Voltage Regulation of Small Power Systems

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Abstract: Voltage is one of the main indicators to measure the quality of power. If the voltage offset exceeds the allowable value, it will have a very negative impact on the economic and security aspects of the power system. Assuring that the voltage offset is within the allowable range is one of the main requirements for the operation of the power system

Keywords: Voltage regulation; Power system analysis

1. Introduction

Power system voltage regulation refers to the technical measures taken to keep the operating voltage of each voltage central point in the power system within the specified allowable range. This lab is to adjust the bus voltages and improve the power system of the given circuit by the following actions:

1. Adjusting transformer taps
2. Changing generator voltages
3. Switching shunt VAR sources

From the equation below, we can clearly see how these factors change the bus voltage.

If we increase the generator voltage, reduce the inductive reactive power or the taps, the voltage of bus would be higher. (Ignore the loss on the transmission line)

$$\frac{V_G}{K}-\frac{PR+QX}{V_G/K}=V_2$$

V_G Is the voltage of the generator

V_2 Is the voltage of the bus

P Is the total power of the load

Q Is the total reactive power of the load (It's usually inductive power)

K Is the turns ratio of the tap-changing transformer

The voltage regulation design of the lab is based on the basic balance of reactive power and reasonable configuration. Otherwise, the reactive power compensation should be performed first.

In this lab, we use the Z_{test} method to make sure which Is the best position to locate the capacitor. The Z_{test} method is recording the voltages on each bus after putting a capacitor on each bus, we can determine the most suitable bus to place the capacitor on by the Z_{test} value.

$$Z_{test}(k)=\sum\Delta v_i$$

2. Method

First, we use Powerworld to draw a single-line diagram according to the content of the lab report and mark the required information in per-unit value. As shown in Figure 1, some bus voltages are smaller than 0.95pu and bus3 has the largest voltage violation.

First, we increase the voltage of the slack bus to its maximum value 1.05pu, it could increase the overall voltage level. The voltage of bus 2 is 0.99pu and bus 4 is 0.96pu, both of them fit the bill. Because if we increase the generator voltage, the power and the reactive the generator conveyed would also be increased. The voltage drops from a higher value, so the minimum value would be a little higher.

Then we change the turns ratio (tap) of the transformer which between bus2 and bus3, it could be clearly seen that the voltage of bus3 and bus4 can both higher than 0.95pu,

But bus 4 and bus 5 couldn't realize that. Because the voltage of the two sides of the transformer would be changed (one side higher and the other side lower), if we change tap of the transformer. In this lab, we try to balance the voltage on both sides of the transformer to ensure the voltage over 0.95pu.

Although we have taken above actions, the voltage of bus5 is still below 0.95pu due to the lack of reactive power. Then we need to take action to supply the reactive power. We use capacitor to compensate reactive power to improve the bus voltage. To find out which bus is most suitable to place the capacitor on, we use the Z_{test} method.

We choose a 5MVAR capacitor, place it on each bus in turn, and then we record the voltage changes on each bus which is shown below in results. According to the result, we can easily determine the bus to put the capacitor, and make the bus voltage over 0.95pu by changing the taps.

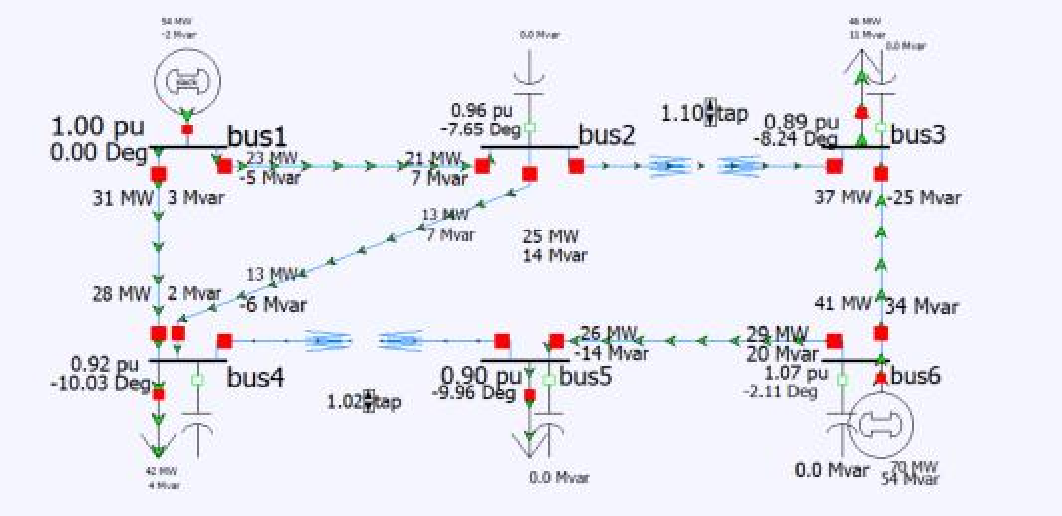

Figure 1. The initial condition

After doing that, we can find that the voltage of every bus is a little small. So we improve the power system by three actions, the final condition Figure 2 is shown below, then we talk about the details.

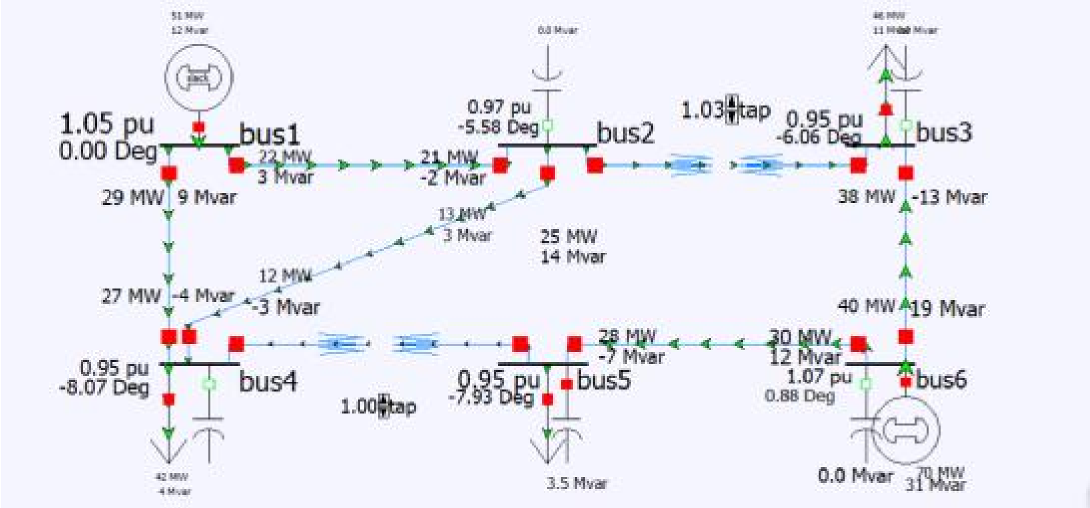

Figure 2. The final condition

3. Results and Discussion

The table below shows the information of Z_{test}, we find that Bus4 and Bus5 is most suitable to place the capacitor. Because they have the largest voltage changes when putting the same capacitor on it. However, comparing these two conditions, it clearly seen that voltage angle is smaller when it placed on Bus5. So Bus5 is the most suitable bus.

Table 1. The results of Z_{test}

	Bus2 voltage	Bus3 voltage	Bus4 voltage	Bus5 voltage	$\Sigma\Delta Vi$
Initial	0.97	0.95	0.95	0.92	0
Bus2	0.98	0.95	0.95	0.92	0.01
Bus3	0.98	0.96	0.95	0.92	0.02
Bus4	0.98	0.95	0.96	0.93	0.03
Bus5	0.98	0.95	0.96	0.93	0.03

After then we change the taps of transformer to balance the two sides voltage of transformer, and the voltages of every bus are all over 0.95pu. To make the power system performed economically, we reduce the capacitance gradually until 3.9MVAR. And this is final condition which is economical and meets the requirements.

The last but not least, the loss of the power system would be fewer in the final condition than that in initial condition. The capacitor can supply capacitive reactive power which can counteract inductive reactive power. According to the equations ($\frac{V_G}{K} - \frac{PR+QX}{V_G/K} = V_2, S = P + jQ$), the apparent power is reducing and the bus voltage is increasing, so the current would be small in the final condition. The main loss of power system is I^2R which is reduced in this condition because of the reduced current.

4. Conclusion

Experimental results showed a clear correlation between the bus voltage and capacitor that place capacitor on bus would improve the bus voltage because of the compensation of the capacitor. In the lab, Z_{test} method is very useful when determine location of the capacitor. Meanwhile, changing the generator voltage can improve the bus voltage too. Because the whole voltage level is increased. Changing the taps of the transformer can also improve the bus voltage, because it can balance the voltage of the two sides. The loss of the system is decreased because of decrease of current. It's very important to improve the power system with these effective actions.

References

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