INDUCING AND ASSESSING NEW TECHNOLOGIES AND PROCEDURES FOR THE ELECTRIC INDUSTRY OF DEVELOPING COUNTRIES

Authors name: **Affiliation:**
Sergio Feitoza Costa COGNITOR – Consultancy, Research and Training Ltd.
CV in http://www.cognitor.com.br/en_home.htm

Keywords: Substations, New Technologies, Optimization, Switchgear , Design, Reduction of costs, validation, High Power , Testing, Laboratory, Simulations, Calculations, IEC Standards, Busbar, Busway, Switchboard, Internal Arcs, Overpressures, Temperature rise, Electrodynamical stresses, Short time currents, Magnetic Fields, Electric Fields, IEC 62271, IEC 61439, Testing Laboratory

1) WHAT MEANS "A "NEW TECHNOLOGY" AND WHY WRITING THIS ARTICLE?

Few years ago, one of my clients, from the electric industry of a developing country, contracted me to create a prioritized list of potentially interesting products using the so-called "new technologies". Their intention was to do a strategic planning to invest human and financial resources for gradually bringing products to the market. They wanted also to create a small group of well-trained experts for developing new solutions. His country do not have testing laboratories for products for substations but are studying about implementing one.

It was a good opportunity for me because along my professional life as researcher, consultant and testing laboratory professional I dealt many times with the theme doing and assessing innovative projects. I was also happy because nowadays it is rare to find companies doing medium and long term planning. Most of the companies think only in the short period of two years ahead.

In this article, I describe some points of this experience, which may be useful to other companies and countries, in similar situations. My focus is on equipment and systems not higher than 145 kV voltage class but some concepts may be extended to other systems.

I live in Brazil and witnessed in the period from 1976 until today a process of growth of the electric industry driven, in the first 10 years, by long-term strategies, which included the construction of testing laboratories and research centers, preparation of good level human resources, consolidation of a system of technical standardization and certification of products. In the first 25 years of this period, we could see how good planning and actions can move the electric industry to go up.

For facilitating the explanations below, I considered two groups of countries with higher or lower access to engineering knowledge (could also be average level of education). I will call them as "developed" and "developing" countries. Related to the stage of development of the analyzed "new technologies projects", I created a classification in 3 groups named (a) Bench design, (b) Prototype design and (c) Commercial project. The timing considered in each one, for the product to arrive to the commercial market was around, respectively, 4 years, 2 years and less than 1 year.
For the size of the manufacturers we divided in a group with the big international ones and another formed by medium and small size manufacturers.

My feeling on technologies for the electrical sector is that, in the last 20 years, the big international manufacturers accommodated in their technological goals. They have now much smaller technology teams located only in the countries of their original headquarters. From time to time, I meet these experts in the international meetings of Cigré and IEC working groups. The big manufacturers develop products and test them in their own testing labs or in others near their factories. In the developed countries, there are several testing labs to choose, on the contrary of what happens in the developing countries. After having a certain product approved in the type tests according to the relevant IEC standards, they start to produce them, mostly, in factories in developing countries. In these countries, the big manufacturers do not have technology teams to develop innovations or to improve existing products.

The small and medium manufacturers work to maintain themselves in a market each time more competitive. Some of them invest to acquire technological knowledge, forming and training small teams. These ones usually succeed and, frequently, after succeeding, some big manufacturer go there and buy them. Most of the small and medium manufacturers do not invest in creating new products because do not have enough people trained to do it. They work hard producing traditional products and trying to adapt or to reproduce some more recent projects that they see as promising.

For example, in Brazil life is difficult for the manufacturers.Taxes are absurdly high although the return on public services provided by governments is very low. The rules and bureaucracy make life difficult for anyone who wants to do the right things. Brazil, nowadays, is possibly the best example in the World of how a rich country, administrated by incompetent government's, do not go ahead due to the average low level of education of the population. Lack of education is the most fertile soil for the growth of corruption, bad politics, inefficient procedures and incompetent decisions.

To attend the purposes of my client, my first idea was to associate the technology needs in their country to the needs of the country where I live. Having this in mind, I started to identify some things that I could call new technology. For me, new technology means, something we are not using yet in big scale but we have the feeling that, soon, will help to improve the way we are currently doing the things. For me the most important aspect of a new technology is the accessibility for use in most of the countries of the global market

For a developed country, a power transformer or a switchgear using a superconductor material is a new technology. It is something already technologically proved but still expensive to produce because do not have yet an acceptable scale of use. What makes a new technology to advance is the positive perception, by the bigger users, that such technology is becoming closer to regular use.

A factor to consider is that, the competition between the manufacturers of developed countries is bigger. Due to this, in the last two decades, they are leaving the comfort of their regions to try to sell products in the emergent markets. The big international manufacturers know that the new coming technologies, when accepted by the developed market, will replace the previous one in these ones. The previous technology will continue to be produced, but now in the developing countries, for many years.

A good example for this, in Brazil, are the medium voltage cubicles / switchgear insulated by SF6 instead of air (AIS). Here, almost are not used although, they are not difficult to develop.

For the development of a new technology, two conditions are essential. The availability of testing laboratories, near the company, to do the prototype test types and a clear understanding of the technical standards, according with, the tests will be made.

Nowadays there are IEC standards providing good openings to reduce the number of tests to be done for a certain product. Examples of these standards are the series IEC 61439 (low voltage switchgear) and the future IEC 62271-307(high voltage switchgear). Nevertheless, without a testing laboratory near it, the local industry do not go ahead because has to do the type tests in the first equipment of a family.

When you do not have a testing lab near you, you have high transportation costs of the tested equipment. In case of failure in the test, normal during developments, you will have expenses with the repetition. Nowadays testing simulations reduced this barrier but a laboratory near you remains fully necessary.

The concepts included in IEC 61439 and IEC 62271-307 created the possibility of replacing tests in an untested equipment which is of the same "family" of an already type tested one. Simulations, calculations and design rules can now replace many tests and avoid a lot of unnecessary repetition of tests. In developing countries, this is especially useful because the availability of testing laboratories is very small. There are details in the articles in this link http://www.cognitor.com.br/download.htm .

IEC standards have an important impact in the technological distance between developing and developed countries. I wrote about this in the previous article "How can IEC standards help to reduce the gap between developed countries and other countries" (free download in the link http://www.cognitor.com.br/ProposalToIEC.pdf). In the real life, only the experts of the developed countries, with rare exceptions, make the IEC Standards. Although the rules are democratic to enable the participation of anyone, the developing countries practically do not participate in the IEC working groups.

Therefore, it is usual that the same manufacturer that is selling a product in the European market telling that life will be better with it say in his factory at the developing country, that the old one is more than sufficient and good. In Brazil, only in 2015 we are near to have IEC 61439 in a version written in Portuguese. IEC published this standard in 2011 making the previous IEC 60439 obsolete.

Publishing IEC standards also in other languages, as Portuguese, would reduce the 5 years gap. Social and technological gaps are increasing the already big distance between the developed and developing countries and this will not have a happy end. The signals are very clear with the increase of World violence, terrorism and now the big immigration from developing areas. We wait for the problem to arrive at a critical point instead of trying to do something in advance.

The objective of this article is to signalize to the electric industry of developing countries like in South America, Asia and many others in the World, the vision of the author about opportunities with "new technologies and procedures" to be explored locally.
In Section 2 there are some examples of the technologies. In Section 3 there are parameters which can be used to analyze and to prioritize the projects to invest, In Section 4 we list some approaches on how to induce new technologies and procedures in the electric industry.

2) EXAMPLES OF "NEW TECHNOLOGIES AND PROCEDURES"

When starting to do the work for my client I did a first visit to their factory. I was still worried on how I would identify the desired new technologies. I started to walk with their team through the factory. It called my attention that was a very clean environment and the people was motivated and concentrated in their tasks. Months after, applying a training to their team, on design techniques, I was impressed with the ease they assimilated the concepts and well applied the software tool SwitchgearDesign I left with them.

In a certain moment, in the factory walk, I saw a bus duct being mounted and remembered a similar case I saw years before It was a 4000 A rated current bus duct made of copper bars mounted in the horizontal position and supported by epoxy insulators as showed in the left side of the Figure 1 (horizontal bars).
I asked them about the short circuit current level and they informed me it was 40 kA with 1-second duration. The application engineer, which was in the group, told me that they had difficulties to approve the prototype in the temperature rise test although it passed easily in the withstand short time current and crest test (electrodynamic forces).

It was visible that the distance between insulators was much smaller than actually needed. Therefore, they were expending more insulators than necessary. There was in the group a young engineer responsible for the design and I asked him why the bars were in the horizontal position. This horizontal position is good when you have to support high electrodynamic forces caused by high short circuit currents. Nevertheless, they are bad for heating dissipation of elevated high rated currents like 4000 A. The young designer told me that they used like that because were following the same design of a previous 4000 A – 65 kA bus duct. I told him that using a smaller cross section bar, but putting them in the vertical position, would permit a final design with less, insulators and less copper. Possibly a reduction around 30% in the cost of the materials.

In this moment, it became clear for me that the easiest "new technology" is to design a better-optimized product, based on engineering calculations and knowing better what is written in the technical standards. For a trained designer this is possible through software tools before going to the testing lab final tests.

Doing a review of their products, they identified a number of good possibilities including the use of different busbar profiles and materials in cubicles / switchboards (see Figure 2). In the article **"**Finding the optimal switchgear design: a comparison between aluminum and copper and an idea of new concept" there is related information (download free in http://www.cognitor.com.br/DesignOptimization.pdf).

Figure 1 – The easiest new technology is to optimize existing products

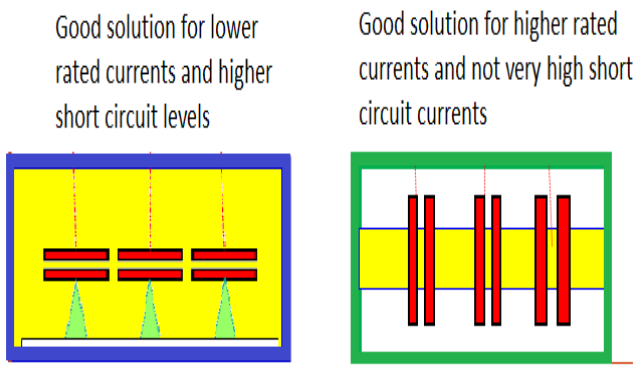
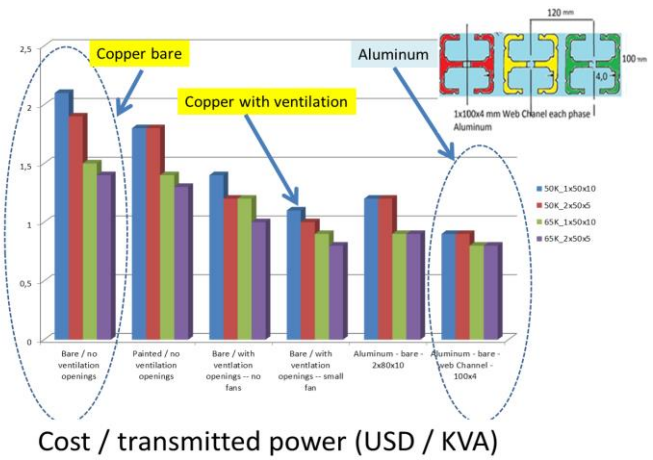


Figure 2 – The use of different busbar profiles and materials in cubicles / switchboards



Cost / transmitted power (USD / KVA)

For a medium or small manufacturer, I do not imagine as promising to develop a 245 or 500 kV circuit breaker or things like this. The main international manufacturers already developed them. Even if you pass and succeed in all the technical steps, when arriving to the commercialization, most of the users will prefer the traditional ones. In addition, you will not have price and force to compete with the big ones.

COGNITOR – Consultancy, R&D & Training
Phone: 55-21-2465 3689 or 55- 21 33934600 or 55-21-9 8887 4600
E-mail: sergiofeitoza@cognitor.com.br Site: www.cognitor.com.br

Nevertheless, in medium voltage distribution systems there are many possibilities for developments, which can be useful in local markets as presented in Table 1.

There are opportunities linked with the downtown replacement of the anti-aesthetic and dangerous by proximity, aerial distribution systems (see Figure 3). In cities of countries, like Brazil, unfortunately, they are still used just near windows. Here, the contribution of the electric industry is not only to produce underground solutions but also making the users and the society aware about other solutions available.

The arguments that underground systems are more expensive and that aesthetic issues are less relevant in a developing country are false. When you install something as in Figure 3 in front of a school or near the windows and vision of people, you are giving an obvious bad example of doing the things.

Other, potentially good, opportunities are linked to solutions for installing "common ducts" with different public services as electricity, phone cables and TV cables. I saw many times municipalities replacing old aerial systems by another new horrible aerial system instead of using the opportunity to replace them by an underground common duct. They say that it is difficult to coordinate this between the companies providing the different services. However in the richest neighborhoods and places where the tourists walk around the underground solutions are used. So, why not extending the use to all users?

Figure 3: An IEC 60282-2 expulsion type fuse installed very near a residential window where children could be

In Table 1, there is a small list of "new technologies and procedures". As you will see, there is nothing new like a superconductor transformer or cable.

Table 1 – Examples of "new technologies and procedures" for developing countries

Technology or procedure	Comments
Maintenance based on the condition (for substations, power transformers, switchgear, cables, underground systems, etc)	This procedure is widely used in developed countries since the 90's but has low use in developing countries. To provide services in this area do not require big investments but require specialized trained.
Medium voltage switchgear / cubicles SF6 insulated	Most of the systems used in developing countries like Brazil are AIS. Here there is a clear opportunity to manufacturers.
Medium voltage switchgear (cubicles) with IAC classification and simultaneous forced ventilation	Optimized design to permit to pass simultaneously in internal arc tests and temperature rise tests
Optimized medium voltage automatic reclosers and switches	Optimized design local solutions
Low voltage switchboard internal arc proof using non-conventional aluminum profiles	Optimized design for high rated currents and high short circuit currents
High current limiting devices (medium voltage) for currents above 90 kA	To be used in places where the short circuit level increased above the level of the other equipment in the substation and no other solution like current limiting reactors are applicable
Underground medium voltage networks in medium / big cities	Aerial systems are unacceptable in cities of developed countries.
Integration of public services in the "common services ducts"	This kind of solution depends on a bigger pressure from the society over the municipalities.
IEC technical standards published in the local language (for example Portuguese) at maximum one (1) year after the publication in IEC (instead of some 4-5 years as occur now)	This is a critical point to reduce the distance to developed countries. As the National Standardization Committees (NSC) are very limited and inefficient to provide fast translations, the exit is to press IEC to create ways to publish in local languages at least the most important standards. The industry associations should be conscious of the importance and put pressure in IEC and in the NSC to do this.
Implementation and proper divulgation of IEC technical standards, considered locally useful but for which there is no technique IEC on the subject	For a technical standard to become an IEC one is a long process. A NSC shall make a proposal which, to go ahead, shall have acceptance of other countries NSC's. A certain subject considered necessary in a certain country may not be a priority for IEC. Therefore, NSCs, instead of having only focus in the translations of already published IEC standards, should develop these other ones. A positive example is the Brazilian Standard NBR 13231 - Fire protection in conventional electricity substation of generation, transmission and distribution systems and also the NBR 8222 – Explosion prevention and fire extinguishing systems for transformers and reactors – Procedure. The last one include an internal arc test in the transformer to verify in, a high power lab, if prevention systems works properly. Another example is the proposal for the Standard Guidelines for the use of simulations and calculations used in IEC products standards http://www.cognitor.com.br/article_competitivity_eng_04102011.pdf The objective is to provide conditions for the replacement of some "easy" tests by a validated virtual simulations lab
Special design of control rooms to reduce the consequences of internal arcs > 50 KA	Special design based in proper ducts and room design (instead of expensive special switchgear)
Synchronizers systems to be used in systems <= 145 kV	These systems are frequently used for system voltages >= 230 kV Here is an extension of the idea for lower system voltages with the objective of switching overvoltages and transient overcurrent.

3) HOW TO ANALYZE AND TO PRIORITIZE THE "NEW TECHNOLOGY" PROJECTS TO INVEST IN

To analyze and to prioritize a set of alternatives of projects it is necessary to address questions on:

- The available engineering knowledge and capability of trained persons
- The available infrastructure, including facilities and manpower;
- How to do a market analysis to check the opportunities, barriers, competitors and the market itself;
- How to check the company technical competence to arrive to the end product;
- How to do a fast economic and financial viability study using sound indicators.
- How to assess the commercial viability (including marketing and trading schemes);
- How to consider positive impacts of non-financial nature difficult to account
- If a successful prototype is reached will be possible to see or competitors can block market entry?

In a big organization, an in-depth study is done when there is already a reasonable assurance that most of the opportunities and barriers are clear and can be overcome. Medium and small companies generally sometimes replace this study by intuitive decisions or by a simplified study. In any case, it is usual, during the analysis, to stablish different weights aspects as exemplified in Table 2

Table 2 – Main questions to consider and the weight of each one

Questions about different aspects	Weight
Time needed for commercialization	25
Stage of development	15
Is there the possibility of a new patent?	10
Are there competitors in the national and international markets	20
Are there partners ? Private ? Public ?	10
Amount of previous investments in the project	5
Probability of success in the vision of the experts	13
Positive impacts (employment and others)	1
Environmental impacts are better than current technology.	1

For each one of these aspects some kind of "points "is attributed and a classification is based in the sum of the weights x points. Because it is difficult to compare a project on the bench phase with another in a more advanced stage the analysis shall be done within each of these groups alone.

For the ones interested in doing a more complete feasibility analysis , you may use the free software Decidix. A free copy and instructions are freely available for download in the site http://www.cognitor.com.br/c_Feasibily_Analysis.htm

4) WHAT TO DO TO INDUCE NEW TECHNOLOGIES AND PROCEDURES IN THE ELECTRIC INDUSTRY

Many actions to induce, to assess and to develop projects for new technologies can be taken by industry associations and directly by each manufacturer. Some examples are listed in the next lines.

As you will see, this list do not include government actions. In fact, the best actions that developing country governments can take to help are to remain small governments in size, not hinder the progress of

the industrial actions, providing a good level of education in the country and to act seriously to set a good example. For example, no one will be motivated seeing that a government has more than 30 ministries, more than 15,000 advisors and taxes among the highest in the world.

Some actions which can be taken by industry associations and directly by each manufacturer are:

- For an industry association, to work for having, near, a high power testing laboratory, at least 750 MVA and a high voltage testing laboratory, for dielectric tests up to 145 kV class.

- For an industry association, to work for having, near, at least one temperature rise tests laboratory, for tests up to 5000 A in medium impedance test objects.

- For an industry association, to work to have a National Standardization Body which is able to provide the relevant IEC standards translated to the local language at maximum one year after the IEC standards is published.

- For a manufacturing industry, to have at least two engineers well trained for doing engineering calculations applicable to the design of equipment and having abilities to understand what is written in the technical standards (don't think this is obvious because it is rare to have just one) . An example of a specific training to prepare people like this is in the link http://www.cognitor.com.br/Training2015.pdf

- For a manufacturing industry, to have a strategic planning "table of new technologies goals" with already defined priorities.

- For a manufacturing industry, to have each year, in course, at least three "new technologies projects" (one bbenchmark design + one prototype design and one commercial project). This is the way to create a culture of innovations in the company and to maintain the fire on.