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Revision Memo

12/03 Appendix C Electrical Design Review Guidelines for Addition of New Loads added to Design Practice and reference can be found in Power for Expansion of Existing Facilities section.

12/99 This revision is a rewrite of Section XXX-A. The changes are covered below by subsection. Also S purpose codes added and revisions marked with an arrow.

REFERENCES – Titles of IPs updated. ANSI / IEEE Standard 141 replaced by latest revision 1993-12-02 rev.

POWER SOURCE REQUIREMENTS – Implications of partial loss of power on plant overpressure protection added. Application of LGF clarified. Calculation added of Adjusted Maximum Demand and Firm Capacity.

PURCHASED POWER – Application of Variable Frequency Drive Systems for power factor correction added.

MAIN SUBSTATION DESIGN – Deleted example of basic spacing requirement and reference only made to DP-XV-G.

DESIGN PROCEDURE - Additional information on design specifications for Front End Loaded projects added. The General Instructions and Information (GII) added to the list of vehicles by which information can be provided to contractors. Title of the document, and references to it, updated to: The Exceptions and Additions to the International Practices.

DESIGN SPECIFICATION CHECKLIST OF INTERNATIONAL PRACTICES
ASTERISK ITEMS – This section has been revised inline with IP revisions.

SAMPLE PLANNING DOCUMENTS – Q8 of Questionnaire for Public Utility to Obtain Definitive Planning data "item 1" corrected to "item 7"

COMPUTER PROGRAMS – Addresses and Contacts updated. Product code added for AST. Available Programs section updated to reflect present nomenclature and available programs.



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SCOPE

This section covers the main source(s) of electric power for refineries, chemical plants, and other large industrial users of electric power where a reliable supply is required. These sources are generally sized 10 MVA and upwards

The sources are either a public utility (purchased power) or in-plant generation, or a combination of the two.

REFERENCES

DESIGN PRACTICE

[Section XV](#) Safety in Plant Design

INTERNATIONAL PRACTICES

IP 4-3-1,	Plant Buildings for Operation and Storage
IP 4-3-2,	Blast Resistant Buildings
IP 16-1-3,	Protection of Electrical Equipment in Contaminated Environments
IP 16-2-1,	Power System Design
IP 16-4-1,	Grounding and Overvoltage Protection
IP 16-6-1,	Substation Layout
IP 16-10-1,	Power Transformers
IP 16-11-1,	Neutral Grounding Resistors
IP 16-12-1,	Switchgear, Control Centers, and Bus Duct
IP 16-12-2,	Control of Secondary Selective Substations With Automatic Transfer

OTHER LITERATURE

ANSI / IEEE (*Institute of Electrical and Electronics Engineers*) Standard 141-1993-12-02, *IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants*. (IEEE Red Book)

ANSI / IEEE Standard 142-1991, *Recommended Practice for Grounding of Industrial and Commercial Power Systems*. (IEEE Green Book)

ANSI / IEEE Standard 242-1986, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems* (IEEE Buff Book).

BACKGROUND

Nearly all refineries and chemical plants are wholly dependent on electric power for operation. Hence, for any refinery or chemical plant consisting of several continuous process units, a reliable power supply is of paramount importance.

While the steam generation facilities in Exxon plants are capable of operation without power, the mechanical drive steam turbines provided are only capable of maintaining a safe condition and are not able to keep process units on stream. In addition to the loss of throughput due to a power failure, there are two other major concerns:

1. Safety of process operations due to the dependence on all the shutdown facilities operating correctly.
2. Damage to equipment caused by thermal shocks.

The loss of the main power source is one of the incidents that can shutdown the whole site, and as the power distribution network is generally one integrated system, great care must be exercised over the main power source installation in order to maintain the integrity of the entire system. Therefore, the main power source is required to be as, or more, reliable than the supply to individual process units.

DEFINITIONS

Adjusted Maximum Demand Based on Firm Load Data

The demand equal to 1.0 times maximum demand.

Adjusted Maximum Demand Based on Non-Firm Load Data

The demand equal to 1.05 times estimated maximum demand.

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DEFINITIONS (Cont)

Back-Up Protection

A form of protection that operates independently of specified components in the primary protective system and that is intended to operate if the primary protection fails or is out of service. In Exxon designs, it usually has the latter function and consists of a time / current graded protection scheme backing up either a unit protection scheme or a downstream time / current graded circuit.

Base Load

The minimum load over a given period of time.

Demand

The load integrated over a specified interval of time expressed in kilowatts, kilovolt-amperes, kilovars, amperes, or other suitable units.

Demand Factor

The ratio of the maximum demand of a system, or part of a system, to the total connected load of the system. The demand factor of a part of the system may be similarly defined as the ratio of the maximum demand of the part of the system to the total connected load of the part of the system under consideration.

Design Basis Memorandum (DBM)

This memorandum provides the selected design which has evolved from a number of designs studied and cost estimated in the planning (pre-DBM) stage of a project. The DBM design is the basis for the design specification. The DBM is issued together with an Investment Basis Memorandum (IBM) which provides the necessary equipment and system data required by the cost engineers.

Distance Protection

Protective relays in which the response to the input quantities is primarily a function of the electrical circuit distance between the relay location and the point of fault.

Diversity Factor

The ratio of the sum of the individual maximum demands of the various subdivisions of a system to the maximum demand of the whole system.

Double Circuit

Two independent circuits run overhead supported by common towers or poles.

Firm Capacity

Total installed capacity minus standby or spare capacity provided for scheduled and unscheduled outages.

Firm Load

Load data derived from actual equipment performance characteristics and duty cycles.

First Line Protection

The protective relay or device which is intended to operate first to trip a circuit or apparatus when a fault or other abnormal condition occurs. Sometimes referred to as "primary protection."

FOW Rating

The output rating of a transformer having its core and coils immersed in oil and cooled by the forced circulation of this oil through external oil-to-water heat exchanger equipment utilizing forced circulation of water over its cooling surface.

General Instructions & Information (G.I.I.)

The Design Specification in each Job Specification which states characteristics of utilities, meteorological design conditions, etc. Items included are voltages and frequency available, the break point between medium voltage and low voltage motors, whether oil mist lubrication is to be applied, etc.



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DEFINITIONS (Cont)

High Voltage System

In Exxon practice, equipment with a normal operating voltage in excess of 34.5 kV.

Island Operation

The operating condition in which parts of a system which normally are connected and operate as one system are disconnected and split into separate operating entities. This includes separation of plant generating busses from public utility supplied busses, separation of stub busses from a synchronizing bus, etc.

Load Factor

The ratio of the average load over a designated period of time to the peak load occurring in that period.

Load Growth Factor (LGF)

An Exxon term which represents the actual amount by which the load is expected to increase as the design is firmed (excluding major basis changes). This increased load can result from many diverse reasons. Perhaps the most significant reason is the increased amount of basic engineering which is applied as the project is developed. Other less significant reasons are lower than expected driver or driven equipment efficiencies, revised process requirements during design development, and revised normal / spare driver designations. If the correct load growth factor is used, the capacity of the system should not change as the design progresses from the planning stage to start-up.

Load Shedding

The process of deliberately removing preselected loads from a power system in response to loss of power source(s) in order to maintain the integrity of the system.

Low Voltage System

In Exxon practice, equipment with a normal operating voltage of 1,000 volts or less.

Maximum Demand

See "8 Hour Maximum Demand" and "15 Minute Maximum Demand."

Medium Voltage System

In Exxon Practice, equipment with a normal operating voltage in the range 1001 to 34,500 volts.

Normal Operating Load

The power consumption at process design throughput under design operating conditions.

OA Rating

The output rating of a transformer having its core and coils immersed in oil and cooled by the natural circulation of air over the cooling surface.

OA / FA / FOA Rating

The output rating of a transformer having its core and coils immersed in oil; the self-cooled (OA) rating is obtained by the natural circulation of air over the cooling surface such as integral cooling tubes or fins, the forced-air-cooled (FA) rating is obtained by the forced circulation of air over this same cooling surface, and the forced-oil-cooled (FOA) rating is obtained by the forced circulation of oil over the core and coils and through to this same cooling surface over which the air is being forced-circulated.

Operation in Synchronism

The connection and operation of two or more power sources, either generating units or purchased power sources, at the same voltage and frequency to share real power and reactive power loads as determined by turbine governor and voltage regulator settings.

Pilot Wire Protection

Protection in which a control circuit is used as the communicating means, between relays at the circuit terminals.

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DEFINITIONS (Cont)

Reactive Power

The product of voltage and the component of alternating current that is in quadrature (90° out-of-phase) with the voltage. Its rate is expressed in kilovars (kvar).

Real Power

The rate of generating, transferring, or using energy expressed in kilowatts (kW). It is the product of voltage and the in-phase components of alternating current.

Reclosure Practice

The practice by public utility companies of re-energizing an overhead open-wire line after the initial clearing of a short circuit by circuit breaker trip. A specified number of reclosures are made with the time delay after each trip specified. Since many open-wire line short circuits are line-to-ground and are not sustained short circuits, this practice provides quick re-establishment of voltage if the fault has cleared itself.

Reserve Capacity Factor (RCF)

An Exxon term which represents the incremental capacity provided to cover sudden load swings and small increases in load which result from changes made by the Owner after start-up to accommodate revised plant running plans. This incremental capacity is intended to be intact at initial plant start-up. It is usually provided in utilities sources and their support facilities only.

Secondary-Selective Substations

Substations having two busses, each supplied by a normally-closed incoming line circuit breaker and connected together by a normally-open bus tie circuit breaker. The term "secondary-selective" is applicable to dual fed substations with or without transformers. The dual sources normally divide the load in non-parallel operation. Upon failure of one source, the substation is isolated from the failed source and the de-energized bus section is connected to the source remaining in service. This "transfer" of load may be manual or automatic.

Source Impedance

The impedance presented by a source of energy to the input terminals of a device or network.

Spot Network Substations

Substations supplied from two or more sources which normally divide the substation load in paralleled operation. Upon failure of one source, the substation is isolated from the failed source by automatic operation of directional overcurrent relaying. This relaying senses current flow from the remaining source back into the failed source and trips the appropriate circuit breakers. Spot-network substations provide high order of supply continuity in the event of faults, but impose higher fault interrupting duty than secondary-selective substations with sources of the same capacity.

Stability Limit

A condition of a linear system or one of its parameters that places the system on the verge of instability. This expression defines the maximum fault clearing time that will permit the generators to remain in parallel with each other and/or the utility, following fault clearing. See also [Section XXX-B, System Stability](#).

Subtransient Reactance (X''_d)

This reactance is the apparent reactance of the generator stator winding at the instant a short circuit occurs, and it determines the current flow during the first few cycles after short circuit. Although the current decreases continuously, it is assumed to be steady for these few cycles. The subtransient reactance approaches armature leakage reactance, differing only by the leakage of damper windings.

Synchronous Reactance (X_d)

This reactance determines the current flow after the transient reactance period when a steady-state condition is reached. It is effective after the transient reactance period. This is assumed usually to be several seconds after the short circuit occurs. The current excludes the effect of the automatic voltage regulator and the turbine or engine governor.

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DEFINITIONS (Cont)

Transformer Reactance

For OA / FA transformers, the reactance is usually expressed as a percentage of the transformer OA rating base. For OA / FA / FOA and FOW transformers, the reactance is usually expressed as a percentage of the FOA or FOW rating.

Transient Reactance ($X'd$)

This reactance is the apparent initial reactance of the stator winding if the effect of all amortisseur or damping windings is ignored and only the effect of the field winding is recognized. This reactance determines the short circuit current for the period between the subtransient and steady-state conditions. The transient reactance is effective up to one-half second to two seconds depending on the design of the generator.

Unit Protection

A protection circuit associated with a particular "unit" of the electrical network that will not operate for faults other than on its unit, e.g., differential protection, transformer Buchholz, motor resistance temperature detectors (RTDs).

Zones of Protection

The parts of the electric system or the apparatus which are protected by a specific protective relay. Most commonly used in conjunction with differential type relays in which the zone limits are the locations of the current transformer sets supplying the differential relays. For other types, the zone limit is the most electrically distant point for which the relay will operate on short circuit or other abnormal condition.

8-Hour Maximum Demand

The greatest root-mean-square value the load can take during any 8-hour period. It is the equivalent thermal aging load.

15-Minute Maximum Demand

The greatest average load which can occur for a 15-minute period. Switchgear continuous ratings are based on this demand.

POWER SOURCE REQUIREMENTS

Before a utility company can be requested to provide power, or an in-plant generation design finalized, the following must be determined:

CAPACITY

The capacity required from the power source is obtained from the process, offsites, and utilities load data lists which summarize the electrical load on the overall system and on system components. The load data is used to establish the capacity requirements for the various elements of the system. Load data summaries for the plant's normal and abnormal operating conditions will show which condition is determining.

The process and offsite designers provide the load data that is the basic input for the electrical system design. The data lists each individual motor load for all processing units and offsite facilities and any other electrical load such as heaters, etc. These data will be "normal" operating loads, unless there are specific operating conditions that substantially increase or decrease the plant load. In this case, as many sets of input load data are required as there are operating conditions. The various operation conditions should be evident from load data provided by process and offsite designers.

Computer programs are available for computation of load data. A program may be used early in the design specification stage on major plant designs and is usually required during the detailed engineering phase by the contractor.

Load Growth Factors (LGF) are applied to the input load data and should be adjusted during the course of the design to reflect the changes in the quality of the load data being used. These are applied because, historically, loads tend to increase as the project is better defined. A Reserve Capacity Factor (RCF) is also applied to provide margin at start-up in power source facilities, for operating flexibility, and small load increases.

The following are the rules for applying the LGF factors to the input load data received by the electrical designer.

1. Load growth factors are applied to load data for process facilities.
2. Load growth factors are not normally applied to load data for offsite and utilities facilities. The factors should have already been applied by the offsite designer in arriving at the required capacity of the specific offsite or utilities system. You should confirm that this is the case. For example a motor associated with a cooling tower will already have LGF applied as part of the sizing of the cooling tower by the offsite designer. However an offsite's pump may not have had LGF applied.

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POWER SOURCE REQUIREMENTS (Cont)

The following load growth factors should be used for equipment sizing, if other factors have not been established for the project.

LOAD BASIS	LOAD GROWTH FACTORS			
	PRE-DBM	DBM	DESIGN SPEC	CONTRACTOR'S OFFICE
Firm Load	10%	0	0	0
Duplicate of Existing Major Drive	10%	5%	0	0
Non-Firm Load	30%	15%	5%	5%

A 10% reserve capacity factor is used at all the stages of a project. It is applied for sizing source facilities, such as generation capacity or purchased power substation capacity, and is intended to provide 10% reserve capacity margin at start-up. Note that this is the reserve required in normally operating units. It should not be confused with reserve capacity provided to cover forced and scheduled outages of generating units.

The application of load growth and reserve capacity factors for the overall utilities requirements of a coal gasification project is illustrated in [Figure 1](#). The selection of the load growth factors for design basis memorandum (DBM) engineering for the same plant is shown in [Table 1](#). Note the majority of the facilities are non-firm loads and one facility's load is sufficiently uncertain to require a 20% LGF.

The use of Load Growth and Reserve Capacity Factors is an effort to improve the accuracy and provide a consistent basis for maximum demand estimates.

Before planning and design of main power source facilities can be finalized, the following must be determined:

1. Two values of load should be calculated: the Normal Operating Load and the 15 Minute Maximum Demand. The normal operating load is calculated by applying a Load Factor in the order of 0.5 to 1.0 to the 15 Minute Maximum Demand. The Load Factor depends on the process units, their interdependence, and the proportion of load for non-process facilities.
2. Basic load data for determining required source capacity is obtained from process, utilities, and offsites load lists, and includes the following:
 - a. Planning or design estimates of new electrical loads (considered Non-Firm Load)
 - b. Maximum demand of existing operating loads (considered Firm Load)
 - c. Maximum demand of estimated future loads for which the project will pre-invest (Non-Firm Load).

Note: If load data indicates a higher load for an alternative operating condition, the higher load should be used if it coincides with the timing of maximum demand on the power source.

3. Adjusted Maximum Demand and Firm Capacity for a main power source are determined from load data as follows:
 - a. Start with basic load data (above) and determine all of the loads that operate simultaneously to contribute to the 15-minute and 8-hour periods of maximum demand on the main power source.
 - b. Add Load Growth Factors (LGF) to the basic load data, in accordance with the LGF table above. LGF accounts for the historical growth in loads from screening through detailed design and startup. With the exception of basic load data, the terms "Load" and "Demand", as used herein, include LGF.
 - c. Calculate Adjusted Maximum Demand by multiplying the sum of all non-firm loads by 1.05, and add the result to the sum of any firm loads. The adjustment factor of 1.05, applied to non-firm load, provides a safety margin in the size of the source above the known historical load growth. If the adjusted load varies significantly with time over 15 minutes or over 8 hours, see below.
 - d. The Firm Capacity required from main power source equipment is the Adjusted Maximum Demand (per above) plus 10% Reserve Capacity Factor (RCF).

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POWER SOURCE REQUIREMENTS (Cont)

If load varies significantly over an 8-hour period, transformers can be sized to meet the "average" load instead of the maximum load. This and other load variation and equipment sizing considerations are discussed below:

1. Use "Adjusted 8-Hour Maximum Demand" plus 10% RCF to size main transformers. This 8-hour demand is a root-mean-square (rms) quantity which can be closely approximated as follows:
 - a. Break the eight-hour period of maximum adjusted-demand into eight one-hour intervals
 - b. Estimate the average adjusted load magnitude (kVA, MVA, A, etc.) for each hour
 - c. Square each magnitude
 - d. Obtain the mean by summing the 8 squared magnitudes and dividing by 8
 - e. Take the square root.
 - f. The result is approximately the effective heating (rms) 8-hour maximum demand in kVA, A, etc.
2. Transformer switchgear and source feeders are rated to meet the larger of maximum transformer rating or Adjusted 15-Minute Maximum Demand plus 10% RCF.
3. In the absence of dedicated source transformers and generators, use Adjusted 15-Minute Maximum Demand plus 10% RCF to size main buses and incoming cables. Adjusted 15-Minute Maximum Demand is typically taken to be the same as Adjusted Maximum Demand (i.e., maximum simultaneous adjusted load). If there is a short duration peak load, use the average adjusted load over the 15-minute interval of maximum demand.
4. For generators, use Adjusted Maximum Demand plus 10% RCF without time averaging.
5. When a minimum firm-sources configuration consists of generators and transformers, the generators are base-loaded with non-time-averaged load. The transformer load curve then consists of the top portion of the total load duration curve with the base loading of the generators removed. The minimum required capacity the transformers is then the adjusted 8-hour maximum demand of this modified load curve. Remember to check the adjusted 15-minute maximum demand of the remaining load for the transformer switchgear and source feeders.

The "Firm Capacity" of up to five power sources is generally taken to be the capacity of the sources remaining when the largest source is out of service. For 6 to 10 sources, the two largest sources would generally be considered out of service. However, if the load varies with time and there is a combination of transformers and generators, the firm source capacity verse effective load may have to be tested in more than one configuration.

NUMBER OF GENERATORS

The number of generators required for an in-plant generation system is covered in [Section XXX-B](#).

PURCHASED POWER

RELIABILITY

A reliable electric power system is essential for continuous process plants and, in some cases, for non-continuous processes where power interruptions can result in unacceptable safety or product loss risks (see Design Practices [Section XV-C](#)).

The most critical component in overall power system reliability is the power supply source. Assuming reliable purchased power is available, the decision to purchase power or install in-plant power generation is an economic decision based on comparison of alternatives having adequate but not necessarily equal reliability levels.

In determining the level of reliability that is adequate, the following factors are assessed: (1) Frequency and duration of total or major potential power outages. This is the most important of the factors and covers the "forced" outage which occurs without warning and causes either a total plant shutdown or a major plant upset; (2) Frequency and duration of power supply conditions which tend to reduce reliability and capability to meet load demands. Typical conditions are more than normal maintenance outages on supply circuits or reduced reserve capacity caused by lower than normal generation availability; and (3) Frequency, magnitude, and duration of voltage dips caused by faults on other customer's circuits which share busses or circuits supplying the plant.

No single maximum forced outage rate sets the minimum acceptable reliability level. The minimum acceptable level is established by process plant type and complexity, cost of lost production and ability to make up lost production, likelihood that the total outage causes immediate or progressive equipment damage, and the complexity of emergency facilities required to provide satisfactory safety and equipment protection levels.

In designing the electrical distribution system, the implications of a partial loss of power on the plant overpressure protection facilities should also be considered. This should be discussed with the process design specialist assigned to the project.

Refer to the NUMBER OF CIRCUITS FROM UTILITY and RELAYING sections on the following pages for other factors affecting reliability.

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PURCHASED POWER (Cont)

From experience, some general statements on reliability level can be made:

1. Public utility power supplies which have experience or calculated data showing a frequency of failure (total or serious disturbance) in the 1 in 3 yr. to 1 in 5 yr. range provide satisfactory reliability levels even for the large complex facilities. Generally, additional investment cannot be justified to improve reliability above this level.
2. Public utility power supplies which have failure rates for total or serious disturbances in the 1 per year to 1 in less than 3 year range are probably marginal for the large complex facility but acceptable for smaller less complex facilities. However, these power supplies should be carefully investigated to determine whether improvements could be made at an acceptable investment level.
3. Public utility power supplies which have total failure or serious disturbance rates exceeding 1 per year are generally not acceptable for large complex facilities. The improvements required to the supply to improve its reliability and their cost should be determined. Also, the economics of providing in-plant generation should be investigated.
4. Voltage dips due to faults in the utility grid should be cleared in the instantaneous to 5-6 cycle range. The voltage drop at the plant main bus should not exceed about 10%. This limit may be difficult to meet when other circuits are electrically close. In such cases, the utility should provide estimates of frequency and magnitude of dips. This data should be assessed for effect on the plant and whether the conditions can be accepted without change.

NUMBER OF CIRCUITS FROM UTILITY

Where the plant is totally dependent on the utility company, a minimum of two incoming circuits is required. These should, where possible, be independent of each other, i.e., come from different busses in the utility grid and be routed independently on separate towers for overhead lines or in separate trenches for buried cables. However, we are often forced to accept two circuits from a utility substation bus supplied from opposite sides of a normally closed tie breaker that are run overhead on common towers (double circuit) to our facilities. We should endeavor to avoid such supply arrangements, but when no other is possible, at least ensure that there are protective relays to open the utility tie breaker, and that a common pilot cable is not used to run control and/or protection circuits. It is usual to carry out maintenance of one circuit of a double circuit overhead line with the other in service, but this point should be confirmed.

When there is in-plant generation, one incoming circuit from utility may suffice. This will depend upon the firm generating capacity and the normal maximum generating capacity. Generally, the design of the utility supply should be based on the largest in-plant generator being out-of-service while operating the plant at maximum demand. In some cases, a two generator outage may be considered, e.g., one on maintenance and a fault on another, if maintenance periods are frequent or of long duration. However, it is more normal to accept load shedding for a two-generator outage, or a financial penalty resulting from exceeding an agreed maximum demand from the utility.

VOLTAGE AND REGULATION

The utility companies have standard voltages and will generally offer the supply from the lowest voltage they have locally with adequate capacity. This voltage in kV may vary from 1 to 10 times the capacity requested in MVA, with the higher loads having a factor nearer unity. This is based on the power being transmitted over one circuit.

Unless incoming transformers can be avoided, the higher the voltage (within reason) the better, as the short circuit level will be higher and also the reliability will be higher.

Variations in utility supply voltage, inplant load variations, and system configuration changes (such as loss of a main transformer) normally lead to the need for an automatic on-load tap changer (LTC) on utility supply transformers. Even where inplant power generators normally control system voltage, a utility-tie transformer usually has an LTC to regulate voltage upon loss of inplant generation or to control power factor. Thus any design that would omit LTC's on main transformers must be carefully evaluated to ensure that voltage and power factor variations are within acceptable limits.

SHORT CIRCUIT LEVEL

Once the supply voltage level is defined, we have little control over the short circuit level of the utility supply. The short circuit level must be high enough to:

1. Avoid excessive voltage drops when starting large motors.
2. Permit large steps of motor re-acceleration after an automatic transfer or supply outage.
3. Provide selectivity and fast clearing times for the back-up protective relaying.
4. Help prevent instability of in-plant generators and synchronous motors.

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PURCHASED POWER (Cont)

Within the limits determined by switchgear availability and cost, a higher short circuit level has advantages over a substantially lower level for large motor starting and for the overall motor re-acceleration system. Typical values of fault levels in MVA and corresponding typical interrupting ratings for switchgear are:

SYSTEM VOLTAGE	SYSTEM OPERATING RANGE OF FAULT LEVEL (MVA)		SWITCHGEAR RANGE (MVA)	
	Min	Max	Min (MVA)	Max (MVA)
10–15 kV	150	1000	300	1000
20–69 kV	500	5000	500	5000
90–150 kV	500	10,000	5000	20,000
160–240 kV	750	15,000	5000	25,000

The system minimum short circuit level is used for stability and voltage profile studies and the maximum short circuit level for equipment rating. When selecting equipment short circuit ratings, the motor contribution from the load should be added to the utility maximum contribution to a short circuit.

A computer program should be used both to determine the maximum short circuit for specifying the switchgear and the minimum short circuit level required for stability and voltage profiles.

POWER FACTOR REQUIREMENTS

There may be little incentive to improve the inherent power factor of the plant unless the public utility insists, or there is a financial incentive in the power contract, or from sizing of equipment such as generators.

Without any correction, a power factor in the range 0.8 to 0.86 lagging can be expected for a load consisting of squirrel cage induction motors operating between half to full load. This can be improved by any of the following:

1. In-plant generation operating in parallel at a low power factor (generating more vars by increasing the excitation).
2. Synchronous motors operating at increased excitation (unity or leading power factor).
3. Application of capacitors.
4. Application of Variable Frequency Drive Systems. (Care should be taken not to induce excessive current or voltage harmonics).

When correction is required, we generally use banks of capacitors connected to the main busbars. This is the most economical solution when there are no large generators or synchronous motors, but has the following disadvantages:

1. No benefit to equipment capacities downstream. The technically ideal location for capacitors is at each individual load so that they are switched with the load and reduce the currents in the upstream cables and transformers to a minimum. However, this solution is costly and it requires locating most capacitors in classified areas.
2. Requires switching off the capacitors during certain conditions such as an automatic transfer to assist in a rapid voltage decay.
3. Can cause harmonics and over voltages on the network.

Public utility contracts may include any of the three following requirements:

1. No requirements at all regarding power factor.
2. Power factor to be always "X" lagging or better (X may be any value between 0.8 and 0.95).
3. kVA maximum demand charge.

For Item 1: We would not correct the power factor unless correction could be justified for energy conservation reasons.

For Item 2: We would correct to the value required.

For Item 3: Calculate the optimum value of capacitors to be installed if any. This may mean correction to 0.95 or even 0.98 lagging.

PARALLELING OF CIRCUITS

The utility may not permit paralleling of their two incoming circuits, either because they could at times be out of synchronism, or to avoid circulating currents. This will determine whether spot network substations can be used and the need for check synchronizing relays on the secondary-selective substations. Often the utility will permit momentary parallel operation but not continuous operation. This allows momentary paralleling during manual transfer operations for secondary-selective substations. However, whether such momentary paralleling is acceptable must be checked with the utility.



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PURCHASED POWER (Cont)

NEUTRAL GROUNDING

Most public utility transmission networks have the system neutral solidly grounded, as there are considerable savings in insulation and lightning arrester costs. Also, high ground fault current levels are acceptable on transmission systems since there are no motors or generators directly connected to such systems. The actual method of neutral grounding should be requested from the utility and stated in the Design Specification.

FREQUENCY LIMITS

On large utility systems, the frequency can be expected not to vary more than about 0.5%, except when there is a major upset. It is the major upset that concerns us, so records of the utility frequency variations during upsets should be obtained.

Frequency relays are not used in our plants unless we have in-plant generation. They are used to separate the generators from the utility to permit running part or all of the plant in island operation (see [Section XXX-B](#)). Frequency relays are also used as part of the protection scheme of synchronous motors.

If the utility has frequency relays, to either break their network into smaller areas or to load shed, their settings should be obtained. The settings should be given in the Design Specification and used to determine the setting of plant frequency relays.

RELAYING

The settings of all the relays in the utility substation at the voltage we receive power are required for three reasons:

1. The plant will be subjected to a loss of voltage for faults on the utility system until they are cleared by the protective relaying. These clearing times are needed for computer studies which are made to check stability under these conditions.
2. To ensure that plant back-up protection coordinates with the utility relaying.
3. Relays that separate the in-plant generation from the utility substation should coordinate where possible with upstream relays in the utility system on feeders to other loads.

Whenever possible, unit zone protection (such as differential) should be applied to the feeders to our plant and ideally for all the utility network at the supply voltage and higher. This improves stability and relay coordination on the plant system.

As a general rule, any bus to which an in-plant generator is connected and the feeders from that bus should have instantaneous protection in order to ensure stability of the generators. (See [Section XXX-E](#) for more details on relaying.)

SURGE PROTECTION

Surge protection, e.g., lightning arresters, should be provided at the termination of the utilities overhead lines at the plant substation. The arrester rating and class should conform to the arresters used by the utility on their system that supplies the plant. Depending on the physical arrangement at the main substation, these same arresters may be used to protect the substation's main transformers.

METERING

Metering for billing purposes is usually designed and installed by the utility. This metering usually requires separate current transformers and possibly a dedicated voltage transformer. Ratio, class, and fusing for these transformers should all be shown on the one-line diagram in the Design Specification.

POWER CONTRACT BILLING (TARIFF)

The details of the proposed power contract with the utility, including tariffs, should be known and tentatively agreed upon during the planning stage of the project. However, as the project progresses, more details are known about the load. The contract should be reviewed again to ensure that the project basis is still sound and to determine the effects of any changed terms. For expansions at existing sites, it is usual for the Owner to carry out all negotiations with the utility.

SPACE REQUIREMENTS

The incoming substation should be located near the perimeter fence at least 150 ft (45 m) from any process units. Refer to [Section XV-G](#) for equipment spacing. Dimensions and spacing requirements for any equipment to be provided by the utility company should be established and covered in the Design Specification.

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PURCHASED POWER (Cont)

DEMARCATON OF RESPONSIBILITIES

LOCATION of the utility incoming lines, a list of all equipment supplied by the utility, and/or equipment which must be provided by the Owner should be established. The demarcation between utility and plant responsibility should be clearly defined in the Design Specification.

GENERATED POWER IN PARALLEL WITH UTILITY

The complexity of a system deriving power from a utility, together with in-plant generation, is much greater than either source on its own for the following reasons:

1. Systems fed entirely by purchased power do not have any relaying to trip distribution circuit breakers for loss of voltage, except in special situations. (The automatic transfer scheme is no exception as it only trips an incoming breaker on low voltage if the alternate supply is healthy. If both in-feeds are lost, neither incoming breaker trips so that no breaker closing is necessary when power is restored.) However, when there is in-plant generation operating in parallel, it is unacceptable to force the generation to shutdown due to a failure of the utility. Therefore, a failure of the utility has to be detected and relaying included to effect separation of the generation and plant load from the utility.
2. The power and var flows can reverse direction in parts of the system.
3. Control of the generator power and var output will be required.
4. Fault levels will change considerably depending on the number of generators connected to the busbars or shutdown for turnaround.
5. Faults on the system should not cause the generator(s) to slip out of synchronism. Whereas a synchronous motor may be switched off during a system disturbance and re-accelerated later, a generator is required to remain on-line whenever possible to provide power to the load.

The design, therefore, should include the following:

1. Relaying to separate generation from the utility when the utility fails.
2. Relaying which senses direction of current flow at specific locations in the system.
3. Control and metering for quantity and direction of power and var flow and bus voltage control.
4. Instantaneous (unit or differential) protection on all circuits operating at the generator voltage that do not have any appreciable reactance such as a transformer or reactor between them and the generator.
5. Synchronizing facilities wherever it is required to connect the generation to the utility or other generators.
6. An event recorder, to enable analysis after faults on the system, is highly recommended.
7. Load shedding facilities to avoid a complete blackout when the load exceeds the generator capability either due to outage of generator(s), loss of utility, or segregation of parts of the network.

In designing to meet the above requirements, some of the points to consider are:

1. Where the point of separation between the utility and in-plant generation should be.
2. What relaying should initiate separation. Generally, a combination of breaker logic, undervoltage relays, and frequency relays are used. See [Section XXX-E](#) for more details.
3. Where and how the watt and var flows should be measured and controlled. Either a combination of a four quadrant power factor meter with watt or ammeter or one instrument that will indicate watts, vars, kVA and power factor can be used for measurement. Factors affecting control are generators' excitation systems capability, range of utility tie transformer tap changers, and the extent to which automatic control will be used.
4. Transformers with on-load tap changers may require a larger tap changer range in order to control var output from the generator(s).
5. Impedance between the generation and utility should be low for stability, but may intentionally need to be high to avoid excessive voltage drops in the plant for faults on utility network.
6. If purchased power is very reliable, consideration can be given to connecting generator(s) to the utility at the point of supply (as if they were generators belonging to the utility), thereby simplifying the tie-ins and relaying but losing the capability of running in island.
7. Power flow through reactors should be minimized.

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POWER FOR EXPANSION OF EXISTING FACILITIES

Tie-in of expansions should be so arranged that the reliability of the existing plant is not impaired. The target should be to arrive at a design identical to that which would exist if the existing plus expansion were installed at the same time as a grass roots plant.

The simplest arrangement is almost certainly the most reliable; also what may appear at first to be a more economical design with reactors and sophisticated switching sequences could prove to be very expensive in the final design and lower in reliability.

Refer to Appendix C, for guidelines on when the electrical content of a project should be reviewed by an electrical specialist. This review is intended to ensure that the rating of electrical equipment is not exceeded and system spare capacity is not eroded as a result of capacity creep when electrical loads are added by new projects.

PURCHASED POWER

Where there are business incentives, plant expansions may be constructed to be completely independent of the plants existing facilities. However, it is more normal to tie-in expansions such that the final outcome is one integrated system.

As far as the tariff is concerned, it is nearly always advantageous to limit the power contract to one supply (which could consist of several circuits with summation metering), thereby taking advantage of the diversity factor and any energy rate reductions.

If additional transformer capacity is required there are alternatives to expand the capacity:

1. Use available capacity at higher temperature ranges of existing transformers, if rating and design permit.
2. Replace existing transformers.
3. Add new transformers in pairs.
4. Add new transformer(s) on radial basis with common spare for existing and additional transformers.

GENERATION ONLY

A new generator will automatically increase the infeed fault level to the switchgear to which it is connected in proportion to the size of the generators. Therefore, reactors may be required, either between generator busses, or to add new stub busses to a synchronizing bus arrangement. (See [Section XXX-B](#) for full details.)

PURCHASED POWER PLUS GENERATION

This is the most difficult system expansion, be it expanding a system already consisting of purchased power plus generation, adding generation to an existing purchased power system, or adding a purchased power supply to an existing generation system. With the increased complexity, great care and much more engineering effort are required to maintain reliability. One exception is where the design for the plant prior to expansion included provision for the future facilities and included them in the network studies.

For details, see [Section XXX-B](#) and the section above on **GENERATED POWER IN PARALLEL WITH UTILITY**.

MAIN SUBSTATION DESIGN

GENERAL

The purchased power supply components are the busses and switching equipment at the public utility supply substations, the supply circuits from the utility substation to the plant, and the switching equipment and step-down transformers at the plant main substation.

Usually the supply circuits are part of the public utility system. The switching equipment and step-down transformers at the plant main substation may be owned by either the public utility or the plant, depending on the power contract.

When the supply voltage is in the 10 to 36 kV range approximately, the supply facilities may be:

1. Either overhead open-wire (bare wire) or insulated underground cable supply circuits.
2. Outdoor air-insulated overhead busses and switches, and individual power circuit breakers or grouped metal clad switchgear either outdoors or in a substation building.

When the supply voltage is above the 36 kV level, the supply facilities are:

1. Normally overhead open (bare) wire. In specific situations where space limitations or other unique circumstances dictate, insulated cable circuits may be used.
2. Outdoor air-insulated overhead busses and switches with individual power circuits breakers. The breakers may be SF6 (Sulfur Hexafluoride), air blast, or bulk oil.
3. SF6 circuit breakers and busses, and associated switches and potential and current transformers. The SF6 equipment can be used outdoors or in a building.

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MAIN SUBSTATION DESIGN (Cont)

Use of SF6 equipment in main substations continues to grow and, where space is limited, can be the only suitable type. A typical space ratio is 1 to 30 favoring SF6 over outdoor air-insulated at 500 kV.

Other ancillary components of purchased power supply facilities are the protection, control and metering voltage and current transformers, and associated protective relays, control devices and meters. The protective relays, control devices and meters are located so they are convenient both for operation and maintenance. Control and metering circuits can be extended to permit operation from locations such as main substation buildings, power plant or process plant central control rooms.

The main power supply transformers reduce the public utility supply voltage down to the plant distribution system medium voltage level. Type and application information on these transformers are covered in the section on transformers.

BUSBAR ARRANGEMENT

A typical design would consist of two incoming circuits, two transformers and a secondary-selective (as detailed in **IP 16-12-2**) or a spot-network substation. Another bus arrangement which is common for larger systems with generation is a synchronizing bus. Other arrangements, particularly for large capacity purchased power substations, are ring bus, double breaker, and breaker-and-a-half. (See [Figures 3](#) through [20](#).)

TRANSFORMERS

Transformer sizing should be based on the plant 8 hour Maximum Demand plus reserve capacity. Where transformers are spared by another power source, the forced cooled rating should be used with fans and/or oil pumps running whether integral or not.

If there are good reasons to believe that there will be a future expansion of the plant, consideration should be given to pre-investing, with the Owner's approval, in a larger transformer or provision of additional forced cooling stages. In any calculations, one must take into account the fact that any increase in power demand will have to come from these transformers, and the very large difference in cost between larger units now as compared with replacement units in the future. Some of the points to consider are:

1. How would capacity be expanded.
2. Land availability.
3. Would larger transformers require changing the secondary switchgear.
4. Downtime to tie-in expansion.
5. Financial incentives for pre-investment, e.g., tax rules, interest rates.
6. Probability of extra capacity being used in the near future.
7. Cost benefit of providing transformer capacity to permit fully utilizing main secondary circuit breaker and bus capacity since this equipment has finite continuous current rating steps.

The main power supply transformers may be supplied by the utility. However, in cases where we own the transformers it is often advantageous to purchase to the utility company specification at one of their standard ratings, as they may do the maintenance and there is always the possibility that they will provide a replacement in the event of an emergency.

The initial design should include on-load tap changers to compensate for variations in the utility supply voltage and cater for the build up of load, especially on the larger transformers where the reactance will be higher. During the final stages of Design Specification preparation or during engineering in the contractor's office, the need for the on-load tap changers should be reviewed. There are costly items, but it is very rare to purchase a main source transformer without an on-load tap changer. An exception would be if the source is a closely regulated distribution voltage and the voltage profile shows acceptable voltage range at utilization voltage levels.

On-load tap changers in the Americas are generally equipped with 33 positions connected to 16 taps above nominal voltage and 16 below; each step being 5/8 percent of the transformer voltage. In Europe and countries following European practice, 21 taps is more normal. Usually ten below and ten above nominal voltage each step being in the range of one to two percent. This will vary with the reactance of the unit.

On-load tap changers may be connected to either the high or low voltage winding. Outside the Americas, the changers are usually on the HV winding up to 150 kV. In the Americas, they may be in either winding. Manufacturers prefer to have the tap changers in a wye (star) winding for several technical reasons.

Transformers with tertiary windings or double secondary windings present voltage regulation problems. The tap changer on the primary winding controls the voltage on the other two windings, thus voltage control is not as good as with a two winding transformer. A second on-load tap changer can be added to a secondary winding, but this can prove costly, thus nullifying the economy of the third winding.

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MAIN SUBSTATION DESIGN (Cont)

Exxon plants require close voltage regulation on the main substation transformer's secondary, because normally there are no on-load tap changing transformers downstream of the main incoming transformers.

Transformer reactance should preferably be the manufacturers standard if it is suitable for the short circuit duty rating of equipment downstream, stability, and motor re-acceleration needs. If a lower reactance than standard is required and costs extra, it may be better to spend the money on larger transformers. This will achieve the same result and give some additional capacity for future loads.

The secondary voltage will usually be in the range of 5 to 36 kV for supply voltages in the range 30 to 300 kV. These secondary voltages are at a level that is economical for distribution and can be used to power large motors either directly or via a dedicated (captive) transformer. Voltages for motors are preferably below 10 kV, but may go up to about 15 kV as a maximum.

Transformer size will be limited by the maximum current rating obtainable for the secondary switchgear. This typically is 3 kA.

Transformer connections (vector reference) should be shown on the one-line diagram together with the system grounding arrangements. Often we use the same transformer connections as the local utility for standardization.

Before finalizing the connections, the following points, which conflict with each other, should be considered:

1. A delta / wye (star) connection is preferred.
2. A wye (star) primary has the advantages that the on-load tap changer, if it happens to be on the primary, will be lower cost than on a delta winding, and it is possible to ground the neutral.
3. A wye (star) secondary permits access to the neutral for grounding.
4. The wye / wye (star / star) connection should be avoided.
5. If the utility insists on the primary being wye (star) connected, then the secondary should preferably be delta and a grounding transformer can be connected to the secondary, which will both provide a neutral for grounding and a power source for the substation.

Preferred USA power transformer ratings are listed in [Table 2](#). Preferred ratings and method for listing maximum capacity differ in other countries.

SWITCHGEAR

The incoming circuits from the utility may or may not be equipped with circuit breakers at the plant end. It may be difficult to justify these breakers for smaller installations, but they should be included whenever possible. One exception is when the circuit to each transformer is supplied from its own dedicated circuit breaker in the utility substation and the utility agrees to a unit protection zone covering the transformer and its feeder cable.

The main substation transformers can be double banked, i.e., connect two transformers to one primary breaker. However, only one transformer per primary breaker is preferred, as the protection and switching maintenance are simplified, thus resulting in higher reliability.

The secondary switchgear usually consists of metal clad compartments with drawout circuit breakers installed indoors. Operation with the tie breaker open (secondary selective) rather than closed (spot network) is more usual. This reduces the range of maximum to minimum short circuit level, which is beneficial for motor re-acceleration and may permit use of lower interrupting rated switchgear. Switchgear continuous current rating should be suitable for the transformer rating including any overload capacity. When operated with spot networks, transformers must be matched in size and impedance, and their on-load tap changers must be equipped for cross compensation control.

REACTORS

Reactors are used to limit short circuit levels but should be avoided whenever possible. Where they are used, they preferably should interconnect networks to permit transfer of power under abnormal conditions rather than be in series with a main power circuit where all power to the load flows through them in normal operating conditions.

Alternatives are to use pairs of transformers with no interconnection between the secondary of each pair, or current limiting explosive fuses between sections of busbars that split up the network when a fault occurs.

Reactors may be of the air cored or oil immersed type. The advantages of the air cored type are that they are less expensive and lighter. On the other hand, the oil-immersed units are less susceptible to contaminants in the atmosphere, do not require special construction features to avoid steel work in the vicinity, and do not require an additional enclosure around them. Both types have been used in Exxon plants with the air core type being more common.

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MAIN SUBSTATION DESIGN (Cont)

PROTECTIVE RELAYING

All incoming circuits, main transformers, and secondary switchgear should each be protected by instantaneous differential (unit) protection plus time and over-current graded back-up protection.

In some instances, the utility company will not provide instantaneous differential (unit) protection on their feeders to the main substation (see **PURCHASED POWER – RELAYING** above). However, differential (unit) protection should still be provided on the main transformers and secondary switchgear for fast clearance of faults in this equipment. The back-up protection should coordinate with the utility relaying.

A separate room may be required to locate the transformer primary breaker relays and sometimes the secondary switchgear relays. This arrangement may be required by the utility company and can be useful where there are many relays that would require some extra dummy panels on the switchboard and/or mounting relays at high level and on the rear of the switchgear.

Protective relaying requirements are more fully covered in [Section XXX-E](#).

TRANSFORMER SECONDARY CIRCUITS

These usually consist of metal enclosed bus duct or cables, either single core or multicore, and either armored or unarmored. Where cables are used, they must be well protected especially if unarmored. They may be run in conduit, cable trays, direct buried, or laid in a concrete trough finished flush with grade, or cable bus in air. Bus duct is only used when distances are short enough to make it economical.

LOCATION AND SPACING

Space must be provided at the boundary fence for the incoming circuit(s). Equipment at the boundary fence may consist of incoming circuit breakers only, or may include the transformers, or all the foregoing plus the secondary switchgear. This will depend on the magnitude of the load and distances to the bulk of the load. The final decision is one of economics plus availability of space.

Whatever arrangement is used, all the equipment mentioned above should meet the spacing guidelines listed in [Section XV-G](#) of the Design Practices.

Dual circuits should be spaced to avoid a single fault affecting both of them. This applies to power cables and control / protection cables. Consideration should also be given in the layout of switchgear and transformers to provide adequate isolation to avoid total loss of power due to a single fault.

CONTROL AND INDICATION

Open and closed indication of all the transformer primary and secondary breakers, plus any interconnecting circuit breakers, is required in either the plant utilities control room and/or the main process control room.

Control of breakers may be required also. One example is when generation is involved. All the breakers with synchronizing facilities will be controlled from a control room unless automatic synchronizing is employed and Owner does not require control at the control room.

Transformer primary breakers are units in the overall utility transmission or distribution system. As such, the utility may require prior notice before any switching can be done by plant operators or may not permit such operations in normal circumstances. Also, these breakers may be part of the utility systems for status, control, and data acquisition (SCADA) with operating control by the system controller only. These details must be specified in detail in plant operating procedures.

Indicating meters should be provided in the control room where the remote control is located to give the operator an appraisal of the electrical power situation. Types of meters usually provided are voltmeters, ammeters, watt, and var meters. In some cases, much more metering is required depending on the tariff, whether there is in-plant generation and Owner preference. These indicators and control devices are often incorporated into a mimic panel that represents the main components of the network or more recently into a microprocessor-based system.

SURGE PROTECTION

If the incoming circuits from the utility consist of uninsulated overhead wires, surge protection will be required at the substation to protect the transformers and equipment downstream. This protection consists of surge diverters (lightning arresters) mounted outdoors connected to the incoming lines upstream of all the substation equipment.

The arresters look like post insulators and consist of the outer insulation and weather protection, with a terminal at the top for connection to the line and mounting base at the bottom which also serves as the other terminal for connection to ground. The arresters may be either:

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MAIN SUBSTATION DESIGN (Cont)

1. Valve type consisting of a gap (spark gap) unit in series with a non-linear resistance valve element. This combination offers very high impedance at normal-voltage, low-surge current conditions, but very low impedance to high-surge current, over-voltage conditions.
2. Metal oxide (zinc oxide or gapless) type which has sufficient non-linearity that a series gap is not required to provide the high impedance-low impedance characteristics.

ENVIRONMENT

A clean environment is required for the protection relays and the contacts on switches and interposing relays. Combinations of hydrogen sulfide contamination, d-c circuits, humidity, silver migration along phenolic surfaces of relays, etc. have resulted in failure to operate and false trip events at various locations.

Use of solid state protective relays is widespread and programmable controllers are also being used in substations. While this equipment avoids some of the problems associated with induction disc and similar mechanical relays, they impose their own requirements for a clean and sometimes temperature controlled environment.

As a result, air filtration or air conditioning will be needed if ambient air is likely to be contaminated with H₂S, dusts, or other contaminants. If air is treated for contamination only, it may be difficult to justify two 100% units since the problem is time related. However, if air conditioning is required to maintain a controlled ambient temperature for equipment, at least two units sized for 50 to 100% of the duty should be provided.

MAIN SUBSTATION AUXILIARIES

A reliable low voltage power supply will be required for substation auxiliary loads which may include the following:

1. Battery chargers.
2. Tap changers.
3. Transformer cooling fans and oil pumps.
4. Air conditioning.
5. Lighting.

This power supply can be obtained from a small tertiary winding on each main transformer, or small transformers connected, with suitable protection, between the main transformers low-voltage terminals and the switchgear. Exxon installations usually use a pair of transformers supplied from the main switchgear if there is no reliable low-voltage supply available from a nearby substation.

DESIGN PROCEDURE – ELECTRICAL DESIGN SPECIFICATION GUIDE

INTRODUCTION

This guide is intended to help new electrical engineers in the preparation of electrical Design Specifications. In the past, the electrical engineer simply went to a previous Design Specification and used it as a guide. Although this assured the continuation of some good features of electrical design, it did not necessarily insure evaluation of certain alternatives which should be considered every time a Design Specification is written. This guide lists pertinent paragraphs from the *International Practices* which should be checked by the engineer to insure that all alternatives have been considered.

PLANNING AND DESIGN BASIS ENGINEERING

Design is a real time dynamic work process which leads to the detailed specification of equipment and facilities. The Basic Design Specification (BDS) covers the critical engineering aspects and unique equipment engineering (e.g. mechanical, rotating equipment, etc.) requirements in sufficient detail so that the Front-End-Loading (FEL) or Engineering, Procurement and Construction (EPC) Contractor can complete the remainder of project definition / detailed engineering.

Three levels of Exxon Engineering BDS definition are typically recognized, reflecting differing levels of detail required based on such factors as the nature of the project, technology employed, contracting strategy etc.

1. Full Basic Design Specification
2. Abbreviated Basic Design Specification
3. Duty Specification

Selection of the type of BDS will be client and job specific. Protection of proprietary information and know-how for competitive advantage will need to be balanced versus job cost and schedule. The contractor would then use the BDS to produce a Front-End Engineering Package (FEED). Additional information on FEL and FEED is contained in *Exxon Engineering Work Processes Manual*.

This guide describes the electrical section of a Full Basic Design Specification.

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The Full Electrical Design Specification engineering is preceded by engineering work done during the planning and Design Basis Memorandum (DBM) stages of a project. [Appendix A](#) provides a Sample Site Survey questionnaire to assist in the planning process. The DBM provides the details of the system design selected from the results of the planning and DBM engineering. The DBM provides a technically feasible and economically viable design to serve the electrical loads of the project. It contains a one-line diagram, load list, equipment lists, system and equipment performance criteria, and results of studies carried out during the engineering. It may also contain specific conditions requiring further attention during the Design Specification engineering.

The equipment list details together with the investment curves references, where appropriate, comprise the IBM which is intended to provide the cost engineers with the information needed to prepare the project cost investment estimates.

Many times, in the absence of a major basis change, the DBM design will essentially be reflected in the Design Specification. It is recommended that the Owner make a detailed review of the DBM in order to understand the basis of the facilities to be provided.

HOW INFORMATION IS PROVIDED TO THE CONTRACTOR

There are four vehicles by which we provide information to the contractor:

1. The Design Specification.
2. The General Instructions and Information (GII) Specification.
3. The *International Practices*.
4. The Exception and Additions to the *International Practices*.

In an ideal situation, a contractor should be able to produce a detailed electrical design using a set of the electrical *International Practices*. Practically, however, this is not the case. There are still too many decisions left by the *International Practices* which the contractor cannot or should not make. These decisions are either made for him in the Design Specification or he is directed to perform studies which will result in a decision.

Exceptions and additions to the *International Practices* indicate to the contractor areas where the *International Practices* are superseded. These usually occur for plant expansions where equipment and/or design are intended to match existing facilities, or sometimes affiliates have their own standards which conflict with specific *International Practice* requirements. These discrepancies are also covered by the exceptions. Ideally, there should be no exceptions to the *International Practices*, but the affiliates' preferences and requests may take precedence.

The Design Specification brings together the *International Practices*, the exceptions and additions, affiliates' preference and requests, and the most up-to-date Exxon Engineering thinking on plant electrical systems. Efforts should be made to include in the Design Specification only those items which are not covered by the *International Practices*.

INFORMATION NEEDED TO WRITE A DESIGN SPECIFICATION

The Design Specification should include all the features of the prepared design and should resolve as many of the alternatives described by the *International Practices* as possible. The items marked with an asterisk in the *International Practices* require a decision. [Table 3](#) provides a check list of International Practice Asterisk items for consideration in preparing an Electric Power Facilities Design Specification. The specification writer is responsible for determining affiliate preferences on these items and for specifying them in either the Design Specification or in IP exceptions. Decision on the remaining items will be made during detailed design.

In addition to resolving the asterisked items, the following information should be available prior to writing an electrical system Design Specification:

1. Power Source Characteristics (see **POWER SOURCE REQUIREMENTS**).
2. Affiliate Preferences on Design Features.
3. Load Description.
4. DBM Design Features.
5. Engineering Survey Data.

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Writing A Design Specification

It should be noted that all the items below may not be necessary. For example, if lighting requirements conform to the *International Practices*, then it would not be necessary to include a section of lighting in the specification. On the other hand, the above items should not preclude any additional items which a Design Specification writer might deem necessary. The use of sections with only statements to the effect that the requirements of the *International Practices* should be met is to be avoided. That the requirements of the *International Practices* be fulfilled is covered adequately in the Design Specification **SCOPE**. The function of the Design Specification is to **supplement** the *International Practices*, **not repeat** the requirements of the *International Practices*.

THE DESIGN SPECIFICATION SHOULD INCLUDE ONLY THOSE ITEMS THAT ARE NOT COVERED IN OTHER DOCUMENTS. BE COMPLETE BUT DO NOT BE REPETITIVE. IF SOMETHING HAS BEEN MENTIONED IN THE *INTERNATIONAL PRACTICES*, IT SHOULD NOT BE MENTIONED IN THE DESIGN SPECIFICATION.

The Design Specification should contain enough detail to enable a contractor to engineer facilities that are flexible, reliable, and require the minimum of maintenance. The *International Practices* contain most details of our requirements for process substations, their power supply, and all facilities downstream. Intermediate distribution systems (say 36 kV), incoming substations receiving power from the utility, and power generation are not completely covered by the *International Practices*; therefore, more details of these upstream facilities, including all relaying and protection, should be included in the Design Specification.

During preparation of the Design Specification, it may not be known if the contract will be "Fixed Price" (Lump Sum) or "Cost Reimbursable." If this is the case, it should be assumed that the contract will be "Fixed Price" and the Design Specification should clearly define the specification scope, with no omissions, and include enough definition to avoid "extras" to the contract. The specification should clearly define contractor, utility, and Owner responsibilities. When more than one contractor will be used, split of responsibilities and interfaces must be stated and checked carefully to avoid overlaps and to insure all electrical facilities, functions, and studies are assigned. All of this must conform to the overall project split of responsibilities.

The term "Owner" should be used in Design Specifications when referring to Exxon / Esso or the customer, not "Owner's Engineer" as used in the *International Practices*.

The following apply to respective sections of **SAMPLE DESIGN SPECIFICATION 94-1** included as [Appendix B](#) in this Design Practice.

1. Scope

The scope describes in a broad sense what the specification covers and lists any exclusions.

2. Design Basis

Generally, the items in the Design Basis are determined during the planning and DBM phases of the project and are not part of the Design Specification effort. These items include:

- Purchased or generated power.
- Pre-investment philosophy.
- Estimated peak demand of the refinery or project and the basis for estimate.
- Voltage levels (may be determined as part of Design Specification effort rather than specified in Design Basis).
- Any atmospheric conditions which might affect design.

3. General

This section points out how the contractor is expected to use the information supplied to him in the Job Specification. It specifies who is responsible for construction power (if not in GII) and directs the contractor to other sources of information, i.e., to the Owner for details of existing equipment.

4. Power Source

This section describes the power source and provides the source characteristics at the distribution system source bus. These characteristics include the following:

- For Generation Source
 - Generator rating (kVA, PF, MW, kV, Hz), and requirements for excitation system, enclosure, etc.
 - Subtransient, transient, and synchronous reactance.
 - Generator bus configuration.
 - Location and contractor responsibilities at the interface.
 - Generator bus grounding details.
 - Special relaying, clearing times for stability, load shedding, and proposed method of voltage and var control.

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- b. For Purchased Power Source
 - 1) System nominal voltage and frequency.
 - 2) Present minimum and future maximum short circuit levels at the source bus.
 - 3) Is source bus neutral effectively grounded?
 - 4) Source bus configuration and number of incoming circuits.
 - 5) Level at which circuits can be paralleled.
 - 6) Voltage regulation at source bus.
 - 7) Limiting kVA of supply (transformer or incoming line).
 - 8) Location of source bus.
 - 9) Power factor correction.
 - 10) Specify contractor and Owner responsibilities at the source bus interface.
5. Distribution System

This section gives substation designations, locations, and types but does not repeat system information given on the one-line diagram. It describes any unusual features, such as three winding transformers, capacitor banks, and special bus configurations.

If the project is an addition to or an expansion of an existing facility, specify the contractor's responsibilities at any tie-in points.

Based on the source bus information above and the load information (**POWER SOURCE REQUIREMENTS**), the design for the distribution system can be developed by determining the following features:

 - a. Location of refinery load centers (refer to load summary).
 - b. Determination of the simultaneous maximum demand at each load center.
 - c. Determination of the type of service required by each load center (radial, primary selective, secondary selective), and which loads can be served from a common bus, i.e., operate and turnaround together.
 - d. Selection of substation locations as close as possible to the load centers being served.
 - e. Selection of distribution and utilization voltage levels and distribution method to each substation (tapped feeder, individual feeder, loop feeder, or series substation).
 - f. Selection of sectionalizing devices (breakers, links, load break switches, disconnect switches).
 - g. The writer usually will have to prepare several system one-line diagrams for cost and reliability comparison before the optimum distribution system can be selected.
6. Load Description

The load description should include the simultaneous maximum demand at each load center, substation load center assignments, and an electrical load summary by substation. The load summary should include the following:

 - a. Voltage level.
 - b. Substation type (secondary selective, radial, etc.).
 - c. Substation transformer rating.
 - d. Load centers served by substation, identified by process or offsite facility or area supplied.
 - e. Maximum simultaneous demand on each substation in kW and kVA.

The load description should also include all assumptions used in formulating the load summary, such as contingencies, assumed power factors, and medium / low voltage horsepower split.
7. Protection and Control

The *International Practices* specify most of what is usually required for protection and control. Sometimes affiliate preferences will require specifying motor controller types and relaying methods. Also, the relaying and metering on main incoming substations, any special reacceleration control, or load shedding requirements are often specified. Differential protection must be specified where required.



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DESIGN PROCEDURE – ELECTRICAL DESIGN SPECIFICATION GUIDE (Cont)**8. Equipment and Construction Procedures**

This section specifies any special design features or affiliate preferences dealing with the following:

- a. Power cabling methods and materials.
- b. Transformers, motors, and other electrical equipment.
- c. Substation building type and layout.
- d. Electrical equipment test requirements.
- e. Turnaround power center locations.
- f. Welding and convenience outlets.

9. Lighting

Lighting is adequately covered by **IP 16-5-1** except for affiliate preferences and whether or not to invoke the security lighting **IP 16-5-2**.

10. Instrument and Essential Services Power Supply

Instrument power supply systems are covered by the *International Practices* except for affiliate preferences, such as expansion or duplication of an existing system. There are two key asterisk items in **IP 16-8-1** that will set the basis for the design configuration for the instrument and essential services power supplies.

Par. 3.5 requires the designer to determine which operating units (or group of units) are critical and independent from other units. Following identification of all groups of critical and independent units, and the site selection of all control centers and remote instrument buildings, the instrument and essential services power supply configuration can be determined from **IP 16-8-1, Pars. 8.1, 9.1, and 9.2**. This will require preparation of one or more one-line diagrams for inclusion into the Design Specification.

Par. 6.2 requires the designer to determine whether or not a standby power generator is required, and for which units/loads. The power source configuration can then be designed per **IP 16-8-1, Figure 1**. This will require preparation of one-line diagrams for the power sources and essential services switchgear configurations.

11. Communications

Communications systems are not covered by the *International Practices*. Depending on the complexity of the system, communications equipment can be covered as a separate specification or as part of the distribution specification. In general, consultation with the affiliate will be necessary before the specification can be written. The general communications systems covered include:

- a. Telephone, facsimile, and electronic mail systems, type, whether purchased or rented, etc.
- b. Ship-to-shore radios.
- c. Intra-refinery communications systems (two-way radios, sound powered phone loops, etc.).
- d. Fire and accident reporting systems.

12. Diagrams

This section should include a one-line diagram and any other diagrams which may not be covered by the *International Practices*, such as an existing distribution system or an unusual instrument power supply systems.

COMPUTER PROGRAMS**GUIDANCE AND CONSULTING**

For up-to-date information on available programs and how to use them, affiliate personnel should get in touch with their Affiliate Library Contact. Exxon Research and Engineering personnel should consult either the Exxon Engineering Section responsible for the technology involved and/or the Technical Computing Group of Exxon Engineering Technology Department (EETD).

The Application Technology Set (AST) Catalog is a data base of the technical and engineering applications used by Affiliate and ER&E Engineers. The prime delivery mechanism for the ATS Catalog is the Windows "help" file format. To request a copy of Windows "help" file version, contact:

- ▶ ER&E Manual Distribution
- OUTLOOK: AMERICAS(MANUAL)
- Exxon Research and Engineering Company