We are in winter, near a small town on the top of a mountain. In night time, air is very chilly and temperature goes below 0° C. Under this conditions the moisture of the air freezes and ice covers everything, including the high voltage cables. Besides, sometimes it snows, and the snow fallen down accumulates on the wires. If the snow is melted by the sun, then it turns on ice during the night. Day by day, the layer of ice grows, and its weight stretches the wires that could be broken. If this happens, people in the village have no power in their houses until the damage is repaired. So a solution is needed for the society providing power.

Fig. 1: *Electric wires covered by ice*

The first proposed solution was to increase the diameter of the copper wires, but it is known that the copper is very expensive and it would be necessary to replace the whole electric line. Another solution would be burying all the cables underground in order protect them, but the investment wouldn't be paid by the small town as well as doubling the number of pylons supporting the wires.
One of the technicians suggests exploiting the heat generated by Joule effect by the wires; nevertheless, it would be necessary to increase the intensity of the current, which would imply an increment of energy consumption.

A non standard solution must be found, let's follow a TRIZ-based problem solving process.

When it is not clear how to solve a problem or which is the problem to solve, the first TRIZ tool to use is the System Operator (paragraph 1.3.3.5), that allows choosing the right problem analyzing the initial situation also from a temporal point of view or in a cause-effect chain. We have to start with the definition of the reference box (*system present)*. It is not significant which is the level of detail or the temporal stage chosen as starting box; besides, it is extremely important to perform a consistent analysis while searching for roundabout problems in the other boxes.
We have the initial problem, that is a lot of ice forms on electric wires and this produce wires broken; so we can choose this scene as central box of our system operator and the elements to

list will be only wires, ice and current, and we have to consider this question: how can the elements of the "system present" counteract the harmful action of the ice on the wires? Now we can complete the scheme as represented in figure 2.

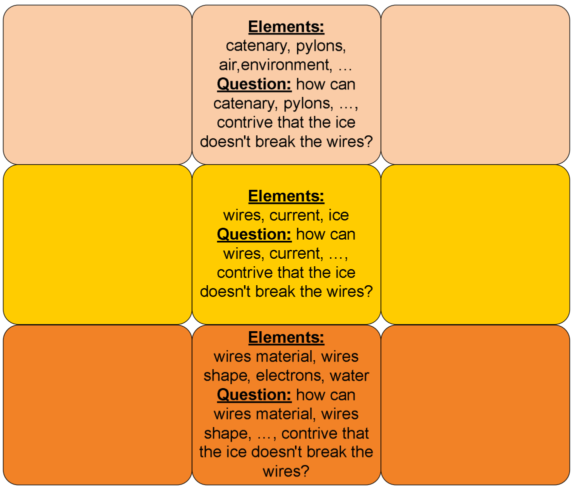


Fig. 2*: search for roundabout problems: present column of the system operator*

Remember that all the boxes on the same column are characterized by the identical "temporal frame", while the boxes on the same row represent the identical system level; it is worth to remember that each column is characterized by the same problem/question, while subjects, i.e. the resources to solve it, change.
Focusing the attention on a column on the left side of the matrix (past) means looking at prevention opportunities: the time of the left boxes is when the big amount of ice is still not formed, but it is in the form of water, snow or humidity and obviously a thin layer of ice.
Vice versa, moving the attention towards the right side of the matrix (future) means admitting that the problem in the present column has not been solved, and a compensative approach should be searched in the future. In this case, on the right column, it is assumed that ice has broken the wires.
As a consequence, different questions/specific problems are associated to the different cells of the System Operator matrix. The completed schema is reported in figure 3. It is worth to notice that in a general situation the System Operator can be constituted by more than 9 boxes, since each subsystem can be further divided in sub-subsystems, each time frame has a past and a future etc. It is suggested to stop the analysis when the question brings to expected tasks out of the business/role of the problem solver (e.g. how to avoid a change of the weather condition?).

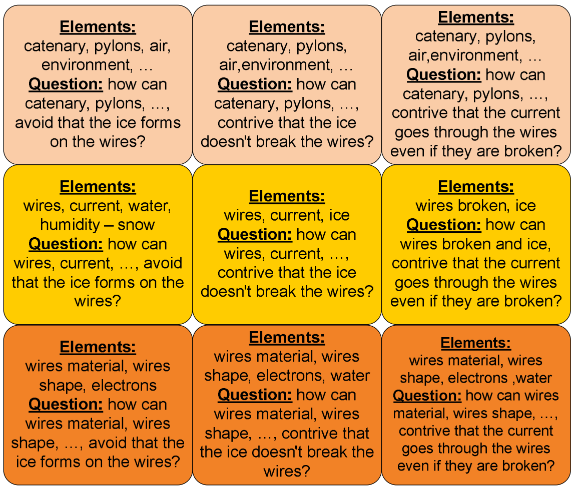


Fig. 2: *Searching for roundabout problems: System Operator completed*

Now we have to choose among nine (possibly more) different specific problems, all aiming at the achievement of the same final goal: supplying the inhabitants of the small city in the mountain with a regular electric power service.
Let's start from the central box.
To better understand how the system works, and how the problem appears, it is useful to build a functional model of the system under the operating conditions corresponding to the selected box of the System Operator.
In this case, the model will be very simple since we have just a few elements. We have to start with representing the useful function (u.f.) of the system: the wires drive or conduct the current. Then we could add all other elements present which take part to the u.f. or are consequences of it, and eventually those who produce or take part to the harmful function, i.e. ice breaks wires. When we have listed all the elements, we have to consider all the actions performed each other. The result is presented in figure 4 .

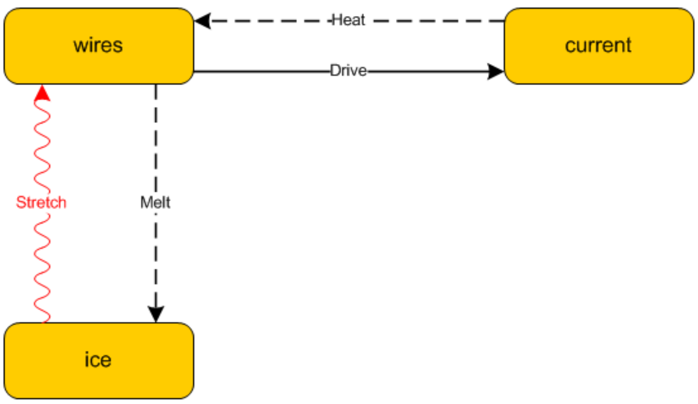


Fig.4: *Functional model describing the situation in the System Present box of the System Operator.*

To avoid the ice breaking the electric cables, we can use the heat generated by the current, despite it is not sufficient to melt ice. So we can imagine to increase current intensity in order to increase the Joule effect and so the temperature of the wires. Now we have to build a functional model under the assumption of a high current flowing through the wires (figure 5).

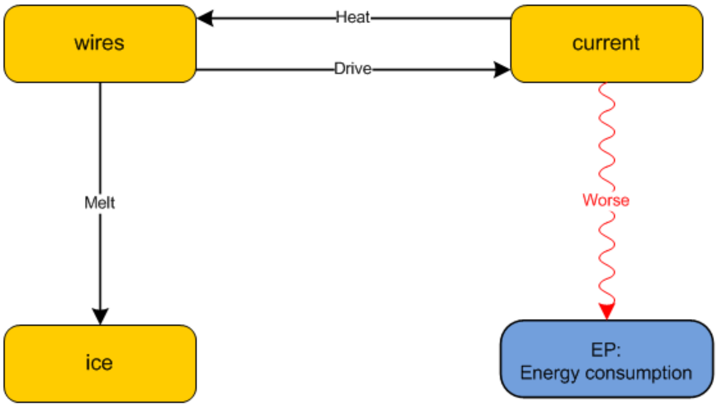


Fig. 5: *Functional model of the system when a high current is applied to the electric line.*

As represented in figure 5, a high current doesn't cause directly a harmful function on some element, but simply the worsening of an evaluation parameter. So we have a contradiction: in fact if the current intensity has a high value the problem with ice is solved, but a harmful function appears towards energy consumption; besides, if the electric current is low, the heat generated by Joule effect is not sufficient to melt the ice. The model of this contradiction is represented in figure 6.

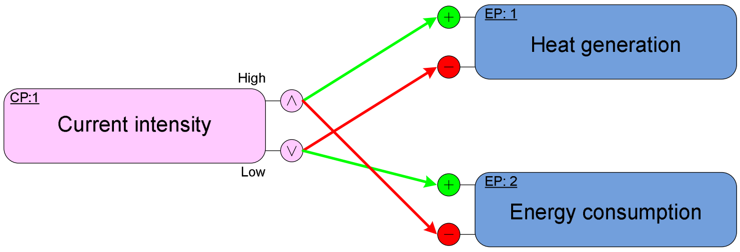
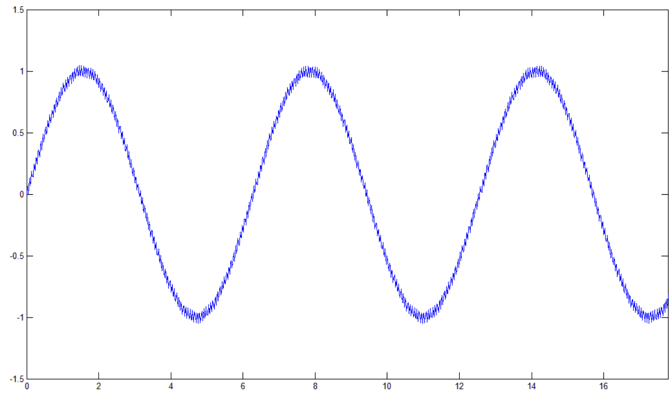


Fig. 6*: the OTSM model of a contradiction (paragraph 5.1.2)*

Following the steps suggested by ARIZ (chapter 3) Operational Zone and Operational Time must be identified.
The Operational Zone can be considered as the sum of the external surface of the wires, the surfaces of ice in contact with them and the section of the wires where current passes through. While the Operational Time is the interval when the ice stretches wires the ice starts forming and during the electric current transmission.
Now, as explicated in paragraph 5.3 of the TETRIS handbook, we can apply the Separation Principles to solve the physical contradiction. The first one is the separation in time: we can apply this principle if the following question has a negative answer: is it true that we want an high value of the current during the whole operational time, and we want a low (normal) value of the current during the whole operational time? It is clear that the answer here is "No!"
In fact, we need extra currents only when the ice stretches wires, and normal current during the rest of time. Which are the resources of super-system or directly available able to change current intensity according to mechanical stress on wires? Moreover a new problem appears: how is it possible to measure the wires mechanical tension or an overload so as to change the current intensity? Possible solutions could be found using the Class 4 of the Standard Solution (chapter 4).
The second principle for overcoming physical contradictions is separation in space. Similarly to the previous one, the principle is relevant in the specific situation if the following question has a negative answer: is it true that we want a high value of the current in the whole operational zone, and we want a low value of the current in the whole operational zone?
Indeed, a high value of the current is needed only on the surface of the wires in order to heat them and to melt ice, while a normal (low) value of the current is required in the rest of the section of the wires to feed the town and avoid energy waste.
What kind of resources do we have within the system, or easily accessible from the super system, to create a different value of the current density on the surface of the wires and in their internal section?
If the personal/team knowledge is not sufficient to answer to this kind of question, we can take into consideration another tool of the TRIZ knowledge base, the Effects Database (paragraph 5.6.4), where we can find the *skin* or *surface effect*, according to which if the alternate current has a high frequency its density near the surface of the wire is greater than at its core.

Therefore we can heat the wires only where we really need without an excessive consumption of energy, by superimposing a high frequency small intensity current on the regular 50-60 Hz power supply.



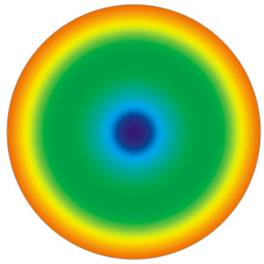


Fig. 7: *left – the main sinusoidal wave of the AC current with the overlap of the high frequency additional current; right – the current density distribution in a cross section of the wire*