FACTS – Flexible AC Transmission Systems
Static Var Compensators

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Answers for energy.
Reference List

Static Var Compensation – rely on our experience

Nowadays, power producers and providers throughout the world are faced with greater demands for bulk power flow, lower-cost power delivery, and higher reliability. Siemens as a leading manufacturer of FACTS devices delivers systems throughout the world.

Lakehead, Canada
in service since 2010

Alligator Creek, Australia
in service since 2009

Bellaire, USA
in service since 2008

Crosby, USA
in service since 2008

Strathmore, Australia
in service since 2007

Sinop, Brazil
in service since 2007

São Luis, Brazil
in service since 2007

Nopala, Mexico
in service since 2007

Segaliud & Dam Road, Malaysia
in service since 2006

Ahafo, Ghana
in service since 2006

Shinyanga & Iringa, Tanzania
in service since 2006

Limpio, Paraguay
in service since 2003

Funil, Brazil
in service since 2001

La Pila, Mexico
in service since 1999

Cerro Gordo, Mexico
in service since 1998

Chinú, Colombia
in service since 1998

Muldersvlei, South Africa
in service since 1997

Rejsby Hede, Denmark
in service since 1997

Adelanto & Marketplace, USA
in service since 1994/1995

Jember, Indonesia
in service since 1994

Feckenham, UK
in service since 1994

Drakelow, UK
in service since 1994

Harker, UK
in service since 1993

Eddy County, USA
in service since 1992

Pelham I + II, UK
in service since 1991

Kemps Creek I + II, Australia
in service since 1989

Brushy Hill, Canada
in service since 1986

Banabuiu, Brazil
in service since 1983

Milagres, Brazil
in service since 1983

Fortaleza, Brazil
in service since 1982

Zem Zem, Libya
in service since 1982

References not described in this brochure
Siemens solutions for advanced power delivery bring a number of major benefits including:

- Steady state and dynamic voltage control
- Reactive power control of dynamic loads
- Damping of active power oscillations
- Improvement of system stability and power quality
- High reliability under system contingencies

The total installed capacity of Siemens Static Var Compensators exceeds 30,000 MVAr granting a true global experience and customer support.

References described in this brochure

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<td>12 2002</td>
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<td>Bom Jesus da Lapa Brazil</td>
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<td>13 1995</td>
<td>19</td>
</tr>
<tr>
<td>Impala, Illovo &amp; Athene South Africa</td>
<td></td>
</tr>
</tbody>
</table>
References worldwide

**Utility Static Var Compensators delivered by Siemens**

- **Bellaire**
  - Center Point Energy, USA
  - (0/140 MVAR)
  - 138 kV
  - 2008

- **Crosby**
  - Center Point Energy, USA
  - (0/140 MVAR)
  - 138 kV
  - 2008

- **Eddy County**
  - SPS, USA
  - (~50/100 MVAR)
  - 230 kV
  - 1992

- **Lakehead**
  - Hydro One, Canada
  - (~40/45 (60) MVAR)
  - 230 kV
  - 2010

- **Nanticoke**
  - Hydro One, Canada
  - (0/350 MVAR)
  - 500 kV
  - 2011

- **Brushy Hill**
  - NSPC, Canada
  - (~20/120 MVAR)
  - 138 kV
  - 1986

- **Elmhurst**
  - ComEd, USA
  - 2 x (0/300 MVAR)
  - 230 kV
  - 2010

- **Adelanto & Marketplace**
  - WSCC, USA
  - (0/388 MVAR)
  - 500 kV
  - 1994/1995

- **La Pila**
  - CFE, Mexico
  - (~70/200 MVAR)
  - 230 kV
  - 1999

- **Cerro Gordo**
  - Luz y Fuerza, Mexico
  - (~75/300 MVAR)
  - 230 kV
  - 1998

- **Nopala**
  - CFE, Mexico
  - (~90/300 MVAR)
  - 400 kV
  - 2007

- **Chinú**
  - ISA, Colombia
  - (~150/250 MVAR)
  - 500 kV
  - 1998

- **Funil**
  - CHERF, Brazil
  - (~100/200 MVAR)
  - 230 kV
  - 2001

- **São Luís**
  - ELETROORTE, Brazil
  - (~20/55 MVAR)
  - 230 kV
  - 2007

- **Sinop**
  - ELETROORTE, Brazil
  - (~150/250 MVAR)
  - 230 kV
  - 2007

- **Milagres**
  - CHESF, Brazil
  - (~70/100 MVAR)
  - 230 kV
  - 1983

- **Banabuiu**
  - CHESF, Brazil
  - (~70/100 MVAR)
  - 230 kV
  - 1983

- **Fortaleza**
  - CHESF, Brazil
  - (~140/200 MVAR)
  - 230 kV
  - 1982

- **Limpio**
  - ANDE, Paraguay
  - (~150/250 MVAR)
  - 220 kV
  - 2003

- **Ahafo**
  - CONCO, Ghana
  - (~40/0 MVAR)
  - 161 kV
  - 2006
Siemens will supply three static Var compensators (SVCs) for different high-voltage levels to Riyadh-based Saudi Electricity Company (SEC) for stabilization of the country’s 60-Hertz power transmission network. The parallel compensation systems will be deployed at three Saudi sites in the Hiteen, Quassim and Afif substations and are scheduled to be ready for operation between mid-2011 and early 2012.

“We are pleased that our field-proven technology will be deployed to stabilize the Saudi power transmission network,” said Udo Niehage, CEO of the Power Transmission Division of Siemens Energy. The three systems ordered are intended for the 380-kV, 132-kV and 33-kV voltage levels and will have a dynamic compensation capacity of as much as 800 MVAr.
In August 2009 Siemens signed the turnkey contract for engineering, delivery of components, erection and commissioning for the Static-Var-Compensators (SVC) at the Nanticoke substation in Canada. The SVC has a nominal operating range of 0 MVAr to 350 MVAr capacitive. The customer, Hydro One, requires the SVC to facilitate post contingency voltage stability in their 500 kV grid associated with the planned shutdown of a central 4000 MW coal-fired generating source.

The Nanticoke SVC includes 5 TSC branches and is equipped with a redundant control system and four single-phase transformers. Start of commercial operation is scheduled for mid 2011.

### Technical Data

<table>
<thead>
<tr>
<th>Customer</th>
<th>Hydro One, Canada</th>
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<tbody>
<tr>
<td>System voltage</td>
<td>500 kV, 60 Hz</td>
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<tr>
<td>Transformer</td>
<td>4 x 117 MVAr</td>
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<tr>
<td>Operating range</td>
<td>0–350 MVAr</td>
</tr>
<tr>
<td>Definition of SVC branch circuits</td>
<td>5 x TSC</td>
</tr>
</tbody>
</table>

![Diagram of Nanticoke SVC](image)
A new Static Var Compensator (SVC) in RTE’s existing 225 kV Cheviré substation is scheduled to be energized in Nantes, in the north-west of France by end of October 2011.

The SVC will provide dynamic control of the 225 kV network voltage of the Brittany region during high demand periods as, in the past, Brittany network was one of the weakest in France. The SVC output will range from 100 MVar inductive to 100 MVar capacitive at 225 kV and additionally contain and control one mechanically switched capacitor bank of 150 MVar.

RTE is managing the largest network in Europe, ensuring connections between France and its neighbors. The utility is an essential link in the European electricity market. It takes part in constructing the European electricity market by playing a structuring role, thus contributing to better use of the different sources of energy on a European level. The SVC from Siemens will help to stabilize the RTE network especially in the Brittany region.

**Technical Data**

<table>
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<tr>
<th>Customer</th>
<th>RTE, France</th>
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</thead>
<tbody>
<tr>
<td>System voltage</td>
<td>225 kV/50 Hz</td>
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<tr>
<td>Transformer</td>
<td>100 MVar</td>
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<tr>
<td>Operating range</td>
<td>100/100 (250) MVar</td>
</tr>
<tr>
<td>Definition of SVC branch circuits</td>
<td>1 x TCR 1 x TSC 1 x Filter MSC</td>
</tr>
</tbody>
</table>

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**France**

- Spain
- Germany
- Belgium
- Luxembourg
- Switzerland
- Italy

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Chevire

**Strengthening the 225 kV network in Brittany, France**
In November of 2008 Siemens Energy, Inc. was awarded a turnkey contract for two 138 kV Static Var Compensators (SVC’s) by Commonwealth Edison Company (ComEd) for the Elmhurst Substation in Chicago, USA. The installation of the Elmhurst SVCs will contribute to the stabilization of the Northeast Subzone (NESZ) within ComEd’s heavily populated northern Illinois service territory. This will be the first SVC application that ComEd has awarded for installation in their system.

Commonwealth Edison Company (ComEd) is a unit of the Chicago-based Exelon Corporation (NYSE: EXC), one of the nation’s largest electric utilities. Its mission is to maintain the performance of its electrical transmission and distributions systems of its region while providing the customers with reliable and economical electrical service. Two Siemens’ SVCs with an availability of nearly 100% will be installed at the Commonwealth Edison substation in Elmhurst, to maintain transmission stability into the future. The turnkey contract includes all equipment and civil works for two identical SVCs, rated at 0/+300 MVar each. One SVC consists of three Thyristor Switched Capacitors (TSC) branches.

During normal operation the SVCs will only be controlling the existing Mechanically Switched Capacitor Banks (MSCs) at Elmhurst to provide steady state VAR support. In case of voltage drop, the TSC’s will respond immediately and offer voltage stability.

Using the TSC’s only in case of an emergency avoids additional losses to the grid.
Islington

Voltage stabilization around Christchurch

System studies by Transpower, the transmission utility in New Zealand, identified insufficient dynamic reactive support under some situations, for satisfactory voltage recovery following a system disturbance in the region surrounding Christchurch in the South Island.

In March 2007 Siemens Energy was awarded a turnkey contract for a SVC at Islington substation. The installed SVC has a nominal swing range of 75 MVAr inductive to 150 MVAr capacitive. The SVC consists of a thyristor controlled reactor (TCR), thyristor switched capacitors (TSC) and 2 fixed harmonic filters. The SVC is connected to the 220 kV bus with a dedicated power (3rd party) transformer.

As turnkey contractor, Siemens was responsible for project management, engineering, procurement, delivery, civil and assembly works as well as site testing & commissioning. Siemens Germany delivered HV switchgear, valves and associated cooling system, control & protection (C&P) systems, Trench reactors and capacitors.

The local Siemens team (on-shore) based in AUS/NZ managed the total project and delivered a successful project on time by carefully managing on-shore and off-shore resources & third-party local suppliers and sub-contractors. The result was an efficient progress of the sequential civil works, construction, installation and commissioning periods. Transpower particularly commended Siemens on construction site management and safety performance.

The Islington SVC entered commercial operation in September 2009.

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<th>Customer</th>
<th>Transpower, New Zealand</th>
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<td>System voltage</td>
<td>220 kV/50 Hz</td>
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<td>Transformer</td>
<td>3 x 50 MVAr</td>
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<tr>
<td>Operating range</td>
<td>–75/150 MVAr</td>
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<tr>
<td>Definition of SVC</td>
<td>1 x TCR</td>
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<tr>
<td>branch circuits</td>
<td>1 x TSC</td>
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<tr>
<td></td>
<td>1 x Filter</td>
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</tbody>
</table>

![Diagram of Islington SVC](diagram.png)
Greenbank & Southpine

Voltage support to the greater area of Brisbane

In April 2007 Siemens Energy was awarded a turnkey contract for two SVCs at Greenbank and South Pine substations in the South East Queensland (SEQ) 275 kV grid of Australia. With the installation customer Powerlink plan to provide sufficient power compensation and to add additional voltage support to the greater area of Brisbane by dynamic reactive power compensation.

The SVCs have a nominal operating range of 100 MVAr inductive to 250 MVAr capacitive with an overload of up to 350 MVAr for one hour. Each SVC consists of one thyristor controlled reactor (TCR), two thyristor switched capacitors (TSC) and three fixed filter circuits for harmonics.

Being the turnkey contractor, Siemens was responsible for design engineering, delivery, civil and assembly works as well as site testing. Transformers were manufactured locally in Australia and Siemens Germany delivered the core technology, i.e. thyristor valves and the SVC control & protection (C&P) system, assembled and tested. The successful team effort by the international management team achieved the completion for both sites on time. Greenbank and Southpine SVCs started operation in 2008.

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<tr>
<td>Operating range</td>
<td>−100/250 (350) MVAr</td>
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Definition of SVC branch circuits

- 1 x TCR
- 2 x TSC
- 3 x Filter
In spring 2005 the refurbishment of Powerlink’s Nebo SVC (originally built by a competitor) was awarded to Siemens. The scope of work for this SVC, consisting of a Thyristor Switched Capacitor (TSC) and a Thyristor Controlled Reactor (TCR) branch, included the thyristor valves and accessories, the thyristor cooling system and the complete control and protection system.

Since the TSC plays an important role in Powerlink’s network, the contract was divided into two parts, the first of which placed two major challenges:

- To replace the damaged TSC valve in only five months – and to integrate a Siemens TSC valve into a competitor’s control and protection system. The key to success was a very detailed status quo investigation including thorough checks of all interfaces – and minute logistic planning.
- The complete Control and Protection System and the TCR valve were successfully refurbished and Powerlink took over the complete refurbished SVC even before the contractual date of practical completion.

### Technical Data

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<tr>
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<td>Operating range</td>
<td>+260 MVAR (capacitive) to -80 MVAR (inductive)</td>
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<td>Definition of SVC branch circuits</td>
<td>1 x TCR 1 x TSC 2 x STF</td>
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</table>
At almost the same time as the Nebo project, Powerlink placed another refurbishment order for nine SVCs in their network. These SVCs are supporting an important railway system in central Queensland used for transporting coal from the inland mines to the coal terminals at Queensland’s coastline. The scope of work included the replacement of the thyristor valves, the cooling system and the web based control and protection system, which encompasses the remote control of the SVCs. To support the coal transport system’s reliability, the SVCs had to remain in service as long as possible throughout the refurbishment project.

Only Siemens was able to offer a solution that limited the outage time per site to 48 hours. This was achieved by introducing a mobile SVC solution that can be used during the main refurbishment work on each site. Thus, shutdown is only required to re-establish connections to the mobile system after disconnecting the existing system and, of course, for testing. The Railway SVC refurbishment project was completed at the end of 2007.
Furthermore Siemens took special care to fulfill the customer’s requirements in terms of noise reduction and architectural appearance. Therefore, the SVC was completely housed in a “barn-type” building equipped with special sound muffling materials and components. The buildings height was kept below 6 meters, made possible by optimizing the equipment configuration inside.

SEAS-NVE, the largest utility in Denmark operates the Nysted Offshore Windpark located south of the island of Lolland. Voltage fluctuations caused by this facility lead to voltage stability problems in the 132 kV transmission system. In June 2005, Siemens was awarded a turnkey project for the construction of an SVC located on the island of Lolland. It provides the necessary reactive power balance for the system, helps to improve voltage quality and increases system stability.

Siemens offered a special solution for this project: the SVC has a 12-pulse configuration consisting of a TCR (Thyristor Controlled Reactor) and a filter in each of the two secondary circuits of the 3-winding step-down power transformer. One of the transformer’s secondary winding is connected in star, while the other is connected in delta. The delivered high-pass filters are tuned to the 11th harmonic and are connected in star. The 12-pulse configuration has the advantage that due to the phase shift in the two secondary busbars of the SVC, the 5th, 7th, 17th and 19th harmonics produced by each of the TCR branches cancel each other out, helping to meet the stringent harmonic requirements.

### Technical Data

- **Customer**: SEAS-NVE, Denmark
- **System voltage**: 132 kV/50 Hz
- **Transformer**: 80.2 MVA
- **Operating range**: +80.2 MVAr (capacitive) to –65 MVAr (inductive)
- **Definition of SVC branch circuits**: 12-pulse configuration
  - 2 x TCR
  - 2 x Filters
One of the largest SVCs in the US is located at Devers 500 kV substation, near Palm Springs, California. The Devers SVC was ordered by SCE (Southern California Edison) as a turnkey project in September 2005 to strengthen the Devers-Palo Verde transmission path from Arizona to California. Since it was put into commercial operation in September 2006 the SVC adds additional voltage support to the Palm Springs area, thus SCE can increase its import transmission capability from Arizona during high demands period.

The full capacitive output of the SVC of 330 MVAr is provided by two TSC branches and two filter branches. The capacitive output of 440 MVAr for 1 h is provided by three TSC branches, two filter branches and one TCR in operation. The SVC’s full inductive output of 110 MVAr is provided by two TCR branches operating in parallel with the filters. In addition to the SVC, an MSC of 165 MVAr connected to the 525 kV bus was included in the scope of supply, conforming a Static Var System (SVS) with total capacitive output of 605 MVAr.

### Technical Data

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<td>Transformer</td>
<td>4 x 100 MVA</td>
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<td>Operating range</td>
<td>+330 MVAr up to –110 MVAr (inductive) +440 MVAr capacitive for one hour +605 MVAr max.</td>
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<td>Definition of SVC branch circuits</td>
<td>2 x TCR 3 x TSC 2 x Filters MSC</td>
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</table>

![Devers SVC Diagram]
Based on planning studies, two major load centers (The Westbank area near New Orleans and the Woodlands area just north of Houston) in Entergy’s network were identified as areas with potential voltage stability problems.

After evaluation of technical, economical and reliability factors, SVCs were considered as the preferred solution for both of these areas. In conjunction with Entergy’s SVC design specifications, two SVCs and a Fixed Series Capacitor (FSC) were awarded on a turnkey basis to Siemens Power Transmission Division in 2004.

The first 300 MVAr SVC was commissioned at the Ninemile 230 kV station in the New Orleans area in May 2005. The second 300 MVAr SVC at Porter 138 kV station as well as the new FSC at Dayton Substation entered into operation in Entergy’s Western Region near Houston, Texas in April 2006.

Technical Data

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<th>Customer</th>
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<td>Transformer</td>
<td>4 x 100 MVA each SVC</td>
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<tr>
<td>Operating range</td>
<td>+ 300 MVar (capacitive) to 0 MVar (inductive)</td>
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<tr>
<td>Definition of SVC branch circuits</td>
<td>3 x TSC</td>
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</table>
The HVDC Baltic Cable (with a transmission capacity of +/-600 MW) was constructed in the early nineties to link the power systems of Germany and Sweden. To ensure optimum dynamic system operation the original plan was to connect the Herrenwyk HVDC converter station in Germany to the 380 kV grid. However, due to changes in the European power market, this connection was abandoned and the HVDC link was consequently connected to the 110 kV network in the Lübeck district, which is inadequately dimensioned in terms of necessary system impedance.

Due to this and based on detailed network studies, E.ON decided to carry out several extensions in the northern German power network between 2003 and 2004. In conjunction with these extensions and considering the highly dynamic behaviour of the Herrenwyk HVDC converter station, E.ON Netz GmbH awarded a turnkey contract to Siemens to build a new SVC on the former site of the Lübeck-Siems power plant in November 2003, in order to ensure voltage quality in its northern 380 kV grid. The Thyristor Controlled Reactors had to be built indoors to fulfill very stringent requirements regarding noise emissions, using special noise damping materials and methods. The project also included the first-ever implementation (in an SVC) of the high-reliable control system based on SIMATIC TDC®, a proven industrial hardware design from Siemens. The SVC was successfully put into commercial operation only 12 months after the contract had been signed.
This Static Var Compensator, located at the 500 kV Bom Jesus da Lapa II substation, maintains voltage stability over the 1100 km long 500 kV overhead transmission line between the Serra da Mesa substation and the Sapeaçu substation near Salvador in the northeast of the country.

This large Siemens SVC with a control rating of 500 MVAR was built in the record time of only 12 months for the Italian Enelpower utility company to strengthen the east-west grid interconnection in Brazil’s northeast under the project name “Interligação Sudeste–Nordeste”. Similar to the solution for the Funil SVC, all electronic power components needed for compensation were installed in steel containers.

Since its commissioning in December 2002, the SVC at Bom Jesus da Lapa II substation has been stabilizing voltage and frequency across the grid, minimizing losses and responding swiftly and reliably to load changes.

### Technical Data

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<th>Customer</th>
<th>Enelpower, Brazil</th>
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<tr>
<td>System voltage</td>
<td>500 kV/60 Hz</td>
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<td>Transformer</td>
<td>4 x 83.3 MVA</td>
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<td>Operating range</td>
<td>+250 MVAR (capacitive) to –250 MVAR (inductive)</td>
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<tr>
<td>Definition of SVC branch circuits</td>
<td>2 x TCR, 1 x TSC, 2 x Filters</td>
</tr>
</tbody>
</table>
Impala, Illovo & Athene

Voltage stability to ensure security of power supply

Richards Bay is a major industrial centre of the Republic of South Africa with aluminium smelter plants, paper mills and open-cast Mining, among others located in the region. With the main generation centres of the Transvaal over 200 km away, maintaining a stable and secure supply to this region is critical. In 1994 and 1995 Siemens successfully installed three Static Var Compensators for the South African Utility ESKOM (Electricity Supply Commission) at their 275 kV substations (Impala and Illovo) and at their newly built 400 kV substation Athene.

The NATAL Static Var Compensators are designed for:

- Fast dynamic network stabilization (voltage stabilisation)
- Reduction of voltage unbalance
- Reduction of network disturbances
- Increasing of transmission capability
- Control of external reactive-power devices

### Technical Data

<table>
<thead>
<tr>
<th>Customer</th>
<th>ESKOM, South Africa</th>
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<tr>
<td>System voltage</td>
<td>275 kV/50 Hz; 400 kV/50 Hz</td>
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<tr>
<td>Transformer</td>
<td>4 x 66.7 MVA</td>
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<tr>
<td>Operating range</td>
<td>+100 MVAr (capacitive) to −300 MVAr (inductive)</td>
</tr>
<tr>
<td>Definition of SVC branch circuits</td>
<td>2 x TCR 3 x Filters</td>
</tr>
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275 kV/400 kV, 50 Hz