Solving Large-Scale Multiperiod OPF Problems Using an AC-QP Algorithm

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Outline

* Introduction
  * Multiperiod Optimal Power Flow (OPF) Problem
* AC-QP OPF Solution Method
* Improved Initialization with an SOCP Relaxation
  * An Illustrative Example
* Conclusions

General Optimal Power Flow (OPF) Problem

$\forall t \in \mathcal{T}:$

$$\min C(P_g(t))$$ ← (Quadratic) Cost of Conventional Generation

subject to:

$$g(x_t) \leq 0$$ ← Operational Limits

$$h(x_t) = 0$$ ← (AC) Power Flow Equations

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Modifications to Traditional OPF Problems

* Wind generation
  * Zero-cost generators
* Storage
  * Nonideal efficiencies
  * Linear state of charge dynamic equations

$$\forall t \in \mathcal{T}:$$

$$b(t+1) = b(t) + T_s \eta_c r_c(t) - \frac{T_s}{\eta_d} r_d(t)$$

$$b(T+1) = b^{term}$$

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Storage → Multiperiod OPF

$\forall t \in \mathcal{T}:$

$$\min C(P_g(t))$$

subject to:

$$g(x_t) \leq 0$$
$$h(x_t) = 0$$

$$\min \sum_{t \in \mathcal{T}} C(P_g(t))$$

subject to: $\forall t \in \mathcal{T}$

$$g(x_t) \leq 0$$
$$h(x_t) = 0$$

Overview of OPF Solution Methods

1. Quadratic program (QP) formulation, separate AC power flow to update losses (AC-QP OPF)
2. Quadratic program (QP), DC OPF
   - Piecewise-linear losses formulation
3. Convex Relaxations
   - *Semidefinite program (SDP)*
   - *Second order cone program (SOCP)*

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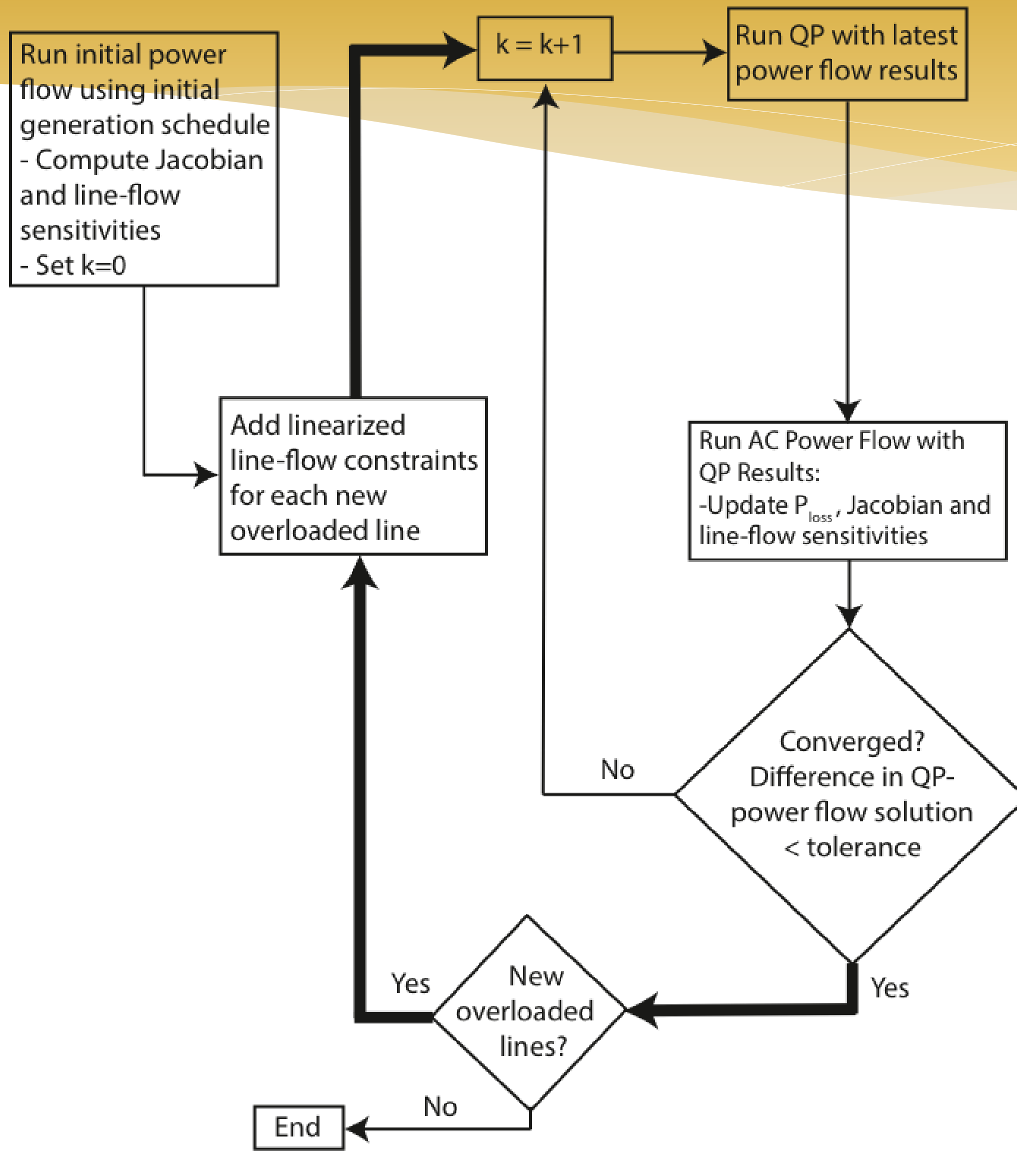
AC-QP Algorithm Overview



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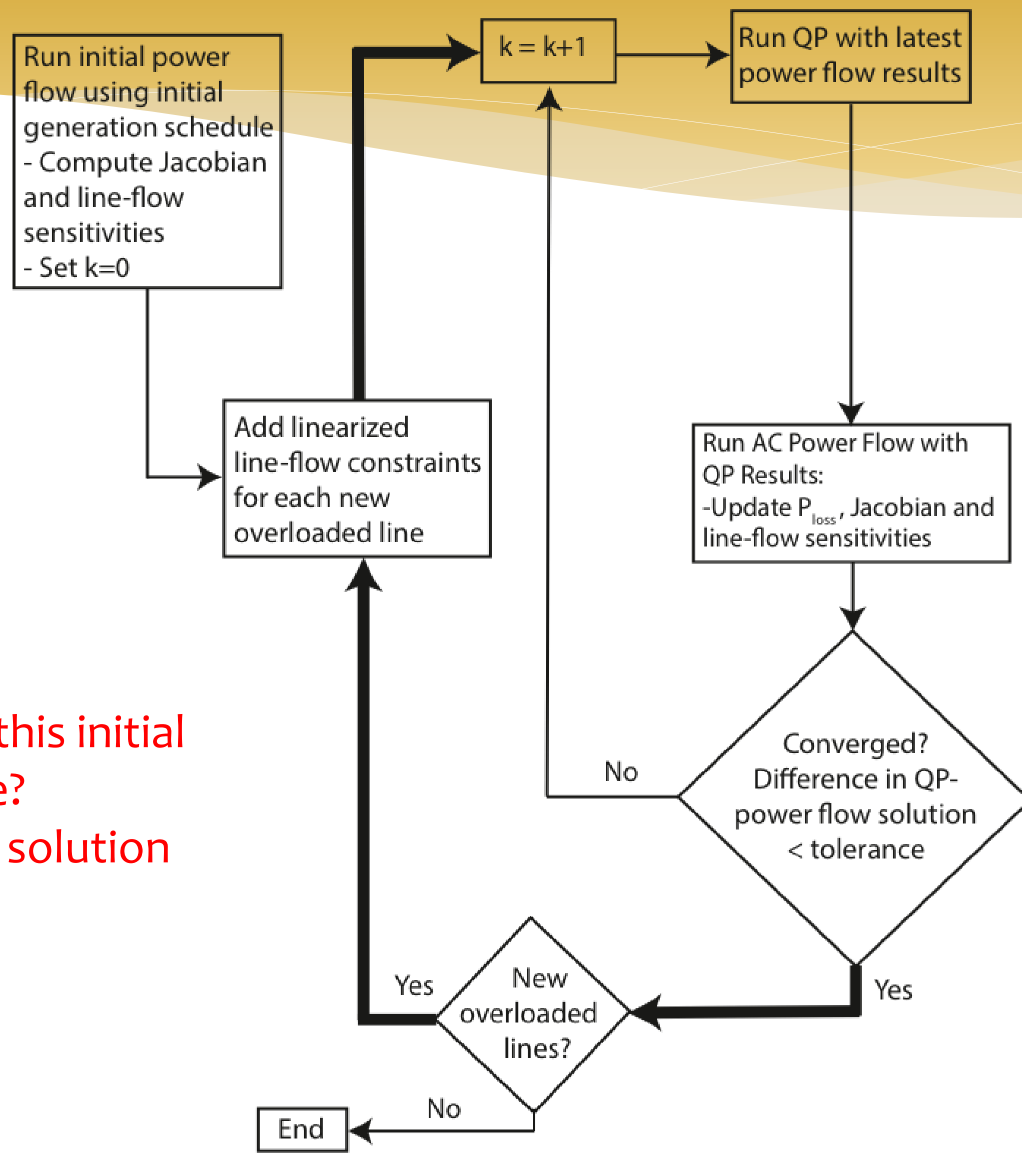
Possible Challenges of the AC-QP OPF Method

* Local minima
* Assessing quality of solution
* Guarantee of convergence
* Convergence rate
  * Execution time sufficiently fast for real-time applications?
  * Timing results depend on the number of QP-power flow iterations.

Basic Algorithm Overview



1. How do we choose this initial generation schedule?
2. How sensitive is the solution to this choice?

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Some Possible Initialization Methods

1. MatPower test case description (or other network description)
   - Assume storage & wind are initially unused.
2. DC-OPF
   - Losses are approximated as 3% of total load at each bus, including both demand & storage charging.
   - Assume voltage magnitudes are those given in the test case description.
3. SOCP Relaxation
   - Collaboration with Dan Molzahn (Argonne National Laboratory)

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Idea: SOCP + AC-QP

SOCP

* In practice, scales well for large networks & moderately long optimization horizons
* When tight, gives globally optimal solution
  * No guarantee of being tight
* Lower bound of globally optimal objective
* No guarantee of AC-feasible solution

AC-QP

* AC power flow & large QP's both scale well for large networks and long horizons
* May result in locally optimal solution
* No guarantee of quality of solution
* AC feasible solution produced
* No guarantee of convergence

An Illustrative Example

* 4-hour horizon, 30-minute sampling time → 8 time steps
* Storage at 10% of nodes in each network
* 60-70 wind nodes added to each network
* Improved quality of the AC-QP solution (% Cost Difference from SOCP Lower Bound):

Test Network	Case Description Init.	DC-OPF Init.	SOCP Init.
Pl-2383wp	0.30	0.80	0.22
PEGASE-2869	0.52	0.43	0.26
PL-3120sp	0.31	0.30	0.30
WECC	–	–	0.02

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Example (Cont.)

* Improved convergence rate (# QP-Power Flow Iterations):

Test Network	Case Description Init.	DC-OPF Init.	SOCP Init.
PL-2383wp	8	5	4
PEGASE-2869	16	8	4
PL-3120sp	7	7	4
WECC	–	–	5

* Improved solution time (Seconds):

Test Network	Case Description Init.	DC-OPF Init.	SOCP Init.
PL-2383wp	90	74	64
PEGASE-2869	240	146	84
PL-3120sp	106	121	80
WECC	–	–	150

Conclusions

* New use of an SOCP relaxation
* Method demonstrated on realistically large networks with storage and wind
* Shown cases where the SOCP relaxation…
  * Achieves significant execution time & convergence improvements
  * Prevents the AC-QP OPF from reaching local optimum
  * Gives a lower bound to assess quality of solution
  * Provides an initial operating point to run AC power flow where other methods fail
    * Useful for actual network planning cases

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Thank You, Questions?