Intelligent Demand Response Scheme for Customer Side Load Management

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Outline

- Introduction
- Demand Response (DR) Schemes
- Expert DR
- Case Study
- Concluding Remarks
Demand Response (DR)

Short-term changes by customers in their accustomed electric consumption patterns to reduce or shift electric load over time...

Action can be initiated by the utility (offering incentives) or by the customers (bidding).

DR Classification:

- Type of agreement between the utility and the customer
  - Incentive Based Programs
  - Reliability Based Programs
- Size/type of customer (commercial, residential or industrial)
DR Implementation

- **Fully automated DR-** does not involve human intervention. The receipt of the external signal automatically initiates pre-programmed demand response strategies.

- **Semi-automated DR-** involves a preprogrammed DR strategy initiated by a human operator at the customer site.

- **Manual DR-** building staff receives a signal and manually reduces the demand. In other words, there is no pre-programmed strategy.
Overall DR Structure

In a semi-automated DR structure...

Using this information the customer makes a decision to comply or refrain.
Local Load Management Policy

- Set of rules with highest priority over any other decision taken by the DR module.

- At the most basic level, the local policy can include a maximum number of allowable interruptions during a day/season, a maximum amount of load reduction during a day/season, a set of critical loads, a minimum number of production lines/demand that needs to be on at any point in time, daily production requirements.

- In more advanced schemes, it considers the dependency of the loads on one another, the maintenance schedule, the required start-up time,...
Decision Engine

- Possible Design Solutions: Expert Systems, Fuzzy Logic

- Selecting the proper technique depends on factors such as the size of the problem, and the level of automation.

- **Expert systems** are easier and faster to implement for smaller problems, but less flexible to changes and are more difficult to extend.

- **Fuzzy systems** are more efficient for problems of larger scales and numerous variables, where developing an expert rule table is difficult. They are also more flexible and easier to expand.

- Expert systems have more of a “white box” approach compared to fuzzy systems. Therefore, they might fit better in a semi-automated approach where the human operator has to be able to fully understand the procedure and override it if necessary.
Case Study

IEEE 34-bus test distribution feeder - characterized by:

- Y-connected constant power/constant impedance loads,
- Three phase or single phase overhead lines,
- Voltage regulators, and shunt capacitors.

Implemented using Simulink + RTLab
Case Study – Demand Response Loads

- DR load model parameters
  - Enroll (respond to DR)
  - Suggested MW level (drP)
  - Incentive $/MWh
  - Duration of DR event
  - Physical lines

- Outputs
  - Measurements (m)
  - Cumulated cost ($)
  - Actual cost (rate) of consumed power ($/MWh)
**DR-Enabled Load Model – Overview**

- **Follow DR if**
  - Load enrolled (no bail out)
  - Reduced cost of power over duration of DR event

- **Output power selection**
  - Bid: routine vs. DR load level
  - Paid rate updated accordingly
  - Intrinsic load power factor
DR-Enabled Load Model – Decision to follow DR

- **Cost estimation with DR**
  - DR suggested load level used
  - @ DR rate

- **Cost estimation without DR**
  - Daily routine load level used
  - @ contract rate

**Decision to follow DR (or not) based on**
- Total cost compared (rate × power)
- Local load management policy of the customer side DR (custom implementation)
DR-Enabled Load Model – Load Dynamics

- Why load dynamics?
  - Loads generally slow to respond (inertia)
  - Some loads cannot be shed without advance notice

- First-order dynamics
  - User-defined time constant
  - $P_{out} > P_{min}$
  - $P_{cmd}$ not exactly the same as desired DR load level (delays)
  - Real cost not exactly the same as cost for decision making (future work?)
Simulation Results

Plots of different loads and costs in the absence of DR events

Hourly (routine) load profile

Hourly cumulated cost paid by customers ($)

Base $100/MWh

Peak $200/MWh
Simulation Results

- In the presence of DR events
  
  Intermittent DR: on, off, on, off, …

- Two loads always follow DR signal.
- One load follows intermittently.
- Two loads never follow DR.

Suggested DR level for all subscribed loads
100 MW, $120/MWh
Summary

- DR an avenue for generation capacity conservation
- DR should be followed if utility or customer has proper incentive
- Load management opportunities for both utilities and customers
- $ Savings! (customers + utilities)

Perspectives

- Subscription management
- Individual load management plans
- Market signals
- Hardware simulation/verification