Assessment of Rapid Power Factor Compensation for High Speed Rail to Power System Stability using PowerWorld Software

Auni Najihah Mohamed Ghazali[1,*], Adlan Ali[1], Mimi Faisyalini Ramli[1]

[1]Faculty of Electrical and Electronic Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, KM 1, Jalan Panchor, 84600 Panchor, Johor, Malaysia

[*]Corresponding author's email: n.aunighazali@hotmail.com

ABSTRACT: In railway electrification of 25 kV AC with 50 Hz supply system of a contact network has essentially an unbalanced system that causes by the power factor which could harm the electrical utilities. To reduce the power factor complication, this paper analyses and evaluates; theoretically and practically, the capacitor bank with the simulation of PowerWorld in order to approach the power factor issue's solutions. The main purpose of this paper is to prove that capacitor bank is one of the most efficient technique of power factor compensation for electrifications of high speed rail.

Keywords: *High Speed Rail; Power Factor; Capacitor;*

1. INTRODUCTION

The synchronous proliferation of the railway high-speed train industry, as well as significant distortions in network voltage and current, has emerged as the primary issue. Power quality (PQ) issues can arise on power lines because they are directly connected to the transmission grid for high voltage. [1]. A severe unbalanced power factor on a high-speed railway can result from uneven distribution of power rail load across different feeders. [2]. An impact to an excess of reactive power consumption, as well as distortion of an input voltage and current, might also have occurred.

One method for compensating power factor for electrification of high speed rail is to add capacitor banks [3]. A capacitor bank functions as to correct the power factor which provides reactive power to the system. It can be used at three different levels of power consumption: substation, load and transmission.

2. METHODOLOGY

There are three different approaches that have been used to attain the objectives of this objectives of this research. Preliminary research, calculation of power factor to determine whether the circuit can be simulated or not and a suitable circuit is designed for simulation.

2.1 Preliminary Research of different method of compensation power factor

Three different correction power factor methods were found during the preliminary research. A capacitor bank that represented as the system's reactive power. [3]. A static var compensator (SVC) a combination of active compensator and filter that improve power factor by adjusting compensation [4], as well as an independent control circuit, the Steinmetz compensation circuit (SCC), which uses variable reactance and capacitor. [4]

2.2 Calculation of capacitor size of capacitor bank by Power Triangle Method

For calculation method, Power Triangle Method are necessary to be carried out in order to calculate the size of the capacitor bank.

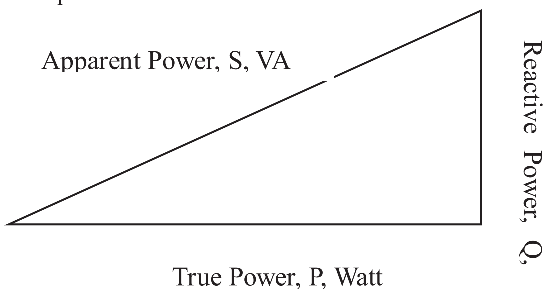

Figure 1: Power Triangle

$$\mathrm{VA} = \sqrt{\mathrm{W}^2 + VAR^2} \tag{1}$$

$$\text{Power Factor} = \frac{\text{True Power, W}}{ApparentPower, VA} = \cos\theta \tag{2}$$

The initial power factor and reactive power, MVAR, were calculated using the power factor formula before proceeding with the simulation. By comparing the calculation and simulation results, the validity of the result is ensured. Table 1 displays the simulated and calculated power factor and reactive power. It demonstrates that there is only a 1% difference.

Table 1 Table of Initial Power Factor and Reactive Power

	Initial (Before Power Factor Compensation)		Initial Reactive Power, Q, MVAR	
Bus Bar	Simulated PF	Calculated PF	Simulated Q (MVAR)	Calculated Q (MVAR)
2	0.60	0.60	7.10	7.06
3	0.79	0.79	4.10	4.10
4	0.72	0.72	5.10	5.11
5	0.66	0.66	6.10	6.03
6	0.55	0.55	8.10	8.05
7	0.54	0.54	8.15	8.26
8	0.65	0.65	6.13	6.19
9	0.72	0.72	5.10	5.10
10	0.66	0.66	6.10	6.03
11	0.46	0.46	10.10	10.23

After reactive power has been attained, the size of the capacitor will be obtained by the subtraction of the old and new reactive power based on table 1.

$$\text{Size of Capacitor, VAR} = \text{OLD Q} - \text{NEW Q} \tag{3}$$

2.3 AC Power Distribution Circuit Design

A circuit consisting of 12 buses and bulk substations has been designed. The traction system will be powered by three feeders from the bulk substations in this model. Voltage per unit, volt, and degree are the bus parameters. Whereas active and reactive power are the load parameters for each bus. A capacitor bank will be installed to compensate for the method, with each busbar representing a railway station. The train's load changes as it passes through the stations. However, because the train load remains constant, the active power of the bus load should be the same, affecting the power factor's behavior.

3. RESULT AND DISCUSSION

A severe inconstancy changes on the power factor before compensation, as shown in graph 1. The distribution of power in this system is clearly unbalanced. Nonetheless, the consistent pattern of a bar graph in graph 2 has unequivocally demonstrated that there is a good power factor value that any power rail distribution system desires.

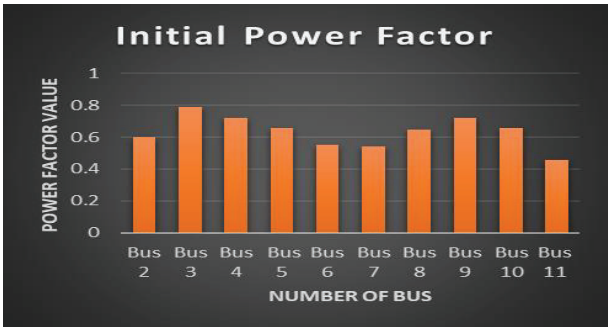

Figure 1 Graph of Initial Power Factor

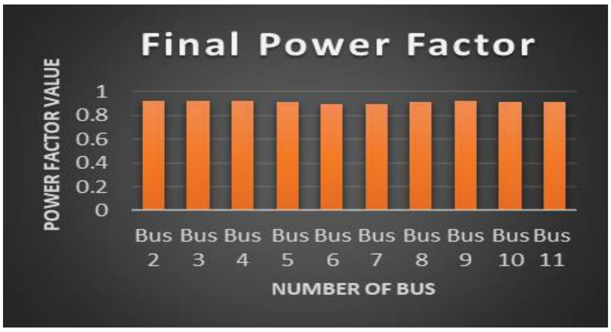

Figure 2 Graph of Final Power Factor

4. CONCLUSION

Capacitor banks are the preferred method of power factor compensation for increasing the reliability and stability of high-speed railway power distribution. By adjusting the power factor values, we can clearly see how adding capacitive load can change the stability of the power system. As a result, it's critical to evaluate the power factor behavior of the power distribution system at all times, especially when the train set's power demand varies dramatically from one station to the next. The capacitor bank's role as a power factor compensator can be demonstrated using simulation results.

ACKNOWLEDGEMENT

The authors appreciate the help they received from Universiti Teknikal Malaysia Melaka in completing this paper.

REFERENCES

[1] H. J. Kaleybar, H. M. Kojabadi, M. Brenna, F. Foiadelli and S. S. Fazel, “An active railway power quality compensator for 2x25kV high-speed railway lines,” in 2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Milan, Italy, 2017, pp. 1–6.

[2] K. Wang, H. Hu, Z. Zheng, Z .He and L. Chen, “Study on Power Factor Behaviour in High-Speed Railways Considering Train Timetable”, in IEEE Transcations on Transportation Electrifications, vol. 4, no. 1, pp. 220-231, March 2018.

[3] Lionginas Liudvinavicius, “Compensation of Reactive Power of AC Catenary System”, in Procedia Engineering, vol. 187, pp. 185-197, 2017.

[4] He, Zhengyou & Zheng, Zheng & Hu, Haitao, “Power quality in high-speed railway systems.” In International Journal of Rail Transportation, vol 4, pp. 71-97, 2016