AECC Planning Department

Planning Criteria

November 20, 2007

Version Tracking

11/20/2007	

	Section
Introduction	1
Coordinated Planning	2
General Criteria	3
Work Plans & Long Range Plans	4
Exceptions	5
Facility Ratings	6
Impedances	7
Model Development	8
Power Flow Studies	9
Short Circuit	10
Stability	11
Voltage Drop	12
Motor Starting	13
Power Quality / Harmonics	14
Outage Reporting	15
Reliability	16

1. Introduction

This document contains the planning criteria, assumptions, and guidelines used by the AECC Planning Department in conducting planning studies. The criteria, assumptions, and guidelines will be used by the AECC Planning Department to meet AECC's responsibilities under SPP Criteria and the NERC Reliability Standards. As a member of the Southwest Power Pool AECC has an obligation to meet the requirements outlined in the SPP Criteria. AECC, as itself and on the behalf of its member distribution cooperatives, is also registered as several functional entities in the NERC Functional Entity Registry and therefore is responsible for meeting compliance for a number of mandatory FERC approved NERC Reliability Standards and FERC approved SPP Regional Reliability Standards. These criteria, assumptions, and guidelines are also the basis for the department's analysis and evaluations of studies such as construction work plans, long range work plans, and other studies provided to the department for review, concurrence, or approval.

The document is considered to be a work in progress and is subject to change as needed. Being a work in progress it may not be all inclusive.

2. Exceptions

The department recognizes there may be exceptions to the criteria, assumptions and guidelines. These should be minimal and not the norm. In no case will an exception create a violation of the SPP Criteria, SPP Regional Reliability Standards, and/or NERC Reliability Standards. If the specific nature of a study results in the use of additional or more stringent criteria than what appears in this document, these exceptions should be identified in the specific study and taken under consideration for inclusion into this document.

3. Coordinated Planning

AECC relationships and obligations with other entities require coordinated planning. AECC's contracts with its members and the Transmission Line Extension Policy call for AECC to be involved and approve construction work plans and long range plans before they are sent to RUS. AECC's transmission service agreements with Entergy, SWPA, AEP/SWEPCO, and the Southwest Power Pool all call for coordinated planning

4. General Criteria

Planning will be conducted using the "one owner" concept. This concept takes into account the impacts to all parties involved including the distribution cooperatives, AECC, transmission owners, and transmission service providers. This concept will be the basis for all studies and evaluations.

SPP Criteria, FERC approved NERC and SPP reliability standards, RUS rules, bulletins and guides, FERC policies and/or APSC rules will form the foundation for the AECC planning criteria. AECC criteria may have higher or more stringent requirements but can not be less stringent than SPP Criteria or SPP standards.

5. Work Plans & Long Range Plans (General)

- LRP and CWP development will be based on RUS Bulletin 1724-101A and 1724-101B.
- The period of the LRP should be a minimum of 10 years. A more reasonable period would be 20 years or at least 4 times the current load level as suggested in the past by RUS.
- There should be at least two transition levels in a LRP.
- Where reasonable, distribution delivery points should be eliminated.
- AECC Design Guidelines will be used in the evaluation of CWP/LRPs.
- In a CWP or LRP where the concentration is on the distribution system a distribution bus voltage of 1.05 pu may be assumed for study purposes.
- For evaluating transmission alternatives the most recent applicable regional models should be used unless a better alternative is available.

4.1 Forecast

- Work Plan and Long Range Plan forecasts should be developed using a RUS approved methodology or equivalent.
- Projections for residential loads which use the REA Factor A and B method as described in Bulletin 45-2 are acceptable.
- Variations between the Work Plan/Long Range Plan forecast and the current Power Requirement Study need to be explained.

4.2 Reliability

- Determination of when to close a loop (transmission or distribution) should be based on the $/kW-mile principle. Other considerations should be included such as the economic conductor analysis, load duration curves, and outage history.

4.3 Economic

- Power cost and escalations should be based on the current rates and reasonable escalation factors.
- Evaluation of alternatives will be based on an annual cost basis of the present worth for an investment.
- The annual cost factor will be developed using the cooperative's latest estimates of Interest, Depreciation, A&G, O&M, Insurance, and Taxes.
- Cost estimates for distribution lines, transmission lines, and substations will be developed and included. These estimates will be based on the cooperative's latest estimates or other reasonable sources.

- Economic Conductor Analysis will determine the most economical conductor for given load levels provided there are no additional restraints such as capacity or voltage drop.
- Cost estimates for line conversions for voltage reasons should take into account the cost of removal of old unit, loss of life due to premature removal, cost of installation for new unit, and incremental cost of new unit.
- The equivalent cost of AECC providing distribution delivery points or increased capacity for backup should be considered in evaluating alternatives.

6. Equipment and Facility Ratings

6.1 General

- Equipment and facilities rating will meet the requirements of NERC FAC-008 and SPP Criteria 12.
- Unless otherwise specified the default rating and parameters in SPP Criteria 12 are used.
- Facilities ratings shall equal the most limiting applicable equipment rating of the individual equipment that comprises that facility.
- Facilities ratings will consider limitations induced by protective equipment continuous settings.
- Where applicable each element shall have both a normal and an emergency rating.
- The Normal Rating is based on a thermal rating at which level the facility can operate continuously without loss of life to the facility involved.
- Emergency Rating is based on a thermal power rating at which level the facility can operate for the time sufficient for adjustment of transfer schedules, generation dispatch, or line switching in an orderly manner with acceptable loss of life to the facility involved.
- Summer and winter ratings shall be computed based upon appropriate seasonal temperatures.
- For jointly owned transmission facilities, the lowest applicable rating determined by the owners of the facility will be used as the facility's rating.

6.2 Transmission & Distribution Lines

- Line (transmission or distribution) is defined as the circuit breaker, line conductor, and jumpers between the circuit breaker and line conductor.
- Transmission circuits shall consist of all load carrying elements between circuit breakers or the comparable switching devices.
- Circuit ratings will be based on the minimum applicable rating of all the elements in series.

6.2.1 Overhead Conductors (Transmission & Distribution)

- Conductor ampacity values will be determined using SPP Criteria and IEEE Std. 738-1993 which is based on the House and Tuttle heat balance method. See Appendix A for additional detail concerning the equations used to determine overhead conductor ratings. Parameters used in the House and Tuttle method for calculating AECC overhead conductors ratings are:
    - Ambient temperatures AECC will use summer and winter ambient temperatures of 40ºC and 10ºC respectively. These ambient temperatures are SPP default values found in Appendix A of SPP Criteria.
    - Conductor temperatures: AECC will use normal and emergency conductor temperatures of 85ºC and 100ºC respectively. Maximum normal and emergency conductor temperatures are specified in SPP Criteria Section 12.2.2.6. Exceptions may be allowed for older lines which were not designed to allow these conductor temperatures and high temperature conductors such as the SSAC conductor also specified in SPP Criteria Section 12.2.2.6.
    - Wind Speed; AECC will use a wind speed of 2 ft/sec perpendicular to the conductor. The wind speed and direction are specified in SPP Criteria Section 12.2.2.4.
    - Elevation: AECC will use a conductor elevation of 700 ft. The 700 ft conductor elevation is the average elevation of all AECC and member cooperatives' transmission lines 69kV and above. Each transmission line elevation was calculated by averaging the elevation of each end. The average of all the above described transmission line elevations was calculated to produce the total average transmission line elevation of 700 ft. "DeLorme 3-D TopoQuads" mapping software was used to determine the elevation of each end of all transmission lines.
    - Conductor direction: AECC will use a standard East-West conductor direction for computing all conductor ratings.
    - Latitude: AECC will use a latitude of 35º North which is the average latitude for the state of Arkansas.
    - Local Sun Time: AECC will use a local sun time of 12:00 p.m.
    - Atmosphere: AECC will use a "clear" atmosphere type for calculating conductor ratings.
    - Conductor Resistance and Diameter Values: Aluminum and copper conductor resistance and diameter values, unless otherwise noted, will come from The Aluminum Association Inc.'s "Aluminum Electrical Conductor Handbook" and the ABB's "Electrical Transmission and Distribution Reference Book" respectively.
    - Infrared Emissivity: Infrared emissivity for aluminum is 0.84 which is based on the average of the table values shown in SPP Criteria Section 12.2.2.3 for "5-10 yrs" and "10-20 yrs". Infrared emissivity for copper is 0.5 which is based on the table value for "normal" in SPP Criteria Section 12.2.2.3
    - Solar Absorptivity: Solar absorptivity for aluminum is 1.0 which is based on the table value for "5 yrs" in SPP Criteria Section 12.2.2.3. Solar

absoptivity for copper is 0.7 which is based on the table value for "normal" in SPP Criteria Section 12.2.2.3.

6.2.2 Underground Conductors

The following parameters will be used to determine both normal and emergency ratings of underground conductors.

- Conductor Temp: 90ºC
- Ambient Temp: 20ºC

6.3 Transformers

- Transformers with both primary and secondary windings energized at 69 kV or above are subject to SPP Criteria 12.
- AECC will rate all transformers according to SPP Criteria 12.
- Ambient Temp: 30ºC
- Normal rating: Highest nameplate rating with forced cooling if available
- Emergency rating: 100% of its highest nameplate rating (minimum)
- Transformers may be operated at levels above nameplate ratings under emergency conditions. Determination of loss of life due to such operation will be as follows
    - 65ºC rise transformers can operate at 120% for an 8 hour peak load cycle and will experience a 0.25% loss of life
    - 55ºC rise transformers can operate at 123% for an 8 hour peak load cycle and will experience a 0.25% loss of life.

6.4 Switches

The normal and emergency ratings for switches will be the same for a given season. The nameplate rating of a switch will be used for its normal and emergency summer ratings. Winter ratings will be developed as described in SPP Criteria Appendix C for 10ºC ambient temperature. The method described in Appendix C is based on the Allowable Continuous Current Class (ACCC) designation of the switch. Appendix C includes tables of the loadability factors for each ACCC designation. If the ACCC designation is not known, the switch will be assumed to be an AO1 class as suggested in Appendix C.

6.5 Wave Traps

The normal and emergency ratings for wave traps will be the same for a given season. The nameplate rating of a wave trap will be used for its normal and emergency summer ratings. (Nameplate ratings are generally based on a maximum ambient temperature of 40℃.) Winter ratings will be established in accordance with the methodology detailed in SPP Criteria Appendix D for 10ºC ambient temperature. As indicated in Appendix D, the loadability factors for dry-type air-cored inductor wave traps and epoxy-encapsulated inductor wave traps differ. If the type of wave trap can not be determined, the wave trap will be assumed to be a dry-type air-cored inductor wave trap when calculating the winter ratings.

6.6 Current Transformers

- Manufacturer nameplate ratings will be used for both normal and emergency summer and winter ratings. If needed, seasonal ratings can be calculated for separately mounted current transformers using their thermal current rating factor.

6.7 Circuit Breakers

- Manufacturer nameplate ratings will be used for both normal and emergency summer and winter ratings. If a circuit breaker is found to be a limiting element in a circuit and is experiencing loadings that limit operations, the methodology outlined in SPP Criteria Appendix F may be used to determine alternate normal and emergency ratings.

6.8 Series and Reactive Elements

- Manufacturer nameplate ratings will be used for both normal and emergency ratings.

6.9 Generators

- For jointly owned generating facilities, the rating will be determined by Entergy or AEP/SWEPCO, as applicable.
- Generator ratings are based on capability tests performed by AECC Power System Operations. These ratings are communicated to the AECC Planning department as per the AECC "Power Plant Ratings Procedures" (FAC-009).
- The AECC Planning uses these ratings in the SPP load flow model update (MOD-010).

6.10 Relay Protective Devices

- Manufacturer nameplate ratings will be used for both normal and emergency ratings.
- Any limitations identified due to the settings of relay protective devices will be reflected in the rating of affected facilities.

6.11 Terminal Equipment

- Manufacturer nameplate ratings will be used for both normal and emergency summer ratings. Winter ratings will be determined using the procedures described in the appropriate appendix of SPP Criteria.
- Bus is defined as the disconnect switches, bus conductor, and jumpers between the disconnect switches and bus conductor.
- Bus conductor ratings will be calculated using the same procedure as transmission lines with the exception of tubing conductor. Buses constructed of tubing will use the ratings specified in the Aluminum Electrical Conductor Handbook. This rating will be used for both summer/winter normal/emergency ratings.
- Buses will be designed with a rating equal to or greater than the adjacent line ratings.

7. Impedances

- Lines

- Impedances will be determined using the process outlined in the Westinghouse T&D Manual
- The 75ºC parameters are used for aluminum
- The 50ºC parameters are used for copper
- Transmission
- Distribution

- Transformers: Nameplate or test report values will be used
- Generator: Nameplate or test report values will be used to determine the applicable ratings.
- Motors: Nameplate data will be used. The average impedance for the NEMA class of the motor will be used if nameplate is not available.

7. Model Development – General
   - Models used in load flow, short circuit, and stability studies will be developed using PSS/e format and in accordance with SPP guidelines and criteria.
   - Models used in voltage drop studies will be developed using PSS/Adept in accordance with RUS guidelines and bulletins.
   - Standard Modeling Parameters for Generating Units:

     The following tables contain the standard parameters which will be used for planning purposes when modeling a coal plant or combustion turbine if the actual parameters are not available. Variations from these parameters may be necessary at times and should be clearly explained. Default values may be used for any parameters not specified in these tables. IREG should be set to the bus number of the high voltage bus connected to the GSU transformer. RMPCT may be set to values other than 100% if there are multiple generator units regulating the same high voltage bus.

     <u>Coal Plant Standard Parameters</u>
     These model parameters are based on the Flint Creek power plant.

PSS/e Parameter	Description	Value
QT	Maximum reactive power output	250
QB	Minimum reactive power output	-150
VS	Regulated voltage setpoint	1.03
IREG	Regulated bus	HV bus
MBASE	Machine base MVA	590
ZR	Machine resistance in pu on MBASE	0
ZX	Machine reactance in pu on MBASE	0.175
RMPCT	Percent of VARs supplied by this machine to support voltage at regulated bus	100
PT	Maximum real power output	500
PB	Minimum real power output	100

Combustion Turbine Standard Parameters
These model parameters are based on the Fulton power plant.

PSS/e Parameter	Description	Value
QT	Maximum reactive power output	75
QB	Minimum reactive power output	-75
VS	Regulated voltage setpoint	1.03
IREG	Regulated bus	HV bus
MBASE	Machine base MVA	170
ZR	Machine resistance in pu on MBASE	0
ZX	Machine reactance in pu on MBASE	0.122
RMPCT	Percent of VARs supplied by this machine to support voltage at regulated bus	100
PT	Maximum real power output	150
PB	Minimum real power output	120

- Transmission Lines:
- Standard Transformer/Autotransformer Impedances:

The following transformer and autotransformer impedances will be used whenever the actual impedances are not available. These impedances will be used for both positive and zero sequence modeling. Resistances are assumed to be zero unless otherwise specified. If an impedance is needed for a transformer or autotransformer size or voltage rating not covered by this criteria, the impedance(s) in this criteria which most closely fits what is needed will be used. All impedances are with respect to the unit's base high winding to low winding rating.

Distribution Substation & Generator Step-Up Transformers
Starting at the first row and moving down, these impedances are based on transformers at the following substations: Springdale, Hickman West #2 and ISES unit 2 GSU.

High Side Nominal Voltage (kV)	Reactance
34.5 & 69	7.0%
115, 138, & 161	8.5%
230, 345, & 500	11.0%

Autotransformers
Starting at the first row and moving down, these impedances are based on autotransformers at the following substations: Lewisville West, Ward and Dell 500 kV.

High Side Nominal Voltage (kV)	Low Side Nominal Voltage (kV)	Rating (MVA)	Impedance		
			Z_{HL}	Z_{LT}	Z_{HT}
115, 138 & 161	69	42	4.5%	17.5%	23.5%
115, 138 & 161	69	100	6.5%	18.5%	28.0%
230, 345 & 500	115, 138 & 161	250	8.0%	31.5%	38.0%

- Distribution lines:
- Capacitors:
    - Switched capacitor steps should be kept small enough to avoid causing annoying voltage fluctuations.
    - The desired level of power factor correction will be determined by economics.
    - Capacitors should be located as near to the load center as possible.
    - In general, capacitors to be installed on single phase extensions of the main three phase line should be balanced so that the correction appears in the substation as if it were a balanced Y-connected bank of capacitors.
- Loads:
    - Residential:
    - Large Power:
    - Motor:
        - The starting power factor of a motor can be assumed to be as follows if no other information is available:
            - Motors under 1000 hp: PF = 0.20
            - Motors 1000 hp and over: PF = 0.15
    - Recommended power factors in the presence of no information to the contrary are 95% for impedance loads and 75% for constant power loads.
    - In the absence of measured results, the recommended general rule of thumb is to use a 60%/40% constant power / constant impedance mixture for summer peak loads, and a 40%/60% split for winter peak loads.
- Regulators:
    - Normally, the voltage level and bandwidth settings will be the same for all regulators installed on the system.
    - The voltage level setting should be as close to the ideal system voltage as possible. A voltage level setting of 122 volts (120 volt base) is recommended for overall system operation.
    - A bandwidth setting of 2 volts is recommended, 1 volt above and 1 volt below the voltage level setting.
    - A time delay of 30 to 40 seconds for the substation regulators should be used in most cases depending upon the load characteristics. If excessive regulator operations are encountered with a 30 to 40 second setting, a longer response time up to a maximum of 60 seconds should be considered.
    - When more than one line regulator is used, time delay settings should increase as you move away from the source.

8. Power Flow Studies

- The AECC Loadflow Procedure will be used as a guide in performing load flow studies. The following parameters will be considered when evaluating the results of a load flow study:
  - For evaluation purposes the thermal limits used for conductors are:
    - Base Case – 100% of rating A
    - Any line that is 100% or greater of rating A in the base case will not be reported in subsequent contingency cases.
    - Contingency Case – 100% of rating B
    - Any line above these limits must have a mitigation plan.
    - Lines loaded at or above 75% will be flagged for development of a mitigation plan.
  - For evaluation purposes the voltage limits used for bus voltages are:
    - Base Case –
      - Bus voltages are considered low if below 95% of nominal voltage
      - Bus voltages are considered high if above 105% of nominal voltage unless there is generation modeled on that bus
    - Contingency Case
      - Bus voltages are considered low if below 90% of nominal voltage.
      - Bus voltages are considered high if above 105% of nominal voltage unless there is generation modeled on that bus

9. Short Circuit Studies

10. Stability Studies

11. Voltage Drop Studies

- Except for special cases, there should not be more than 2 stages of re-regulation beyond the substation.
- The maximum regulated voltage drop on primary distribution lines should not exceed 8 volts (120 volt base) at the extremities.
- The following equipment should not be thermally loaded by more than the percentages shown:
  - Substation and line voltage regulators – 100% of nameplate rating
  - Oil circuit reclosers – 70% of nameplate rating
- Primary conductors should not be loaded over 80% of their thermal rating (50% for major tie lines between substations)

12. Motor Start Studies

- A motor starting study should be performed if the motor horsepower exceeds approximately 30% of the supply transformer base kVA rating if no generators are present. If generation is present and no other sources are involved, a study is

required if the motor horsepower exceeds 10% to 15% of the generator kVA rating.

- Acceptable voltage for motor starting is 85% of rated.
- Acceptable voltage at the starting motor terminals is 80% of rated. (NEMA design B only)
- Acceptable voltage at the terminals of other motors during starting is 71% of rated. (NEMA design B only)
- Acceptable voltage for solid state control devices is 90% of rated.
- Acceptable flicker is a 3% change in voltage.

13. Power Quality / Harmonics

14. Outage Reporting

15. Reliability

16. Sectionalizing Studies

- The use of more than 3 or 4 reclosers or other automatic sectionalizing devices in series on any circuit usually is not justified.
- Branch lines tapped off the first main line section, even short taps, should be sectionalized if possible.
- Where main lines branch, a sectionalizing device should be used in at least one line and preferably in both, at or near the junction point.
- In general, a capacitor fuse link should melt in 300 seconds at 150-300% of rated current. Fuses for small capacitors should have at least a 5 ampere rating, to minimize the likelihood of fuse failure due to lightning or transient surges.

- Distribution
    - Thermal limits for conductors???
    - Substation & line voltage regulators – 100% of nameplate
    - Oil circuit reclosers – 70% of nameplate
    - Primary conductors – 80% of thermal rating (50% for major ties)

7.1 Power Factor

- One goal of planning studies such as CWP/LRPs is to reach unity power factor. For CWP/LRPs development the final plan should include a plan for reaching unity power factor.
- Internal studies for large load additions may be studied at power factor levels other than unity.
- AECC is striving to maintain a power factor of 98% on all its delivery points year round and where possible, limit the kvar loading to a maximum of 3000 kvar.

7.2 Voltage Levels

- For CWP/LRP evaluation voltage levels should be maintained to Range A as defined in RUS 1724D-113.
    - Minimum – 118 volts regulated, 114 volts unregulated (120 volt base)
    - Maximum 126 volts (120 volt base)
- For transmission studies the following levels should be maintained
    - Base Case
        - Minimum – 95% of nominal
        - Maximum – 105% of nominal
    - Contingency Case (n-1)
        - Minimum – 90% of nominal
        - Maximum – 105% of nominal

7.3 Voltage Regulation

- No regulation on transmission
- Two levels of regulation beyond the substation regulators may be used on distribution feeders before a major improvement is required.
- For LRPs – maximum voltage drop on an unregulated basis will be limited to 8 volts on a 120 volt base in the last period of the plan.
- Maximum voltage drop can be staged through the transition periods as a mean of reaching the 8 volt max in the last period of a LRP as follows:
    - Period 1 & 2 – 8 volts max with one level of line regulation
    - Period 3 – 12 volts max unregulated
    - Period 4 (final) – 8 volts max unregulated

7.4 Substation

- Cooperative's standard transformer sizes
- 10 Mva minimum for new transformers

7.5 Distribution

- Cooperative's standard conductor sizes

7.6 Autotransformers / Transformers

- Fan rating will be used to determine when transformer will be replaced

AECC Overhead Conductor Ratings Calculations

Sun Altitude

H_C = sun altitude for 12pm (noon)

From Table 2 of IEEE Std. 738-1993, H_C = 78 degrees for 35 degrees North latitude.

Air Film Temperature

T_{film} = air film temperature (degrees C)

$$T_{film} = \frac{(T_C + T_A)}{2}$$

	Summer	Winter
Normal Rating	62.5	47.5
Emergency Rating	70	55

Density of Air

ρ_f = density of air

$$\rho_f = \frac{0.080695 - 0.2901*10^{-5} * H_C + 0.37*10^{-10} * H_C^{\,2}}{1 + 0.00367 * T_{film}}$$

	Summer	Winter
Normal Rating	0.065455	0.068524
Emergency Rating	0.064022	0.066954

Absolute Viscosity of Air

μ_f = absolute viscosity of air

$$\mu_f = 0.0415+1.2034*10^{-4}*T_{film}-1.1442*10^{-7}*T_{film}^{2}+1.9416*10^{-10}*T_{film}^{3}$$

	Summer	Winter
Normal Rating	0.048622	0.046979
Emergency Rating	0.049430	0.047805

Thermal Conductivity of Air

K_f = thermal conductivity of air

$$K_f = 0.007388+2.27889*10^{-5}*T_{film}-1.34328*10^{-9}*T_{film}^{2}$$

	Summer	Winter
Normal Rating	0.008807	0.008467
Emergency Rating	0.008977	0.008637

Velocity of Air Stream

V_w= velocity of air stream (ft/hr)

V_w= (2 ft/s)(3600 s/hr) = 7200 ft/hr

Wind Direction Factor

K_{angle}=wind direction factor (This factor is multiplied by the convective cooling term.)

$K_{angle}=1.194-\cos(\phi)+0.194*\cos(2\phi)+0.368*\sin(2\phi)$

Where: ϕ=angle between wind and axis of conductor (degrees)

$K_{angle}=1$

Forced Convection Heat Loss

q_{c1}=forced convection heat loss equation 1

$$q_{c1}=\left[1.01+0.371\left(\frac{D*\rho_f*V_w}{\mu_f}\right)^{0.52}\right]*K_f*(T_c-T_a)$$

Where: D=conductor diameter (inches)

T_c=conductor temperature (degrees C)

T_a=ambient temperature (degrees C)

Summer/Normal Rating:

$q_{c1}= [1.01+0.371(9692.65*D)^{0.52}*0.008807*(T_c-T_a)$

Summer/Emergency Rating:

$q_{c1}= [1.01+0.371(9325.48*D)^{0.52}*0.008977*(T_c-T_a)$

Winter/Normal Rating:

$q_{c1}= [1.01+0.371(10501.99*D)^{0.52}*0.008467*(T_c-T_a)$

Winter/Emergency Rating:

$q_{c1}= [1.01+0.371(10084.07*D)^{0.52}*0.008637*(T_c-T_a)$

q_{c2}=forced convection heat loss equation 2

$$q_{c2}=\left[0.1695\left(\frac{D*\rho_f*V_w}{\mu_f}\right)^{0.6}\right]*K_f*(T_c-T_a)$$

Where: D=conductor diameter (inches)

T_c=conductor temperature (degrees C)

T_a=ambient temperature (degrees C)

Summer/Normal Rating:

$q_{c2}= [0.1695(9692.65*D)^{0.6}*0.008807*(T_c-T_a)$

Summer/Emergency Rating:

$q_{c2}= [0.1695(9325.48*D)^{0.6}*0.008977*(T_c-T_a)$

Winter/Normal Rating:

$q_{c2}= [0.1695(10501.99*D)^{0.6}*0.008467*(T_c-T_a)$

Winter/Emergency Rating:

$q_{c2}= [0.1695(10084.07*D)^{0.6}*0.008637*(T_c-T_a)$

Radiated Heat Loss

q_r=radiated heat loss

$$q_r = 0.138 * D * \varepsilon * \left[\left(\frac{T_c + 273}{100} \right)^4 - \left(\frac{T_a + 273}{100} \right)^4 \right]$$

Where: D=conductor diameter (inches)
ε=emissivity
T_c=conductor temperature (degrees C)
T_a=ambient temperature (degrees C)

Total Solar and Sky Radiated Heat Flux

Q_s=total solar and sky radiated heat flux for clear atmosphere

$Q_s = -3.92414+5.92762*H_c-0.17856*H_c^2+0.003223*H_c^3-3.3549*10^{-5}*H_c^4+1.80527*10^{-7}*H_c^5-3.7868*10^{-10}*H_c^6$

Q_s=95.6685

Corrected to 700 ft above sea level:

Multiplier=$1+3.5*10^{-5}*H_e-1.0*10^{-9}*H_e^2$ Where H_e=elevation (ft above sea level)

Multiplier=1.02401

Q_s=95.6685*1.02401=97.9655

Projected Area of Conductor

A'=projected area of conductor (ft^2 per lineal foot)

A'=D/12

Azimuth of the Sun

Z_c=sun azimuth (degrees)

From Table 2 of IEEE Std. 738-1993, Z_C = 180 degrees for 35 degrees North latitude.

Azimuth of Line

Z_l=azimuth of line (degrees)

Z_l=90 degrees for an East-West line (see Sample Calculations in IEEE Std. 738-1993 section 2.6.1.4 Solar Heat Gain)

Solar Heat Gain

$\Theta = \cos^{-1}[\cos(H_c)*\cos(Z_c-Z_l)]$

$\Theta = 90$

q_s=heat gain from the sun

$$q_s = \alpha * Q_s * \sin(\Theta) * A' = \alpha * Q_s * \sin(\Theta) * \frac{D}{12}$$

$q_s = \alpha * D * 8.16379$

Where: α=solar absorptivity
D=conductor diameter (inches)

Conductor Electrical Resistance

$R(T_c)$=60Hz ac resistance per lineal foot of conductor at T_c (ohms/ft)

$$R(T_c)=\left[\frac{R(T_{High})-R(T_{Low})}{T_{High}-T_{Low}}\right]*(T_c-T_{Low})+R(T_{Low})$$

Where: T_{High}=maximum conductor temperature for which the conductors's 60Hz resistance is specified

T_{Low}=minimum conductor temperature for which the conductor's 60Hz resistance is specified

T_c=conductor temperature

Conductor Current (Conductor Rating)

I=conductor current (amps at 60Hz)

$$I=\sqrt{\frac{q_c+q_r-q_s}{R(T_c)}}$$

Where: q_c=the greater of q_{c1} and q_{c2}