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# Introduction To Design of Gas Insulated Lines With $N_2/SF_6$ Mixtures

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## Introduction

Gas Insulated Lines (GILs) are specific electric power equipment used to transmission and/or distribution of electric energy. Such buses may be a profitable alternative for traditional equipment like shielded air-insulated busbars or conventional power cables, especially in difficult and non-typical site conditions. Their principal advantages are: considerable greater ability to power transmission, facility of assembly in difficult areas, high operational reliability (without operating maintenance), safety of service, resistance to external effects. The next argument for attractiveness of GILs is more and more using of very compact GIS (Gas Insulated Switchgears), ready to cooperate with GIL installations. Although such installations are relatively costly, they are less expensive than power cables of comparable power transmission.

Construction of a GIL is hardly complicated because its one phase is a form of two metal coaxial cylinders (insulated by compressed $SF_6$), divided into gas-tight sections, equipped with barrier and spacer epoxy insulators (Fig.1). Despite of simple construction, each GIL must be built with the best conducting and insulating materials, and otherwise – must be made and assemble very conscientiously. Electric insulation of the GIL works in specific and rather hard operating conditions resultant from electrical, mechanical and thermal loads during the operating time (the two last loads concern insulators). One of characteristic features of such insulation is a great susceptibility to non-uniform electric field, much more intensive than inside traditional busbars. This feature makes one to particular conscientious choice and dimensioning of gas and solid insulation which is co-decisive about reliability, mass, cost and assembly conditions of the GIL [2].

## Design procedure of GILs

The procedure applied to of a single-pole GIL insulated by compressed $SF_6$ was worked out in Institute of Power System and Control of Silesian University of Technology [5]. General algorithm used to multicriterial optimization of GIL constructions is presented in Fig.2. This procedure fulfils simultaneously several different technical requirements. All of them can be divided on three groups: electrical, mechanical and thermal [3, 4]. Electrical requirements amount to selection of suitable combination of transverse dimensions, not exceed the permissible level of the electric stresses for a long time, and to assurance so that electric field should be as small as possible (prevention from partial discharges in any form). Transverse dimensions of the outer shield should be select to transverse dimensions of the central conductor, so that:

- prevent from partial discharges in any form in normal operating conditions,
- assure the sufficient electric strength under working pressure and test voltages during production and shakedown tests,
- assure the sufficient electric strength level of a decompressed gaseous section under the maximum permissible operating voltage and during the failure decrease of $SF_6$ pressure.

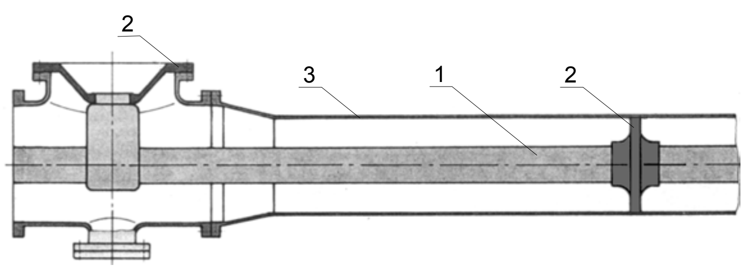


**Fig. 1.** The sketch of a single-pole GIL: 1 – conductor, 2 – spacer, 3 – outer shield

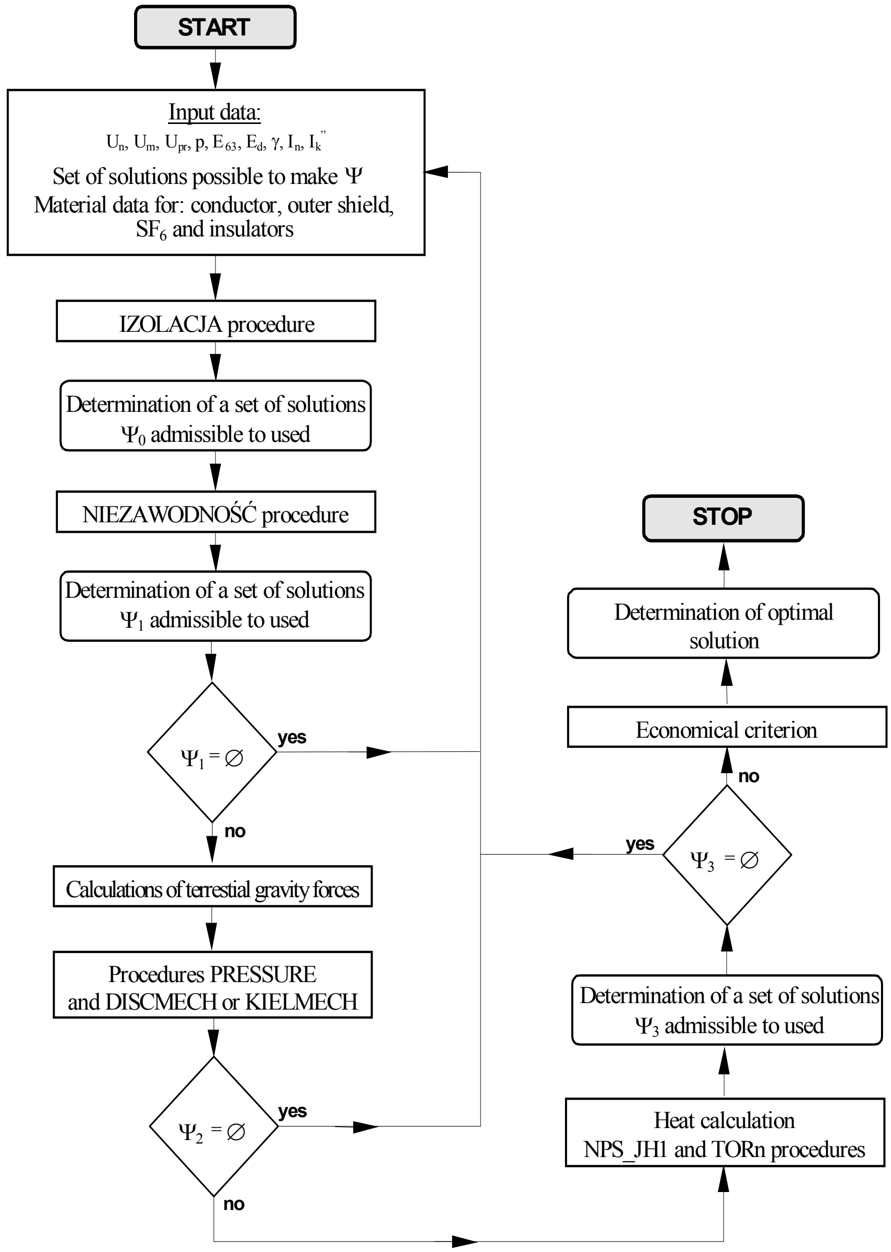


**Fig. 2.** General algorithm used to multicriterial optimization of GIL constructions

There are two main types of mechanical requirements. The first type is concerned with the influence of terrestrial gravity force (earthpull) on all construction of the GIL. The deflection should not exceed the permissible value for this kind of a construction. The second type of mechanical requirements is concerned with an influence of $SF_6$ dynamic pressure which occurs only after very rare ignitions of short-circuit arc inside one of gaseous sections. The last phenomenon decides the mechanical hazard of insulators, especially barrier spacers. The level of this hazard depends on the protective action of safety-valves (e.g. blow-out discs or other pressure relief valves) because such protective devices may decrease significantly pressure shocks and lead to decompression of a gaseous section. The calculation result of mechanical stresses inside insulators in these conditions must not exceed the permissible value.

Heat calculations aim at verification of the busbar (designed under other rules) in respect of thermal requirements. Such requirements are fulfill when the temperature of GIL elements does not exceed the maximum temperature limits: for normal operational conditions (long-lasting alternating current) and for short duration short-circuit conditions. These calculations are also applicable to the following tasks: optimization procedures, mechanic strength calculations, selection of compensators prevented thermal elongations, and evaluation of thermal expansion of bus conductors.

**Characteristic of $N_2/SF_6$ mixtures**

$SF_6$ is the main insulating medium for discussed designing method. In last years the global warming potential of $SF_6$ has prompted discussion on replacing it in power equipment. This ecological factor and the reduced costs make the use of $N_2/SF_6$ mixtures with small $SF_6$ contents a preferable medium in GILs.

$N_2/SF_6$ gas mixtures have excellent insulating properties, but question is how features of these mixtures introduce to GILs designing methods? In last CIGRE publications we find work results about application of these mixtures in novel technologies, and more important aspects related to characteristics of $N_2/SF_6$ mixtures. These characteristics are very useful "interface" between two compressed gaseous media: $N_2/SF_6$ mixture and pure $SF_6$.

Many features of $N_2/SF_6$ mixtures can be demonstrated by their intrinsic electric strength. In CIGRE publication [1] the following diagrams are presented: the normalised values of the intrinsic electric strength $E^0_{cr}$, the required pressure $p^0$ for mixtures of equal intrinsic electric strength, and the resulting total amount and leakage rate $q^0$ of $SF_6$ (Fig. 3). In our GILs designing methods we can apply these dependences.

The normalised intrinsic electric strength $E^0_{cr} = (E/p)_{cr} / (E/p)_{crSF6}$ for $N_2/SF_6$ mixtures is a function of the $SF_6$ contents. Such quantity permits to analyse the essential properties and advantages of $N_2/SF_6$ mixtures and provides a basis for many fundamental considerations. It is important that even mixtures with low $SF_6$ contents are capable to withstand high electric strength. For example, the mixture with only 20% $SF_6$ content exhibits 69% of the electric strength of pure $SF_6$ at equal gas pressure. The second diagram connected with the above one is the normalised pressure $p^0$ of $N_2/SF_6$ mixture $p^0 = 1/E^0_{cr}$. For example containing of 20% $SF_6$, a modest of the increase pressure (about 45%) is necessary to recover the electric strength of pure $SF_6$.

Apart from electric strength and normalised pressure the total amount of $SF_6$ is required for a given application. Such information results from the normalised quantity $q^0 = x\, p^0$ of $SF_6$ in mixtures of equal intrinsic electric strength. A mixture containing 20% $SF_6$ reduces the required amount of $SF_6$ by 71% compared with pure $SF_6$ of equal electric strength. $SF_6$ leakage is also governed by the quantity $q^0$ when mixtures are applied in electrical equipment of the same design, material and quality. Leakage would also be reduced by 71% in the considered example.

Large amounts of insulating gases are needed in GILs. For example, a 420 kV GIL, 10 km long, with diameter of 600 mm containing pure $SF_6$ would require about 200 tons of $SF_6$. It is 20% of the total $SF_6$ currently utilised in HV plants in Germany. A $N_2/SF_6$ mixture of containing 80% $N_2$ and 20% $SF_6$ with a pressure of 0.8 MPa requires only about 58 tons of $SF_6$ (29% of the pure $SF_6$). Besides, when a gas mixture is used then the reduction in the total amount of $SF_6$ and its leakage rate would be minimal.

**Recapitulation**

- Gas insulated lines (GILs) are specific and interesting technical solutions in many circumstances for transmission and/or distribution of a large amount of electric energy.
- There is a computer-aided procedure, which can be useful to design of GIL constructions filled with compressed and pure $SF_6$.
- Such a procedure, taking to account electrical, thermal and mechanical requirements, can be useful also to design of GILs filled with compressed $N_2/SF_6$ mixtures (with its important changes).
- Specific "interfaces" between chosen features of $N_2/SF_6$ mixtures and $SF_6$ result from diagrams presented in Fig. 3.

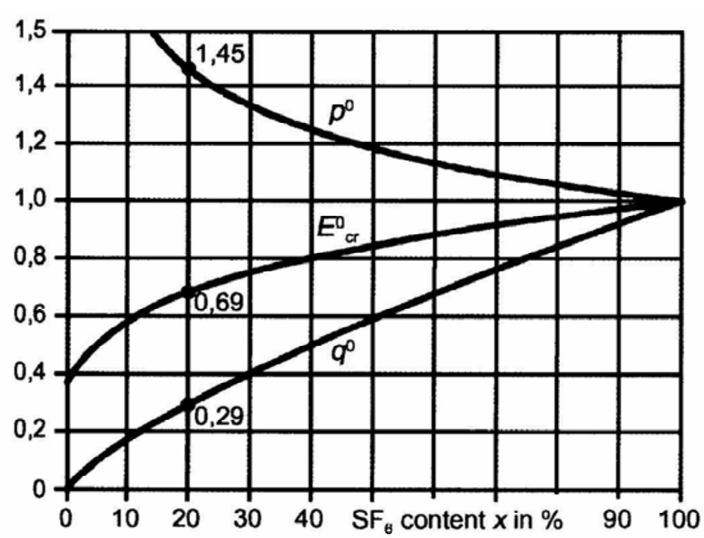


**Fig. 3.** Normalised intrinsic electric strength $E^0_{cr}$, normalised pressure $p^0$ required for equal electric strength and resulting normalised quantity $q^0$ of $SF_6$ as a function of the $SF_6$ contents $x$ [1]

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**Z. Gacek, T. Rusek. Dujomis izoliuotų linijų su $N_2/SF_6$ mišiniais projektavimo įvadas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2005. – Nr. 7(63). – P. 66–69.**

Analizuojamos dujomis izoliuotos linijos (GILs), esant aukštai įtampai ir didelei srovei šynose. Pateikiami kompiuterinio GILs su suslėgtomis $SF_6$ dujomis projektavimo, atlikto Silezijos universiteto Galios ir Kontrolės sistemų institute Gliwice. Nustatyta, kad tai gali praversti apskaičiuojant technines konstrukcijas, užpildytas $N_2/SF_6$ mišiniais, kuriose $N_2$ yra vyraujantis veiksnys. Il. 3, bibl. 5 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).



**Z. Gacek, T. Rusek. Introduction to Design of Gas Insulated Lines with $N_2/SF_6$ Mixtures // Electronics and Electrical Engineering. – Kaunas: Technologija, 2005. – No. 7(63). – P. 66–69.**

The so-called Gas Insulated Lines (GILs), specific high voltage and heavy current busbars, are characterized. A computer-aided procedure to design of GILs filled with compressed $SF_6$, worked out in Institute of Power System and Control of Silesian University of Technology in Gliwice, is presented. It has been stated that such a procedure can be useful also to calculate technical constructions filled with $N_2/SF_6$ mixtures in which $N_2$ is a predominant factor. Ill. 3, bibl. 5 (in English; summaries in Lithuanian, English and Russian).



**З. Гацек, Т. Русек. Введение в проектирование газом изолированных линий с $N_2/SF_6$ примесями // Электроника и электротехника. – Каунас: Технология, 2005. – № 7(63). – С. 66–69.**

Анализируются газом изолированные линии (GILs), когда применяется высокое напряжение и сильный ток. Представлены результаты компьютерного моделирования газом изолированных линий. Предлагается эти явления использовать в технических конструкциях, заполнены смесью $N_2/SF_6$. Элемент $N_2$ является доминирующим фактором при эксперименте. Ил. 3, библ. 5 (на английском языке; рефераты на литовском, английском и русском яз.).