Automated Substation ‘Back-Feeding’

Reduction in system losses through automated isolation of transformers and re-distribution of load to adjacent substations

Steve McElveen
Design Manager
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Scenario – reduce transformer losses

• Distribution transformers are typically approx. 97% efficient
• 3% of their energy rating is wasted
  – Iron losses (or core losses) – caused by the magnetising effect of the transformer core
    • Typically 0.5% - 1.0% of transformer rating
    • Remains relatively constant regardless of load
    • Can be reduced through improved materials and by reducing harmonics
  – Copper losses – caused by the heating effect of the current flowing
    • Typically 2.0% - 2.5% of load
    • Directly related to the level of demand/load \(W = I^2 \times R\)
    • Affected by harmonics caused by non-linear loads
    • Can be reduced through improved load balancing, improved filtering, and demand side management

• Transformers could be switched off and load transferred to adjacent substations when demand is within certain limits
Some constraining factors

- Substations supply a geographical area, typically <300m radius
- Interconnecting cables will introduce voltage drop relative to the load being supplied
- Supply voltage must be kept within statutory limits (max -6% / 14v)
- 300mm² cable rated at 470A / approx. 300kVA
- Optimum conditions are:
  - 255m x 300mm²
  - Max current 250A
  - Voltage drop 11.79v (2.9%)
  - approx. 173kVA
Modern LV Network Design

- Substation placed close to load centre
- Radial feeders (typically 4-6) radiating out from substation
- Cables sized (and tapered) according to load
- No LV interconnection to adjacent substations
- No remote control or monitoring of LV feeders
Interconnection – Option 1

- Radial feeders could be extended to interconnect with adjacent substation(s)
- Would need to be connected where cable sizes and loads are within limits
- Remote control/monitoring of interconnecting feeders would be required
- Remote control of transformer switches required to facilitate isolation of transformer
Interconnection – Option 2

- New interconnectors laid directly between substations
- Link boxes installed at strategic positions to facilitate cross-connection between substations
- Remote control/monitoring of link boxes would be required to facilitate switching and transferring of loads
- Remote control of transformer switches required to facilitate isolation of transformer
Low Voltage Underground Link Box

- Typically 2-way or 4-way
- Allow networks to be interconnected so that supplies can be maintained during substation maintenance etc.
- ‘Links’ are usually inserted manually
- Remote control options being developed to reduce risks
• **WEEZAP** – automated monitoring devices installed at substations
• **LYNX** – remote controlled/automated devices that can be retro fitted to standard Tyco, Sicame and Prysmian distribution link boxes
Deployment of Link Boxes in existing grids

• Several conditions need to be met before link boxes can be deployed
• Proximity of substations to each other
  – Typical radius for a substation ‘district’ is ≈ 300m
• Interconnecting cables need to be of sufficient current carrying capacity
  – Typical 300mm² Al cable rated at 470A / approx. 300kVA
• Statutory voltage levels need to be maintained
  – UK 230v +10% - 6% (253v – 216v)
• Optimum conditions are:
  – 255m x 300mm²
  – Max current 250A
  – Voltage drop 11.79v (2.9%)  
    – approx. 173kVA
• 4-way link boxes can be used so that load is shared between 2 or 3 substations
• Link box needs to be readily accessible – operation and comms.
• Concerns regarding commercial viability can be offset against improved operational maintenance, reduced outage, and resilience benefits
Transients due to use of Transformer Switching

- When running normally, the flux produced in the core is in quadrature with the applied voltage as shown in Fig.1 i.e. the flux wave will reach its maximum value ¼ cycle after the voltage wave reaches its maximum value.
- But practically it is not possible to have flux at the instant of switching on the supply of transformer - the steady state value of flux will only reach after a finite time, depending upon how fast the circuit can take energy.
- When a power transformer is switched on it acts as a simple inductance, so the flux in the core also will start from its zero value at the time of switching on the transformer, and can jump to double its steady state maximum value – as in Fig.2.
- The transformer will draw a very high peaky current from the source which is called magnetizing inrush current
- This current is transient in nature and exists for few milliseconds – the inrush current may be up to 10 times higher than the normal rated current of transformer.
- Can cause various problems on the network, including:
  - nuisance fuse or breaker interruptions
  - arcing and failure of primary circuit components such as switches
  - necessitating over-sizing of fuses or breakers
  - the injection of noise and distortion back into the mains.
Typical urban residential area
Typical urban residential area
Typical package substation

- Transformer
- LV Feeder Pillar
- HV Switch
Typical package substation

11kV / 400v transformer, typically 500kVA

LV Switch or circuit breaker, usually manually operated

Feeder fuses or circuit breakers

Transformer circuit breaker – can be remote operated

HV Switches, usually manually operated

LV Feeder 1
LV Feeder 2
MV Ring

LV Feeder 3
LV Feeder 4
MV Ring
LV Interconnection to allow ‘back-feeding'
LV Interconnection to allow ‘back-feeding'

- **SUBSTATION A**
  - LB1 ‘closed’
  - Substation A is now also supplying 50% of substation B load

- **SUBSTATION B**
  - LV Switch opened
  - HV Switch opened
  - Transformer B switched ‘off’

- **SUBSTATION C**
  - LB2 ‘closed’
  - Substation C is now also supplying 50% of substation B load
## Typical Transformer Losses

<table>
<thead>
<tr>
<th></th>
<th>Tx Rating</th>
<th>Load</th>
<th>Fe Losses (1.0%)</th>
<th>Cu Losses (2.5%)</th>
<th>Total Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substation A</td>
<td>500kVA</td>
<td>300kVA</td>
<td>5kVA</td>
<td>7.5kVA</td>
<td>12.5kVA</td>
</tr>
<tr>
<td>Substation B</td>
<td>500kVA</td>
<td>300kVA</td>
<td>5kVA</td>
<td>7.5kVA</td>
<td>12.5kVA</td>
</tr>
<tr>
<td>Substation C</td>
<td>500kVA</td>
<td>300kVA</td>
<td>5kVA</td>
<td>7.5kVA</td>
<td>12.5kVA</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>15kVA</strong></td>
<td><strong>22.5kVA</strong></td>
<td><strong>37.5kVA</strong></td>
<td></td>
</tr>
<tr>
<td>Substation A</td>
<td>500kVA</td>
<td>450kVA</td>
<td>5kVA</td>
<td>11.25kVA</td>
<td>16.25kVA</td>
</tr>
<tr>
<td>Substation C</td>
<td>500kVA</td>
<td>450kVA</td>
<td>5kVA</td>
<td>11.25kVA</td>
<td>16.25kVA</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>10kVA</strong></td>
<td><strong>22.5kVA</strong></td>
<td><strong>32.5kVA</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Saving</strong></td>
<td></td>
<td>5kVA</td>
<td></td>
<td></td>
<td>(13%)</td>
</tr>
</tbody>
</table>
Thank You
Do you agree that interconnecting substations (at low voltage) could provide a cost-effective solution to load-balancing?

Do you agree that automation of LV interconnection can be practically achieved through the use of ‘smart’ link boxes?