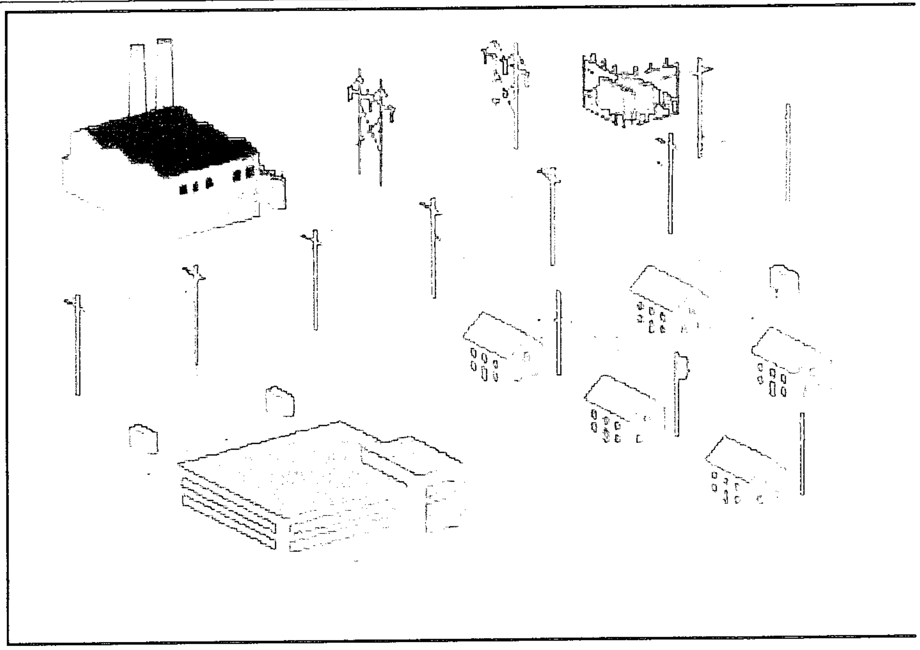
Case 20/20 + 5/5 project poster

25/25

Transmission and Distribution Systems



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Modernization

Underground Residential Distribution

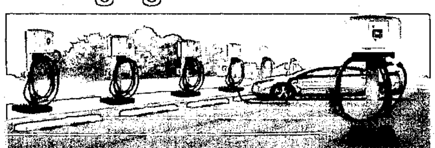
Main Components include:

-Pedestals, Manholes, Underground Conduits, cables and Pad-Mounted Transformers

ADVANTAGES	DISADVANTAGES
Attractive: Aesthetic appeal, neater and more modern area. Unobstructed view	Higher costs (approx. 5times more expensive to run underground lines as it is to run overhead power)
Highly reliable and usually unaffected by weather = less prone to outages	Increased difficulty finding and fixing faults within the underground system
Worthwhile: trees add beauty and value to the property, appealing to buyers	Longer outage periods
Require less right-of-way maintenance	Digging and tree roots can be problematic

PHEV Charging Stations

- Public Charging: AC Level 2 - 240V/40A

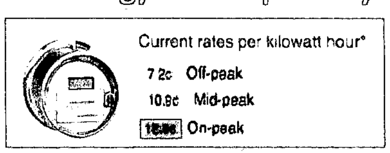


Renewable Energies: Solar Street Lights

- No underground wiring or connections to the grid
- Reduce Overall Load of neighborhood by 8.8kVA (3.6kWh/day)

Smart Meters and In-Home Displays

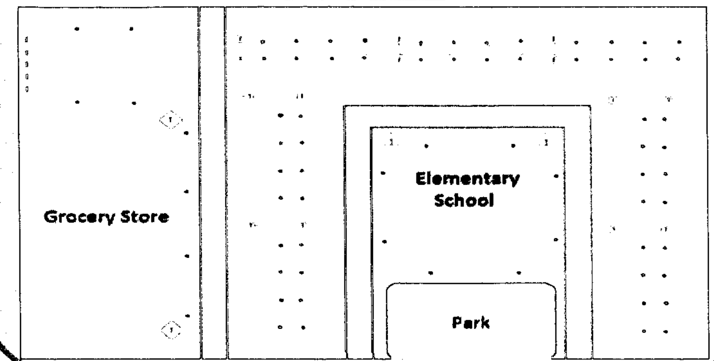
- Reduces stress on the grid by reducing peak demand
- Reduces overall energy consumption by 15%



Green Technologies For Green Communities

Layout Considerations

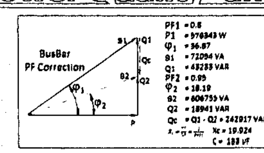
Our Design

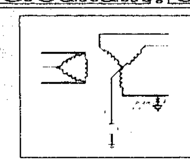


Economical use of Transformers

- 112 houses = 14x15kVA Transformers
- Grocery Store + PHEV Charging Stations = 2x160kVA Transformers
- Elementary School = 2x100kVA Transformers

Power Quality and R-Grounding Scheme

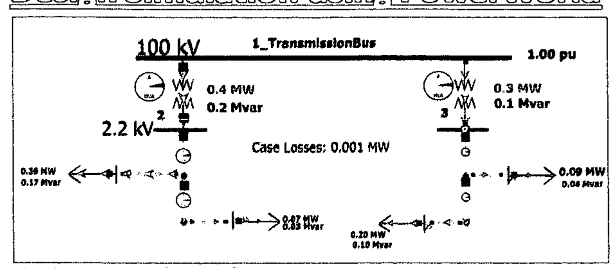




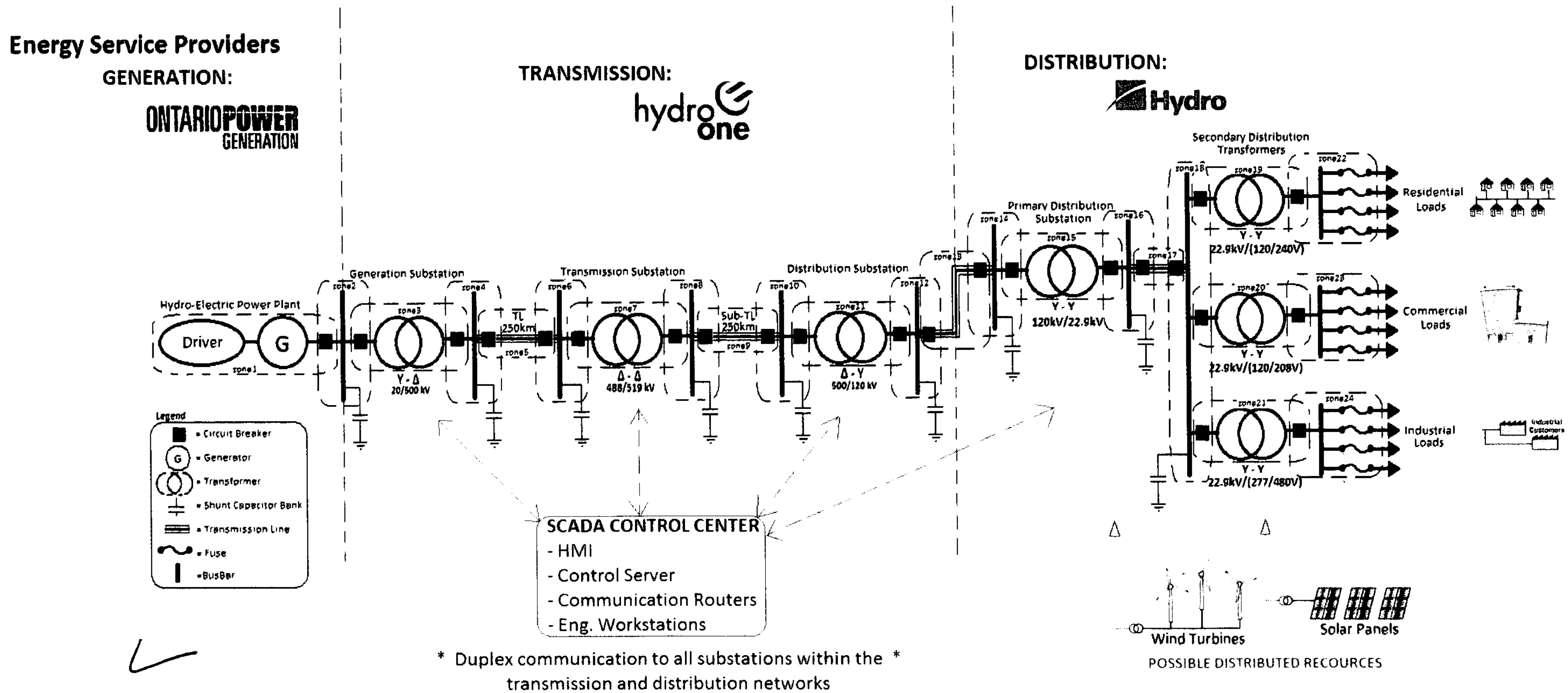
$$R = \frac{V_{LN}}{I_G}$$

Shunt Capacitor Banks

Design Simulation using PowerWorld



Below is a block diagram displaying the integration of generation, transmission and distribution power systems, as well as possible energy service providers, control centers, customers and distributed resources. Protection equipment, zoning and power factor correction equipment are also displayed.

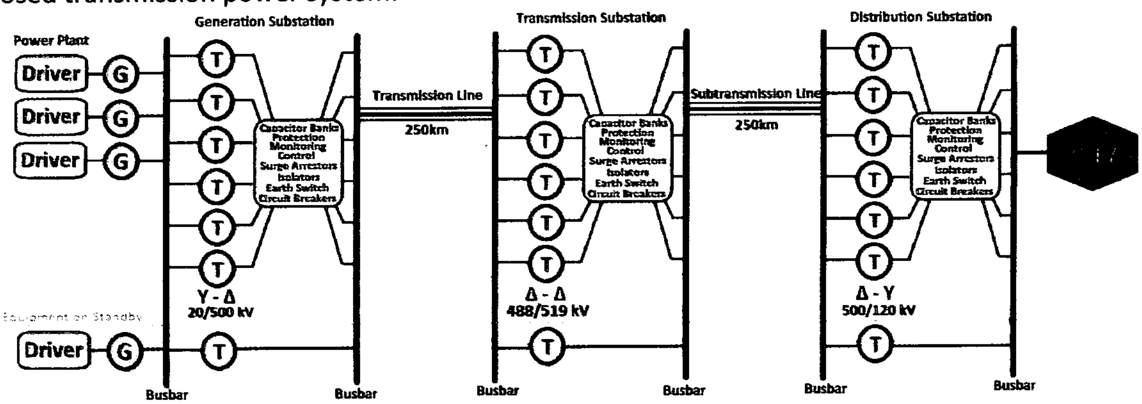


1.0 ABSTRACT

A power plant delivers a transmission line with 500kV and 1800A at 60Hz, which is feeding a city 500km away. A Substation lies halfway between the city and the generator. The city requires a minimum of 120 kV with a peak current of 1600 A. This report discusses the design of the power plant, substations, transformers and transmission lines specifications as well as the design of the distribution and utilization system to provide electricity to the city.

2.0 Transmission Power System Design Layout (CASE STUDY 1)

The following figure includes the various equipment, protective devices and general layout of the proposed transmission power system.



2.1 Transmission Line Parameter Calculations

A transmission line can be represented by an ABDC Network, which relates the input and output voltages and currents as shown below.

$$V_S = AV_R + BI_R$$
$$I_S = CV_R + DI_R$$

To meet our design criteria, we set Vs = 500kV, Is = 1800=2000 for safety. Since the design is a 2 conductor system, the ABCD Network will be determined for only one circuit, where Vs=500kV, Is=1010A, Z_{line}=15.27 + j60.58Ω, and Y_{line} = -j7.2x10^{-8}s as determine in the cable specifications. Thus, using the transmission line impedance Z_{line} and Y_{line}, we can determine the ADBC parameters:

$$\boldsymbol{A} = 1 + \frac{Z * Y}{2} == 1 + \frac{1}{2}[(15.27 + j60.58) * (-j7.2x10^{-8})] = 1 + j5.52x10^{-7}\Omega$$

$$\boldsymbol{B} = Z = 15.27 + j60.58\ \Omega$$

$$\boldsymbol{C} = Y\left(1 + \frac{Z * Y}{4}\right)$$

$$\boldsymbol{C} = (-j7.2x10^{-8}) * \left\{1 + \frac{1}{4}[(15.27 + j60.58) * (-j7.2x10^{-8})]\right\} = -2x10^{-14} - j7.23x10^{-8}\ \Omega$$

$$\boldsymbol{D} = 1 + \frac{Z * Y}{2} == 1 + \frac{1}{2}[(15.27 + j60.58) * (-j7.2x10^{-8})] = 1 + j5.52x10^{-7}\ \Omega$$

Using the ABCD Network parameters as previously found, we can now determine the voltage V_R and current I_R at the receiving end of the 250km transmission line using the two following equations with two unknowns:

$$Vs = A * V_R + B * I_R \qquad Is = C * V_R + D * I_R$$

We find:

V_R = 484595.84 -j61190.88 = 488.44 ∠-7.19° kV

I_R = 1010 + j0.0351 A = 1010 ∠0.002° A

Power Factor = cos(-7.19-0.002) = 0.992 leading

We can also find the efficiency of the first part of the transmission line:

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} x100 = \frac{V_R I_R \cos\theta_R}{V_s I_s \cos\theta_s} x100$$

$$\eta = \frac{(488443.9) * (1010) * \cos(-7.19 - 0.002)}{(500000) * (1010)\cos(0)} x100$$

η= 96.92%

Now, we can determine, working backwards, the voltage and current at the sending end of the transmission substation by setting the following parameters at the receiving end of the distribution substation:

$$V_R = 500kV \qquad and \qquad I_R = 1010\,A$$

Using the same ABCD parameters since the same conductor is used, we obtain the following values at the sending end of the transmission substation:

V_s = 515406.15 +j61189.96 = 519.025 ∠6.77° kV

I_s = 1009.99 - j0.0356 A = 1010 ∠-0.002° A

Power Factor = cos(6.77 - (-0.002)) = 0.993 lagging

Which has the following corresponding efficiency:

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} x100 = \frac{V_R I_R \cos\theta_R}{V_s I_s \cos\theta_s} x100$$

$$\eta = \frac{(500000) * (1010) * \cos(0)}{(519025) * (1010)\cos(6.77 - (-0.002))} x100$$

η= 97.01%

2.2 Voltage Regulation

The voltage regulation is determined using the following:

$$VR = \frac{|V_{no\text{-}load}| - |V_{full\text{-}load}|}{|V_{full\text{-}load}|} \times 100\%$$

With a longer cable, V_{out} will decrease due to a voltage drop. If VR = 0, then $V_{in} = V_{out}$ which is ideal. Thus, we want the smallest voltage regulation possible (smaller then 20%). The following corresponds to the voltage regulation of the system:

$$VR(First\ 250km) = \frac{|500 - 488.44|}{488.44} x\ 100\% = 2.37\ \%$$

$$VR(Last\ 250km) = \frac{|529.025 - 500|}{500} x\ 100\% = 5.8\ \%$$

Thus, we can conclude that the system has good voltage regulation.

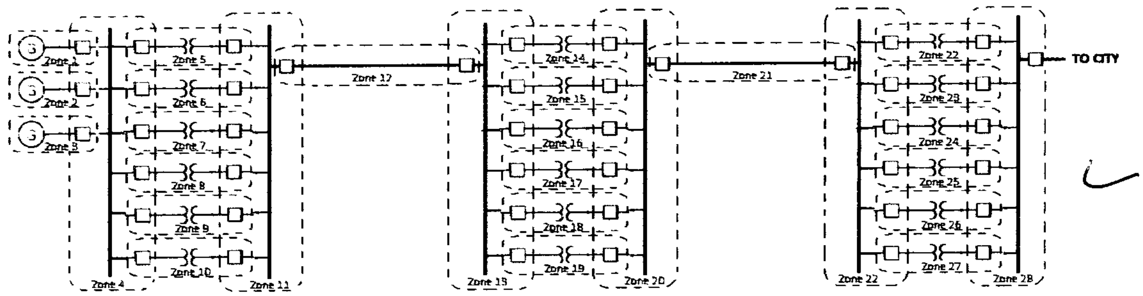
3.0 Power System Specifications

Below is a summary of the specifications determined in Case Study 1, assuming a uniform frequency of 60Hz for all equipment. These values were used in previous transmission line and VR calculations .

Power Plant Specifications		
Turbine	Model and quantity	3 Francis Turbines
	Speed Range	83 to 100 rpm
	Power Output	20 MW
Synchronous Generator	# Poles	8
	Voltage Range	20 kV
	Output Range	450 MVA
	Power Factor	0.8-0.85
	Quantity	3 for a total of 1350 MVA
Generator Substation		
Step Up Generator Transformers	Step-up Range	20 kV to 500 kV
	Transformer Turns Ratio	1:25
	Transformer Rated Power	200 MVA
	Design/ Configuration	3 Phase, Y - Δ
	Quantity	6 working at 80% of full capacity
	Transformer Efficiency	~ 98%
Transmission Line		
Tower Structure	Tower Type	3L2 Waist-Type
	Voltage Range	110kV - 735 kV
	Number Conductors/Phase	2/Phase * 3 phases = 6 conductors
	Lightning Protection	2 Shield wires; Material is EHS Steel
Cable Specifications	Type	Cardinal ACSR
	Current Carrying Capacity	1010 A
	Rated Voltage	Up to 500kV
	Resistance	0.0982 Ω/mile
	Inductive Reactance	0.0390 Ω/mile
	Shunt Capacitive Reactance	0.089 Ω/mile
	Length	250km each
Insulator Specifications	Material	Toughened Glass
	Quantity	24 insulators/string for 500kV line
Transmission Substation		
Tap Transformers	Quantity and Type	6 Tap Transformers
	Rated Power	200 MVA
	Design/ Configuration	3 Phase, Δ- Δ
Distribution Substation		
Step Down Distribution Transformers	Quantity/Type	6 Step-Down Power Transformer
	Rated Power	200 MVA
	Turns Ratio	5:1 (500kV/120kV)
	Design/ Configuration	3 Phase, Δ-Y
	Efficiency	~98%

4.0 Protection Zoning (CASE STUDY 2)

As described in Case Study 2, the following protection zones will be implemented to simplify fault isolation in a fast and efficient way. The boxes represent the circuit breakers, which are located in overlapping regions in order to isolate the fault when required.



4.1 Protection Equipment [1]

Protection Component	Types	Function	What they Protect
Instrument Transformers	Current Transformer	Steps down the current to standardized levels	Safer working environment
	Voltage Transformer	Steps down the voltage to standardized levels	Safer working environment
Relays	Over Current Relay (instantaneous/delay)	Relays information of fault to circuit breaker	Instrument transformers
	Directional Relays	Relays information of fault currents in only one direction	Multiple source systems
	Impedance Relays	Relays information in response to voltage-current ratio	Transmission/Distribution lines
	Differential Relays	Relays information depending on a difference current	Generators, buses and transformers
Breakers	Circuit Breakers	Controlled by relays, open when a fault is detected	General system protection
	Reclosers	Automatically interrupts and reclosed an AC circuit	General system protection
	Fuses	Low resistance resistor that interrupts excessive current	General system protection
Lightning Protection	Surge Arrestors	Divert damaging lighting-induced transients to ground	Conductor, transformer switchgear protection
	Shield Wires	Prevent direct strike to line	Transmission line

4.2 Protection Equipment Ratings

Generator Transformer CT ratio calculations (3 phase, 200MVA, 20kV/500kV):

$$I_{rated(p)} = \frac{S}{V_P * \sqrt{3}} = \frac{200x10^6}{20x10^3 * \sqrt{3}} = 5773.5\ A$$

From table 10.2 in the book, we select a CT ratio of 6000:5 for the primary. This ratio gives the following primary current:

$$I_P = 5773.5 * \frac{5}{6000} = 4.811\ A$$

Following the same method, we can also determine the CT ratio for the secondary circuit:

$$I_{rated(s)} = \frac{S}{V_S * \sqrt{3}} = \frac{200x10^6}{500x10^3 * \sqrt{3}} = 230.94\ A$$

From table 10.2 in the book, we select a CT ratio of 250:5 for the secondary. This ratio gives the following secondary current:

$$I_S = 230.94 * \frac{5}{250} = 4.619\ A$$

Following the above steps for the transmission and distribution transformers, we obtain CT ratios of 250:5 for both the primary and secondary of the transmission transformers, and CT ratios of 250:5 for primary and 1000:5 for secondary of the distribution transformers.

4.3 Circuit Breaker Sizing

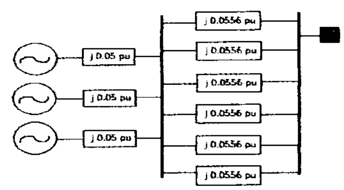
In order to size the circuit breakers, the following calculations were made. The base value of the system is Sbase=900MVA. Assuming that fault currents can reach values up to 20times the normal rating, the corresponding Ssc=18000MVA. Using these values, we can find the impedance of the grid:

$$Z_{Grid,pu} = \frac{S_{Base}}{S_{sc}} = \frac{900\ MVA}{18000MVA} = j0.05\ pu$$

From table A-2 of typical transformer leakage reactances, a rating of highest voltage winding of 500kV corresponds to a leakage reactance of 0.16-0.34 pu. Thus, the transformer leakage reactance will be set to j0.25pu. We can now determine the transformer impedance:

$$Z_{TR} = \frac{S_{TR}}{S_{Base}} * Z_{Leakage} = \frac{200MVA}{900MVA} * j0.25 = j0.0556\ \Omega$$

Since the power plant is composed of 3 generators and the generating substation composed of 6 transformers, we can find the equivalent reactance to be Zeq = j0.0259 pu. We can now determine the short circuit apparent power and corresponding short circuit current that will be used to size the circuit breakers:



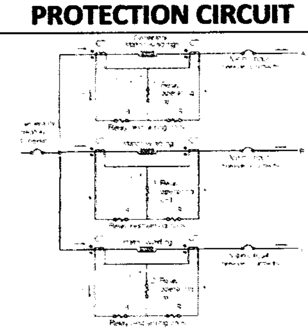
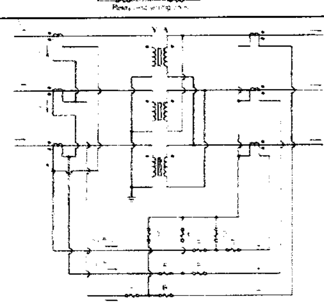
$$S_{SC} = \frac{S_{Base}}{Z_{eq}} = \frac{900MVA}{j\ 0.0259\ pu} = 34749\ MVA$$

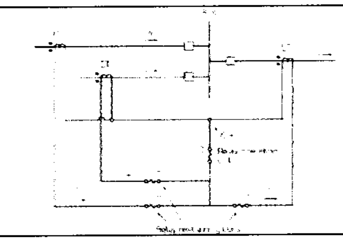
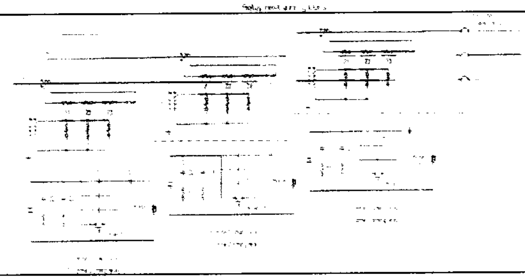
$$I_{SC} = \frac{S_{SC}}{V * \sqrt{3}} = \frac{34749x10^6}{500x10^3 * \sqrt{3}} = 40.124\ kA$$

Thus, the following circuit breakers would be sufficient for the above ratings [2]:

Circuit Breaker Ratings			
Rated Max. Voltage	**Rated Cont. Current**	**Rated Short-Circuit Current**	**Type**
550 kV	2000-3000 A	40 kA	Outdoor - Gas Insulated

The summary of the CT ratios and protection circuits are shown in the table below [3].

DEVICE	PROTECTION CIRCUIT	Equipment Ratings
3-PHASE SYNCHRONOUS GENERATOR PROTECTION CIRCUIT (CT + Differential Relays + CB)		$I_R = \frac{450x10^6}{20x10^3 * \sqrt{3}}$ $I_R = 12900.38$ CT Ratio -> 13000:5
3-PHASE TRANSFORMER PROTECTION CIRCUIT (Δ-Y Connection) (CT + Differential Relays + CB)		Generator Transformers CT Ratio (P) -> 6000:5 CT Ratio (S) -> 250:5 Transmission Transformers CT Ratio (P) -> 250:5 CT Ratio (S) -> 250:5 Distribution Transformer CT Ratio (P) -> 250:5 CT Ratio (S) -> 1000:5

BUSBAR PROTECTION CIRCUIT (CT + Differential Relays + CB)		BUS 1 CT Ratios -> 13000:5 CT Ratios -> 6000:5 BUS 2 CT Ratios -> 250:5 BUS 3 CT Ratios -> 1000:5
3PHASE TRANSMISSION LINES (CT + VT + Impedance Relays + CB)		PHASE 1 CT Ratios -> 1200:5 PHASE 2 CT Ratios -> 1200:5 PHASE 3 CT Ratios -> 1200:5

5.0 Standards [4],[5]

Technical specifications/equipment	Standards
CT and VT Standard Ratings	IEEE C57.13
High Voltage Circuit Breaker Standards	IEEE C37.04-1999
National Electric Reliability Corporation (NERC)	Standards related to development, modification or withdrawal of electric reliability standards for bulk power systems in North America.
Federal Energy Regulatory Commission (FERC)	Regulates the interstate transmission of electricity, natural gas and oil.
Ontario Energy Board (OEB)	Regulates province's electricity and natural gas sectors in the public interest.
Independent Electricity System Operator (IESO)	Direct the operation and maintain reliability of the grid
SCADA Standard Protocols	IEC 60870-5-101, IEC 61850 and DNP3
BPL	IEEE 1901 (frequencies below 100MHz)
STATCOM	IEEE SA - P1052: Guide for Functional Specs of STATCOM Systems

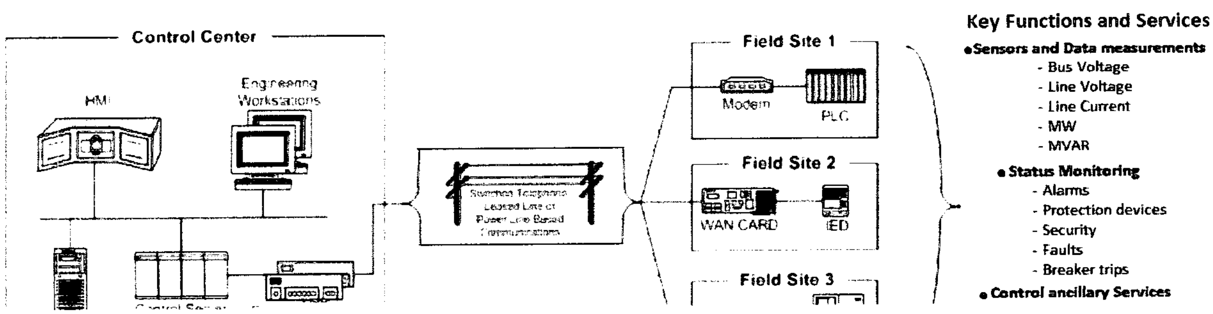
6.0 Flexible AC Transmission System (FACTS)

FACTS are technologies that can control AC transmission system parameters, increase power transfer capability and improve voltage regulation. FACTS devices include [6]:

- **Unified power flow controllers**
- **Static VAR compensators** (SVC): Static VAR Compensators: absorb reactive power during light loads and deliver reactive power during heavy loads.
- **Static synchronous compensators** (STATCOM): Is a regulating device that uses power electronics to control power flow and improve transient stability.

7.0 Supervisory Control and Data Acquisition (SCADA) System [7]

SCADA is designed to collect field information, transfer it to a central computer facility and display the information to the operator, allowing the operator to monitor or control an entire system from a central location in real time. The main components as well as proposed design for the power system are below :



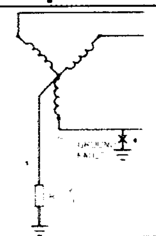
8.0 Distribution Power System (CASE STUDY 3)

From the Distribution Substation, which is the bulk power substation, we need to step down the sub-transmission voltage to a primary distribution feeder rating of 20MVA for 22.9kV. This primary feeder will then reach secondary distribution transformers, which will step down the 22.9 kV to voltage that are suitable for 3 different types of loads; Residential, Commercial and Industrial. The transformer ratings are listed in the table below [8].

Primary Distribution Transformers	
Type	Step Down Pole Mounted Transformer
Primary Voltage/Secondary Voltage	120kV/22.9kV
Turns Ratio	6:1
Rated Power	20 MVA
Design/ Configuration	3 Phase, Y-Y (4 wire)
Efficiency	98%
Frequency	60 Hz
Maximum Quantity from Dist. Substation (900MVA)	900MVA/20MVA = max. 45 transformers
Secondary Distribution Transformers (RESIDENTIAL)	
Type	Step Down Pole Mounted Transformer
Primary Voltage/Secondary Voltage	22.9kV/ (120/240)V (split phase design)
Rated Power	50 kVA
Design/Configuration	3 Phase, Y-Y (3 wire)
Efficiency	98%
Frequency	60 Hz
Maximum quantity per primary transformer	20MVA/0.05MVA = max. 400 transformers
Secondary Distribution Transformers (RESIDENTIAL/COMMERCIAL)	
Type	Step Down Pole Mounted Transformer
Primary Voltage/Secondary Voltage	22.9kV/ (120/208)V
Rated Power	300kVA
Design/ Configuration	3 Phase, Y-Y (4 wire)
Efficiency	98%
Frequency	60 Hz
Maximum quantity per primary transformer	20MVA/0.3MVA = max. 66 transformers
Secondary Distribution Transformers (INDUSTRIAL)	
Type	Step Down Pole Mounted Transformer
Primary Voltage/Secondary Voltage	22.9kV/ (277/480)V
Rated Power	500kVA- 1MVA
Design/ Configuration	3 phase, Y-Y (4 wire)
Efficiency	98%
Frequency	60 Hz
Maximum quantity per primary transformer	20MVA/1MVA = max. 20 transformers

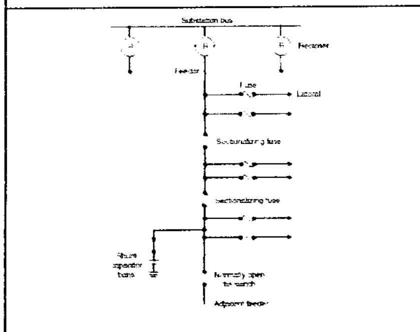
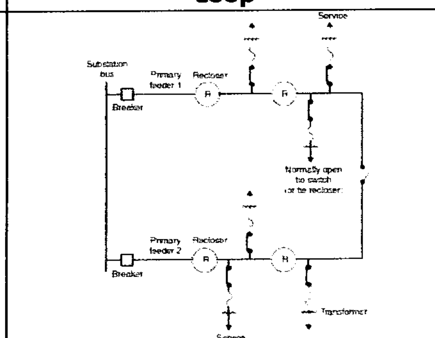
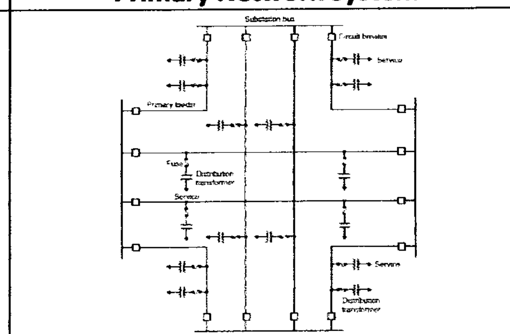
9.0 Grounding Scheme

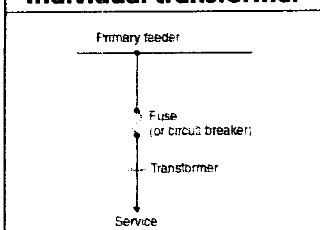
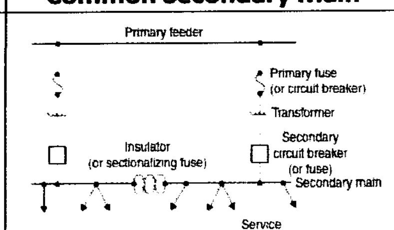
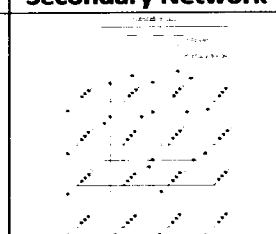
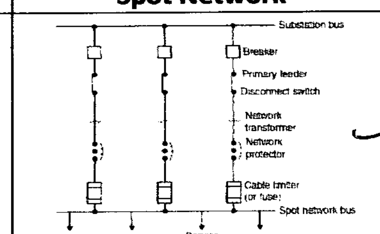
Since the distribution network is composed of primary and secondary Y-connected transformers, a neutral grounding scheme will be used throughout the network. Specifications are shown below. The grounding is done through an small impedance that is used to limit short circuit currents.

Type of Grounding	Example Circuit	Locations	Resistance Values
Neutral R-Grounding		-Frequent intervals along the primary - Distribution Transformers - Customer's service entrances	$R = \frac{V_{LN}}{I_G} = \frac{V_{LN}}{400}$ R(residential->V_{LN}=240V) = 0.6 Ω R(commercial->V_{LN}=240V) = 0.52 Ω R(industrial->V_{LN}=480V) = 1.2 Ω

10.0 Primary and Secondary Distribution Topologies

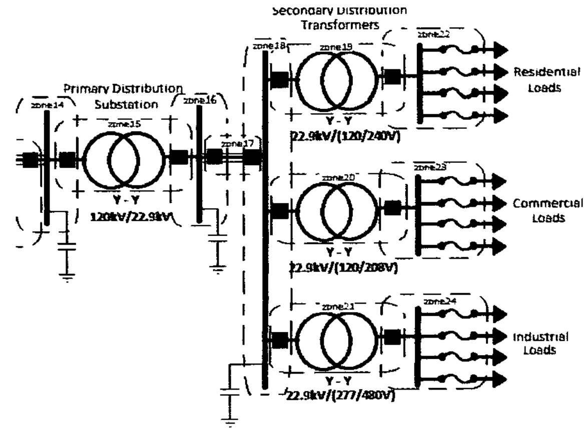
Within the primary distribution and secondary distribution, various topologies exist to accommodate for different load densities. These topologies are summarized below [9].

Primary Distribution Topologies		
Radial	**Loop**	**Primary Network System**
		
- Low-load density areas - Suburban Residential	- Medium load density areas - High service reliability -Residential/Commercial	- High load densities -Highest reliability - Large Cities/downtown

Secondary Distribution Topologies			
Individual transformer	**Common Secondary Main**	**Secondary Network**	**Spot Network**
			
- Single service - Rural area -Unusually large load	- Accommodate diverse loads - Residential/Commercial	- High density loads - Downtown area - high reliability	- Concentrated load - High-rise building/Industrial - High reliability

For this distribution network, primary distribution will be a combination of radial and loop systems and the secondary distribution will be a combination of common secondary main and spot network systems in order to accommodate for residential, commercial and industrial loads.

11.0 PROTECTION



The protection zones for the distribution network are shown to the right. The distribution network also requires protection equipment similar to those listed in the transmission network. A table summarizing the protective equipment to be used within the Distribution network is below [10].

Type of Protection Equipment	Function/What they protect
Fuses	Between laterals and feeders, distribution transformer protection
Reclosers	Feeder protection
Sectionalizing fuses	Radial Feeder protection
Tie switches	Along lines, connected to adjacent feeders (in case of emergency)
Cable Limiters	Special fuses used on commercial/industrial transformers
Circuit Breakers/Relays	Primary/Secondary Distribution Transformer and Feeder protection

Following the same method as used in case study 2, we must now determine the current transformer and circuit breaker ratings in order to effectively protect the distribution network against faults.

Transformer	Calculations	CT Ratio	CB Ratings
Primary Distribution Transformer	$I_{rated(p)} = \frac{S}{V_P * \sqrt{3}} = \frac{20x10^6}{120x10^3 * \sqrt{3}} = 96.22A$ $I_P = 96.22 * \frac{5}{100} = 4.811\ A$ $I_{rated(s)} = \frac{S}{V_S * \sqrt{3}} = \frac{20x10^6}{22.9x10^3 * \sqrt{3}} = 504.24\ A$ $I_S = 504.24 * \frac{5}{500} = 5.04\ A$	Primary CT Ratio 100:5 Secondary CT Ratio 500:5	Rated Voltage: 22.9kV Rated Isc: 60 kA Type: Outdoor Gas Insulated
Secondary Distribution Transformer (Residential)	$I_{rated(p)} = 1.26\ A$ $\quad I_P = 0.126\ A$ $I_{rated(s)} = 240.56A$ $\quad I_S = 4.811\ A$	Primary CT Ratio 50:5 Secondary CT Ratio 250:5	Rated Voltage: 240V Rated Isc: 80 kA Type: Outdoor /Gas
Secondary Distribution Transformer (Commercial)	$I_{rated(p)} = 7.56\ A$ $\quad I_P = 0.756\ A$ $I_{rated(s)} = 1443.4A$ $\quad I_S = 4.811\ A$	Primary CT Ratio 50:5 Secondary CT Ratio 1500:5	Rated Voltage: 208 V Rated Isc: 85 kA Type: Outdoor/Gas
Secondary Distribution Transformer (Industrial)	$I_{rated(p)} = 25.2\ A$ $\quad I_P = 2.521\ A$ $I_{rated(s)} = 2084.3A$ $\quad I_S = 4.342\ A$	Primary CT Ratio 50:5 Secondary CT Ratio 2400:5	Rated Voltage: 480V Rated Isc: 93 kA Type: Outdoor/Gas

Fuses will also be used to protect the various types of transformers used within the secondary distribution network. Fuse specifications for the secondary distribution transformers are shown in the table to the right [11].

LV Fuse sizes

Transformer size	Type	Nominal impedance	Max fuse size amps	Normal fuse size: Residential non electric heating	Normal fuse size: Residential electric heating & Industrial / Commercial
1000 kVA 3Ø	Pole mounted	4.75%	**630**	315	400
500 kVA 3Ø	Pole mounted	4.75%	**400**	315	400
315 kVA 3Ø	Pole mounted	4.75%	**400**	315	400
50 kVA 3Ø	Pole mounted	4.5%	**200**	200	200

12.0 Power Quality

To keep voltage within ANSI limits, there will be load tap-changing distribution substation transformers, and additional voltage regulators and shunt capacitors banks will be used to perform the following[12]:

- Reduce Voltage Drop
- Reduce Power Losses
- Improve Power Factor

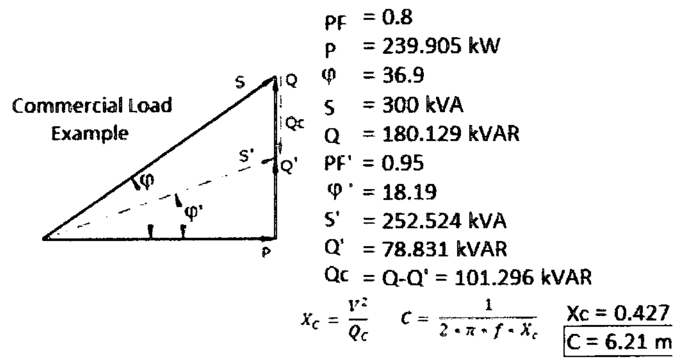
Shunt capacitor banks will be added at least substation and transformer in order to improve the power factor. The commercial transformer is rated at S=300KVA and will assume PowerFactor = 0.8. We want to increase the PF=0.95. The following method is used to determine the required shunt capacitance value:

$$\Theta = \cos^{-1}(0.8) = 36.9^{o}$$
$$P = \cos(36.9) * 300000 = 239.905\ kW$$

$$Q = \sqrt{S^2 + P^2} = \sqrt{300000^2 + 239905} = 180.126\ KVAR$$

While keeping P constant, we want to determine the new value of Q', S' and Θ' which corresponds to;

$$\Theta' = \cos^{-1}(0.95) = 18.19^{o}$$
$$Q' = \tan(\Theta') * P = \tan(18.19) * 239905 = 78.830kVAR$$
$$S' = \frac{P}{\cos(\Theta')} = \frac{239905}{\cos 18.19} = 252.524kVA$$
$$Q_C = Q - Q' = 180126 - 78830 = 101296\ VAR$$
$$X_C = \frac{V^2}{Q_C} = \frac{208^2}{101296} = 0.4271$$



Finally, using this value we can determine the required capacitance value:

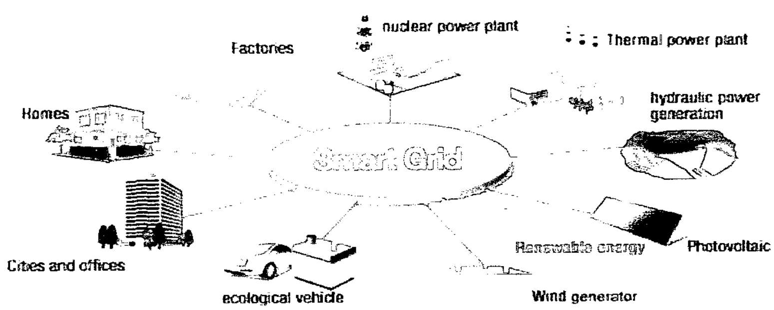
$$C = \frac{1}{2 * \pi * f * X_c} = \frac{1}{2 * \pi * 60 * 0.4271} = 6.21\ mF$$

Following the same method, assuming that we increase the PF from 0.8 to 0.95, we obtain the following shunt capacitor bank values for the entire power system:

Transformer	Secondary Voltage	Apparent Power	Shunt Capacitance
Generation Transformer	500 kV	200 MVA	0.715 µF
Transmission Transformer	500 kV	200 MVA	0.715 µF
Distribution Transformer	120 kV	200 MVA	12.42 µF
Primary Transformer	22.9 kV	20 MVA	341 µF
Secondary transformer (residential)	120/240 V	50 KVA	777.5 µF
Secondary transformer (commercial)	120/208 V	300 KVA	6.21 mF
Secondary transformer (industrial)	277/480 V	1 MVA	3.88 mF

13.0 Smart Grid Deployments

The power grid is a work in progress, and as technology advances, the methods with which power is distributed will continue to evolve, ensuring a safer, more streamlined and efficient smart grid. This will include the integration of renewable energies, communication technologies, system automation, plug-in-hybrid-electric vehicles (PHEV) as well as overall smarter homes, as can be seen below.



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