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A Novel Approach for Improvement of Power Quality in Transmission System by Using Distributed Power- Flow Controller

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Abstract: **The Electronic based FACTS controllers are static equipment. Its principle purpose is to control AC transmission. The parameters of FACTS are enhancement of controllability, ability of power transfer, control of line impedance, load angle and the magnitude of bus voltage. A unified power controller is to be a static device and this system device should have quick reactive transmission. This paper focuses on the issues like voltage sag and swell of power quality. DPFC is used to moderate the voltage variation and improve power quality and also used to couple the phase controllable bridges to produce current which is injected into a transmission line by using series of transformers.**

The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) which is coupled with common DC link. The DPFC eliminates the common dc link between the shunt and series converters and also it performs in transmission line to exchange real power between converters at the 3rd harmonic frequency. The DPFC employs several 1-phase converters like D-FACTS concepts as the series compensator. These concepts reduce the rating of the components and offer a high reliability. Since the DPFC can immediately control the active and reactive power flow and the voltage magnitude, it implies a great potential for power oscillation damping. The case study contains a DPFC located in an exceedingly single-machine infinite bus power grid with 2 parallel transmission lines that simulated in MATLAB/Simulink. The bestowed simulation results of a DPFC device wont to improve the facility quality.

***Keywords*— Power Quality, voltage Sag and voltage Swell, Unified Power Flow Controller, Distributed Power Flow Controller**

I. INTRODUCTION

Now a day's demand for power grows radically. Expansion in transmission and generation is constrained with the rigid environmental constraints and limited availability of resources .How ever their courses the power systems to be operated close to be stability limits. The power electronics based FACTS which defined by IEEE, through this is a supplementary static equipment it is very helpful in control of one or more ac-transmission system parameters to improve controllability , enhance power-transfer capability[1].The past years, major concern of the power Companies was to produce/provide quality electrical power . The concept of FACTS design is to enhance the Controllability and to improve the operation of existence Power system capacities by

Means of reliable and high-speed power electronic devices. The devices are used its place of mechanical controllers which are used to moderate the voltage fluctuations. The facts devices are very helpful to understand the power quality problems. To moderate the mentioned power quality problems, the operation of facts devices such as unified power flow controller (upfc) and synchronous static compensator. A distributed power flow controller, introduce a novel facts device, is used to moderate voltage and current waveform variation and improve power quality in short duration (few seconds)[10]. The dpfc has similar capability of upfc to balance the line parameters, i.e. Line impedance, load angle and bus voltage magnitude and improve power quality [11].

II. DPFC OPERATING PRINCIPLE

In comparison of UPFC, the main advantage is to eliminate the large DC-link and provide using Third - harmonic current to exchange of active power. The DPFC fundamental principle and operation are explained below.

A. DC link eliminated and Exchange of real power

In case of DPFC which is used to employ as affiliati on between the DC terminal of shunt device and also the AC terminal of series converters, rather than direct affiliation using DC-link for exchange of real power between converters. The approach of exchange of real power is basic concept of non-sinusoidal elements. To analyze the active power, it is combination of voltage quantity and current quantity and it also analyse active power by using equivalent circuit of DPFC structure. For active power P=VI Cos ϕ

$$P=\sum V_I\, I_I\, COS\, \Phi_I$$

Wherever V_i is the voltage magnitude of i^{th} harmonic and I_i are current magnitude of i^{th} harmonic, respectively, and ϕ_i is the phase angle between the voltage and current.

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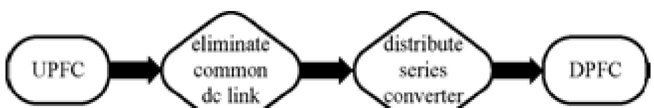

Fig.1. power Flow diagram from UPFC to DPFC

Generally DPFC of a shunt converter be able to absorb real power at one frequency and generate other frequency. The power flow diagram of DPFC structure shown in fig. (1) The DPFC is located in transmission line between two bus systems as shown in (Fig.2), at the same time as the power supply generates the active power, and shunt converter has the facility to absorb power in fundamental frequency of current.If 3rd harmonic component is attentive in star-delta transformer. Output terminal of the shunt converter injects the third harmonic current into the neutral of delta-star transformer (Fig.3). Accordingly, the harmonic current flows through the transmission line. This harmonic current controls the DC voltage of series capacitors (Fig.2). Illustrate how to exchange of active power between the shunt and series converters are very conveniently by using DPFC. As exposed, above and beyond the input components, namely the shunt and series converters.

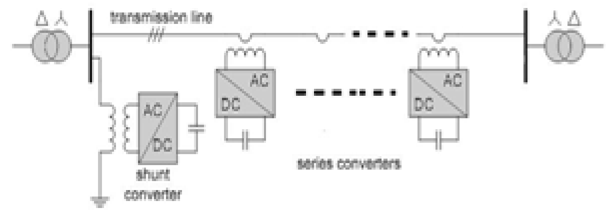

Fig.2. DPFC Structure

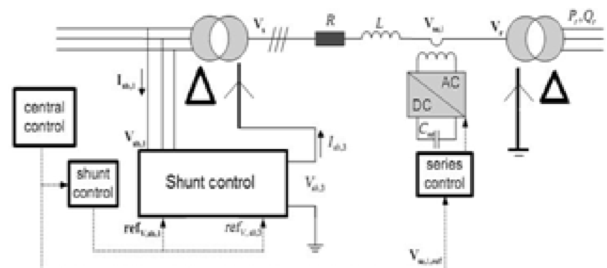

Fig.3. DPFC control structure

DPFC also requires a high-pass filter is shunt connected at the other side of the transmission line, and two star–delta transformers at both side of the line. If 3rd harmonic component is selected to interchange of active power in the DPFC and high-pass filter is mandatory to create a locked loop for the harmonic current. The 3rd harmonic current is surrounded by the delta-winding of transformer. This type of connection is nothing but connecting the cable between the delta winding of a transformer and ground. It is also connected to load side with provide star and ground/Δ- transformer to eliminating third-harmonic components.

B. Mathematical modelling of DPFC

In order to investigate the impact of shunt-series converters on power systems effectively, appropriate models of these devices are analysed shown in fig (4) shows, the shunt converter current i_{shunt}, can be written as:

For shunt current $I_{shunt} = I_t + I_q$

Where it is in phase with V_i and I_q is quadrature to V_q

The voltage sources V_{s1} ,V_{s2},V'_{s1},V'_{s2} has replaced by instead of series converters. The X_{s1}, X_{s2}, X's1, X1s2 are reactance of parallel transmissions lines. The magnitude and phase angle of series converters are controllable, in this paper we assume that they have same values.

$$V_{s1} = V_{s2} = V'_{s1} = V'_{s2} = rV_i e^{i\lambda}$$

Where r and λ are relative magnitude and phase angle respect to V_i respectively

$$I_{s1} = V_{s1}/jx_{s1} = -jb_{s1}\, rV_i e^{i\lambda}$$
$$I_{s2} = V_{s2}/jx_{s2} = -jb_{s2}\, rV_i e^{i\lambda}$$
$$I^1_{s1} = V'_{s1}/jx_{s1} = -jb'_{s1}\, rV_i e^{i\lambda}$$
$$I^1_{s2} = V'_{s2}/jx_{s2} = -jb'_{s2}\, rV_i e^{i\lambda}$$

Where $b_{s1}=1/x_{s1}$, $b_{s2}= 1/x_{s2}$, $b^1_{s1}=1/x^1_{s1}$ and $b^1_{s2}=1/x^1_{s2}$
The active power supplied by the shunt current source can be calculated as follows:

$$P_{shunt} = \mathrm{Re}\,[V_i\,(-I^*_{shunt})] = -V_i\, I_i$$

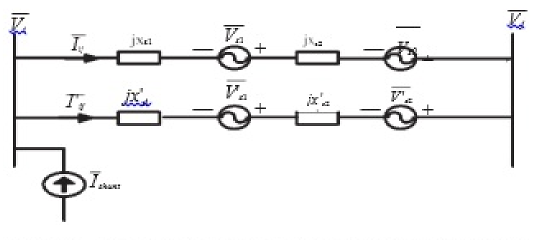

Fig.4.DPFC converters of case study

Neglect the DPFC losses

$$P_{shunt}=P_{series} = P_{s1}+ P_{s2}+ p^1_{s1}+ P^1_{s2}$$

The apparent power supplied by the series converter V_{s1} can be calculated as follows:

$$S_{s1}=V_{s1}\, I^*_{ij} = rV_i e^{ij}\, [(V_i +V_{s1}+V_{s2} -V_j)/j\,(x_{s1} + x_{s2})]^*$$
$$P_{s1} = (b_{s1} + b_{s2})\, [rV_iV_j \sin(\Theta_i- \Theta_j+\lambda) -rV^2_i \sin(\lambda)]$$
$$Q_{s1} = (b_{s1} + b_{s2})\, [r\, V^2_i \cos(\lambda) +2r^2V^2_i -rV_i\, V_j \cos(\Theta_i-\Theta_j+\lambda)]$$

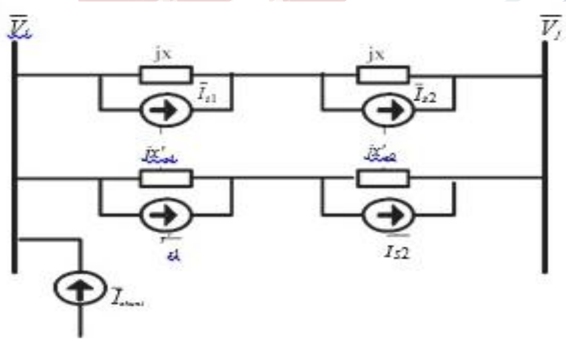

Fig.5. representation of a series voltage sources by current sources.

$$P_{s2} = (b_{s1} + b_{s2})\, [rV_iV_j \sin(\Theta_i- \Theta_j+\lambda) -rV^2_i \sin(\lambda)]$$
$$Q_{s2} = (b_{s1} + b_{s2})\, [r\, V^2_i \cos(\lambda) +2r^2V^2_i -rV_i\, V_j \cos(\Theta_i-\Theta_j+\lambda)]$$
$$P'_{s1} = (b'_{s1} + b'_{s2})\, [rV_iV_j \sin(\Theta_i- \Theta_j+\lambda) -rV^2_i \sin(\lambda)]$$
$$Q'_{s1} = (b'_{s1} + b'_{s2})\, [r\, V^2_i \cos(\lambda) +2r^2V^2_i -rV_i\, V_j \cos(\Theta_i-\Theta_j+\lambda)]$$
$$P'_{s2} = (b'_{s1} + b'_{s2})\, [rV_iV_j \sin(\Theta_i- \Theta_j+\lambda) -rV^2_i \sin(\lambda)]$$
$$Q'_{s2} = (b'_{s1} + b'_{s2})\, [r\, V^2_i \cos(\lambda) +2r^2V^2_i -rV_i\, V_j \cos(\Theta_i-\Theta_j+\lambda)]$$

C. Advantages of DPFC

The DPFC has more advantages then UPFC when compared and the advantages are,

1).High Reliability

The combination of series and shunt converters are very reliable, as there is no feedback connection, and it is also very reliable converters redundancy rises the DPFC reliability for the period of converters operation. In case of failure in any one of the series converters, the others can continue to effort.

2) Highly management Capability

The structure of DPFC has extremely manageable capability compare to UPFC it will management all parameters of a transmission network, like line impedance, impedance angle, and voltage magnitude

3) Lowest price

The cost of DPFC device is low compare to UPFC, if the 1-phase series devices ratings are less than one 3-phase converter. Moreover, the series converters haven't any high voltage isolation in conductor connecting single-turn transformers which are accustomed to drop the series converters.

III. DPFC CONSTRUCTION

The DPFC is design is three control methods: series control, shunt control and central controller.

A. Series Control

The basic function of series controller is used to maintain the capacitor dc voltage. by using the third-harmonic frequency components and to produce series voltage at the fundamental Frequency that is approved by the central control.
If DPFC Controller inputs area unit series capacitance voltages, line current, and series voltage reference within the dq-frame.

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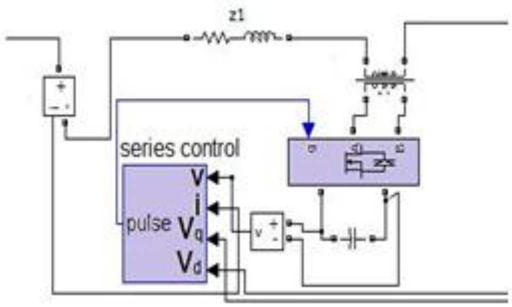

Fig.6. functional diagram for series converters

The diagram of the series converters in MATLAB/SIMULINK setting is incontestable to analyzing the results of a system as

Shown in (Fig.6).Any series controller incorporates a low-pass and a 3rd-pass filter to make fundamental and 3rd –order harmonic currents separately. In this diagram to design a two single-phase phase locked loop area unit accustomed take frequency, phase angle information from the system. The diagram of series controller is as shown in (fig.6).

B. Shunt Control

The design of shunt converters includes connected to 3-phase back to back converter, this converter absorb the active power from grid at fundamental frequency and control the dc voltage from capacitor between in the converter and one single-phase converter. Different task of the shunt device is to inject constant 3rd harmonic current inject into the lines through the neutral cable of delta/star transformer.

C. Central Control

If design of central control is generate the reference signal from the shunt and series converters of a DPFC structure .It is absorbed on the DPFC responsibilities at the power-system side, such as power-flow controller, low-frequency power oscillations and balancing of an unsymmetrical components. According to the system condition the central control provides equivalent voltage reference signals for the series converters and reactive current signal for the shunt converter. All the reference signals generated by the central control are at the fundamental frequency.

IV. PROPOSED SYSTEM

Generally upfc device has some difficulties to exchange of real and reactive power, and also completely mitigation of voltage sag and voltage swells, in case any device (series (or)shunt) will be failure UPFC is not operated because of feedback connection. By placing DPFC exchange of real and reactive power is easily transfer in transmission system. The completely simulation diagram of DPFC is shown in (fig.7). If system consists of a 3-phase source is connected to non-linear RLC load through parallel transmission lines (both lines are equal lengths).the simulation system parameters are given table-I.

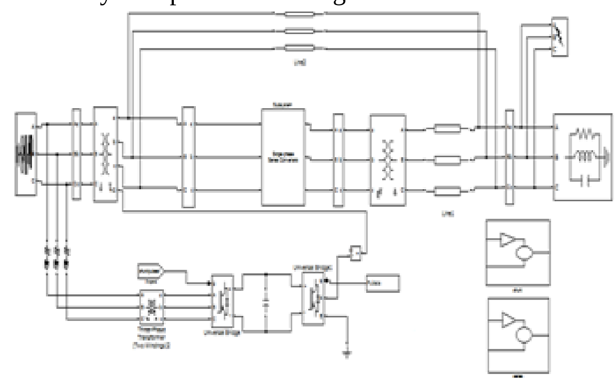

FIG.7. SIMULATION MODEL OF THE DPFC

V. SIMULATION RESULTS

To simulate the dynamic performance of a three-phase fault is created to the load. The duration of fault time is 0.7 seconds (70-110 mill second).

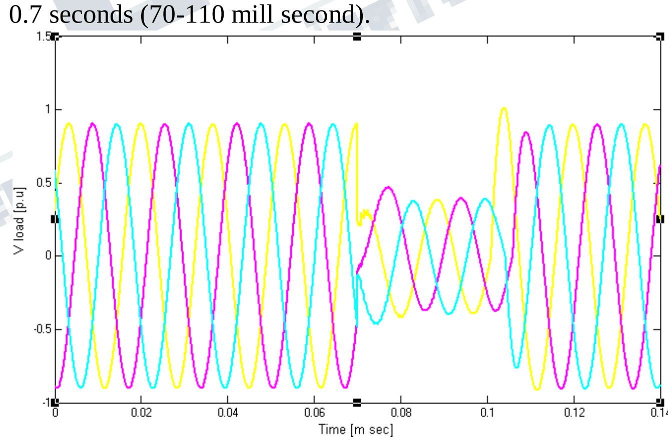

Fig.8. Three-Phase load voltage sag without DPFC.

To observe above (fig.8), the important of voltage sag is for the period of fault, not including DPFC device ,the voltage sag value is about 0.55 p.u. by providing DPFC load voltage sag mitigate efficiently as shown in (fig.9) below.

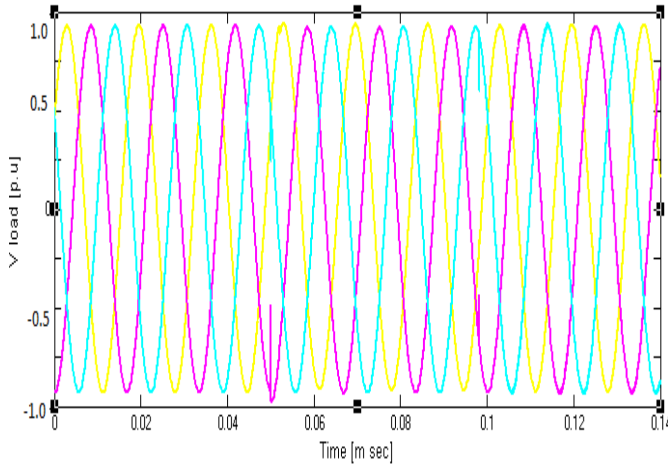

Fig.9.Mitigation of Three-Phase load voltage sag with DPFC

Similarly to simulate voltage swell/dips (Fig.10). To observe the voltage/current swell is about 1.3 per-unit, for the period of the fault. By providing DPFC load voltage/current swell mitigate efficiently as shown in (fig.11) below.

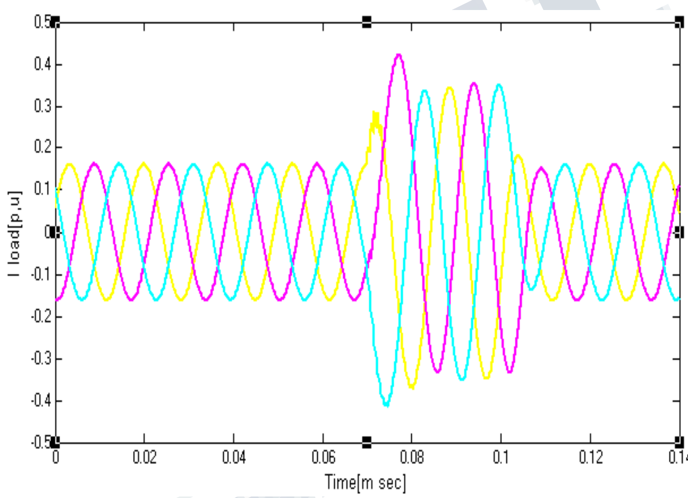

Fig.10. Three-Phase load current swell without DPFC

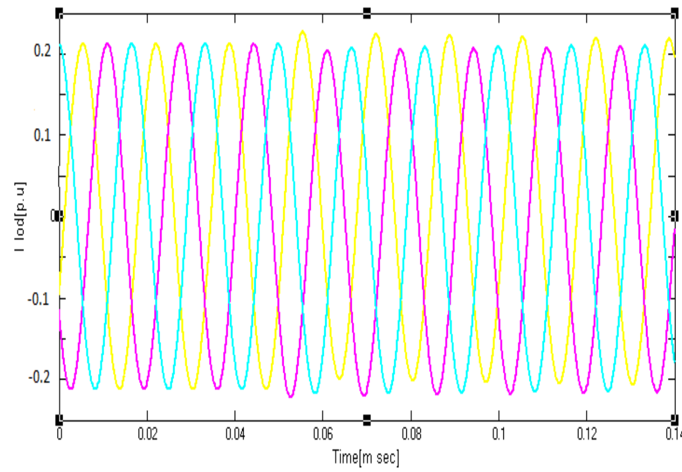

Fig.11. Three-Phase load current swell with DPFC

To analyze load voltage harmonic analysis without presence of DPFC in FFT analysis is illustrated in shown (Fig. 12). It can observe later than DPFC accomplishment in the system, The even harmonics are eliminated and odd harmonics are reduced within satisfactory limits, and also total harmonic distortion (THD) of load voltage is minimize from 55.06 to 0.51 percentage at 60 Hz Fig. (13), i.e., the standard THD is less than 5 percent in IEEE standards.

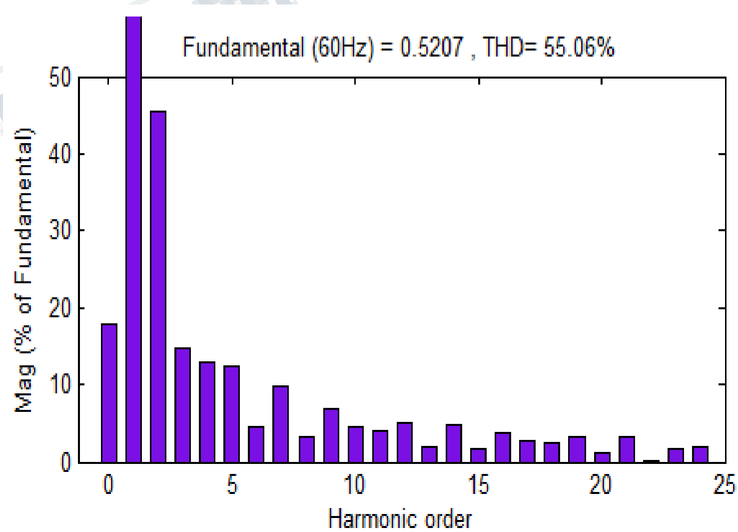

Fig.12. Total harmonic distortion of load voltage without DPFC

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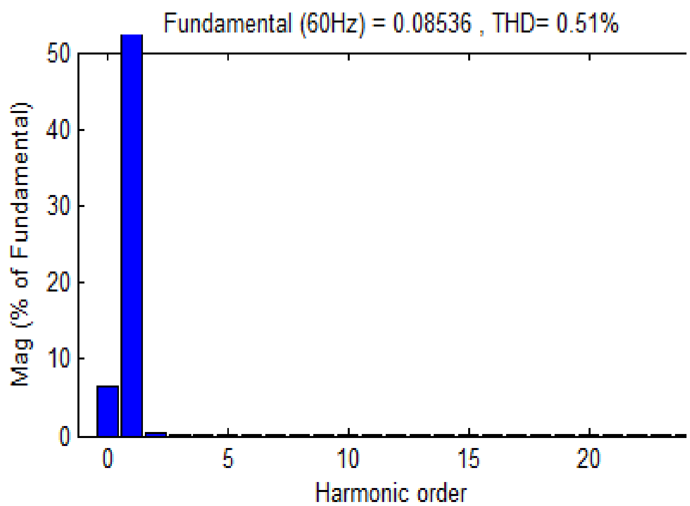

Fig.13. Total harmonic distortion of load voltage with DPFC

VI. CONCLUSION

In this study, to improvement of power quality in power system, there are some efficient methods are used to moderate the voltage sag and voltage swell. By using FACTS controllers to reduce the power quality disturbances, in case UPFC replaced by novel FACTS controllers is called distributed power flow controller (DPFC) is offered. The DPFC control structure is related to unified power flow controller (UPFC) and has a similar manage ability to balance the line parameters, like bus voltage magnitude, line impedance and load angle. on the other hand, the DPFC offer several advantages, in compare with UPFC, such at the same time as high control capability, high reliability, and low cost. The entire cost of a DPFC is as well much lower than that of UPFC, for the reason that no high-voltage isolation is necessary at the series-converter component and the rating of the apparatus of is low. The DPFC is model and three control loops, i.e., central controller, series control, and shunt control are design. If the system is analyzed to one machine, is connected to infinite-bus system, with and without DPFC and also it's proved that the shunt and series converters. The DPFC can exchange of real power at the 3rd -harmonic frequency and series converters are capable to inject convenient active and reactive power at the fundamental frequency. To simulate the energetic performance of a three-phase fault is measured near to the load. Shows with the aim of the DPFC give a satisfactory performance in power quality improvement and controlling of power.

TABLE-I
SIMULATION SYSTEM PARAMETERS

Parameters	values
Three phase source	
Rated voltage	230 kV
Rated power/Frequency	100MW/60HZ
X/R	3
Short circuit capacity	11000MW
Transmission line	
Resistance	0.0120 p.u per km
Inductance/ Capacitance reactance	0.120 p.u per km /0.0120 p.u per km
Length of transmission line	100 km
Shunt Converter 3-phase	
actual power	60 MVAR
DC link capacitor	600 µF
Coupling transformer (shunt)	
actual power	100 MVA
Rated voltage	230/15 kV
Series Converters	
Rated voltage	6 kV
actual power	6 MVAR
Three-phase fault	
Type	RYB-G
Ground resistance	0.01ohm

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