Transformer Explosion versus Arrow of Time

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Abstract: In this article there is presented a relationship between entropy generation and lifetime of a power transformer, i.e. a power system far- from- equilibrium. The Second Law of Thermodynamics states that every system becomes disordered in time. A huge number of components in a power system interact with each other, sometimes in ways that engineers do not anticipate. In complex, chaotic power systems interplay of the components leads to surprising outcomes. The breakdown of the power grids, blackouts and power outages around the world have fed concerns about the reliability of power systems. It is generally accepted that a consident theory for complex power systems far- from- equilibrium does not exist. Deterministic chaos is only one possible consequence; form of self-organisation of a power system in which there is an overload of entropy. Simple way to express the entropy law in a transformer is that in a lubrication system the parts and subsystems tend to disintegrate over time. The break, break down, break up, friction, oil cavitation (or nucleate boiling, or weathering), chemical reactions, water production from oil, rust, die, decay, wear out, transformer explosions, and generally move from a state of higher organisation to one of lower organisation, from order to disorder. The origin of the power transformer explosions is internal rather than external. Entropy is imperceptible, therefore it is impossible to determine what caused those serious problems. The destroyed exergy, or the generated entropy is responsible for the less-than-theoretical efficiency and lifetime of a transformer. The thermodynamical *Arrow of Time* is characterized by the increase of entropy according to the Second Law. Entropy generation has important impact on the earth's environment and sustainable development. Shorter power system lifetime (*arrow of time*) can be very expensive. The interruption in the electric power supply to any region of a country would be much larger than the economic loss to the energy sector alone. Major blackouts are a byproduct of a complex power system and only fundamental change in the system thinking can extinguish them. Minimal entropy generation is a general evolution criterion for the power systems. Entropy Feedback Intensity Control allow in an elegant way a reduction of entropy generation of a power transformer and thus increase of both order and *the arrow of time*.

Keywords: *Arrow of time*, blackout, cavitation, entropy, exergy, explosion, transformer.

1 Introduction.

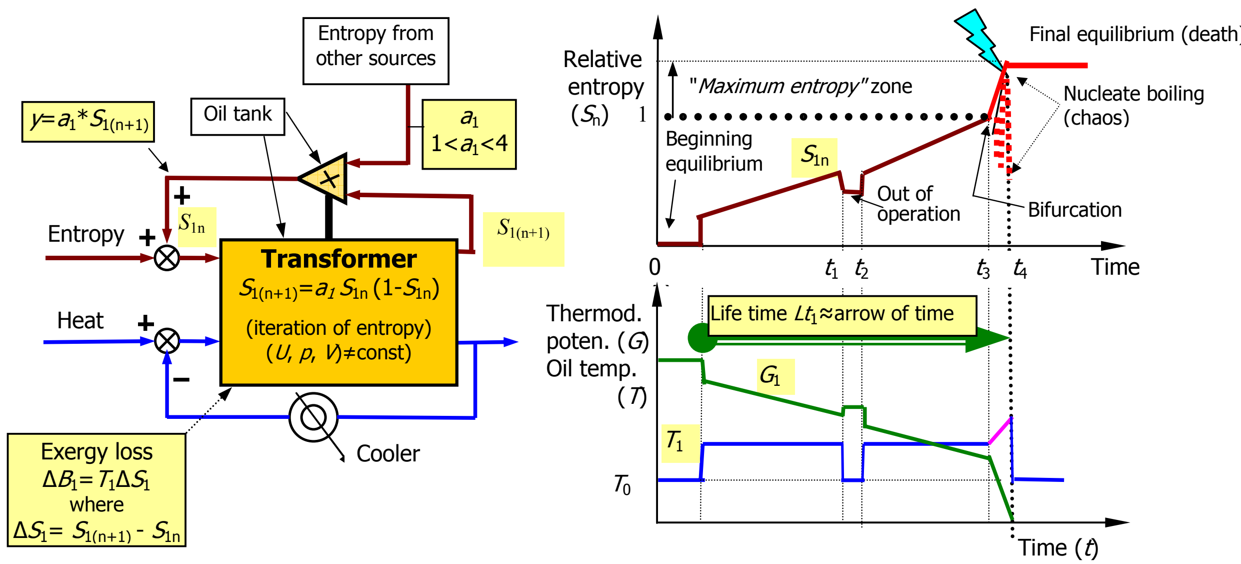
Sustainable power systems are systems with minimal entropy production and maximal efficiency. Simple way to express the entropy law in the power engineering is that in a closed system all components and subsystems tend to disintegrate over time. The break, break down, break up, rust, cavitation (or nucleate boiling), chemical reactions, gas and water production, oil tank explosions, transformer explosions, die, decay, friction, wear out or generally move from a state of higher organisation to one of lower organisation, from order to disorder.

Already in the 20s of the 20th century it became clear that thermodynamic concepts coming from the *steam century* do not describe comprehensively the complexity of the Mother Nature. The science of classical thermodynamics is built on the concept of equilibrium states. In reality, all processes take a definite time to happen and, therefore, always proceed out of equilibrium.The change is defined by the final and beginning equilibrium states of the system. Power systems that exchange entropy with their exterior do not simply increase the entropy of the exterior, but may undergo dramatic spontaneous transformations to new *self-organisation*, explosion, blackout or death.

Thermodynamic potential is a fundamental measure of a system capacity to perform work. Every process requires the consumption of some thermodynamic potential, thus we are able to compare different energy-conversion processes. The two essential forms of stored potential are energy and order. Each energy transfer or conversion, all else being equal, should be arranged so that the total change in entropy (entropy generation in a power system) is a minimum. An engineer designing a power system is expected to aim for the highest possible technical efficiency at a minimum cost under the prevailing technical, economic and legal conditions, but also with regard to ethical, ecological and social consequences.

2 Power engineering.

As an example of this thermodynamics-based approach, the thermodynamics associated with a power transformer can be examined. A concept called entropy that is a measure of the amount of energy no longer capable of conversion into work in transformer after a transformation process has taken place. It is thus measure of the unavailability of energy dissipated in friction, cavitation, filtration, etc. Entropy can also be shown to be a measure of the level of disorder of a power system like a power transformer or a whole power grid.



Thermodynamic potential:

$$G=U+pV-T(S_n+S_v+S_A) \quad (1)$$

where:
G - Gibbs potential (free ehthalpy), U-internal energy, p-oil pressure, V-oil volume, T-oil temperature, S_n-oil entropy, S_v-vibrational
entropy, S_A-acoustic entropy

Figure 1. Block diagram of a power transformer, an unsustainable system far- from- equilibrium.

2.1 Classical solution

The operating system (figure 1) is far- from- equilibrium. It is generally accepted that a consident theory for systems far- from- equilibrium does not exist. The only candidates with this property which are known up to now are the so called class IV *cellular automata*. In these models the evolution is open, i.e. there exists no *goal function* which can determine the longtime behavior.

Due to exergy destruction or entropy production it is evident from above equation that the Gibbs potential (G) is zero when it is in equilibrium with the environment (death). But from the traditional method of an energy balance no information is available on the degradation of energy or destruction of exergy. The exergy method of analysis can clearly indicate the locations of energy degradation. Exergy is destroyed whenever an irreversible process occurs. The destroyed exergy is proportional to the generated entropy. When an exergy analysis is performed on a transformer, the thermodynamic imperfections can be quantified also as exergy destruction, which is wasted work or wasted potential for the coming production of work.

It is important to note that a possible goal function for an energy system strongly depends on the time scale on which this system is considered. All spontaneous processes proceed to maximum entropy of an power system. A direct consequence of fundamental importance is the implication that at thermodynamic equilibrium the entropy of a system is at relative maximum. In a closed power system (in operation) where there is a state of maximum entropy the existence of both *negative absolute temperature* and *false vacuum* is possible. A local temperature formula can be constructed for electronic motion in atoms and molecules, which allows the existence of negative absolute temperature in a local sense. False vacuum is a region of space that appears to be empty (i.e. oil/fuel tank ullage), but actually contains stored energy. When this stored energy is released, the false vacuum is said to decay. The exergy transfer from the transformer body to the oil associated with entropy transfer depends on the entropy level of oil. The destroyed exergy, or the generated entropy is responsible for the less-than-theoretical efficiency of the power system. [1] At the present moment in the power transformers large quantities of entropy are created. The thermodynamic potential (*G*) in a transformer becomes lower and lower. This must be taken into account by power engineering.

2.2 Virtual solution with an "*absolute*" filter in a transformers lubrication system.

"*Absolute*" filtration techniques have become an important operation in the downstream processing of various industrial processes, especially in the power engineering. One of the major concerns in the *absolute* filtration is the exergy destruction or entropy generation on the membrane surface. [2] During these interactions, the fluid has a natural tendency to undergo irreversible processes and thereby increase the entropy of the transformer. Entropy generation in an irreversible process during membrane filtration is associated with production of cold plasma (electrons and positrons, i.e. fermions). It was found that the entropy production rate during filtration, cavitation and friction is very sensitive to the concentration of entropy (fermions) in oil (positive feedback mechanism).

Due to entropy generation unexpectedly the transformer (figure 2) is more far- from- equilibrium! So in the 90s of the 20th century *absolute* oil filter were commonly installed at transformers in the whole world. This "virtual solution" of the issue of entropy was unfortunately unsuccessful. In the whole world there occur transformer explosions. In many countries due to entropy, much blackouts and wide energy crisis had occurred.

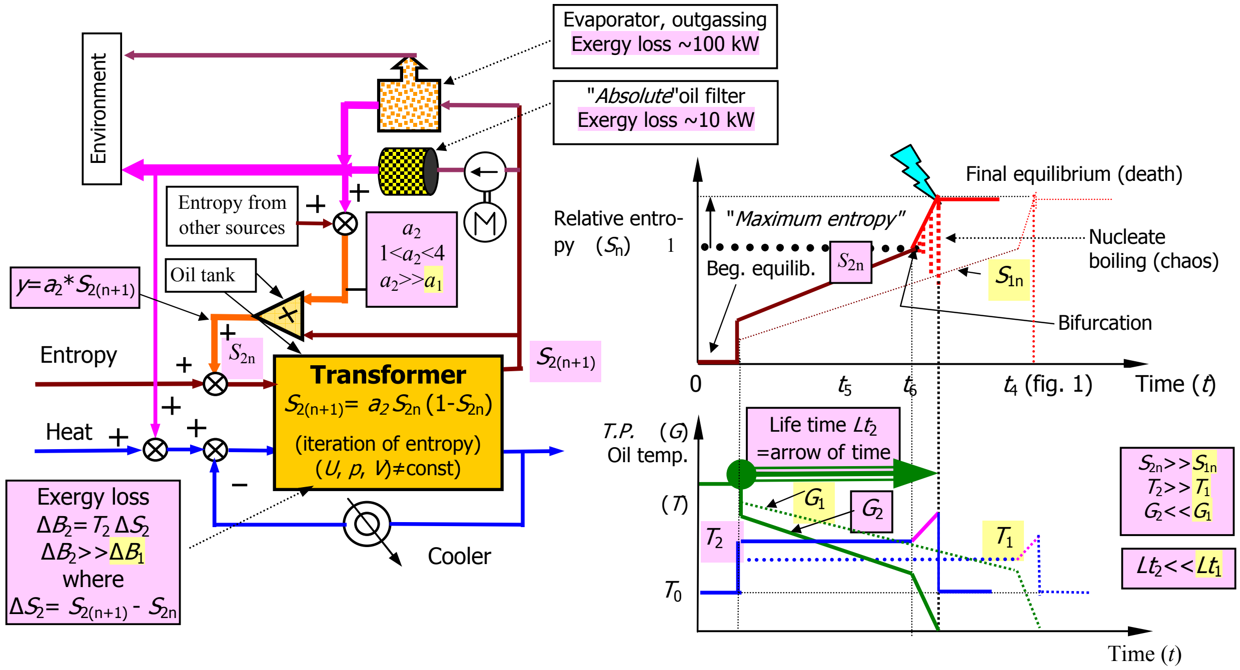


Figure 2. Block diagram of a power transformer, an unsustainable system with an "*absolute*" filter, the worst-case far- from- equilibrium, "*maximal entropy production*", maximal de Broglie wave frequency.

The origin of the transformer explosions is internal rather than external. Entropy is imperceptible, therefore it is impossible to determine what caused these transformer explosions. But a survey of current literature shows that a consistent and accepted methodology of research of issue of entropy has well yet to be developed. Entropy generation is associated with production of cold plasma (electrons and positrons).

3 Failure of classical description.

The evolving systems are not isolated. The Second Law does not fully describe what takes place in them-more precisely, between them and their environment. Exergy, once destroyed, is unavailable to perform further work. In a closed system (the one in which there are no entropy outputs only entropy inputs like exergy losses), disorder, corrosion, cavitation, friction, etc. must increase. Entropy increases as order decreases. However, in the open system negative entropy can offset the entropy produced within the system and may even exceed it. Thus ΔS in an open system need be positive: it can be zero or negative. The open system can be in a stationary state (ΔS=0).

Table 1. Characterisation of a power system: entropy vs. Entropy Feedback Intensity Control Factor "***a***".

Entropy Feedback Intensity Control Factor"*a*"	
0<***a***<1	1<***a***<4
Feedback mechanism	
Negative Sustainable power system	Positive Unsustainable power system

Thermodynamics	
Linear→Onsager's Linear energy (entropy) transfer	Non-linear→Prigogine's Non-linear energy (entropy) transfer

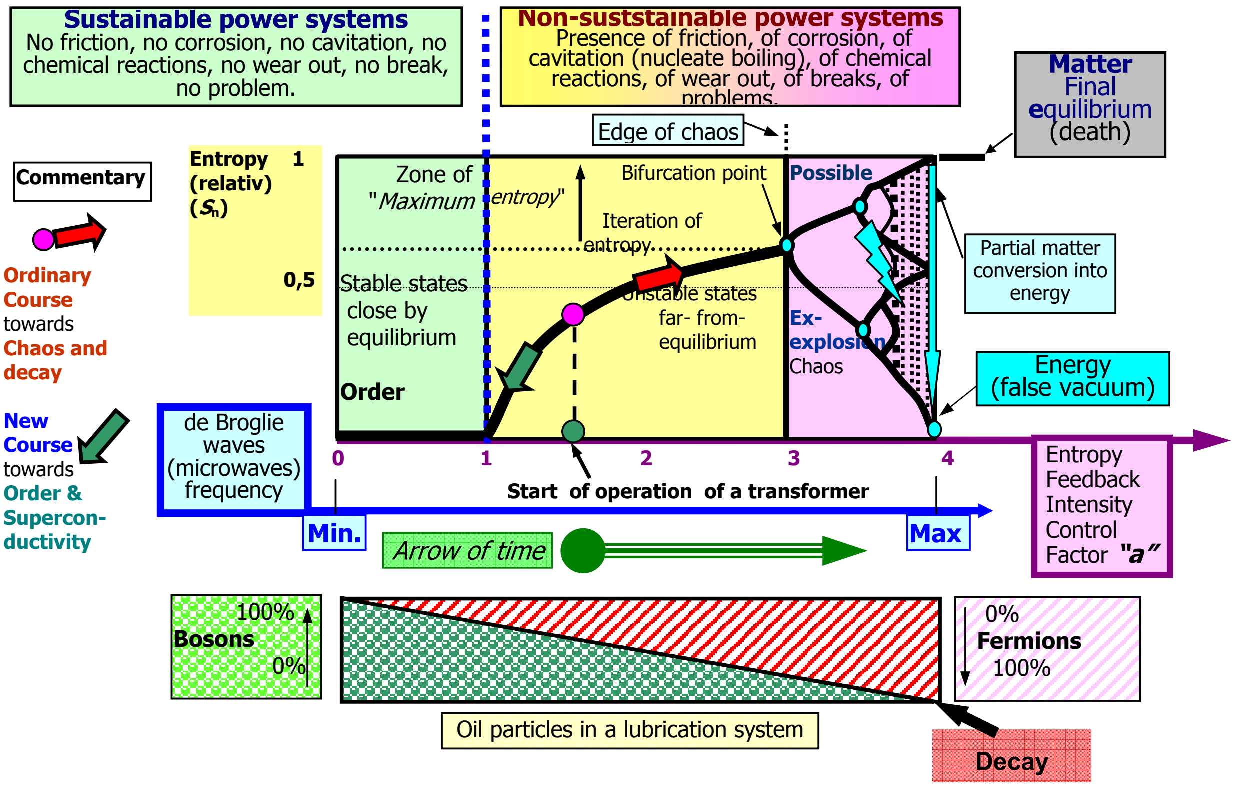


Figure 3. Feigenbaum diagram (FD) for a power transformer with iteration of entropy. For such systems FD is an appropriate ***goal function*** which can determine the long-time behavior.

How a non-equilibrium power system evolves over time can depend very sensitively on the system's microscopic properties. Far- from- equilibrium, the smallest of fluctuations can lead to radically new behaviour on the macroscopic scale. Existing thermodynamic theory cannot throw light on the behaviour of non-equilibrium systems beyond the bifurcation point as we leave equilibrium behind. A power transformer is in a critical state if very small perturbations induce an answer of the system at all time and space scales. To describe the one-way evolution of such non-equilibrium systems, we must construct mathematical models based on equations that show how various observable properties of a system change with time. In agreement with the Second Law, such sets of equations describing irreversible processes always contain the *arrow of time*. Deterministic chaos is only one possible consequence; form of self-organisation in which there is an overload of entropy.

Systems of many interacting oil particles with a relatively high energy exibit phase transition between high entropy state and a low entropy state with a core-halo structure (bubbles formation). Extensive studies revealed that during such a transition entropy has to undergo a discontinous jump from a state a local entropy maximum to a state with different temperature, which is the global entropy maximum.

4 Transformer explosions.

Transformers do not have an indeterminate life (*arrow of time*). Transformer design engineers tell us that a transformer can be expected to last 30 to 40 years under "ideal conditions." But, that is clearly not the case. In the 1975 study, it was found that the average age at the time of failure was 9.4 years. In 1985 study, the average age was 11.4 years. In 2003 study, the average age at failure was 14.9 years. Several transformer explosions have happened in recent years, some of them giving extremely strong explosion development. Modern power grids are extremely complex and widespread. Surges in power lines can cause massive network failures and damage in power generation plants. Transformer explosions can lead to surges and blackouts. The basic causal factors of these failures remain the same: entropy. Transformers generate large amounts of entropy when in service, and bubbles formation take place. There is an uncontrolled risk of an explosion in connection to oil - filled transformers. An arc is often created when the current flows through the vaporized transformer oil, and a short circuit occurs.

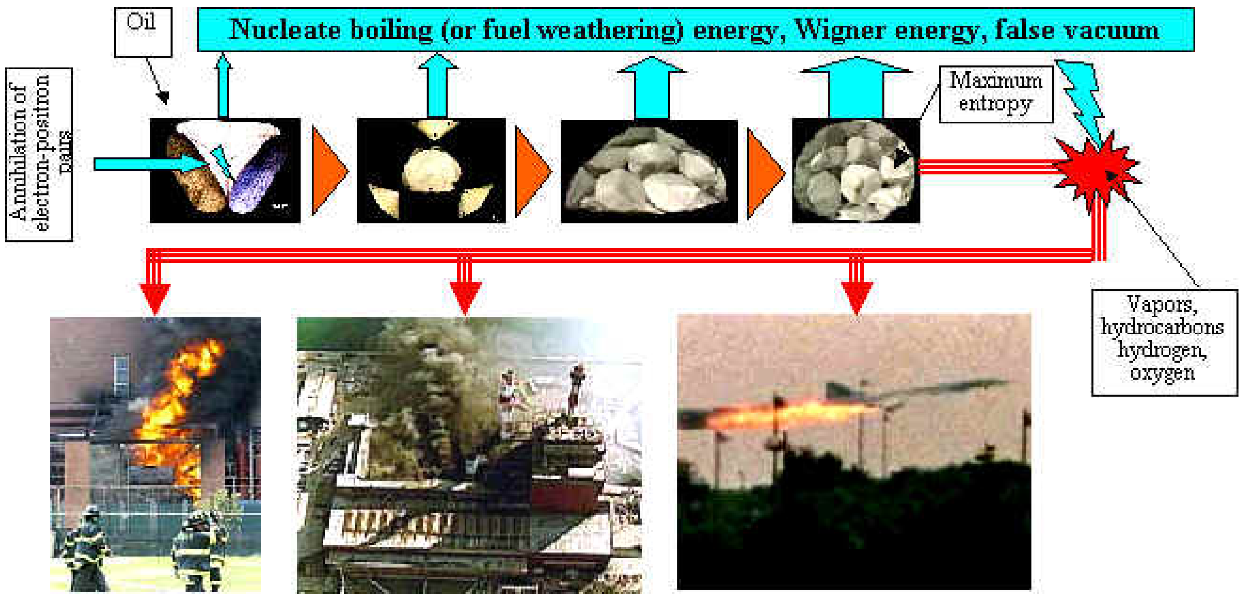


Figure 4. The problems of power engineering remain open for exploration

Under certain conditions, a closed system like a transformer *can* be described by a *negative absolute temperature*. Not all systems have the property that the entropy increases monotonically with energy density. In some cases, as energy is dissipated in the system, the number of available microstates, or configurations, actually decreases for some range of energies. For this system, the entropy does not go on increasing forever. There is a maximum energy. At this maximal energy, there is again only one microstate *false vacuum* the entropy is again zero. So in a transformer we have created a system where, as we dissipate more and more energy, temperature starts off positive, approaches positive infinity as maximum entropy is approached. After that, the temperature becomes negative infinite, coming down in magnitude toward zero, but always negative, as the energy density increases towards maximum. This system can be *self* realized in the real world. This condition can easily be met in transformer oil in vapor phase for the case of considerable exergy destruction in a power transformer before an explosion. The present research of the transformer explosions suggests that such catastrophic *false vacuum* state is taking place.

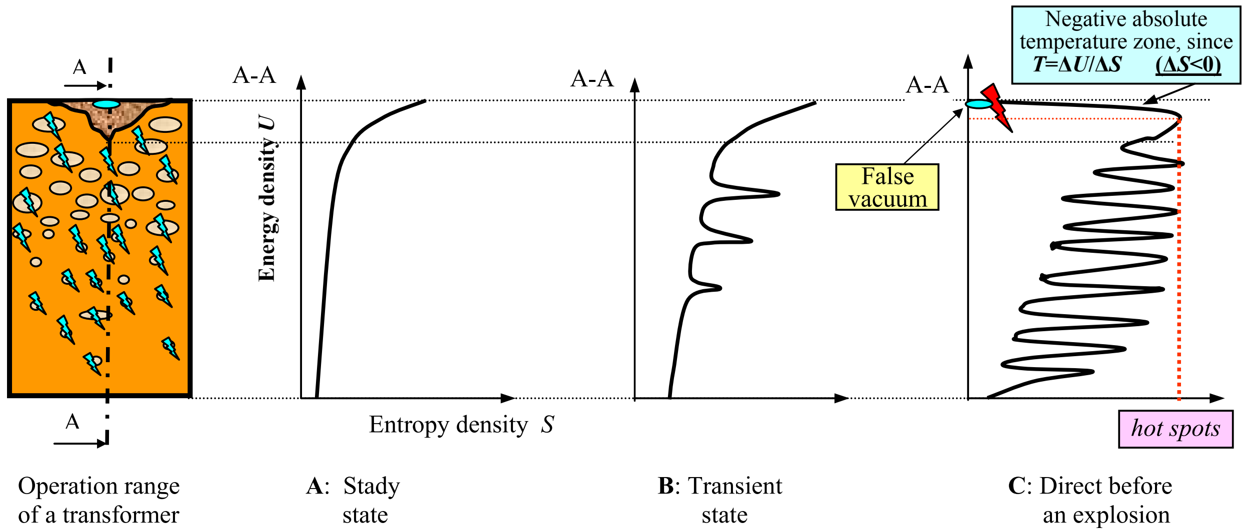


Figure 5. Operation range of a transformer.

This scenario leads to an explosion, when the false vacuum state finally ends. The *arrow of time* of a transformer vanishes in fire.

Figure 6. Transformer on fire

India, December 24, 2002, USA, September 24, 2003

Ponchkula, Substation Ramgarh-Madanpur Huston

As physicists have already found out through quantum mechanics, the structure of the world is richer than our language can express and our brains comprehend. Many problems of the power engineering remain open for exploration. Now, there is a lot of hard work to do regarding entropy in the 21st century. Thus the power engineers cannot abolish the entropy law and the *arrow of time*.

5 System protection technologie, transformer life extension.

Second Law Analysis (*SLA*) techniques can be used to evaluate the performance of transformers, etc. The thermodynamical *arrow of time* is characterized by the increase of entropy according to the Second Law. The appearance of an *arrow of time* is a natural consequence of the evolution of a power system from a highly improbable, highly ordered, initial low entropy state towards the most probable, most stable, high entropy state. The transformers are not in equilibrium, and they have a clearly defined *arrow of time*.

A process is internally reversible if no entropy is generated within the system boundaries. The problem is that when we destroy the exergy in the power system we add internal energy (because *T* increase), and we also add entropy (because *S* increase). If we want to continue using a lubrication system of a transformer to do work, we have to remove the entropy as well as the heat, so there is no accumulation of entropy (see figure 7). The Entropy Feedback Intensity Control allow in an elegant way a local reduction of entropy and thus increase of order. This may be an opportunity to learn more about the extraordinary efficiency of biological energy conversion systems. The solution of entropy issue ("blocking" the Second Law) would significantly reduce the number of transformer failures, and the unexpected interruption of power.

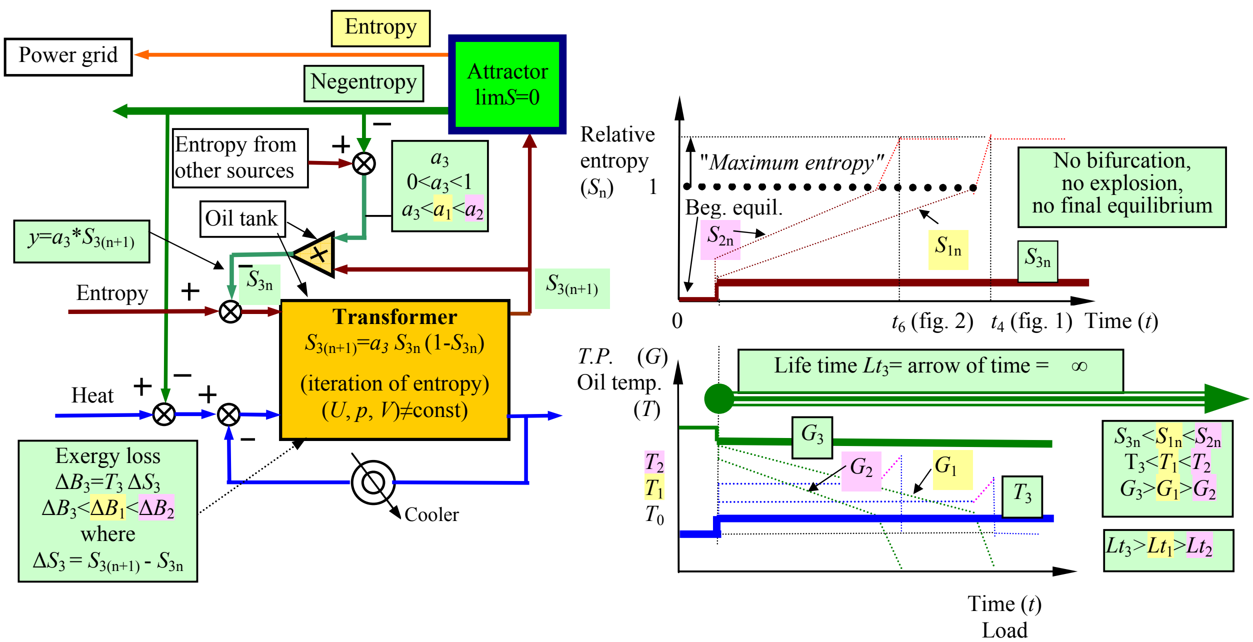


Figure 7. Entropy Feedback Intensity Control (*EFIC*), a sustainable transformer close by equilibrium, "*minimal entropy production*", minimal de Broglie wave frequency.

6 Conclusion.

Life is a system in steady-state thermodynamic disequilibrium that maintains its constant distance from equilibrium (death) by feeding on low entropy from its environment-that is, by exchanging high-entropy outputs for low entropy inputs. The same statement would hold verbatim as a physical description of a transformer. A corollary of this statement is that an organism (or a power system) cannot live in a medium of its own waste products (entropy=wasted energy). Entropy is a special agent for attacking electrical power infrastructure. Although very little is known about entropy, this weapon is sometimes referred to as a "soft bomb" since its effects are confined to the electrical power facility. We cannot continue in our present methods of using power transformers.

6 References.

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