# A STUDY ON THE TRANSIENT STABILITY IMPROVEMENT USING HVDC-LIGHT

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**ABSTRACT**

The understanding of the transient stability on power systems is very important to power engineer. Theoretically, there were two types of stability in power systems which are steady-state stability and transient stability. Since transient stability gives a big impact to power systems operation, so, the study on the transient stability is conducted. There were many Flexible AC Transmission Systems (FACTS) devices that can be used to improve the transient stability on the power system network, such as Unified Power Flow Controller (UPFC), Static VAR Compensator (SVC), Thyristor-Controlled Series Capacitor (TCSC), Dynamic Voltage Restorer (DVR), High Voltage Direct Current – Light (HVDC-Light) and so on. HVDC-Light was an idea to connect the power network from Bakun to peninsular Malaysia through the submarine cable.

HVDC-Light has been chosen to be analyzed since this technology has not been completed. So, the simulation for this system has been designed in PSCAD software. HVDC-Light comprises two Voltage Source Converters (VSCs), one operating as rectifier and the other operating as inverter. The simulation of this project involves the two buses system, synchronous machine and generator. So, the circuit without the HVDC-Light and the circuit with HVDC-Light are designed in the PSCAD software. Then, the comparison of the output which consists of active power, reactive power, voltage and internal phase angle for the synchronous machine between those two circuits will be made. The result shows that HVDC-Light improved the transient stability and power generation on the power systems network..

## 1.0 INTRODUCTION

The deregulation of the electricity market together with increasing constraints resulting from social opposition to the installation of new facilities puts new demands on the operators of transmission and distribution systems. These new trends enhance the need for flexibility, power quality and increased availability of transmission and distribution systems by using tools which can be implemented with limited investments, short delivery times and short planning and decision making horizons. FACTS is a term denoting a whole family of concepts and devices for improved use and flexibility of power systems. Some of these devices have today reached certain maturity in their concept and application; some are as a matter of fact quite established as tools in power systems. One of the FACTS devices is HVDC Light, a new DC transmission system technology, still consisting of well-known components forming the system. HVDC Light is very suitable for DC power transmission for a number of applications.

HVDC-Light is a new DC transmission system technology which is used to improve transient stability and power flow of the power system network. HVDC-Light is very suitable for DC power transmission as well as for reactive power generation and consumption. One HVDC-Light unit is capable of transmitting up to about 200 MW, as of today. The same unit can also be used to generate or consume up to about 200 MVAR. These properties are controlled independently of each other, and this is one of many features with HVDC-Light.[1]

### Basic operation of HVDC Light

As explained before, HVDC-Light comprises two Voltage Source Converters (VSC), which at the sending end converter works as rectifier (ac power to dc power) while the receiving end converter works as inverter (dc power to ac power). So, these two converters are main part of the HVDC system as shown in figure 1.1. [2]

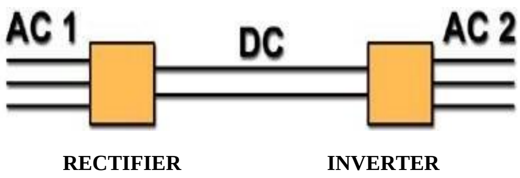


**Figure 1.1:** Two voltage source converter in HVDC-light system**.**

Thyristor is main device in HVDC-Light system converter for triggering and turning off purposes. They are stacked (series-parallel) to provide desired rating, say 200 kV, 2 kA in an assembly what is known as a “valves”. The main requirements of the valves are:

To allow current-flow with low voltage drop across it during the conduction phase and to offer high resistance during non-conducting phase.

To withstand high peak inverse voltage during non-conducting period.

To allow a reasonably short-commutation margin angle during inverter operation.

Smooth control of conducting and non-conducting phases.

A number of valves are connected in series to withstand DC voltages in the range of 500 to 600 kV or more.

These valves act as either rectifier (at sending end) or as inverter (at receiving end). The power flow can be reversed by changing the direction of DC voltages at two ends and not the current. This is possible due to bidirectional nature of the converters at two ends. The converters comprise the valves in “bridge connected” mode. A bridge may consist of 3, 6, 12 valves. Bridge form allows higher DC voltage. The model of VSC is shown in Figure 1.2. [1]

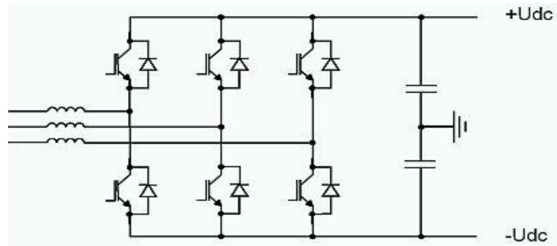


**Figure 1.2:** Voltage source converter

In this project, the transistor will be replaced with thyristor as shown in Figure 1.3. The rectifier and inverter will be controlled by adjusting the firing angle for the thyristor. Firing pulses are generated using comparison of the reference signals to triangular signals. This is the concept of the Pulse Width Modulator (PWM) system. These two sets of signals (reference and triangular ones) are needed, which are one will be set for turning on and the second one (a negation of the first set of signals) will be set for turning off. Two signals are being sent to each switch, the first one tells to turn on or off, the second one determines an exact moment of switching and is used by interpolation procedure which allows for exact switching between time steps.

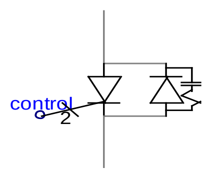


**Figure 1.3:** Component Of voltage source converter

AC voltage control at the sending end is achieved by the exciter of the synchronous generator. Power flow is achieved by controlling the phase angle of the ac side voltage of the sending end converter. Besides that, reactive power generated by the sending end converter is held to a low value by adjusting the magnitude of the voltage on the ac side.

### 1.2 Advantages and Disadvantages of HVDC

The main advantages of HVDC compared with HVAC are:

**1.** Economically attractive to transmit a large amount of power over long distance.

**2.** Improve transient stability and dynamic damping of the oscillation.

**3.** Its possible to connect two AC system with different frequencies or which are not simpler synchronized by means of HVDC.

**4.** Less line transmission.

**5.** DC lines has no reactive power problems.

The disadvantages of HVDC are:

**1.** The higher cost of converter stations compared with an ac transformer substations.

**2.** The need to provide filters and associated equipment to ensure acceptable waveform and power factor on ac side.

## 2.0 METHODOLOGY

There are two main parts to do this project.

- Simulation using PS-CAD
- Analysis of the result

### 2.1 Circuit for the System with HVDC-Light.

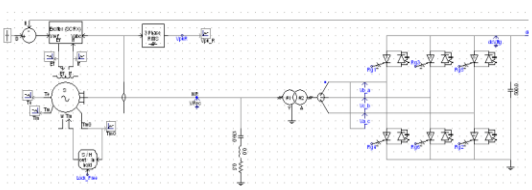

**Figure 2.2** Circuit at sending side

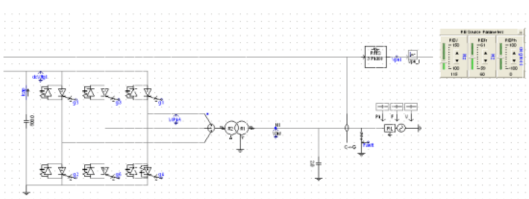

**Figure 2.3** Circuit at receiving side

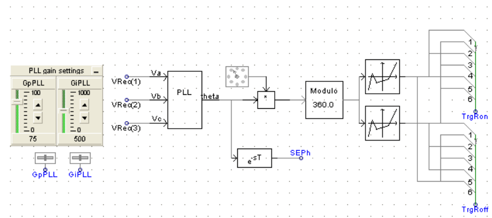


**Figure 2.4** Phase Lock Loop Setting

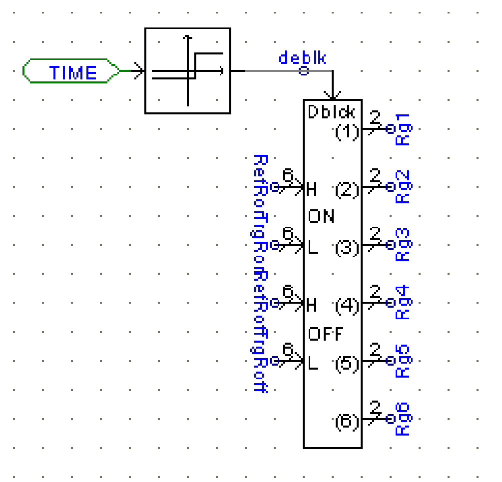


**Figure 2.5** Firing Angle Pulse Settings (Rectifier)

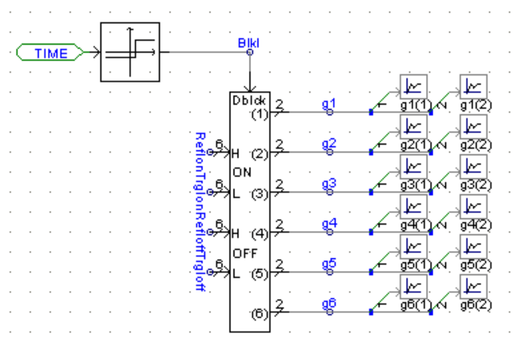


**Figure 2.6** Firing Angle Pulse Settings (Inverter)

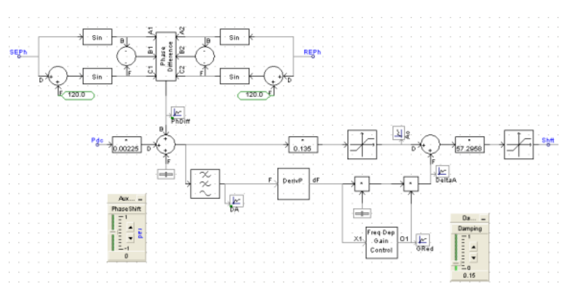

**Figure 2.7** Open Loop Power Flow Controllers.

## 3.0 RESULTS AND DISCUSSION

After the circuits with and without HVDC-light are drawn, the output graph for both circuits is gathered. The graphs that have been considered to be compared are the active and reactive power at sending and receiving part, internal phase angle for the synchronous machine, voltage rms in p.u for sending and receiving part and line voltage in kV for sending and receiving part. Besides that, the power flow reading taken from the circuit breaker will be used to prove that power flow of the system is improved and to find the power factor of the system.

As explained before, transient stability studies deal with the effect of large and sudden disturbances. So, fault is applied to the system to gives the transient condition for the system. So, fault is applied at 2.1 seconds and the duration of fault is 0.05 seconds. This project will discuss only for the single-line-to-ground fault which is commonly happen at power systems network.
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### 3.1 Results for the System without HVDC-Light

Figure 3.1.1, 3.1.2 3.1.3 and 3.1.4 shows the graphs obtained from the simulation in p.u at sending and receiving. Figure 3.1.1 for reactive power, figure 3.1.2 for active power, figure 3.1.3 for voltage rms and figure 3.1.4 for internal phase angle for the synchronous machine. Figure 3.1.5 shows the graphs for the line voltage in kV at sending and receiving.

It's clearly shown that after the fault occurs at 2.1 seconds; all the graphs will lose the stability and will take more than 5s to regain back the stability. So, if these conditions happen to the actual power system network, it will cause for the damaging of the synchronous machine and the whole power system might be paralyzed if the unstable part is not recovered to stability.

Besides that, for the internal phase angle for the synchronous machine, its clearly shows that the angle will lose the stability after the fault occur. The angle seems will not regain the stability.

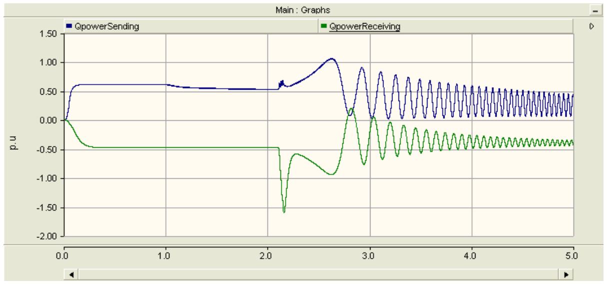


**Figure 3.1.1** : Graph for Reactive Power.

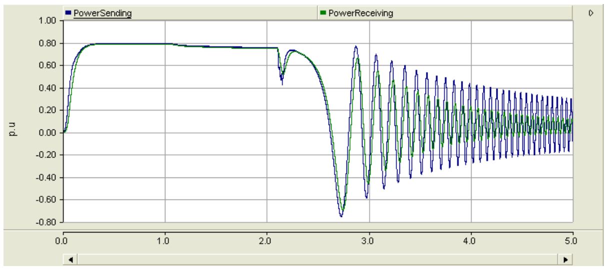


**Figure 3.1.2** : Graph for Active Power.

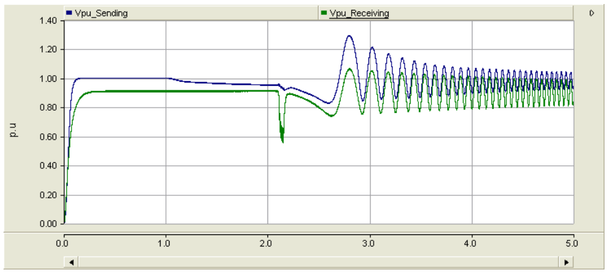


**Figure 3.1.3** : Graph for Voltage RMS.

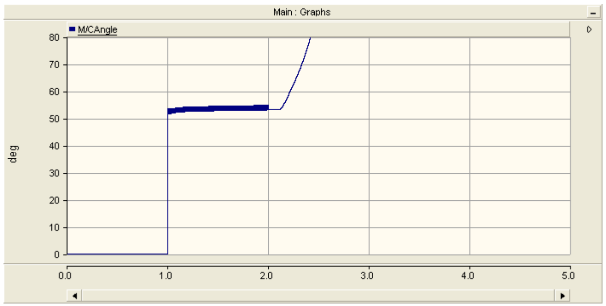


**Figure 3.1.4**: Graph for Internal Phase Angle for Synchronous Machine

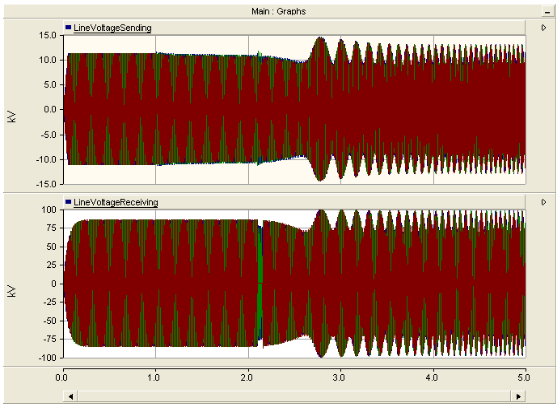


**Figure 3.1.5:** Graphs for Line Voltage at Sending and Receiving

### 3.2 Results for the System with HVDC-Light

To make comparisons between the system without HVDC-Light and the system with HVDC-Light, the same circuit has been designed. The transmission line is replaced by the cable with the same length. All the setting for the synchronous machine, filter, generator and fault is still the same as before. So, the comparisons can be made clearly.

Figure 3.2.1, 3.2.2, 3.2.3 and 3.2.4 shows the same graphs as before in p.u at sending and receiving. Figure 3.2.1 for reactive power, figure 3.2.2 for active power, figure 3.2.3 for voltage rms and figure 3.2.4 for internal phase angle for the synchronous machine. Figure 3.2.5 shows the result for the line voltage at sending and receiving.

It is clearly shown that, after single-line-to-ground fault occurs at 2.1 seconds, all the graph will take only 0.7s to regain the stability. Besides that, the internal phase angle for the synchronous machine will not lose the stability and considerably stable.

So, it is proved that HVDC-Light technology improved the transient stability of power systems network which caused by single-line-to-ground fault. Besides that, for long-distance transmission line, HVDC-Light is very useful to transmit a constant power DC which can decrease the losses along the transmission line. If sudden disturbances occur, HVDC-Light technology system will take a short period of time to regain the stability and will not cause any damage of the machines.

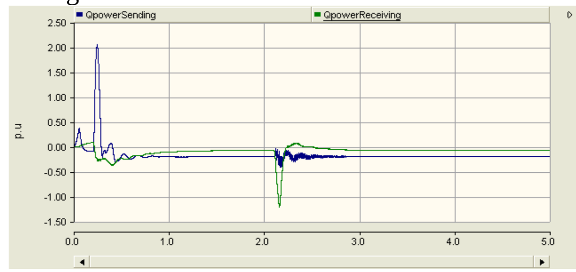


**Figure 3.2.1**: Graph for Reactive Power.

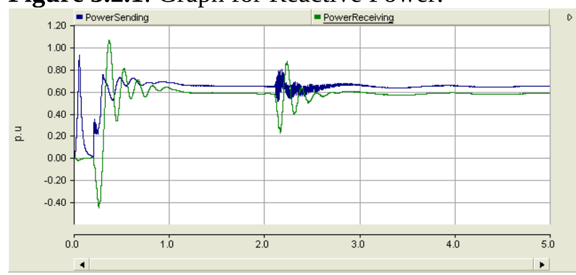


**Figure 3.2.2**: Graph for Active Power

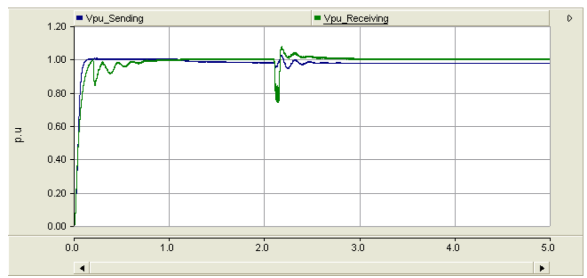


**Figure 3.2.3**: Graph for Voltage RMS.

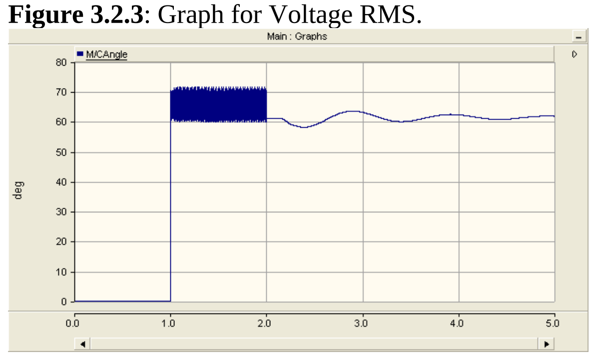


**Figure 3.2.4**: Graph for Internal Phase Angle for Synchronous Machine

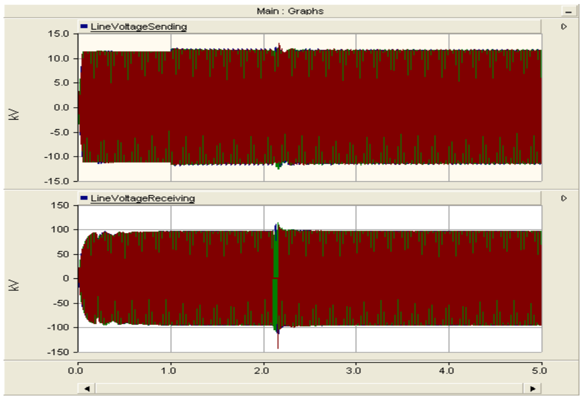


**Figure 3.2.5**: Graphs for Line Voltage at Sending and Receiving

### 3.3 Results for Power Flow and Power Factor

As the transient stability for the system is shown in the previous graphs, so, the power flow of the system will be shown as the Table 3.1 below.

| **SENDING PART** | | **RECEIVING PART** | |
|---|---|---|---|
| ACTIVE POWER | 26.63 [MW] | ACTIVE POWER | -18.84 [MW] |
| REACTIVE POWER | 22.02 [MVAR] | REACTIVE POWER | 41.47 [MVAR] |
| POWER FACTOR | 0.7635 | POWER FACTOR | 0.4136 |
| VOLTAGE | 0.9410 [p.u] | VOLTAGE | 0.8318 [p.u] |

**Table 3.1**: Results for the Power Flow and Power Factor (without HVDC-Light)

From the table, it is clearly shown that the power factors of the system without HVDC-Light for both sending and receiving part are not suitable for the system. As we know, the suitable value for the power factor of the power system is nearly to 1. So, the power factor and power flow of this system is improved using HVDC-Light.

| **SENDING PART** | | **RECEIVING PART** | |
|---|---|---|---|
| ACTIVE POWER | 60.92 [MW] | ACTIVE POWER | -52.33 [MW] |
| REACTIVE POWER | -18.88 [MVAR] | REACTIVE POWER | 7.234 [MVAR] |
| POWER FACTOR | 0.9552 | POWER FACTOR | 0.9906 |
| VOLTAGE | 0.9759 [p.u] | VOLTAGE | 1.0011 [p.u] |

**Table 3.2**: Results for Power Flow and Power Factor (with HVDC-Light)

When the HVDC-Light technology is applied to the system, it is clearly shown in Table 3.2 that the power flow and power factor at steady-state condition has been improved. The power factor value, both at the sending and the receiving part, is close to 1, which is the nominal value for better power generation.

### 3.4 Summary

The circuits that have been drawn in PSCAD software consist of two-buses system of the system without HVDC-Light and with HVDC-light. The comparisons that has been made between these two circuits has considered the same length of the transmission system, which in other words, the system without HVDC-light used 100km of AC transmission line and the system with HVDC-light used 100km of DC cables. So, the comparisons can be made clearly. From the results obtained, it shows clearly that HVDC-Light improved the transient stability and power quality of the power systems.

## 4.0 CONCLUSION

The transient stability of the power systems can be improved using HVDC-Light with two circuits using PSCAD software has been discussed. The first circuit is for without HVDC-Light and other is for the system with HVDC-Light.

After the simulation is done, the results clearly show that HVDC-Light technology improved the transient stability and power quality of the power systems by comparing the graphs between two circuits. A single-line-to-ground is applied to the systems at 2.1 seconds to give the impact of the transient stability.

The system with HVDC-Light took just only 0.5s to regain the stability, whereas the system without HVDC-Light took more than 5s to regain the stability. Besides that, the internal phase angle for the synchronous machine loses the stability after the fault occurred for the system without HVDC-Light. If this happens to the actual system, the synchronous machine might be damaged. But, when HVDC-Light is used, the internal phase angle for the synchronous machine does not lose the stability after the fault occurred.

As we know, the ideal power factor of the power systems is approximately one. This is very important to ensure minimal losses on the transmission line while power is transmitted by the generator. From the simulation, the system with HVDC-light improved the power factor of the power system.

## 5.0 ACKNOWLEDGEMENT

First of all, praise is only to **Allah s.w.t** for His bounty and blessing upon us who have give me strength and ability to complete this project and report. I would like to express my sincere appreciation to my supervisor, Ir Harizan Che Haris and Prof. Madya Pauziah Arsyad for their suggestions, guidance and invaluable advice upon completing this project. Explicit thankfulness was given to my parents who gives their loves and support for me directly or indirectly and to my entire friend for their time and support, giving ideas, comment and encouragement. This project wouldn't be possible without the helps from all of them.

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