Effects of Induction Motor Using Unbalance Voltage

Pakkawee Hayamin[1]
and Chaiyapon Thongchaisuratkrul[2]
Department of Teacher Training in Electrical Engineering,
Faculty of Technical Education,
King Mongkut's University of Technology North Bangkok, Thailand
[1]saman_may@hotmail.com
[2]srptc@hotmail.com

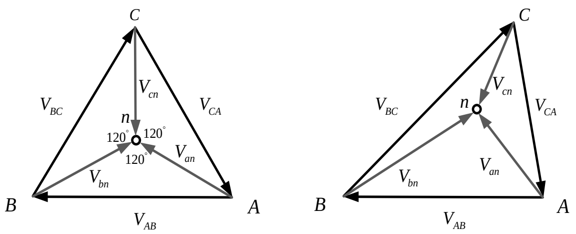
***Abstract* - This article presents the effects of inductive motor was operated under imbalanced voltage condition. It was functional test of electric motor at field work by analyzing effect to motors in 3 aspects as followed: temperature, efficiency and performance of motor. Result and analysis from functional test found an increasing of motor temperature which operated under imbalanced voltage as well as decreased of its performance. The continued operation of electric motor in such conditions caused the deteriorated insulation and short circuit in tested motor.**

***Keywords* - Effects, Induction Motor, Unbalance Voltage**

I. INTRODUCTION

Most issues from using inductive motor in field work was about its efficiency and performance which lower than requirement. This may cause from many factors as followed [1-2] Most of factors that affect to motor are: 1) Environment: if motor was operated under unsuitable environment such as dusty area, dirt or high humidity, 2) Mechanical factor: if motor worked overloaded or started too often shall be damaged, and 3) electrical factor should be considered as major cause of motor issues. If motor was operated at lower or higher voltage than its performance therefore motor shall work without performance and efficiency [3-4].

Electrical problems affect motor operation, most issues caused by ignorance of precheck voltage before operation. The mentioned issues can be found in both small and large industrial plants. Most of them are experienced with imbalance of 3 phase voltage [5-6]. Factors also affect to imbalanced voltage condition were overloaded of one-phase electric and did not concern of 3-phase group load, there is an imbalance between voltage phases and its voltage.



a) Symmetrical Phasor Diagram b) Asymmetrical Phase-to-Phase

Fig. 1 Phasor Diagram of Voltage

Imbalanced voltage can directly affect to machine, conveyor system or tools that were operated under 3-phase voltage as well as affect to entire electric system of whole plant for example an imbalanced electrical power from increased current flow in electric wire. These effects also affect to efficiency, performance and shorten life time of three-phase motors as well as machine have to stop operating for fixing, maintenance or replacing broken motor [7-8].

This research was conducted for functional test of electric motors in field work by analyzing effect to motors in 3 aspects as followed: temperature, efficiency, and performance. The result will be guidelines to study effect or damage caused by imbalanced voltage during motor operation and benefit for those who are interested.

II. ANALYSIS [9-14]

Analysis of imbalance voltage percentage according to NEMA specifications can be calculated from following equation.

A. Percent of Imbalanced Voltage

$$\%VUB = \frac{V_{\max\ dev}}{V_{avg}} \times 100 \tag{1}$$

$$V_{avg} = \frac{V_{ab} + V_{bc} + V_{ca}}{3} \tag{2}$$

Equation (1) shows that the calculation Percent Unbalance Voltage which $\%VUB$ is imbalanced voltage percentage $V_{\max\ dev}$ is maximum deviation voltage either one phase and V_{avg} is average voltage. The equation (2) shown that the calculation average voltage motor which V_{ab}, V_{bc}, V_{ca} is voltage of both phases.

B. Percent of Imbalanced Electric Current

$$\%CUB = \frac{C_{\max\ dev}}{C_{avg}} \times 100 \tag{3}$$

$$C_{avg} = \frac{C_{ab} + C_{bc} + C_{ca}}{3} \tag{4}$$

Equation (3) shows that the calculation Percent Unbalance Voltage which $\%CUB$ is imbalanced current percentage $C_{\max\ dev}$ is maximum deviation current either one phase and C_{avg} is average Current. The equation (4) shown that the calculation average current motor which C_{ab}, C_{bc}, C_{ca} is voltage of both phases.

C. Motor Temperature

Motor temperature is an estimation of maximum temperature during operation.

$$T_{rise,unb} = T_{rise,rated} \times \left(1 + \frac{\%\Delta T}{100}\right) \tag{5}$$

Equation (5) shows that the calculation temperature motor which $T_{rise,unb}$ is temperature caused from imbalanced voltage percentage $T_{rise,rated}$ is maximum acceptable insulation temperature as shown in Table I and $\%\Delta T$ is percentage of increased electric motor temperature.

D. Percentage of Increased Temperature

Analysis of increased motor temperature percentage was varied as doubled in percentage of imbalanced voltage.

$$\%\Delta T = 2 \times (\%VUB)^2 \tag{6}$$

E. Motor Efficiency [15-16]

Motor efficiency under NEMA specification is calculated from the ratio of output electric power (P_{out}) to input electric power (P_{in}) and its value is shown in percentages.

$$\eta = \frac{P_{out}}{P_{in}} \times 100 \tag{7}$$

Equation (7) shows that the calculation motor efficiency which η is efficiency motor P_{in} is input power and P_{out} is output power.

F. Motor Performance [17-18]

Electric motor performance analysis under NEMA specification, is defined ratio of input electric power and motor power rate at ($P_{name\ plate}$) and its value is shown in percentages.

$$Performance = \left(\frac{P_{in}}{P_{name\ plate}}\right) \times 100 \tag{8}$$

Equations (8) shows that the calculated performance motor method as NEMA specification, while performance motor, P_{in} is input power and $P_{name\ plate}$ is nameplate power motor.

III. OPERATION

Functional Test of Factors Affect to motor, imbalanced voltage condition by testing inductive electric motors of 6.6kV 125A 1200kW 50Hz, which was not separated the transformer operation between one-phase and three-phase power supply.

Fig. 2 Inductive Electric Motor

The test of imbalanced voltage motor is record of electric power from normal operation then analyzed factors that affected to motor. Test results of motor operation under imbalanced voltage conditions are as follows.

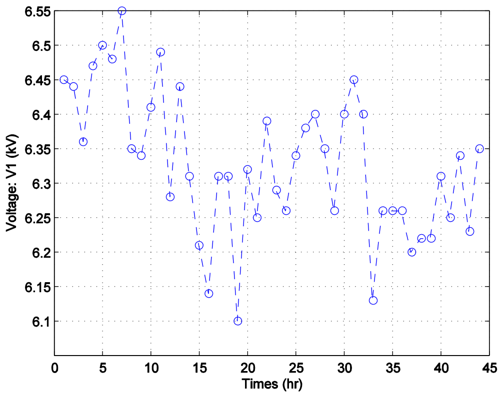


Fig. 3 Voltage Line 1

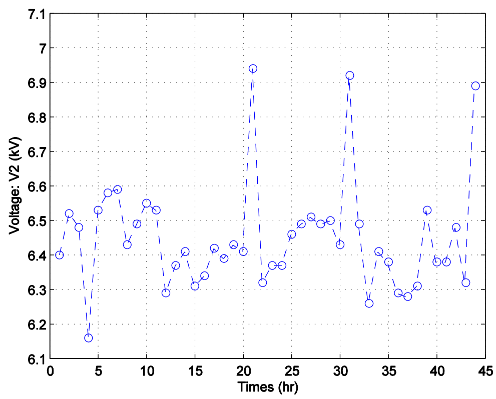


Fig. 4 Voltage Line 2

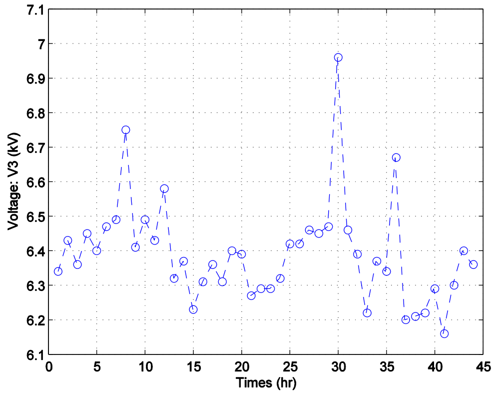


Fig. 5 Voltage Line 3

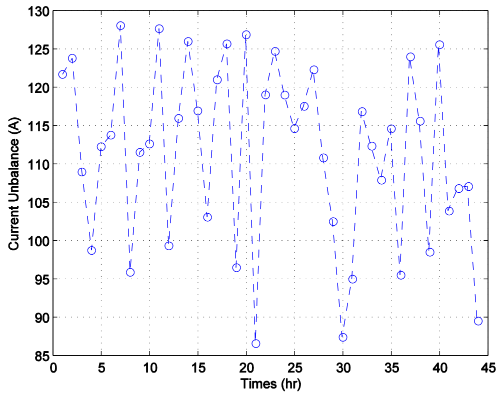


Fig. 6 Current Motor

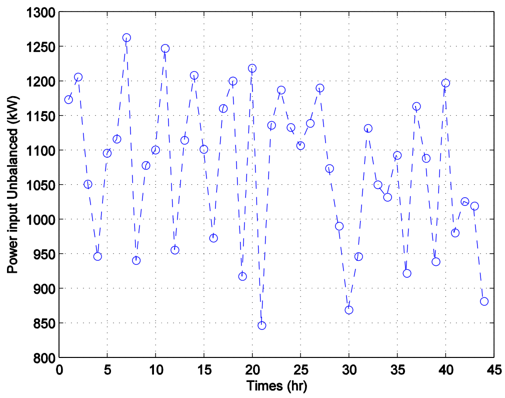


Fig. 7 Power Motor

IV. TEST RESULT ANALYSIS

Testing of inductive motor operated under imbalanced voltage condition caused from imbalanced voltage percentage which high to 7%, as shown in fig. 8, which was very high rate of motor operation.

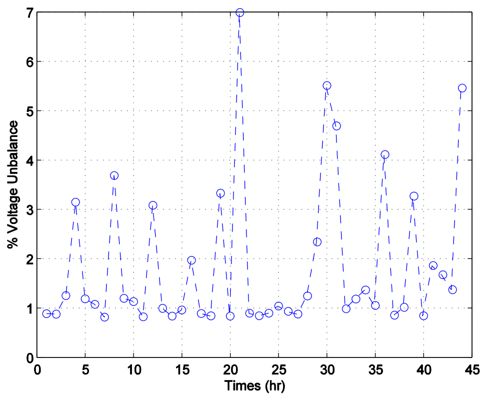


Fig. 8 Voltage Unbalance Percent

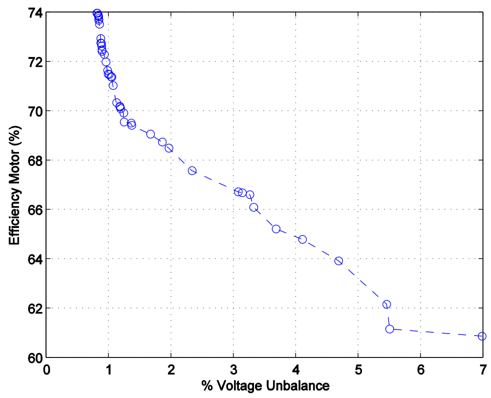


Fig. 10 Efficiency Motor

A. Motor Temperature

Motor temperature analysis found that motor operated under imbalanced voltage condition which was higher than 5% shall affect to motor temperature, as Fig. 9 shown the sort of temperature of operating motor, If motor is operated at % VUB = 7%, motor temperature will be as high as 218 $^{\circ}C$.

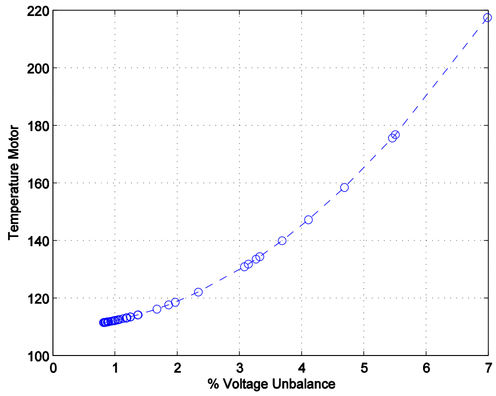


Fig. 9 Temperature Motor

B. Motor Efficiency

Motor efficiency analysis found electric motor which was operated under imbalanced voltage condition shall lower its efficiency. The test had been conducted while electric motor was operated at imbalanced voltage 1% with 74% efficiency, as motor was operated at imbalanced voltage for 7%, its efficiency was 61% means it decreased for about 13% from normal condition.

C. Motor Performance

Motor performance analysis found electric motor which was operated under imbalanced voltage condition shall lower its efficiency. The test had been conducted while electric motor was operated at imbalanced voltage 1% with 98% efficiency, as motor was operated at imbalanced voltage for 7%, its efficiency was 71% means it decreased for about 27% from normal condition.

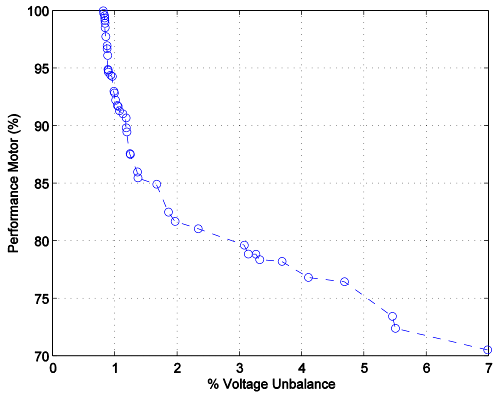


Fig. 11 Performance Motor

V. SAMMARY

The functional test of electric motor which operated under imbalanced voltage conditions and analyzed the effect to motor in three aspects such as temperature, efficiency and performance. Test results from electric motors from field applications where the installation area did not separate transformer from one-phase and three-phase power supply. Therefore, percentage of imbalanced voltage was up to 7% resulted to motor temperature reached to 218 and motor efficiency was decreased to 13% or at 61% and motor performance was decreased to 27% or at 71%, respectively. From functional test of electric motors which operated at such condition as its percentage of imbalanced voltage wash higher caused motor temperature was increased, as well. It also resulted in reduced performance and performance.

REFERENCES

(Arranged in the order of citation in the same fashion as the case of Footnotes.)

[1] Tavner, P.J. and Penman, J. (1987). "Condition Monitoring of Electric Machines". Research Studies Press and John Wiley & Sona.

[2] IEEE. (1997). "IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems". IEEE STD, pp. 493-1997.

[3] Thappadung, Y. (2007). "Impact on Performance of 3-Phase Induced Motor at imbalanced Voltage". Industrial Technology Review, Vol. 13(165), pp. 111-113.

[4] Hayamin, P. and Thongchaisuratkul, C. (2013). "Condition Assessment of Inductive Motor Operation". Industrial Technology and Robotics Conference, Bangkok.

[5] Sangiemsak, T. (2006). "The analysis of effects from imbalanced three-phase voltage to stator current of inductive motor is based on phase angle of factorial equation of imbalanced voltage as an indicator". Vol. 26, Vol. 2(2), pp. 131-144.

[6] Mangmeechai, R., Lamyong, P., and Chatuchai, C. (1998). "Performance analysis of inductive motors which operated under unstable voltage conditions". The 21th Electrical Engineering Conference, King Mongkut's University of Technology Thonburi, Bangkok.

[7] Sri Chandra, P. (2013). "Issues from Imbalanced Voltage in electric motor". Industrial Technology Review, Vol. 13(165), pp. 111-113.

[8] Sornpradith, C. (2006). "Imbalanced Voltage". Articles, Electrical and Industrial, November-December.

[9] Winter. (2005). "Stopping a Costly Leak: The Effects of Unbalanced Voltage on the Life and Efficiency of Three-Phase Electric Motors". Energy Matters, U.S. Department of Energy.

[10] Harley, R.G., Makram, E.B., and Duran, E.G. (1988). "Effects of unbalanced networks and unbalanced faults on induction motor transient stability". IEEE Transactions on Energy Conversion, Vol. 3(2), pp. 398-403.

[11] Hofmann, P. and Pilly, P. (2002). "Derating of Induction Motors with a Combination of Unbalanced Voltages and Over-or Undervoltages". IEEE Transactions on Energy Conversion, Vol. 17(4), pp. 485-491.

[12] Kersting, W.H. and Phillips, W.H. (1997). "Phase frame analysis of effects of voltage unbalance on induction machines". IEEE Transactions on Industry Applications, Vol. 33(2), pp. 415-420.

[13] Pillay, P. (1997). "Practical considerations in applying energy efficient motors in the petrochemical industry". IEEE IAS Magazine, Vol. 3(1), pp. 32-40.

[14] Spring. (2005). "Electric Motor Voltage Quality Problems". U.S. Department of Energy - Energy Efficiency and Renewable Energy.

[15] Eliminate Voltage Unbalance. (2005). "Industrial Technologies Energy Efficiency and Renewable Energy Program". Motor System Tip Sheet.

[16] Woll, R.F. (1975). "Effect of unbalanced voltage on the operation of polyphase induction motors". IEEE Transactions on Industry Applications, Vol. IA-11(1), pp. 38-42.

[17] Motor Challenge. "Determining electric motor load and efficiency". The energy savings network.

[18] A Guidebook for Industrial Efficiency.

APPENDIX

TABLE I
MAXIMUM ACCEPTABLE MOTOR TEMPERATURE

Class of Insulation System	A	B	F	H
Time rating (shell be continuous or any short-time rating give in 10.36)				
temperatire rise (based on a maximum ambient temperature of 40 °C)				
a. Windings, by resistance method				
1. Motor with 1.0 service factor other those given in Items a. 3 and a. 4	60	80	105	125
2 . All motors with 1.15 or higher sevice factor	70	90	115	-
3. Totally-enclosed nonvetilated motor with 1.0 sevice factor	65	85	110	135
4. Motor with encapsulated windings and with 1.0 service factor, all enclosures	65	85	110	-
b. The temperatures attained by cores, squirrel-cage windings, and miscellaneous parts (such as brusholders, brushes, pole tips, etc.) shall not in jure the insulation or the machine in any respect				

TABLE II
CLASS OF INSULATOR UNDER IEC 85 STANDARD

Temperature Class Tolerance	Maximum operation Temperature Allowed		Allowable Temperature Rise at full load 1.0 service factor motor	Allowable Temperature Rise at full load 1.15 service factor motor
	°C	°F	°C	°C
Class A	105	221	60	70
Class B	130	266	80	90
Class F	155	311	105	115
Class H	180	356	125	-