Based on The Comparative Study of The Economic Load Coefficient of a Double-Winding Transformer in Operation in A Certain Area

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Abstract. Extract the transformer parameters in operation in a certain area. After considering the selection of transformer characteristic parameters and the transmission in the system, the load coefficients of 17 double-winding transformers with 3 capacities are calculated theoretically. It is concluded that the economic load coefficient of various types of transformers in actual operation and the general value is about 0.5. People used to transformer economic load coefficient is 0.75 questioned.

1. Introduction
The economic load coefficient of transformer is not only theoretical, but also practical and practical. For a long time, people used to say the transformer economic load coefficient is 0.75, so it is concluded that the transformer performance is the best when it is close to full load. In this paper, through a large number of examples, the economic load coefficient of the transformer has a more objective and accurate conclusion.

2. Model selection of double-winding transformer
Practical operation to select an area of 17 sets of double winding transformer as the calculation model, obtain the corresponding capacity and the nameplate parameters of transformer, 17 sets of transformers, the nominal capacity of 20 MVA of 5, 10 sets of rated capacity of 31.5 MVA, rated capacity of 50 MVA (2), according to the transformer capacity since the childhood, no-load current I0 percent since list as follows:
Table 1. Parameters of 17 double-winding transformer nameplates in actual operation in a certain area

| Name of main transformer | Nominal capacity S0(MVA) | Capacity than | No-load current I0% | No-load loss P0(KW) | Short circuit voltage Uk% | Short circuit loss PK(KW) |
|-------------------------|--------------------------|---------------|---------------------|---------------------|--------------------------|--------------------------|
| Tai#2                   | 20                       | 1/1           | 0.14%               | 15.9                | 10.36%                   | 92.85                   |
| Xu#1                    | 20                       | 1/1           | 0.30%               | 19                  | 9.56%                    | 86                      |
| Xu#2                    | 20                       | 1/1           | 0.32%               | 18.8                | 9.53%                    | 86.1                    |
| Ni#1                    | 20                       | 1/1           | 0.46%               | 23.35               | 10.70%                   | 103.54                  |
| Ni#2                    | 20                       | 1/1           | 0.69%               | 25.5                | 10.70%                   | 103.54                  |
| ZHeng#1                 | 31.5                     | 1/1           | 0.11%               | 20.96               | 10.48%                   | 118.68                  |
| ZHeng#2                 | 31.5                     | 1/1           | 0.13%               | 21.25               | 10.56%                   | 115.7                   |
| Gao#1                   | 31.5                     | 1/1           | 0.24%               | 25.88               | 10.32%                   | 143                     |
| Dong#2                  | 31.5                     | 1/1           | 0.24%               | 29.25               | 10.78%                   | 125                     |
| Gao#2                   | 31.5                     | 1/1           | 0.26%               | 25.56               | 10.32%                   | 143                     |
| Dong#1                  | 31.5                     | 1/1           | 0.29%               | 29.64               | 9.95%                    | 126.88                  |
| Guang#1                 | 31.5                     | 1/1           | 0.40%               | 31                  | 10.40%                   | 148                     |
| Guang#2                 | 31.5                     | 1/1           | 0.40%               | 31                  | 10.30%                   | 146                     |
| Pang#1                  | 31.5                     | 1/1           | 0.87%               | 23.25               | 10.43%                   | 88                      |
| Pang#2                  | 31.5                     | 1/1           | 0.82%               | 23.5                | 10.43%                   | 81.54                   |
| Fan#2                   | 50                       | 1/1           | 0.09%               | 29.7                | 10.63%                   | 158.53                  |
| Fan#1                   | 50                       | 1/1           | 0.10%               | 31.3                | 10.51%                   | 184.77                  |

3. Calculation principle and basis of economic load coefficient of double-winding transformer

The ratio of the actual load carried by the transformer to its rated output is called the load factor of the transformer, expressed by. In the operation of transformer, its active power loss rate and reactive power loss rate are nonlinear changes with the change of load. In its nonlinear curve, there is always a lowest point, the load coefficient of the lowest point of the active power loss rate is the active power economic load coefficient, expressed by $\beta_{jp}$; The load coefficient at the lowest point of the reactive power consumption rate is the reactive economic load coefficient, expressed by $\beta_{jQ}$. The economic load coefficient of transformer is the theoretical point of economic operation, on the basis of the economic load coefficient, the economic operation range of transformer can be deduced, which is of practical significance for the implementation of economic operation of transformer.

$$\beta_{jp} = \sqrt{\frac{P_0}{P_K}}$$

$P_0$-- transformer no-load loss, from transformer nameplate parameters
$P_K$-- Transformer rated load loss (short circuit loss), from the transformer nameplate parameters
$\beta_{jp}$-- Transformer active economic load coefficient, obtained by calculation

$$\beta_{jQ} = \sqrt{\frac{I_{0\%}}{U_{k\%}}}$$

$I_{0\%}$-- Percentage of no-load current, from transformer nameplate parameters
$U_{k\%}$-- Percentage of short circuit voltage, from transformer nameplate parameters
$\beta_{jQ}$-- The economic load coefficient of transformer reactive power is obtained through calculation
3. Calculation of economic load coefficient of double-winding transformer

One transformer with rated capacity of 20MVA, 31.5MVA and 50MVA is selected respectively for calculation of active power economic load coefficient, reactive power economic load coefficient and comprehensive economic load coefficient.

3.1. Calculation of rated transformer capacity of 20MVA

According to the query model, the nameplate parameters of tai# 2 transformer are obtained as follows:

$I_0\% = 0.14\%, P_0 = 15.9\text{KW}, U_k\% = 10.36\%, P_K = 92.85\text{KW}$

According to the calculation formula:

$$\beta_{jp} = \sqrt{\frac{P_0}{P_K}} = \sqrt{\frac{15.9}{92.85}} = 0.414$$

$$\beta_{jQ} = \sqrt{\frac{I_0\%}{U_k\%}} = \sqrt{\frac{0.14\%}{10.36\%}} = 0.116$$

$$Q_0 \approx S_0 = I_0\% S_N \times 10^{-2} = 0.14\% \times 20000 \times 10^{-2} = 28\text{kvar}$$

$$Q_K \approx S_K = U_k\% S_N \times 10^{-2} = 10.36\% \times 20000 \times 10^{-2} = 2072\text{kvar}$$

$$P_{OZ} = P_O + K_QQ_0 = 15.9 + 0.05 \times 28 = 17.3\text{ KW}$$

$$P_{KZ} = P_K + K_QQ_K = 92.85 + 0.05 \times 2072 = 196.45\text{ KW}$$

$$\beta_{jZ} = \sqrt{\frac{P_{OZ}}{P_{KZ}}} = \sqrt{\frac{17.3}{196.45}} = 0.297$$

Similarly, the economic load coefficients of other 4 transformers with rated capacity of 20MVA are calculated as follows:
Table 2. Table of calculation results of economic load coefficient of 5 transformers with rated capacity of 20MVA

| Name of main transformer | Nominal capacity $S_N$(MVA) | Capacity than | No-load current $I_0$% | No-load loss $P_0$(KW) | Short circuit voltage $U_K$% | Short circuit loss $P_K$(KW) | Active economic load factor $\beta_{jp}$ | Reactive economic load factor $\beta_{jQ}$ | Economic equivalent of reactive power $K_Q$ | Integrated economic load factor $\beta_{jZ}$ |
|-------------------------|----------------------------|---------------|------------------------|------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Tai#2                   | 20                         | 1/1           | 0.14%                  | 15.9                   | 10.36%                      | 92.85%                      | 0.414                       | 0.116                       | 0.05                        | 0.297                       |
| Xu#1                    | 20                         | 1/1           | 0.30%                  | 19                     | 9.56%                       | 86                          | 0.470                       | 0.177                       | 0.05                        | 0.348                       |
| Xu#2                    | 20                         | 1/1           | 0.32%                  | 18.8                   | 9.53%                       | 86.1                        | 0.467                       | 0.183                       | 0.05                        | 0.348                       |
| Ni#1                    | 20                         | 1/1           | 0.46%                  | 23.35                  | 10.70%                      | 103.5%                      | 0.475                       | 0.207                       | 0.05                        | 0.364                       |
| Ni#2                    | 20                         | 1/1           | 0.69%                  | 25.5                   | 10.70%                      | 103.5%                      | 0.496                       | 0.254                       | 0.05                        | 0.392                       |

As can be seen from the above table, 5 transformers with the same rated capacity of 20MVA have an active economic load coefficient of 0.141-0.496. Reactive economic load coefficient 0.116-0.254; Comprehensive power economic load coefficient Both are less than 0.5. The coefficients are illustrated as follows.

Figure 1. The rated capacity of 5 transformers is 20MVA economic load factor

3.2. Calculation of rated capacity of transformer is 31.5MVA

According to the query model, the nameplate parameters of zheng #1 transformer are obtained as follows:

$I_0$%--0.11%, $P_0$--20.96KW, $U_K$%--10.48%, $P_K$--118.68KW

According to the calculation formula:
\[
\beta_{jp} = \sqrt[3]{\frac{P_0}{P_K}} = \sqrt[3]{\frac{20.96}{118.68}} = 0.420
\]
\[
\beta_{jQ} = \sqrt[3]{\frac{I_0}{U_K \%}} = \sqrt[3]{\frac{0.11\%}{10.48\%}} = 0.103
\]

\[Q_0 \approx S_0 I_0\% S_N \times 10^{-2} = 0.11\% \times 31500 \times 10^{-2} = 34.65 \text{kvar}\]

\[Q_K \approx S_K U_K\% S_N \times 10^{-2} = 10.48\% \times 31500 \times 10^{-2} = 3301.2 \text{kvar}\]

\[P_{0Z} = P_0 + K_Q Q_0 = 20.96 + 0.05 \times 34.65 = 22.69 \text{KW}\]

\[P_{KZ} = P_K + K_Q Q_K = 118.68 + 0.05 \times 3301.2 = 283.74 \text{ KW}\]

\[
\beta_{jZ} = \sqrt[3]{\frac{P_{0Z}}{P_{KZ}}} = \sqrt[3]{\frac{22.69}{283.74}} = 0.283
\]

Similarly, the economic load coefficients of other 9 transformers with rated capacity of 31.5MVA are calculated as follows:

**Table 3.** Table of calculation results of economic load coefficient of 10 transformers with rated capacity of 31.5MVA

| Name of main transformer | Nominal capacity $S_n$(MVA) | Capacity than | No-load current $I_0$% | No-load loss $P_0$(KW) | Short circuit volt age $U_K$% | Short circuit loss $P_K$(KW) | Active economic load factor $\beta_{jp}$ | Reactive economic load factor $\beta_{jQ}$ | Economic equivalent of reactive power $K_Q$ | Integrated power econom y load factor $\beta_{jZ}$ |
|--------------------------|-----------------------------|---------------|------------------------|------------------------|-----------------------------|-----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| ZHeng#1                  | 31.5                        | 1/1           | 0.11%                  | 20.96                  | 10.48%                      | 118.68%                     | 0.420                           | 0.103                           | 0.05                            | 0.283                           |
| ZHeng#2                  | 31.5                        | 1/1           | 0.13%                  | 21.25                  | 10.56%                      | 115.7%                      | 0.429                           | 0.111                           | 0.05                            | 0.287                           |
| Gao#1                    | 31.5                        | 1/1           | 0.24%                  | 25.88                  | 10.32%                      | 143                         | 0.425                           | 0.153                           | 0.05                            | 0.312                           |
| Dong#2                   | 31.5                        | 1/1           | 0.24%                  | 29.25                  | 10.78%                      | 125                         | 0.484                           | 0.149                           | 0.05                            | 0.335                           |
| Gao#2                    | 31.5                        | 1/1           | 0.26%                  | 25.56                  | 10.32%                      | 143                         | 0.423                           | 0.159                           | 0.05                            | 0.312                           |
| Dong#1                   | 31.5                        | 1/1           | 0.29%                  | 29.64                  | 9.95%                       | 126.8%                      | 0.483                           | 0.171                           | 0.05                            | 0.347                           |
| Guang#1                  | 31.5                        | 1/1           | 0.40%                  | 31                     | 10.40%                      | 148                         | 0.458                           | 0.196                           | 0.05                            | 0.346                           |
| Guang#2                  | 31.5                        | 1/1           | 0.40%                  | 31                     | 10.30%                      | 146                         | 0.461                           | 0.197                           | 0.05                            | 0.348                           |
| Pang#1                   | 31.5                        | 1/1           | 0.87%                  | 23.25                  | 10.43%                      | 88                          | 0.514                           | 0.288                           | 0.05                            | 0.382                           |
| Pang#2                   | 31.5                        | 1/1           | 0.82%                  | 23.5                   | 10.43%                      | 81.54                       | 0.537                           | 0.280                           | 0.05                            | 0.385                           |
As can be seen from the above table, 10 transformers with the same rated capacity of 31.5MVA have an active economic load coefficient of 0.420-0.537. Reactive economic load coefficient 0.103-0.288; Comprehensive power economic load coefficient Less than 0.6. The coefficients are illustrated as follows:

![Economic load factor of 10 transformers with rated capacity of 31.5MVA](image)

**Figure 2.** Economic load factor of 10 transformers with rated capacity of 31.5MVA

### 3.3. calculation of rated capacity of transformer is 50MVA

The parameters of fan #1 transformer nameplate can be obtained by querying the model as follows:

- \( I_0\% = 0.10\% \)
- \( P_0 = 31.3\text{KW} \)
- \( U_k\% = 10.51\% \)
- \( P_K = 184.77\text{KW} \)

According to the calculation formula:

\[
\beta_{jp} = \frac{P_0}{P_K} = \sqrt{\frac{31.3}{184.77}} = 0.412
\]

\[
\beta_{jQ} = \frac{I_0\%}{U_k\%} = \sqrt{\frac{0.10\%}{10.51\%}} = 0.098
\]

\( Q_0 \approx S_0 = I_0\%S_N \times 10^{-2} = 0.10\% \times 50000 \times 10^{-2} = 50\text{kvar} \)

\( Q_K \approx S_K = U_k\%S_N \times 10^{-2} = 10.51\% \times 50000 \times 10^{-2} = 5255\text{kvar} \)

\( P_{OZ} = P_0 + K_QQ_0 = 31.3 + 0.05 \times 50 = 33.8\text{KW} \)

\( P_{KZ} = P_K + K_QQ_K = 184.77 + 0.05 \times 5255 = 447.52\text{ KW} \)

\[
\beta_{jZ} = \frac{P_{OZ}}{P_{KZ}} = \sqrt{\frac{33.8}{447.52}} = 0.275
\]

Similarly, the economic load coefficient of another transformer with rated capacity of 50MVA is calculated as follows
Table 4. Table of calculation results of economic load coefficient of two transformers with rated capacity of 50MVA

| Name of main transformer | Nominal capacity $S_n$(MV A) | Capacity than | No-load current $I_0$% | No-load loss $P_0$(K W) | Short circuit voltage $U_k$% | Short circuit loss $P_k$(K W) | Active economic load factor $\beta_j\rho$ | Reactive economic load factor $\beta_j\varphi$ | Economic equivalent of reactive power $K_q$ | Integrated power economy load factor $\beta_jZ$ |
|-------------------------|-------------------------------|---------------|------------------------|--------------------------|-----------------------------|-----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Fan#2                   | 50                            | 1/1           | 0.09%                  | 29.7                     | 10.63%                      | 158.5%                      | 0.433                           | 0.092                           | 0.05                           | 0.274                           |
| Fan#1                   | 50                            | 1/1           | 0.10%                  | 31.3                     | 10.51%                      | 184.7%                      | 0.412                           | 0.098                           | 0.05                           | 0.275                           |

As can be seen from the above table, two transformers with the same rated capacity of 50MVA have an active economic load coefficient of 0.412-0.433. Reactive economic load coefficient Comprehensive power economic load coefficient Both are less than 0.5. The coefficients are illustrated as follows

![Figure 3. The rated capacity of 2 transformers is 50MVA economic load factor](image)

4. Conclusion

By checking the economic load coefficient of 17 double-winding transformers in actual operation in a certain region, the following table shows that the economic load coefficient of active power is 0.412-0.537. Reactive economic load coefficient the comprehensive power economic load coefficient is 0.274-0.392, which indicates that the actual economic load coefficient deviates greatly from 0.75. The size of the economic load coefficient of each transformer should be determined according to the calculation results of the technical parameters of the transformer itself, instead of making uniform uniform provisions.
Table 5. A list of economic load coefficients of 17 double-winding transformers in operation in a certain area

| Name of main transformer | Nominal capacity Sn(MVA) | Capacity than | No-load current I0% | No-load loss P0(KW) | Short circuit voltage Uk% | Short circuit loss Pk(KW) | Active economic load factor βjp | Reactive economic load factor βjQ | Economic equivalent of reactive power KQ | Integrated power economy load factor βZ |
|--------------------------|--------------------------|---------------|---------------------|---------------------|--------------------------|--------------------------|-------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Tai#2                    | 20                       | 1/1           | 0.14%               | 15.9                | 10.56%                   | 92.85                    | 0.414                         | 0.116                           | 0.05                            | 0.297                           |
| Xu#1                     | 20                       | 1/1           | 0.30%               | 19                  | 9.56%                    | 86                       | 0.470                         | 0.177                           | 0.05                            | 0.348                           |
| Xu#2                     | 20                       | 1/1           | 0.32%               | 18.8                | 9.53%                    | 86.1                     | 0.467                         | 0.183                           | 0.05                            | 0.348                           |
| Ni#1                     | 20                       | 1/1           | 0.46%               | 23.35               | 10.70%                   | 103.54                   | 0.475                         | 0.207                           | 0.05                            | 0.364                           |
| Ni#2                     | 20                       | 1/1           | 0.69%               | 25.5                | 10.70%                   | 103.54                   | 0.496                         | 0.254                           | 0.05                            | 0.392                           |
| ZHeng#1                  | 31.5                     | 1/1           | 0.11%               | 20.96               | 10.48%                   | 118.68                   | 0.420                         | 0.103                           | 0.05                            | 0.283                           |
| ZHeng#2                  | 31.5                     | 1/1           | 0.13%               | 21.25               | 10.56%                   | 115.7                    | 0.429                         | 0.111                           | 0.05                            | 0.287                           |
| Gao#1                    | 31.5                     | 1/1           | 0.24%               | 25.88               | 10.52%                   | 143                      | 0.425                         | 0.153                           | 0.05                            | 0.312                           |
| Dong#2                   | 31.5                     | 1/1           | 0.24%               | 29.25               | 10.78%                   | 125                      | 0.484                         | 0.149                           | 0.05                            | 0.335                           |
| Gao#2                    | 31.5                     | 1/1           | 0.26%               | 25.56               | 10.32%                   | 143                      | 0.423                         | 0.159                           | 0.05                            | 0.312                           |
| Dong#1                   | 31.5                     | 1/1           | 0.29%               | 29.64               | 9.95%                    | 126.88                   | 0.483                         | 0.171                           | 0.05                            | 0.347                           |
| Guang#1                  | 31.5                     | 1/1           | 0.40%               | 31                  | 10.40%                   | 148                      | 0.458                         | 0.196                           | 0.05                            | 0.346                           |
| Guang#2                  | 31.5                     | 1/1           | 0.40%               | 31                  | 10.30%                   | 146                      | 0.461                         | 0.197                           | 0.05                            | 0.348                           |
| Pang#1                   | 31.5                     | 1/1           | 0.87%               | 23.25               | 10.43%                   | 88                       | 0.514                         | 0.288                           | 0.05                            | 0.382                           |
| Pang#2                   | 31.5                     | 1/1           | 0.82%               | 23.5                | 10.43%                   | 81.54                    | 0.537                         | 0.280                           | 0.05                            | 0.385                           |
| Fan#2                    | 50                       | 1/1           | 0.09%               | 29.7                | 10.63%                   | 158.53                   | 0.433                         | 0.092                           | 0.05                            | 0.274                           |
| Fan#1                    | 50                       | 1/1           | 0.10%               | 31.3                | 10.51%                   | 184.77                   | 0.412                         | 0.098                           | 0.05                            | 0.275                           |

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