

## 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.

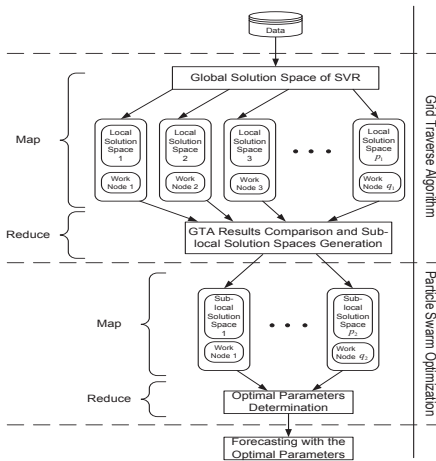
## Key Problems and Solutions

- 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  $C$ ,  $\omega$ , and  $\gamma$ , compute  $\Lambda_j$  and  $H$ . (2) Initial the work notes.
- Map phase: (1) Send the elements of  $H$  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

$$\min J(S) = \text{Re} \left\{ \sum_{j=1}^N \sum_{k=a}^c V_j^* \sum_{l=1}^N \sum_{p=a}^c V_l^p \left( \sum_{i=1}^m a_{ij}^0 a_{il}^0 v_i^{pk} \cdot S_l^p \right) \right\}$$

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

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

$$\left\{ \begin{array}{l} 0.95 \cdot |V_{norm}| \leq |V_i^a|, |V_i^b|, |V_i^c| \leq 1.05 \cdot |V_{norm}| \\ \left| \frac{V_i^p}{avg_i} - avg_i \right| \leq 3\%, \text{ and } avg_i = \sum_{p=a}^c |V_i^p| / 3 \\ |I_{branch,j}^p| \leq I_{j,max} \end{array} \right.$$

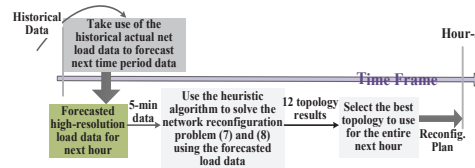
$$i = 1, 2, \dots, N; \quad j = 1, 2, \dots, M; \quad l = a, b, c; \quad p = a, b, c.$$

where

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

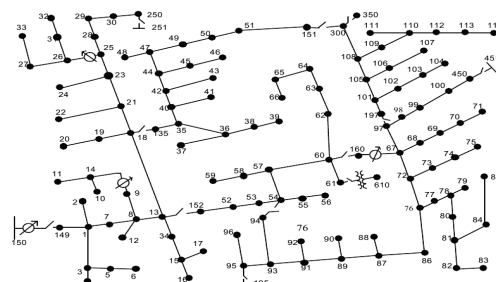
$$\begin{cases} \sum_{k=1}^M |S_k| = N - d \quad \text{and} \quad \sum_{l=1}^{M_k} |S_l| \leq M_k - 1 \\ \text{rank}(A) = N - d \end{cases}$$

## Proposed Network Reconfiguration Approach



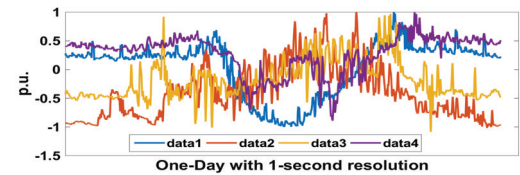
## Test Bench

- Test bench: IEEE 123-bus distribution system



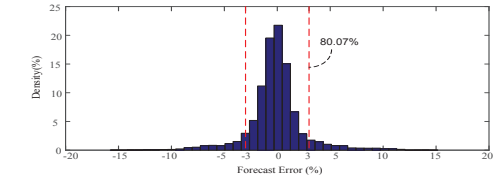
## Forecasting Results

- Four profiles of forecasted net loads for four different regions



One-Day with 1-second resolution

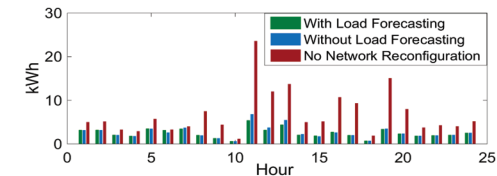
- Percentage error of forecast results



## 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, 105-108 (for 15-30 mins) 87-89, TS-2, 29-30, 108-300 (for 30-60 mins)	0.089% 2.686%
7	87-89, TS-2, 29-30, 108-300	2.55%
8	87-89, TS-2, 29-30, 105-108 (for 0-10 mins) 87-89, TS-2, 29-30, 87-89 (for 10-60 mins)	-- 53.02%
9	91-93, TS-2, 29-30, 57-60 (for 0-20 mins) 67-72, TS-2, 29-30, 57-60 (for 20-60 mins)	0.484% 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) 67-72, TS-2, 29-30, 57-60 (for 10-15 mins) 67-72, TS-2, TS-3, 57-60 (for 15-45 mins)	-- 2.336% 1.685% 0.575%
11, 12, 13	67-72, TS-2, 18-21, 57-60 (for 45-60 mins) 67-72, TS-2, 18-21, 57-60	23.32% --
14	67-72, TS-2, 18-21, 57-60 (for 0-15 mins) 67-72, TS-2, 18-21, 57-60 (for 15-20 mins) 67-72, TS-2, 18-21, 57-60 (for 20-30 mins) 67-72, TS-2, 18-21, 57-60 (for 30-35 mins) 67-72, TS-2, 18-21, 57-60 (for 35-45 mins) 67-72, TS-2, 18-21, 57-60 (for 45-55 mins) 67-72, TS-2, 18-21, 57-60 (for 55-60 mins)	-- 0.721% 3.212% 3.805% 1.080% 2.547% 0.975%
15	67-72, TS-2, 18-21, 57-60 (for 0-10 mins) 67-72, TS-2, 18-21, 57-60 (for 10-30 mins) 67-72, TS-2, 18-21, 57-60 (for 30-60 mins) 67-72, TS-2, 18-21, 57-60 (for 0-25 mins) 67-72, TS-2, 21-23, 57-60 (for 25-30 mins)	2.435% 0.862% -- 3.060%
16	67-72, TS-2, 18-21, 57-60 (for 30-35 mins) 67-72, TS-2, 18-21, 57-60 (for 35-45 mins) 67-72, TS-2, 18-21, 57-60 (for 45-50 mins) 67-72, TS-2, 18-21, 57-60 (for 50-60 mins) 67-72, TS-2, 21-23, 57-60 (for 0-10 mins)	1.745% 4.084% 2.053% --
17	67-72, TS-2, 21-23, 57-60 (for 10-15 mins) 67-72, TS-2, 21-23, 57-60 (for 15-25 mins) 67-72, TS-2, 21-23, 57-60 (for 25-60 mins)	2.420% 7.240% 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) 67-72, TS-2, 21-23, 57-60 (for last 45 mins)	0.354% 0.501%



## Conclusion

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