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Massive electricity and communications blackouts on Earth as effect of change the Sun activity

Keywords

CME (Coronal Mass Ejection), resilience modelling, blackout, electrical networks, communications networks, carrington event

Abstract

This article shown examples of rapid failure in electrical and communication systems under Threats of CME (Coronal Mass Ejection) from the sun flare. Is presented the past and present results of impact of CME to the Earth magnetosphere. Under these events are generate the massive geomagnetic storms. The solar flare merging from the sun Surface, and emitted powerful bursts of radiation and particles emission CME (Coronal Mass Ejection). This radiation under contract with the Earth magnetosphere ionize upper atmosphere and generate geomagnetic storms. The power of magnitude of geomagnetic storms can destroy or hard damaged the electrician and communications networks. Wide range of these failure can influence to the whole economy of each country. Last information's from astronomers suggest that in future, in next 50 years, we can expect on Earth a strongly change of sun activity. This article have suggestion to take into consideration for Resilience Modelling for the electrical and communication systems an influence of CME (Coronal Mass Ejection).

1. Introduction

Still developing wider use of electricity to powering big and small apparatus in houses and companies. That can be stop by one accident. A massive blackouts of electrical networks. Source of this accident is outside of Earth. That is our everyday morning star – the Sun. Since first use of electrical power network in September 1882 are noticed a failure this system as influence of the Sun activity. Flares generated by the Sun are linked with a some form of solar activity – the CME (Coronal Mass Ejection). CME has big kinetic and electricity energy. Under time of contact with the Earth magnetosphere this ionize upper atmosphere and generate geomagnetic storms. Under normal activity of electrical networks this can generate a surge voltage. That can destroy a transformers and cables.

2. Paper review

In history are noticed a several big blackouts of electrical systems. First damage from CME was in 1859. In this year at the end of August the English astronomers Richard C. Carrington and Richard Hodgson observed on the Sun numerous sunspots. on September 1 they sow a massive with solar flare (*Figure 1*).

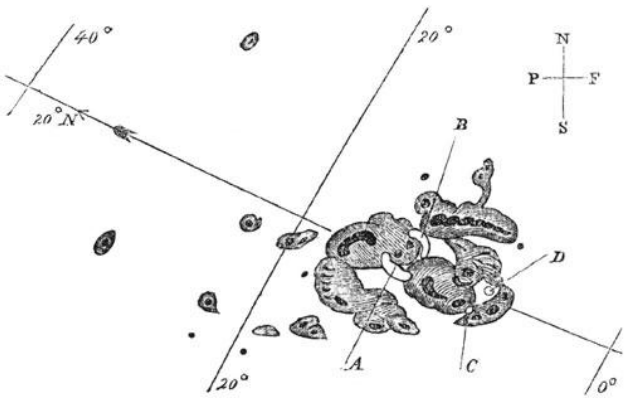

Figure 1. Sunspots of 1 September 1859 seen by Richard Carrington [1]

This flare was associated with a major coronal mass ejection (CME) and travelled directly toward Earth, taking 17.6 hours to make the 93 million mile journey [31]. On Earth begun the giant geomagnetic storm. Activity of this phenomena failed a telegraph systems in Europe (England, Sweden), North America, Bahama Islands, Cuba, India and Australia. Many times the telegraph operators had electric

shocks [12], [20], [42]. Later next CME's hits into Earth magnetopause.
In 1882 Novembers CME failed a telegraph systems in Europe and USA. Were noticed telluric current five times stronger than normal was present [5]. In May 1921, 14-15, on Earth was observed a strongly geomagnetic storm. In this time were use a wide electric networks. This event disturb a work of telegraph telephone and electric power networks in USA, Europe, Australia, New Zeeland. Surge voltage generated in over-ground lines are moved interference to undersea cables which connected Europe with America and Australia with other world [7], [9], [39]. In USA was paralyzed a telegraphic and telephone lines from northeast states to southwest, from Maine to Arizona and New Mexico [29], and from Main to Ohio [6]. The signal system of New York Central Railroad was damaged by fire of the signal tower [9], [40]. In Switzerland were noticed telluric current in telegraphic lines in north regions with power 20mA [13]. In north-west France were paralyzed a telegraphic lines [11], [16]. In Paris between 14-15 May 1921 were seen an aurora borealis [1]-[2]. In Poland were also noticed a damage of telegraph and telephone lines. In this time Poland was just after close a war with Soviet Russia. Bad conditions of telegraph and telephone lines were explained as a lack of proper maintenance [15].

Figure 2. Burned Transformer in Hydro-Québec's power grid in 1989 [34]

In 9 March 1989 was noticed a biggest damages by CME on Earth. In this day to Earth come CME ejected on sun 6 March. In the same day on Sun was big CME, that 13 March come to Earth. This evoke a huge geomagnetic storm. His activity cuts a control over some satellites in polar orbits and tripped circuit breakers on Hydro-Québec's power grid (*Figure 2*). This damage a transformers of big power a and as result evoke a huge blackout in Quebec province in Canada [19]. In Sweden five 130 kV lines were tripped [17]. In 28-29 October 2003 were noticed next CME, called Halloween Solar Storms. This disturb work of some satellites but didn't damage an electric systems on Earth. Over Europe was seen an Aurora Borealis [41].
In January 2008 American National Academy of Sciences (NAS) prepared an extraordinary report titled: Severe Space Weather Events--Understanding Societal and Economic Impacts: A Workshop Report (2008). In this paper was first calculation of economic results after expected CME hits into Earth in 2012. They use to analysis a historical data of power the CME from 1921 year. If similar impact hit a earth the total economic cost would be:
- Future severe geomagnetic storm scenario: $1 trillion to $2 trillion in the first year,
- Depending on damage, full recovery could take 4 to 10 year [35].
In this report was shown expected result for American electric network system. In opinion of NAS severe space weather event in the US could induce ground currents that would knock out 300 key transformers within about 90 seconds, cutting off the power for more than 130 million people (*Figure 3*).

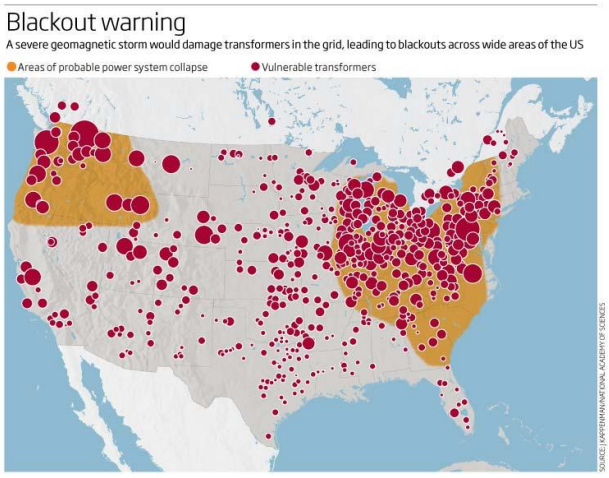

Figure 3. Map of expected blackout regions in USA after simulated CME with power from 1921 [8]

NAS report suggest that loss of key infrastructure for extended periods due to the cascading effects from a space weather event (or other disturbance) could lead to a lack of food, given low inventories and reliance on just-in-time delivery, loss of basic transportation, inability to pump fuel, and loss of refrigeration [35].
In March 2009 "New Scientist" presented article where was opinion that Europe is neither sufficiently

prepared because Europe's electricity grids are highly interconnected and extremely vulnerable to cascading failures. As example was presented accident from 2006 year. When in Germany was the routine switch-off of a small part of electric grid, caused a cascade power failure across western Europe, only In France five million people were left without electricity for two hours [8].
In 2011 OECD published report with suggestion that in the regions with highest regional conductivity we would expect the most severe consequences under CME impact for electric networks [27], (*Figure 4*) [28]. This means they find the new critical factor for electric network.

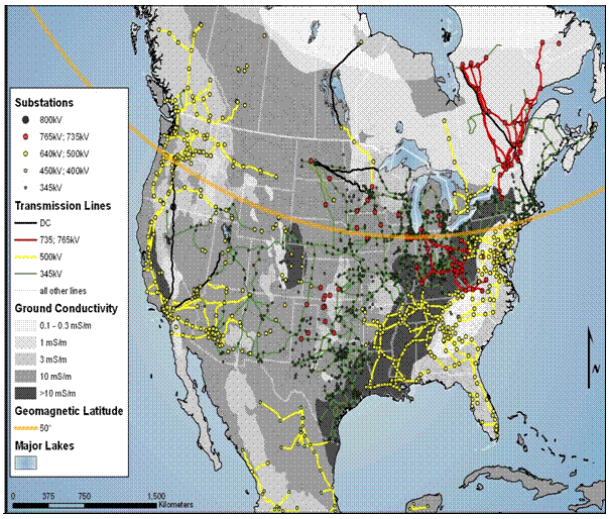

Figure 4. Vulnerability of North American Electric Power Assets to Geomagnetic Storms [28]

In 23 July 2012 were noticed a huge CME (*Figure 5*). In this day two CME's, separated by only 10 to 15 minutes, went through nearly y Earth's orbit (*Figure 6*) [43]. If this eruption had come nine days earlier, when the ignition spot on the solar surface was aimed at Earth, every 25 days, our planet would have been on the trajectory of CME and it would have hit the planet. This extreme solar super storm could evoke faced severe technological consequences. this poses high-consequence event to severe threats to critical infrastructures of the modern society. It can wreak havoc with the electrical grid, disabling satellites and GPS, and disrupting our increasingly electronic lives. The total economic impact in the first year alone could reach $2.6 trillion worldwide. A potential full recovery time would take of 4-10 years. They are based on 2008 Report results [33].

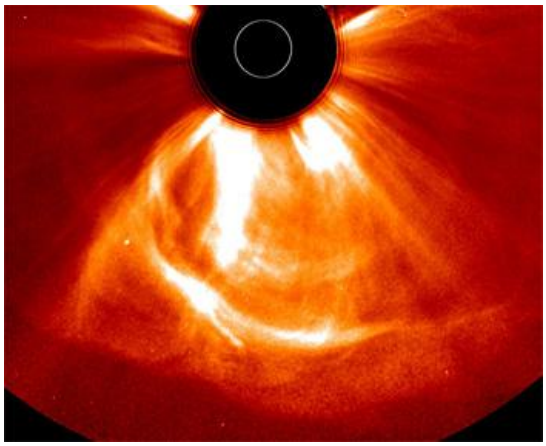

Figure 5. This image captured on July 23, 2012 shows a coronal mass ejection that left the sun [33]

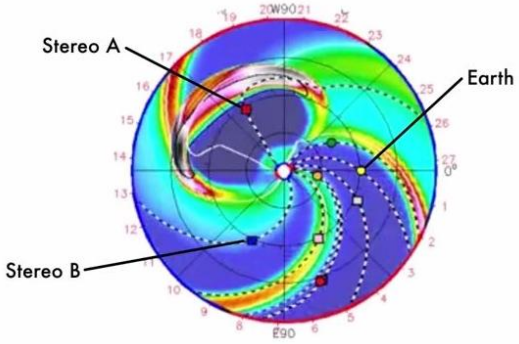

Figure 6. The Major Solar Eruptive Event in July 2012 [32]

Fortunately this didn't. Problem is with this, that we don't know a mechanism of production of the frequency and power of Coronal Mass Ejection on the sun. Coronal Mass Ejection generated geomagnetic storm on earth. The intensity of a geomagnetic storm can be measured by counting the number of solar charged particles that enter the Earth's magnetic field near the Equator. This number is called the Disturbance storm time., or Dst. Power of solar storm was estimated:

1) Dst = -1600, Carrington event, September 2, 1859 [26]
2) Dst = -900, May 14-15, 1921 [26]
3) Dst = -589, March 13, 1989 Superstorm [26]
4) Dst = -472, November 20, 2003 [26]
5) Dst = -401, October 30, 2003 [26]
6) Dst = -1200, July 23, 2012 [32]

3. Definition of the problem

Since extended European Union the UE Parliament would like to release an energetic market. The base for this activity is Directive 2005/89/EC of the European Parliament and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure

investment. There is point: With a view to insuring the functioning of the internal energy market, the largest competitive market for electricity and gas in the world, the European Union (EU) establishes obligations to safeguard security of electricity supply and undertake significant investment in electricity networks. Blackouts in both the EU and US have highlighted the need to define clear operational standards for transmission networks and for correct maintenance and development of the network [14] to safeguard security of electricity supply and infrastructure investment [21]. UE decided to finance a several technological solution important for UE. Specially a commonly electric network (*Figure 7*).

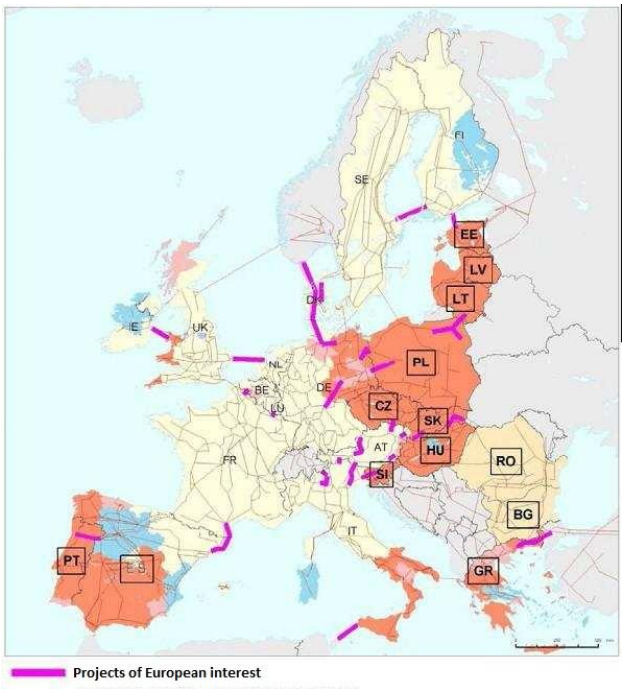

Figure 7. Electric network in project of European interest [18]

Area of this network are connected a regions which occurred a consequences of CME in the past (*Figure 8*). The reach of 1859 CME impact is beyond the reach of map border. Then the map border (*Figure 8*) is reach of 1859 CME impact. Additional on map (*Figure 8*) are shown the reach of aurora borealis from 2004 and 2014 to compare a potentially area of influence the CME.

The Coronal Mass Ejection can indicate a strong electric current in electrical grid (*Figure 9*). Geomagnetically induced currents GIC are induced in the transmission lines and flow to ground through transformers. In the time of flow from the earth go into the grounded neutral of a three-phase autotransformer, where it divides evenly in each phase of the transformer. In the transformers it create, combined with the AC magnetic field, an extra magnetic field that saturates the transformer core [23], [27].

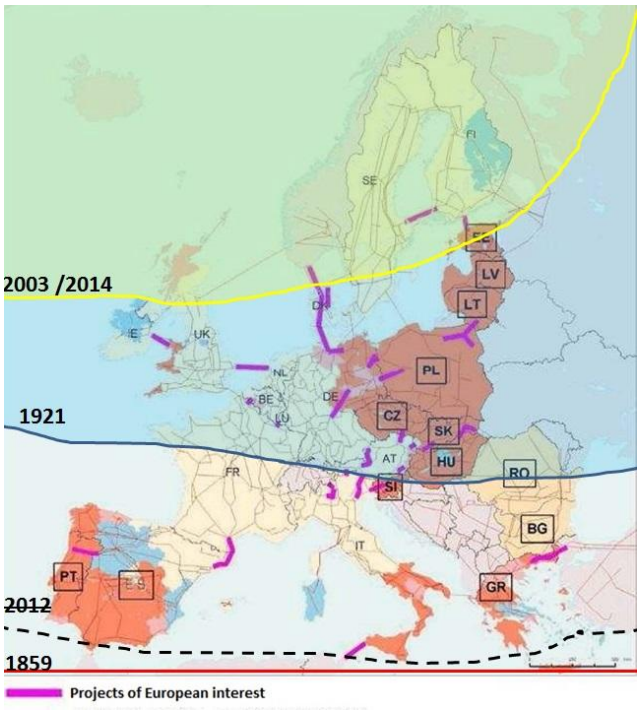

Figure 8. Network of high volts lines in Europe with reconstruction of the range of visibility of the Aurora Borealis from 1859, 1921, 2003, 2014, and suggestion of the reach of not the former 2012 CME. Own work based on [11]-[13], [16], [18], [20], [36], [38],

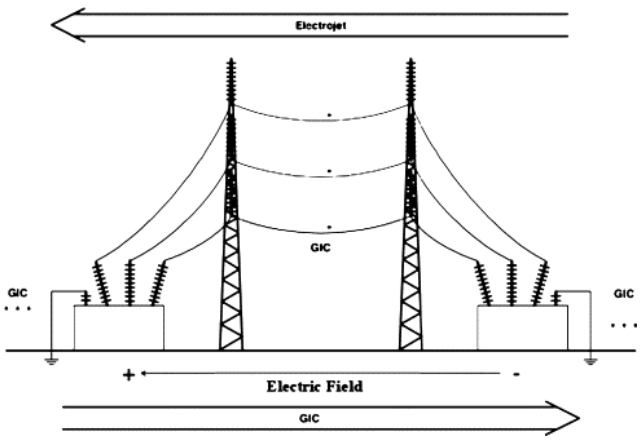

Figure 9. Mechanism of Geomagnetically induced currents GIC [23]

The strong electric currents that would flow through the electrical grid are likely to cause melting and burn-through of large-amperage copper windings and leads in electrical transformers of big power. An owners of electrical networks have only a handful of transformers a big power in reserve. Most of the regions affected by the collapse would remain without power until new transformers could be built

for customers

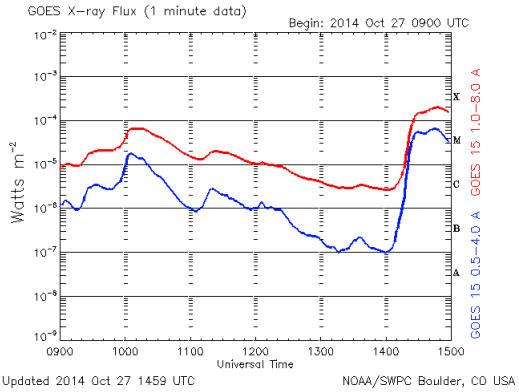

Figure 10. Goes-xray-flux in Oct 27, 2014, NOAA [3]

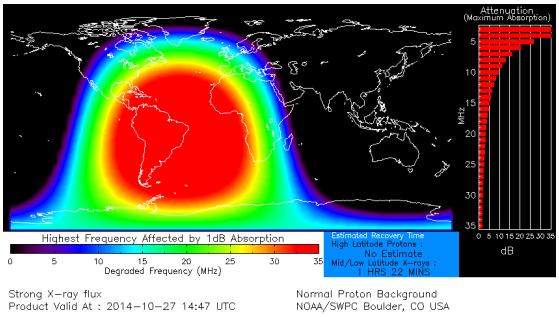

Figure 11. Map with radio blackout on 27 October 2014 [3]

Had the spare not been available, a new custom-built transformer would have been required, potentially idling the power plant for years. The typical manufacture lead times for these transformers are 12 months or more [26].

The second threat are sun flares. the sun ejected also hot ionized particles from its corona, it can send a shock wave through the solar wind. That can be a UV radiation which ionized Earth's upper atmosphere. That can evoke the communications wide area blackout of the range of radio frequency, since low to high. In last half year are noticed two these accidents.

First on 27 October 2014 (*Figure 10*), (*Figure 11*) and second 13 January 2015 (*Figure.12*), (*Figure 13*). For reaction for these threat we have on Earth only 15 minutes to safety switch off all our electronic system [25].

Problem Is: Is It European Common Electrical Network Ready To Contact With Coronal Mass Ejection ?

In opinion in March 2009 “New Scientist” in Europe responsibility for dealing with space weather issues is "very fragmented" [8].

Based on report of NAS is possible to shown that in Europe are a number of actors:

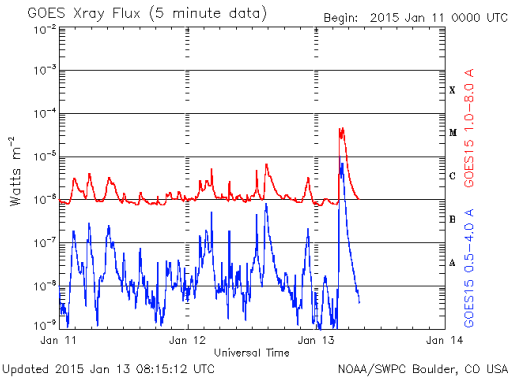

Figure 12. Goes-xray-flux in Jan 12, 2015, NOAA [30]

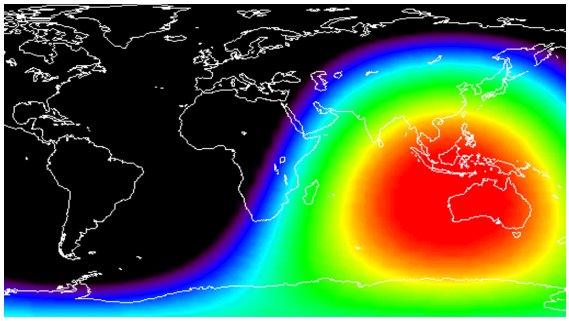

Figure 13. Map with radio blackout on 13 January 2015 [37]

• ESA (European Space Agency) with SWENET, Space Weather European Network, author od NSA reports suggest that it is ideally positioned to be the foundation of an operational European space weather infrastructure. But to do that, it now needs to find an appropriate long-term home in the broader European landscape.

• EU (European Union) which has been supporting several space activities:

- COST (Cooperation on Space and Technology) support of human networking and trans-ionospheric radio propagation (including space weather effects)
- DIAS (coordinated system for digital ionosonde measurements and their dissemination),
- SOTERIA (science exploitation of space weather data)

• Number of national space weather programmes in several countries—in Belgium, France, Germany, Spain, Finland, Italy, Poland, Portugal, Switzerland, Sweden, and the United Kingdom. Denmark and Norway with specialized interests through leadership roles in specific projects—for Denmark the ESA/SWARM mission to study Earth’s magnetic field with greater resolution and for Norway the exploitation of Svalbard as a super-observatory for space weather phenomena.

Report NSA suggest that European decision makers have limited awareness of space weather [35].

4. Discussion

Protection of high volts electric network conductors and transformer windings, the transformer type and mode of connection, and the method of station grounding and resistance are based on the directional orientation of the transmission lines, their lengths, the electrical Direct Current resistance of the transmission [27]
In the regions with highest regional conductivity we would expect the most severe consequences under CME impact for electric networks [28]. In Europe conductivity of earth is high on south coast of North and Baltic seas. (*Figure 14*)
America (USA) did an analysis of the risk of damaging the power grid, and Europe does not. If will be in future the CME with range over past from 1921, similar as in 1859 or which doesn't in 2012, the damage of European electric network will be huge. Based on report of OCED [27] and [28], is possible to see, that under CME with high energy in middle Europa can generate an induced current, which thus the high earth conductivity in this area can do a huge demolition in electric network system (*Figure 14*).

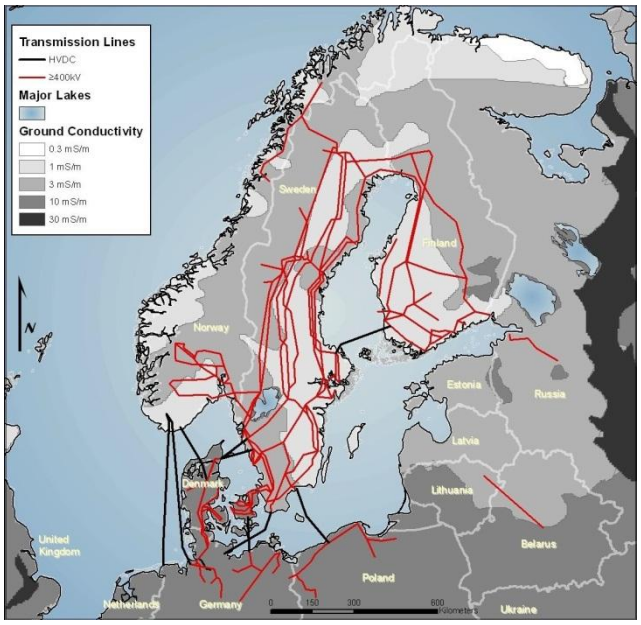

Figure 14. Comparison of localization the main electrical lines in Europe with the ground conductivity as a vulnerability of European electric power grids to geomagnetic storms [28, p.29]

Currently transformers are directly grounded points zero. Under time of geomagnetic storm that could become a source of GICs, flowing to the network from the ground. However prevention entering GICs into the network through a combination of Grounding is the best long-term solution.
The challenge of building new systems caused protecting for transformers is create a path, which automatically celebrating capacitor during downtime and allow the flow of high value to the land of the AC [24]. Next possibility that is [20]:
- large capacitors to protect transformers at power plants, which are the elements of your critical power systems,
- adaptation the energy networks so that they can be quickly and safely turn off the alarm after the announcement of the sun.

5. Summary

Desire to build over European energy network requires raising safety measures for CME. As for the technical solutions lashing before moving generated during a magnetic storm GIC. It can arise in any country. we are unable to predict the time and force the next coronal mass ejection in the sun.
Since 2002 ESA has Pilot Project, "Real-time forecast service for geomagnetically induced currents." The goal of the project is a Develop a forecast service to be used by electrical power companies that mitigate the effects of geomagnetically induced currents (GIC) Caused by the space weather [42].
Preparation of new solution for transformers of big power would may be a new path for European Framework Programme. This could develop new construction of the fast circuit breakers for high voltage and new construction of effective grounding systems for electric apparatus. In 2014 British Government decided that The Met Office open a new forecast center dedicated to so-called "space weather" that means the solar storms can have disruptive influence at the surface of Earth [4].
In my opinion, should expand its scope of operation for the whole Europe. A possible thanks to this event will be the goal of rapid response before CME for securing data grids and telecommunication networks, mobile telephony, internet before power loss.
I think that is possible to start of build a new construction of transformers with full return path, and power grid with fourth cable as a back power-line. but these new construction can generate increasing of cost of transmissions of electric power.
Solution for this is creation by TSO and DSO the "islands of powering", similarly as now are the local small power plants inside center of cities which may powering a close regions or develop the source of electric power, (as an electric backup system) from small renewable energy resources with small power, to powering important few public offices for safety and health (hospitals, water supply and canalization to protect before epidemic from grubby (cholera or hepatitis) [22].

The situation of August 2012 can repeat. We are unable to predict or stop it. The safety problem of electrical network activity from the Sun's CME's should be discussed for reliability of the electric grid infrastructure in the Poland.

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