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Use Of Transformers With An Open-Delta Connection To Perform Short-Circuit Test On Three-Phase Engines

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Abstract **The following work involves the use of an incomplete three-phase transformer, which does not have the high voltage side winding, or the low voltage winding of the same phase, applying an open delta connection.In order to perform the blocked rotor test to asynchronous motors, it is necessary to have a three-phase source capable of supplying variable voltage and a high current module. By means of transformer, which was disassembled, having access to the connections and windings thereof, the open triangle connection was made, modifying the windings of the low voltage side.Finally, the prototype was tested, the rotor test locked to a three-phase 75HP motor. The results were favorable.**

Keywords—Blocked rotor test, Asynchronous motors, Open delta transformer.

I. INTRODUCTION

The laboratory of the Department of Electric Engineering of the regional college located in San Nicolás has a Variac which is able to supply a three-phase system of up to 380 V /18A and is used to perform different tests. However, this Variac is not able to perform a short-circuit test to a 75 HP engine requested by a nearby company as it does not provide enough current. Therefore, a three-phase 800kVA transformer with a ratio of 3.3 / 0.4 / 0.231kV was used with a DY11 connection, which lacked an entire column, to generate a three-phase voltage and current system capable of supplying the necessary current values to perform a blocked rotor test.

Both HV windings of the transformer were fed, connected in an open-delta configuration to a low voltage Variac and to the terminals of the engine to be tested at the LV side of the winding.

In order to obtain a three-phase system at the transformer secondary, we took advantage of the fact that each secondary column is made of two concentric windings. Using half of one of the columns, the u phase was obtained and the v phase was obtained using half of the other column. The w phase was achieved by connecting the other halves of each column.

With this configuration and connection, a balanced three-phase system was constructed, capable of supplying the current needed to perform a blocked rotor test on a 75 HP engine, and the equipment is still available to perform future tests with a current of up to 578 Amp.

II. OPEN-DELTA CONNECTION

Electrical power distribution companies use three independent pieces of equipment connected to each other in a triangle/triangle configuration.

When one of them is out of service and there is no transformer by means of which to change the broken equipment, it is possible to keep the system working at a lower voltage as an emergency measure. Figure 1 shows the basic connections of a bank with an open triangle configuration.

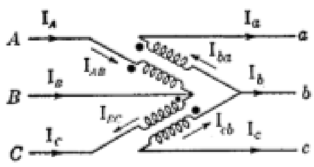

Fig. 1. Connections of an open-delta transformer

When applying voltage to the primary of the transformer (balanced three-phase voltage), the secondary side gets slightly unbalanced voltage. This is due to the voltage drop that takes place at the inner impedances. This unbalance is negligible at all times, as it is not significant, being of approximately 0.5%.

III. CURRENT TRANSFORMER

The equipment available at the High-voltage laboratory is an 800kVA transformer, with a ratio of 3.3/0.4kV. Its connection group was D/yn11, as shown in figure 2. The connection of its HV side has a triangular configuration and the LV side a star configuration, with the star center exposed to connect the neutral conductor.

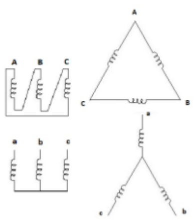

Fig. 2. D/yn11 connections

This is the standard connection group used in Argentina and its exposed neutral terminal admits 231V single-phase loads, connected to the LV side.

Each of the coils of this transformer is made of electrolytic copper bars, with a purity of 99.9%. Each loop of the HV side is made of a single bar, while the LV side is made of ten (10) parallel bars. Besides, it is out of the cell and it is not cooled by oil.

Currently, this transformer has no high and W phase LV coil, and therefore it was not used at all.

Due to the lack of coil in one phase, the windings are connected in an open triangle configuration, as shown in Figure 3.

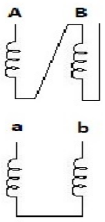

Fig. 3. Current connection of the transformer.

The HV side has an open triangle connection, while the LV side is connected as a two-phase system with neutral.

IV. Connection Analysis

The LV side coil was constructed in two layers so it is possible to reduce it in 50%. This reduction is made by interrupting the number of parallel bars per loop, and keeping half of them, i.e. five bars.

This coil reduction does not affect the number of loops, so the transformation ratio remains unchanged. Neither is the section of the loop affected, so the admisible current is reduced by half and therefore the resulting voltage and power is reduced.

This coil fragmentation is carried out in each of the LV windings.

The resulting coils are connected opposite to the remaining ones, as shown in figure 4. This figure shows that the connection has an open∆/Y arrangement, hence the symbol is V/yn. Coils are also connected in series, resulting in a phasor of the remaining phase.

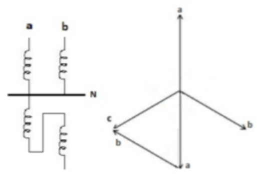

Fig. 4. V/yn connections

Terminals identification for the connection of windings in opposition is made by means of a galvanometer. Continuous voltage is applied and the deflection observed.

For this connection, there is a three-phase, LV system with a Y center available.

The new LV phase is displaced by 120° from the other ones. The module of this phase is equal to that of the others, so the system is not unbalanced.

V. First Run

By means of a three-phase autotransformer, sinusoidal, alternate voltage was applied at a frequency of 50Hz to the HV side. Voltage was increased to reach 128.6V of line voltage, measured with a Fluke multimeter model 107.

Because the number of loops at the LV side is kept, the transformation ratio remains the same, with a line voltage of 15.6V and a phase voltage of 9.2V.

As a first check, it was made sure that the 3 line voltages were equal.

Voltage between u and v phases is 15.6V, with a value equal to the voltage between v-w and w-u phases. Therefore, because they form the sides of the triangle, each of them has the same value and they are displaced by 120°.

It is worth highlighting that all voltage values are effective values.

VI. Verification of the Test:

In order to verify the results of the connection, a Schneider PCM4000 Powerlogic network analyzer and a Fluke multimeter model 107 were used.

Voltage of sinusoidal phases were observed with Powerlogic software, as shown in Figure 5.

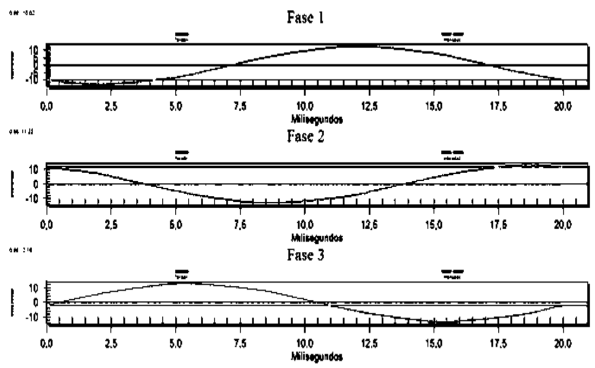

Fig. 5. Voltage of u-v-w phases

These LV side voltages do not have harmonics that distort waveform, with predominance of the wave fundamental component.

Voltage values are also worth noting in Figure 5. Here it can be seen that the peak voltage is 9.19V, in agreement with the values measured.

These voltages are displaced by 120° respectively, as can be seen in Figure 6.

Fig. 6

Values have been verified in vacuum.

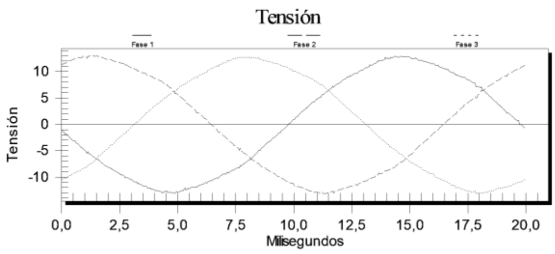

Fig. 6. Voltage displacement

At the LV side load, a small variation in w phase can be observed, caused by an impedance increase that can be considered negligible.

Transformer's parameters:

As previously verified, voltage remains sinusoidal, phase voltages are displaced by 120° and their modules kept. But this modification of the equipment causes a power decrease

This decrease, as previously explained, is caused by the reduction in the windings section, at the LV side. This happens although neither the section nor the loops of the windings were modified at the HV side.

Therefore, calculations are carried out to verify power and currents that we consider nominal based on this modification.

LV nominal power. Due to a 50% decrease at the secondary conductor section, the

I_{adm} is reduced in the same proportion, so the initial 800kVA lowers to 400kVA.

LV nominal current. I_n a similar manner, when the current decreases, it is defined according to equation 1.

$$I_{2n} = \frac{S_{nV-y}}{\sqrt{3}\times U_{2n}} = \frac{400kVA}{\sqrt{3}\times 0{,}4kV} = 578A \qquad (1)$$

LV side nominal current is 578A.

VII. HIGHEST POWER AT PRIMARY SIDE

Having in mind that the admissible current at the primary is 140A, the highest power of the open triangle at the HV side is defined by equation 2:

$$S_{1V} = 2 \times I_{1nD} \times U_{1n} = \quad (2)$$

$$S_{1VM} = 2 \times 140A \times 3{,}3kV = 924kVA$$

causing the highest power at the HV side, in an open Δ arrangement, to be higher than the power at the HV side in a triangular arrangement. This power shall not be considered nominal, as it was obtained from a modification of the coils.

Nominal current at the HV side. As previously explained, the highest power cannot be considered nominal, as we would be overloading the secondary. It was also explained that the transformation ratio has not been modified, so equation (3) represents the secondary nominal current at the HV side:

$$I_{1nV} = \frac{I_{2n}}{a} = \frac{578A}{3300/400} = 70A \qquad (3)$$

Being the nominal current at the open triangle side equal to 70A.

Nominal power at the HV side.

From equation (4), power at the HV side is:

Therefore, powers at LV and HV sides are equal.

$$S_{1V} = \sqrt{3} \times I_{1nV} \times U_{1n} = (4)$$

$$S_{1V} = \sqrt{3} \times 70A \times 3{,}3kV = 400kVA$$

VIII. RESULTS AND DISCUSSION

In order to perform a blocked rotor test (which requires nominal current to flow at a reduced voltage) the transformer previously described was used, connecting the engine, whose plate data are detailed in Table 1, to the secondary

TABLE I. ENGINE PLATE DATA

Plate data - wound rotor CGE 75HP engine	
Power	75 HP
Stator nominal voltage (Vs)	380 V
Stator nominal current (Is)	107 A
Rotor nominal voltage (Vr)	258 V
Rotor nominal current (Ir)	140 A
Nominal speed	970 rpm

The following measuring instruments were used for these tests: a Fluke multimeter, model 107, a CIRCUTORmultimeter, model DHB 324 and a METREL meter, model MI 2086, EUROTEST 61557, to measure voltage and power.

This test was satisfactorily performed, with the results shown in Table 2:

TABLE II. DATA FROM THE BLOCKED ROTOR TEST

Short-circuit Test					
Line voltage (V)		*Phase voltage (V)*		*Line currents (A)*	
U uv	47	U un	28	I R	88,8
U vw	47	U vn	28	I S	89
U wu	46	U wn	26	I T	88,7

As can be seen in Table 2, there are no differences in the results obtained, showing that the use of the transformer with the modifications described is feasible.

Modifications to the equipment were inexpensive and it can be used to perform the various tests conducted at the High Voltage Laboratory.

IX. CONCLUSIONS

Based on the theoretical knowledge gained from the subject “Electric Machines I” concerning transformers, coils were modified at the LV side of the transformer in order to be used to conduct the tests required by the Department of Electrical Engineering. To do this, the identification of homologous terminals was taken into account to correctly connect the coils, which allowed us to generate the star center.

For the connection groups, the diagram of voltage phasors was constructed, which simplified the task of arranging the coils in series to obtain the “w” phase.

Finally, thanks to the use of different instruments for measuring voltage, and above all, to the reports issued by the PCM4000 Powelogic network analyzer, the theoretical proposal concerning the construction of an open Δ /Triangle connection group was verified (V/yn)

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