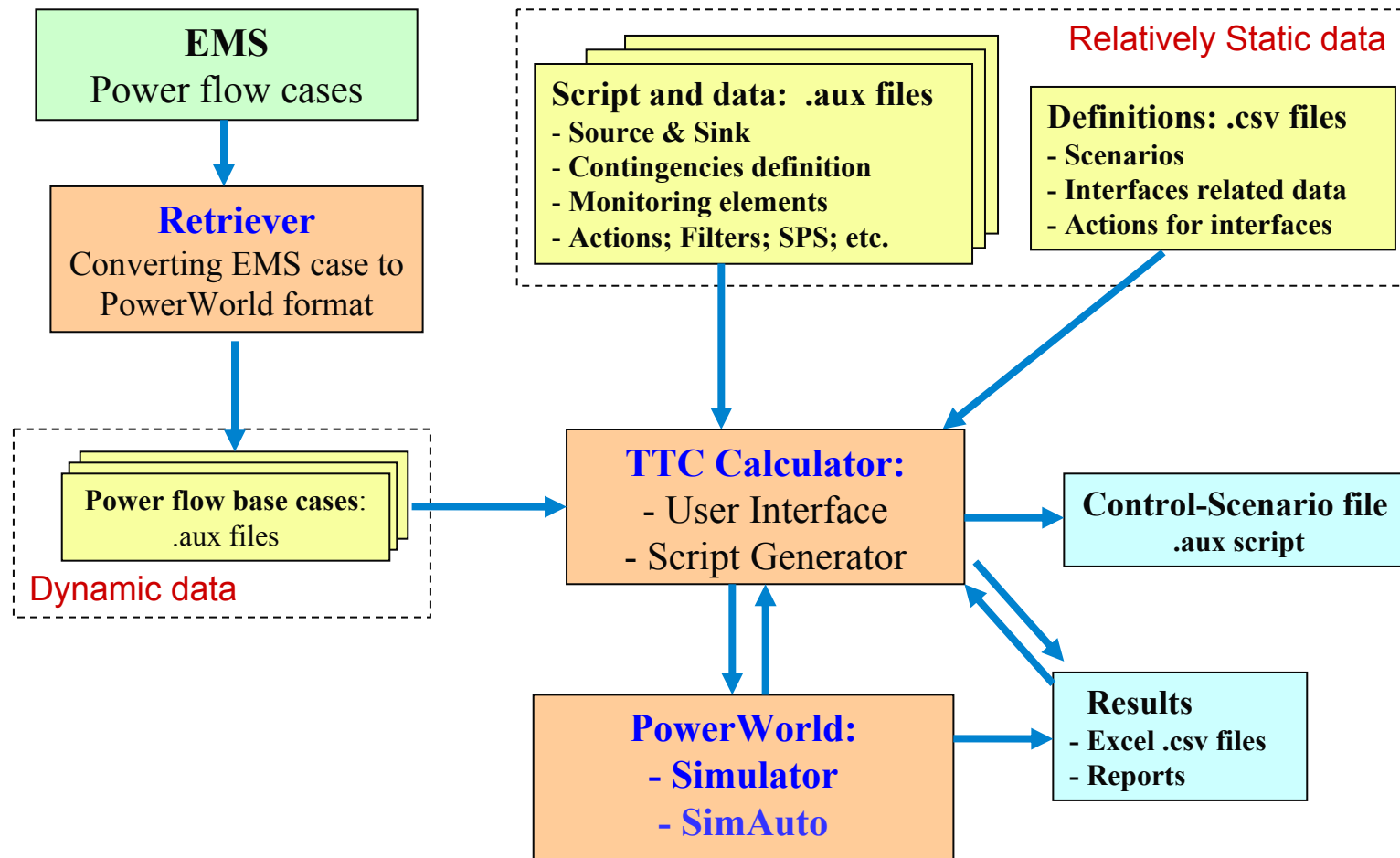
Step 3: Select pre-defined system conditions relevant to TTC calculations

Step 4: Push “Run” button

Step 5: Analyze results

In general, the calculations can be classified as
“Push one button” process

Data Flow Chart

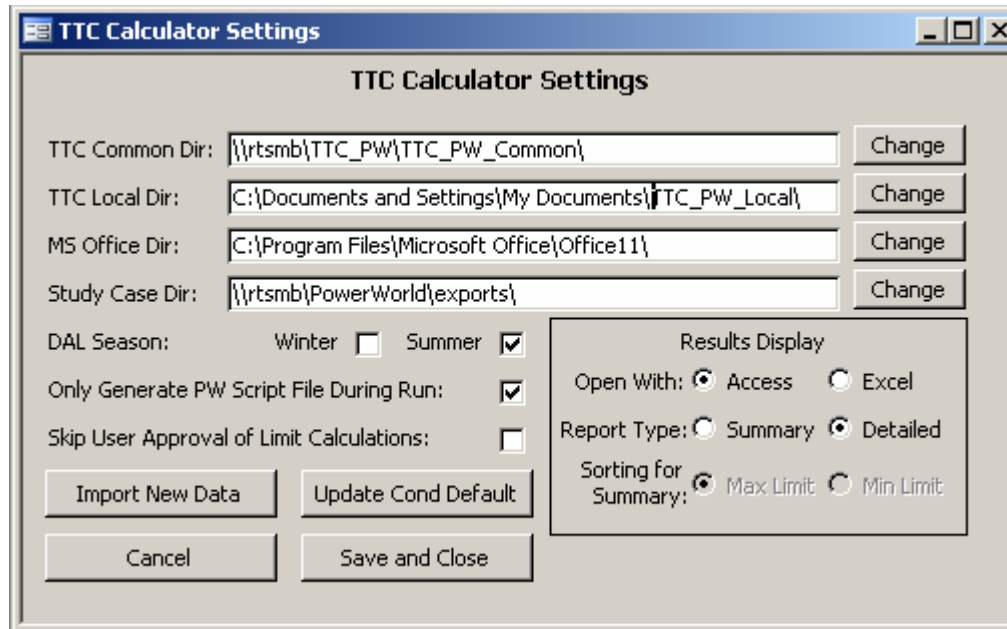


Main Menu

The screenshot shows the 'ISO New England TTC Calculator' window. At the top, there are input fields for 'Date' (9/28/2007) and 'Hour'. Below these are 'Study Case' and 'Results File' fields, both with file selection icons. The 'Ratings' section includes a dropdown for 'NSTAR' (Sep2007) and a button for 'DAL Season' (SUMMER). The 'Type of Calculation' section has radio buttons for 'All Interfaces and Scenarios' and 'Single Interface' (selected), a dropdown for 'Interface' (CT-Imp), checkboxes for 'Run all Scenarios for selected Interface' and 'Run a specific Scenario' (checked), a dropdown for 'Type of Limit' (2ndLine), and a dropdown for 'Scenario' (Sackett PS tap = +3). The 'Conditions' section has a list of checkboxes: 'WSG1 Available', 'WSG2 Available', 'WS10 Available', 'Open Line 1385', 'Open Cross Sound Cable', 'Limit CAN1 and CAN2', and 'Limit NHHB output'. There are 'Save Log' and 'Clear Log' buttons. At the bottom, there is a log window showing '10/11/2007 9:31:25 AM - ISO New England TTC Calculator - Initialized' and a row of buttons: 'Run', 'Approve', 'View Results', 'Settings', and 'Close'.

- A. GUI uses “TTC process” language
- B. All engineering knowledge on TTC calculation process and software settings are pre-defined and hidden in .aux files
- C. Regular User can run calculations but cannot change critical data in .aux files
- D. Authorized User has full access to all critical data
- E. Batch or Single Scenario calculations

Settings



- Establish links with shared data on server and data on local machine
- Set a selection criteria for summary report – “best case scenario” (operation) or “worst case scenario” (planning)
- Other settings and service functions

System conditions

The screenshot shows the 'ISO New England TTC Calculator' window. It includes the following fields and options:

- Date: 9/28/2007
- Hour: (empty)
- Study Case: model_pf_pwrflow_jduffy_09_28_07 osd1_20070929_175434.aux
- Results File: TTC_09-28-2007_all.csv
- Ratings: NSTAR: Sep2007, DAL Season: SUMMER
- Type of Calculation:
 - ☐ All Interfaces and Scenarios
 - ☒ Single Interface
- Interface: CT-Imp
- ☐ Run all Scenarios for selected Interface
- ☒ Run a specific Scenario
- Type of Limit: 2ndLine
- Scenario: Sackett PS tap = +3
- Conditions (highlighted):
 - ☒ WSG1 Available
 - ☒ WSG2 Available
 - ☒ WS10 Available
 - ☒ Open Line 1385
 - ☒ Open Cross Sound Cable
 - ☒ Limit CAN1 and CAN2
 - ☒ Limit NHHB output
- Buttons: Save Log, Clear Log

Allows user to apply current system conditions which are not reflected in EMS but impact results of TTC

- Availability of fast start units for relieving local overloading
- Compliance with Operating Procedures

Results - Detail

ISO New England TTC Calculation Report												
ISO New England TTC Calculation - Detail												
Date: 09/28/2007												
Study Case: wrflow_tczywncy_09_28_07osd1_20070927_115757.aux												
System Status WSG1: Available Line 1385: Open WSG2: Available CSC: Open WS10: Available CAN 1+2: Limited NHHB: Limited Ratings DAL: SUMMER NSTAR: Sep2007												
Interface	Limit Type	Scenario	DAL	Limit (MW)	Contingency	Limiting Element	Limit Used	Solution Type	Tripped Gen (MW)	Load Shed (MW)	Tripped Unit(s)	Apv
BOSTN	2ndLine	Phase Shifterstep= -3	☒	2757	337 + 394	T146-1	169	FULL	0	0		☒
BOSTN	2ndLine	Phase Shifterstep= -3	☒	2814	337 + 394	S145-1	168	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= -3	☒	2939	337 + 394	S145-2	165	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= +6	☒	1989	337 + 394	110-511-4	208	FULL	0	0		☒
BOSTN	2ndLine	Phase Shifterstep= +6	☒	2023	337 + 394	110-510-4	208	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= +6	☒	2468	337 + 397	110-511-4	208	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= +3	☒	2548	337 + 394	110-511-4	208	FULL	0	0		☒
BOSTN	2ndLine	Phase Shifterstep= +3	☒	2550	337 + 394	110-510-4	208	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= +3	☒	3126	337 + 394	T146-1	169	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= 0	☒	2968	337 + 394	T146-1	169	FULL	0	0		☒
BOSTN	2ndLine	Phase Shifterstep= 0	☒	3018	337 + 394	S145-1	168	FULL	0	0		☐
BOSTN	2ndLine	Phase Shifterstep= 0	☒	3108	337 + 394	S145-2	166	CTG_FAIL	0	0		☐
CT-Imp	2ndGen	Base	☐	2073	ZB16	4X	478	FULL	1099	0	MIL3	☒
CT-Imp	2ndGen	Base	☐	2086	ZB17	6X	477	FULL	1099	0	MIL3	☐
CT-Imp	2ndGen	Base	☐	3347	330	395-1	1550	FULL	1099	0	MIL3	☐
CT-Imp	2ndLine	Base	☐	1467	1254 + 1723	1322	141	FULL	0	0		☒
CT-Imp	2ndLine	Base	☐	1877	330 + 395	1821	228	FULL	0	0		☐
CT-Imp	2ndLine	Base	☐	1890	330 + 395	1768	163	FULL	0	0		☐
CT-Imp	2ndLine	Base	☒	2391	330 + 395	1836	280	FULL	0	0		☒
CT-Imp	2ndLine	Base	☒	2392	330 + 395	1821	280	FULL	0	0		☐
CT-Imp	2ndLine	Base	☒	2468	347 + 395	1821	280	FULL	0	0		☐
LWSEMA	2ndGen	Tiverton on EcoMin	☐	908	CNL1	D21	215	FULL	200	0	CAN1	☒
LWSEMA	2ndGen	Tiverton on EcoMin	☐	933	342	D21	215	FULL	200	0	CAN1	☐
LWSEMA	2ndGen	Tiverton on EcoMin	☐	1084	128	D21	217	FULL	200	0	CAN1	☐
LWSEMA	2ndGen	Base	☐	838	CNL1	D21	218	FULL	200	0	CAN1	☒
LWSEMA	2ndGen	Base	☐	853	342	D21	218	FULL	200	0	CAN1	☐
LWSEMA	2ndGen	Base	☐	1007	128	D21	218	FULL	200	0	CAN1	☐

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Results - Summary

ISO New England TTC Calculation Report											
ISO New England TTC Calculation - Summary Max											
Date: 09/28/2007											
Study Case: pwrflow_tczywczy_09_28_07osd1_20070927_115757.aux											
System Status						Ratings					
WSG1: Available		WSG2: Available		WS10: Available		DAL: SUMMER					
Line 1385: Open		CSC: Open		CAN 1+2: Limited		NHHB: Limited		NSTAR: Sep2007			
Interface	Limit Type	Scenario	DAL	Limit (MW)	Contingency	Limiting Element	Limit Used	Solution Type	Tripped Gen (MW)	Load Shed (MW)	Tripped Unit(s)
BOSTN	2ndGen	Phase Shifterstep= -1	☐	4416	ZB11	T146-1	146	FULL	570		M8G1 M8G2 M8S5
BOSTN	2ndLine	Phase Shifterstep= +1	☐	2652	337 + 394	T146-1	145	FULL	0	316	
BOSTN	2ndLine	Phase Shifterstep= 0	☒	2968	337 + 394	T146-1	169	FULL	0	0	
CT-Imp	2ndGen	Base	☐	2073	ZB16	4X	478	FULL	1099		MIL3
CT-Imp	2ndLine	Base	☐	1467	1254 + 1723	1322	141	FULL	0	924	
CT-Imp	2ndLine	Base	☒	2391	330 + 395	1836	280	FULL	0	0	
LWSEMA	2ndGen	Tiverton on EcoMin	☐	908	CNL1	D21	215	FULL	200		CAN1
LWSEMA	2ndLine	Base	☐	356	331 + 342	D21	220	FULL	0	0	
NRST	2ndGen	Haw& Nor reactors IN SERVICE	☐	881	1001	1880-3	250	FULL	36		NRW1
NRST	2ndLine	Haw& Nor reactors IN SERVICE	☐	543	1001 + 1130	1880-3	240	FULL	0	79	
NRST	2ndLine	Haw& Nor reactors IN SERVICE	☒	622	1001 + 1130	1880-3	312	FULL	0	0	
SWCT	2ndGen	Haw& Nor reactors IN SERVICE	☐	1610	321	89003B-1	235	FULL	444		BHCC
SWCT	2ndLine	Base	☐	787	387 + 362	1783-1	159	FULL	0	268	
SWCT	2ndLine	Haw& Nor reactors IN SERVICE	☒	1056	387 + 362	1783-1	184	FULL	0	0	
WESTCT	2ndGen	Base	☐	2073	362	1784-1	283	FULL	444		BHCC
WESTCT	2ndLine	Haw& Nor reactors IN SERVICE	☐	1026	362 + 387	1784-1	283	FULL	0	466	
WESTCT	2ndLine	Haw& Nor reactors IN SERVICE	☒	1492	362 + 387	1783-1	184	FULL	0	0	

Computation Time. Scenarios

- Transfer Limits are calculated by **full AC solution**. Linearized solutions can give error up to 10%-20%, which is not acceptable for DAM and RT operation
- Scenario is a single run of Power World ATC tool. Scenarios reflect different system conditions (availability of equipment, phase shifter settings, etc.) and different type of contingencies (N-1, 2ndGen, 2ndLine)
- Computation time of one Scenario takes about 1 min (PowerWorld Simulator V.12, single CPU)

Type of Run	Number of interfaces	Number of scenarios
Batch	Multiple, pre-selected (currently 6)	Multiple, pre-selected (currently 55-65)
Single Interface	One	Multiple, pre-selected (currently 4-25)
Single Scenario	One	One

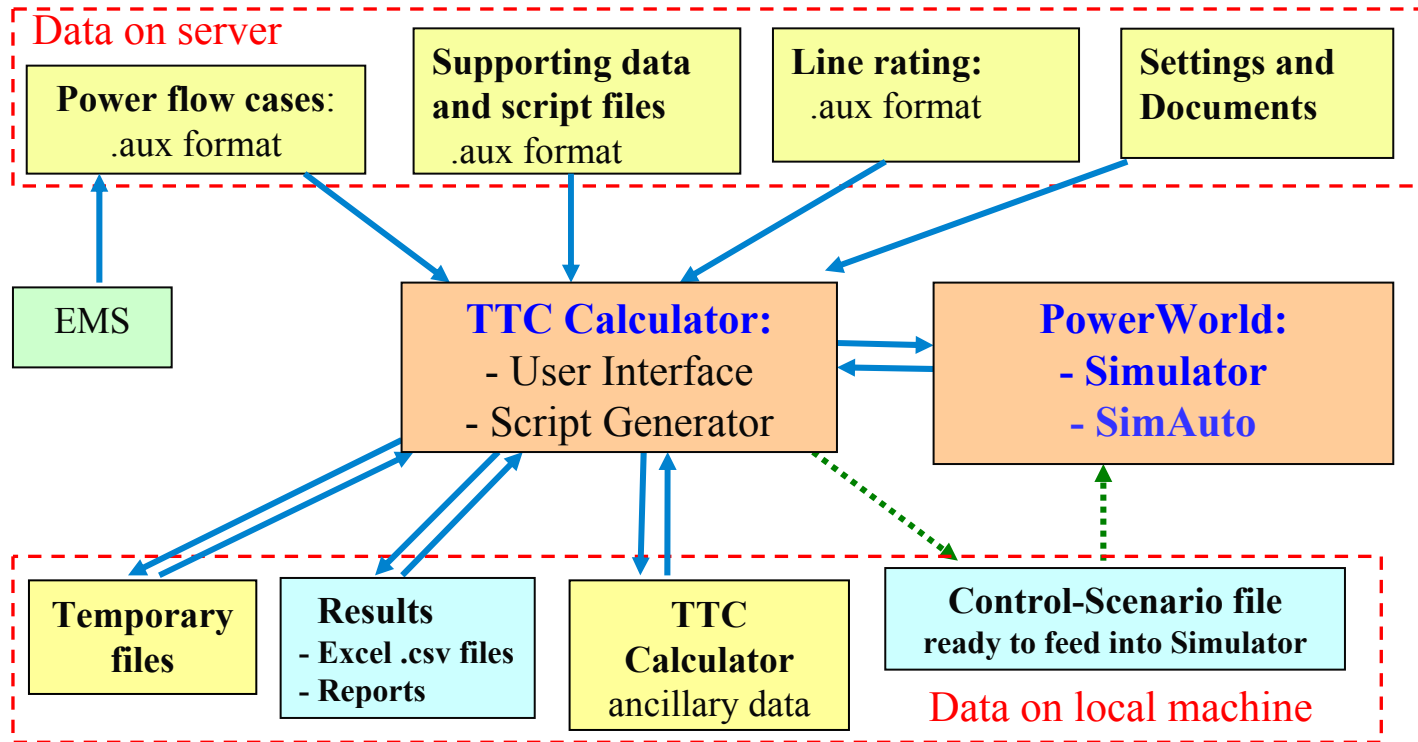
TTC Calculator: Major Accomplishments

- Dramatically increased process efficiency. Time reduction from 12hr to 1hr now, and to a few minutes in the near future
- Increased reliability and consistency of results by excluding all possible subjective factors and human errors
- Incorporation of expert engineering knowledge on TTC calculation process into formal .aux files and make them available for use by any user. Separating unassuming user from critical data.
- Very short learning curve for users with different backgrounds.
- Opportunity to adapt new process for Real Time operation and other applications (FTR, FCM)

**“TTC Calculator” is the new level of application
Power World tools in production environment**

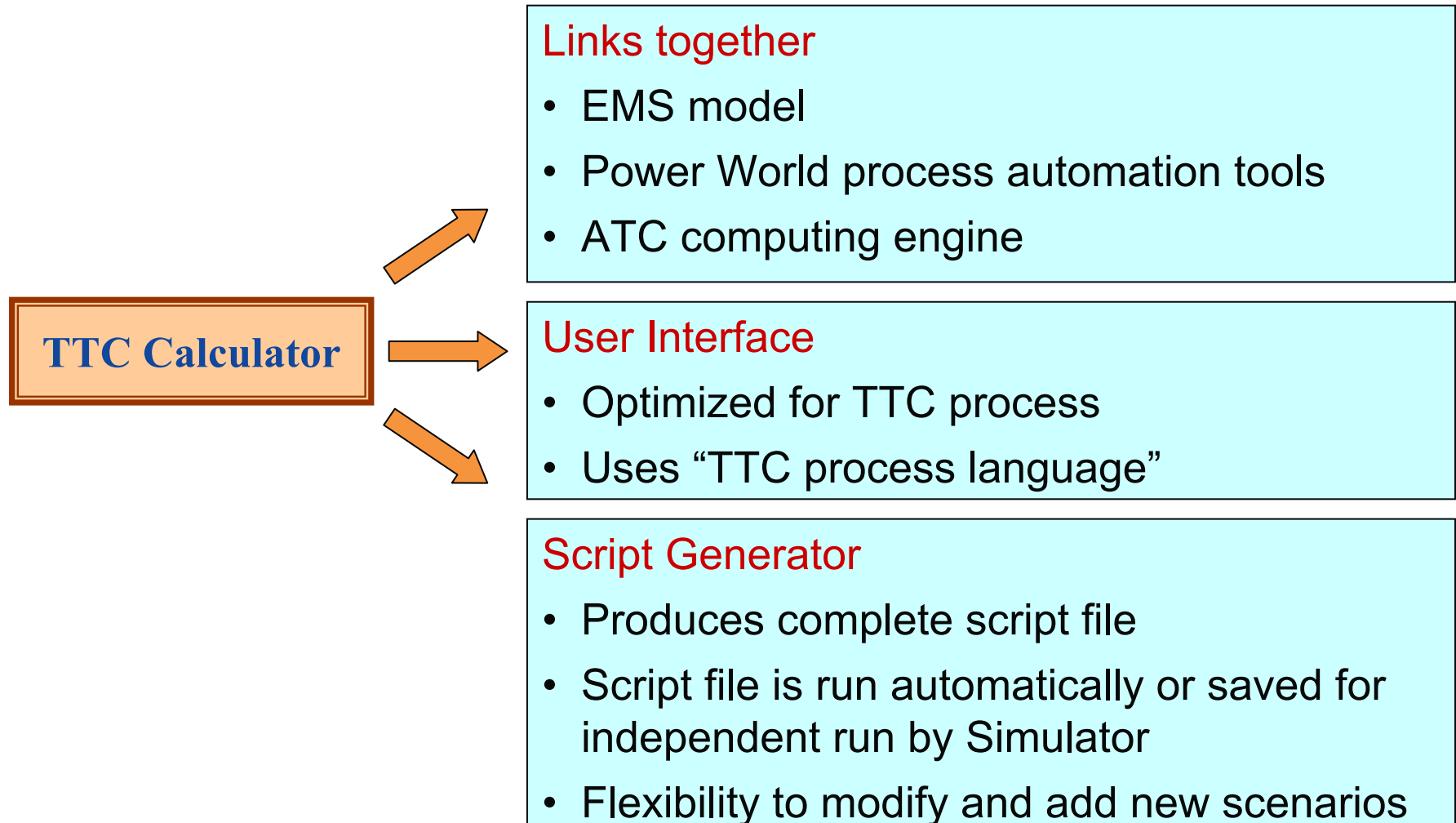
TTC Calculator: design features

TTC Calculator: Functional Scheme



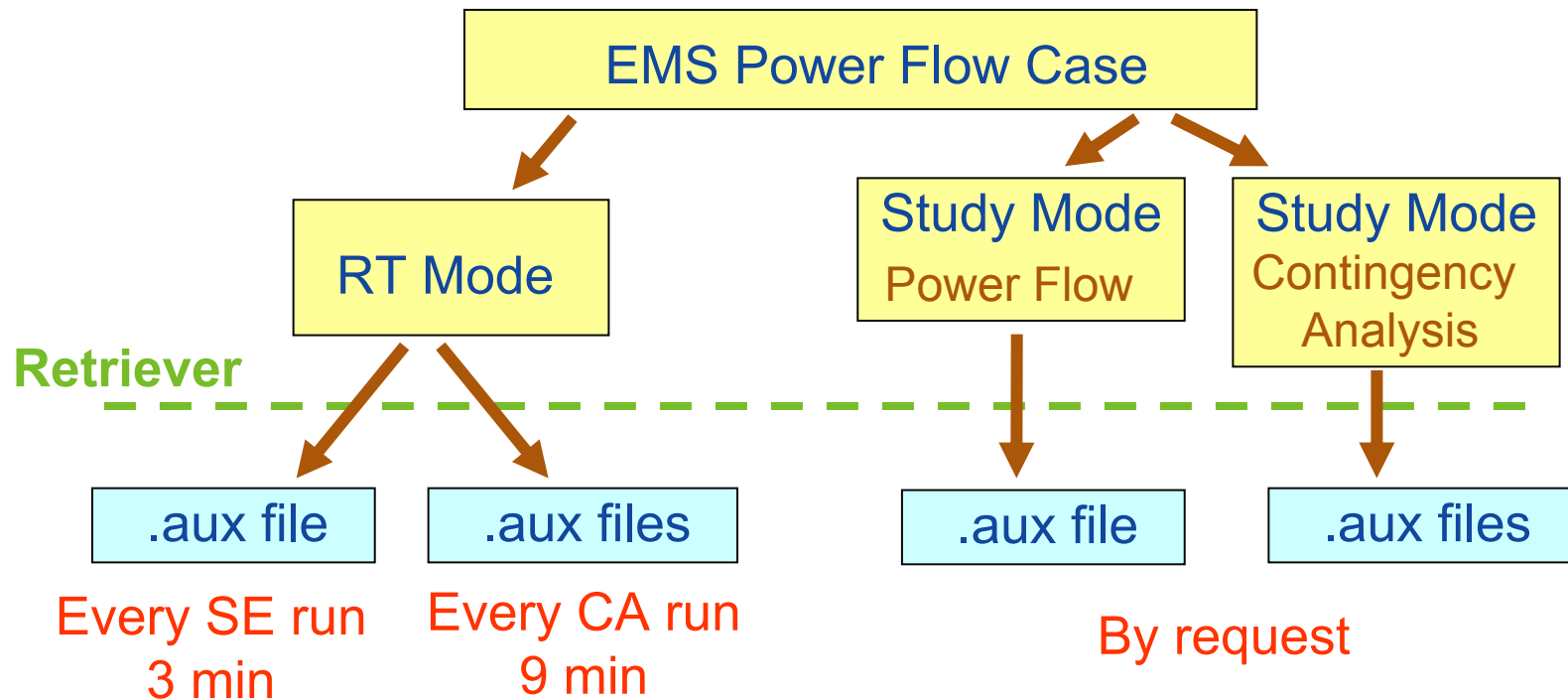
- Cyber security: Critical data in protected area on server
- Multi user environment with ability to have individual settings for each user to optimize solution for a specific task
- Easy to maintain

Major Functions

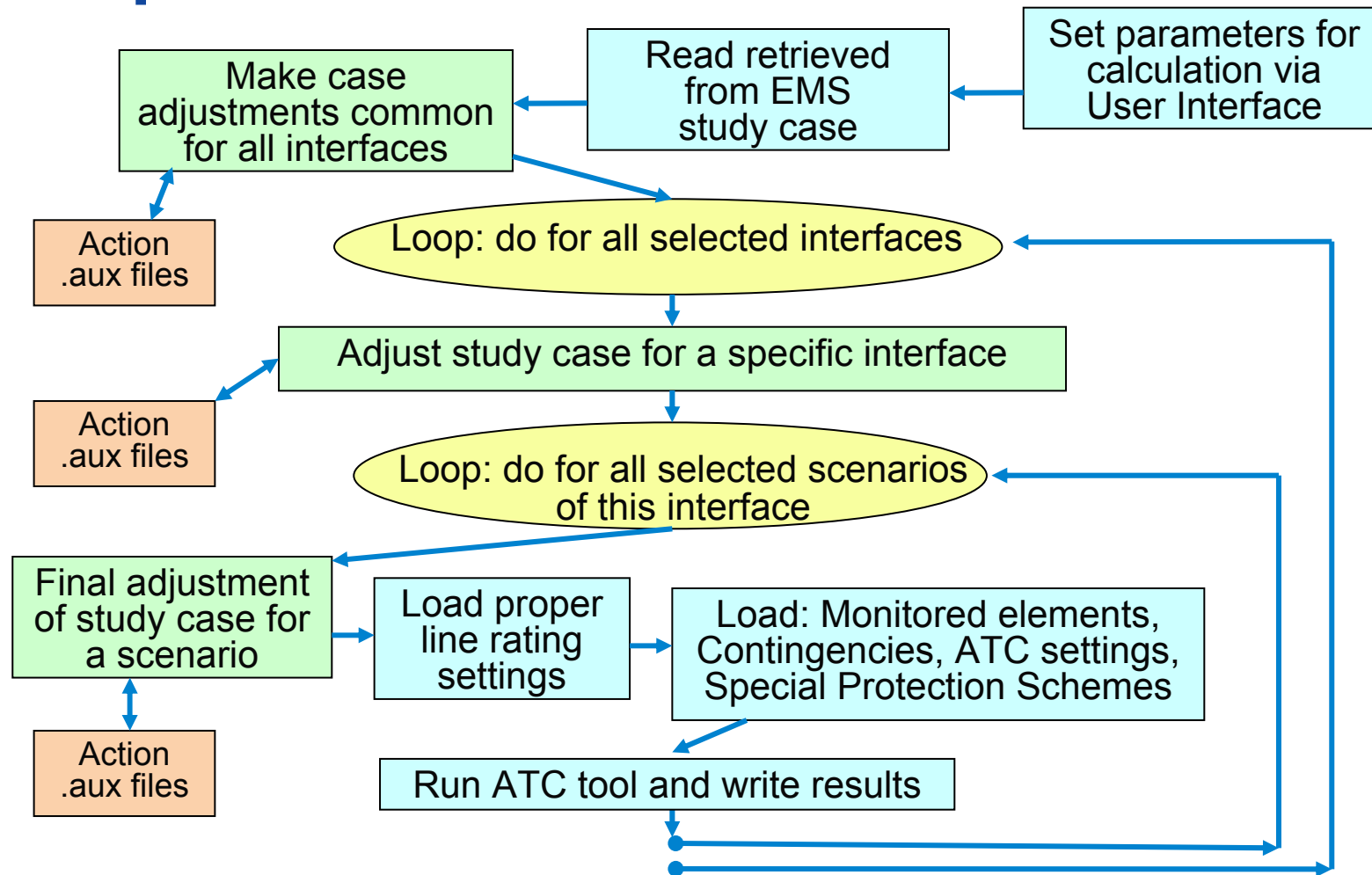


EMS and Power World integration

Retriever and Plant Information (PI) system provide capability to convert EMS power flow case into PowerWorld .aux format



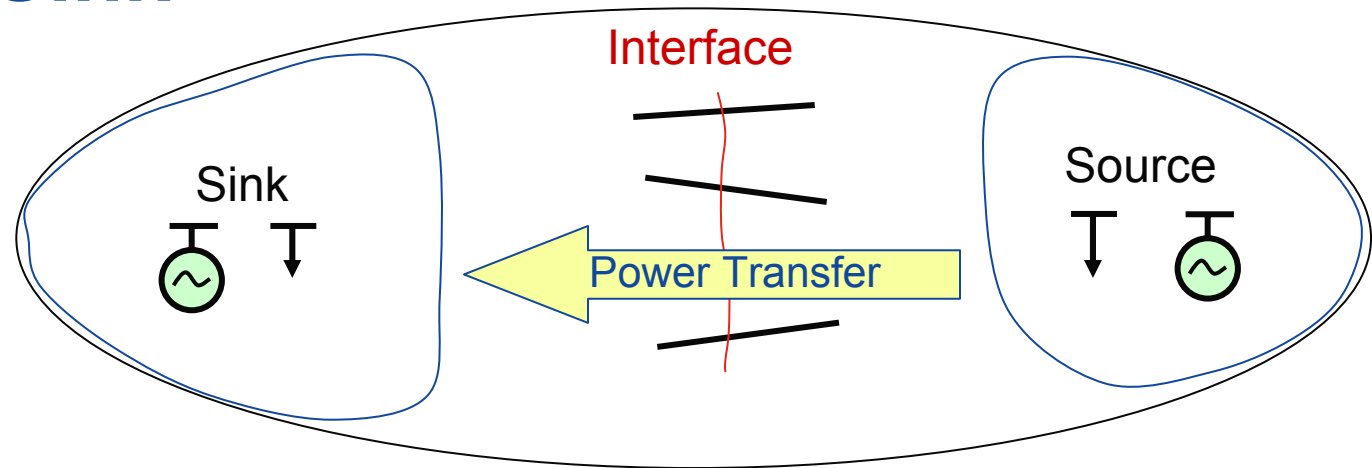
Script Generator



- **Universal structure for any scenario**
- **Introduction new scenario does not require coding and is data driven**

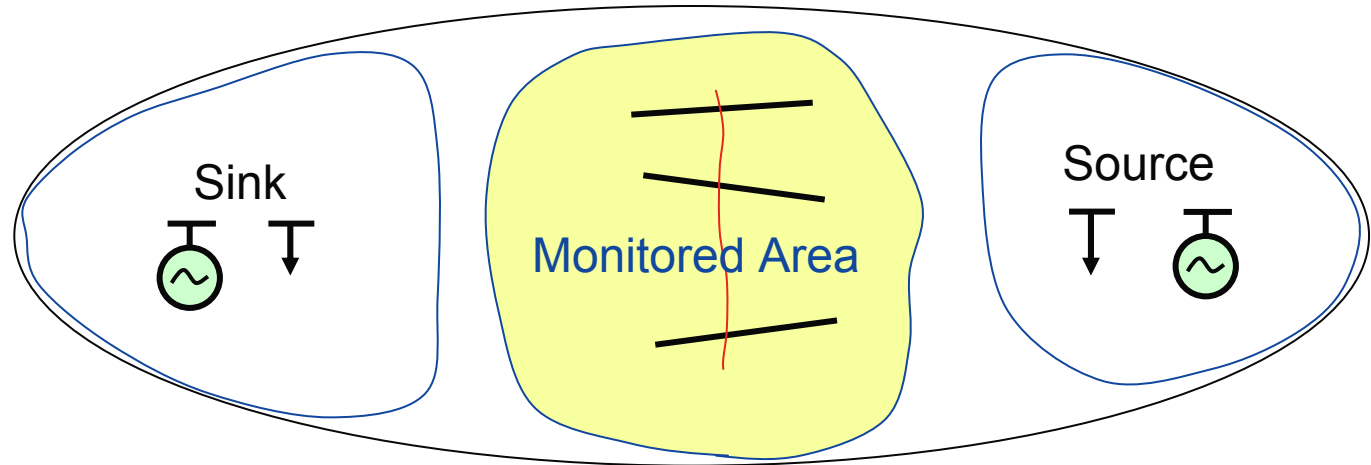
More details of supporting .aux files

Source - Sink



- Respect capacity limits: $P_{load} > 0$, $P_{min} < P_g < P_{max}$
- Locate Source and Sink far away from interface; include both generators and loads
- Capacity of available on-line units in the Source is often not sufficient to hit TTC limit. Assign additional Source units and bring them on-line if they are off-line in study case
- Change load only after generator resources are exhausted

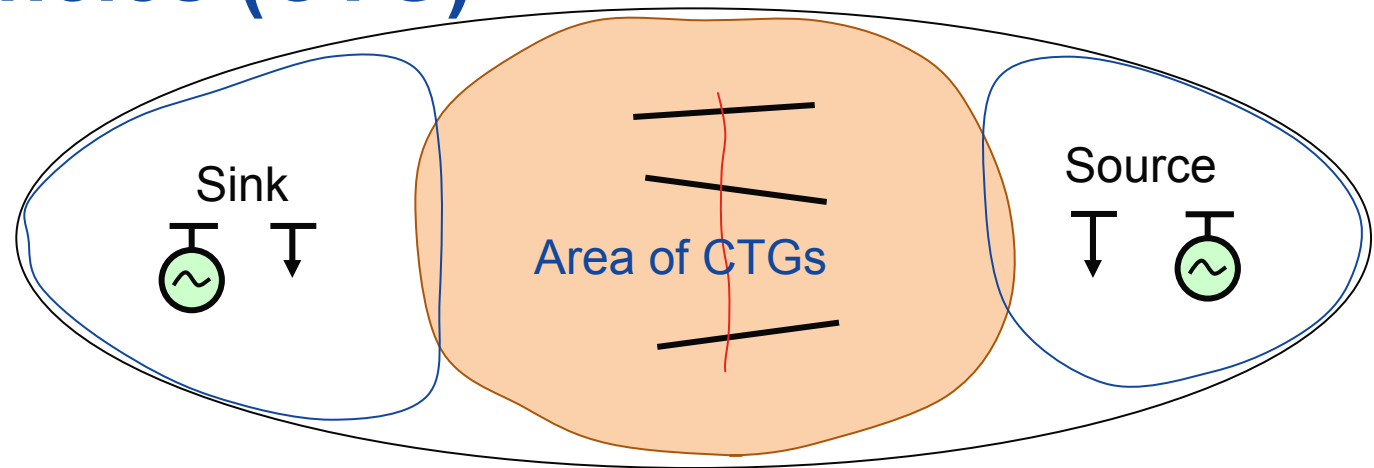
Monitored Elements



Selection of Monitored area as a compromise between

- Maximal system coverage around interface and
- Avoiding remote areas prone to local overloading due to relative arbitrariness of Source and Sink configuration and their day-to-day change

Contingencies (CTG)



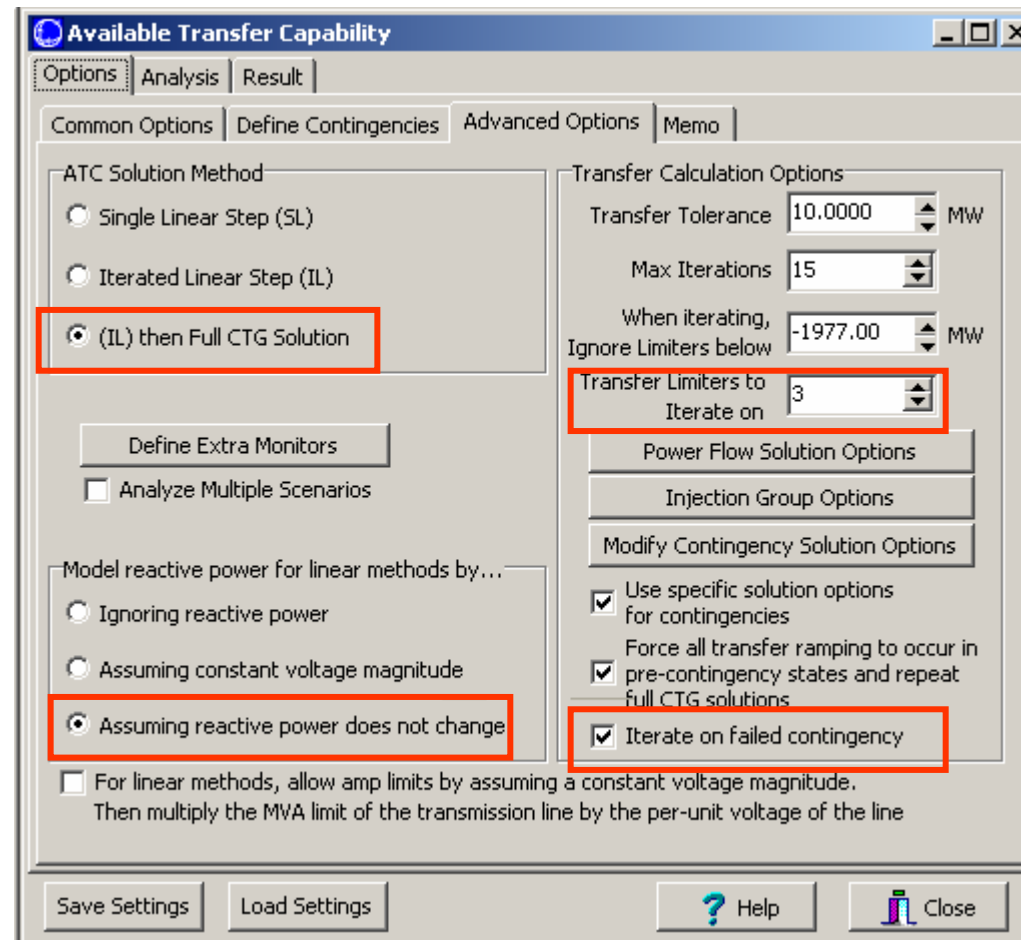
Reduce total number of CTGs to those significantly affecting interface area. Each interface has individual set of CTGs

Power World can generate N-2 CTGs as simple combinations of single CTGs. That could be more conservative comparing to NERC reliability requirement related to N-2 CTGs.

Special treatment of CTGs involving tripping of generators (2ndGen)

- Automatic selection of largest generators
- Proper AGC settings to pick up tripped power

ATC Settings



Coordinated settings to get reliable and accurate solution at min time

Automatic following changes in EMS

EMS power system model experiences frequent changes and results of TTC Calculator must be consistent

To increase reliability and reduce maintenance efforts, design of supporting .aux files shall automatically incorporate ongoing EMS changes

Examples of developed at ISO-NE pertaining procedures:

- Load participation factors follow load weights in EMS load tree
- Generation of N-k contingencies based on CTG labels (like 337 + 394) and single CTG definition in EMS

Near Future Plans

Near Future Plans

- A. Adopt TTC Calculator for Real Time operation. Key feature is implementation of “consolidated model” (without near to zero impedance branches) in all Power World tools
 - Expected 5-8 times reduction in current on-line computation time
 - Improved convergence of solution
- B. Day Ahead Market: Extend TTC calculation for every hour for the next 24 hours
- C. Develop automated combined calculation of Thermal Limits and Voltage Stability, PVQV tool
- D. Multi-CPU calculation of TTC to satisfy Real Time requirements
 - Natural paralleling by Interface and Scenario
 - Script generator can produce complete script for each Scenario very quickly

Thank you

