Power Consumption Management and Control for Peak Load Reduction in Smart Grids Using UPFC

M. R. Aghaebrahimi, M. Tourani, M. Amiri

Presented by: Mayssam Amiri
Outline

1. Introduction
2. The Proposed Method
3. UPFC Placement
4. Peak Load Reduction Management Model
5. Simulation and results
6. Conclusions
Introduction

- Smart Grids
- Renewable Energies
- Reduction in Peak Demand Using Smart Grid Technology

- In this paper, a power consumption management model is introduced to control the peak load reduction in a Smart Grid using the Unified Power Flow Controller (UPFC).
Introduction

➢ In the past, utilities were not able to apply much control over consumers, because they were considered solely as “Customers”.

➢ In Smart Grids, customers are economic partners in the energy markets, too.

➢ With appropriate consumption management, a win-win situation can be created for both utilities and consumers.

➢ A power system, by application of power control using load and generation information, is capable of reducing some of the problems facing it, such as high transmission and distribution losses, changes in bus voltage (over- or under-voltage), etc.
The Proposed Method

- FACTS devices are among the control tools which can have a significant effect on the power flow in different directions.

- The UPFC can be modeled in two ways:
  - Coupled model
  - Decoupled model

![UPFC's decoupled model]
The Proposed Method

- Energy management system tasks:
  - Load Forecasting
  - Optimization of FACTS Devices’ Parameters (off-line)
  - Online Control of FACTS Devices' Parameters
  - Customers' Energy Consumption Management

Energy Management System (EMS)

Energy management system
The Proposed Method

- Steps:
  - optimal placement of UPFC
  - Peak load reduction management model
UPFC Placement

- The placement of UPFC means finding the installation place and the optimized operational parameters of it.

Objective Functions:

- Reduction in investment costs:
  - UPFC installation cost: \( I_C = C \times S \times 1000 \)
  - cost function of the UPFC: \( C_{UPFC} = 0.0003s^2 - 0.2691s + 188.22 \)

- Reduction in generation costs: \( Costgen = aP_g^2 + bP_g + c \)

- Loss Reduction:
  \[ CostP_{\text{Loss}} = C_{Loss} \sum_i \sum_j (P_{ij} - P_{ji}) \]

- Overload Cost Reduction: \( CostOvl = C_{OVL} \prod_{\text{Line}} OVL \)
UPFC Placement

- **Constraints:**
  - UPFC constraints
  - Generators constraints
  - Load flow constraints

- **Optimization Method:**
  - Genetic Algorithm
  - Each solution: \( \text{Fitness}_i = d \cos t\text{gen}_i + I_{c_i} - d \cos t\text{loss}_i - d \cos t\text{vol}_i \)
  - output of each generator in the network
  - UPFCs active and reactive power output
  - the place of installation of each UPFC.
Peak Load Reduction Management Model

➢ After UPFC placement:

✓ the Smart Grid analyzes the load forecasting data through EMS and the present condition of the network
✓ introduces the selected buses for load reduction
✓ new setting of UPFC parameters
✓ new consumption tariffs.

➢ Actually, the output of EMS is the new strategy of consumption.
Peak Load Reduction Management Model

- **Objective Functions:**

  - **Reduction of extra costs due to selling power in peak period:**
    
    \[
    Cost_{dv} = \begin{cases} 
    0 & P_g < P_{dv} \\
    \sum \text{Costgen-Tariff} \times P_D & P_g \geq P_{dv}
    \end{cases}
    \]

  - **Reduction of losses**
  - **Management of lines’ transmitted power**

- **Constraints:**

  - **UPFC constraints**
  - **Load flow constraints**
  - **Load management constraints:**
    
    \[P_i^{\text{dec}} \leq P_i^{\text{max}}\]
Peak Load Reduction Management Model

- **Optimization Method:**

- A combination of fuzzy approach and GA is used.
- This combination will eliminate errors in normalizing the objectives.
- Linear Fuzzy membership functions are used for fuzzification of loadability factor and transmission costs.
- Each feasible solution is consisted of the nominated buses for load changing, the amount of each change, and UPFCs parameters.

- Utility cost reduction membership function:

  \[ G_1 = \text{cost} + \text{costploss} + \text{cuincome}(p_{dec}) \]

- Lines’ loadability membership function:

  \[ G_2 = \Pi_{\text{Line}} \text{Ovl} \]

- Fuzzy evaluation:

  \[ \text{Fit}(G) = a\mu_1(G_1) + b\mu_2(G_2) \]
Simulation and results

- The 39-bus New England network is used.
- 46 transmission lines and 19 consumption buses
Simulation and results

- **UPFC Placement Results:**

  - Running the optimum power flow before UPFC placement process.

  - Under this conditions, the power loss and OVL of the network in peak hours are 31 MW and 5.86, respectively.

  - It is assumed that the optimum current for each line of the network is 75% of its nominal current.

<table>
<thead>
<tr>
<th>Gen. No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output(MW)</td>
<td>1218</td>
<td>451</td>
<td>971</td>
<td>450</td>
<td>450</td>
<td>459</td>
<td>683</td>
<td>450</td>
<td>450</td>
<td>573</td>
</tr>
</tbody>
</table>
Simulation and results

✓ The network’s active data (MW):

<table>
<thead>
<tr>
<th>Bus 1</th>
<th>Bus 3</th>
<th>Bus 12</th>
<th>Bus 15</th>
<th>Bus 16</th>
<th>Bus 18</th>
<th>Bus 20</th>
<th>Bus 21</th>
<th>Bus 23</th>
<th>Bus 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>1104</td>
<td>9.2</td>
<td>8.5</td>
<td>320</td>
<td>329.4</td>
<td>158</td>
<td>628</td>
<td>274</td>
<td>274.5</td>
<td>308.6</td>
</tr>
<tr>
<td>224</td>
<td>139</td>
<td>281</td>
<td>206</td>
<td>283.5</td>
<td>322</td>
<td>500</td>
<td>233.8</td>
<td>522</td>
<td></td>
</tr>
</tbody>
</table>

✓ The network’s reactive data (Mvar):

<table>
<thead>
<tr>
<th>Bus 1</th>
<th>Bus 3</th>
<th>Bus 12</th>
<th>Bus 15</th>
<th>Bus 16</th>
<th>Bus 18</th>
<th>Bus 20</th>
<th>Bus 21</th>
<th>Bus 23</th>
<th>Bus 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>4.6</td>
<td>88</td>
<td>32.3</td>
<td>32.3</td>
<td>300</td>
<td>103</td>
<td>115</td>
<td>84.6</td>
<td>92.2</td>
</tr>
<tr>
<td>47.2</td>
<td>17</td>
<td>75.5</td>
<td>27.6</td>
<td>26.9</td>
<td>2.4</td>
<td>184</td>
<td>84</td>
<td>176</td>
<td></td>
</tr>
</tbody>
</table>
Simulation and results

✓ UPFC placement result:

<table>
<thead>
<tr>
<th>Place of Installation (Line)</th>
<th>Active Power (MW)</th>
<th>Reactive power at Bus-j (MVar)</th>
<th>Reactive power at Bus-i (MVar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>390</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>16</td>
<td>180</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

✓ Generators output after placement:

<table>
<thead>
<tr>
<th>Gen. No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output(MW)</td>
<td>1154</td>
<td>526</td>
<td>809</td>
<td>525</td>
<td>510</td>
<td>520</td>
<td>570</td>
<td>517</td>
<td>517</td>
<td>506</td>
</tr>
</tbody>
</table>
Simulation and results

- Peak Load Reduction Management Results:
  
  - Initially, the evaluation of solutions for each objective is done separately.
  
  - After the simulation program is run, the Fuzzy results will be attained.
  
  - UPFC parameters result:

<table>
<thead>
<tr>
<th>Place of Installation (Line)</th>
<th>Active Power (MW)</th>
<th>Reactive power at Bus-j (MVar)</th>
<th>Reactive power at Bus-i (MVar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>200</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>160</td>
<td>150</td>
<td>0</td>
</tr>
</tbody>
</table>
Simulation and results

✓ Active load reduction for each bus (MW)

<table>
<thead>
<tr>
<th></th>
<th>Bus 1</th>
<th>Bus 3</th>
<th>Bus 12</th>
<th>Bus 15</th>
<th>Bus 16</th>
<th>Bus 18</th>
<th>Bus 20</th>
<th>Bus 21</th>
<th>Bus 23</th>
<th>Bus 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>353</td>
<td>3.6</td>
<td>0.68</td>
<td>51.2</td>
<td>26</td>
<td>13</td>
<td>200</td>
<td>0</td>
<td>0</td>
<td></td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>22</td>
<td>22</td>
<td>16</td>
<td>45</td>
<td>77</td>
<td>40</td>
<td>37</td>
<td>208</td>
<td></td>
</tr>
</tbody>
</table>

✓ By implementation of this management model, the peak load is reduced by 1307 MW, the power losses are reduced from 27.22 MW to 22.25 MW, and OVL reduces from 1.68 to 1.12.
Conclusions

- The reduction of power consumption at peak hours not only reduces the utility’s cost of generation and operation, but also can bring about considerable benefits for the customers who co-operate with the utility towards realizing the Smart Grid.

- In the model proposed in this paper, a number of buses in a Smart Grid are selected for power reduction and the amount of changes in the power consumption is determined for each of them to reduce the peak demand.

- This load management model maximizes the efficiency with minimal changes in consumption.
Thank You

Questions?