Electrical, Electronics and communications, and Computer Engineering

Voltage Profile Enhancing Using HVDC for 132KV Power System: Kurdistan Case Study

Truska K. Mohammed Salih*
Assist. Lecturer
Department of Automation Industrial Technology
Erbil Technology College
Erbil Polytechnic University
Erbil, Iraq
truska.muhamad@epu.edu.iq

Zozan Saadallah Hussain
Lecturer
Technical Institute of Mosul
Northern Technical
Mosul, Iraq
zozan.technic@ntu.edu.iq

Firas Saaduldeen Ahmed
Assist. Lecturer
Technical Institute of Mosul
Northern Technical University
Mosul, Iraq
firas_saad@ntu.edu.iq

ABSTRACT

Nowadays power systems are huge networks that consist of electrical energy sources, static and lumped load components, connected over long distances by A.C. transmission lines. Voltage improvement is an important aspect of the power system. If the issue is not dealt with properly, may lead to voltage collapse. In this paper, HVDC links/bipolar connections were inserted in a power system in order to improve the voltage profile. The load flow was simulated by Electrical Transient Analyzer Program (ETAP.16) program in which Newton- Raphson method is used. The load flow simulation studies show a significant enhancement of the power system performance after applying HVDC links on Kurdistan power systems. The bus voltages are significantly increased after connecting High Voltage Direct Current.

Keywords: High Voltage Direct Current (HVDC) Link,; Voltage profile; Load Flow Analysis, and ETAP.

تطبيق تكنولوجيا أنظمة الجهد العالي المباشر (HVDC) لنظام الطاقة في كردستان باستخدامETAP

فراس سعدالدين احمد
مدرس مساعد
قسم التقنيات الكهربائية
المعهد التقني/الموصل
الجامعة التقنية الشمالية
موصل- العراق

زوزان سعدالله حسين
مدرس
المعهد التقني/الموصل
الجامعة التقنية الشمالية
موصل، العراق

تروسكة خالد محمد صالح*
مدرس مساعد
قسم أتمتة التكنولوجيا الصناعية
الكلية التكنولوجية/اربيل
جامعة العلوم التطبيقية/اربيل
اربيل، العراق

الخلاصة

أنظمة الطاقة في الوقت الحاضر عبارة عن شبكات ضخمة تتكون من مصادر طاقة كهربائية ، ومكونات حمولة ثابتة ومجمعة ، متصلة عبر مسافات طويلة بواسطة خطوط نقل التيار المتردد .يعد تحسين ملف الجهد أحد الجوانب المهمة لنظام الطاقة .إذا لم يتم التعامل مع المشكلة بشكل صحيح ، فقد يؤدي ذلك إلى انهيار الجهد .في هذا البحث ، تم إدخال روابط / HVDC توصيل ثنائي القطب

<div dir="rtl">

في نظام الطاقة من أجل تحسين ملف الجهد. تمت محاكاة تدفق الحمل بواسطة برنامج ETAP.16 الذي تم فيه استخدام طريقة نيوتن- رافسون. تظهر نتائج المحاكاة لتدفق الحمل تحسنًا كبيرًا في أداء نظام الطاقة بعد تطبيق وصلات HVDC على أنظمة الطاقة في كردستان.

</div>

Abbreviation
ETAP : Electrical Transient Analyzer Program
HVDC: High Voltage Direct Current
FACTS: Flexible Alternating Current Transmission System
STATCOM: Static Synchronous Compensator
UPFC: Unified Power Flow Controller
SVC: Static Var Compensator
TCPST: Thyristor Control Phase Shifting Transformer
TCSC: Thyristor-Controlled Series Capacitors
QPSO: Quantum Behaved Particle Swarm Optimization

1. INTRODUCTION

Nowadays power systems are a huge networks that consist of electrical energy sources, static and lumped load components, connected over long distances by A.C. transmission lines**(Kubba and Esmieel, 2018)**. Currently, the basic structure of power system experiences significant changes to guarantee the availability, sustainability, and stability of the future electrical power system infrastructure**(Habbi and Alhamadani, 2018)**. As a result, power system operation and development face several difficulties, including variable energy demands, tighter security margins, and volatile injections from renewable energy sources. The development of HVDC links provides many solution for the flexible and efficient transmission of power system that can support the power system in the future. During normal operation, High Voltage Direct Current (HVDC) link provides more controllability of the A.C. power system **(Ismail et al., 2021).** HVDC links can be used to optimize the A.C. power flow in the power system to avoid congestions and to obtain an economic gain. In addition, during dynamic situations, HVDC links can be used to support the power system's transient stability. In spite of their cost, HVDC circuits can be more attractive than HVAC circuits for many reasons such as that they have a higher capacity for transfer power, and they don't force the maximum angular difference constraints on the model, it is mean that the Kirchhoff's second law doesn't apply to the HVDC circuits loops **(Liu et al., 2010)**.The cross-channel link was put into operation in-between England and France in 1961. The A.C. systems were connected by two single conductor submarine cables (64km, ± 100kV) with two bridges each rated at 80 MW. The mid-point of the converters was grounded at only one terminal so that ground currents not flow. Sea-return wasn't used due to its impact on the navigation of ships using compasses. It is connected between two asynchronous systems which have the same nominal frequency (60Hz)**(Ahmed et al., 2022)**. In 1965, the Sakuma Frequency Changer was put into operation, which interconnects two asynchronous systems (50Hz, and 60Hz) in Japan. It is the first zero length D.C. link and is confined to a single station. It is able to transmit 300 MW in both directions at a nominal voltage (250 kV). In this paper HVDC links used because it differs from FACT devices, it is not only a compensation device, but it can transfer bulk power across long distance **(Hussain et al., 2021).** In this paper, HVDC links/bipolar connection were inserted in a power system in order to improve the voltage profile. The load flow was simulated by Electrical Transient Analyzer Program (ETAP.16) program in which Newton- Raphson method is used

1.1 HVDC Transmission System

The HVDC transmission system, is generally used to connect two separate A.C. systems and transmit long distance bulk power**(Muhammad, 2019).** The first commercial HVDC application installed in 1954 connected between the island of Gotland and Swedish mainland with a rating of 20MW **(Long and Nilsson, 2007)**. In an HVDC system, electrical power is taken from an A.C. system and converted to D.C. by a converter and then transmitted to the receiving end by a cable or transmission line. Then, the electricity converted back to A.C. by another converter and inserted into the receiving A.C. power system. HVDC link provide many advantages such as control the power flow rapidly and accurately , improves the performance, economy , and efficiency of the A.C. power system **(Wang and Redfern, 2010)**. The basic HVDC system is shown in Figure 1. In equation 1 the D.C. current is defied by I_{dc} which can be calculated as

$$I_{dc} = \frac{U_f - U_i}{R} \tag{1}$$

Where:
I_{dc} : Current along the DC transmission line
U_f: Voltage at the rectifier
U_i: Voltage at the inverter
R: Resistance along the transmission line.

The converter station can be operating as a rectifier or inverter. When the converter is used to convert A.C. to D.C. it is called rectifier and in contrast, is called inverter. The direction of power transmission could be set by the magnitude of both voltages. If $U_f > U_i$, the power is transmitted toward the receiving end (inverter side), while when $U_f < U_i$ the power is transmitted toward the rectifier. Figure 1 show the equivalent model of a HVDC system in ETAP. Direct current link is classified into five types, Back to Back, Monopolar, Homopolar, bipolar, and multi-terminal connection **(Sood, 2018)**.
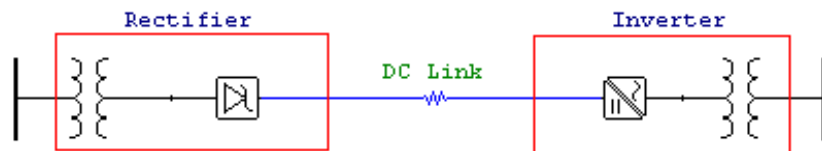

Figure 1. Equivalent model of a HVDC system.
[Screen shot from ETAP program]

1.2 Voltage Profile Improvement

(Iqbal et al., 2018) proposed a scheme for improving bus voltages and reduce losses in the 33-bus radial distribution system. The under voltage problem have been solved by the optimal placement of DSTATCOM. Also, Direct Load Flow (DLF) technique for load flow calculations and Load Sensitive Factor (LSF) along with voltage deviation is used in the objective function for the optimal location of Direct Generation (DG) on the MATLAB platform. **(Sheshagiri and Ram, 2018)** used SVC to investigate the voltage improvement and loss reduction under different load condition. The effectiveness of SVC in loss reduction and voltage enhancement was studied. The

reactive load changes are applied on the 6-bus IEEE system and the voltage profile observed. It is observed that reactive load is increased in steps 10%, 20%, 30%, 40% and so on then compared the results with the original power flow results to improve voltage and reduce system losses. **(Rambabu et al., 2011)** presented a systematic method by which installed an optimal location of fact devices to be installed on 5 bus IEEE power system. Newton-Raphson algorithm is used to incorporate FACTS devices model to perform load flow analysis. From this study, it was observed that the performance of Unified Power Flow Controller (UPFC) on the system is considered to be the best when located optimally comparatively with respect to each of the three devices. **Sode-Yome and Mithulananthan (2004)** made a comparison between the shunt capacitor, STATCOM, SVC, to improve the voltage stability.

Many performance measurements have been compared under different conditions for the 14 bus IEEE system. It was observed that both SVC and STACOM behave better than a simple shunt capacitor, but these controllers are more expensive than the shunt capacitor. **(Bhaskar et al., 2009)** and **(Idris et al., 2010)** have presented the FACTS devices models such as SVC, TCPST, TCSC and how they improve voltage profile. (**Thapa and Mohan, 2013**) analyzed the effects of STATCOM on the voltage profile and both active and reactive power of different buses before and after fault occurrence in the power system. **(Marefatjou and Soltani, 2013)** studied the important phenomenon of the power system and voltage stability by using continuation power flow method, and focused on increasing stability and maximum load ability of a system by considering the optimal location of FACTS devices in power system. They located STATCOM based on Quantum behaved Particle Swarm Optimization (QPSO) algorithm to improve voltage stability and to increase loadability using a 24-bus power system. They conclude that the best place to install STATCOM is the bus which has the highest loadability and therefore is the best terms of the voltage stability also have the lowest power losses. However, STATCOM can increase system increase the loadability margin of power systems. **(Salama et al., 2014)** applied HVDC link on 400kV Egyptian power system. They obtained that the power nodal prices are reduced because the voltage profile for buses is improved after inserting an HVDC link.

2. METHODOLOGY

2.1. Electrical Transient Analyzer Program (ETAP)

The Electrical Transient Analyzer Program (ETAP) is an electrical engineering program that provides a base program with optional modules that allow the user to perform design, modeling, analysis, monitoring, optimization, control, and automation of electrical power systems. In addition, ETAP performs numerical calculations with tremendous speed, automatically applies industry accepted standards, and provides easy to follow output reports (Brown et al., 1990).

This tool is used by many of companies, educational institution, and government bodies, it provides a comprehensive solution for power generation, transmission, distribution, and transportation technologies, low voltage power, industrial system applications. The most common applications of ETAP comprise power transmission and distribution grid analysis, simulation and real-time monitoring of power systems, coordination and protective device design, transient simulation and automatic relay testing, user-defined dynamic system design and analysis, ground grid system analyzer, cable pooling and cable thermal analysis, data exchange analysis and power system control (Abass et al., 2020).

ETAP contains an integrated A.C. / D.C. power system analysis tool to examine A.C. / D.C. load flow and short circuits. It can identify the most suitable battery bank for a wide range of backup plans by investigating the battery charging and discharging feature. Its real-time monitoring system continuously observes the network distribution to increase the efficiency, increase profit and minimize losses. Benefits of using ETAP simulation software are: (Patil and Porate, 2009).

- It is a fully graphical electrical transient analyzer program & supported by Microsoft Windows.
- It provides library for almost all components of the power system.
- More Accurate result with less simulation time.

2.2. Load Flow Calculation Methods in ETAP

ETAP provides four load flow calculation methods: Adaptive Newton-Raphson, Newton-Raphson, Fast-Decoupled, and Accelerated Gauss-Seidel (Abass et al., 2021a). They possess different convergent characteristics, and sometimes one is more favorable in terms of achieving the best performance. It can be select any one of them depending on your system configuration, generation, loading condition, and the initial bus voltages(Abass et al., 2021b).

2.3. Newton-Raphson Load Flow Method

The Newton-Raphson method formulates and solves iteratively the following load flow equation:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta V \end{bmatrix} \qquad \text{(2) [ETAP]}$$

where ΔP and ΔQ are bus real power and reactive power mismatch vectors between specified value and calculated value, respectively; ΔV and $\Delta \delta$ represents bus voltage magnitude and angle vectors in an incremental form; and J1 through J4 are called Jacobian matrices.

The Newton-Raphson method possesses a unique quadratic convergence characteristic. It usually has a very fast convergence speed compared to other load flow calculation methods. It also has the advantage that the convergence criteria are specified to ensure convergence for bus real power and reactive power mismatches. This criterion gives you direct control of the accuracy you want to specify for the load flow solution. The convergence criteria for the Newton-Raphson method are typically set to 0.001 MW and Mvar.

The Newton-Raphson method is highly dependent on the bus voltage initial values. A careful selection of bus voltage initial values is strongly recommended. Before running load flow using the Newton-Raphson method, ETAP makes a few Gauss-Seidel iterations to establish a set of sound initial values for the bus voltages. Gauss-Seidel iterations illustrated in Equation (3.2).

$$\overline{V}_i^{(k+1)} = \overline{V}_i^{(k)} + \overline{Y}_{ii}^{-1} \left(\frac{\overline{S}_i^*}{\overline{V}_i^{(k)}} - \sum_{j=1}^{i-1} \overline{Y}_{IJ}\overline{V}_J^{(k+1)} \right) + \cdots - \overline{Y}_{ii}^{(-1)} \qquad (3)$$

The Newton-Raphson method is recommended for use with any system as a first choice.

Insertion HVDC Link Compared to AC infrastructures, HVDC lines offer the possibility to set and control active power flows going through them. Figure 2 describes an equivalent model of a HVDC system, which consists of two convertor stations. One station works as a rectifier while the other operates as an inverter.
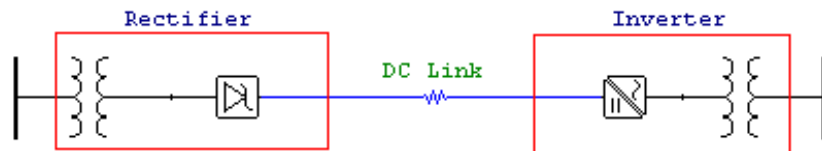

Figure 2 Equivalent model of a HVDC system.
[Screen shot from ETAP program]

The rating D.C voltage can be determined using the equation (3.3).

$$V_{dc} = Prim.\, kV_{Rated} \frac{3\sqrt{2}}{\pi} \frac{SeckV}{Prim.kV(1+Tap)}\ Bridge\ Number \qquad (4)\ [ETAP]$$

Where $Prim.\, kV_{Rated}$=100kV.
Tap= 0, 1, 2 …
Bridge number = 0, 1, 2 …

In this paper, HVDC links are inserted in Kurdistan power system in order as improve voltage profile of the power system.

2.4. Description of Kurdistan 132kV, 50Hz Power System
The study case which used in this paper is the Kurdistan 132 kV, 50Hz power system. Kurdistan power system is used because it is suffer from under voltage specially those busses that far away from the generation stations. The system consists of 36 buses, eight generators and 51 transmission lines. Single line diagram is shown in **Fig.3**. Generation and load demands of system, and transmission line data are illustrated in table 1 and **Table 2.**
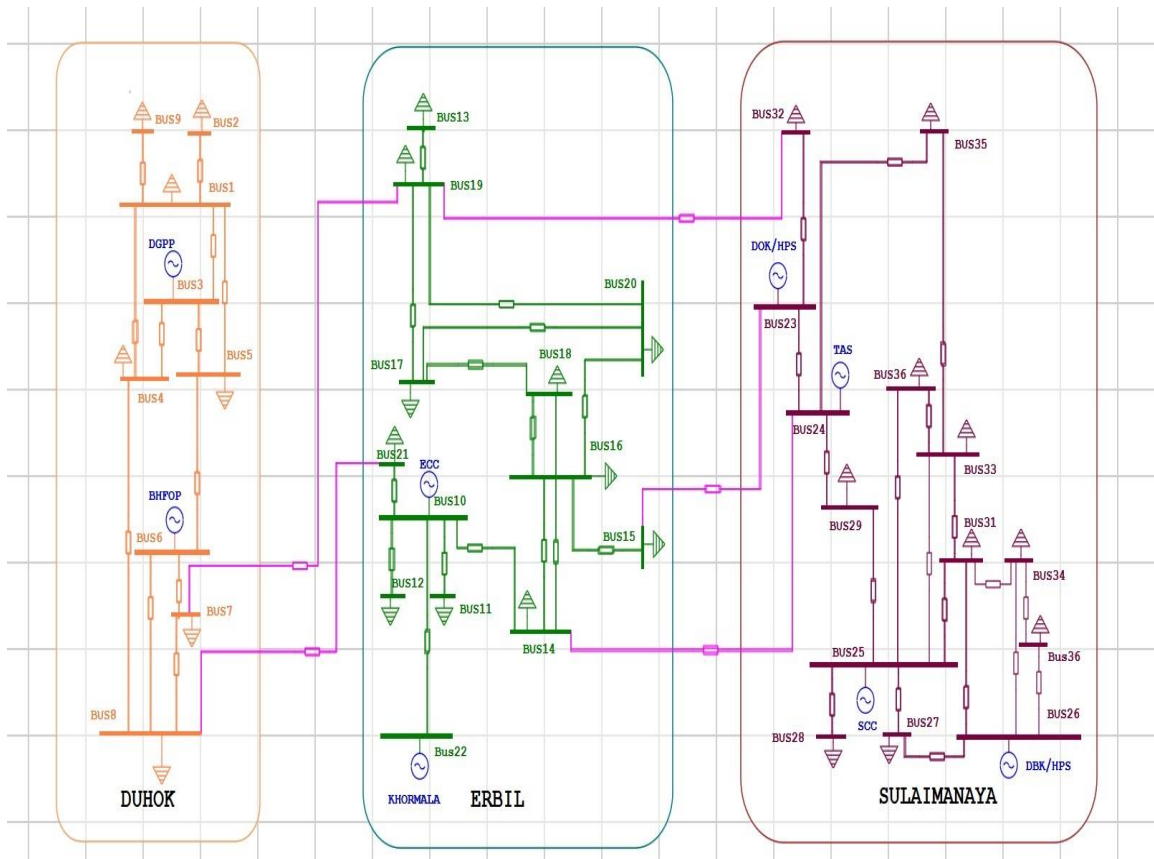
Figure 3. Single line diagram of 132kV, 50Hz Kurdistan power system.

Table 1. Generation and load demands of 132kV, 50Hz Kurdistan power system.

Bus.no	Generation		Loads	
	MW	Mvar	MW	Mvar
1			100	62
2			50	31
3	55	34.1		
4			90	55.8
5			105	60
6	140	86.8		
7			70	43.4
8			60	37.2
9			65	40
10	250	155		
11	970	601.4		

12			160	99.2
13			200	124
14			100	62
15			80	49.6
16			55	34.1
17			200	124
18			95	58.9
19			130	80.6
20			90	55.8
21			120	74.4
22			70	43.4
23	200	124		
24	475	294.5		
25	650	403		
26	160	99.2		
27			140	85
28			50	31
29			60	37.2
30			85	50
31			110	68.2
32			150	93
33			130	80.6
34			90	55.8
35			60	37.2
36			145	90

Table 2. Transmission lines parameters for Kurdistan power system.

Type	Type (Details)	RO (Ω/km)	XO (Ω/km)	R1 (Ω/km)	X1 (Ω/km)	B ($\times 10^{-6}$) (Ω/km)
LARS	Single Circuit-Single Lark Conductor	0.3275	1.231	0.147	0.428	2.66
TEAS	Single circuit-Single Teal Conductor	0.3275	1.218	0.0.097	0.415	2.75

TLAS	Single Circuit-Twin Lark Conductor	0.3065	1.109	0.0725	0.3065	3.7
TTES	Single circuit-Twin Teal Conductor	0.2805	1.113	0.0485	0.301	3.78
LARD	Double Circuit-Single Lark Conductor	0.378	1.28	0.147	0.4	2.87
TEAD	Double circuit-Single Teal Conductor	0.327	1.27	0.097	0.387	2.97
TLAD	Double Circuit-Twin Lark Conductor	0.3065	1.165	0.0735	0.728	4.13
TTED	Double circuit-Twin Teal Conductor	0.2805	1.159	0.0485	0.2725	4.26

3. RESULTS AND DISCUSSION

In this study, after many attempts, we discovered that the best locations for HVDC link to overcome the under voltage are as follows:

Case 1: High Voltage Direct Current (HVDC) link between bus 2 and bus 25

Case 2: High Voltage Direct Current (HVDC) link between bus 8 and bus 26

Case 3: both HVDC link

Load Flow Analysis of the three cases carried out using ETAP program in which Newton- Raphson method is used. With HVDC link/compensating device, voltage profile of busses has been increased when compared with A.C. network. Figure 4 shows the difference between the voltages of each bus before and after inserted the HVDC link between bus25 and bus 2 (**case1**). Some of bus voltages increased but others not changed. For example the voltage profile of bus 2 is increased from 0.92 p.u to 1 p.u, bus 13 from 0.89 p.u to 0.956 p.u, and for bus 36 from 0.92 p.u to 0.955 p.u. but some buses voltage unchanged.
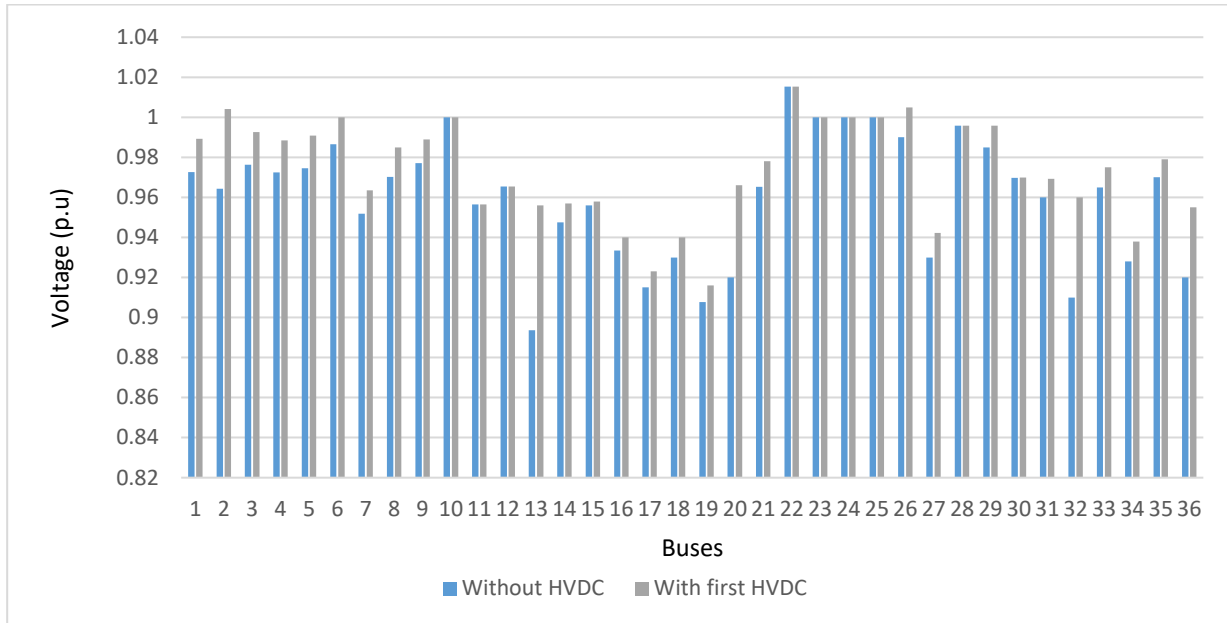
Figure 4. Bus voltages with/without HVDC link (case1) .

In **Fig. 5**, it is obvious that also the buses voltage increased after inserting the HVDC link between bus26 and bus8 (case 2) but with less effect because the power station at bus 26 generate less power than the one at bus25. The power station at bus 26 generate 160 MW but power station at bus 25 generate about 650 MW.

For example the voltage profile of bus 2 is increased from 0.92 p.u to 0.97 p.u, bus 13 from 0.89 p.u to 0.95 p.u, and for bus 36 from 0.92 p.u to 0.95 p.u. but some buses voltage unchanged.
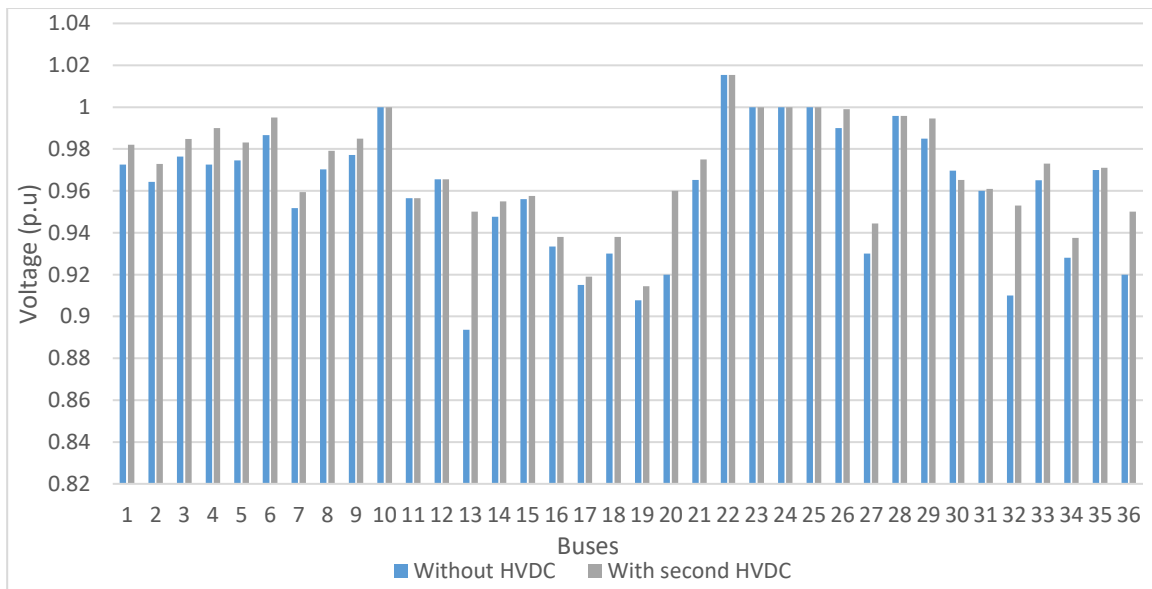

Figure 5. Bus Voltages with/without HVDC link (case 2).

Fig. 6 shows that the voltage profile for some buses increased much more when both HVDC links were inserted at the same time (**case3**) but still unchanged for others. For example a significant rise of voltage observed at bus2 which connected directly to HVDC link, its voltage increased from 0.96 p.u to 1p.u.the voltage, also the voltage of bus13 increased from 0.8936 p.u to 0.96 p.u, and the voltage of bus27 increased from 0.93 p.u to 0.95 p.u, bus36 increased from 0.92 p.u to 0.96 p.u. But some buses voltage still unchanged.
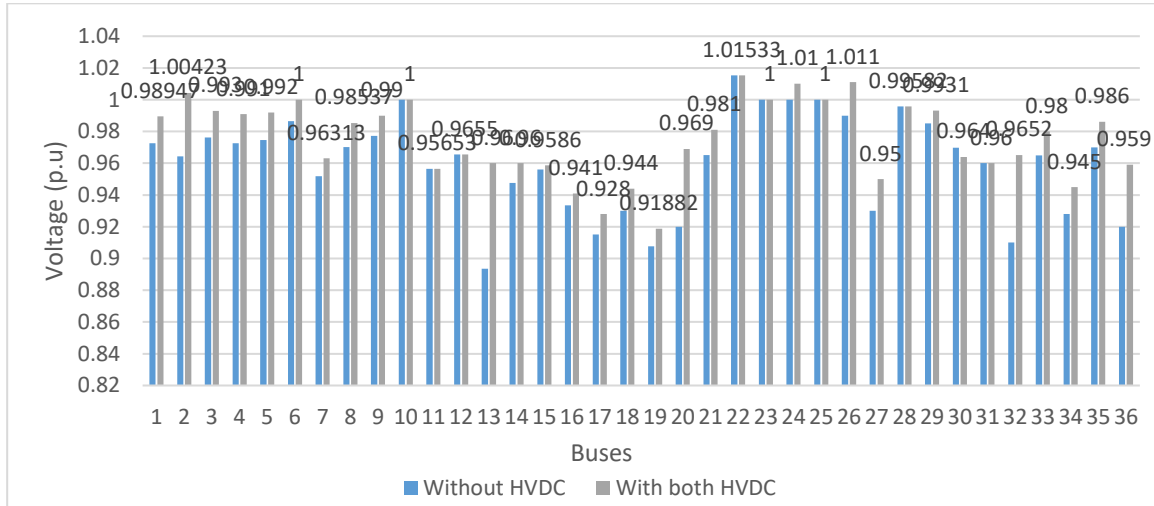

Figure 6. Bus voltages with/without HVDC links (case3).

4. CONCLUSION

The feasibility of HVDC on voltage profile enhancement in Kurdistan network has been studied in this paper through simulations with ETAP.16 program in which Newton Raphson method has been used. The HVDC links have been applied to 36 bus- Kurdistan power system. In the 36 bus network, the voltage profile is enhancement after applying HVDC links separately. Three cases are implemented. It is obtained from the results that the voltage profile is increased at all three cases but in different ratios. In case 1, the bus voltages are improved more than case 2. But the voltage profile is enhanced much more when both links are applied together (case 3). Some buses are needed to enhance voltage just like bus13 and bus 27, are located far away from the generator station and suffer from voltage drops. Their voltages are rose from 0.8936 p.u to 0.96 p.u, and from 0.93 p.u to 0.95 p.u respectively, also the voltage of bus36 increased from 0.92 p.u to 0.96 p.u.

REFERNCES

- ABASS, A., PAVLYUCHENKO, D. & HUSSAIN, Z. S. Methods Comparison for Optimal Capacitor Placement in Distribution System. 2020 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), 2020. IEEE, 1-6.

- ABASS, A. Z., PAVLYUCHENKO, D. & HUSSAIN, Z. S. 2021a. Survey about impact voltage instability and transient stability for a power system with an integrated solar combined cycle plant in Iraq by using ETAP. Journal of Robotics and Control (JRC), 2**,** 134-139.

- ABASS, A. Z., PAVLYUCHENKO, D. A., PROKOPOV, A. V. & ZOZAN, S. H. 2021b. Load Flow and Transient Stability Analyses for an Integrated Solar Combined Cycle Station in Iraqi Southern by Using ETAP. Journal of Siberian Federal University. Engineering & Technologies, 14**,** 5-16.

- AHMED, F. S., HUSSAIN, Z. S. & SALIH, T. K. M. 2022. Enhancing performance for three-phase induction motor by changing the magnetic flux density and core material using COMSOL. International Journal of Electrical and Computer Engineering (IJECE), 12**,** 62-72.

- BHASKAR, M. A., SUBRAMANI, C., KUMAR, M. J. & DASH, S. S. Voltage profile improvement using FACTS devices: A comparison between SVC, TCSC and TCPST. 2009 International Conference on Advances in Recent Technologies in Communication and Computing, 2009. IEEE, 890-892.

- BROWN, K., SHOKOOH, F., ABCEDE, H. & DONNER, G. Interactive simulation of power systems: ETAP applications and techniques. Conference Record of the 1990 IEEE Industry Applications Society Annual Meeting, 1990. IEEE, 1930-1941.

- HABBI, H. M. & ALHAMADANI, A. 2018. Implementation of power system stabilizer based on conventional and Fuzzy Logic Controllers. Journal of Engineering, 24**,** 97-113.

- HUSSAIN, Z., DALLALBASHI, Z. & ALHAYALI, S. Reviews of using solar energy to cover the energy deficit after the recent war in Mosul city. International Conference on Data Science, E-learning and Information Systems 2021, 2021. 254-265.

- IDRIS, R. M., KHAIRUDDIN, A., MUSTAFA, M. & KALAM, A. 2010. Optimal allocation of multi-type FACTS devices using bees algorithm for ATC enhancement in deregulated power system. International Review of Electrical Engineering, 5.

- IQBAL, F., KHAN, M. T. & SIDDIQUI, A. S. 2018. Optimal placement of DG and DSTATCOM for loss reduction and voltage profile improvement. Alexandria Engineering Journal, 57**,** 755-765.

- ISMAIL, S. Y., HUSSAIN, Z. S., THABET, H. T. & THABIT, T. 2021. Using PI Controller Unit for Controlling the Water Temperature in Oil Fired Heaters by PLC Techniques. PRZEGLĄD ELEKTROTECHNICZNY, ISSN**,** 0033-2097.

- KUBBA, H. A. & ESMIEEL, M. T. 2018. Flexible Genetic Algorithm Based Optimal Power Flow of Power Systems. Journal of Engineering, 24**,** 84-96.

- LIU, C., ZHANG, B., HOU, Y., WU, F. F. & LIU, Y. 2010. An improved approach for AC-DC power flow calculation with multi-infeed DC systems. IEEE Transactions on Power Systems, 26**,** 862-869.

- LONG, W. & NILSSON, S. 2007. HVDC transmission: yesterday and today. IEEE Power and Energy Magazine, 5**,** 22-31.

- MAREFATJOU, H. & SOLTANI, I. 2013. Optimal placement of STATCOM to voltage stability improvement and reduce power losses by using QPSO algorithm. Journal of Science and Engineering, 2**,** 105-119.

- MUHAMMAD, T. K. 2019. Performance improvement of interconnected 400kV, 50Hz Kurdistan and Iraq power systems using proposed HVDC link. Zanco Journal of Pure and Applied Sciences, 31**,** 131-136.

- PATIL, P. S. & PORATE, K. Starting analysis of induction motor: A computer simulation by ETAP power station. 2009 Second International Conference on Emerging Trends in Engineering & Technology, 2009. IEEE, 494-499.

- RAMBABU, C., CBULESU, Y. & SAIBABU, C. 2011. Improvement of voltage profile and reduce power system losses by using multi type facts devices. International Journal of Computer Application, 13.

- SALAMA, A. Y., SHALABY, M., AZIZ, A. A. & REFAI, R. 2014. Aswan HighDam/Cairo proposed HVDC transmission system. Beni-Suef University Journal of Basic and Applied Sciences, 3**,** 37-44.

- SHESHAGIRI, M. & RAM, B. Voltage Improvement and Loss Reduction with Static-Var Compensator (SVC) Subjected to Reactive Load Changes. ICRTEMMS Conference Proceedings, 2018. Swarna Bharathi lnstitute of Science and Technology, 149-152.

- SOOD, V. K. 2018. HVDC Transmission. Power Electronics Handbook. Elsevier.

- THAPA, B. & MOHAN, T. M. 2013. Analysis of controller effects of statcom on power system during the fault condition. IJAIR, 2.

- WANG, H. & REDFERN, M. A. The advantages and disadvantages of using HVDC to interconnect AC networks. 45th International Universities Power Engineering Conference UPEC2010, 2010. IEEE, 1-5.