SNS AC POWER DISTRIBUTION AND RELIABILITY OF AC POWER SUPPLY

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Abstract:

When designing any power system under the new Construction Design and Maintenance (CDM) regulations (OSHA, NEC) and safety will be an important factor. It is worth acknowledging that safety and reliability can conflict. This can happen when safety considerations require the introduction of additional complexity, such as the provision of safety interlocks, which reduces reliability.

Safety must always take precedence and additional steps will be required to maintain the required reliability.

OBJECTIVE

The objective of modern installation design is to provide a continuous supply to critical loads. In most situations, the steps taken to achieve this will include some of the following:

- Provision of a separate, independent supply from the grid
- Provision of a standby generator
- Provision of an uninterruptible power supply
- Dualling of the distribution system, including any local transformers, busbars etc.
- Separation of critical and non-critical loads
- Provision of maintenance facilities to enable servicing without removing power from critical loads.

There are many routes to achieving a particular level of reliability for an installation and each has an associated cost. Selecting the optimum approach required a careful analysis of the site requirements and safety risks posed by failure and the cost of each solution.

Reliability assessments are an aid to good engineering but cannot function alone. The designer must carefully interpret the results to ensure that the optimum solution is achieved.

Reliability assessments enable system designers and planners to make informed judgments and decisions about the: -

- choice of system configuration
- manufacturer of the equipment
- type of components/equipment
- interface to other equipment
- trade-offs between reliability and cost
- choice of system that best meets the SNS requirements

The assessment provides a failure probability figure for the system based upon known or estimated statistical failure rates for each component. It does not indicate that the system will not fail more frequently - it is a guide to the average reliability. No manufacturer can provide a lifetime guarantee for the reliability of their products!

As technology advances and solid-state devices replace electro-mechanical devices, it is generally assumed that new systems will be more reliable than their predecessors. However, the increasing complexity of solid-state systems means that there are many more components involved, each of which has a finite reliability. The probability of failure must be minimized by careful design and by introducing redundant elements arranged so that they can take over until the faulty elements have been identified and repaired.

In lieu of the above stated criteria for reliability assessment, the SNS project has chosen electrical power distribution design as follows:

- Two independent 161kV feeds from TVA – reliability very good
- Two 47.5MVA transformers with a tie breaker on the 13.8kV secondaries – reliability good
- Radial (star configuration) feed to substations and RF transformers was chosen over loop feed as cost preserving mean – cable failures on 13.8kV distribution rare, reliability considered good
- (underground utilities, e.g. cable duct banks, are designed for radial feed and upgrade at this point would delay the project by six months, later upgrade would disrupt the accelerator operation for at least ten months to one year)
- Loop feed was chosen for CHL compressors – reliability excellent
- Generator –UPS redundancy for computer communications and PPS has been chosen – reliability excellent
- Generator redundancy to support emergency operations (safety) were chosen – reliability – excellent
- Linear and non-linear loads were separated and are on different transformers on the LV side

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- K-factor transformers are used for non-linear loads to prevent transformer losses and neutral conductor overheating
- Harmonic filters are implemented
- Connected equipment is specified to comply with IEC 61000 (flicker, harmonics, etc.)
- Maintenance - an important part of reliability of the system and this can not be omitted in reliability assessment.
- Lastly, the choice of equipment manufacturer and availability of spare parts is crucial for SNS accelerator systems reliability

The following are some of the factors that contribute to the difficulty of assessing reliability accurately.

- Inconsistency in manufacture - not all components will have exactly the same lifetime
- Inconsistency in installation – quality, environment, usage
- Consequential damage (or over-stressing) of a component caused by partial or catastrophic failure of another
- Incomplete repair, e.g. components which may have been over-stressed by the failure of another were not replaced and may have shortened lifetimes
- Poor replacement, e.g. replacement components not of same quality as those originally fitted
- Failures not being accurately reported and therefore not included in statistics
- Environmental factors, e.g. systems run at higher temperatures will experience shorter lifetime
- Problems due to poor maintenance, e.g. failure to keep air vents clear will cause local hot spots and result in earlier failure

It is important to appreciate that reliability predictions are subject to uncertainty. This arises from a number of factors:

- There is an inherent uncertainty in transferring failure (or success) data to different applications and environments.
- It may be unclear what constitutes a failure in various situations.
- The effect of human actions and interpretations may be uncertain.
- Predications are naturally based upon historical data. Differences in technology, changes in design team personnel and the changing specification of the product all introduce possible sources of error into predictions.
- The rate of occurrence of failure may not be constant with respect to time.
- Predication methods often have to be over simplified in order to make problems tractable.
- Confidence limits with respect to the statistical data being assessed.

Reliability assessments are an aid to good engineering and consideration should be given to the following:

- Well-proven engineering practices.
- All statistical information is assessed to a common base.
- Previous designs and processes should be reviewed to determine the capability of the new product.
- Statistical analysis should always be tempered by engineering judgment. Parallel redundancy for example, can be introduced to improve the overall probability of successful operation of a system, but it may not be effective if the same inherent fault mechanisms exist within the parallel items.

Reliability is the product of the component count and the number of redundant paths that will allow the product or system to perform satisfactorily until the faulty elements have been repaired. Therefore, the less complex the system you design, with fewer components and more redundant paths, the more reliable the system will perform without loss of power.

The future full operation of SNS should prove that good engineering practices were chosen and data shall be shared with the particle accelerator community.

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