Guide Form Specification

Harmonic Filter and Capacitor Bank Application Studies

Note: Brown text should be deleted in the final specification. It is included in this document to provide background information and assistance for the development of your specification.

Power capacitor banks and harmonic filter banks are most often applied to utility, industrial, and commercial power systems for their benefits in the area of power factor correction, loss reduction, voltage support, improved voltage regulation, reduction in apparent power (KVA reduction), IEEE 519 compliance, and reduction of voltage/current distortion. In renewable power plants, their requirements are often dictated by an interconnect requirement. Their application, however, may require various power system studies to ensure they do not negatively impact the power system and are properly designed and specified for trouble free operation.

This guide form specification provides guidance on the specification of these studies.

1 General Description

1.1 Various power systems studies are required to evaluate the application and performance of a three-phase medium voltage metal-enclosed power capacitor bank that preliminary consists of _____ kvar at _____ kv.

If the reactive power rating or kvar requirement is not known and is to be determined as part of this study, then use the paragraph below and delete the above specification section.

1.2 Various power systems studies are required to evaluate the application of a three-phase medium voltage metal-enclosed power capacitor bank. The capacitor bank is being applied to correct the systems power factor to 0.98 lag. (Change as required to state objective or performance requirement of the capacitor bank or harmonic filter bank).

If it is known that harmonic filters will be utilized, use the following paragraph and delete the above two specification section.

1.3 Various power systems studies are required to evaluate the application of a three-phase harmonic filter bank. The harmonic filter bank is being applied to correct the systems power factor to _____ (for example 0.98 lag) and also to maintain the systems harmonic voltage and current distortion within IEEE 519 limits. (Change as required to state objective or performance requirement of the capacitor bank or harmonic filter bank).

For a renewable power plant, consider using the following study description.

1.4 A harmonic study is required to assess the following related to a PV (or windfarm) plant.

1.4.1 Evaluate whether the design of the plant, particularly the staging of switched capacitor banks in the plant substation, shall result in undesirable resonance conditions.

1.4.2 Assess whether the capacitor banks themselves may be subjected to voltage and current harmonics in access of their design limits.

1.4.3 Assess compliance of the plant with IEEE 519-1992 recommended limits on current and voltage distortion.

2 Submittals

2.1 Submittals shall include the following

2.1.1 Preliminary study criteria and assumptions shall be reviewed and approved by (company name) prior to commencing the study. The level of details and the study scenarios to be simulated may vary depending on project specific and Utility interconnection requirements. A software tool (ex. ETAP, EasyPower) based on the level of detail required and the target audience (Utility, Owner requirements) shall be used.

2.1.2 The report shall include the following

2.1.2.1 Study criteria and mythology

2.1.2.2 Summary results tables with interpretation of the results

2.1.2.3 A graphical one-line representation of the plant model

2.1.2.4 IEEE 519 compliance tables

2.1.2.5 Impedance Scans for key results

2.1.2.6 Conclusions and recommendations and filter design parameters should a harmonic filter be required

3 Study Objectives

The following are typical study objectives. Delete or modify study objectives to meet your requirements.

3.1 Determine the required reactive power rating to correct the plant's power factor to 0.98 Lag at maximum plant load. Load data to make this determination will be provided in the form of electric utility bills, a load table, customer reported data, identified on the one-line diagram, or will be presented in a power system measurement report. This data will be provided to the successful bidder.

3.2 The study shall confirm the application of a shunt power capacitor bank(s) will not excite resonance conditions that result in voltage distortion greater than 5% for all operating conditions. Where such resonance conditions can occur an appropriate tuned or de-tuned harmonic filter bank shall be designed, specified, and examined as part of this study.

3.3 Where VFD motor starters or RVSS motor starters are utilized, the study shall examine these start conditions and ensure they do not interfere with the capacitor/harmonic filter bank's operation. When such interference can occur, the study shall determine an appropriate mitigation strategy to prevent such interference.

On systems where there is significant amounts of nonlinear load (large rectifiers, VFD drives, cycloconverters, arc furnaces, inductions furnaces it is usually mandatory that filters be used. In such cases, consider the following paragraph.

3.4 The study shall determine a harmonic filter design that will bring the plant into compliance with IEEE 519 voltage and current distortion limits while correcting the plant's power factor to 0.98 Lag. The filter design shall account for existing and planned future loads and shall be designed with a 100% design margin. Additionally the design shall account for ambient voltage distortion.

The harmonic filter design (if required) shall accommodate partial load levels while maintaining a power factor near unity (partial load operation) and acceptable levels of voltage and current distortion on the main filter system bus.

3.5 The study shall determine the maximum stage reactive power rating to limit the system voltage change to 1.5%. Binary switching, where possible, shall be utilized to reduce the number of required capacitor stages.

3.6 An equipment design and specification based on the results of the study shall be provided in the appendix of the study report. The equipment specification shall not be proprietary in nature.

4 Study Scope

For suppliers and consulting firms to quote a power system study, the scope of the project must be well defined. For example, what portion of the power system must be modeled? How much of the source must be modeled? Should the low voltage source be modeled? What about individual harmonic producing devices, do they need to be modeled? What data will be provided by the customer? These are questions that can often be answered by an experienced engineer quoting the project when key study objectives are provided as well as a system one-line diagram. For this reason, a sketch of the network to be modeled, or a one-line diagram should be provided with the specification. Additionally background information for why the study is being requested is always helpful. The section should define the type and extent of studies to be conducted. You may choose to delete some of the listed studies.

4.1 Network Model

4.1.1 The utility grid shall be modeled as an Thevenin equivalent. Additional bus segments on the utility system may be modeled as required in particular if there are any known harmonic sources (FACTS Devices, large non-linear loads such as VFDs, arc furnaces, etc), or sinks (cap banks) in the electrical proximity to the point of interconnect.

4.1.2 Electrical parameters for the circuits and equipment within the plant shall be based on the single line diagrams and equipment data sheets. Harmonic contributions for the non-linear devices shall be based on information from the manufacturer. Non-linear loads may be modeled as harmonic current sources for harmonic load flow analysis if the software being used cannot use generic or vendor supplied converter/inverter models.

4.1.3 Approximate and estimated values may be used in the absence of detailed load, design, or network information. The report shall lists all assumptions.

4.1.4 ETAP, EasyPower, PSCAD, EMTP, PSS/E, PSS/U, or SKM shall be used. The input data file in asci (if available form software package) and in binary format shall be provided with the final report.

4.2 The following studies as they relate the application of the shunt power capacitor banks and harmonic filter banks are required:

4.2.1 **Harmonic Analysis** including harmonic impedance scans as viewed from capacitor / harmonic filter bank bus and also from major non-linear load bus, as well as other bus as required by the study. Also, IEEE 519 compliance calculations at PCC, calculation of voltage distortion at major load centers, and current distortion calculation at PCC and all harmonic filter banks and capacitor banks.

Should IEC or other voltage/current distortion limits or standards apply, be sure to mention them here as well as in the standards section of this specification.

4.2.2 **Load Flow Analysis** to show impact of capacitor bank/harmonic filter bank, including power flow changes and step voltages throughout network.

In most cases, detailed load flow analysis is conducted by the EPC or customer's engineer. Load flow analysis conducted by suppliers of capacitor banks and harmonic filter banks is normally limited to voltage rise calculations as a result of reactive power flow. This analysis is normally included to determine the number of stages (or steps) that are required to limit objectionable voltage rise. Typically, NEPSI recommends a voltage rise no greater than 3%, with a preferred value limited to 1.5%.

4.2.3 **Transient Analysis** to show switching transient duty on switches/breakers and selection of transient inrush reactors and transient outrush reactors (if required). This study shall be conducted using EMTP-RV.

4.2.4 **Short Circuit Analysis** to validate system modeling and confirm short circuit rating of feeder breaker.

4.3 The study should account for normal system operation as well as abnormal operation of the facility.

Abnormal operation may include maximum and minimum source short circuit levels, open and close tie breakers, 6-pulse or 12-pulse operation of 12-pulse and 18-pulse power converters respectively, operation of

plant on standby generation, etc. Defining abnormal operation states to analyze defines the number of cases

("scenarios") that must be analyzed and reported on.

4.4 The results of the study shall be summarized in a written report. The written report shall, at minimum, include the following key sections:

- Key objectives of the study
- Executive summary
- Key study recommendations and the basis of the recommendations
- IEEE 519 compliance review
- Harmonic analysis results
- System impedance scans
- Recommend filter/capacitor bank design with all ratings (if required)
- Filter impedance scans if recommended
- Expected harmonic filter currents
- Voltage rise calculations based on energization of filter/capacitor bank stages
- Description of system model, including all assumptions.
- A listing of all input data
- A non-proprietary equipment specification detailing all components to be purchased
- Preliminary one-line diagram of equipment and equipment layout

4.5 The study engineer(s) shall be available by WebEx for an initial kick off meeting as well as a meeting to present the key results of the study.

5 Power System Data

This section contains data that is typically used in conducting harmonic analysis, power capacitor application studies, and harmonic filter design studies. Not all of the data listed below is required to do a study. You should delete data that you do not intend to supply. In so doing, it leaves the option to the supplier quoting the project to list additional data requirements that you do not intend to supply.

At minimum the study engineer will require the short circuit impedance between the source and the application of point of the capacitor/harmonic filter bank, the location and rating of all capacitor banks/harmonic filter banks on the system, the reactive power requirements for any capacitor/harmonic filter bank that might be applied, and the harmonic currents generated on the system to be studied.

5.1 The following data will be supplied to the successful bidder. Additional data not shown but required to do the study shall be identified with the bid.

5.1.1 Performance requirements of power capacitor bank/harmonic filter bank.
5.1.2 A description of planned expansions, plant operating scenarios, contingency operation of plant.
5.1.3 System one-line diagram showing system to be modeled.
5.1.4 Minimum, maximum, and average short circuit level of supplying utility.
5.1.5 Identification of PCC (Point of Common Coupling) on one-line diagram.
5.1.6 Service transformer(s) base power rating and leakage impedance.
5.1.7 Location and rating of proposed capacitor bank (if known).
5.1.8 Location and ratings of existing capacitor banks and harmonic filter banks.
5.1.9 Utility bills for calculation of reactive power requirements.
5.1.10 Interval data from electric service provide
5.1.11 Load table showing expected load (kw, kvar, kva, pf).
5.1.12 Harmonic measurement data.
5.1.13 Non-linear load data of significant loads.

6 Power System Simulation Software

6.1 The supplier shall utilize industry accepted software that utilizes complex modeling techniques, for short circuit, load flow, harmonic analysis, and transient analysis to predict system performance parameters. Acceptable software packages include:

- ETAP
- EasyPower
- SKM
- EMTP-RV (for transient studies)

6.2 The input data file, created with the latest available version of the simulation software must be must provide with the final report. No exceptions allowed.

7 Compliance with Standard & Codes

The power system study shall utilize the following standards and codes:

- IEEE 519-2014, *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*
- IEEE Std. 18-2012, *IEEE Standard for Shunt Power Capacitors*
- IEEE Std. C37.99-2012, *IEEE Guide for the Protection of Shunt Capacitor Banks*
- IEEE Std. 1036-1992, *IEEE Guide for Application of Shunt Power Capacitors*
- IEEE Std. 399-1997, *Chapter 10, Recommended Practice for Industrial and Commercial Power System Analysis*
- IEC 61000-3-6, *Harmonic emission limits for customers connected to MV, HV and EHV Systems.*

8 Supplier Quality System

8.1 The supplier shall have third party certification by an internationally recognized accreditation body to the most recent version of the ISO 9001 standard for quality management systems. The certification certificate shall be provided with the quote.

8.2 The supplier shall have on staff, experienced, licensed professional engineers (PE's) with degrees in power engineering (preferably with advanced degrees) as evidence of technical proficiency. Engineers conducting the study shall have a minimum of 10 years' experience in conducting harmonic analysis and harmonic filter design.

9 Bid Requirements

9.1 Supplier must state all exceptions to the Bid. If no exceptions are taken, the supplier must state that there are no exceptions.

9.2 The supplier must provide resumes for all engineers involved with the study

9.3 Quotes shall be fix price.

10 Acceptable Product & Suppliers

10.1 The supplier must have a Quality Assurance Program.

10.2 Supplier must perform harmonic analysis on a regular basis.

10.3 Supplier must also be a supplier of metal-enclosed capacitor banks and harmonic filter banks and must be able to supply equipment and guarantee performance of the equipment to the studies they conduct and their recommendations.

10.4 Acceptable Suppliers/Suppliers:

Northeast Power Systems, Inc.
66 Carey Road
Queensbury, NY 12804

Phone: 518-792-4776
Fax: 518-792-5767

Webpage: www.nepsi.com
Quote request: sales@nepsi.com