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Installation of Automatically Controlled Compensation Banks

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ABSTRACT: In fact, the problem of arranging one or more capacitor(s) to form a constant level of compensation in electrical power system is quite significant. The two major problems that the modern power systems are facing are voltage and angle stabilities. There are various approaches to overcome the problem of stability arising due to small signal oscillations in an interconnected power system. Installing power system compensation systems with generator excitation control system provides damping to these oscillations. However, with the advancement in the power electronic technology, various reactive power control equipment are increasingly used in power transmission systems.

KEYWORDS: Automatic Control, compensation systems, capacitors, transmission.

INTRODUCTION

Requirements for power quality are becoming an important element in contracts for the supply of energy. Growing market and an emerging energy competition make the Client becomes more demanding. The area of reactive power compensation is gaining increasing importance worldwide. If suitably designed, it is capable of improving voltage quality significantly, meaning that losses in equipment and power systems are reduced, the permissible loading of equipment can be increased, and the over-all stability of system operation improved. Ultimately, energy use and CO_2 emission are reduced. A power network is mostly reactive. A synchronous generator usually generates active power that is specified by the mechanical power input. The reactive power supplied by the generator is dictated by the network and load requirements. A generator usually does not have any control over it. However the lack of reactive power can cause voltage collapse in a system. It is therefore important to supply/absorb excess reactive power to/from the network. Shunt compensation is one possible approach of providing reactive power support. Requirements for power quality are becoming an important element in contracts for the supply. Regardless of classical solutions, installation of systems improving the quality of energy directly at the Client, energy distributors begin to assemble the reactive power compensation systems in switching substations. This creates a very attractive, but also very demanding market sector. Series capacitors are an economical method of reducing the reactance of high and extra high voltage lines. They produce an improvement in static and dynamic stability, a reduction in voltage drop, and an increase in power transfer capacity. They also provide wide range of automatic capacitor banks with harmonic filters. These equipments are supplied completely assembled and are ready for use. It is only necessary to connect it to the mains with cable of adequate cross section, and to supply the operation signal from a suitable current transformer [1].

Traditional reactive power compensation equipments with electromechanical contractors, have a well proven performance in installation where the load has, slow variations and it is not very sensitive to voltage fluctuation. Today, however, more and more industrial installations, include electronic equipments that are very sensitive to voltage variations (PLC, computers, etc.) and also have very fast changing working cycles (automatic welding machines, robots, etc.). Reactive power compensation with static contractors (Thyristor switch) offers the best answer to these new industry requirements. Compensation in power systems is, therefore, essential to alleviate some of these problems, series/shunt compensation has been in use for past many years to achieve this objective.

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PRINCIPLE FOR USING AUTOMATIC COMPENSATION

These capacitor banks are made up of a combination of capacitor steps (step = capacitor + contactor) connected in parallel. Switching on and off of all or part of the capacitor bank is controlled by an integrated power factor controller. Automatically regulated banks of capacitors allow an immediate adaptation of compensation to match the level of load.

A bank of capacitors is divided into a number of sections, each of which is controlled by a contactor. Closure of a contactor switches its section into parallel operation with other sections already in service. The size of the bank can therefore be increased or decreased in steps, by the closure and opening of the controlling contactors [2].

A control relay monitors the power factor of the controlled circuit(s) and is arranged to close and open appropriate contactors to maintain a reasonably constant system power factor (within the tolerance imposed by the size of each step of compensation). The current transformer for the monitoring relay must evidently be placed on one phase of the incoming cable which supplies the circuit(s) being controlled, as shown in Figure 1.

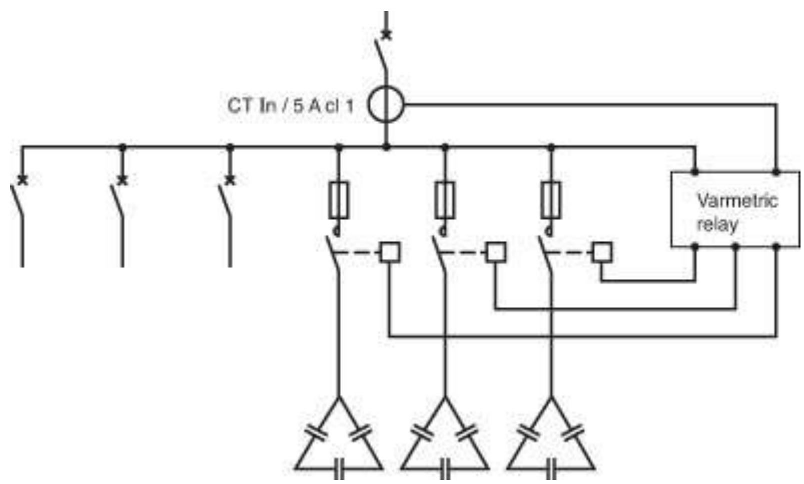

Fig. 1: The principle of automatic-compensation control

The reactive power supplied by the capacitor bank can be adjusted according to variations in the power factor and the load of the receivers. The equipment is applied at points in an installation where the active-power or reactive power variations are relatively large, for example:

- At the bus bars of a main distribution switch-board,
- At the terminals of a heavily-loaded feeder cable.

Where the KVAR rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate.

A Varset Fast capacitor bank is an automatic power factor correction equipment including static contactors (thyristors) instead of usual contactors. Static correction is particularly suitable for a certain number of installations using equipment with fast cycle and/or sensitive to transient surges [3].

The advantages of static contactors are:

- Immediate response to all power factor fluctuation (response time 2 s or 40 ms according to regulator option)
- Unlimited number of operations
- Elimination of transient phenomena on the network on capacitor switching
- Fully silent operation

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By closely matching compensation to that required by the load, the possibility of producing overvoltages at times of low load will be avoided, thereby preventing an overvoltage condition, and possible damage to appliances and equipment. Overvoltages due to excessive reactive compensation depend partly on the value of source impedance. This kind of equipment provides automatic control of compensation, maintaining the power factor within close limits around a selected level. Such equipment is applied at points in an installation where the active-power and/or reactive-power variations are relatively large, for example:

- At the busbars of a general power distribution board
- At the terminals of a heavily-loaded feeder cable

Where the KVAR rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate. Above the 15% level, it is advisable to install an automatically-controlled bank of capacitors. Control is usually provided by contactors. For compensation of highly fluctuating loads, fast and highly repetitive connection of capacitors is necessary, and static switches must be used.

A device that is connected in parallel with a transmission line is called a shunt compensator , while a device that is connected in series with the transmission line is called a series compensator . These are referred to as compensators since they compensate for the reactive power in the ac system. We shall assume that the shunt compensator is always connected at the midpoint of transmission system, while the series compensator can be connected at any point in the line. We shall demonstrate that such connections in an SMIB power system improves [4]:

- voltage profile
- power-angle characteristics
- stability margin
- damping to power oscillations

The following figure shows the size and location of capacitor in an electrical system.

Fig. 2: Size and location of capacitor in an electrical system

VARIOUS TYPES OF COMPENSATION BANKS

Type of Capacitor Bank as per Its Application

Fixed type capacitor banks

The reactive power supplied by the fixed capacitor bank is constant irrespective of any variations in the power factor and the load of the receivers. These capacitor banks are switched on either manually (circuit breaker/switch) or semi automatically by a remote-controlled contactor. This arrangement uses one or more capacitor to provide a constant level of compensation. These capacitors are applied at the terminals of inductive loads (mainly motors), at bus bars.

Disadvantages:

- Manual ON/OFF operation.
- Not meet the require kvar under varying loads.
- Penalty by electricity authority.
- Power factor also varies as a function of the load requirements so it is difficult to maintain a consistent power factor by use of Fixed Compensation i.e. fixed capacitors.
- Fixed Capacitor may provide leading power factor under light load conditions, Due to this result in overvoltages, saturation of transformers, mal-operation of diesel generating sets, penalties by electric supply authorities.

Application:

- Where the load factor is reasonably constant.
- Electrical installations with constant load operating 24 hours a day
- Reactive compensation of transformers.
- Individual compensation of motors.
- Where the kvar rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate.
- Size of Fixed Capacitor bank $Q_c \leq 15\%$ kVA transformer

Automatic Type Capacitor Banks

The reactive power supplied by the capacitor bank can be adjusted according to variations in the power factor and the load of the receivers. These capacitor banks are made up of a combination of capacitor steps (step = capacitor + contactor) connected in parallel. Switching on and off of all or part of the capacitor bank is controlled by an integrated power factor controller [3,4].

The equipment is applied at points in an installation where the active-power or reactive power variations are relatively large, for example:

- At the bus bars of a main distribution switch-board,
- At the terminals of a heavily-loaded feeder cable.

The advantages of static contactors used in these systems are :

- Immediate response to all power factor fluctuation (response time 2 s or 40 ms according to regulator option)
- Unlimited number of operations
- Elimination of transient phenomena on the network on capacitor switching
- Fully silent operation

Type of Capacitor as per Construction

Standard Duty Capacitor

Construction: Rectangular and Cylindrical (Resin filled / Resin coated-Dry)
Application:

- Steady inductive load.
- Non linear up to 10%.
- For Agriculture duty.

Heavy-duty Capacitors

Construction: Rectangular and Cylindrical (Resin filled / Resin coated-Dry/oil/gas)
Application:

- Suitable for fluctuating load.
- Non linear up to 20%.
- Suitable for APFC Panel.
- Harmonic filtering

LT Capacitors

Application:

- Suitable for fluctuating load.
- Non linear up to 20%.
- Suitable for APFC Panel & Harmonic filter application.

Type of Capacitor as per Configuration

Star-Solidly Grounded

- Initial cost of the bank may be lower since the neutral does not have to be insulated from ground.
- Capacitor switch recovery voltages are reduced
- High inrush currents may occur in the station ground system.
- The grounded-Star arrangement provides a low-impedance fault path which may require revision to the existing system ground protection scheme.
- Typically not applied to ungrounded systems. When applied to resistance-grounded systems, difficulty in coordination between capacitor fuses and upstream ground protection relays (consider coordination of 40 A fuses with a 400 A grounded system).
- Application: Typical for smaller installations (since auxiliary equipment is not required)

Star-Ungrounded

Industrial and commercial capacitor banks are normally connected ungrounded Star, with paralleled units to make up the total KVAR. It is recommended that a minimum of 4 paralleled units to be applied to limit the over voltage on the remaining units when one is removed from the circuit [2].

If only one unit is needed to make the total KVAR, the units in the other phases will not be overloaded if it fails.

In industrial or commercial power systems the capacitors are not grounded for a variety of reasons. Industrial systems are often resistance grounded. A grounded Star connection on the capacitor bank would provide a path for zero sequence currents and the possibility of a false operation of ground fault relays.
Also, the protective relay scheme would be sensitive to system line-to-ground voltage Unbalance, which could also result in false relay tripping.

Application: In Industrial and Commercial.

Delta-connected Banks

Delta-connected banks are generally used only at distributions voltages and are configured with a single series group of capacitors rated at line-to-line voltage. With only one series group of units no overvoltage occurs across the remaining capacitor units from the isolation of a faulted capacitor unit.

Therefore, unbalance detection is not required for protection and they are not treated further in this paper.

Application: In Distribution System.

EFFECT OF SERIES AND PARALLEL CONNECTION OF CAPACITOR

Parallel Connection

This is the most popular method of connection. The capacitor is connected in parallel to the unit. The voltage rating of the capacitor is usually the same as or a little higher than the system voltage.

Series Connection

This method of connection is not much common. Even though the voltage regulation is much high in this method, It has many disadvantages.

One is that because of the series connection, in a short circuit condition the capacitor should be able to withstand the high current. The other is that due to the series connection due to the inductivity of the line there can be a resonance occurring at a certain capacitive value. This will lead to very low impedance and may cause very high currents to flow through the lines [5].

CONCLUSIONS

This paper presents an approach to installation of various types of capacitors and compensation banks used in electrical power transmission system. The Automatic controlled capacitor banks are seems to be very cost effective and easily installed systems rather than other traditional systems as per the revisions performed in the paper. Such equipment is applied at points in an installation where the active-power and/or reactive-power variations are relatively large.

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