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INVESTIGATION OF PERFORMANCE OF 3-PHASE ASNCHRONOUS MACHINE UNDER VOLTAGE UNBALANCE

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ABSTRACT

Induction motors are widely used in industries due to various techno-economic advantages .Voltage unbalance causes a lot of ill effects on induction motors. The problem of voltage unbalanced has attracted special attention amongst electrical engineers dealing with power quality issues in recent past. The adverse effects of voltage unbalance in Induction motors are Over heating, line-current unbalance, derating, torque pulsation, and inefficiency. The overheating leads to winding insulation degradation. This paper examines the proper application of the three phase induction motors when supplied by unbalance Voltage. The proposed work show that poor power quality voltages have bad effects over the motor performance: loss temperature rise, rated hp, efficiency, reliability. Finally this paper presents some recommendations to improve the performance.

Keywords: *Induction Motors, Loss Temperature Rise, Rated Hp, Efficiency, Reliability, Derating, Torque Pulsation*

1. INTRODUCTION

Voltage unbalance is regarded as a power quality problem of significant concern at the electricity distribution level. Although the voltages are quite well balanced at the generator and transmission levels the voltages at the utilization level can become unbalanced due to the unequal system impedances and the unequal distribution of single-phase loads An excessive level of voltage unbalance can have serious impacts on mains connected induction motors. The level of current unbalance that is present is several times the level of voltage unbalance. Such an unbalance in the line currents can lead to excessive losses in the stator and rotor that may cause protection systems to operate causing loss of production. Although induction motors are designed to tolerate a small level of unbalance they have to be derated if the unbalance is excessive. Voltage unbalance also has an impact on ac variable speed drive systems where the front end converter consists of three-phase rectifier systems.

2. VOLTAGE VARIATIONS AND UNBALANCE

Voltage variations are random variations of voltage magnitudes, mainly due to arc furnaces loads, frequent or cyclic motor operations involving speed variations etc. Voltage unbalance is the non-equality of voltage magnitudes and /or voltage angles among the three-phases at any given point of time, mainly due to the unequal distribution of single-phase loads, asymmetry of line and transformer winding impedances, time varying operation of single-phase loads, traction loads, blown out fuses on three-phase capacitor banks, adjustable speed drives operations etc. The most important reason for voltage unbalance is a mismatch of reactive power demand between the industrial utilities and the generating stations. Due to varying operating times of single-phase and three-phase loads, there exists definite possibility of voltage variations above and below the rated value, in both balanced and unbalanced form. Thus, voltage variation and unbalance can be classified into balanced overvoltage (BOV), balanced undervoltage (BUV), unbalanced overvoltage (UBOV) and unbalanced undervoltage (UBUV). BOV is the condition wherein the three-phase voltages are individually and equally greater than the rated voltage value, BUV is the condition wherein the three-phase voltages are individually and equally lesser than the rated voltage value. UBOV is the condition wherein the three phase voltages are not equal to each other, in addition the positive sequence component of the voltage is greater than the rated voltage value while UBUV is the condition wherein the three phase voltages are not equal to each other, in addition the positive sequence component of the voltage is lesser than the rated voltage value. There is a very less possibility that all three-phase voltages remain constant at all times, hence the analysis carried out in this paper is limited to UBOV and UBUV cases

3. COMPARISONS OF VARIOUS DEFINITIONS OF VOLTAGE UNBALANCE

The following three definition of the voltage unbalances have been given according to different standards:

NEMA Definition

The **NEMA** definition of voltage, also known as the line voltage unbalance rate (LWR), is given by Max. voltage deviation from the avg. line voltage magnitude' 100 %LVUR= Avg. line voltage magnitude

IEEE Definition

The **IEEE** definition of voltage unbalance, also known as the phase voltage unbalance rate (PUVR), is given by Max. Voltage deviation from the avg. phase voltage mamitude'100 **%PVUR=** Avg. phase voltage magnitude

Exact Definition

The Exact definition of voltage unbalance is defined as the ratio of negative sequence voltage component to the positive sequence voltage component. The percentage unbalance factor (VUF), is given by Negative sequence voltage component * 100 %VUF = Positive sequence voltage component

Causes of unbalanced voltages

Some of the more common causes of unbalanced voltages are:

- Unbalanced incoming utility supply
- Unequal transformer tap settings
- Large single phase distribution transformer on the system
- Open phase on the primary of a 3 phase transformer on the distribution system
- Faults or grounds in the power transformer
- Open delta connected transformer banks
- A blown fuse on a 3 phase bank of power factor improvement capacitors
- Unequal impedance in conductors of power supply wiring
- Unbalanced distribution of single phase loads such as lighting
- Heavy reactive single phase loads such as welders

Adverse Effect of Voltage Unbalance

The adverse effects of unbalanced voltages on induction motors have been studied at least since the 1950s . It is common to study the behavior of the positive and negative sequence components of the unbalanced supply voltage to understand the effect of an unbalance on the motor. The positive sequence voltage produces a positive torque, whereas the negative sequence voltage gives rise to an air gap flux rotating against the forward rotating field, thus generating a detrimental reversing torque. So in fact when neglecting non-linearities, for instance due to saturation, the motor behaves like a superposition of two separate motors, one running at slip s with terminal voltage V_p per phase and the other running with a slip of (2-s) and a terminal voltage of V_n . The result is that the net torque and speed are reduced and torque pulsations and acoustic noise may be registered. Also, due to the low negative sequence impedance [$R'_2/(2-s)$], the negative sequence voltage gives rise to large negative sequence currents. At normal operating speeds, the unbalanced voltages cause the line currents to be unbalanced in the order of 6 to 10 times the voltage unbalance.

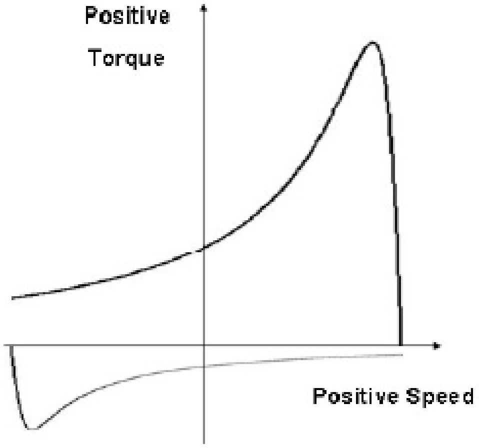


Fig.1 Graphical representation of the positive and negative sequence torques of an induction motor subjected to unbalanced supply voltages

From Figure 1 it is clear that the entire torque-speed curve is reduced. In that context, three points of particular interest on the resulting curve are the starting, the breakdown and the full load torque. It is clear that the motor takes longer to speed up in this case. This changes the thermal behavior of the motor and leads to decreased service life if not early failure. Note that this is due to the negative torque and/or the reduced positive torque. Moreover, if full load is still demanded, the motor is forced to operate with a higher slip, increasing rotor losses ($R'_2/(2-s)$) and thus heat dissipation. The reduction of peak torques compromises the ability of the motor to ride through dips and sags. Premature failure can only be prevented by derating the machine according to standards, allowing it to operate within its thermal limitations.

Mitigation of voltage unbalance and its effects

Establishment of zero voltage unbalance on a distribution system is clearly impossible due to (a) randomness of the connection and disconnection of single-phase loads (b) uneven distribution of single-phase loads on the three phases and (c) inherent asymmetry of the power system. However, there are utility system level mitigation techniques as well as plant level mitigation techniques that can be used to improve the voltage unbalance and its effects.

Utility level techniques:

- Redistribution of single-phase loads equally to all phases.
- Reduction of the system unbalance that arise due to system impedances such as those due to transformers and lines.
- Single-phase regulators have been suggested as devices that can be used to correct the unbalance but care must be exercised to ensure that they are controlled carefully not to introduce further unbalance.
- Passive network systems and active power electronic systems such as static var compensators and line conditioners also have been suggested for unbalance correction. Compared to passive systems, active systems are able to dynamically correct the unbalance.

Plant level techniques:

- Load balancing.
- Use of passive networks and static var compensators.
- Equipment that is sensitive to voltage unbalance should not be connected to systems which supply single-phase loads.
- Effect of voltage unbalance on ac variable speed drives can be reduced by properly sizing ac side and dc link reactors.

4. SIMULATED EFFECTS OF VOLTAGE UNBALANCE ON INDUCTION MOTORS

Matlab simulation of Induction motor considering voltage unbalance for 3.05% , 3.94% is carried out

COMPARISION OF POWER FACTOR

NORMAL

S.NO	TORQUE (N-M)	PF a	PF b	PF c
1.	8	0.65	0.65	0.65
2.	10	0.719	0.719	0.719
3.	12	0.769	0.769	0.769
3.05% unbalance				
1.	8	0.609	0.564	0.73
2.	10	0.678	0.657	0.78
3.	12	0.729	0.721	0.82
3.94% unbalance				
1.	8	0.517	0.621	0.79
2.	10	0.600	0.715	0.829
3.	12	0.664	0.856	0.855

COMPARISION OF PHASE CURRENTS

S.NO	T(N-M)	Ia	Ib	Ic
1	8	6.316	6.311	6.311
2	10	7.134	7.125	7.13
3	12	8.06	8.05	8.053
3.05% unbalance				
1	8	7.103	5.712	6.221
2	10	7.866	6.444	7.084
3	12	8.724	7.287	8.024
3.94% unbalance				
1	8	7.352	4.794	7.056
2.	10	8.062	5.609	7.987
3.	12	8.894	6.535	8.988

NORMAL

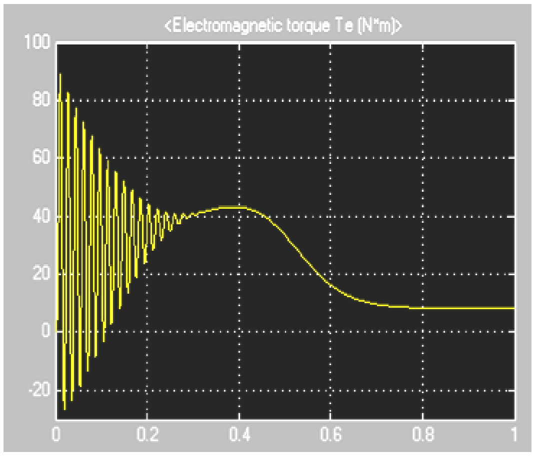
COMPARISION OF CU LOSS, EFFICIENCY, SPEED

NORMAL

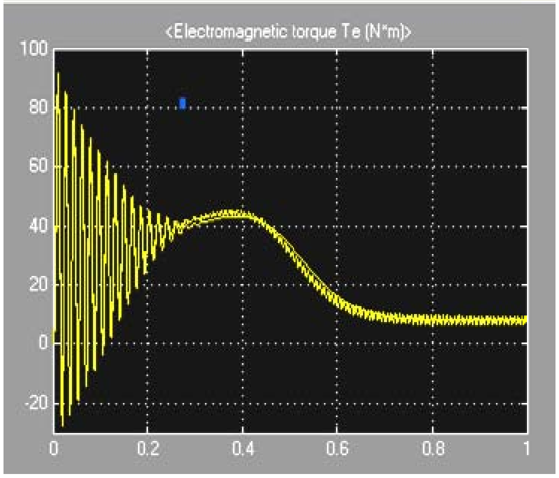
S.NO	T(N-M)	CU LOSS	EFFi	N
1	8	51.99	0.9410	1749
2	10	66.32	0.9330	1735
3	12	84.64	0.9201	1720
3.05% unbalance				
1	8	66.79	0.8625	1751
2	10	84.19	0.9108	1737
3	12	85.49	0.9101	1723
3.94% unbalance				

1	8	55.15	0.8912	1749
2	10	69.69	0.8879	1734
3	12	88.11	0.9066	1720

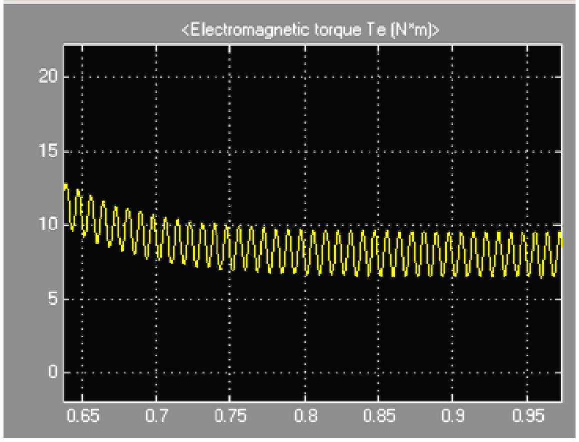
COMPARISION OF TORQUE NORMAL



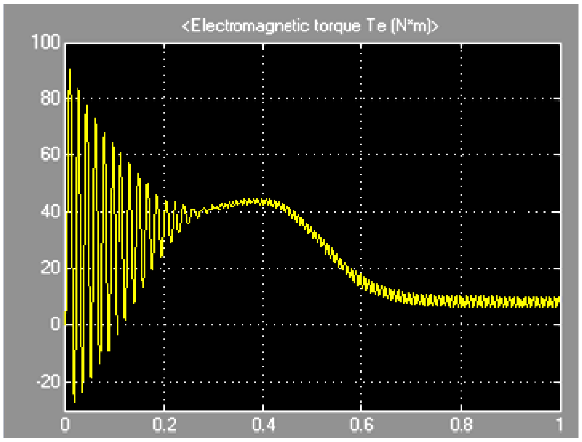
3.05% UNBALANCE



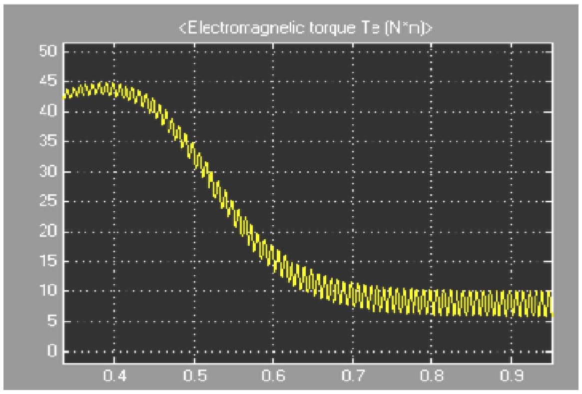
3.05% UNBALANCE

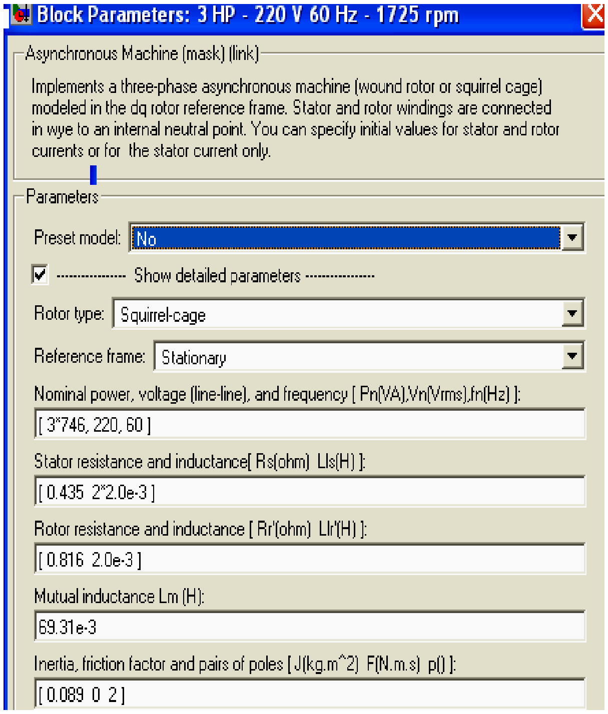


3.94% unbalance



3.94% unbalance





Block Parameters: 3 HP - 220 V 60 Hz - 1725 rpm

Asynchronous Machine (mask) (link)

Implements a three-phase asynchronous machine (wound rotor or squirrel cage) modeled in the dq rotor reference frame. Stator and rotor windings are connected in wye to an internal neutral point. You can specify initial values for stator and rotor currents or for the stator current only.

Parameters

Preset model: No

☑ ------------- Show detailed parameters -------------

Rotor type: Squirrel-cage

Reference frame: Stationary

Nominal power, voltage (line-line), and frequency [Pn(VA),Vn(Vrms),fn(Hz)]:

[3*746, 220, 60]

Stator resistance and inductance[Rs(ohm) Lls(H)]:

[0.435 2*2.0e-3]

Rotor resistance and inductance [Rr'(ohm) Llr'(H)]:

[0.816 2.0e-3]

Mutual inductance Lm (H):

69.31e-3

Inertia, friction factor and pairs of poles [J(kg.m^2) F(N.m.s) p()]:

[0.089 0 2]

5. CONCLUSION

Comprehensive overview of factors that affect the determination of the efficiency of motor driven systems and energy consumption is presented. Some vagaries in efficiency determination are exposed and discussed. Also the need for the cognizance of operating realities such as unbalanced supply conditions, which standards presently ignore, is stressed. Finally, some important techniques to save energy in motor driven systems are presented.

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