NREL
Transforming ENERGY

# IEEE-NASPI Oscillation Source Location Contest – Case Development and Results

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2. ISO New England

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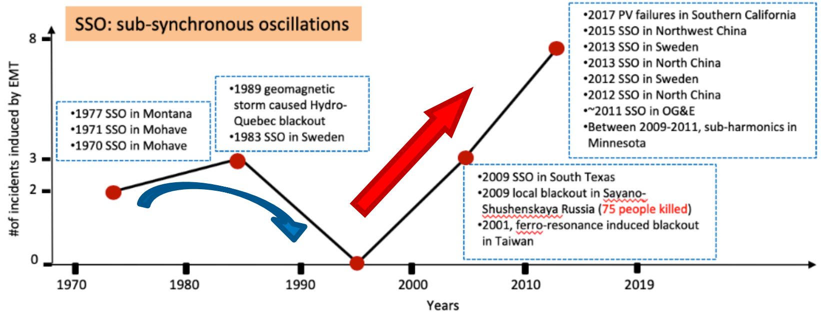
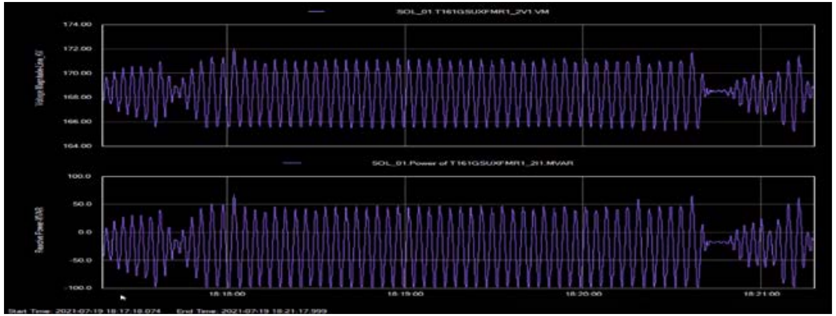
# Power System Oscillations

- A marginal state between stable and unstable
- Potential dynamic risks
- Historic events involving oscillations
  - 1996 Blackout
  - 2003 Blackout
  - 2009 TX SSO
- Should be mitigated timely




- **SSO caused by traditional synchronous machines had been taken care of**
- **SSO & other fast dynamic issues are surging caused by increased IBRs**

Source: https://www.youtube.com/watch?v=TLWvSoBAjOc



0.29Hz oscillations involving PV
IRPWG Meeting on Aug. 19, 2021
Source: TVA

# Oscillation Source Location (OSL) Contest

- Joint effort by IEEE OSL Task Force and NASPI [1-2].
- Objective: evaluating the efficiency of OSL methods and their applicability for practical implementation.
- Contest Highlights:
  - ➢ 60 teams from 11 countries signed up
  - ➢ 21 submissions
- Special thanks
  - ➢ Contest coordinator: Frankie Zhang (ISO New England)
  - ➢ Web support: Kai Sun (UTK), Teresa Carlon (PNNL)
  - ➢ WECC-240 bus base case: Jin Tan and the rest of the NREL team
  - ➢ TSAT simulation technical and license support: **Powertech Labs**

## IEEE-NASPI Oscillation Source Location Contest

In recent years, large-amplitude sustained oscillations have been observed in power grids around the world, thanks to widely deployed PMUs. Many of the observed oscillations did not appear in traditional model-based studies. Such oscillations are either due to unmodeled dynamics or unexpected periodic inputs. Since these oscillations are not represented in the simulation models, they are not visible in the planning studies and no mitigation measures can be designed offline. Therefore, finding the originating source(s) is crucial in real-time operations. Finding the source(s) not only enable timely mitigation measures and ensure secure grid operations, but also help generator owners manage asset health and investigate asset failures at an early stage.

The 2021 IEEE-NASPI co-hosted Oscillation Source Location (OSL) Contest aims to help the academia and vendors further develop & improve the currently available OSL tools, and help utilities identify & evaluate OSL tools for real-time use. The contest is open to the public; any individual, team or entity (except the committee members or their affiliations) can participate.

**Committee**

- Ning Zhou (Binghampton University)
- Jim Follum (Pacific Northwest National Laboratory)
- Athula Rajapakse (University of Manitoba)
- Bin Wang (National Renewable Energy Laboratory)
- Slava Maslennikov (ISO New England)
- Mani Venkatasubramanian (Washington State University)
- Evangelos Farantatos (Electric Power Research Institute)
- Jeff Bloemink (Powertech Labs)

[1] https://www.naspi.org/node/890
[2] http://web.eecs.utk.edu/~kaisun/Oscillation/2021Contest/

# OSL Methods

- Some existing methods (by 2015) for locating the oscillation source [3]

| Category | Key Idea | Cons |
|---|---|---|
| Damping torque | The generator with a negative damping torque coefficient is the source | Possible unavailability of rotor angle and speed data. Possible failures under forced oscillation cases. |
| Mode shape | Largest magnitude, most leading phase of the mode shape or their combinations may indicate the source | Lack of a theoretical foundation. Possible failures for cases having weakly damped/undamped oscillation together with forced oscillation. |
| Energy | The device producing dissipation energy is the source | Strong assumption in modeling loads and network. Lack of theoretical proofs for multi-mode cases. |
| Equivalent circuit | The source of the equivalent circuit is the source of the oscillation | Possible failures when the phasor concept cannot be applied, e.g. non-sinusoidal oscillations. Lack of theoretical proofs for multi-mode oscillation cases. |
| Hybrid | A larger difference between simulations and measurements indicates the source | Possible unavailability of the accurate model of the entire system. |
| Traveling wave | The closer to the source, the earlier the location will exhibit oscillation | Inaccurate and unreliable detection of the oscillation arrival time. Unavailability of the wave speed map in real-time. Lack of investigations on multi-mode cases. |
| Machine learning | An offline trained decision tree from model-based simulations to locate the source using online measurements | Possible unavailability of the accurate model of the entire system. Can be only applied to forced oscillation cases. |

- New methods, e.g. effective gen Z [4], UIO [5], RPCA [6], and harmonics [7].

[3] **Bin Wang**, Kai Sun, “Location Methods of Oscillation Sources in Power Systems: A Survey,” Journal of Modern Power Systems and Clean Energy, 2017
[4] S. C. Chevalier, P. Vorobev and K. Turitsyn, "Using Effective Generator Impedance for Forced Oscillation Source Location," in IEEE Transactions on Power Systems, vol. 33, no. 6, pp. 6264-6277, Nov. 2018
[5] M Luan, D Gan, Z Wang, H Xin, “Application of unknown input observers to locate forced oscillation source,” Int Trans Electr Energ Syst., 2019
[6] T. Huang, N. M. Freris, P. R. Kumar and L. Xie, "A Synchrophasor Data-Driven Method for Forced Oscillation Localization Under Resonance Conditions," in IEEE Transactions on Power Systems, vol. 35, no. 5, pp. 3927-3939, Sept. 2020
[7] S. Roy, W. Ju, N. Nayak and B. Lesieutre, "Localizing Power-Grid Forced Oscillations Based on Harmonic Analysis of Synchrophasor Data," 2021 55th Annual Conference on Information Sciences and Systems (CISS), 2021

# Energy based OSL

- Energy method [8] → Dissipating energy flow (DEF) [9]

- Calculation and physical meaning

$$W_{ij}^{D} \approx \int \left( \Delta P_{ij} d\Delta\theta_{ij} + \Delta Q_{ij} \frac{d(\Delta V_i)}{V_i^*} \right)$$
$$= \int \left( 2\pi \Delta P_{ij} \Delta f_i dt + \Delta Q_{ij} \frac{d(\Delta V_i)}{V_i^*} \right)$$

- How to get DEF tool?
  - ➢ OSLp software by ISO-NE, free of charge at [10]
  - ➢ DSATools/DSAOA built-in DEF since Release 20.0 [11]

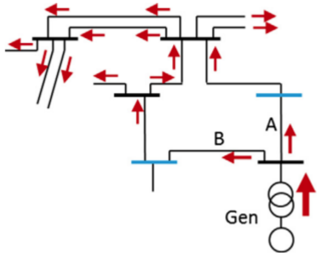



**Fig. 3.** Oscillation source location for April 5, 2013 event.

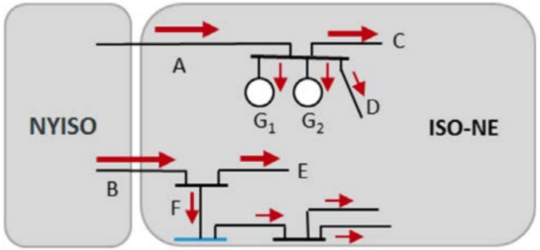
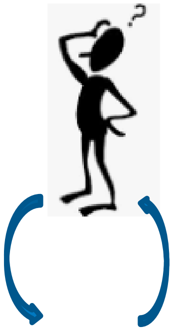



**Fig. 4.** Locating the source of oscillations for June 17, 2016 event.

[8] L Chen, Y Min, W Hu, "An energy-based method for location of power system oscillation source," IEEE Transaction on Power Systems, 28(2):828-836, 2013
[9] S Maslennikov, **B Wang**, E Litvinov, "Dissipating energy flow method for locating the source of sustained oscillations," International Journal of Electrical Power and Energy Systems, 2017
[10] https://www.iso-ne.com/participate/support/request-software
[11] https://www.dsatools.com/wp-content/uploads/2020/05/DSAOA-20.0-Release-Notes.pdf

# Data Flow Process



Input data preparation

Run TSAT

Convert results into "test cases library" format

PMU Emulator to mimic P/M PMU class

Add "missed" samples

Synthetic PMU data set

Final verification and benchmarking by OSLp

Scenario design:

- High-level description
- Technical implementation

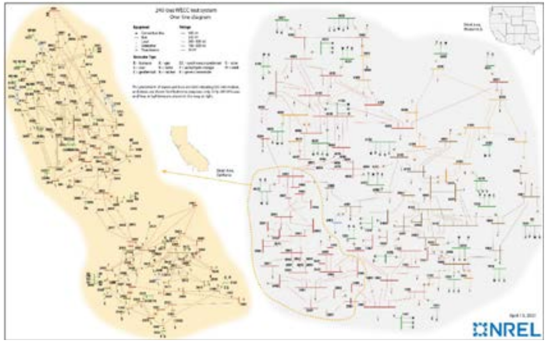
- **What are the desired cases, and the implementation challenges?**
- **How did we conquer them with DSATools?**

# Philosophy for Creation of Simulated cases for the OSL Contest

- The cases should be representative for real-life situations
  - Realistic combination of local and interarea natural oscillations with realistic modeling of all components
  - Representative Synthetic PMU measurements as a result of time-domain simulation
    - Partial system observability by PMUs
    - Processing measurements to mimic P/M class of PMU
    - Introduce missed/bad PMU samples, **colored noises**
- Properties of FO:
  - **Located at Generator (Governor & Exciter), Load, HVDC**
  - **Variable magnitude and frequency**
  - Not necessary/clear inception and limited duration
  - **Multiple sources and resonance with natural modes**
- Do not create bias for any known source locating method

# Challenge 1: Adding Power System Stabilizers (PSSs)

- Test system: 240-bus reduced WECC system developed by NREL [12].
- High renewable penetration (~20%).
- Power flow and dynamic data in PSS/E format now available at [13].
- Poorly damped local modes [12].




**Dynamic Models:**
GENROU, SEXS, TGOV1, HYGOV, GAST, REGCA, REECB, REPCA.

"Local oscillation modes around 1Hz have low damping ratios…because of the lack of stabilizer models." [12]

**Challenge 1: where and how much to add to make a realistic-looking case?**

| No. | Mode Freq (Hz) | Mode Damping Ratio (%) | No. | Mode Freq (Hz) | Mode Damping Ratio (%) |
|---|---|---|---|---|---|
| 1 | 0.3669 | 17.61 | 14 | 1.1808 | 4.73 |
| 2 | 0.5225 | 1.98 | 15 | 1.1906 | 4.5 |
| 3 | 0.598 | 1.06 | 16 | 1.2174 | 5.39 |
| 4 | 0.6927 | 1.25 | 17 | 1.2356 | 5.6 |
| 5 | 0.7282 | 1.13 | 18 | 1.2509 | 6.36 |
| 6 | 0.7624 | 1.5 | 19 | 1.2729 | 3.77 |
| 7 | 0.8648 | 1.26 | 20 | 1.2977 | 5.24 |
| 8 | 0.8896 | 1.73 | 21 | 1.3023 | 7.78 |
| 9 | 0.958 | 1.42 | 22 | 1.3394 | 7.9 |
| 10 | 0.9777 | 1.61 | 23 | 1.3416 | 5.6 |
| 11 | 1.0372 | 3.07 | 24 | 1.406 | 4.56 |
| 12 | 1.1457 | 5.33 | 25 | 1.4248 | 4.47 |
| 13 | 1.1464 | 3.97 | 26 | 1.4364 | 10.76 |

[12] H. Yuan, R. Sen biswas, J. Tan, Y. Zhang, "Developing a Reduced 240-Bus WECC Dynamic Model for Frequency Response Study of High Renewable Integration," 2020 T&D
[13] https://www.nrel.gov/grid/test-case-repository.html

# Challenge 1: Adding PSSs

- DSATools/SSAT – Small signal analysis tool.
- SSAT is very efficient: 10-sec runtime for this case with >2000 state variables.
- **Where to add**: Identified 10 critical machines for adding PSSs based on eigenvalues and eigenvectors (mode shape, participation factors) from SSAT.
- Added IEEEST PSS model [14] to the above 10 machines.
- **How much to add**: Sensitivity of eigenvalues to the variation of key IEEEST parameters, e.g. T1 and KS, can be calculated by SSAT. Easy to find parameters for reasonable damping ratios (6%-10% or higher).

**Real part of eigenvalue**

IEEEST PSS parameters

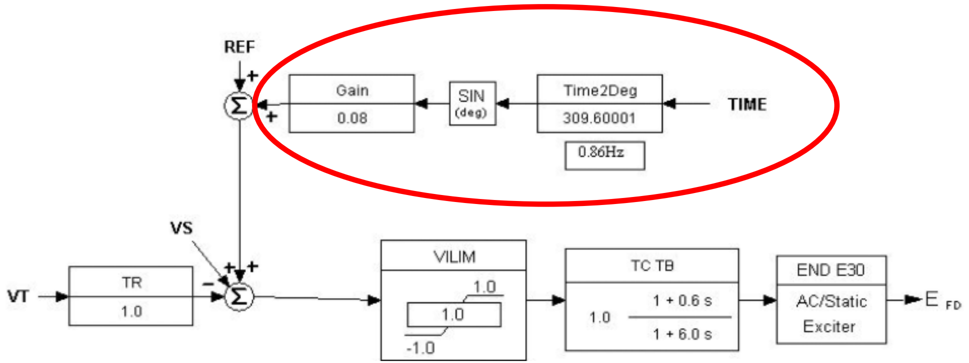
Sensitivity Mode Data Tabulation

| No. | Device ID | imeter N | Base Value | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. | Real Sens. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Real, 1/s | -0.4269 | -0.348 | -0.2975 | -0.3805 | -0.2466 | -0.3174 | -0.5222 | -0.5402 | -0.473 | -0.4135 |
| | | | Frequency, Hz | 0.3792 | 0.5383 | 0.6144 | 0.7084 | 0.741 | 0.7797 | 0.8911 | 0.9118 | 0.98 | 0.9951 |
| | | | Damping,% | 17.64 | 10.23 | 7.68 | 8.52 | 5.29 | 6.47 | 9.29 | 9.39 | 7.66 | 6.6 |
| 1 | 1333 [H ALLEN 20.0] 'G ' 'IEEEST' | T1 | 3 | -0.0153 | -0.0004 | -0.0014 | -0.0014 | -0.0031 | -0.0003 | -0.0115 | 0.0007 | -0.0007 | -0.0877 |
| 2 | 2030 [MEXICO 20.0] 'G ' 'IEEEST' | T1 | 4 | -0.0055 | -0.0014 | -0.0001 | -0.0006 | -0.0001 | -0.0003 | -0.0705 | -0.0256 | -0.0001 | -0.0058 |
| 3 | 2438 [MESA CAL20.0] 'WG' 'IEEEST' | T1 | 11 | -0.0067 | -0.0014 | -0.0012 | 0.0002 | -0.0089 | -0.0012 | 0.0005 | -0.0018 | 0 | -0.0001 |
| 4 | 2630 [HAYNES3G20.0] 'G ' 'IEEEST' | T1 | 4 | -0.0066 | -0.0014 | -0.0009 | 0.0001 | -0.0032 | 0 | -0.0361 | -0.0801 | -0.0012 | -0.0029 |
| 5 | 3931 [ROUND MT20.0] 'NH' 'IEEEST' | T1 | 10 | 0 | -0.0001 | -0.0022 | 0 | -0.0002 | 0.0002 | 0 | 0 | 0.0003 | 0 |
| 6 | 4131 [COULEE 20.0] 'H ' 'IEEEST' | T1 | 7 | -0.0029 | 0.0003 | -0.0032 | 0.0006 | -0.0035 | -0.0181 | 0 | 0 | 0.0001 | 0 |
| 7 | 6235 [MONTA G120.0] 'H ' 'IEEEST' | T1 | 10 | 0.0001 | -0.0035 | 0.0006 | -0.0004 | 0 | -0.0007 | 0 | 0 | 0.0001 | 0 |
| 8 | 6533 [EMERY 20.0] 'C ' 'IEEEST' | T1 | 7 | -0.0011 | -0.0163 | 0.0008 | -0.0062 | -0.0013 | -0.0026 | 0 | 0 | 0 | -0.0002 |
| 9 | 7031 [COLOEAST20.0] 'G ' 'IEEEST' | T1 | 7 | -0.0056 | -0.0089 | -0.0249 | -0.038 | -0.0014 | -0.0006 | 0 | -0.0003 | 0 | -0.0001 |
| 10 | 8034 [RNCHSECO20.0] 'G ' 'IEEEST' | T1 | 3 | -0.0006 | 0.0007 | -0.0117 | -0.005 | -0.0002 | -0.0173 | -0.0009 | -0.0006 | -0.1342 | -0.001 |
| 11 | 1333 [H ALLEN 20.0] 'G ' 'IEEEST' | KS | 3 | -0.0146 | -0.0004 | -0.0014 | -0.0012 | -0.0029 | -0.0004 | -0.0116 | 0.0011 | -0.0007 | -0.0855 |
| 12 | 2030 [MEXICO 20.0] 'G ' 'IEEEST' | KS | 3 | -0.007 | -0.0018 | 0 | -0.0008 | -0.0001 | -0.0004 | -0.0934 | -0.032 | 0 | -0.0076 |
| 13 | 2438 [MESA CAL20.0] 'WG' 'IEEEST' | KS | 3 | -0.0242 | -0.0051 | -0.0045 | 0.0009 | -0.0321 | -0.0043 | 0.0017 | -0.0068 | 0.0001 | -0.0001 |
| 14 | 2630 [HAYNES3G20.0] 'G ' 'IEEEST' | KS | 3 | -0.0084 | -0.0016 | -0.0013 | 0.0002 | -0.0042 | 0 | -0.0454 | -0.1072 | -0.0013 | -0.0041 |
| 15 | 3931 [ROUND MT20.0] 'NH' 'IEEEST' | KS | 3 | 0.0001 | -0.0005 | -0.0071 | 0.0002 | -0.0008 | 0.0009 | 0 | -0.0002 | 0.0009 | 0 |
| 16 | 4131 [COULEE 20.0] 'H ' 'IEEEST' | KS | 3 | -0.0062 | 0.0007 | -0.0073 | 0.0013 | -0.0079 | -0.0418 | 0 | 0 | 0.0002 | -0.0001 |
| 17 | 6235 [MONTA G120.0] 'H ' 'IEEEST' | KS | 3 | 0.0002 | -0.0114 | 0.002 | -0.0014 | -0.0001 | -0.0022 | 0.0001 | -0.0001 | 0.0002 | 0 |
| 18 | 6533 [EMERY 20.0] 'C ' 'IEEEST' | KS | 3 | -0.0026 | -0.0373 | 0.0016 | -0.0139 | -0.0029 | -0.0061 | 0.0001 | -0.0001 | -0.0001 | -0.0003 |
| 19 | 7031 [COLOEAST20.0] 'G ' 'IEEEST' | KS | 3 | -0.0126 | -0.0191 | -0.0571 | -0.0884 | -0.0033 | -0.0015 | -0.0002 | -0.0006 | 0.0001 | -0.0002 |
| 20 | 8034 [RNCHSECO20.0] 'G ' 'IEEEST' | KS | 3 | -0.001 | 0.0006 | -0.0115 | -0.0047 | -0.0002 | -0.0162 | -0.0008 | -0.0007 | -0.1324 | -0.0011 |

[14] T. Xu, A. B. Birchfield and T. J. Overbye, "Modeling, Tuning, and Validating System Dynamics in Synthetic Electric Grids," in IEEE Transactions on Power Systems, vol. 33, no. 6, pp. 6501-6509, Nov. 2018

# Challenge 2: Adding forced oscillations (FOs)

- Previously [15-16], adding an FO involves MANUALLY preparing a user-defined model (UDM) by DSATools/UDM editor.
- Cases design requires testing FOs at different controls (governor or excitation), different generators, with different forcing frequencies, and at load/HVDC.




Block diagram of the external force used for WECC 179-bus based oscillation test cases library [15-16]

[15] http://web.eecs.utk.edu/~kaisun/Oscillation/1f.html
[16] S. Maslennikov, **B. Wang**, Q. Zhang, F. Ma, X. Luo, K. Sun, E. Litvinov, "A Test Cases Library for Methods Locating the Sources of Sustained Oscillations," IEEE PES General Meeting, Boston, MA, July 17-21, 2016.

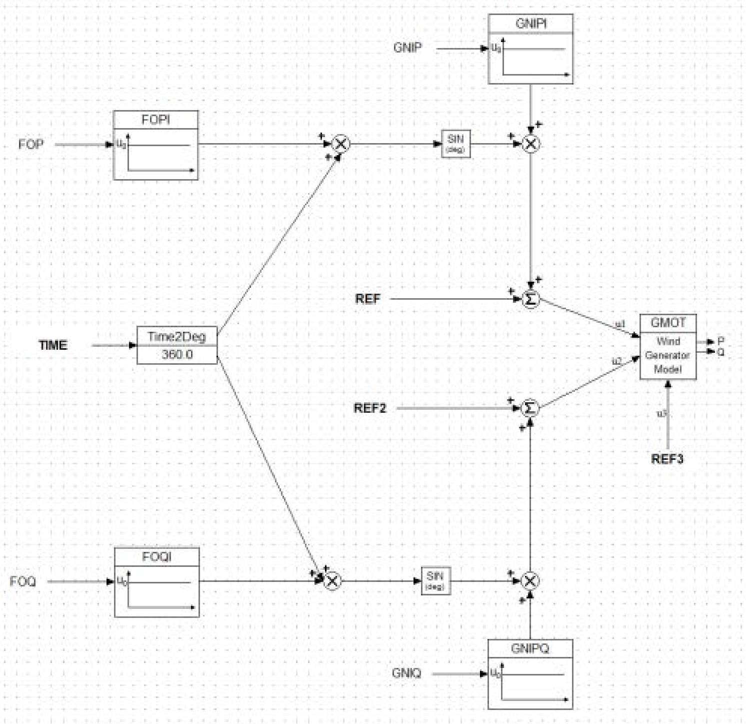
# Challenge 2: Adding FOs

- DSATools/Template UDM models.
- Developed by Jeff Bloemink (Powertech Labs)
- FOs at TGOV1, SEXS, load have been implemented as a list of template UDM models: FOINJECT, TGOV1FO, SEXSFO.
- Example: FO at load.

  '$TMPLT','FOINJECT',BUS,ID,SBASE,FOP,GNIP,FOQ,GNIQ/

  '$TMPLT','FOINJECT',1002,'IM',1,0.614,25,0.614,0/

- Testing different FOs can be easily scripted and automated.



# Challenge 2: Adding FOs

- With the new Template UDM models, it is easy to
  - ➢ scan thru many (1000+) interesting cases
  - ➢ find out cases to fail OSL methods based on (1) largest magnitude (mode shape) and (2) DEF.

9 out of 13 final contest cases have the largest oscillation amplitude in MW flow that is not at the actual source(s). [17]

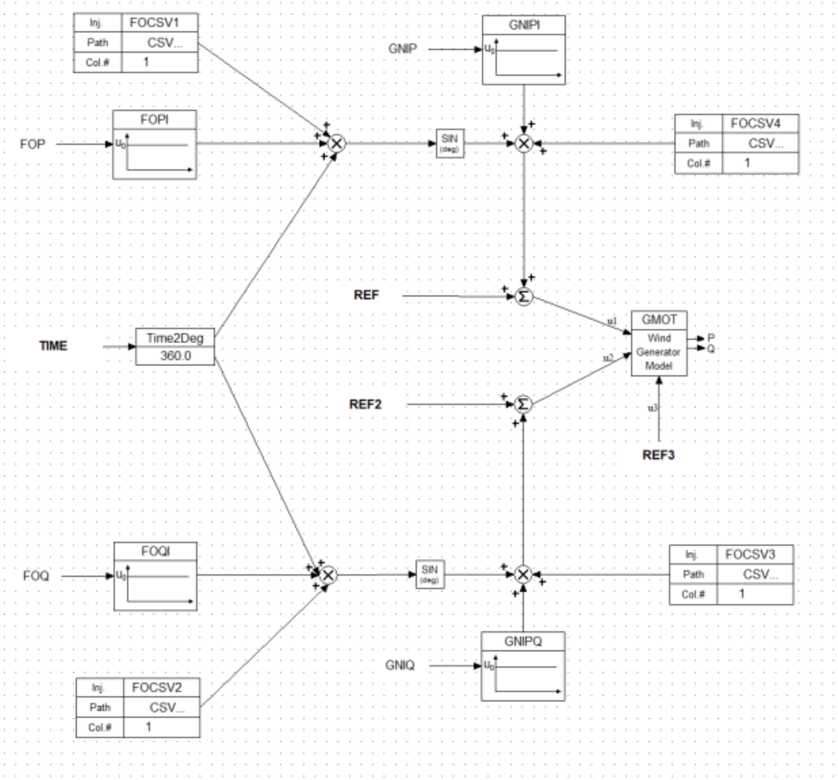
| | | | Identification of Source Generator | | | Identification of Source Power Plant | | | Identification of Source Area | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of FO | Frequency of FO, Hz | Cases of generators with FO | Correct identifi-cation cases | Success rate | Average success rate | Correct identifi-cation cases | Success rate | Average success rate | Correct identifi-cation cases | Success rate | Average success rate |
| Governor | 0.379 | 31 | 30 | 96.8% | 98.9% | 30 | 96.8% | 98.9% | 31 | 100.0% | 100.0% |
| | 0.614 | 31 | 31 | 100.0% | | 31 | 100.0% | | 31 | 100.0% | |
| | 1.27 | 31 | 31 | 100.0% | | 31 | 100.0% | | 31 | 100.0% | |
| Exciter | 0.379 | 93 | 12 | 12.9% | 60.1% | 79 | 84.9% | 86.9% | 83 | 89.2% | 94.7% |
| | 0.614 | 96 | 71 | 74.0% | | 76 | 79.2% | | 91 | 94.8% | |
| | 1.27 | 91 | 85 | 93.4% | | 88 | 96.7% | | 91 | 100.0% | |

Comprehensive statistics of DEF's effectiveness [18]

[17] http://web.eecs.utk.edu/~kaisun/Oscillation/download/2021_IEEE_NASPI_OSL_Contest_Solution_Key.pdf
[18] S. Maslennikov, "Efficiency of the DEF method for locating the source of oscillation," OAWG, March 18, 2021

# Challenge 3: Variable FO frequency and magnitude

- DSATools/Template UDM models.



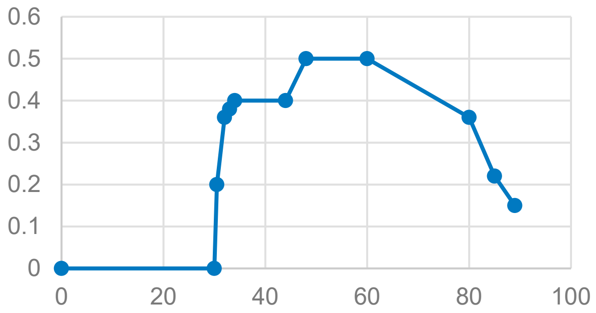

'$TMPLT','FOINJECTCSV',BUS,ID,SBASE,FOP,GNIP,FOQ,GNIQ,CSVFILEFO,CSVFILEFOGN/

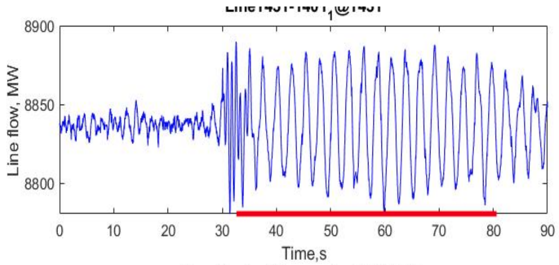
'$TMPLT','FOINJECTCSV',1002,'IM',1,0.614,25,0.614,0,'Frequency.csv','Magnitude.csv'/

Case3_FO_Magnitude...

C20

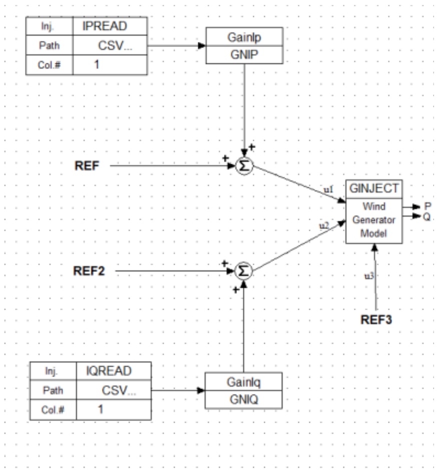
| | A | B |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 30 | 0 |
| 3 | 30.5 | 0.2 |
| 4 | 32 | 0.36 |
| 5 | 33 | 0.38 |
| 6 | 34 | 0.4 |
| 7 | 44 | 0.4 |
| 8 | 48 | 0.5 |
| 9 | 60 | 0.5 |
| 10 | 80 | 0.36 |
| 11 | 85 | 0.22 |
| 12 | 89 | 0.15 |



# Challenge 4: Adding Colored Noises

- Colored noises: very small load fluctuations added during time domain simulations.
- DSATools/Template UDM models.




'$TMPLT','INJECTCSV',BUS,ID,SBASE,GNIP,GNIQ,CSVFILEIP,CSVFILEIQ/

'$TMPLT','INJECTCSV',2612,'IM',1.0,1.0,1.0,'iptimeseries.txt','iqtimeseries.txt'/

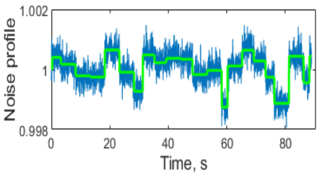
iptimeseries.txt

iqtimeseries.txt

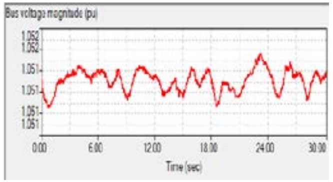
Time (s) Ip/Iq

| | A | B |
|---|---|---|
| 1 | 0 | 0.99963 |
| 2 | 0.033333 | 0.99988 |
| 3 | 0.066667 | 1.0001 |
| 4 | 0.1 | 1.001 |
| 5 | 0.13333 | 1.0008 |
| 6 | 0.16667 | 0.99962 |
| 7 | 0.2 | 1.0009 |
| 8 | 0.23333 | 1.0002 |
| 9 | 0.26667 | 0.99998 |
| 10 | 0.3 | 1.0006 |
| 11 | 0.33333 | 1.0003 |
| 12 | 0.36667 | 1.0004 |
| 13 | 0.4 | 1.0008 |
| 14 | 0.43333 | 1.0008 |

Noise Profile




Simulated voltage magnitude



# Features of Resulting 13 Contest Cases [19]

- It becomes possible or easier with DSATools to achieve these features.

| Case | Key Features |
|---|---|
| 1 | Easy case to "warm up" |
| 2 | Observable source; resonance with local mode |
| 3 | Non-observable source in the exciter; resonance with system-wide inter-area mode |
| 4 | Non-observable source in the governor; resonance with system-wide inter-area mode |
| 5 | Variable frequency of FO |
| 6 | Non-observable source; resonance with local mode |
| 7 | Source in the exciter; strong interaction with controls |

| Case | Key Features |
|---|---|
| 8 | Observable source; resonance with regional inter-area mode |
| 9 | 2 sources: (1) FO source in the governor (2) wrong tuning of PSS in another generator |
| 10 | 2 sources of FO resonating with local and inter-area modes |
| 11 | Source of FO in Load |
| 12 | Rectangular shape of forced signal creating wide spectra of oscillations |
| 13 | Source of FO in HVDC |

[19] http://web.eecs.utk.edu/~kaisun/Oscillation/contestcases.html

# Summary of OSL Contest Results

Energy-based methods are most efficient

| Team | 1/2 | 1/2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Score | 110 | 110 | 99 | 82 | 77 | 76 | 71 | 68 | 62 | 57 | 55 | 44 | 47 | 46 | 45 | 42 | 38 | 37 | 25 | 18 | 17 |
| Used Method 1 | | X | X | X | X | X | X | X | X | | X | | | | | | | | | X | |
| Used Method 2 | | | | | | | | | | X | X | | | | | X | | | X | | |
| Used Method 3 | | X | X | X | | | | | | | | X | X | X | X | | X | X | | | X |
| Used Method 4 | X | | | | | | | | | | | | | | | | | | | | |

Details of implementation could be critical

ML and Model-based method are less efficient

Methods
1: Energy-based
2: Oscillation shape and magnitude
3: Machine Learning and Model-based analytic
4: Cross Power Spectra Density

# Summary

- DSATools makes the case design process much easier:
  - SSAT efficiently calculates and visualizes eigenvalues/eigenvectors
  - SSAT provides sensitivity analysis
  - Template UDM models for adding a variety of FOs, and colored noises
  - DSAOA built-in Prony analysis, curve statistics table, and DEF analysis

# Thank you!

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