Equivalent Test Bed in PSCAD and PSLF for Studying Advanced Power Systems Controller Performance

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I. BACKGROUND

- **An increased interest for developing an advanced controller for inverter-based renewable energy resources to provide reliability support to the grid.**
- **Urgent need to ensure the integrity of newly developed models for renewables in positive-sequence simulators for large power system studies.**
- **Validation of the dynamic performance of the proposed model with detailed electromagnetic models.**

Electromagnetic simulation	Electromechanical simulation
• Facilitates accurate study of inverters and their control strategies • Problem of excessive solution time: cannot be used for interconnection-level studies • For example, PSCAD.	• Detailed analysis of controls associated with power electronics' dynamic is not possible • Reasonable solution time: can be used for interconnection-level studies • For example, PSLF.

- **Key challenge**
  - ➢ It is difficult to find a reference system with identical machine models in PSLF and PSCAD.
  - ➢ The initialization technique of the system dynamic states with base case power flow is different between PSCAD and PSLF.
- Therefore, a systematic approach is taken to develop an equivalent test bed in PSCAD and PSLF.

PSCAD ⟷ **Equivalent test bed** ⟷ **PSLF**

- Creation of the test bed would enable the following:
  - ➢ Easy validation of any user-defined model in PSCAD and PSLF
  - ➢ PSCAD version of the test bed would be useful to study unbalanced fault scenarios that could not be studied in positive-sequence tools.

II. PROPOSED METHODOLOGY

- **The IEEE 9-bus system was used to create two equivalent standard test cases in PSCAD and PSLF.**
- **Five steps were taken in the process.**

1. **Validate the power flow in PSCAD and PSLF.**
2. **Select the equivalent machine models.**
3. **Obtain the same predisturbance steady state in PSCAD and PSLF.**
4. **Fine-tune the machine parameters.**
5. **Integrate the inverter-based model with controller in the network.**

Table I. Power Flow Results in PSCAD and PSLF

	PSLF		PSCAD		Error	
	Volt. Mag. (p.u.)	Volt. Ang. (deg.)	Volt. Mag. (p.u.)	Volt. Ang. (deg.)	Volt. Mag. (p.u.)	Volt. Ang. (deg.)
Bus 1	1.04	0	1.039	0.021	0.001	0.021
Bus 2	1.025	9.35	1.025	9.33	0	0.020
Bus 3	1.025	5.14	1.024	5.12	0.001	0.020
Bus 4	1.025	-2.22	1.025	-2.19	0	-0.030
Bus 5	0.999	-3.68	0.9996	-3.64	-0.0006	-0.04
Bus 6	1.012	-3.57	1.012	-3.53	0	-0.04
Bus 7	1.027	3.80	1.026	3.77	0.001	0.030
Bus 8	1.017	1.34	1.017	1.32	0	0.02
Bus 9	1.033	2.44	1.032	2.42	0.001	0.02

Table II. Machine Models Used in PSCAD and PSLF

Type	Equipment	PSCAD	PSLF
Hydro-power plant at Bus 2	Generator	Sync1	Genrou
	Exciter	AC1A	Exac1
	Turbine/ Governor	Hydro Tur1/ Hydro Gov 1	Hygov4
Steam power plant at buses 1, 3	Generator	Sync1	Genrou
	Exciter	AC1A	Exac1
	Turbine/ Governor	Steam Tur1/ Steam Gov4	Ieeeg1

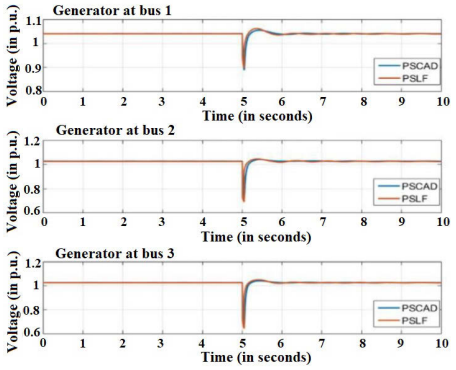

Fig. 1. Terminal voltage of different generators in the IEEE 9-bus system for a bolted three-cycle fault at Bus 8

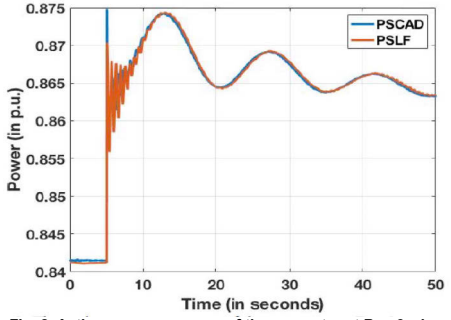

Fig. 2. Active power response of the generator at Bus 3 when 30-MW load is increased at Bus 6

III. APPLICATION OF THE TEST BED

- **The test bed created was used to validate the modeling of the synthetic inertia controller in PSLF from the detailed modeling in PSCAD.**
- **A renewable machine with synthetic inertia controller (wind, solar photovoltaics, or battery storage) is integrated into the system.**

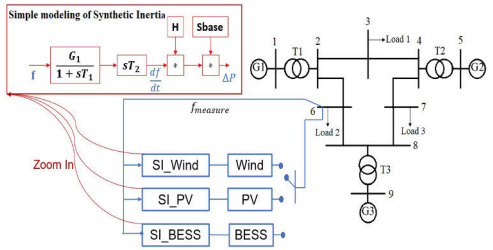

Fig. 3. Integration of the synthetic inertia controller for a renewable machine in the IEEE 9-bus system

Event
- 30 MW of load at Bus 6 is increased at 1 s.

Observation
- In response to the frequency dip, the renewable machine increases its active power output because of synthetic inertia controller action.
- The active power response of the renewable source in PSLF is similar to the one in PSCAD.
- The user-defined model of the battery with synthetic inertia developed in PSLF can reflect an accurate frequency dynamic response, like the detailed model in PSCAD.

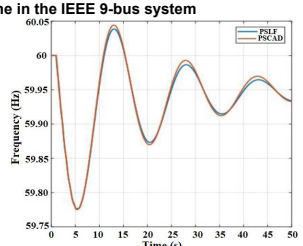

Fig. 4. Frequency response

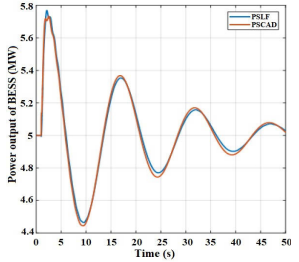

Fig. 5: Active power response of BESS

V. CONCLUSION

- **A systematic approach is proposed to develop an equivalent test bed in PSCAD and PSLF.**
- **An equivalent 9-bus system with photovoltaics, wind or battery has been developed in PSCAD and PSLF. The same dynamic response and frequency response of the system is achieved in PSCAD and PSLF.**
- **Further, a user-defined model of synthetic inertia was developed for renewables in PSLF and validated with the detailed model presented in PSCAD.**
- **The proposed equivalent test bed will help validate the performance of advanced frequency controllers from the detailed modeling to positive-sequence simulation tools.**

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