ComEd
An Exelon Company

Electric Power Delivery

To Big Cities

Zafar Choudhry, PE

IEEE PES T&D Conference & Exposition

Chicago, April 2008

Problem Definition

a) **Socio-economic incentives are a major factor in the movement of population to big cities**

b) **Increasing demand of electric power has strained the utility infrastructure in cities**

c) **Fix is neither simple nor cost effective**

1: Number & Voltage of Transmission Lines

- **With higher voltage levels:**
  a) **Fewer lines are needed to transmit power, making efficient use of ROW corridors**
  b) **Line outage impact is significant**
  c) **Technical difficulties**
- **With lower voltage levels:**
  a) **More lines are needed to transmit power**
  b) **Line outage impact is insignificant**
  c) **No technical difficulties**

2: Sub-Transmission Network

- **ROW limitations, safety concerns & city regulations force the use of cables:**
  a) **Higher fault currents due to low impedance of cables**
  b) **Prolonged outages due to difficulty in fault detection & repair**
  c) **Difficulty in voltage control due to high capacitance of cables**
  d) **Installation in city streets, tunnels & canals**

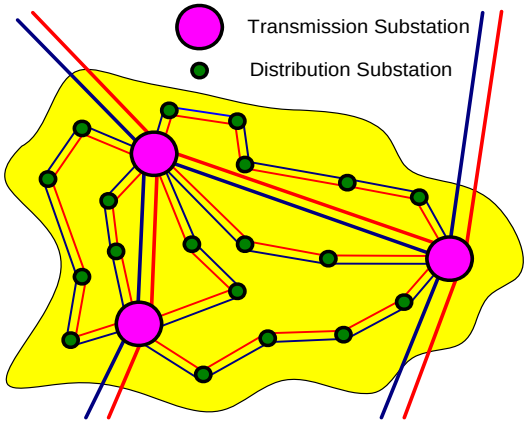
3-1: High Fault Currents

- **Causes:**
  a) **Multiple lines to transmit large quantities of power to high density city load**
  b) **Generation in the city**
  c) **Use of low impedance cable circuits**
- **Possible Solutions:**
  - **Split network design**
  - **Radial network design**
  - **Series inductors in cable circuits**

3-2: High Fault Currents

- **Split network design:**
  a) **Power system is split into two large independent networks laid side by side**
  b) **Have separate busses at substations**
  c) **Carry equal magnitude of load**
  d) **Designed to switch loads**

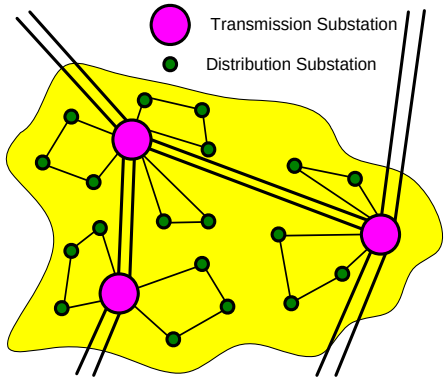
Split Network Design



3-3: High Fault Currents

- **Radial network design:**
  - **a) Small independent networks with 2-3 substations laid in loop format**
  - **b) Fed from a single source substation**
  - **c) Carry different magnitude of load**

Radial Network Design



3-4: High Fault Currents

- **Series inductors in cable circuits:**
  - **a) Limits fault current but also impedes the flow of power**
  - **b) Should not result in load imbalance**
  - **c) Should not lead to underutilizing the cable capacity**

4-1: Disparity in System Strength

A big city tends to import power from all directions. It is problematic if one side is not strong enough to support city load

- **Possible solutions:**

a) **Phase shifting transformers**

b) **Generation on weak system side**

c) **Transmission substation on weak system side**

d) **Transmission ring around a big city**

4-2: Disparity in System Strength

- **Phase shifting transformers:**

a) **Regulate flow of power from weak system to city network**

b) **Does not resolve capacity deficiency issue**

c) **Possible connectivity issue on distribution feeders originating from across the phase shifting transformer**

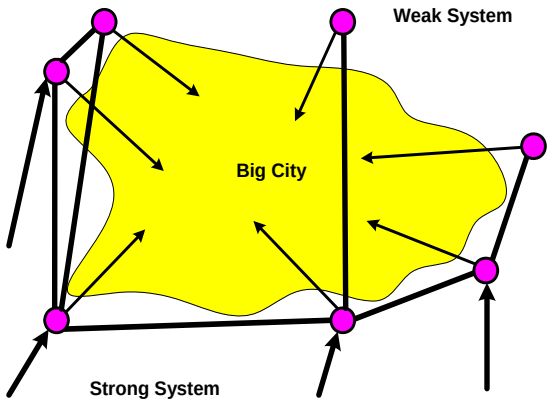
4-3: Disparity in System Strength

- **Generation on weak system side:**
  - a) **Resolves capacity deficiency issue**
  - b) **High cost of land & fuel transportation discourage new generation in big cities**
  - c) **Clean air legislation may impact economic viability of generation**

4-4: Disparity in System Strength

- **Transmission substation on weak system side:**
  - a) **This substation is connected to strong sources using cable circuits in city streets**
  - b) **Resolves capacity deficiency issue**

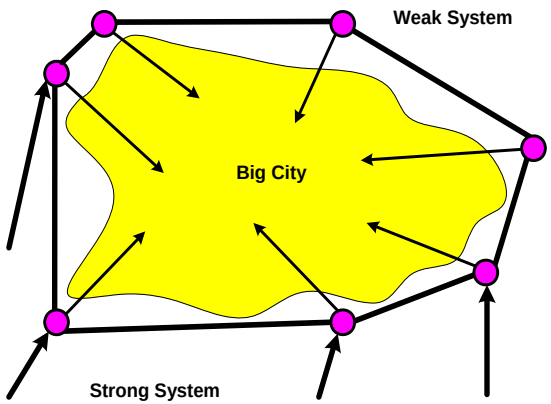
Substation on Weak System Side



4-5: Disparity in System Strength

- **Transmission ring around a big city:**
  - **a) Ring is connected to multiple sources**
  - **b) Ring feeds multiple transmission substations around the city**
  - **c) Creates an even profile of system reliability on all sides of the city**
  - **d) Resolves capacity deficiency issue**

Transmission Ring around the City



5-1: Management of Reactive Power

a) Customers consume reactive power (VARs) as part of their load

b) Lines produce and consume VARs

c) Reactive devices produce and consume VARs

d) A balance between VAR consumption and VAR production is vital for voltage support and system stability

5-2: Management of Reactive Power

- **Dynamic reactive devices (fast responding):**
  a) **Expensive but critical for voltage stability**
  b) **Generator, synchronous condenser, or any thyristor switched & controlled inductor/capacitor (SVC, STATCOM)**
- **Static reactive devices (slow responding):**
  a) **Provide voltage support**
  b) **Switched capacitors and inductors**

6: Substations in the City

a) **Scarcity of land, safety concerns & city regulations force the use of indoor substations that are costlier**
b) **Substations in high-rise buildings**
c) **Underground substations in gardens, churches & public parking**

7-1: Power Quality

Expanded use of power electronics have made city residents increasingly sensitive to power quality issues

- **Generally power quality is defined as:**
  - **a) Continuity of power supply**
  - **b) Distortion-free wave shape without harmonics, transients & voltage sag**

7-2: Power Quality

- **Electric utilities should ensure that:**
  - **a) Power Plants generate power that is free from wave-shape distortion**
  - **b) Power delivery system meets power quality standards**
  - **c) Industrial customers minimize and address power quality issues**
  - **d) Encourage vendors to improve equipment design to ride through power quality issues**

8-1: Switchgear Arrangement

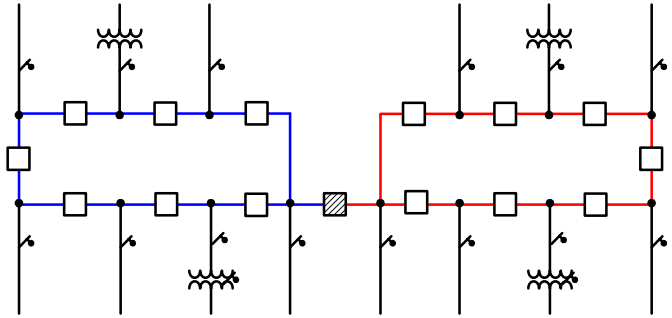
A substation is like a door to pass electric power from one network to the other

- **The right switchgear arrangement could:**
  - **a) Mitigate impact of system outages**
  - **b) Contain cascading outages**
  - **c) Help islanding during system collapse**
  - **d) Better manage market flows**
  - **e) Maintain system reliability**

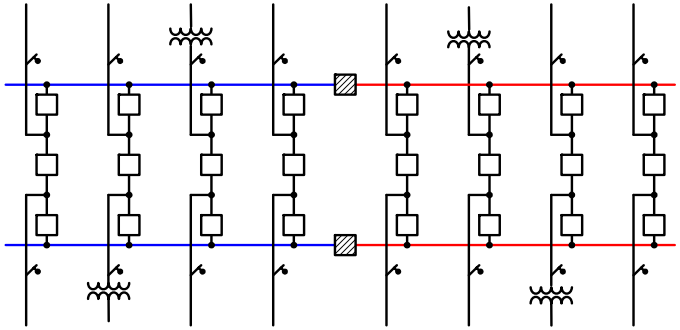
8-2: Switchgear Arrangement

- **Considerations to select:**
  - **a) Reliability level versus cost**
  - **b) Ease in maintenance**
  - **c) Ability to regulate market flows**
  - **d) Environmental concerns**
  - **e) Flexibility of expansion**
  - **f) Operating flexibility**

Ring Bus with Bustie



Breaker and a Half



Double Bus Single Breaker