# Short-Term Load Forecasting-Based Automatic Distribution Network Reconfiguration

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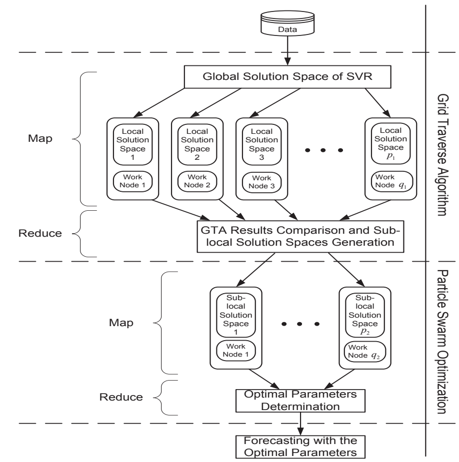
## Background and Objectives

- Distribution system loads become more fluctuant and unpredictable.
  - Large impacts from end users to distribution system
  - More stochastic abrupt deviations than transmission systems.
- Traditional distribution reconfiguration cannot meet the requirements of modern distribution systems.
  - Traditional distribution reconfiguration is static.
  - Dynamic end user profiles require a dynamic control strategy for distribution system reconfiguration.
- An automatic distribution network reconfiguration approach is designed based on short-term load forecasting.

## Key Problems and Solutions

- How can the best parameters for the SVR be computed?
  *Based on parallel computation frameworks, such as Hadoop and Spark, a parallel computation architecture is designed based on "**Mapreduce**" to reduce the computation time in the two-step parameter optimization approach.*
- How can the forecasting results be used in network reconfiguration?
  *The network reconfiguration is solved every 5 min., leading to 12 results of the system topology for the next hour. The topology that achieves the **most loss reduction** will be selected and used for the entire next hour.*

## Main Architecture of the SVR




## Parallel GTA for Parameter Optimization

- Objective: Solution space decomposition and local solution spaces selection of the global optimization problem.
- Initialization: (1) Initial $\boldsymbol{C}, \boldsymbol{\omega}$, and $\boldsymbol{\gamma}$, compute $\boldsymbol{\Lambda}_j$ and $\boldsymbol{H}$.
  (2) Initial the work notes.
- Map phase: (1) Send the elements of $\boldsymbol{H}$ to all the work notes.
  (2) In different work notes, the received elements of H are computed in parallel.
- Reduce phase: (1) Collect computation results from all work notes.
  (2) Compare results, and select one or several local solution spaces for next step.

## Problem Formulation of Network Reconfiguration

$$\min J(S) = \mathrm{Re}\left\{\sum_{j=1}^{N}\left[\sum_{k=a}^{c} V_j^{*} \cdot \sum_{i=1}^{N}\left(\sum_{p=a}^{c} V_i^{p} \cdot \left(\sum_{l=1}^{m} a_{il}^{0} a_{jl}^{0} y_l^{pk} \cdot S_l^{2}\right)\right)\right]\right\}$$

$$= \sum_{j=1}^{N}\sum_{k=a}^{c}\sum_{i=1}^{N}\sum_{p=a}^{c}\left\{e_j^{k} \cdot \left(e_i^{p} \cdot g_{ij}^{pk} + f_i^{p} \cdot b_{ij}^{pk}\right) + f_j^{k} \cdot \left(f_i^{p} \cdot g_{ij}^{pk} - e_i^{p} \cdot b_{ij}^{pk}\right)\right\}$$

$$s.t. \begin{cases} P_{inject,i}^{l} = \sum_{k=1}^{n}\sum_{p=a}^{c}\left\{e_i^{l}\left(g_{ik}^{lp} \cdot e_k^{p} - b_{ik}^{lp} \cdot f_k^{p}\right) + f_i^{l}\left(g_{ik}^{lp} \cdot f_k^{p} + b_{ik}^{lp} \cdot e_k^{p}\right)\right\} \\ Q_{inject,i}^{l} = \sum_{k=1}^{n}\sum_{p=a}^{c}\left\{f_i^{l}\left(g_{ik}^{lp} \cdot e_k^{p} - b_{ik}^{lp} \cdot f_k^{p}\right) - e_i^{l}\left(g_{ik}^{lp} \cdot f_k^{p} + b_{ik}^{lp} \cdot e_k^{p}\right)\right\} \end{cases}$$

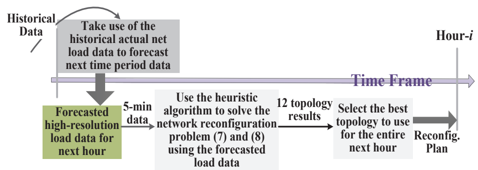
$$\begin{cases} 0.95 \cdot \left|V_{norm}\right| \le \left|V_i^{a}\right|, \left|V_i^{b}\right|, \left|V_i^{c}\right| \le 1.05 \cdot \left|V_{norm}\right| \\ \left|\dfrac{\left|V_i^{p}\right| - avg_i}{avg_i}\right| \le 3\%, \ and\ avg_i = \sum_{p=a}^{c}\left|V_i^{p}\right| \Big/ 3 \\ \left|I_{branch,j}^{p}\right| \le I_{j,\max} \\ i = 1,2,\dots,N; \ \ j = 1,2,\dots,M; \ \ l = a,b,c; \ \ p = a,b,c. \end{cases}$$

*where*

$$S_j = \begin{cases} 1, \ switch\ j\ is\ closed\ and\ current\ direction\ keeps\ same. \\ -1, \ switch\ j\ is\ closed\ and\ current\ direction\ is\ opposite. \\ 0, \ switch\ j\ is\ open. \end{cases}$$

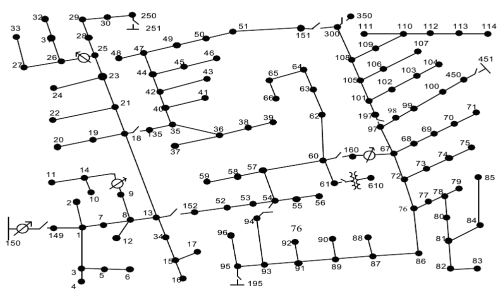
$$\begin{cases} \sum_{k=1}^{M}\left|S_k\right| = N - d \quad and \quad \sum_{i=1}^{M_k}\left|S_i\right| \le M_k - 1 \\ rank(A) = N - d \end{cases}$$

## Proposed Network Reconfiguration Approach



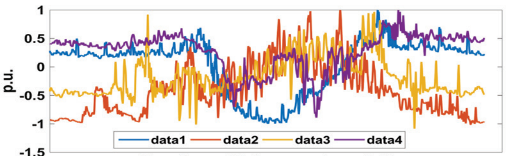

## Test Bench

- Test bench: IEEE 123-bus distribution system



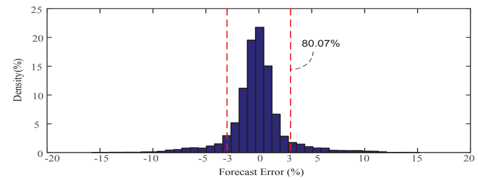
## Forecasting Results

- Four profiles of forecasted net loads for four different regions




One-Day with 1-second resolution

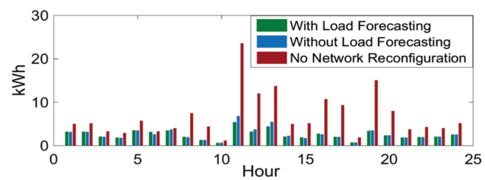
- Percentage error of forecast results




## Reconfiguration Results

- Results of open switches

| Hour | Opened Switches | Loss Reduction |
|---|---|---|
| 1 | 93-95, TS-2, 29-30, 101-105 | 36.71% |
| 2, 3, 4, 5 | 93-95, TS-2, 29-30, 101-105 | -- |
| 6 | TS-1, TS-2, 29-30, 101-105 (for 0–15 mins) | 0.089% |
| | TS-1, TS-2, 29-30, 105-108 (for 15–30 mins) | 2.686% |
| | 87-89, TS-2, 29-30, 108-300 (for 30–60 mins) | 2.55% |
| 7 | 87-89, TS-2, 29-30, 108-300 | -- |
| 8 | 87-89, TS-2, 29-30, 105-108 (for 0–10 mins) | 3.356% |
| | 87-89, TS-2, 29-30, 57-60 (for 10–60 mins) | 53.02% |
| 9 | 91-93, TS-2, 29-30, 57-60 (for 0–20 mins) | 0.484% |
| | 67-72, TS-2, 29-30, 57-60 (for 20–60 mins) | 5.513% |
| 10 | 67-72, TS-2, 29-30, 57-60 (for 0–5 mins) | -- |
| | 67-72, TS-2, TS-3, 57-60 for (5–10 mins) | 2.336% |
| | 67-72, TS-2, 29-30, 57-60 for (10–15 mins) | 1.685% |
| | 67-72, TS-2, TS-3, 57-60 for (15–45 mins) | 0.575% |
| | 67-72, TS-2, 18-21, 57-60 for (45–60 mins) | 23.32% |
| 11, 12, 13 | 67-72, TS-2, 18-21, 57-60 | -- |
| 14 | 67-72, TS-2, 18-21, 57-60 (for 0–15 mins) | -- |
| | 67-72, TS-2, 21-23, 57-60 (for 15–20 mins) | 0.721% |
| | 67-72, TS-2, 18-21, 57-60 (for 20–30 mins) | 3.212% |
| | 67-72, TS-2, 21-23, 57-60 (for 30–35 mins) | 3.805% |
| | 67-72, TS-2, 18-21, 57-60 (for 35–45 mins) | 1.080% |
| | 67-72, TS-2, 21-23, 57-60 (for 45–55 mins) | 2.547% |
| | 67-72, TS-2, 18-21, 57-60 (for 55–60 mins) | 0.975% |
| 15 | 67-72, TS-2, 18-21, 57-60 (for 0–10 mins) | -- |
| | 67-72, TS-2, 21-23, 57-60 (for 10–30 mins) | 2.435% |
| | 67-72, TS-2, 18-21, 57-60 (for 30–60 mins) | 0.862% |
| 16 | 67-72, TS-2, 18-21, 57-60 (for 0–25 mins) | -- |
| | 67-72, TS-2, 21-23, 57-60 (for 25–30 mins) | 3.060% |
| | 67-72, TS-2, 18-21, 57-60 (for 30–35 mins) | 1.783% |
| | 67-72, TS-2, 21-23, 57-60 (for 35–45 mins) | 1.745% |
| | 67-72, TS-2, 18-21, 57-60 (for 45–50 mins) | 4.084% |
| | 67-72, TS-2, 21-23, 57-60 (for 50–60 mins) | 2.053% |
| 17 | 67-72, TS-2, 21-23, 57-60 (for 0–10 mins) | -- |
| | 67-72, TS-2, 18-21, 57-60 (for 10–15 mins) | 2.420% |
| | 67-72, TS-2, 21-23, 57-60 (for 15–25 mins) | 7.240% |
| | 67-72, TS-2, 18-21, 57-60 (for 25–60 mins) | 3.520% |
| 18, 19, 20, 21, 22, 23 | 67-72, TS-2, 18-21, 57-60 | -- |
| 24 | 67-72, TS-2, 18-21, 57-60 (for first 15 mins) | 0.354% |
| | 67-72, TS-2, 21-23, 57-60 (for last 45 mins) | 0.501% |




## Conclusion

- Compared to other approaches, the proposed approach can reduce loss and operation times. In the future:
  1. Consider more factors—such as weather, irradiance, and temperature—as inputs for system state forecasting.
  2. Build a big data platform to visualize the numerical results with Google Earth, SQL, Java, and Python.