Power Flow with HVDC lines

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Introduction:

HVDC systems are used to distribute power over long distances. They are the realistic economic and technical alternative to AC systems. They help to transmit this power over long distances, via cable, between networks. These networks operate at different frequencies to provide additional power without increasing the short circuit ratio of the AC system. This system decreases the power loss and provide grid access for renewable sources. They also result in less space requirements for DC towers, compared to AC towers.

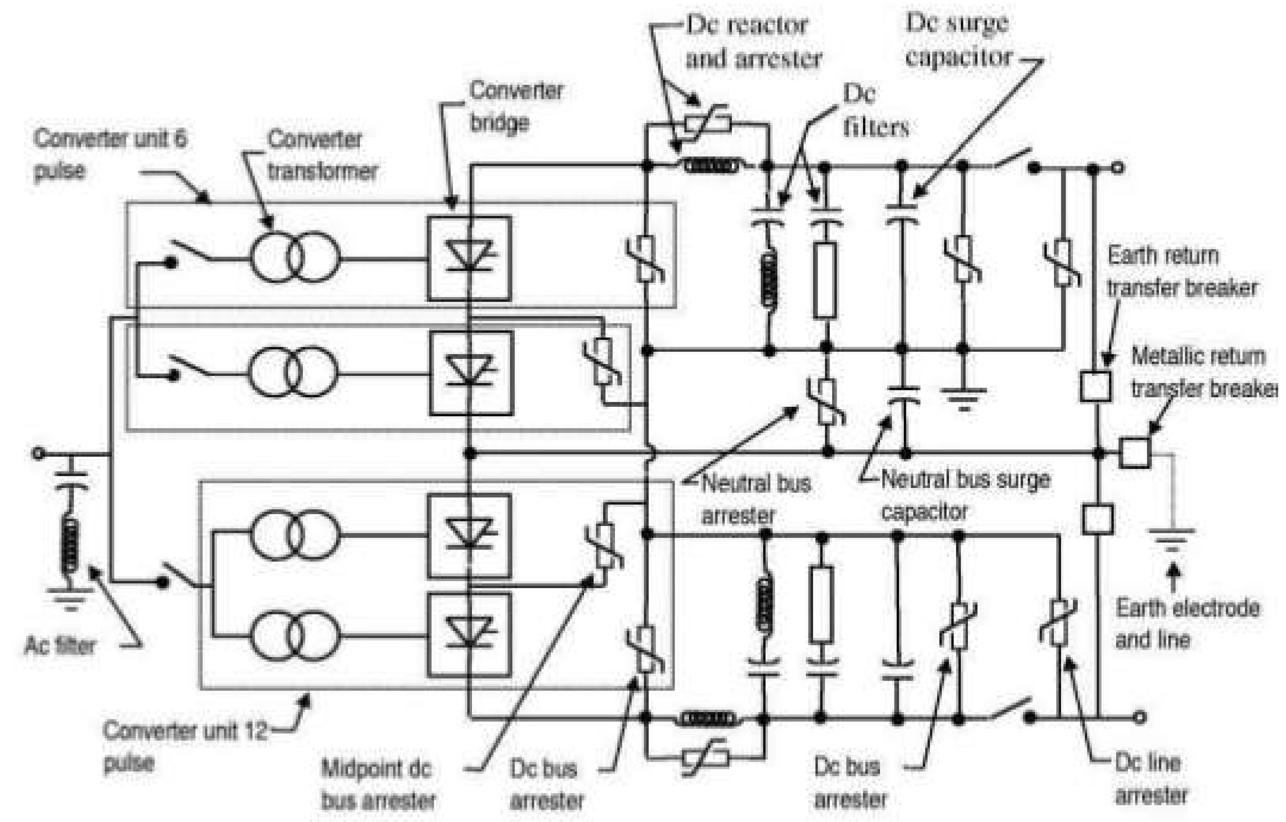

Figure 1: Image of an HVDC system

Benefits

- ❑ Cost efficient
- ❑ System stabilizes faster
- ❑ Lower power loss
- ❑ Lower amount of cables required for the same purpose
- ❑ Easier to control flow of power

COST: AC vs DC Transmission

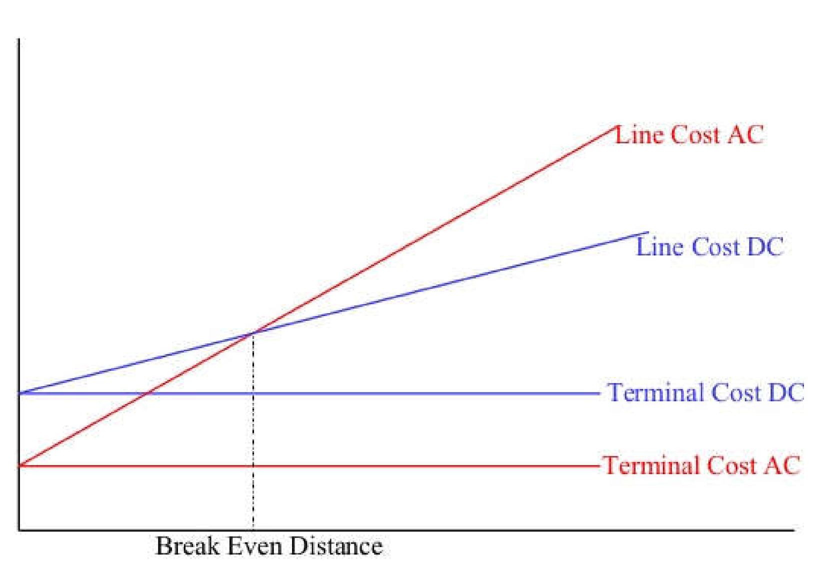

Figure 2: Cost Comparison

Method

We used a 14-bus system to analyze power flow after adding HVDC lines. Taking a look at the set up, we determined where we could put the HVDC lines. We connected buses that were not already connected. Using PSAT, a Matlab toolbox, we were able to take a look at how the power flow was affected. We took a look at the differences in the phase angles and the reactive powers.

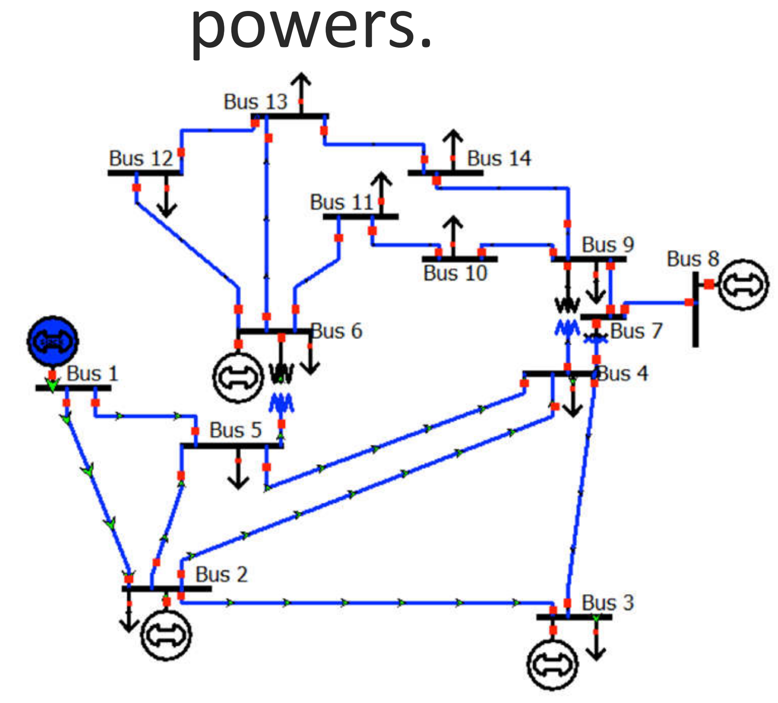

Figure 3: IEEE bus system set up

The Newton Raphson Method

To calculate power flow, a commonly used algorithm is used, known as the Newton Raphson Method. It uses what are called iterations. Below are some of the equations. When using PSAT, a Matlab toolbox, this method is used.

$$\Delta y^{(i)} = -[g_y^{(i)}]^{-1}\, g^{(i)} \quad (1)$$

$$y^{(i+1)} = y^{(i)} + \Delta y^{(i)} \quad (2)$$

$$\tau(\mathrm{y}) = g^{(i)} + g_y^{(i)}\left(y - y^{(i)}\right) \quad (3)$$

Figure 4: Newton Raphson Equations

Results

When comparing the static report of the original system, and the system after adding HVDC lines, we took a look at the differences between the phase angles, the reactive and active powers. When looking at any power flow, having voltage and current that are too out of phase result in inefficient power. Too much reactive power can result in this as well. When testing the connections there were cases that just couldn't work because the difference in the phase angle was too great. Below is a chart comparing the phase a ngles of the system with (blue) and without HVDC lines connected (orange).

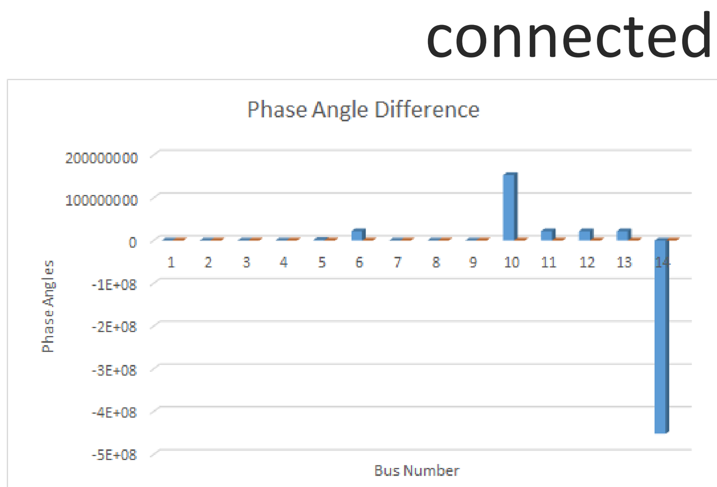

Figure 5: Bad Connection, Buses 4 and 6