Effect of High-Speed Train on the Electrical System of The Provincial Electricity Authority Case study of Khon Kaen

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ABSTRACT

The effects of high-speed trains on the electrical system of Provincial Electricity Authority (PEA) were investigated in this work. In Northeast Region 1 - PEA responsibility, Khon Kaen, Udon Thani and Nong Khai province are the part of the route of the high speed train. The model in this study is simulated by using the DIgSILENT program set as the standard voltage at 25 kV, 50 Hz AC. Auto-transformer was used to load an overhead single phase to the train as it can power up in the longer distance. High-speed train is loaded and set in motion by a single load impedance. It connects to the PEA at115 kVA systems together with 3 phase by power transformer of 115 kV / 25 kV that is maximum load of 24 MW. The proper voltage for high-speed trains is 1.03 p.u. or 118.45 kV, which is the standard of the power supply. The current unbalance of power stations of 9.32% affectted on the customer side including the setting of appropriate new protective equipment as well as the high-speed train control system with converter load. Model train speed will produce harmonic distortion of voltage (%THD) at 0.62%, which give the results in higher electrical resistance wires, causing the loss of power lines, interfering with the protection of the electrical meter and disturbing measurement. In addition, the maximum fault at the high speed train in the 115 kV electrical system has the maximum current of 67.70 kA. These results lead to plan and support the electrical system information for the high speed train in Thailand.

Keywords: High speed train, Power quality, Harmonics

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Introduction

The study of the high-speed rail system mostly presented about the value of the investment, environmental impact and economics issue. Therefore, this article is aimed to study the impact of high-speed trains that affect the electrical system of the PEA by simulation of high-speed train traction system expected to be used in Thailand in the near future. The electricity power supply process is shown in Fig. 1 to define the voltage standard at 25 kV, 50 Hz AC (Andrea M, 2007) that auto-transformer is used to load a single phase overhead using Digsilent Program. The power of electricity report in the area of Khon Kaen Province will be used for this study by assigned the high-speed train to be the moving loads which is impedance by a single block. It connects to the Provincial Electricity Authority (PEA) powered through 115 kVA together with three phase systems by defined the power transformer at 115kV/25kV calculated maximum load at 24 MW along with currently PEA power system performance testing by voltage measurement, the use of unload high-speed trains and a high-speed trains system to connect to the electrical system. Harmonics measurements are aimed to compare the different test of high-speed trains by using the standard harmonics of high-speed trains and the impact of the power stations of the PEA and authors substation.

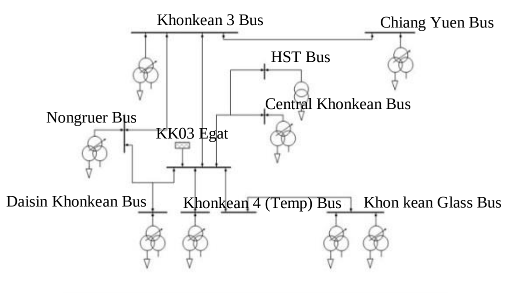

Figure 1 115 kV electricity supply process in Khon Kean.

Background Theory

The impact on electrical system

Power supply of the high-speed train is connected to the high voltage power system will result in the failure of several patterns which can be summarized asfollows

The voltage unbalance

The voltage unbalance is caused by the excessive load on each phase. In the case of a high speed train system, voltage unbalance due to the most of high-speed rail load are using the single phase loads so affected tothe PEA electrical system as resulted bellowing. The current unbalance and voltage unbalance increasing losses of synchronous and asynchronous machine and impacting to the control device.

Calculate voltage unbalance factor (Chaiya C, 2010)

$$k = \frac{U_{n.s.c}}{U_{p.s.c}} \ or \ k \approx \frac{S_L}{S_{SC}}$$

$U_{p.s.c}$ is positive sequence component of voltage ,

$U_{n.s.c}$ is negative sequence component of voltag ,

S_L is single phase norminal power,
S_{SC} is three phase short circuit power.

Harmonics

High-speed trains drive by using the AC motor may cause the over spread of harmonics current. If the harmonics current flows into the electrical system, it will affected to the current and voltage of power system in irregular shaped from the regular power supply. Besides, the communication system and signaling system will be disrupted due to the electronic circuit malfunctions.

The Evaluation oftheharmonicseries

IEC and IEEE standards use the total harmonics distortion in evaluate distortion level. The harmonic series distortion of high-speed train system has shown the result as following:

- Individual harmonics currents (I_V), total harmonics currents distortion (I_T)

$$I_V = \sqrt[\alpha]{\sum_{n=1}^{N} I_{vn}^{\alpha}}, I_T = \frac{\sqrt{\sum_{v=2}^{N} I_v^2}}{I_1} \times 100\%$$

- Total harmonics voltage distortion (U_T)

$$U_T = \frac{\sqrt{\sum_{v=2}^{N} U_v^2}}{U_1} \times 100\%$$

Results and Discussions

The study were done by collecting statistical data load power of substation in the area of the PEA study as far as possible in the power of the PEA. (PEA 2015). The processor voltage power supply suitable for maximum load to see more results in Table 1, data load appropriate for the load most of the PEA will be at 1.03 pu 118.45kV of supply by analyzing the substation. as far as possible in the power of the PEA.

Table 1 Data load appropriate for the load most of the PEA will be at 1.03 p.u.118.45 kV.

Substation	Distance (km)	Load (MW)	Q (MVAR)	Voltage (kV)
Khonkean 3	KK03(17.50)	36.57	21.44	117.10
Nongruer	KK03(32.75)	20.84	11.28	117.18
Khonkean 4	KK03 (0.20)	14.33	8.55	118.40
Chaing Yuen	KK03(41.50)	13.34	8.01	115.76
Central Khonkean	KK03 (1.80)	12.06	7.41	118.36
DaisinKhonkean	KK03 (6.00)	10.03	5.84	118.17
Khonkean Brewery	KK03 (20.00)	8.70	5.10	117.70
Khonkean Glass	KK03 (20.00)	6.69	3.86	117.70

Normally, the Electricity Generating Authority of Thailand (EGAT) generates the voltage at 118.45 kV. When high speed train traction load is connected, traction transformers 115 kV/25 kV, 50 MVA thought critical power their secondary site 24 MW. Test runs supply 1.03 p.u. The results show in Table 2.

Table 2 The result of connect traction load to PEA electrical distribution grid line.

Substation	Distance (km)	Load (MW)	Q (MVAR)	Voltage (kV)
HST KK	KK03(1.80)	24.00	13.20	118.23
Khonkean 3	KK03(17.50)	36.57	21.44	117.10
Nongruer	KK03(32.75)	20.84	11.28	117.18
Khonkean 4	KK03(0.20)	14.33	8.55	118.40
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The results from program is presented the voltage of the PEA's power supply in the115 kV systems. The substation is considered by voltage supply to farthest power station area where as Cheang Yuen substation. The distance from Main supply station is 41.50 km. In order to maintain the supply voltage level to PEA standard (Quality S of PEA), the voltage level should not be less than 115 kV. The trial result without high speed train load found that power station should supply load at 1.03 p.u 118.45 kV. During HST loaded, the voltage level will be at 1.03 pu 118.45 kV and capable to supply power. The Voltage trial result at Cheang Yuen substation is presented at 115.76 kV which considered the standard and quality of PEA. Given the current unbalance of power supply from the Electricity Generating Authority of Thailand (EGAT) with high speed train load it is found that the current unbalance at 9.32%.

The harmonics impact on high-speed train connected to the 115 kV system of PEA grid. As the train is an AC motors so it caused to the harmonics providing, generate harmonics in the standard IEE1000 (IEE1000) and prove the impact by trial run shown in Fig. 2

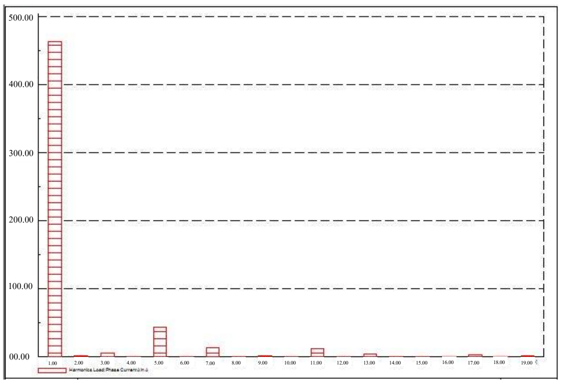

Figure 2 The current harmonics for high speed train.

The trial results for the high speed train harmonics and the total harmonics distortion at bus high speed train of 0.62%., which is above will result in higher electrical resistance wires, causing the loss of power lines, interfering with the protection of the electric meter and distortion measurement.

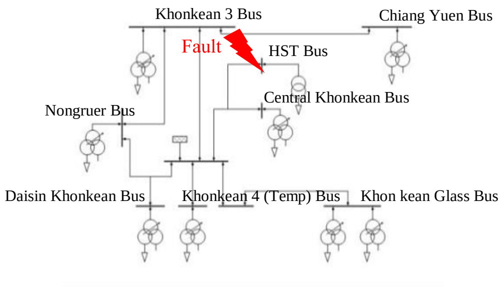

Figure 3 The point of three-phase short circuit fault at the high speed train substation.

Several factors determine the fault in the electrical 115 kV system . At high speed train Bus show in figure 3. The most critical condition is three-phase short circuit fault. The result for maximum current fault at power source is 67.70 kA which affect the flow trips the electricity supply to be optimized.

Conclusions

The high speed train connected to the PEA 115 kV power system is simulated by Digsilent Software. The power supply supported of PEA, including the impact of high speed train system and the impedance of power supply. This able to support the current load of high speed trains. To reduce the voltage unbalance. The impacts of current unbalance at 9.32% and the harmonics of high speed train system must be in settle standards. To avoided the affected to consumer and power supply station. The harmonics filter set up is highly required in order to maintain the standards of harmonics level.

Acknowledgements

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References

Andrea M, Paolo P, Maurizio V, Simplified Modeling of 2 25-kV AT Railway System for the Solution of Low Frequency and Large-Scale Problems. IEEE TRANSACTIONS ON POWER DELIVERY 2007, VOL. 22, NO. 1.

IEC 1000: Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques Section 7: General Guide on Harmonics and Inter harmonics Measurements and Instrumentation for Power Supply Systems and Equipment Connected.

Chaiya C, The Power Quality handbook. The Engineering Institute of Thailand under H.M. the king's Patronage 2010: 133-143

Provincial Electricity Authority (PEA), Statistical data load power of substation in Khon Kean 2015