Annual of the University of Mining and Geology "St. Ivan Rilski"
vol.44-45, part III, Mechanization, electrification and automation in mines, Sofia, 2002, pp. 107-109

ASSESSMENT FF LOSSES IN POWER ELECTRONIC STRUCTURES IN KEY MODE

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SUMMARY
Theoretical investigation of the possibility of maximum losses while switching a //// electronic structure (transistor, IGBT, etc.) in key mode operation. The settings are; switch process duration and maximum possible change rate of element conductivity. The presumption is that because of noise and other deviations from normal mode, the form of signal, which governs the power element, can be changed according to an arbitrary rule. Determined are the most unfavorable rule to change conductivity and the value of its losses.

We know (S. Tabakov, Research work for academic degree) that a significant part of losses in electronic converters are to be found in switching electronic elements. The way to determine these losses is treated by a great number of publications (S. Tabakov, хабилитационен труд, Tz. Grigorova, Paper On дисертация, Giteva etc., Annual Of IZM). In all cases it is presumed that the rule of changing the governor signal upon the time is known and that it is near to the optimum in order to minimize losses on switching (conducting and blocking). There are a number of formulas to determine losses according to the electric parameters of the power mode and governing impulse.

The losses at blocking the power elements are significant for the converter efficiency as well as for its reliable operation, since a power transistor or OGBT is damaged irreversibly even at a lower excess of admissible losses. On the other hand, it is possible that at a given moment, due to some external influence, the governing impulse form is changed considerably to separate the maximum capacity of the power element while switching. We presume a given duration of ΔT of the process and we are looking for the most unfavorable switching rule. We have to take into consideration that it is a physical fact that each switch element, regardless of its kind, has some maximum conductivity change rate upon the time. $G^{I}_{MOT}\left[\frac{\Omega^{-1}}{s}\right]>0$ for conducting and $G^{I}_{M3}\left[\frac{\Omega^{-1}}{s}\right]<0$ for blocking.

Because of the complexity of this phenomenon we can admit with first approximation that this maximum rate is a constant for the whole range of change G.

When load is purely active and the presence of паразитен inductivity is not taken into consideration, the capacity of switching element is also not taken into consideration.

The replacing diagram is shown on Figure 1.

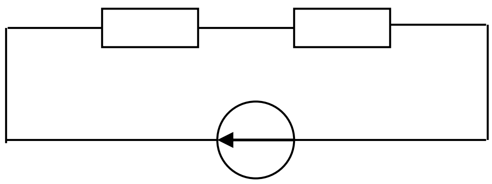

Figure 1.

The task for the conductivity case is determined as follows:
We search the kind of function $G_{ПР}=G_{ПР}(t)$ in the interval from:

$t=0$ *to* $t=\Delta T_{ОГ}>0$, *whereas* $G_{ПР}(\Delta T)=G_{ПРMAX}$,

$\frac{dG_{ПР}}{dt}\le G^{I}_{MOT}$ for $0\le t\le \Delta T_{OT}$,

whereas the value is

$$\Delta W=\int_0^{\Delta T_{OT}} U^2\frac{G_{ПР}(t)}{(RG_{ПР}(t)+1)^2}dt=Max.$$

The variation analysis, according to the restrictions is quite large. As a result we get the following solution. For:

$0\le t\le t_1; G_{ПР}(t)=\frac{t}{Rt_1}$;

for $t_1\le t\le t_2; G_{ПР}(t)=\frac{1}{R}$;

for $t_2\le t\le \Delta T_{OT}; G_{ПР}(t)=G_{ПРМ}-$

$-\Delta T_{OT}G^{I}_{MOT}$, *where*

$$t_1 = \frac{1}{RG_{MOT}^I}; t_2 = \Delta T_{OT} - \frac{G_{\Pi PM} - \frac{1}{R}}{G_{MOT}^I}.$$

The graph is shown on Figure 2.

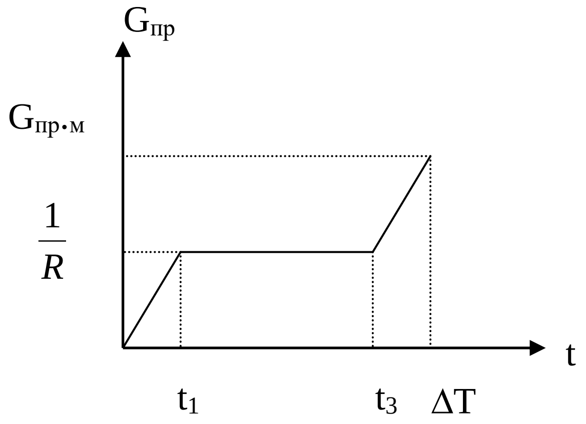

Figure 2.

The rule for change of the value *G пр* upon the time shows that the maximum energy emitted by the element during one conducting state is determined by the formula:

$$\Delta W_{OT} = \frac{U^2}{4R}\left(\Delta T_{OT} - \frac{G_{\Pi PM}}{G^I{}_{MOT}}\right) +$$
$$+ \frac{U^2}{R^2 G_{MOT}^I}\left[\ln\frac{RG_{\Pi PM}+1}{2} + \frac{1}{RG_{\Pi PM}+1} - 0{,}31\right] =$$
$$= \frac{U^2}{4R}\left(\Delta T_{OT} - \frac{G_{\Pi PM}}{G_{MOT}^I}\right) +$$
$$+ \frac{U^2}{R^2 G_{MOT}^I}\left[\ln\left(RG_{\Pi PM}+1\right) + \frac{1}{RG_{\Pi PM}+1} - 1\right]$$

For all real cases $RG_{\Pi PM} >> 1$, or the conductivity of the transistor in complete conducting state is much greater than the conductivity of the purely active load. If the time for blocking the transistor ΔT is much greater than the relation $G_{\Pi PM}/G_{MOT}^I$, we can use the simplified formula with a small positive error:

$$\Delta W = \frac{U^2}{4R}\Delta T .$$

When the switching element is blocked, we do the same investigation. It is obvious that the maximum energy at a single blocking is emitted when the conductivity of the key element is changed according to the graph from Figure 3.

For the total energy emitted by the element we get the equation:

$$\Delta W_3 = \frac{U^2}{4R}\left[\Delta T_3 - \frac{G_{\Pi PM}}{G_{M3}^I}\right] +$$
$$+ \frac{U^2}{R^2 G_{M3}^I}\left[\ln\frac{RG_{\Pi PM}+1}{2} + \frac{1}{RG_{\Pi PM}+1} - 0{,}31\right] =$$
$$= \frac{U^2}{4R}\left[\Delta T_3 - \frac{G_{\Pi PM}}{G_{M3}^I}\right] +$$
$$+ \frac{U^2}{R^2 G_{M3}^I}\left[\ln\left(RG_{\Pi PM}+1\right) + \frac{1}{RG_{\Pi PM}+1} - 1\right].$$

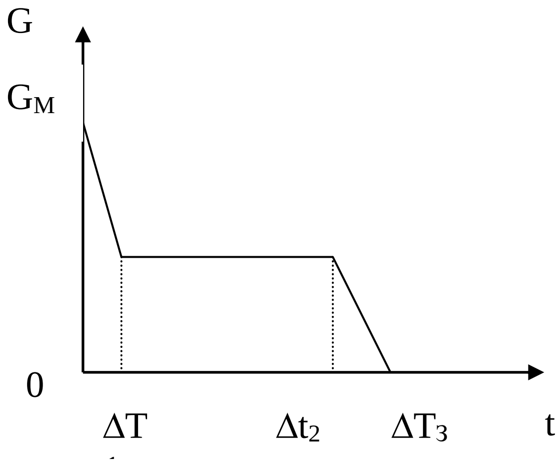

Figure 3.

To have a better idea of the dimension of the upper limit of losses, we will determine the losses at two more probable hypotheses for the blocking process. The first one admits that during blocking with duration ΔT, the voltage at the ends of the switching element grows according to a linear rule:

$u = U\,\dfrac{t}{\Delta T_3}$, where U is the constant voltage of the power supply source. When the load is purely active, the current during blocking is changed according to the rule:

$$i = \frac{U}{R}\left(1 - \frac{t}{\Delta T}\right)$$

Losses are;

$$\Delta W_3 = \frac{U^2}{6R}\Delta T_3 .$$

The result is for example by 30% less than the determined upper limit.

According to the second hypothesis, we admit that during time ΔT, the switching element conductance is lowered from its maximum value to zero, according to a linear rule. In this case we have:

$$\Delta W_3 = \frac{U^2 \Delta T}{R^2 G_M}\left(\ln\left(RG_M + 1\right) + \frac{1}{RG_M + 1} - 1\right)$$

Because of $RG_M >> 1$, during the second assumption, we have losses several times less than during the first one.

CONCLUSION

The results enable us to assess with a certain positive error the cases when there is no exact data about the processes. To determine the upper limit, it is sufficient to know the nominal voltage, nominal current and time for full conducting and blocking. They can be determined by an oscillogram of the work current.

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