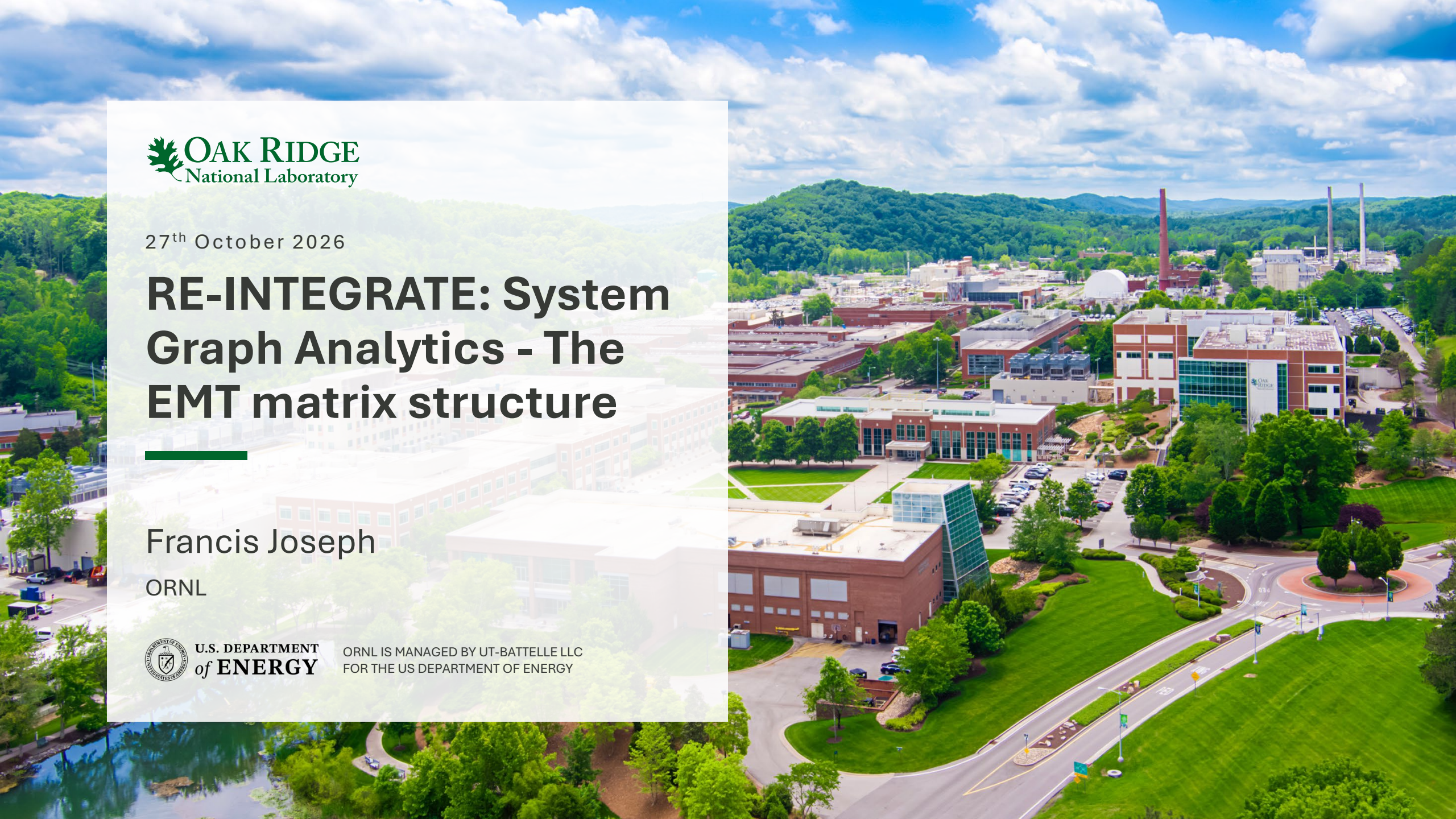


OAK RIDGE National Laboratory

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RE-INTEGRATE: System Graph Analytics - The EMT matrix structure

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ORNL

U.S. DEPARTMENT of ENERGY

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EMT Initiative - WG3: Solvers Working Group

Scope & Objectives

Advance solver technologies and architectures for electromagnetic transient (EMT) simulation to address slowness of simulations and limited scalability of such simulations, with emphasis on near real-time studies of large-scale power grids comprising tens of millions of nodes and millions of inverters.

Research Focus

1. Structure-aware solvers to optimize solve
2. DAE properties-based optimization of integration
3. CPU, GPU, and multi-node parallelism
4. Approximate solves
5. Multi-timestep solves
6. AI-based methods

Impact

Speedup; Automation; Parallelism; Extensibility; Scalability; Intelligence

The heart of EMT solution: Matrix solve

EMT DAEs

$$M\dot{x} = f(x, u, t)$$
$$0 = g(x, u, t)$$

Discretization

Non-linear equations

$$0 = f1(x, u, t)$$
$$0 = g(x, u, t)$$

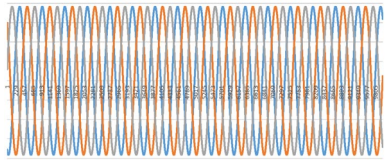
Linearization

Linear system of equations

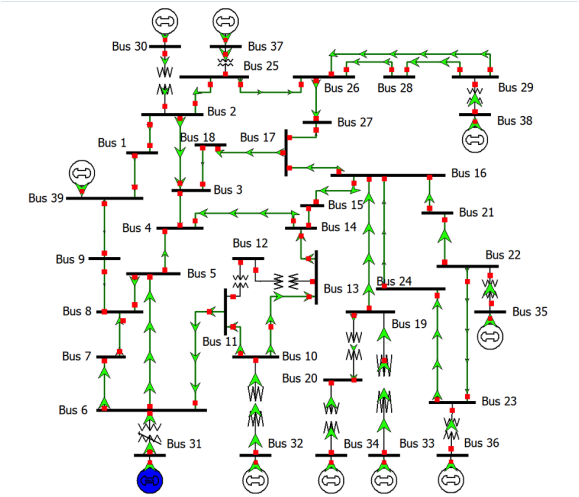
$$A\,x = b$$

Solve

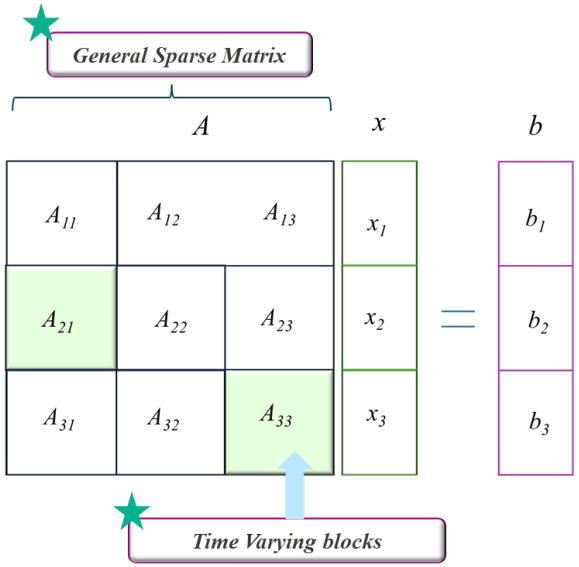
Results



Switching hybrid analog-discrete systems



Discrete non-linear systems



Structure-specific formation

No. of Inverse Required = EMT needs these at every time step, 1s simulation with step of 1μs is 1 million inverses

Question for WG

Can we use properties of the power system to solve this matrix efficiently – reducing time for linear solve?

Structure in Matrices

Power system topology results in different matrix pattern

General Sparse Matrix

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

Intelligence Block

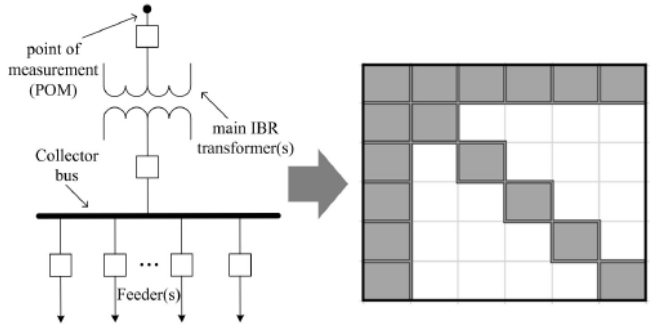
- Block Diagonal (BD)
- Bordered Block Diagonal (BBD)
- Nested Bordered Block Diagonal (NBBD)
- Block Tri Diagonal (BTD)

Matrix Structure based on the network topology

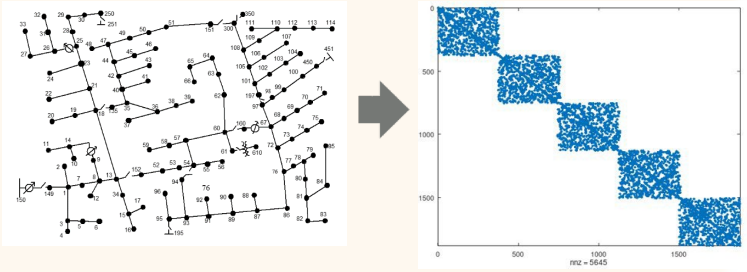
BD Matrix

$$\begin{bmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

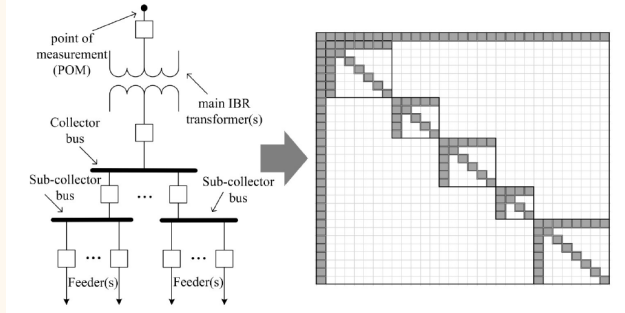
BBD Matrix



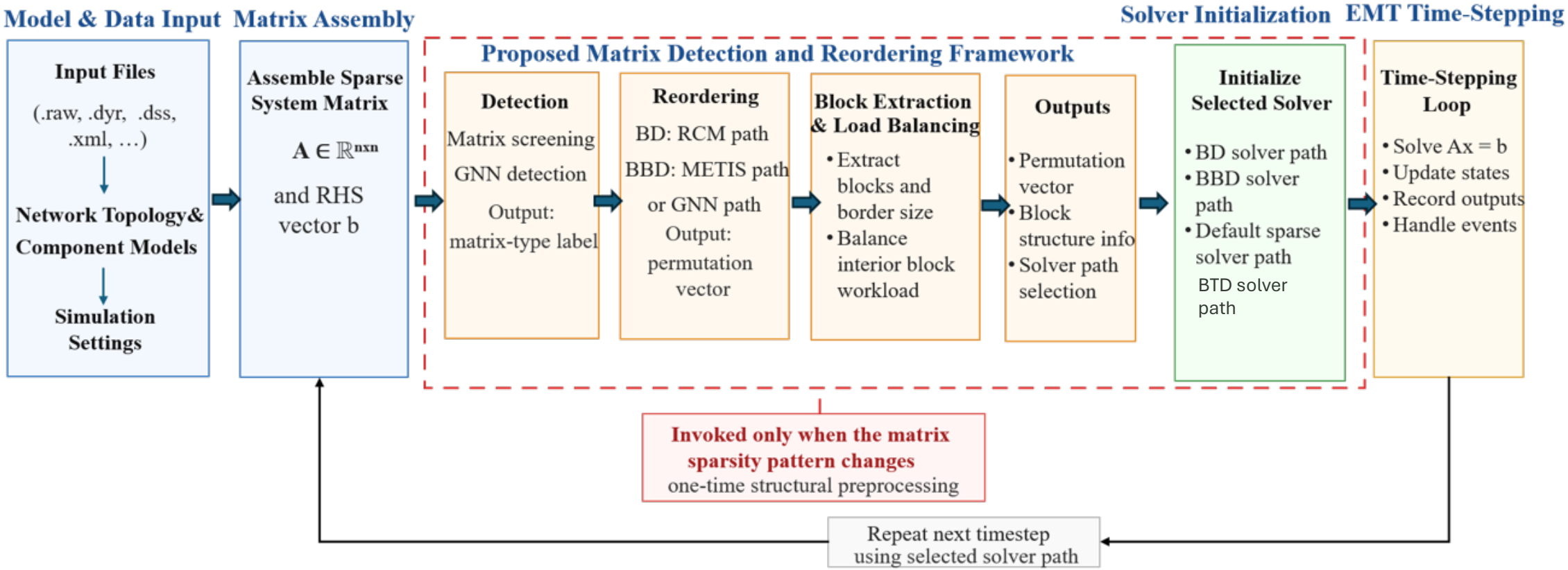
BTD Matrix



NBBD Matrix



Structure-aware runtime path for EMT sparse linear systems



Thank You

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