

ELECTRIC TRANSFORMERS PARALLEL WORKING

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ABSTRACT. The electric transformers parallel working provides the continuous supply with electric currents of electric consumers, therefore, in the case of fault for the one of the transformers, the load is taken over by the other transformers and the consumers electric power is not interrupted, thus providing one of the vital conditions for their working and namely their operating safety.

Key words: Operating safety, parallel working, transformation report, connections group, short circuit voltage.

ПАРАЛЕЛНА РАБОТА НА ЕЛЕКТРИЧЕСКИ ТРАНСФОРМАТОРИ

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РЕЗЮМЕ. Паралелната работа на електрическите трансформатори осигурява непрекъснато подаване на електрически ток към консуматорите, следователно, в случай на неизправност на един от трансформаторите, натоварването се поема от останалите трансформатори и не се прекъсва подаването на електрическа енергия, като по този начин се осигурява едно от основните изисквания за работа, а именно безопасна експлоатация.

Ключови думи: безопасна експлоатация, паралелна работа, група на свързване, напрежение на късо съединение.

Introduction

For the working of transformers with a good power factor and high output, it is necessary that their loads be close to the nominal ones.

The transformers load alters at certain hours during the day and night and in different seasons of the year. For an economic operation, instead of one, two or more transformers are mounted which work in parallel during the highest load. When the load decreases, some transformers are disengaged, so that the working transformers operate at a load close to the nominal one.

Electric transformers work in parallel, when their primary windings are supplied from the same source of energy, and their secondary windings are connected to the common bars where the consumers network is supplied.

Conditions for a parallel working of electric transformers

Fig.1 indicates the parallel working scheme of two mono-phasic transformers.

In order not to have circulation currents between transformers and the load be distributed among the transformers working in parallel to their nominal power, when they are coupled in parallel the following conditions have to be met:

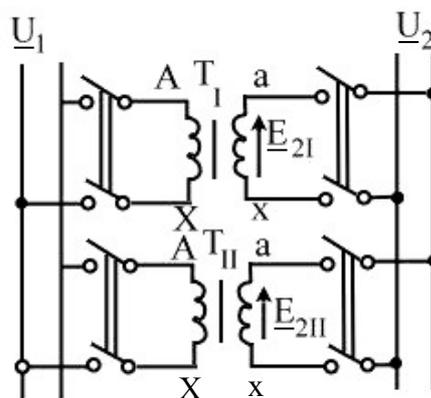


Fig.1 The parallel working scheme of two mono-phasic transformers.

1. primary and secondary nominal voltages of the transformers have to be equal ($U_{1nI}=U_{1nII}=U_1$; $U_{2nI}=U_{2nII}=U_2$). This condition is practically met by equalling the transformation reports, meaning $k_I=k_{II}$;
2. tri-phased transformers must have the same groups of connections.
3. The short-circuit nominal voltages of the transformers have to be equal, meaning: $u_{kIn} \% = u_{kIIIn} \%$ their active and inductive components respectively be adequately equal;
4. identical marked terminals of the transformers windings be connected to the same network conductor, both on the primary part and on the secondary part;

If the parallel coupled transformers comply with all the conditions, their vectorial diagrams at the load working built in relative units they come one over another. In this case, all the transformers are loaded with proportional loads with their nominal powers, and the transformers load currents are arithmetically summed. Practically, only the second condition has to be thoroughly met, for the first and third conditions tolerances being accepted. Besides, the sum of their loads does not have to be higher than the sum of their nominal powers.

If the aforementioned conditions are met, t.e.m. E_{2I} and E_{2II} induced in transformers secondary windings (fig.1) are in phase and equal in size, and there are no equalizing currents in the transformers windings.

If the first condition is not met – **the equality between the transformation reports**, the equalization current appears, which is conditioned by the difference between the secondary t.e.m., meaning:

$$I_{-eg} = \frac{\Delta E}{Z_{KI} + Z_{KII}}$$

where:

Z_{KI}, Z_{KII} - transformers internal reactance.

At the transformers loading, the equalization current is overlapping with the load one. Moreover, the secondary higher t.e.m. transformer (at the pit transformers – with lower transformation report) is overloaded and the higher transformation report transformer is under loaded.

Because overload is not admitted, it is necessary to reduce the common load of transformers. If the difference between the transformation reports is considerable, it becomes practically impossible for the transformers to work in parallel. This is why, according to standards, the parallel coupling is admitted for transformers, where the difference between their transformation reports is not more than 0,5% in comparison with the average geometric value of these reports, meaning:

$$\Delta k\% = \frac{k_I - k_{II}}{\sqrt{k_I \cdot k_{II}}} \cdot 100\% \leq 0,5\%$$

If the second condition is not met - **tri-phased transformers have the same group of connections** - the line secondary t.e.m. of the two transformers are detached one from the others with a multiple angle of 30° .

For example, if a transformer has 0 group, and the other 11 group, their line t.e.m. are split one from the other by 30° (fig.2), resulting $\Delta E = 0,52E_2$, for which the equalization current reaches a higher value and the transformers parallel working is not possible.

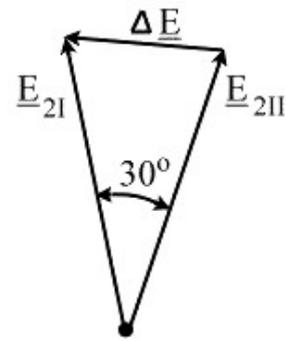


Fig.2 Vectorial diagram of t.e.m. in the case of transformers with connection groups 0 and 11, which will be coupled in parallel

We have to take into consideration that by adequately permuting the windings terminals, in some cases we can achieve the parallel working of transformers with different groups of connections. Fig. 3 displays the scheme of parallel connection of two tri-phased transformers.

If the parallel working conditions are met, the voltmeters indications V_1 and V_2 are zero. These voltmeters have to have their field not smaller than the double value of the network voltage.

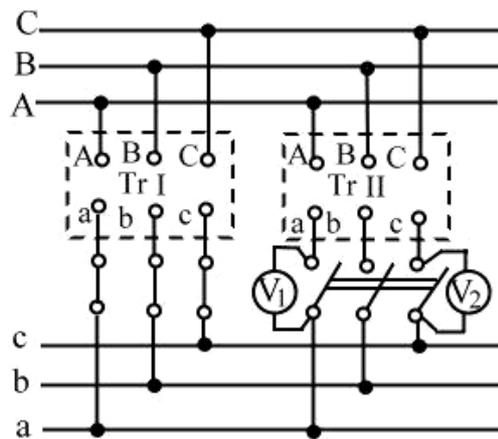


Fig.3 The scheme of parallel connection of two tri-phased transformers. .

If only the third condition is not met – **the equality of the short-circuit nominal voltages**, the load is not distributed in proportion with the nominal powers of transformers. The external characteristic of the transformer with higher $u_k\%$, is strongly sloped for the abscissa axis (the external characteristic of the transformer T_{II}) in comparison with the transformer with lower $u_k\%$ (fig.4).

For one and the same secondary voltage U_{2S} for the second transformer in load, the T_I transformer is loaded with higher current than the T_{II} transformer. In order not to reach the T_I overloading, one has to reduce the common load, which does not use the entire power of transformers working in parallel.

If one takes into consideration that not always we can choose transformers with the same $u_k\%$, the standards admit the parallel connection of the transformers with a difference between the short-circuit voltages without overcoming $\pm 10\%$ of their arithmetic mean value.

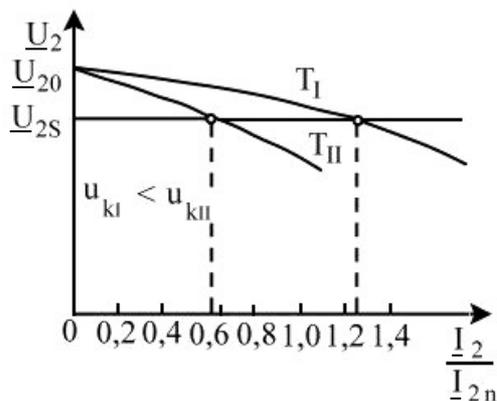


Fig.4 External characteristics of the two transformers coupled in parallel

The difference between the components of relative voltages at short-circuit is higher the higher the difference between nominal powers of transformers is. That is why for the parallel working it is recommended for the report between the nominal powers of transformers not to be higher than 3:1.

If the fourth condition is not met ($E_{2I} \neq E_{2II}$) in the closed circuit of secondary windings acts the resulting t.e.m. ΔE , equal with the difference between E_{2I} and E_{2II} . Because the circuit impedance is relatively small, under the t.e.m. action ΔE , the equalization current going through the secondary windings of transformers reaches considerable values even when the load is decoupled.

At the transformers loading, the equalization current adds to their load current and leads to overloading. Moreover, it fault is possible. This is why before the transformers parallel coupling one checks whether t.e.m. E_{2I} and E_{2II} are in phase and equal in size. For supplying the parallel winding of the transformer coupling to work in parallel, in its secondary winding a voltmeter or electric lamp are connected (one of the secondary outputs remains open and in the place of the switcher the measurement device or lamp are connected).

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Is all the parallel working conditions are met, the voltmeter indicates zero or the lamp does not switch on, because $\Delta E = E_{2I} - E_{2II} = 0$. In this case the two transformers can work in parallel.

The voltmeter and electric lamp has to bear a voltage which is twice the secondary nominal voltage. This is necessary, because if the first connection condition of the second transformer with the homonymous output terminals transformer with the same conductor of the network is not met, t.e.m. E_{2I} and E_{2II} may be summed-up.

Conclusions

The parallel working of electric transformers is justified by the following advantages:

- increased degree of exploitation working;
- keeping a low level of losses in the transformation process, by altering the number of transformers working according with the required load, thus the use of transformers working at a maximum output;
- replacing the high powers and weights transformers with admissible limits weights transformers.

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