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Voltage Sag mitigation using shunt FACT devices in Induction Motor Drives

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Abstract

The development of the modern power system has led to an increasing complexity in the study of power systems, presents new challenges to power system stability, and in particular, to the aspects of transient stability and small-signal stability. An assessment study of different shunt FACTS devices for compensating disturbances due to voltage variation in power systems is presented. In this paper. Namely, Static Compensator (STATCOM) Static Var Compensator (SVC) and D-STATCOM are considered. This paper shows the superiority of DSTATCOM over STATCOM and STATCOM over SVC in increasing motor speeding up and improving system voltage profile particularly at starting.

1. Introduction

Operation of induction machines directly connected to the power system has been an issue of investigations in stability studies for a long time . The characteristics of induction motor loads and how their transient behavior influence the voltage stability of power systems is well known, and the most relevant solution to improve system stability is often reactive compensation close to the source of instability . Induction motors need reactive power at starting and are effective on system voltage. Starting of a large electrical motors connected to bus with small short circuit power, will produce disturbance for supply network and local consumers. This disturbance generally is in form of voltage dip and will cause do decrease power quality of network. For compensation disturbance during the starting, it is proposed to use FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) such as SVC or STATCOM. These types of compensators mode rapidly and increase motor speeding up and improve the voltage profile.

In many of the applications of IM is started using DOL starter. Thus, IM draws high current during its starting period which not only heats the motor, but also causes voltage drop in supply lines. Thereby affecting the working of other equipments supplied from the same lines [1]. The starting period of IM depends upon the factors such as, motor construction, its condition and its loading condition. Typically, the starting period is about 1 sec.; therefore there is a voltage sag in the supply voltage during this period. Voltage sag is an rms reduction in the AC voltage, at the power frequency, for durations from a half cycle to a few seconds .The solutions approached for compensation of voltage sag are either shunt injection of reactive current or series injection of voltage. The shunt injection of reactive current for voltage sag mitigation can be implemented by using custom power device like DSTATCOM. The series injection of voltage can be implemented by using custom power device like DVR. Former approach is superior to the later.

2. Characteristics Of Voltage Sag

According to IEC Standard 61000-2-8, 2000, IEEE standard 1346, 1998, a voltage sag is described as a "two dimensional (2D) electromagnetic (EM) disturbance, the level of which is determined by both voltage magnitude and time".

Following are the important characteristics of voltage sag.

i) Voltage sag Magnitude

ii) Voltage sag Duration

Voltage sag magnitude is defined as the remaining voltage during the event.

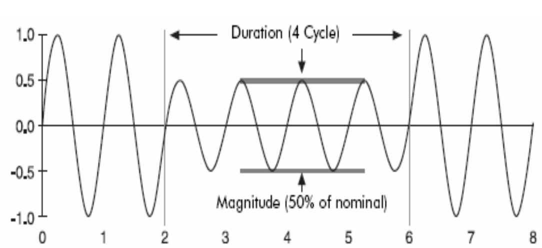

Fig.1. Voltage sag magnitude and duration

3. Static Var Compensator

Static VAR Compensator (SVC) is a first generation FACTS device that can control voltage at the required bus thereby improving the voltage profile of the system. The primary task of an SVC is to maintain the voltage at a particular bus by means of

reactive power compensation (obtained by varying the firing angle of the thyristors). SVCs have been used for high performance steady state and transient voltage control. SVCs are also used to dampen power swings, improve transient stability, and reduce system losses by optimized reactive power control. Static Var Compensators are shunt connected static generator absorbers whose outputs are varied so as to control voltage of the electric power systems. In its simple form, SVC is connected as Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR) as shown in Fig. 2.
The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. The effective reactance of the FC-TCR is varied by firing angle control of the anti-parallel thyristors. The firing angle can be controlled through a PI (Proportional + Integral) controller in such a way that the voltage of the bus, where the SVC is connected, is maintained at the reference value. Installations may be at the midpoint of transmission interconnections or at the line ends.

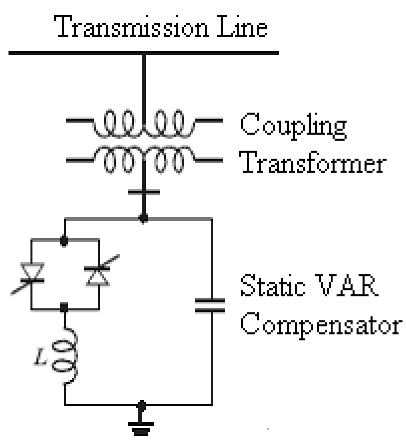

Fig.2 Configuration of SVC

4. STATCOM

STATCOM applications are based on so-called voltage sourced converters (VSC) using Gate Turn-Off Thyristors (GTO), Integrated Gate-Commutated Thyristors (IGCT) or Integrated Gate Bipolar Transistors (IGBT). Contrary to thyristors these semiconductor not only can be switched-on by firing pulses but also can be switched-off any time by control. Figure 3 shows the operation principle of a VSC. The VSC generates the voltage at its ac terminals. Magnitude and phase angle of that voltage are determined by the STATCOM controls with respect to the actual system voltage V_N to achieve a requested current I_N. In principle, the current I_N can be anywhere within the circle marked "maximum current of converter". For reactive power compensation purposes, however, the current will be controlled to be either leading or lagging the system voltage V_N by about 90 deg. Angles different than 90 deg cause active power exchange with the ac system. To a little extent that is necessary also for STATCOM operation covering power losses of the converter. When connected to an energy storage or to another VSC forming a DC transmission system the current angle and magnitude will be determined by the active and reactive power requirements independently from one another. The operation principle of a VSC allows maintaining a required current magnitude within a wide range of system voltages.

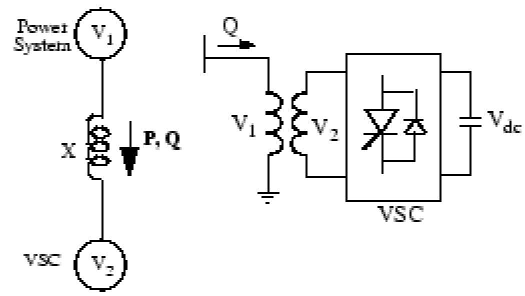

Fig.3 Configuration of STATCOM

5. DSTATCOM

When used in low voltage distribution systems the Static Compensator (STATCOM) is normally identified as Distribution STATCOM (D-STATCOM). In general, D-STATCOM is used to generate or absorb reactive Power. The basic electronic block of the D-STATCOM is the voltage Source Converter (VSC) that converts an input DC voltage into a three phase output voltage at fundamental frequency [9]. In its most basic form, the D-STATCOM configuration consists of a Voltage Source Converter (VSC), a DC capacitor for energy storage; a coupling transformer connected in shunt with the AC system, and associated control circuits [10]. In this arrangement, the steady-state power exchange between the device and the AC system is mainly reactive. Fig. 4 shows the schematic representation of the D-STATCOM. Regulating the amplitude of the D-STATCOM output voltage controls the reactive power exchange of the D-STATCOM with the AC system. If the amplitudes of the D-STATCOM output voltage and the AC system voltage are equal, the reactive current is zero and the DSTATCOM does not generate/absorb reactive power. If the amplitude of the D-STATCOM output voltage is increased above the amplitude of the AC system voltage, the current flows through the transformer reactance from the D-STATCOM to the AC system, and the device generates reactive power (capacitive). If the amplitude of the D-STATCOM output voltage is decreased to a level below that of the AC system, then the current flows from the AC system to the D-STATCOM, resulting in the device absorbing reactive power (inductive). Since the D-STATCOM is generating/absorbing only reactive power, the output voltage and the AC system voltage are in phase, when neglecting circuit losses. The current drawn from the D-STATCOM is 90° shifted with respect to the AC system voltage, and it can be leading (generates reactive power) or lagging (absorbs reactive power).A capacitor is used to maintain dc voltage to the inverter. An uncontrolled rectifier based six diodes used to keep the capacitor charged to the required level.

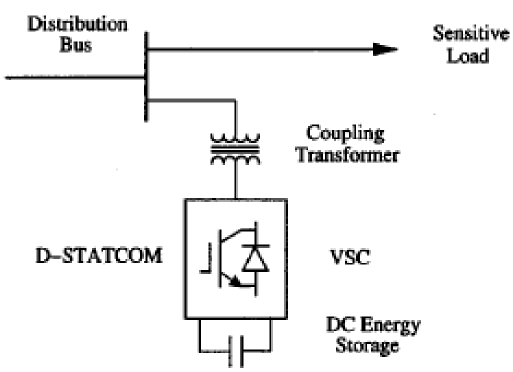

Fig. 4. . Schematic representation of the D-STATCOM as a custom power controller

6. Conclusion

By using FACTS devices for starting of induction motor the significant reduction in both total real power loss and total reactive power loss is obtained. The voltage regulation at the point of common coupling (PCC) is much better with a properly tuned D-STATCOM. D-STATCOM output voltage controls the reactive power exchange of the D-STATCOM with the AC system Finally, it can be concluded that the D-STATCOM used in this study can contribute significantly to the improvement of power quality in unbalanced distribution systems.

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