Flexible AC Transmission Systems
Series Compensation
Nowadays, power producers and deliverers all over the world are faced with greater demands for bulk power flow, lower-cost power delivery, and higher reliability. Siemens solutions for advanced power delivery translate into a number of solid benefits including:

- Increase of energy transfer without adding new transmission lines
- Direct control of the transmission path, voltage and flow
- Minimized delivery cost as generation sources change
- High reliability under contingencies
- Improvement of power quality

Siemens supplies Fixed Series Capacitors as well as Thyristor-Controlled SC’s and of course, Siemens latest development Thyristor-Protected Series Capacitors. Series Capacitor installations made by Siemens increase power transfer capacity on existing transmission systems all over the world.

WAPA – ASC Kayenta
in service since 1990

Hydro-Québec – FSC Montagnais
in service since 1993

GENER – FSC Atacama
in service since July 1999

ELETRONORTE – FSC Imperatriz & Presidente Dutra
in service since March 1999

FURNAS – TCSC Serra da Mesa
in service since March 1999

SCE – TPSC Vincent #1 to #3
in service since 2000/2001/2002

SCE – TPSC Midway #1 and #3
in service since 2004/2005

JPEPC – two FSC’s Yangcheng
in service since 2000

ENTERGY – FSC Jacinto
in service since May 2000

FURNAS – FSC Samambaia
in service since December 2002

FURNAS – FSC Ibiuna
in service since December 2002

Tian-Guang TCSC
in service since November 2003

Hechi – FSC
in service since November 2003

Maputo – FSC Mozambique
in service since April 2003

Cuddapah-Gooty-FSC
will be in service August 2004

Dayton FSC
will be in service in May 2006

TALA Project will be in service in 2006

Lexington– FSC Valley – FSC
in service since November 2003/Dezember 2003

São João do Piauí – FSC Brazil
in service since August 2004

Eldorado Lugo and Moenkopi
will be in service May and June 2006

Without description

EVN Vietnam 2 FSC’s
will be in service 2006

CFE Mexiko – five FSC’s
in service since 2003

Southern California Edison – SSRD Los Angeles USA
in service since 1981

Sichuan Electric Power – China 3 FSC’s
will be in service in June 2006

Shahin – Alusa – 2 FSC’s
Marabá – Açailândia
in service since 2004

Power Grid of India – Lucknow 2 FSC’s
will be in service November 2006
Kayenta –
World’s First 3-Phase Thyristor-Controlled Series Capacitor

Customer: WAPA (Western Area Power Administration)
Project Name: ASC Kayenta
Location: in north-eastern Arizona, USA in the middle of the 320-kilometer Shiprock-to-Glen Canyon 230-kV transmission line
Capacitor Rating: 55 Ohm/165 MV Ar (conventional)
40 Ohm/120 MV Ar (conventional)
15 Ohm/45 MV Ar (ASC)
Compensation Degree: up to 70% conventional
up to 100% TCSC
Thyristor Data: 100mm Ø thyristors
3.5 kA continuous current
5.5 kV blocking voltage
Digital control and protection system: Siemens SIMADYN D

In 1990, Siemens completed a joint project with WAPA for the world’s first transmission system with a continuously variable, three-phase thyristor-controlled series capacitor installation at the Kayenta substation in Arizona, USA. The series capacitor consists of two 230-kV conventional series capacitor banks, each rated at 165 MVAr with a single-phase impedance of 55 Ohms. One of the two 55-Ohm banks is split into a 40-Ohm and a 15-Ohm segment. This allows the addition of Thyristor-Controlled Reactors (TCR) in parallel with the 15-Ohm segment.

This provides direct control of the transmission line impedance and offers several advantages to conventional fixed series capacitors. The Kayenta Advanced Series Compensation (ASC) operates in the following manner: when a controlled reactor is connected in parallel with a series capacitor, the net series compensation seen by the transmission line is the impedance that results from the capacitor and reactor. By varying the impedance of the parallel reactor, the total impedance of the compensation is changed. The ASC controls the reactor current as well as the line current, so the ASC can smoothly control the capacitive impedance from 15 Ohms to 60 Ohms.
Montagnais –
Fixed Series Capacitor in Canada

<table>
<thead>
<tr>
<th>Customer:</th>
<th>Hydro-Québec (HQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name:</td>
<td>Montagnais FSC</td>
</tr>
<tr>
<td>Location:</td>
<td>Poste Montagnais, Canada</td>
</tr>
<tr>
<td></td>
<td>North East Network</td>
</tr>
<tr>
<td>Capacitor Rating:</td>
<td>30 Ohm, 2300 A, 1500 MVAr</td>
</tr>
<tr>
<td></td>
<td>(3 x 476 MVAr)</td>
</tr>
<tr>
<td>Compensation Degree:</td>
<td>40%</td>
</tr>
<tr>
<td>MOV Data:</td>
<td>44 MJ MOV energy capability</td>
</tr>
<tr>
<td></td>
<td>40 kA_{peak} MOV current at protective level</td>
</tr>
<tr>
<td></td>
<td>252 kV/2.58 pu protective level</td>
</tr>
<tr>
<td>Digital control and protection system:</td>
<td>Siemens SIMADYN D</td>
</tr>
</tbody>
</table>

Part of New York’s electric energy is supplied by Hydro-Québec, from the hydroelectric power plant “Churchill Falls” on the coast of Labrador in Newfoundland. To increase the transferable power of the 735-kV transmission line from the power plant Churchill Falls to Montreal – a distance of about 1200 km, Hydro-Québec decided to install three 3-phase series capacitors at the Montagnais substation in the Canadian province Québec. From Montreal, some of the electricity is transmitted via the HVDC back-to-back link at Chateauguay in Canada to the network operated by the New York Power Administration in the USA. Montagnais is one of the most important facilities in Hydro-Québec’s eastern power network, because it is not far away from the generators in Churchill Falls.

In 1993, Hydro-Québec placed an order with Siemens for the supply and installation of the three series capacitors, because Siemens was able to fulfill the special technical demands in accuracy and reaction time needed for the extreme conditions in the Canadian winter. Siemens was also the first manufacturer whose surge arresters succeeded in withstanding Hydro-Québec’s extra tough pressure relief tests for the 735-kV application, involving a full discharge of a specially set-up bank of original capacitors.

The Montagnais series capacitor is able to withstand the extreme temperatures from –50 °C to +40 °C. The series capacitor installation helps to improve the transmission line stability and is able to compensate up to 40% of the inductive line impedance, thus enhancing the transferable power to 6000 MVA.
Atacama –
Fixed Series Capacitor
in Chile

Customer: GENER
Project Name: Atacama FSC
Location: in the Atacama desert in northern Chile
Capacitor Rating: 96.65 Ohm/490 MVar at 1.3 kA
Compensation Degree: 70%
MOV Data: 69 MJ MOV energy capability
9.17 kA\(_{peak}\), MOV current at protective level
345 kV/1.94 pu protective level

Digital control and protection system: Siemens SIMADYN D

There has been considerable investment in new and powerful three-phase transmission systems during the 1990’s, especially in Latin America. A typical example is the 400-km-long 345-kV AC transmission system for carrying power across the Andes from Salta in Argentina to Zaldivar in Chile. The utilities chose three-phase AC transmission in this case because not only is it less costly than a compatible DC link but there is also the possibility to extract power anywhere along the transmission line. To maximize the amount of active power that can be transferred and to ensure stable operating conditions, all AC transmission systems of this length and capacity require series compensators. For this 633-MW AC interconnection, Siemens has supplied one fixed series compensator for the Atacama substation. This series capacitor design includes several special features, for example, due to the altitude of 2840 m, the insulation has been rated for a 500-kV system, while the system voltage is only 345 kV.

For the same reason, the series capacitor has not been equipped with a series gap, but with a comparatively high value of 69 MJ of arrester energy per phase. The Atacama series capacitor is the first series compensation system where polymer casing arresters are used. This reduces the weight of the installation and therefore improves the seismic withstand capability of the platform.
Imperatriz & Presidente Dutra – Serra da Mesa
North-South Interconnection in Brazil

Brazil’s national energy holding Electrobrás had been planning to connect the northern with the southern power networks for a long time. Finally, the heavy increasing demand for electric energy in the south decided the issue to build the North-South Interconnection line. The network in the south, south-east, central and mid west regions supplies energy to the area of the country south of the capital, Brasília, and the network in the north and north-east provides energy to the areas north-east of Bahia to Belém on the Amazon delta.

Most of the electric power of both networks is generated in hydroelectric power plants, for example from the power plant Xingó at the São Francisco river. The backbone of the interconnection line is the 500-kV transmission line from Imperatriz to Serra da Mesa.

The North-South Interconnection, with its capacity of 1300 MW, enables a more flexible expansion of the hydroelectric power plants along the Tocantins river. In 1997, Siemens received the order to supply three series capacitors as part of the first North-South Interconnection in Brazil. The scope consisted of two fixed series capacitors in the northern network in Eletronorte’s substations Imperatriz and Presidente Dutra and one thyristor-controlled series capacitor in the southern network at Furnas substation Serra da Mesa.
Serra da Mesa
Customer: FURNAS – Centrais Elétricas S.A.
Project Name: Serra da Mesa (SdM)
Location: north of Brasilia, Brazil
Capacitor Rating: 13.27 Ohm (blocked valve) and 15.92 Ohm (TCSC)/107.46 MVar at 1.5 kA
Compensation Degree: 5–6% (continuous)
7–15% (temporary)
TCR Data: 100 mm Ø 5.5 kV electrically triggered thyristors
23.9 kV nominal valve voltage at 3.55 kA
1.123 MJ Valve MOV
87.3 kV protective level
MOV Data: 22.46 MJ MOV energy capability
27.2 kA_{peak} MOV current at protective level
89.8 kV/2.65 pu protective level
Digital control and protection system: Siemens SIMADYN D
Vincent #1 to #3 –
World’s First Thyristor-Protected Series Capacitors

Customer: Southern California Edison (SCE)
Project Name: Vincent #1 to #3
Location: near Palmdale, north of Los Angeles, CA, USA in the Vincent-to-Midway 500-kV transmission lines
Capacitor Ratings: 23.23 Ohm/401 MVAR at 2.4 kA
Compensation Degree: ~ 35%
Thyristor Valve Data: 125 mm Ø light-triggered thyristors
55.8 kV nominal valve voltage
8 MJ Valve MOV
2.3 pu protective level
>110 kA short-circuit current (9-cycle)
Digital control and protection system: Siemens SIMADYN D

The Vincent substation, north of Los Angeles, is part of the western US 500-kV transmission network, connecting the northern US hydropower plants to the Southern California load centers. In spring 1998, Southern California Edison planned to replace five of the existing series capacitors at the Vincent and Midway substations with new ones. During the engineering and tender stage for the new series capacitors, Siemens decided to offer a totally new type of series capacitor to meet the high requirements, not protected by MOV or GAP but protected by a thyristor valve. Siemens received the turnkey contract in March 1999. Due to Siemens’ experience in conventional series capacitors and SVC installations, the first thyristor-protected series capacitor (TPSC) at the Vincent substation near Palmdale was completed in only 13 months and by the middle of April 2000, the world’s first TPSC was in commercial operation. In July 2001 and in May 2002, the two remaining TPSC’s at the Vincent substation were in commercial operation.

Due to the fact that the Vincent substation is only 8 miles away from the Saint Andrews fault, the platform and other equipment have been designed to meet the extra high seismic requirements. The TPSC design is future-oriented and can be adjusted to match the increasing requirements in HV transmission systems, for example it is possible to extend the Vincent and Midway TPSC’s to full TCSC operation.
Midway #1 and #3 –
Thyristor-Protected
Series Capacitors

Customer: Southern California Edison (SCE)
Project Name: Midway #1 and #3
Location: near Buttonwillow, north of Los Angeles, CA, USA in the Vincent-to-Midway 500-kV transmission line
Capacitor Ratings: 23.23 Ohm/401 MVar at 2.4 kA
Compensation Degree: ~ 35%
Thyristor Valve Data: 125 mm Ø light-triggered thyristors
55.8 kV nominal valve voltage
8 MJ Valve MOV
2.3 pu protective level
Digital control and protection system: Siemens SIMADYN D

The Midway #1 and #3 refurbishments are successor projects of the Vincent TPSC projects. The two series capacitors are located at PG&E’s Midway substation near Buttonwillow, California. The Midway substation is also part of the western US 500-kV transmission network.

In September 2003, Siemens received the order to renew the Midway #1 and #3 series capacitors. The design of the Midway series capacitors is identical with the Vincent TPSC’s, with only some minor differences in the control and protection system.

The first Midway TPSC #1 will be in commercial operation by December 2004 and the second installation Midway TPSC #3 will be finished about half a year later in June 2005.
| **Customer:** | Jiangsu Provincial Electric Power Company (JPEPC) |
| **Project Name:** | Yangcheng |
| **Location:** | in Sanbao substation, China |
| **Capacitor Rating:** | 29,92 Ohm/500 MVAr at 2.36 kA |
| **Compensation Degree:** | 40% |
| **MOV Data:** | 56.55 MJ MOV energy capability |
| | 40 kApeak MOV current at protective level |
| | 230 kV/2.3 pu protective level |
| **Digital control and protection system:** | Siemens SIMADYN D |

In fall 1999, Siemens, in close cooperation with the local PTD office in Shanghai, succeeded in winning a hard-fought battle with the competition for the first series compensation system in China. Fixed series compensation has been found as the appropriate choice not only to enable the desired power increase but also to stabilize the two interconnected strong networks by reducing the connecting line impedance. The compensation system is one part of the Yangzhou No. 2 Power Plant Project, Jiangsu, China. The customer JPEPC (Jiangsu Provincial Electric Power Company) awarded Siemens the project which comprised delivery of the equipment, CIF Shanghai, and installation and commissioning supervision. The project consists of two 3-phase Fixed Series Capacitor (FSC) compensation systems, each with a reactive power of 500 MVAr and an operational voltage of 500 kV. Both of the FSC's have been installed and commissioned in the Sanbao substation.

The picture shows a successful gap trigger after a single-phase staged-fault test.
Jacinto –
Fixed Series Capacitor in Texas, USA

Customer: ENTERGY Services Inc.
Project Name: Jacinto
Location: near Cleveland in Texas, USA
Capacitor Rating: 21 Ohm/223 MVar at 1.88 kA
Compensation Degree: 70%
MOV Data: 54.8 MJ MOV energy capability
12 kApeak MOV current at protective level
128.4 kV/2.3 pu protective level
Digital control and protection system: Siemens SIMADYN D

In 2000, Entergy Services Inc. required an upgrade for the energy transfer capacity of the AC transmission lines for the Houston Area, because of the increasing demand for power. The easiest solution to enhance the energy transfer capacity for the Houston Area was to install one Series Capacitor at the Jacinto substation near Cleveland, Texas. In summer 2000, Siemens was awarded the turnkey project from Entergy Services Inc. to supply and install one 230-kV Fixed Series Capacitor at the Jacinto substation. The series capacitor installation was completed by June 15, 2001. The Jacinto Series Capacitor has been constructed without a spark gap, but for future demands, the addition of a spark gap has been foreseen in the design of the platform and control equipment.
Customer: FURNAS – Centrais Elétricas S.A.
Project Name: Samambaia
Location: near Brasilia, in the north-south energy transmission network in Brazil
Capacitor Rating: 31.75 Ohm/252 MVar at 1.628 kA
Compensation Degree: 48%
MOV Data: 24.8 MJ MOV energy capability
20 kApeak MOV current at protective level
168.1 kV/2.3 pu protective level
Digital control and protection system: Siemens SIMADYN D

In September 2001, Siemens received a turnkey contract from Furnas to install one series capacitor at Samambaia substation, near the capital Brasilia. The capacitor bank design is identical to the Ibiuna FSC, although Samambaia consists of only one segment. The installation in Samambaia was finished in May 2003.
Parallel to the Samambaia project, Furnas required to install one series capacitor in the 525-kV transmission line from the Ibiuna to Bateias substation.

The turnkey contract for the Ibiuna project was awarded to the Siemens/Schneider Consortium in September 2001. The series capacitor bank is designed to have two segments in series because of the arrangement of the series capacitors in the AC system and the identical requirements of the Furnas specification the designs of the capacitor banks are identical.

The Ibiuna installation was finished in March 2003.
Customer: State Power South Company
Project Name: Tian-Guang TCSC
Location: PingGuo substation, Guangxi Province, P.R. China
Capacitor Rating: Fixed segment: 29.2 Ohm, 2000 A, 350 MVAr
Controlled segment: 4.15 Ohm to 12.45 Ohm, 2000 A, permanently operated at 4.57 Ohm, 55 MVAr
Compensation Degree: Fixed segment: 35%
Controlled segment: 5%
TCR Data: Reactor: 2.1 mH, 2000 A
Thyristor valve: 10 kV, 2000 A, light-triggered thyristor (LTT)
MOV Data: Fixed segment: 37 MJ
Controlled segment: 6 MJ
Digital control and protection system: Siemens SIMADYN D

The South China power grid is a complex power system combined with long-distance AC and DC lines for power transmission to the load center, at the sending end of which there are several power supplies and AC and DC lines, resulting in wide differences in system operation modes. The increasing demand for electric power in the Chinese south provinces requires extension of the HV power grid. The Tian-Guang TCSC and the Hechi FSC are part of this west-to-east network improvement. Their location has been carefully selected, and together with the Tian-Guang and the Gui-Guang HVDC links they ensure future energy supply and contribute reliability and improvement for the consumers.

Reasons and purposes for the installation of the Tian-Guang TCSC
In power systems, TCSC’s are mainly used for the purposes of system transient stability improvement, low-frequency power oscillation mitigation, system power flow control and subsynchronous resonance mitigation. According to the analysis on the Tian-Guang TCSC project, the TCSC mainly serves for system stability improvement and low-frequency oscillation mitigation. As there are several AC power transmission lines at the same voltage
level and in the same power transmission direction, the purpose of the construction of Tian-Guang TCSC is to further improve the capabilities of AC transmission lines within the South China power grid and improve the capabilities of the whole network in respect of disturbances.

It is recognized that the installation of a TCSC on inter-regional ties is a good means of mitigation of interregional low-frequency oscillations. Due to the fact that a TCSC is adopted in west-to-east power transmission lines within the South China power grid, the PSS configurations are simplified. Setting of the PSS parameters is easy and the dynamic stability of the system is improved.

**The series compensation system at Hechi substation**

Being an important 500-kV substation in Guangxi Province under South China power network, Hechi substation is also an intermediate substation for transmission from Guizhou power system and the future Longtan hydropower station to the load center of Guangdong and Guangxi provinces.

The purpose of construction of the series compensation project for Hechi substation is to further increase the transmission capability and anti-disturbing capability of the whole network.
Customer: MOTRACO
Project Name: Maputo FSC
Location: Maputo, Mozal substation
Capacitor Rating: 28.44 Ohm/344 MVAr at 2.007 kA
Compensation Degree: 50%
MOV Data: 19 MJ MOV energy capability, 11.5 kApeak MOV current at protective level, 195 kV/2.4 pu protective level
Digital control and protection system: Siemens SIMADYN D

In May 2002, Siemens received the turnkey contract from MOTRACO to install two series capacitor banks in the MOTRACO network. MOTRACO is an independent transmission company owned in equal shares by three utilities: EdM from Mozambique, SEB from Swaziland and ESKOM from South Africa. The MOTRACO network consists of two 400-kV transmission lines from ESKOM (Camden and Arnot substation) to the Maputo substation. The transmission line from Camden to Maputo is intersected by a 400-kV busbar in Swaziland at Edwaleni II substation. The bulk of the energy which is transferred via these transmission lines is for the Mozal aluminum smelter in Maputo. The capacity of the aluminum smelter will be increased. Therefore also the lines have to be upgraded to cope with the increased power demand. As part of this upgrade, Siemens supplies the two fixed series capacitor banks. One bank is installed directly in Maputo substation in the Edwaleni-Maputo line. The second FSC is installed in Barberton substation approximately halfway between Arnot power station and Maputo substation close to the city of Barberton, in the Republic of South Africa. Both FSC’s have been in commercial operation since mid April 2003.
Barberton – Fixed Series Capacitor in the Republic of South Africa

<table>
<thead>
<tr>
<th>Customer:</th>
<th>MOTRACO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name:</td>
<td>Barberton FSC</td>
</tr>
<tr>
<td>Location:</td>
<td>Barberton substation, near Nelspruit, in the Republic of South Africa</td>
</tr>
<tr>
<td>Capacitor Ratings:</td>
<td>44.24 Ohm/535 MVAR at 2.007 kA</td>
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<tr>
<td>Compensation Degree:</td>
<td>50%</td>
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<tr>
<td>MOV Data:</td>
<td>18.8 MJ MOV energy capability, 12.3 kA_{peak} MOV current at protective level, 287 kV/2.29 pu protective level</td>
</tr>
<tr>
<td>Digital control and protection system:</td>
<td>Siemens SIMADYN D</td>
</tr>
</tbody>
</table>
Cuddapah – Gooty
Fixed Series Capacitor in India

Customer: Powergrid Corporation of India Ltd.
Project Name: Cuddapah Substation
Location: India
Capacitor Ratings: 36.9 Ohms/201.8 MVAr/1.35 kA
Compensation degree: 40%
MOV Data: 46 MJ MOV energy capability,
14.5 kApeak MOV current at protective level
156.1 kV/2.22 pu protective level

Digital control and protection system: Siemens SIMADYN D

Customer: Powergrid Corporation of India Ltd.
Project Name: Gooty Substation
Location: India
Capacitor Ratings: 33.2 Ohms/181.5 MVAr/1.35 kA
Compensation degree: 40%
MOV Data: 60.8 MJ MOV energy capability,
14.7 kApeak MOV current at protective level
145.4 kV/2.29 pu protective level

Digital control and protection system: Siemens SIMADYN D

The 40% fixed series compensation at Southern Region is part of POWERGRID’s 400 kV network development in the Hyderabad and Bangalore area. The banks are installed on both circuits of the Nagarjunasagar to Cuddapah 400 kV S/C lines at Cuddapah Substation, and on both circuits of the Gooty to Neelamangla 400 S/C lines at Gooty Substation. All four banks have the same capacitor design although the rating at Gooty is slightly lower than in Cuddapah. The banks are equipped with metal oxide varistors (MOV) as overvoltage protection for the banks. A triggered spark gap is used during internal faults to limit the energy accumulation of the MOV. The State-of-the-art digital protection system SIMADYN D with optic signal transmission from platform to ground protects the banks in case of internal and external faults.
Dayton –
Fixed Series Capacitor
Texas in USA

Customer: ENTERGY Services Inc.
Project name: Dayton
Location: Dayton Station, Dayton in Liberty County, Houston Texas
Capacitor Ratings: 24.33 Ohm/258 MVAr at 1.88 kA
Compensation Degree: 70%
MOV Data: 55MJ MOV Energy capability
15 kApeak MOV current at protective level
145 kV/2.25 pu protective level

Digital Control System: Siemens SIMADYN D

July, 2004 – The Entergy Corporation awarded three high voltage transmission projects to Siemens Power Transmission & Distribution, Inc. The new installations will help Entergy to increase reliability and capacity on its power transmission system in order to help meet increasing demand in its Western Service Area.

The three FACTS (Flexible AC Transmission Systems) projects will include two Static VAR Compensators (SVC) and one Fixed Series Capacitor (FSC) that will be built at three primary Entergy substations in Texas and Louisiana.

The Dayton FSC will be basically a copy of the Jacinto FSC project which was installed by Siemens for Entergy in the year 2001. The main differences being the higher reactive power (223/258 MVAr) and the higher protective level (128.4/145 kV).

The Dayton FSC system also does not include a Spark Gap but provision has been made for the inclusion of one at a later date.
Siemens compensation equipment improves transmission capacity in Indian high voltage grid

Siemens received this order in May 2004 from the Power Grid Corporation of India Ltd. in New Delhi to set up four compensation systems featuring state of the art thyristor technology. The purpose of this new equipment is to improve the transmission performance and the reliability of the 400 kV overhead line between Purnea in eastern India and Gorakhpur in the north of the country. The order includes the construction and installation work involved in the systems, along with supply and engineering of all the high-voltage components, the control and protection devices and the thyristor valves.
The Power Grid Corporation of India Ltd. (PGCIL) is constructing a 475 km long overhead line from Purnea in the state of Bihar via Muzafarpur to Gorakhpur in the state of Uttar Pradesh. This project transmits surplus energy from eastern India to the conurbations around Delhi, where the existing generation capacity can no longer meet demand.

For the systems in Purnea and Gorakhpur respectively, Siemens is supplying two thyristor-controlled series compensation systems and two fixed compensation systems. Series compensation systems enhance the transmission capacity of the overhead line and ensure stability in the grid. The light-triggered thyristors (LTTs) used are notable for their very high current carrying capacity and blocking voltage. Direct light-triggered thyristors make it possible to reduce the number of electronic components in the converter valves by about 80%. A further advantage of this modern thyristor design is that all the firing and monitoring electronics are at earth potential; the equipment is consequently accessible during operation.

Siemens is the only supplier to use LTTs in so-called FACTS (Flexible AC Transmission System) projects. With energy markets developing and expanding dynamically all over the world, such solutions provide significant ways of improving the characteristics of high-voltage transmission networks.

This order underlines the capability of Siemens as undisputed market- and technology leader in the controlled series compensation technology segment.
### Lexington –
**Fixed Series Capacitor in Virginia, USA – Gap Less Design**

<table>
<thead>
<tr>
<th>Customer</th>
<th>Dominion Virginia Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name</td>
<td>Lexington &amp; Valley FSC's</td>
</tr>
<tr>
<td>Location</td>
<td>near Rockbridge Bath, Virginia</td>
</tr>
<tr>
<td>Capacitor Ratings</td>
<td>13.1 Ohm/355 MVar at 3 kA</td>
</tr>
<tr>
<td>Compensation degree</td>
<td>60%</td>
</tr>
<tr>
<td>MOV Data</td>
<td>43.8 MJ MOV energy capability, 23.0 kApeak MOV current at protective level for each segment, 130 kV/2.33 pu protective level</td>
</tr>
<tr>
<td>Digital control and protection system</td>
<td>Siemens SIMADYN D</td>
</tr>
</tbody>
</table>

In August 2002 Siemens succeeded in winning a series capacitor contract with Dominion Virginia Power. To accommodate increased power generation at the Bath County Pumping Station, Dominion had to add two series capacitors to the Virginia 500-kV-network in the Bath County Area. Each of the two transmission lines from the Bath County Pumping Station, one leading to the Lexington substation and the other leading to the Valley substation, have been equipped with a fixed series capacitor of 60% compensation level.

The Valley FSC has been in commercial operation since November 13th 2003 and the Lexington FSC has been in commercial operation since December 2nd 2003.
Valley –
Fixed Series Capacitor
in Virginia, USA – Gap Less Design

Customer: Dominion Virginia Power
Project name: Lexington & Valley FSC’s
Location: near Weyers Cave, Virginia
Capacitor Ratings: 18.7 Ohm/505 MVar at 3 kA
Compensation Degree: 60%
MOV Data: 87.2 MJ MOV energy capability
28.3 kA_{peak} MOV current at protective level for each segment
184 kV/2.32 pu protective level
Digital Control System: Siemens SIMADYN D
São João do Piauí –
Fixed Series Capacitor in Brazil

Customer: CHESF
Project Name: São João do Piauí
Location: State of Piauí, Brazil

**BCS 1**
- **Capacitor Ratings:** 52.83 Ohm/484 MVAr at 1.75 kA
- **Compensation degree:** 70%
- **MOV Data:**
  - 72.1 MJ/MOV energy capability
  - 15.4 kA<sub>peak</sub> MOV current at protective level for each segment
  - 283 kV/2.17 pu protective level

**BCS 2**
- **Capacitor Ratings:** 47.69 Ohm/437 MVAr at 1.75 kA
- **Compensation degree:** 70%
- **MOV Data:**
  - 79.9 MJ/MOV energy capability
  - 13.7 kA<sub>peak</sub> MOV current at protective level for each segment
  - 262 kV/2.22 pu protective level

**Digital control and protection system:** Siemens SIMADYN D

In summer of 2003 the São João do Piauí Series Compensation System located in the Brazilian Maranhão-Bahia 500 kV AC-network has been awarded to Siemens. The power demand of the growing Brazilian industries requires an economical solution for an increase of power transfer capability with the existing lines. Fixed series compensation has been found as the appropriate choice not only to enable the desired power increase but also to stabilize the interconnected networks by reducing the connecting line impedance. Starting of commercial operation of two capacitors located in two serial lines is scheduled for August 2004.

São João do Piauí series capacitor project consists of two series capacitor installations connected in series on two different lines entering São João do Piauí substation. The design of the components has been carried out by intensive studies to find an optimized solution for power transfer increase and stabilization of the existing network. With a nominal power rating of 484 MVA for Boa Esperança bank and 437 MVA for Sobradinho bank the São João do Piauí series capacitors will provide stable and increased power transfer through the Maranhão-Bahia 550 kV AC system corridor.
Eldorado-Lugo and Eldorado-Moenkopi –
Series Capacitors in Nevada/USA

Customer: Southern California Edison (SCE)
Project name: Eldorado
Location: near Boulder City, NV, USA
Capacitor Ratings
- Lugo 199 MVar/segment
- Moenkopi 162 MVar/segment
Compensation degree:
- Lugo 17.5%/segment
- Moenkopi 11.7%/segment
MOV Data:
- FSC’s 22.9 MJ/Phase
- TPSC’s ca. 3 MJ/Phase
Digital control and protection System: Siemens SIMATIC TDC

In September 2004 Siemens succeeded in winning the contract for the refurbishment of two series capacitor installations at Edisons Eldorado Substation southwest of Boulder City, Nevada.

As a result of new power generation installed in the Las Vegas area the fault duty on the 500 kV transmission network is above the design ratings of the existing equipment and therefore the two series capacitors “Lugo” and “Moenkopi” at the Eldorado Substation need to be replaced. It is the intention to increase the power transfer between Arizona/Nevada and Southern California within the next few years.

The so called Eldorado-Moenkopi SC is in series with the transmission line leading to the Moenkopi substation in Arizona and the Eldorado-Lugo SC is in series with the transmission line leading to the Lugo substation in Southern California.

The Lugo series capacitor installation will consist of two segments, one segment will be a FSC and the other segment will be a TPSC.

The Moenkopi series capacitor installation will consist of three segments, two segments will be FSC’s and the other segment will be a TPSC.

The Lugo SC has been scheduled to be in service on March 15th 2006 and the Moenkopi SC has been scheduled to be in service on June 1st 2006.
If you have any questions about Power Transmission and Distribution, our Customer Support Center is available around the clock.

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The information in this document contains general descriptions of the technical options available, which do not always have to be present in individual cases. The required features should therefore be specified in each individual case at the time of closing the contract.

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