Modeling and Co-optimizing Integrated Transmission-Distribution (ITD) Systems using PowerModelsITD.jl

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Abstract & Motivation

Conventional electric power systems (EPS):

- Generation
- Transmission System Operators (TSO)
- Distribution System Operators (DSO)



Electric Power Systems (EPS) stages

Problems & Current Practices

- T&D systems operated **independently**
 - Distribution modeled as **passive loads**
 - Transmission modeled as voltage sources



Distribution is becoming more **active** with **DER** 2. (e.g., solar PV, batteries)







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3. Grid operators are **unable to coordinate** resources across **T&D** boundaries

- **Coupling** T&D is **non-trivial**
- Unable to coordinate resources and unlock DER flexibility
- No/limited visibility of DERs from transmission
- **Unable** to explore **effects** of:
 - High-penetration of DER in T&D
 - **Demand-response** programs in T&D
 - VRE & DER coordination in T&D
 - Extreme weather events in T&D

Coordination (Co-optimization) between **T&D** is/will be **essential** for **optimal operation** of the grid.

To fill this gap, we developed a first-of-its-kind framework that supports and enables the **Co-optimization** of **T&D systems**

PowerModelsITD.jl

What is **PowerModelsITD.jl**?

- **Open-source** tool (Written in **Julia**)
- Based on LANL multi-infrastructure ecosystem
- Used for modeling and optimizing T&D systems
- **Solve** steady-state **ITD Optimal Power Flow (OPF)**
- Evaluate diverse network formulations
- **Common** research **platform** for **emerging** formulations





GitHub [[1] https://github.com/lanl-ansi/PowerModelsITD.jl

[2] Ospina, J., et al. (2023). Modeling and Rapid Prototyping of Integrated Transmission-Distribution OPF Formulations with PowerModelsITD.jl. IEEE Transactions on Power Systems. [3] Ospina, J., et al. (2023). On the Feasibility of Market Manipulation and Energy Storage Arbitrage via Load-Altering Attacks. Energies, 16(4), 1670.

Formulations:

- Relaxations

- Linear Approximations

- NLP

- Hybrid

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Example Use Case

Large-scale T&D system Co-optimization

500 buses **224** Gens

@ 2.80 Ghz

RAM: 128 GB

CPU: x6 Cores





Total: 19,637 nodes & 20,595 edges

Formulation	\$/hr	Time (s)	Iterations
ACP-ACPU	422,095.2350	525.154	94
IVR-IVRU	422,095.2348	360.954	99
NFA-NFAU	412,286.7567	10.860	24
ACR-FBSUBF	422,074.7218	226.852	97
BFA-LinDist3	412,286.7567	146.084	45
SOCBF-LinDist3	421,529.7893	241.203	75

Capabilities (R&D and Industry)



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13 distribution systems w/ **759 - 3,403** nodes (range)



decomposition methods are being developed to increase size & parallelize