American Journal of Applied Sciences 9 (6): 906-908, 2012
ISSN 1546-9239

Power-Voltage Characteristics of Power System with the Short Transmission Line

Prechanon Kumkratug
Department of Electrical Engineering, Faculty of Engineering at Si Racha,
Kasetsart University, 199 M.6, Tungsukhla, Si Racha, Chonburi, 20230, Thailand

Abstract: Problem statement: Power-Voltage curve provides very important information for voltage stability analysis. The exact short transmission line model consists of the resistance and reactance. The resistance causes in the active line loss. It is not easy task to achieve the power-voltage curve characteristics of power system with the exact short line model. **Approach:** This study applied the concept of the Newton-Raphson method to iteratively solve the nonlinear power flow equations. The power-voltage (P-V) curve characteristic of the system without line loss and with line loss were plotted and compared on various cases. **Results:** It was found from the study that the resistance of the line obviously provides negative effects on the voltage stability. The line loss causes in the decrement of the critical point. It was found that the leading power factor could increase the critical point of P-V curve. **Conclusion:** The exact short line model can be considered for voltage stability analysis of the system with the short transmission line.

Key words: Voltage stability, voltage collapse, critical voltage, critical power, power-voltage curve, newton-raphson, reactive power, active power

INTRODUCTION

Power system stability is classified as rotor angle stability and voltage stability. Voltage stability is in power systems which are heavily loaded, disturbance or have a shortage of reactive power. Nowadays, the demand of electricity has dramatically increased and a modern power system becomes a complex network of transmission lines interconnecting the generating stations to the major loads points in the overall power system in order to support the high demand of consumers. It is becoming increasingly important to fully utilize the existing transmission system assets due to environmental legislation, rights-of-way issues and costs of construction and deregulation policies that introduced in recent years. A number of Flexible AC Transmission System (FACTS) controllers, based on the rapid development of power electronics technology, have been proposed for better utilization of the existing transmission systems (Padma and Rajaram, 2011; Subramani *et al*., 2012; Osuwa and Igwiro, 2010; Nabhan and Abdallah, 2010; Zarate-Minano *et al*., 2010).

The evaluation of the Power-Voltage (P-V) curve of the power system is one of the most important research areas for power engineers because it indicates the maximum power load. If the load is increased beyond the maximum value, the voltage will be collapsed and then the system is considered as unstable.

The transmission line is one of the most important parts in power system components. Most of the fault occurs at the transmission line. It is generally divided into three major categories; short, medium and long model whose distance are about 80 km, above 80-250 and above 250 km, respectively. Many previous researches used simple transmission line model by neglecting its resistance or capacitance. To fully utilization the existing system, the exact transmission line should be further investigated.

This study investigated the effects of line loss in short transmission line on voltage stability. The mathematical model of the power flow is systematically derived. The concept of the Newton-Raphson method is applied to iteratively solve the nonlinear power flow equations. The Power-Voltage (P-V) curve characteristic of the system without line loss and with line loss are plotted, discussed and compared on various cases.

MATERIALS AND METHODS

Mathematical model: Consider the simple system as shown in Fig. 1. The generator supplies the active power and reactive power, which is transferred through a transmission line to the load. The voltage at generator bus (V_S) is considered as constant value. The short transmission line model is represented by a impledant Z. The load is represented by the active (P_R) and reactive power (Q_R).

The line current is given by:

$$\begin{aligned} I &= \frac{V_S - V_R}{Z} = \frac{V_S\angle\theta_S - V_R\angle\theta_R}{Z\angle\gamma} \\ &= \frac{V_S\angle(\delta-\gamma)}{Z} - \frac{V_R\angle(\delta-\gamma)}{Z} \end{aligned} \quad (1)$$

From the line current as given in Eq. 1, the complex power load is written by Eq. 2:

$$\begin{aligned} S_R &= P_R + jQ_R = V_R I^* \\ &= \frac{V_R V_S}{Z}\angle(\gamma-\delta) - \frac{V_R^2}{Z}\angle\gamma \end{aligned} \quad (2)$$

Then the active and reactive power load are given by Eq. 3 and 4:

$$P_R = \frac{V_R V_S}{Z}\cos(\gamma-\delta) - \frac{V_R^2}{Z}\cos\gamma \quad (3)$$

And:

$$Q_R = \frac{V_R V_S}{Z}\sin(\gamma-\delta) - \frac{V_R^2}{Z}\sin\gamma \quad (4)$$

The objective of this study is to evaluate the voltage at load bus (V_R) with various cases of load. This study applies the Newton-Raphson method to iteratively solve the nonlinear Eq. 3 and 4 given by:

$$\begin{bmatrix} \Delta P_R \\ \Delta Q_R \end{bmatrix} = \begin{bmatrix} \dfrac{\partial P_R}{\partial\delta} & \dfrac{\partial P_R}{\partial V_R} \\ \dfrac{\partial Q_R}{\partial\delta} & \dfrac{\partial Q_R}{\partial V_R} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} \quad (5)$$

The general form of Eq. 5 is given by:

$$\begin{bmatrix} \Delta P_R \\ \Delta Q_R \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} \quad (6)$$

This study will investigate the effect of line loss on voltage stability of the system and be compared that of without line loss. Without line loss, the active and reactive power are given by:

$$P_R = \frac{V_R V_S}{X}\sin\delta \quad (7)$$

And:

$$Q_R = \frac{V_R}{X}\left[V_R - V_S\cos\delta\right] \quad (8)$$

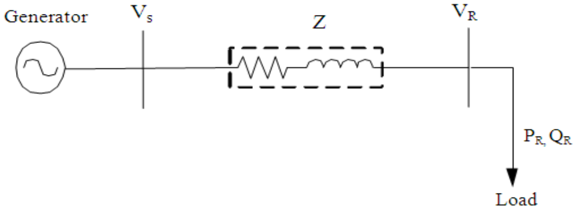

Fig. 1: Configuration of a simple radial power system for illustration of voltage instability

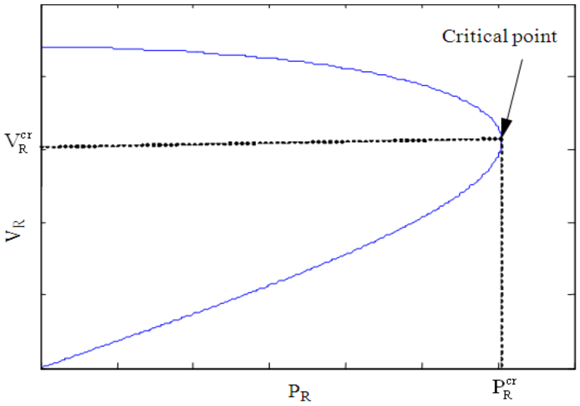

Fig. 2: P-V curve

The characteristic of the P-V curve for neglecting line loss can be obtained by solving Eq. 6-8 and it is shown in Fig. 2. The power system is operated in upper part of the P-V curve. The head of the P-V curve is called the critical point (V_R^{cr}, P_R^{cr}). The critical point provides very important information to power system engineers. If the system supplies load beyond P_R^{cr}, it causes in voltage collapse.

RESULTS

The proposed method is tested on the sample system consider the diagram of sample system is shown in Fig. 1. The system supplies power which is transferred through a 40 km transmission line to the load. The system voltage at the generator bus is 220 kV.

Figure 3 and Fig. 4 show the P-V curve of the system without and with line loss for various power factors, respectively. Table 1 summarizes the critical point (V_R^{cr}, P_R^{cr}) of the system without and with line loss for various power factors.

DISCUSSION

It can be seen from the Fig. 3 and Table 1 that without line loss at unity power factor the maximum active power load is around 1210 watts and the critical voltage is around 155 kV.

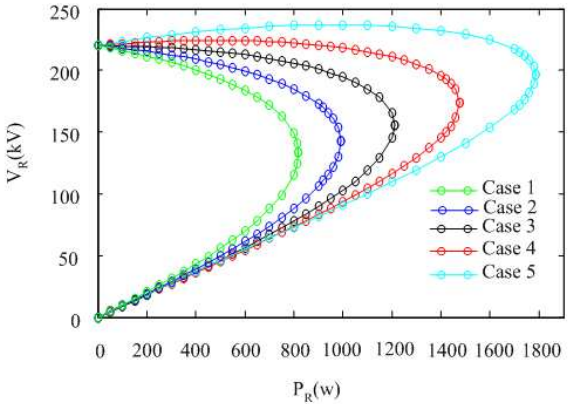

Fig. 3: P-V curve of the sample system without line loss for various power factors

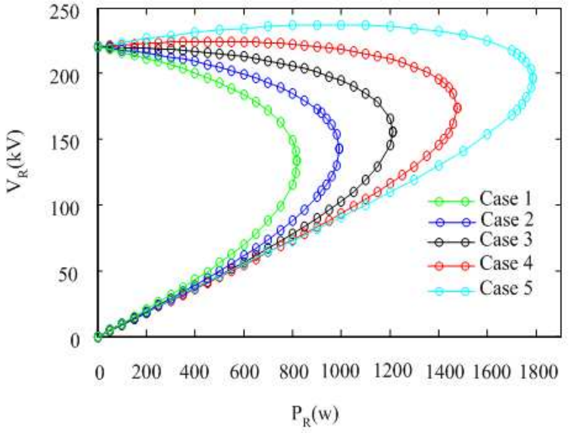

Fig. 4: P-V curve of the sample system with line loss for various power factors

Table 1: The critical point of the system without and with line loss for various power factors

		Without line loss		With line loss	
Case	tan ϕ	P_R^{cr} (W)	V_R^{cr} (kV)	P_R^{cr} (W)	V_R^{cr} (kV)
1	0.4	819.20	133.221	663.21	122.297
2	0.2	991.96	142.421	773.30	128.676
3	0.0	1210.00	155.563	900.27	137.415
4	-0.2	1476.00	173.505	1038.88	149.046
5	-0.4	1787.20	196.466	1181.11	163.212

The power factor affects on the critical point of the system. The increment of the leading power factor makes it possible to supply more power to the load. With tan ϕ = - 0.4, the capability of the system for sending the active power to the load is around 1787 W. In contrast, with lagging power factor the critical point of the system is decreased. It can be observed from Fig. 4 and Table 1 that the line loss of the short transmission line provides the negative effect on voltage stability. With line loss and unity power factor, the maximum power load is decreased to 900 W. It may be mentioned here that actual short transmission line consists of the line loss. Thus the evaluation of the P-V curve of the system should considered the exact short transmission line.

CONCLUSION

This study investigated the effects of line loss in short transmission line on voltage stability. The mathematical model of the power flow is systematically derived. The concept of the Newton-Raphson method is applied to iteratively solve the nonlinear power flow equations. The Power-Voltage (P-V) curve characteristic of the system without line loss and with line loss are plotted, discussed and compared on various cases.

It was found from the study that the resistance of the line obviously provides the negative effects on the voltage stability. The line loss causes in the decrement of the critical point. In addition, it was found that the leading power factor can significantly increase the critical point of P-V curve. Thus to achieve the actual capability of the system, the exact short line model is needed to be considered.

REFERENCES

Osuwa, J.C. and E.C. Igwiro, 2010. Uninterruptible power supply using solar rechargeable battery. Phys. Int., 1: 77-82. DOI: 10.3844/pisp.2010.77.82

Nabhan, I. and M. Abdallah, 2010. A novel low-power CMOS operational amplifier with high slew rate and high common-mode rejection ratio. Am. J. Eng. Applied Sci., 3: 189-192. DOI: 10.3844/ajeassp.2010.189.192

Padma, S. and M. Rajaram, 2011. Fuzzy logic controller for static synchronous series compensator with energy storage system for transient stability analysis. J. Comput. Sci., 7: 859-864. DOI: 10.3844/jcssp.2011.859.864

Subramani, C., S.S. Dash, V. Kumar and H. Kiran, 2012. Implementation of line stability index for contingency analysis and screening in power systems. J. Comput. Sci., 8: 585-590. DOI: 10.3844/jcssp.2012.585.590

Zarate-Minano, R., T. Van Custsem, F. Milano and A.J. Conejo, 2010. Sexuring transient stability using time domain simulations within an optimal power flow. IEEE Trans. Power Syst., 5: 243-253. DOI: 10.1109/TPWRS.2009.203069