RESEARCH PAPER

Performance improvement of interconnected 400kV, 50Hz Kurdistan and Iraq power systems using proposed HVDC link

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ABSTRACT:
The performance has become the most interested in any power system research area. This study aims to maintain voltage profile within standard range with adequate reactive power required in all the bus systems, which are considered as the important factors that affecting the economical and operational costs and the services quality. In this paper, the study and improvements of performance are proposed applied on the interconnected 400kV, 50Hz Kurdistan and Iraq power systems using ±500kV, 300MW HVDC link simulated by ETAP program.

KEY WORDS: HVDC; FACTS; Reactive Power; Voltage profile; Load Flow Analysis.

INTRODUCTION:

High voltage direct current (HVDC) technology has features that make it particularly attractive for some transmission implementation. It is vastly known as being useful for asynchronous interconnections, long-distance bulk-power transmission, and long submarine cable (M. P. Bahrman et al., 2007).

The simplified diagram of HVDC link is shown in Fig.1. A simple representation of an HVDC system, describing the basic principle of bidirectional electric power transfer between two AC systems (or nodes).

The AC power is converted into DC at a converter station (rectifier), and then transmitted to the receiving point through an underground cable or an overhead line. At the receiving end converter station (inverter), the power is converted back to AC and then injected into the receiving AC network. In the back-to-back schemes, the two converters are placed at the same location and coupled only by short busbars. The transmitted power is independent of the AC supply frequency and phase (Benasla et al., 2018).

The variation of transmission costs with distance for both ac and dc transmission are shown in Fig.2. For distances less than the breakeven distance, AC tends to be less expensive than DC but for longer distances it is cost more. For overhead lines, the “breakeven distances” lies from 400 to 700 km depending on the per unit line costs but for cable system the “breakeven distance” vary between (25-50 km) (V. K. Sood., 2004)

1. Types of HVDC Systems

There are three types of HVDC applications

1. Monopolar link
Monopolar link consists of one conductor and return path is provided by sea or permanent earth. It is commonly operating with negative polarity with regard to ground to decrease radio interference and corona losses. It has the half rating of corresponding bipolar link rating and it is not economically compared to EHV ac schema for submarine cables longer than 25 km and of 250 MW power rating.

2. Bipolar link

This is the most common type of HVDC link in which used with overhead long-distance systems and B2B HVDC system. It has two conductors, operating with both positive and negative polarities with regards to the earthed tower structure.

Example of bipolar HVDC link: Ranchi-Delhi single bipolar overhead line (length 810 km), 1,500 MW, operating at ± 500 kV.

3. Homopolar link

A homopolar link has two or more conductors with same polarity, always negative, and usually operates with ground as the return conductor. If a fault occurred on any one of the conductors, the converter equipment can be reconnected to another healthy conductor can supply power

2. Reactive power control and voltage support

Several major blackouts experienced in different countries around the world have been related to voltage stability phenomena [Andersson et al., 2005]. For this reason, voltage stability enhancement has become a challenging issue in planning and security assessment of power systems. Voltage stability is very dependent on the demand for reactive power, and thus it is essential to balance reactive power supply and demand to maintain the scheduled voltage levels. HVDC can contribute to the stabilization of the AC voltage during steady-state and transient conditions by switching shunt capacitors and filters banks and/or by modulating the station's reactive power consumption through the firing angle of the converters. [Benasla et al., 2018].

3. HVDC and FACTS Transmission Systems

At the end of past century, HVDC has been introduced, offering new dimensions for long distance transmission. It has begun with transmit a little amount of power about many hundreds MW. Later, growing continuously to transmit about 3 - 4 GW among long-distances using one bipolar line only.

Flexible AC Transmission Systems (FACTS) have been sophisticated to enhance the long-distance ac transmission performance (N. Hingorani, 1993). After that, technologies have been expanded to those devices that control load flow as well (V. Sitnikov et al., 2003). The base concept of both HVDC and FACTS can be clarified by the basic equation

\[
P = \frac{U_1 U_2}{X} \sin(\delta 1 - \delta 2)\text{………… (1)}
\]

Power transmitted between two system depends on voltages on the both sides, the line impedance and the angle difference between both nodes.

There are many devices used to increase ac system flexibility such as Static Var Compensator (SVC), thyristor-controlled series capacitive Compensator (TCSC), thyristor-controlled phase-shifting device, thyristor-controlled electrical energy storages, and Static Synchronous Series Compensator (SSSC).

3.1 Static Var Compensator (SVC)

The first generation of FACTS devices (SVC) was introduced in 1970s. It is a shunt-connected absorber capable of exchanging capacitive and inductive power to control the power system parameters. The first (SVC) was installed in Nebraska in the 1974. An SVC can enhance transient stability by support the voltage dynamically and improve the steady state stability to increase swing oscillation damping (Gandoman et al., 2018).

In (P. V. Chernyaev et al., 2018), both shunt and series controlled reactive power compensation devices are used to improve the steady state performance and increase of transient stability margin and small signal of long-distance AC electric power transmission line of the (±500 kV 1030 km) Imperatriz – Serra da Mesa power system in Brazil. The components of SVC are shown in Fig.3.  

3.2 Thyristor controlled series compensator (TCSC)
An TCSC is a series compensation device that improves the transmission line capacity by decreasing its series impedance (Virulkar VB et al., 2016). It is more economical and simpler compared to FACTS devices because it doesn’t need interfacing equipment such as high voltage transformer. The schematic diagram of TCSC is shown in Fig .4.

### 3.3 Static synchronous compensator (STATCOM)

The first STATCOM was installed in 1991 in Japan rated at ±80 MVAR and supplies voltage stabilization in Lnumaya substation (Gandoman et al., 2018). Unlike an SVC, it doesn’t need large capacitive or inductive components to provide reactive power to high voltage transmission systems (Hemeida MG et al., 2017). The block diagram of STATCOM is shown in Fig.5.

### 3.4 Static synchronous series compensator (SSSC)

The Static Synchronous Series Compensator (SSSC) is a series connected FACTS device, it is controlling the power flow in the transmission lines, improve system stability, and enhance power oscillation damping (Virulkar VB et al., 2016). An SSSC has been more effective than the STATCOM for enhancing subsequent sw damping (V. Sitnikov et al., 2003). Fig.6 shows the static synchronous series compensator.

### 3.5 Unified Power Flow Controller UPFC

Unified Power Flow Controller (UPF) as shown in Fig.7 is consist of static synchronous compensator (STATCOM) and a static series compensator (SSSC) coupled by a common DC-link to allow bidirectional flow of real power between the shunt output terminals of the STATCOM and the series output terminals of the SSSC. “The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers” (A. Muhammed, 2012)

4. Description of Study Case

The system under study is the interconnection between Iraq and Kurdistan 400 kV, 50Hz power systems. It consists of 25 buses, thirteen generators and many transmission lines. Two HVDC links are used in order to improve the buses voltage profile and compensate reactive power of bus loads. The first case study is connected between Erbil and Khouralzoubir (Basra) long of 1000 km distance, and the second case study is between Erbil Al-Nasirya along of 750 Km distance. Single line diagram of 400kV, 50Hz of Kurdistan-Iraq power systems is shown in Fig 8.

5. Results

**A. Analysis of Load Flow with an enhancement to overcome the Under Voltages Problem**

Load Flow Analysis of the 400kV, 50Hz Kurdistan-Iraq power system carried out using ETAP program in which Newton-Raphson method is used and it is observed that some of buses are over and under voltage that can be clearly seen in figures below. Voltage profile of busses has been increased when compared with the network without HVDC link/Compensating device.

Fig. 9 shows that some buses voltage increased by adding HVDC link between Erbil and Khouralzoubir (Basra) long of 1000 km distance, in the other hand it can noticed that other busses voltage profile also can be increased if another HVDC link between Erbil and Al-Nasirya long of 750 Km distance as it illustrated in figure 10.

**B. Analysis of Reactive power compensation**

As shown in figures (11,12), the HVDC link that connected between Erbil and Khouralzoubir is more affect than that connected between Baghdad and Al-Nasirya on the amount of reactive power, which means that the reactive power reduced more when HVDC link between Erbil and Khouralzoubir(Basra).
6. Conclusion

From the results we can concluded, that the voltage profile of buses are increased and the reactive power are decreased after the load flow implemented using ETAP program for proposed interconnected of 400kV, 50Hz Kurdistan and Iraq power systems using two proposed HVDC links. Also, it can be noticed that the HVDC link connected between Erbil and Khour-alzoubir (Basra), is more effective than the second HVDC link connected between Erbil and Al-Nasiryain.

| Features                  | AC                  | DC                  |
|---------------------------|---------------------|---------------------|
| Transmission cost         | ±500kV ROW: 60m     | 800kV ROW: 85m      |
| Stability                 | Power transfer inversely proportion with transmission line distance | Power transfer unaffected by transmission distance |
| Voltage control           | Reactive power control required in order to maintenance constant voltage | DC-line doesn’t require any reactive power |
| Line compensation         | SVC OR STATCOM are needed | Not required |

Table 1: Comparison of AC-DC transmission

![Figure 1. Simplified diagram of HVDC link](image1)

![Figure 2. Comparison of AC/DC transmission line cost (V. K. Sood, 2004).](image2)

![Figure 3. The components of SVC](image3)

![Figure 4. Schematic diagram of TCSC](image4)

![Figure 5. Block diagram of STATCOM](image5)

![Figure 6. Static synchronous series compensator diagram](image6)
Figure 7. Basic structure of UPFC [8]

Figure 8. Single Line Diagram of 400kV, 50Hz Kurdistan-Iraq power system

Figure 9. Bus Voltage for Iraq-Kurdistan 400kV, 50Hz power system with/without HVDC link between Erbil and Khouralzoubir

Figure 10. Bus Voltage for Iraq-Kurdistan 400kV, 50Hz Power System with/without HVDC link between Erbil and Al-Nasirya

Figure 11. Reactive Power magnitude with/without HVDC link between Erbil and Khouralzoubir (Basra)

Figure 12. Reactive Power magnitude with/without HVDC link between Erbil and Al-Nasirya
7. References

Andersson G, Donalek P, Farmer R, Hatziargyriou N, Kamwa I, Kundur P, et al. Causes of the 2003 major grid blackouts in North America and Europe, and recommended. IEEE Trans Power System 2005;20:1922–8.

A. Muhammed, Reactive Power management of Kurdistan Power System by using Flexible Alternating Current Transmission Systems FACTS Technologies. ZANCO Journal of Pure and Applied Sciences Vol.22, No.2, 2012

Chernyaev, M. A. Khazov and A. N. Belyaev, "Operating condition analysis of flexible AC transmission lines with controlled series and shunt compensation devices," Conference of Russian Young Researchers in 2018, pp. 598-603.

Gandoman, F.; Ahmadi, A.; Sharaf, A.; Siano, P.; Pou, J.; Hredzak, B.; Agelidis. Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems. Renew. Sustain. Energy Rev. 2018

Hemeida M G, Rezk Hegazy, Hamada Mohamed M. A comprehensive comparison of STATCOM versus SVC-based fuzzy controller for stability improvement of wind farm connected to multi-machine power system. Electr Eng 99. 2017. p. 1–17.

M. Benasla, T. Allaoui, M. Brahimi, HVDC links between North Africa and Europe: Impacts and benefits on the dynamic performance of the European system. Renew. Sustain. Energy Rev. Vol.82, Part 3, Feb. 2018, Pages 3981

M. P. Bahrman, B. K. Johnson, The ABCs of HVDC transmission technologies, Power and Energy Magazine, IEEE 5 (2) (2007) 32–44.

N. Hingorani, “Flexible ac transmission,” IEEE Spectrum, vol. 30, no. 4, pp. 40–45, Apr. 1993 [3] P. V.

Virulkar VB, Gotmare GV., Sub-synchronous resonance in series compensated wind farm: a review. Renew Sustain Energy Rev 2016;55(3):1010–29.

V. K. Sood, HVDC and FACTS Controllers—Applications of Static Converters in Power Systems. Norwell, MA: Kluwer, 2006.

V. Sitnikov, W. Breuer, D. Povh, D. Retzmann, M. Weinhold, “Benefits of FACTS for large Power Systems”, Cigré Conference, 17-19. Sept. 2003, St.-Petersburg, Russia.