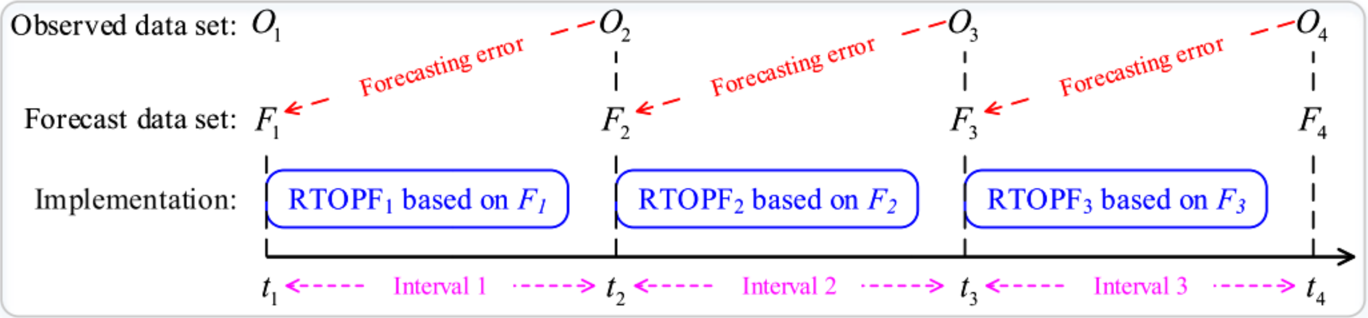

Fast Batched Solution for Real-Time Optimal Power Flow With Penetration of Renewable Energy

Authors: Shengjung Huang, Venkata Dinavahi

Team Members

| James, MS OR 1st year

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| Vishal, MS OR 1st year

Authors' Background

- **Shengjun Huang**
  - B.S. and M.S. degrees in Management Science and Engineering from the National University of Defense Technology, Changsha, China (2012, 2014)
  - Ph.D. degree in Electrical and Computer Engineering from the University of Alberta, Canada (2018)
  - Lecturer with the College of Systems Engineering, National University of Defense Technology (*2019**)
  - 15 Publications and 220 Citations
  - Areas of Interest: Power System Planning and Design and Energy System Modeling and Optimization
- **Venkata Dinavahi**
  - Ph.D. degree in Electrical and Computer Engineering from the University of Toronto
  - Professor at the University of Alberta (*2001**)
  - 254 Publications and 6788 Citations
  - Fellow of IEEE, Registered Professional Engineer, active within IEEE Public Energy Systems
  - Areas of Interest: Real Time Simulation Of Large-Scale Power Systems and Embedded and Reconfigurable Systems Design

**Note: information is sparse, dates are presumed*

Introduction and Main Ideas

Introduction

- Optimal Power Flow problem: Deciding the optimal operating conditions (minimizing a quadratic power generation cost in this case) for a power-plant based on (predicted) demand.

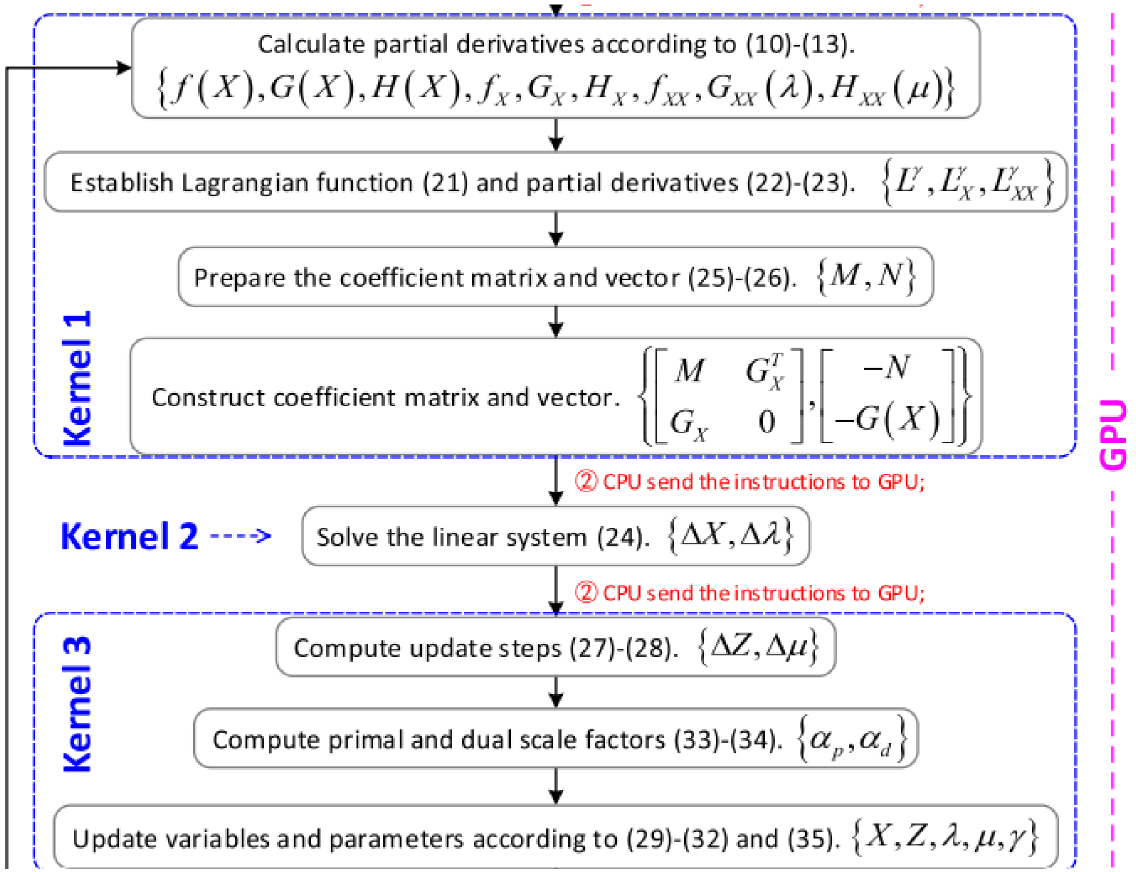
- The authors present a more accurate and faster method of solving the Real Time Optimal Power Flow problem (RTOPF) in the presence of renewable energy sources

- Problems of focus in this paper:
  - Integrating renewable energy efficiently – Renewable energy sources are uncertain
  - Need to solve the problem quickly – Calculations are happening in real time with short decision intervals

- High-level solution approach:
  - Use multiple scenarios to account for uncertainty in renewable energy
  - Accelerate the solution process using GPU – more on this on next slide

RTOPF with GPU Parallelization

- Solution Approach:
  - Three-stage framework with GPU acceleration
    1. Scenario Generation
    2. Scenario Solutions (w/ GPU)
    3. Hot-start of real problem
  - Enhances processing speed for real-time power distribution
- Optimization Algorithm:
  - Primal-Dual Interior Point Method (PDIPM).
  - Solves the QP model for optimal power flow



Paper Results – Computational Speedup

Computational Time in Seconds

Cases	14-bus	57-bus	118-bus	300-bus
Regular CPU	20.51	106.95	890.95	2,125.40
Parallel CPU	2.29	11.38	91.91	208.47
Regular GPU	1.51	5.88	43.54	85.05
Batched GPU	0.51	2.20	17.19	37.80

Speed-Up vs Regular CPU Method

Cases	14-bus	57-bus	118-bus	300-bus
Regular CPU	1.00	1.00	1.00	1.00
Parallel CPU	8.95	9.40	9.69	10.20
Regular GPU	13.60	18.19	20.47	24.99
Batched GPU	40.22	48.61	51.83	56.23

Citations

- Real-Time Active-Reactive Optimal Power Flow with Flexible Operation of Battery Storage Systems
- Applications of Novel Hybrid Bat Algorithm With Constrained Pareto Fuzzy Dominant Rule on Multi-Objective Optimal Power Flow Problems
- Low-Cost Analysis of Load Flow Computing Using Embedded Computer Empowered by GPU
- GPU-based parallel real-time volt/varoptimisation for distribution networkconsidering distributed generators

Future steps

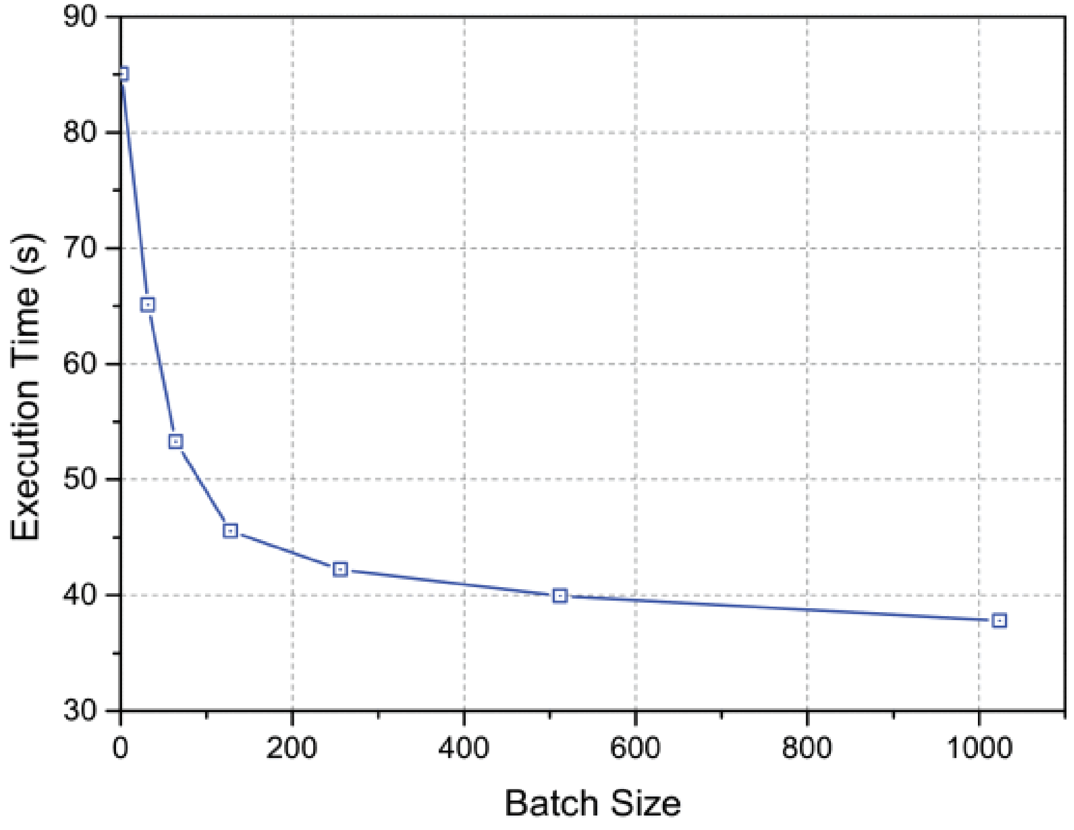
Next Steps

- Path Forward
  - Work in a similar order to the paper
    - CPU implementation
    - CPU parallel implementation
    - GPU implementation
    - GPU Batched implementation
- Difficulties
  - Address data access issues by exploring partnerships or public datasets
  - Clarify which components are implemented in CUDA C for GPU acceleration and adapt or develop equivalent CPU methodologies

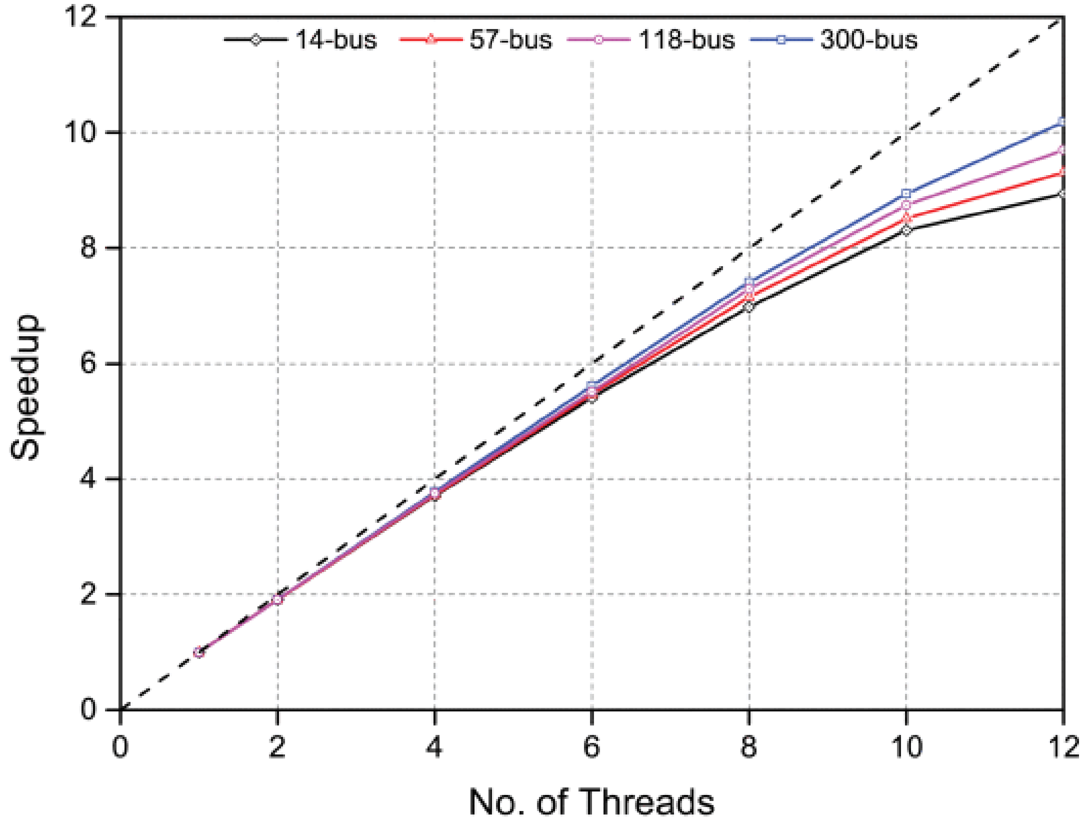

THANK YOU!

Appendix – Advantages

Computation Time vs GPU Batching Size



Speedup (compared to CPU) vs # Threads



Hot Start Advantage

No. of scenarios	32	64	128	256	512	1024
No. of iterations for the final hot start linear system	8	5	3	2	1	1

Appendix – Multi Stage Solution

Stage 1 (Light)	1.1 Gather meteorological data for the next interval; 1.2 Forecast the REG power output with prediction algorithms; 1.3 Scenario generation and reduction.
Stage 2 (Heavy)	2.1 Gather thermal generator status to form ramp constraints; 2.2 Forecast power loads to form power balance constraints; 2.3 Formulate RTOPFs based on each scenario; 2.4 Solve these RTOPFs in parallel and maintain a lookup table.
Stage 3 (Light)	3.1 Gather REG status to determine the closest scenario; 3.2 Index the RTOPF solution from the lookup table; 3.3 Formulate RTOPF based on the REG status obtained in 3.1; 3.4 Utilize the solution given in 3.2 as a hot-start point, solve the RTOPF developed in 3.3.