

Modeling of Demand Response Contracts With Operational Reliability Indices In Distribution Management System

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Distribution Management & Demand Response Stakeholders

Regulated Utilities
& Distribution Grid
Operators



ISOs, PXs, Transmission Grid
Operators sending signals
to cause Demand Response

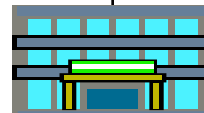


» **Point to Point (P2P), Wireless & Internet Communications**

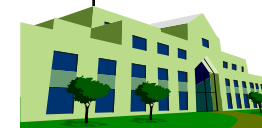
Demand Response
Service Providers
DRSPs



Transmission &
Distribution Data
Service Providers



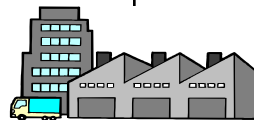
Load Aggregators
& Curtailment
Service Provider
(LA, CSP)



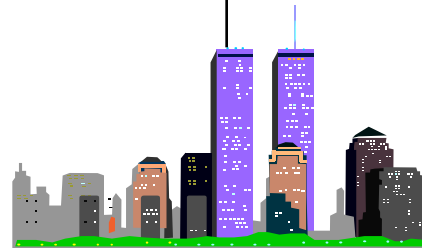
AMI Communications/End Points, P2P, Wireless & Internet



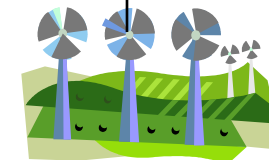
Residential/ Solar



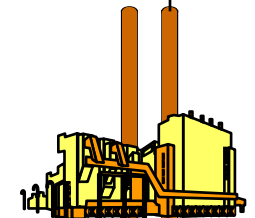
Industrial / Solar Farms



Commercial

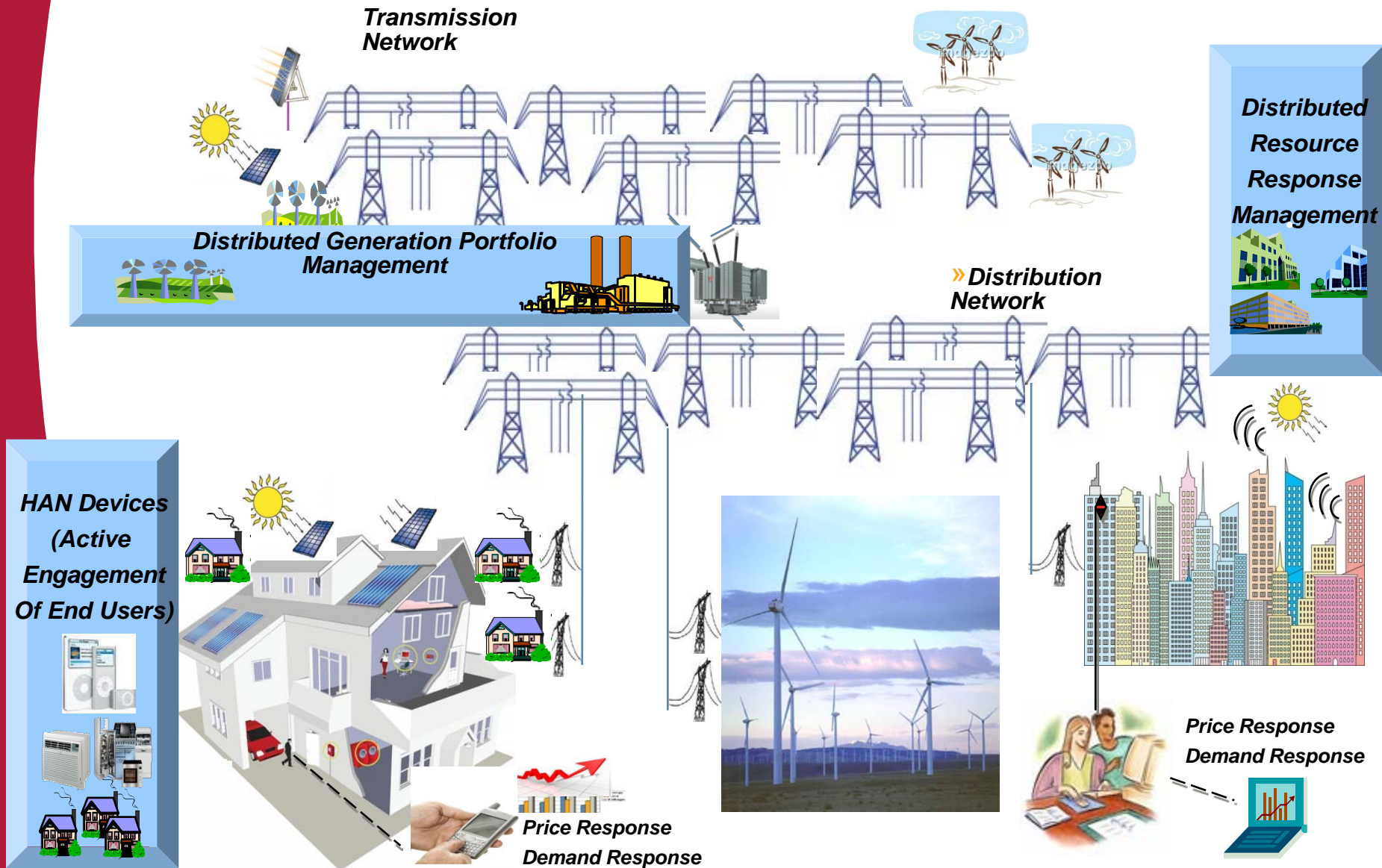


Wind



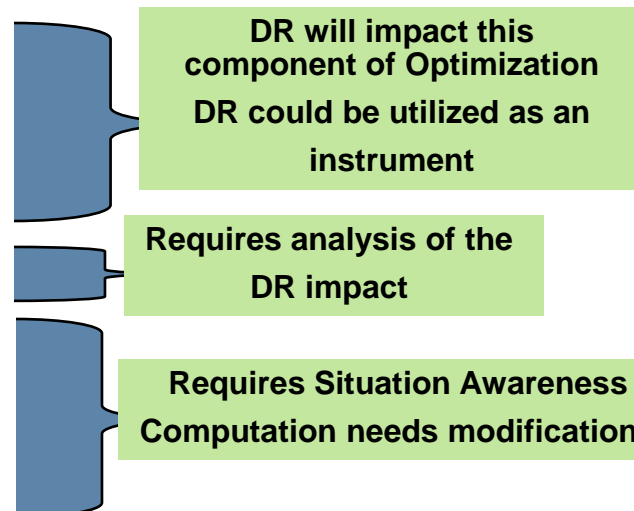
Distributed Gen

Distribution Management & Demand Response Paradigm Shift in Distribution Operation



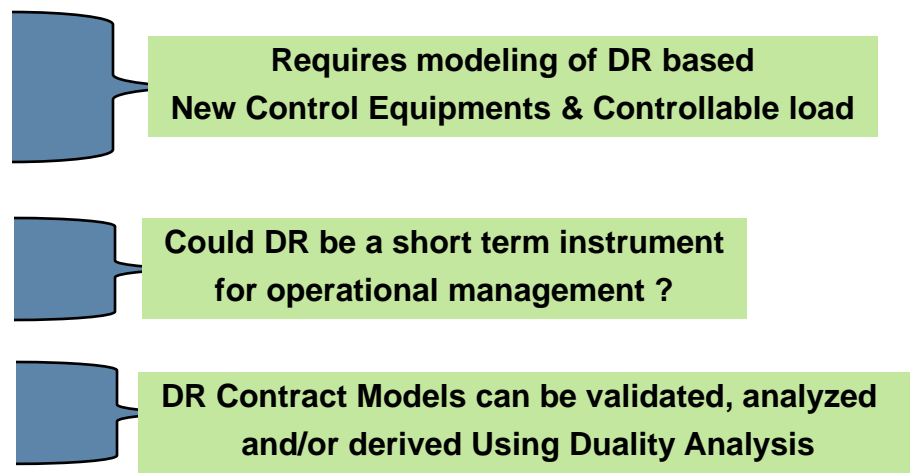
▶ **Minimize**

- ◆ Energy Losses
- ◆ Voltage Swings
- ◆ Reactive Power flows
(Maximize Operating Margin of DSS)
- ◆ Switching Operation
- ◆ System Availability Interruption Duration Index (SAIDI)
- ◆ System Availability Interruption Frequency Index (SAIFI)
- ◆ Customer Average Interruption Index (CAIDI)
- ◆ Crew Operation Cost



▶ **Subject to:**

- ◆ Distribution Power Flow Equations
- ◆ Voltage Deviation Within Limits
(Operational and Customer Quality)
- ◆ Equipment Operational Limits
- ◆ Operational Crew Constraints
- ◆ Service Level Agreements
(Distributed Resource Contracts)
(Demand Response Contracts)



▶ (IEEE Std. 1366) SAIDI System average interruption duration index is the average length of a sustained customer outage, in minutes. SAIDI is expressed in minutes / hours per year per customer

▶ SAIDI without DR

$$SAIDI = \frac{\sum \text{Number of customers affected} \times \text{Duration of Interruptions}}{\text{Total number of customers}}$$

▶ SAIDI with DR

$$SAIDI = \frac{\sum(\text{Number of customers affected} * \text{Duration of Interruptions})}{\text{Total Number of Customers}} - \frac{\sum(\text{Number of customers responded} * \text{Duration of Event})}{\text{Total Number of Customers signed up for DR Program}}$$

- ▶ **(IEEE Std. 1366) SAIFI** - system average interruption frequency index is the average number of sustained outages (defined as more than five minutes in duration), SAIFI is expressed as interruptions per year, per customer over a defined area such as a utility system or region.
- ▶ **SAIFI without DR**

$$SAIFI = \frac{\sum \text{Number of customers affected by interruptions}}{\text{Total number of customers}}$$

- ▶ **SAIFI with DR**

$$SAIFI = \frac{\sum \text{Number of customers affected by interruptions}}{\text{Total number of customers} - \frac{\sum \text{Number of customers responded to DR events}}{\text{Total Number of Customers signed up for DR Program}}}$$

- ▶ **(IEEE Std. 1366)** CAIDI customer average interruption duration index is the index among customers experiencing sustained outages, the average length of the outage. CAIDI is expressed in hours per year per customer interrupted

- ▶ **CAIDI without DR**

$$CAIDI = \frac{\sum \text{Number of customers affected} \times \text{Duration of Interruption}}{\sum \text{Number of customers affected by interruptions}}$$

- ▶ **CAIDI with DR**

$$CAIDI = \frac{\sum (\text{Number of customers affected} * \text{Duration of Interruptions})}{\sum \text{Number of customers affected by Interruptions}} - \frac{\sum (\text{Number of customers responded} * \text{Duration of Event})}{\sum \text{Total Number of Customers responded to for DR events}}$$

- ▶ **Reliability Contracts – Primarily driven by Transmission Reliability Purposes. Distribution Management must recognize the DR event and integrate into distribution operation**
 - ◆ Load Responding as Emergency Reserves
 - ◆ Energy Only Option
 - ◆ Capacity Only Option
 - ◆ Full Emergency Option

- ▶ **Economic Operation Contracts**
 - ◆ Price Responsive Demand
 - ◆ Base Curtailable Program (BCP)
 - ◆ Demand Bidding
 - ◆ Critical Peak Pricing
 - ◆ Direct Load Control (DLC)
 - ◆ Time Of Use (TOU)
 - ◆ Capacity Market Programs (CAP)
 - ◆ Ancillary Service (A/S)

► Distribution Operational Planning

- ◆ Incorporate DR Contract for analyzing goals
- ◆ DR could be used as instrument to help achieving operational goals
- ◆ New Operating paradigm require re-definition of operational reliability indices

► Real-Time Distribution Operation

- ◆ Distribution Management System - “Event Follower” in case of Real-Time Emergency DR event initiated by Transmission Operator
- ◆ Distribution Management System - “Event Moderator” for Distribution Control Center initiated Real-Time Economic DR event
- ◆ Distribution Management System - “Event Integrator for Distribution System Control” for Customer initiated Real-Time Economic DR event, such as Price Responsive Demand