Using a synchronous condenser - when and why?
Electrical power system challenges in mining projects

- Low short circuit power on plant level = weak network
  - Remote location far away from generating stations requires
  - Long transmission lines consequences
- Inductive resistance of the transmission line reduces beside other factors the fault level in the function of the length of the line

\[ S_{sc} = f(\text{line length}) : S_{in} = 700 \text{ MVA} : U = 230 \text{ kV} : 1 \text{ single line and 2 lines in parallel} \]

Relation between line length and short circuit level
Electrical power system challenges in mining projects

- Non linear loads are dominating the load condition
  - Power requirements for a 100 000 t/d plant are about 120 MW
  - Today these drive systems are adjustable in speed (non linear load)
    - Gearless Mill drives
    - Conveyor belts
    - Mine hoists
    - Shovel Bagger
    - Pumps
  - The amount of non linear loads reach 70 to 80% of the total installed power
  - Non linear loads are not providing any usable short circuit power
  - Power electronic for drives are producing
    - network related commutating harmonics
    - Speed depending harmonics
    - Interharmonics
  - This facts are not supporting also the stiffness of the plant network
Electrical power system challenges in mining projects

- When is considered a network weak or strong?

  - Too weak
    - Starting and stopping of large drive systems provoke unacceptable voltage drops and overvoltage in the distribution bus system
    - Commutation problems in cyclo converters
    - Excessive harmonic content - challenge to correct it
    - Correct function of drive power electronic protection in question
    - In general - rule of thumb - when fault level on PCC in MVA is lower as 6 times of installed power in MW

  - Too strong
    - Selection of protective elements is a challenge, because above 40 kA short circuit current, commonly used protective elements are rare to exist
    - In cases where transformer impedance is used to limit short circuit currents it is not uncommon to have impedances around 20%
Improvement of power system fault level

Best engineering practices

• Rise transmission line voltage
• Install parallel lines
• Install at plant site supporting power generation
• Install a synchronous condenser
Improvement of power system fault level

- Rise transmission line voltage
  - Rising the transmission line voltage is very effect full to increase the short circuit level on the PCC

However, it is practicable only in dedicated overhead lines (new lines) and often restricted by weather condition.
Improvement of power system fault level

- Install parallel lines
  - Installing parallel lines is frequently applied and gives excellent results in pushing the fault level up

- It is practicable on existing and new overhead lines
Improvement of power system fault level

- Install at plant site supporting power generation
  - It is technically a excellent solution
  - No attenuation of fault level because power has not be transported over the overhead line
  - Power produced at plant site can be fully used
  - This approach make sense for plants in very remote areas
  - For instance 30 MVA power generation at plant site, the fault level will be lift up by 200 MVA

- But also this solution it is largely outweighed by the disadvantage like
  - Transport fuel to the remote areas
  - Logistical and technical obstacles
  - Additional maintenance and spare parts required
Improvement of power system fault level

- Install a synchronous condenser
  - Increase in plant network short circuit capacity
  - Smooth and step less control of power factor
  - Smooth control of plant medium voltage at main distribution bus
  - Reduction in switching action of PFC/ harmonic filter units
  - Transient voltage stability specially during extreme voltage variations (Sudden voltage fluctuation due to major load start, trips or faults).
  - Does not generate harmonics
Other network interrelations

Aspects

• Compliance of Harmonic standards
• Harmonic generation sources
• Transformer switching effects
• Parallel resonances in networks
Electrical power system challenges in mining projects

- Other network interrelations
  - Compliance of harmonic standards
    - Utilities are obliged to grant on the PCC a defined network quality which is defined by standards
    - Plant operators are obliged also to fulfill the network quality in terms of harmonics
    - The most common standard is the IEEE 519
    - Filter and compensation units have to be implemented on the plant level to comply with the standard
Electrical power system challenges in mining projects

- Other network interrelations
  - Harmonic generation sources and power factor
    - Electrical equipment consuming non-sinusoidal currents has to be considered as a source of harmonic currents
    - Only real linear loads like resistive, capacitive and inductive without iron core don’t produce harmonics
    - All others such as Transformers, AC Motors, Drives contribute on harmonic pollution
    - All asynchronous motors, non linear loads etc. decrease the network targeted power factor and have to be consequently corrected
    - 12 pulse Cyclo converter generate the known network commutated current harmonics like 5th, 7th, 11th 13th etc.
    - 12 pulse Cyclo converter create in addition also speed dependent current harmonics
Electrical power system challenges in mining projects

- Other network interrelations
  - Harmonic generation sources and power factor
Electrical power system challenges in mining projects

- Other network interrelations

  - Transformer switching effects
    - Switching on transformer or saturable inductances harmonic emission effects will be noted
    - The inrush current of transformers and AC Machines depends on the phase angle of the switching instant and the remanent magnetisation of the active iron part
    - The inrush current contains all integer low order harmonics including zero order for DC components
    - The harmonic components decay with the time constant between several seconds and up to minutes

  - Consequences
    - Heavy distortion of the network by creating strong 2nd harmonic
    - 2nd harmonic bears in it the potential danger to hit parallel resonance in weak networks
Other network interrelations

- Parallel resonances in networks

  Low short circuit level

  &

  high amount of non linear loads with low power factor

  requires

  large amount of VARs from Filters and / or SVCs

  This can be done only until a certain limit….high risk of network

  parallel resonance

\[
\text{Parallel resonance } f = \frac{2 \sqrt{S \ (MVA)}}{Q \ (MVAr)}
\]

As more Q are added as lower is the parallel resonance

Danger for network stability
Value proposition for using Synchronous Condenser

- So how SC can participate in solving the problem?
  - Increase in plant network short circuit capacity
  - Smooth and step less control of power factor
  - Smooth control of plant medium voltage at main distribution bus
  - Reduction in switching action of PFC/ harmonic filter units
  - Transient voltage stability specially during extreme voltage variations (Sudden voltage fluctuation due to major load start, trips or faults).

- … with the following attributes…
  - High operational reliability
  - Low maintenance, only periodic bearing greasing
  - Does not generate harmonics
  - High life expectancy
  - Avoid / reduce undesirable equipment and system shutdown
Salient features of Synchronous Condenser

- Step less import and export of reactive power by changing field current (excitation).
- Effective control of plant voltage by varying the amount and direction of reactive power.
- Short time over load capability even under serious low voltage situations, unlike other dynamic systems like SVCs.
- Does not cause any transients on the grid while connecting or disconnecting.
- Operation does not cause any parallel resonance with supply network.
- Does not produce harmonics.
- Can react to network transient voltage variation with countermeasures within milliseconds.
Design criteria for Synchronous Condenser

- Electrical design
Improvement of power system stability and short circuit power using synchronous machine

Influence on Plant Power System Network
Using SC ..... 

- SC decreases effective network impedance.
- Moves existing parallel resonance towards higher frequencies.
- Avoid parallel resonances close to line frequency which is a concern for plants having inter-harmonic components.
- The strong inter harmonics from cyclo-converters could get amplified by the parallel resonance near the fundamental frequency. This can cause mechanical oscillations in supply generator and may result in network instability and/or generator damages.
Impact of SC on network impedance and short circuit power: Case study results

- **Impedance diagram without SC in operation**
  - Parallel resonance exist at 71Hz with an amplification factor of 10 with mechanical excitation frequency of 11 Hz (71-60).
  - At fundamental frequency the network impedance is 3 times higher comparing with and without harmonic filters.
  - Network Voltage sensitivity to sudden load change is 3 times higher with harmonic filters.

- **Impedance diagram with SC in operation**
  - Parallel resonance moved away to 95 Hz with 30% reduction in amplitude and mechanical excitation frequency of 35Hz (95-60).
  - Fundamental frequency network impedance dropped to 25% of the above case and voltage sensitivity reduced by 4 times from above case.
Recent installation: Antapaccay (Xstrata, Peru)

- 320 MVA system short circuit power from utility.
- Two 220-33 kV / 75MVA Transformers with 7.5% short circuit impedance.
- Two 38 MVAr PFC system consisting of 4th, 5th, 7th, 11th and 17th harmonic filter units connected to both 33 kV / 60Hz bus.
- Two synchronous condensers with 20MVA rated power.
- Total plant load 100 MVA including two Ball mills of 16.4 MW and one SAG mill of 24 MW, and 8 MW of cyclo-converter-fed conveyor drives.
Other scenario for power system stability

- More dynamic response would be needed with regard to reactive power compensation.
- More usage of synchronous condensers to boost network short circuit levels.
- An optimum mix of conventional harmonic filter systems with dynamic systems like STATCOMs.
- SVC and TCR would be used together with the tuned filter system to obtain voltage and system stability. (With status information exchange)
- Needs carefully planned power quality installations and measures.
- Large mining complex together with more exigent local regulations will result in increased application of compensation technologies for power quality.
Other scenario for power system stability

- Control philosophy
  - A major part of Consumers are big consumers like SAG and Ball Mills
  - In case of possible network disturbances in weak networks a plant process study would be helpfully
  - The target of this study should lead to the fact which process drive can be switched off or reduced the power requirement by decreasing the speed without to interrupt the production process as a whole.
  - A switching off concept developed together with the process department would solve some of the problems in weak networks
  - In concrete, the switching of concept could define at what level of under voltage the different drives would reduce their speed or to trip.
Summary of ..using SC when and why?

- Power system challenges in mining projects
- Value proposition and salient features of SC
- Design criteria and equipment interface for SC
- Impact of SC on plant supply voltage
- Impact of SC on network impedance and short circuit power including case study and results
- Details on recent installation
- Future and other scenarios
- SC installation in other applications

“Installation of SC is one of the solutions by ABB for power system stability related problems”
