SUMMARY

The distribution transformers load is characterised by a slow but continuous increase from year to year. Therefore, one has to check that the load does not exceed the technical limits of the transformer but also one has to decide on the best economical moment to make a replacement by a larger transformer.

Technical limits for transformer operation.
The operating limits are set by the IEC standard 354:

a) The current should never exceed 150% of the rated current
b) The hot spot temperature should not exceed 140°C
c) The top oil temperature should not exceed 105°C
d) The hot spot temperature may temporarily exceed 98°C but the cumulated ageing should be kept at rated level.

Practical limits for distribution transformers:
The load of the distribution transformers is made up of tens or even hundreds of separate loads behaving independently but resulting in repetitive daily cycles with typically one peak in the evening. One might have two peaks on the day but, anyway, the load level is far from constant.

The report gives the results of simulations from which it is concluded that the practical load limit comes from the criterion a) here above. Only in few cases does the top oil temperature reach the limit of 105°C before the current peaks reach the 150% level. As a corollary, load monitoring only by transformer temperature monitoring is not the best choice.

Economical aspects
When the load increases, a moment comes where the replacement of the transformer becomes technically mandatory. After the replacement by a unit of higher rating, the losses will be reduced and this has a positive effect on the operating cost of the transformer. One might think of anticipating the replacement to take advantage of this benefit earlier.

Search for optimal replacement year
We considered the situation where the load increase would require a replacement of a transformer within a term of ten years and then looked back if there was an economically optimal moment to do the replacement.

The parameters of the economical model are given in the report. A simulation horizon of 20 years was used. Attention has been paid to the evaluation of the residual value of the transformers when they are replaced and at the end of the simulation horizon.

An important qualitative conclusion was that there is no optimal moment to make the replacement, it has to be done either immediately, either as late as possible.

Search for ‘break-even’ loads
Therefore, the decision making process was reformulated and one simply considered it on a purely incremental base. The question becomes: is there an advantage to replace the transformer this year instead of next year?

The answer is positive for high load levels and negative for low load levels: the load that makes the limit between both cases (‘break-even load’) was determined for several values of the parameters.

The conclusion was that in most of the cases, there is no economical interest to anticipate on the transformer replacement.

Important influence parameters are:
- The age of the transformer to be replaced: can it be re-installed and re-used elsewhere for a significant period?
- The ratio between the peak and average load
- The energy tariffs.

Load monitoring
If one wants to run the transformers closer to their technical limits, a better monitoring of the load will be necessary. In the report some monitoring methods are briefly overviewed.

General conclusions
- There is an interest for running he distribution transformers closer to their technical limits.
- To do this in a safe way, a simple thermal monitoring is not sufficient.
- There will be a market for modern monitoring devices with flexible possibilities for data transfer from isolated distribution cabins.
La charge des transformateurs de distribution est caractérisée par une augmentation lente mais constante d’année en année. Pour cette raison, il est nécessaire non seulement de vérifier que la charge n’excède pas les limites techniques des transformateurs, mais également de choisir le moment économiquement le plus opportun pour les remplacer par de plus gros transformateurs.

**Limites Techniques de fonctionnement des transformateurs.**
Les limites de fonctionnement sont données par la norme CEI 354 :

a) le courant ne devrait jamais excéder 150 % du courant assigné ;
b) la température du point chaud ne devrait pas excéder 140°C ;
c) la température maximale d’huile ne devrait pas excéder 105°C ;
d) la température du point chaud peut temporairement excéder 98°C, mais le vieillissement cumulé doit être maintenu à la valeur assignée.

**Limites pratiques des transformateurs de distribution**
La charge des transformateurs de distribution est constituée de dizaines ou même de centaines de charges séparées se comportant indépendamment, mais résultant en un cycle journalier répétitif avec typiquement une pointe en soirée. Il peut y avoir deux pointes par jour, mais dans tous les cas, la charge est loin d’être constante.

L’article donne le résultat de simulations qui porte à conclure que la charge limite pratique provient du critère a) ci-dessus. Dans de rares cas, la température d’huile atteint la limite de 105 °C avant que le courant de pointe n’atteigne le niveau de 150 %. En corollaire, le suivi de la charge basé uniquement sur la température du transformateur n’est pas le meilleur choix.

**Aspects Economiques**
Lorsque la charge augmente, un moment arrive où le remplacement du transformateur devient techniquement obligatoire. Après remplacement par une unité de puissance supérieure, les pertes vont être réduites, et ceci a un effet positif sur le coût de fonctionnement du transformateur. Ceci pourrait amener à songer à une anticipation du remplacement pour profiter plus tôt de l’avantage de ce bénéfice.

La recherche de l’année de remplacement optimale
Nous considérons la situation où l’accroissement de la charge impose un remplacement du transformateur dans les dix ans, et recherchons ensuite s’il y a un moment économiquement optimum pour effectuer le remplacement.

Les paramètres du modèle économique sont donnés dans l’article. Une période de simulation de 20 ans fut utilisée. L’attention fut attirée sur l’évaluation de la valeur résiduelle du transformateur lors de son remplacement, ainsi qu’à la fin de la période de simulation.

Une conclusion qualitative importante fut qu’il n’y a pas de moment optimum pour effectuer le remplacement, il doit avoir lieu soit immédiatement, soit aussi tard que possible.

**Recherche de point de basculement de charges**
A cette fin, le processus de prise de décision fut reformulé, et fut simplement considéré sur une base purement incrémentale. La question devint : y a-t-il un avantage à remplacer le transformateur cette année plutôt que l’année prochaine ?

La réponse est positive pour les hauts niveaux de charge et négative pour les faibles niveaux de charge : la charge qui représente la limite entre les deux cas (break-even load) fut déterminée pour quelques valeurs de paramètres.

La conclusion fut que dans la plupart des cas, il n’y a pas d’intérêt économique à anticiper un remplacement de transformateur.

Les paramètres d’influence importants sont :
- L’âge du transformateur à remplacer : peut-il être réinstallé et réutilisé autre part, pour une période significative ?
- Le rapport entre la pointe et la charge moyenne.
- Les tarifs d’énergie.

**Suivi de la charge**
Si l’on veut faire fonctionner le transformateur plus près de ses limites techniques, un meilleur suivi de la charge est nécessaire. Dans l’article, quelques méthodes de suivi sont rapidement survolées.

**Conclusions générales**
- Il y a un intérêt à faire fonctionner les transformateurs de distribution plus près de leur limites techniques.
- Pour le faire en toute sécurité, la simple surveillance thermique n’est pas suffisante.
- Il y aura un marché pour des appareils de surveillance modernes, possédant des possibilités flexibles de transfert de données des cabines de distribution isolées.
INTRODUCTION

The distribution transformers load is characterised by a slow but continuous increase from year to year. Therefore, one has to check that the load does not exceed the technical limits of the transformer but also one has to decide on the best economical moment to make a replacement by a larger transformer.

In this report we consider first the technical criteria that have to be considered for the follow-up of the transformer load and the determination of the limit situations where an action has to be taken to avoid excess loading. Further we look for the opportunity to make savings by anticipating the replacement of the transformer by a unit of higher rating. Finally, possible monitoring methods are briefly commented.

TECHNICAL LIMITS FOR TRANSFORMER OPERATION

2.1 Ratings and overload capability.

The rated power of a distribution transformer is the power it can deliver in steady state and standard ambient conditions (20 °C) for 30 years. Attention is given to the thermal ageing of the paper-oil insulation for which the Montsinger law is taken as reference since decades: a 6K increase of the insulation temperature doubles the ageing velocity. As the loading of a transformer is not continuous, there are plenty of periods where this ageing mechanism is on a very low rate and, as a consequence, there is a provision left to ‘overload’ the transformer for certain periods of times. Therefore IEC published a loading guide [1] to help the user.

The temporary load of a transformer shall never exceed 150 %: this provision is made to avoid harmful currents for the terminals, connections or any component of the transformer.

For the rest, the overload capability is governed by the temperature rise of the transformer.

Top oil and hot spot temperature rise:

The cooling of oil immersed distributions transformers occurs by natural convection of oil inside the transformer tank. The temperature of the oil under the cover (upper surface) of the transformer is referred to as the top oil temperature. The hot spot is referred as the place of the winding where the highest temperature appears. The hot spot temperature is decisive for the thermal ageing of the insulation. A reference value of 98°C is used: it corresponds to a service life of 30 years. IEC 354 gives a formula to determine the hot spot temperature in steady state:

\[ \text{Ths} = T_{to} + 1.1 \times g \times (I / In)^{1.6} \]

The relative ageing velocity is given by:

\[ V = 2^{(\text{Ths}-98)/6} \]

Operating limits according to IEC 354

a) The current should never exceed 150 % of the rated current
b) The hot spot temperature should not exceed 140°C
c) The top oil temperature should not exceed 105°C
d) The hot spot temperature may temporarily exceed 98°C but the cumulated ageing should be kept at rated level.

Practical limits for distribution transformers

The load of the distribution transformers is made up of tens or even hundreds of separate mostly residential customer loads behaving independently, but resulting in repetitive daily cycles with typically one peak in the evening. One might have two peaks in a day but, anyway, the load level is far from constant (see example diagram).

In this chapter we demonstrate that, due to the specific load profiles of the distribution transformers, it is the criterion a) here above (the peak load) that will be the practical service limit. This results from simulation calculations.
2.2 Reference load profiles

For the simulation calculations, we used crude simplifications of the load profiles with a few shaping parameters. The load profile was characterised by:
- a base level $B$
- a peak level $H$
- a peak duration $D$
- the ‘peak shoulders’ have a level at mid height between $B$ and $H$
- each ‘peak shoulder’ has a duration $D/2$

Following combinations where considered:
- $B/H = 0.2, 0.4, 0.6, 0.8$
- one peak of 2 h
- two peaks of 1 h per day (with 8 h between successive peaks)
- ambient temperatures of 10, 20, 30, and 40 °C.

2.3 Transformer model and simulation method

The classical thermal model of a distribution transformer is build around two variables: the winding temperature and the oil temperature. The temperature rise is driven by the power losses inside the transformer. The relation between the temperature rise and the transformer load is given in IEC 354. The transient behaviour is governed by two time constants:
- the thermal time constant for the cooling of the winding by the oil: close to 15 min (we took 1000 s)
- the thermal time constant for the cooling of the oil by the ambient air: we made the calculations with values of 2 and 3 hours.

The calculations were repeated with increasing load in order to determine at which level of load the operating limits mentioned here above were met. For each case where a limit is met, the computed top oil temperature and the peak current is recorded.

As far as the criterion of the cumulated ageing is concerned, we took some provision to take into account the fact that the load differ from day to day and from season to season: an acceptable excess of ageing for one day will be compensated by lower stresses on other days. Due to the very non linear nature of the ageing process we considered that it is still conservative to accept a relative ageing of 1.4 for the peak days. The argument for that value is that for 5 periods at peak level there will be at least 2 periods at a significantly lower level of load in a week.

2.4 Simulation results

The main result is that for most of the cases, one reaches the peak load (150%) before any of the other limits is reached. The top oil temperature is generally still far from its limit when the peak load is reaching 150%. The simulation results for daily peaks of 2h are given in the table below: it gives the top oil temperature corresponding to the load level for which the first operating limit is met.

<table>
<thead>
<tr>
<th>Amb. Temp = 10°C</th>
<th>Tau transfo = $2h$</th>
<th>Tau transfo = $3h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B/H = 0.2$</td>
<td>79 °C</td>
<td>68 °C</td>
</tr>
<tr>
<td>$B/H = 0.4$</td>
<td>81 °C</td>
<td>71 °C</td>
</tr>
<tr>
<td>$B/H = 0.6$</td>
<td>85 °C</td>
<td>75 °C</td>
</tr>
<tr>
<td>$B/H = 0.8$</td>
<td>90 °C</td>
<td>83 °C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amb. Temp = 20°C</th>
<th>Tau transfo = $2h$</th>
<th>Tau transfo = $3h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B/H = 0.2$</td>
<td>89 °C</td>
<td>78 °C</td>
</tr>
<tr>
<td>$B/H = 0.4$</td>
<td>91 °C</td>
<td>81 °C</td>
</tr>
<tr>
<td>$B/H = 0.6$</td>
<td>95 °C</td>
<td>85 °C</td>
</tr>
<tr>
<td>$B/H = 0.8$</td>
<td>98 °C</td>
<td>93 °C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amb. Temp = 30°C</th>
<th>Tau transfo = $2h$</th>
<th>Tau transfo = $3h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B/H = 0.2$</td>
<td>92 °C</td>
<td>88 °C</td>
</tr>
<tr>
<td>$B/H = 0.4$</td>
<td>101 °C</td>
<td>91 °C</td>
</tr>
<tr>
<td>$B/H = 0.6$</td>
<td>105 °C</td>
<td>95 °C</td>
</tr>
<tr>
<td>$B/H = 0.8$</td>
<td>99 °C</td>
<td>93 °C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amb. Temp = 40°C</th>
<th>Tau transfo = $2h$</th>
<th>Tau transfo = $3h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B/H = 0.2$</td>
<td>103 °C</td>
<td>98 °C</td>
</tr>
<tr>
<td>$B/H = 0.4$</td>
<td>105 °C</td>
<td>101 °C</td>
</tr>
<tr>
<td>$B/H = 0.6$</td>
<td>105 °C</td>
<td>103 °C</td>
</tr>
<tr>
<td>$B/H = 0.8$</td>
<td>98 °C</td>
<td>95 °C</td>
</tr>
</tbody>
</table>

2.5 Interpretation of the results

If we consider the computation results and disregard the cases where $B/H = 0.8$ (that is an average load that is higher than 80% of the peak), there are only four cases where the operating limit is something else than the peak load. These cases are found with high (40°C) ambient temperatures and especially when the thermal time constant of the transformer is at the low side.

The main conclusion is that it is not sufficient to monitor the top oil temperature in order to detect when a distribution transformer has to be replaced by a unit of higher rating: a follow-up of the peak loads is necessary.
Notes: Other practical aspects may lead to take additional margins with respect with the technical limits presented here:
- a reserve may be necessary for the temporary take-over of loads from a neighbouring distribution network
- when the transformer is protected by a fuse switch combination with fuses put in enclosures, those might limit the overload capability

3 ECONOMICAL ASPECTS

When the load increases, a moment comes where the replacement of the transformer becomes technically mandatory. After replacement by a unit of higher rating the losses will be reduced and this has a positive effect on the operating cost of the transformer. One might think of anticipating the replacement to take advantage of this benefit earlier.

3.1 Transformer parameters

The main parameters are the purchase price and the level of losses. We considered the following values:

<table>
<thead>
<tr>
<th>kVA</th>
<th>160</th>
<th>250</th>
<th>400</th>
<th>630</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price (€)</td>
<td>3309</td>
<td>4625</td>
<td>6579</td>
<td>9250</td>
</tr>
<tr>
<td>No-load losses (W)</td>
<td>280</td>
<td>395</td>
<td>565</td>
<td>795</td>
</tr>
<tr>
<td>Load-losses (W)</td>
<td>1850</td>
<td>2600</td>
<td>3650</td>
<td>5200</td>
</tr>
<tr>
<td>Destruction cost (€)</td>
<td>179</td>
<td>259</td>
<td>356</td>
<td>500</td>
</tr>
</tbody>
</table>

The power loss values are close to European present practice. Lower values could be considered for the losses of new transformers but the purchase price would be higher. For the time being, we consider that both effects would compensate in the analysis.

To make a cost balance we also need estimations of the intervention costs for a transformer replacement; we considered:
- 1 250 € to install the new transformer
- 250 € to remove and ship the old one away.

A point that later appeared to be important is the residual value of the transformer that is recovered. Normally, it will be used at another place and this has to be valued. In order to fix this, we considered that the transformer itself had an intrinsic value linearly decreasing over a 30 years period but that a penalty should be applied because if a N year old transformer is installed, the installation, dismantling and destruction costs have to be recovered over a shorter service period. We expressed this by the following relation:

$$Cost\text{\,year} = \frac{1}{(30-N)} \left[ Val(N) + \frac{C_{inst} + C_{dism}}{(1+i)^{N}} \right]$$

Val (N) is the value of a N year old transformer that is installed: it should be such that the yearly service costs as given in the expression are equal whatever the age of the transformer is.

Note: in this case we compare transformers with the same levels of losses; that’s why we may disregard the cost of losses in this comparison.

So, mathematically, ‘Cost/year’ is a constant and Val(0) is known, that is the purchase price of a new transformer, therefore, we can compute Val(N) for any N: that is the residual value of a N year old transformer.

3.2 Load and energy tariffs

We characterised the load by:
- a linear growth (factor g = 1.02 for 2% increase per year)
- a peak to average ratio (factor ‘Peak’, default value = 2)
- a factor of presence at the peak (factor Pf = 0.75): it gives the ratio between the peak load of the transformer and its load at the moment of the peak for the utility; it is useful to determine the impact of the transformer losses on the ‘power’ term of cost of the energy (see below).

Energy tariffs: 3.75 € / 100 kWh + 175 € / kW peak

3.3 Simulation horizon

For investment and cost comparisons choices have to be made about how costs and assets in the long term are taken into account. We simply used a yearly actualisation rate (default value was 1.08 ; i = 0.08) and extended the calculation over a horizon of 20 years. We checked that an horizon of 30 years does not significantly affect the results. The main reason is of course that the weight of any cost after 20 years is rather small but also because we included the residual value of the transformer at the end of the period in the complete balance.

3.4 Search for optimal replacement year

We consider the situation where the load increase would require a replacement of a transformer within a term of ten years and then looked look if there is an economically optimal moment to do the replacement.

We computed the complete costs over a period of 20
years as a function of the replacement year (from year 0 = immediate replacement, up to year 9).

First case: 20 year old 400 kVA transformer, with an average load of 254 kVA at year 0 increasing up to 300 kVA at year 9. At that moment replacement by a 630 kVA is certainly mandatory because of peak loads reaching 600 kVA.

The total costs in function of the replacement year:

<table>
<thead>
<tr>
<th>Replacement year</th>
<th>Total cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21998</td>
</tr>
<tr>
<td>1</td>
<td>21804</td>
</tr>
<tr>
<td>2</td>
<td>21617</td>
</tr>
<tr>
<td>3</td>
<td>21438</td>
</tr>
<tr>
<td>4</td>
<td>21227</td>
</tr>
</tbody>
</table>

It appears that the costs are continuously decreasing; there is no reason to anticipate on the technical limits to make the replacement.

This trend can be inverted by considering other cases. Surprisingly enough, the parameter that we found to have a strong influence is the age of transformer in service.

Second case: The same calculation with a 5 year old transformer gives:

<table>
<thead>
<tr>
<th>Replacement year</th>
<th>Total cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>17845</td>
</tr>
<tr>
<td>1</td>
<td>17942</td>
</tr>
<tr>
<td>2</td>
<td>18026</td>
</tr>
<tr>
<td>3</td>
<td>18096</td>
</tr>
<tr>
<td>4</td>
<td>18156</td>
</tr>
</tbody>
</table>

This time, the total costs increase: there is an interest to immediately proceed to the replacement. This is because the transformer that is recuperated is valuable, it can be placed and stand elsewhere for a long time.

We suppose of course that this opportunity exists.

Similar inversion of the trend can also be obtained by taking an actualisation rate of 2% (I = 0.02 instead of 0.08).

A first conclusion is that a difference in one year for the replacement does not influence the costs that much; the relative differences in total cost (for a difference of one year) are typically within 1%. That is low with respect to the poor precision on the true values of the problem parameters. In the interpretation we will essentially draw qualitative conclusions.

An important qualitative conclusion is that there is no optimal moment to make the replacement, it is either immediately or as late as possible. We considered several examples and never found a minimum for an intermediate value of N (sometimes, a (very flat) maximum can be obtained).

Therefore, the decision making process may be reformulated and one may simply consider it on a purely incremental base.

### 3.5 Incremental approach - Limit values

We reformulate the problem and the question becomes: is there an advantage to replace the transformer this year instead of next year? If no, the question can be reconsidered in the same way one year later.

What are the differences if the replacement is done in year 0 instead of in year 1?

Positive:
- the difference in the costs of the losses
- the difference in the residual value of the old transformer

Negative:
- one year anticipation on investments and costs (strongly linked to the actualisation rate)
- the difference in the residual value of the new transformer at the end

The balance will be positive for high load levels and negative for low load levels. It is then interesting to search for the load giving the equilibrium (at continuation, we call it the ‘break-even load’): it gives a qualitative indication on the load level at which the replacement could be done.

The table of page 5 gives the computed ‘break-even’ loads for a 400 kVA transformer with some variation of specific parameters. The corresponding peak load is given in column 2. If it exceeds the temporary overload capability of 600 kVA (150%) it means that the break-even load is beyond the technical operating limits.

### Comments on the results

The break-even load is rather sensitive to the age of the transformer. This is because of the residual value of the transformer: the anticipated replacement is economically viable if the transformer to be replaced can be re-installed and used elsewhere for a decade or two.

The peak factor (or ratio between the peak- and average load) is also an important parameter. A rough statement could be that if the average load is < 2 * the peak load, it is likely that an anticipated replacement of the transformer is not economically interesting.

The energy tariff that applies for the utility is also of importance. The results are both sensitive to the price for energy (€/100 kWh) and to the price for the peak power demand (€/kW). It is now rather difficult to predict what will be the trend in the coming years: the liberalisation plays a role, the prices of primary energy are also of concern and, finally, one might imagine that national regulators could create some incentives to reduce the energy losses where it is technically possible.

### Influence of transformer rated losses

We considered here transformers with rated losses representative of the present usage; one could also consider to replace a transformer with elevated losses by a modern one with reduced losses. We made a couple of simulations from which we could conclude that the break-even load is further increased for transformers with high losses. The fact is that they will
definitely be put out of service and this affects the global balance.
Conclusion about the economical aspects

Economical calculation of that kind are not very precise and could further be discussed but our conclusion is that, for the time being, the period of replacement of distribution transformers will not be dictated by possible economical advantages but by appropriate consideration of the technical limits, with a trend to run the transformers up to higher loads than previously.

4 MONITORING OF DISTRIBUTION TRANSFORMER LOAD

Many distribution transformers in service are oversized with respect to their actual load. Furthermore, the load of a distribution transformer is made up of numerous customers: it is not very sensitive to the individual variations and is rather stable. For these two reasons little effort has been done up to now to monitor the load of distribution transformers. If one wants to run the transformers closer to their technical limits, a better monitoring of the load will be necessary.

Indirect monitoring is often done by measuring the temperature of the top oil; for small transformers that are largely oversized it is sometimes sufficient to place thermo-sensitive paper strips; they serve as a verification that the load is still far away from the limits. More often, a thermometer with indication of the peak temperature is used. As we have seen in §2, the relation between this temperature and the overload limit is not obvious. A monitoring of the temperature rise (that is the difference between the top oil temperature and the ambient temperature) would be more efficient.

The best choice is to monitor the peak currents because they generally determine the practical load limit for the transformer. This can be done with peak A-meters that are placed on the low voltage side of the transformer.

Up to now, modern digital devices that are able to compute the hot spot temperatures from temperature and current measurements have not penetrated the market. We see two reasons for that:
- Auxiliary equipment for distribution transformers (protection, monitoring, ..) may not be too expensive
- The hot spot temperature and the thermal ageing of the transformer are generally not the limiting factor for distribution transformer operation.

We nevertheless expect that a drastic change could occur owing to the telecommunication possibilities that appear now. The fact is that most of the distribution transformers are located in simple cabins without possibility of remote monitoring. Tomorrow the transfer of data via radio telephony over Internet will become a rather common and cheap feature.

This will be the decisive change that will make modern monitoring devices with digital signal processing and telecommunication features (or at least handsome data interfaces) much more attractive for transformer load monitoring.

5 GENERAL CONCLUSION

- There is an interest for running he distribution transformers closer to their technical limits.
- To do this in a safe way, a simple thermal monitoring is not sufficient.
- There will be a market for modern monitoring devices with flexible possibilities for data transfer from isolated distribution cabin.

REFERENCES
[1] IEC 354 Transformer loading guide