FLICKERS - CAUSE, IMPACT ON THE ENVIRONMENTAL AND MITIGATION

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ABSTRACT

This paper describes the routine activities to the customer power quality reclamations in flickering appearance of incandescent light bulbs with during the long period of time, where the appearance coincided with new customer connecting to the consumption areas – Electrodistribution Sremska Mitrovica, which covers the territory of two municipalities, Sremska Mitrovica and Šid, at about 1449 km2 and with about 125,000 inhabitants. The customer, EAF plant, installed capacity of 50 MW, is the direct cause of interference - flickers. The paper describes the cause and place of origin effects, extent and impact of flicker phenomena, are described of measurements, the results of measurements and the standards in this area, given the proposal to overcome the problem. The measurements were performed at voltage levels 110 kV, 20 kV and 0.4 kV in wide area. Measured the impact and extent of flicker by voltage levels from 110 to 0.4 kV and the geographical territory, in different locations and consumption of substations 110 / x kV in the near vicinity, with about of 44,500 customers.

By analysing the measured results, during two years almost, and comparison with national and international standards we find the impact level of flickering expressed on a wide area, the region where the customer, STATCOM installation is suggested.

INDICATION THE SOURCE

Problems in the territory part Elektrovojvodina began to notice in October 2010 when the number of complaints on the power quality increased and the common denominator was the appearance of flickering incandescent bulbs. Because a large area was affected by this phenomenon, power quality measurements were taken at several points. Our intention was to check the power quality parameters – flickers. Flicker, as impression of unsteadiness of visual sensation induced by a light stimulus, the luminance or spectral distribution of which fluctuates with time, has the greatest impact on the functioning of the human brain. The response of the human eye has the characteristic of a band-pass filter between 0.5 Hz and 35 Hz, with maximum sensitivity to the luminous flux at a frequency around 8-9 Hz. For incandescent light sources, voltage fluctuations of circa 0.3% of the average value are detected at this frequency. Physiological effects depend on the amplitude of luminous flux changes, the frequency spectrum and the disturbance duration. The brain response to the light stimulus has an inertial characteristic with a time constant of circa 300 ms, meaning that slow changes of luminous flux are followed and fast changes are 'smoothed'. For instance, two short changes in the luminous flux, occurring within 300 ms, are perceived as a single change. Short changes of luminous flux, followed by a longer pause, are more annoying. The phenomenon of flicker is more dominant in the periphery of the visual field than in those areas on which the observer's attention is focused. The voltage fluctuation necessary to produce perceptible flicker is independent of the type of supply voltage (ac or dc) used for the lamp.

The major negative effects can be observed as a disorientation, vertigo, and nausea - inducing effect of a strobe light flashing at 1 Hz to 20 Hz, approximately the frequency of human brainwaves (the Bucha effect). The effects are similar to seizures caused by epilepsy (in particular photosensitive epilepsy), but are not restricted to people with histories of epilepsy. During a standard EEG recording intermittent photic stimulation is significant for the detection of photosensitive patients. Photo paroxysmal discharges, which are often generated in the occipital regions, indicate a genetically determined photosensitivity and may occur in more than 1% of healthy subjects. During the time one is exposed to this phenomenon, it can be a trigger for an epileptic seizure. Photosensitive epilepsy (PSE) is a form of epilepsy in which seizures are triggered by visual stimuli that form patterns in time or space, such as flashing lights, bold, regular patterns, or regular moving patterns. Flicker vertigo is an imbalance in brain-cell activity caused by exposure to low-frequency flickering (or flashing) of a relatively bright light

Fig. 1 The affected area

Because of the very serious impact this phenomenon has on human health, we got down to measure. In Fig.1 can see geographic affected area.

MEASURING

When we started with the measurements we wanted to monitor the occurrence of propagation of flicker on different voltage level and geographic distribution. We pointed at the customer with 50 MW electric arc furnace, near by the power station 400/220/110 kV, as a potential flickers' source, according to the connection date. The EAF plant is connected with 110 kV busbar by power line which is long 5-6 km (Fig 1). Power distribution network which consists of power transformers 110/35 kV, 110/20 kV, 35/10 kV, 20/0.4 kV and 10/0.4 kV, with different length of power lines, fiders, with different number of distribution power stations x/0.4 kV, used for flickers' mitigation.
Measurements by voltage level at different distances from the source give us very important informations about flicker's mitigation through distribution network.
Measurement was under IEC 61000–4–30 class A equipment with wavelet transform as a mathematical tool for analysing, which guarantees high accuracy of the results obtained.
Electric arc furnaces are known to produce voltage fluctuations or flicker, especially during random arc behaviour during meltdown of the charge. Voltage fluctuation should be observed as a result of reactive power's fluctuations, which is expressed. We can notice it in Fig 2. – active and reactive power in delivery point (billing measure device).

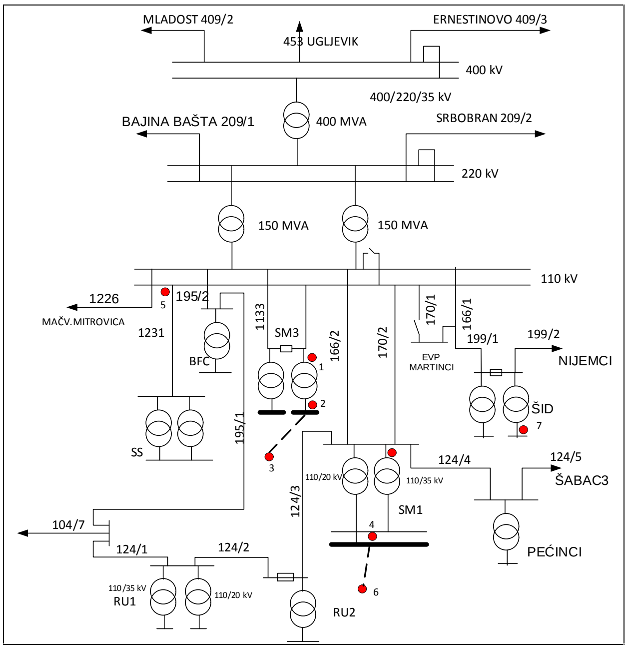

Fig. 2 Measuring points

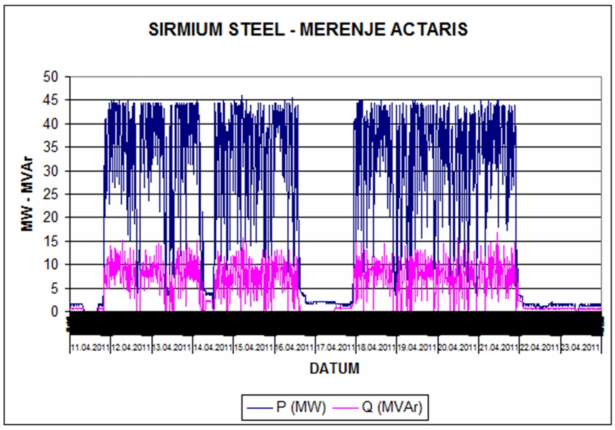

Fig. 3 EAF P(MW) and Q (MVAr)

Reactive power, as the fast-time variable, is the main cause of voltage fluctuations, in addition to the negative impact on equipment operation, may be a serious problem when it comes to human health.
This disturbance caused by the flicker is a function of perception intensity and duration of exposure and is expressed by two parameters: the short-term Pst (measured during 10 min) and long-term Plt (measured during 120 min (1)), according EN 50160, IEC 6100-3, with a note that was passed, SRP EN 50160 in 2008.

$$Plt = \sqrt[3]{\sum_{i=1}^{12} Pst_i^{\,3} / 12} \qquad \text{………………..} \ (1)$$

Power analysers (512 points/period, 4U, 3I) were set and measurements were continued for almost 2 years.

RESULTS 1

Next figures give us some results in the same period as billing diagram, where we can see P, Q.

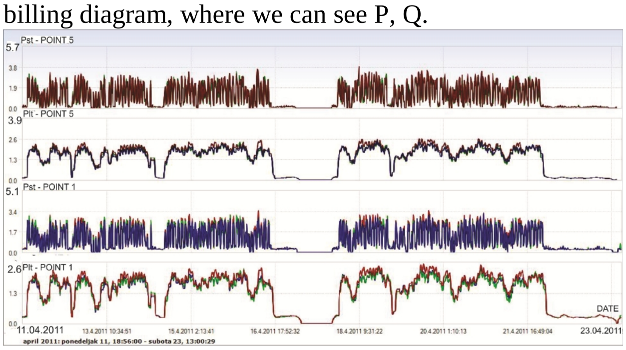

Fig. 4 Pst and Plt measure in point 5 and point 1

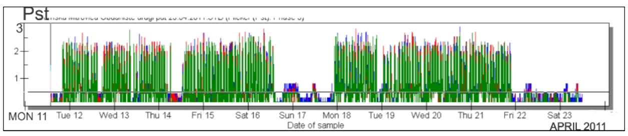

Fig. 5 Pst – Power station 20/0.4 kV

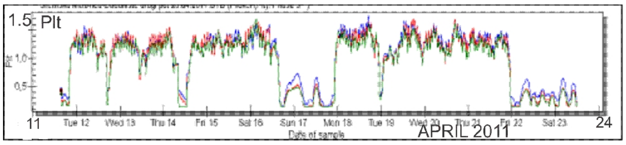

Fig. 6 Plt – Power station 20/0.4 kV

We can notice a great similarity between diagrams. This is very strong evidence, explanation where flickers were born. We can find that Pst reaches the highest value in point 5 (nearest EAF – 5 – 6 km from), Pst ≈3.8, then in point 1 (9-10km), Pst ≈ 3.4, voltage level 110 kV. In low voltage network, measure „by depth“, in power station 20/0.4 kV, at 0.4 kV busbar, Pst ≈ 2.8. Results with Plt are very similar: from Plt≈2.6 (110kV) to Plt≈1.5 (0.4 kV).

As we can see: the given results of measurements of flicker value exceeds the permissible limits. We must recall that the allowed values are, according to EN 50160: $P_{lt} < 0.8$ $P_{st} < 1$. These results were used as the basis for negotiations on overcoming problems related to flicker.

Because of the fluctuations P and Q, and specific unbalanced technological cycle of EAF, there is a problem with furnace performances (Fig. 7) – these unbalance induces large active and reactive power variations and decrease the active power transfered to scrap.

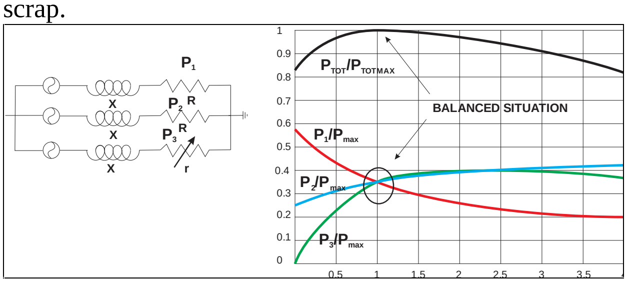

Fig. 7 Unbalance affects the furnace performance

These fluctuations induce flicker effect on the power network (2)

$$\Delta V = R\frac{\delta P}{3V_0} + X\frac{\delta Q}{3V_0} \quad .... \quad (2)$$

It is necessary to observe that the customer had fixed capacitor bank for compensation and a reactive filter for suppression of the third harmonic. As part of the activities undertaken, the goal was to stabilise voltage and to reduce electrical disturbances on power network. It was necessary to rapidly and accurate compensate the large reactive power fluctuations and load unbalancing in all melting phase.

SOLVING PROBLEMS

The STATCOM is a new type of Static VAR compensator that thanks to its faster response time of reactive power control facilitates a maintaining of higher voltage grid reducing the flicker effect at its minimum value. (Fig. 8.)

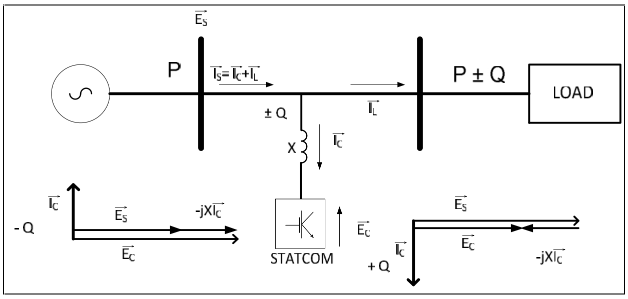

Fig. 8 STATCOM

This is very simplified block diagram, otherwise STATCOM product based on VSC modular multilevel topology and large area of press pack IGBT/IEGT devices, with coupling transformer, capacitor modules, power modules, cooling subsystem, etc… After starting STATCOM plant measurements were taken, at the same points, as before.

RESULTS 2

Because of the same presentation results, here is the billing diagram in the same way as before. (Fig.9.)

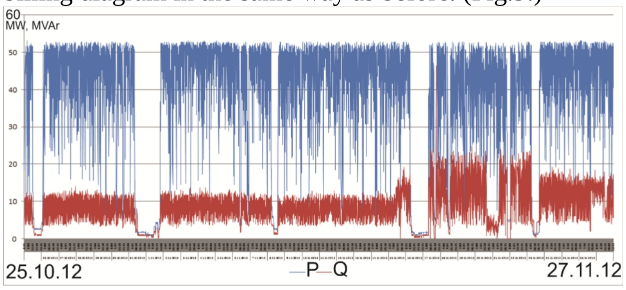

Fig. 9 P-Q diagram (billing)

In Fig.10. 11. and 12. we can see what’s happening with flicker’s parameters when STATCOM is on.

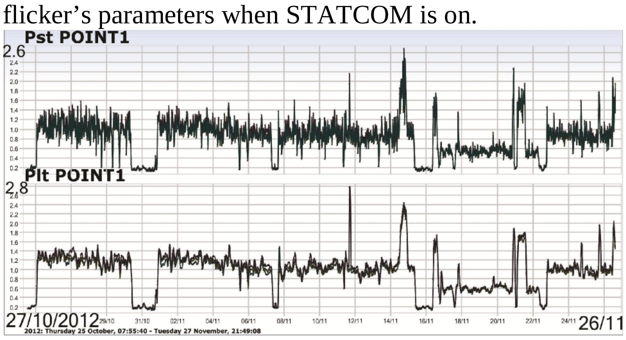

Fig. 10 Pst and Plt – 110 kV

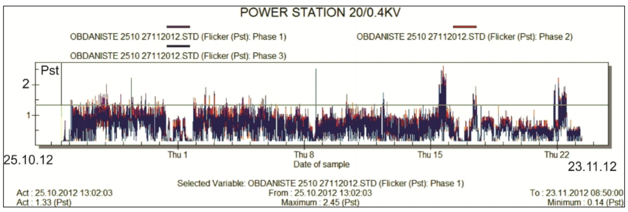

Fig. 11 Pst – 0.4 kV

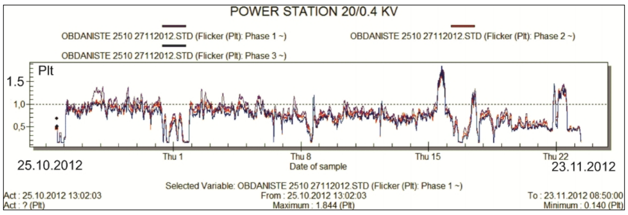

Fig. 12 Plt – 0.4 kV

These diagrams at the beginning, when STATCOM started, indicate the flicker mitigations. Presented interval is from 25.10. to 27.11.2012. We can notice three subintervals: from 25.10. to 17.11. from 17 to 23.11. and from 23.11. to 27.11.2012. In the first period Pst = 1.2 – 1.4, Plt = 1.2 – 1.4, at 110 kV voltage level, Pst≈1, Plt≈1 at 0.4 kV voltage level. This is period with very good reactive power compensation, flicker mitigation is not good enough. The second interval is period of very good flicker's mitigation: Pst ≈ 0.6, Plt ≈ 0.6 at 110 kV voltage level, Pst and Plt < 0.5 at 0.4 kV, but reactive power is increasing. The third period is attempting to balance between reactive power' compensation and flicker's mitigation. Pst and Plt ≈ 1. STATCOM device is under fine tuning, in the condition of testing software up to day.

CONCLUSION

This factor of power quality is very dangerous for human's brain, his influence was felt in a wide area, measurements are extensive and long-term, troubleshooting is very expensive and requires a very high adjustment of equipment.

Flicker's mitigation and propagation depends on the position of the source of disturbance in the high voltage grid and during the design and connection customer like this must be taken of the potential impact on the environment - it's a cheaper solution.

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