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INFLUENCE OF THE THERMAL POWER PLANT WITHDRAWAL ON 110 kV NETWORK STEADY STATE

BY

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Abstract. Energy policy must take into account the conservation of primary non-renewable energy and the protection of environment. The paper presents an analytical approach for determining the influence of classical thermal power plant temporary or permanent withdrawal for retrofitting, on voltage level and power losses, in 110 kV distribution networks. A study case for a real distribution network is provided at the end of the paper.

Key words: distribution network; steady state; thermal power plant.

1. Introduction

The humanity global problems regarding the food ensuring, the pronounced increase of population, the energy crisis, environmental protection and conservation, concerns more and more people, from ordinary people to specialists from the international scientific community. The environment preserving and protecting are problems induced by accelerated development of human society. The sustainable development concept was evolved, covering today the economic, social and environmental objectives.

The energy policy is defined as that part of the economic policy that treats power supply, conversion, distribution and use. Energy policy must take into account the conservation of primary non-renewable energy and the

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protection of environment (Bostan *et al*., 2007; Georgescu *et al.*, 2012; Godfrey, 2004; Istrate *et al.*, 2000). Presently, the energy resources are coal, hydrocarbons (petroleum and natural gas); water, wind and solar; nuclear fuels; biomass. In a globalized economy, the energy strategy of a country is realized in the context of current developments and changes (Arion, 2004; Cogălniceanu *et al.*, 1998). This topic has been also studied by researchers worldwide, by using analytical approach (Friederich *et al.*, 2002) and artificial intelligence approach (Deshpande *et al*., 2012).

In the paper, the influence of classical thermal power plant temporary or permanent withdrawal (for retrofitting) on voltage level and power losses, in 110 kV distribution networks are studied.

2. Power, Environement and Climate

An exhaustive approach of environmental engineering is doomed from the beginning; the authors have focused on the environmental impact of power and heat production, transport, distribution.

Today, the humanity has entered in a new power era, characterized by continuously increase of energy prices and climate change threats. Globally, the power supply sector generates over 60% of greenhouse gases (GHG), emissions, representing one of the main causes of climate change (Bostan *et al*., 2007; Negulescu *et al*., 1995).

The material and social consequences concerning the climate change is manifested in a prominent way, on the economy, health and all inhabitants' life and the environment. For example, global warming forecast with 1.8,…,4.0°C until 2,100 could lead to seas/oceans rising with 18,…,59 cm. The climate change caused by GHG in power supply sector is considered as „the greatest and widest-ranging market failure regarding the market economy of all times", constituting a major threat to world economy (Arion, 2004; Bostan *et al*., 2007; Negulescu *et al*., 1995).

However, in addition to the GHGs, the monoxide and dioxide carbon (CO, CO_2), sulfur dioxide (SO_2) and nitrous oxides (NO_x), also exert an extremely negative impact on the environment, causing the so-called acid rains. Another negative effect generated by fossil fuels burning is the penetration in atmosphere of radioactive substances such as thorium and uranium.

Consequently, the conventional energy sources based on hydrocarbons combustion performs also a strongly negative influence on the environment and human health. These conventional energy sources based on fossil fuels increase the pressure on the environment, affecting at the same time, the climate.

The aforementioned aspects are at the base of increase confidence regarding the alternative energy sources, known in the literature as sources of renewable energy (SRE), non-conventional or clean energy for improving energy efficiency. The SRE are as follows: solar energy, thermal energy, wind energy, hydraulic energy, geothermal energy, bioenergy.

Conventional fossil fuels and nuclear are energy storage sources being inevitably exhaustible sources of energy. Unlike these, the SRE are "energies obtained from the environment resources, having a continuous and repetitive character" (Bostan *et al*., 2007; Georgescu *et al*., 2012; Leca *et al*., 1997). The energy obtained by combustion of conventional fuels flows in an open circuit, and contributes to the environment pollution with various GHG emissions. In the case of SRE usage the energy flow in a closed circuit, because according to the energy conservation law, the quantity of energy remains unchanged, maintaining the thermal balance of the environment, this one not being affected.

In this sense, the European Commission proposed a set of documents, i.e. the EU Energy Policy, whose the main objectives are: the reduction of GHG emissions by 30% by 2020 compared with 1990; the increase of the renewable energy sources from 7% in 2006 to 20% in 2020; the increase of bio-fuels to at least 10% of all fuels by 2020; the reduction of primary energy consumption by 20% through a improved energy efficiency, in the reference year (2020). According to the objectives specified in the EU White Paper, the electricity produced from SRE in Europe in 2010 is presented in Table 1.

Table 1
The Potential for Renewable Energy in the European Union

Renewable Energy Sources	Electricity, [TWh/year]
Eolian	80.0
Hydro:	355.0
✓ High power	300.0
✓ Low power	55.0
Photovoltaic	3.0
Biomass	230.0
Geothermal	7.0
Total	675.0

In the literature (Bostan *et al*., 2007; Georgescu *et al*., 2014; Ionescu *et al*., 1997) some predictions on global energy consumption worldwide have been made for the period 1970,...,2030 for the main energy sources (Fig. 1).

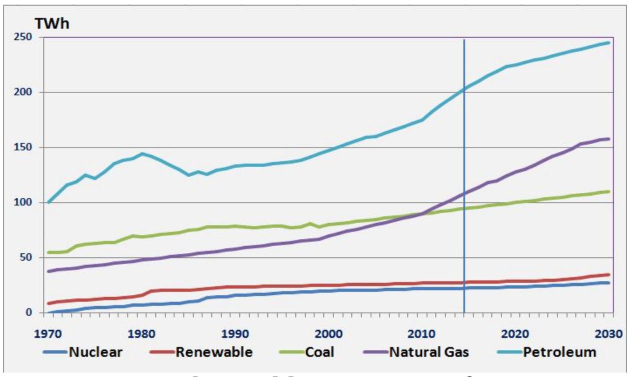

Fig. 1 – The world consumption forecast between 1970,…,2030.

3. The Influence of Thermal Power Plant Withdrawal from Operation on the 110 kV Networks Steady State

The power system consists of all electricity sources, electrical transmission and distribution networks and final users, having a single operating state. Essentially, this single state is influenced by the system configuration, by power balance and the operating characteristics of the whole system. The transport and distribution of electricity are accompanied by the occurrence of voltage drops and power losses with values between 10% and 15% of electricity produced in all power plants.

Power flow, voltage level and power losses computation allows an objective assessment of power quality, of the cost of electricity transmission and distribution, and a rational operation of various power networks etc.

In Romania, due to power sector privatization, the energy market development already has been separated from administrative point of view in electricity transmission (high and very high voltage) and distribution (high, medium and low voltage) activities. The separation was performed at 110 kV power networks. Usually, the thermal power plants (TPP) were placed in urban areas, to supply the thermal energy to the industrial, administrative, social - cultural and residential users. As mentioned above, the classical TPP with electricity and heat generation have a negative impact on the environment caused by greenhouse gas emissions. In this context, the most polluting TPP are those using solid fuel (coal), followed by those using liquid fuel (fuel and oil). A low environmental impact exercises the modern coal heat plants (CHPs) that use natural gas.

In the majority towns from Romania, the TPP installations and the heating urban systems are usually old (30,...,40 years), outdated technologies leading to reduced operating efficiencies and a high price both of electricity and heat supplied to final users. Lately, the high price of heat determined a big number of users to choose alternative heating solutions for homes or other spaces. The typically adopted solution was the apartment thermal plants (ATP) which use, frequently, the natural gas. However, this alternative solution is suitable for urban areas with a low user density. For downtown areas with a high user density, the ATP has a number of disadvantages, such as: high pollution of the environment without the reduction possibility; explosion caused for an inadequate operation and the lack of supervision by qualified personnel.

In the past decades, the majority of TPP from Romania (used for thermal energy production in form of hot water and heat) were not upgraded or retrofitted, the used primary energy is high, and the centralized heating systems have low yields and relatively high heat losses, leading to a continuous increase of the heat price for final users. In this context, the TPP become increasingly ineffective, and some of them were partially or permanently withdrawn from operation, to improve their technologies (refurbishment) or decommissioning.

In the paper, the theoretical results obtained by simulation of TPP partially or permanently withdrawn from operation on distribution networks steady state were analyzed. Thus, for a real distribution network (110 kV) the following main aspects were tracked: the active and reactive power flow for peak load in power lines and transformers; all elements loading at peak load; the voltage level in all network buses (high and medium voltage) at peak load; power and energy losses at peak load on network overhead lines and power transformers. Moreover, the absorbed power from the electricity transmission network at peak load was analyzed.

4. Study Case

For the proposed analysis, a real 110 kV power distribution network from Iasi, Romania was considered. The single line diagram of the 110 kV analyzed system is shown in Fig. 2.

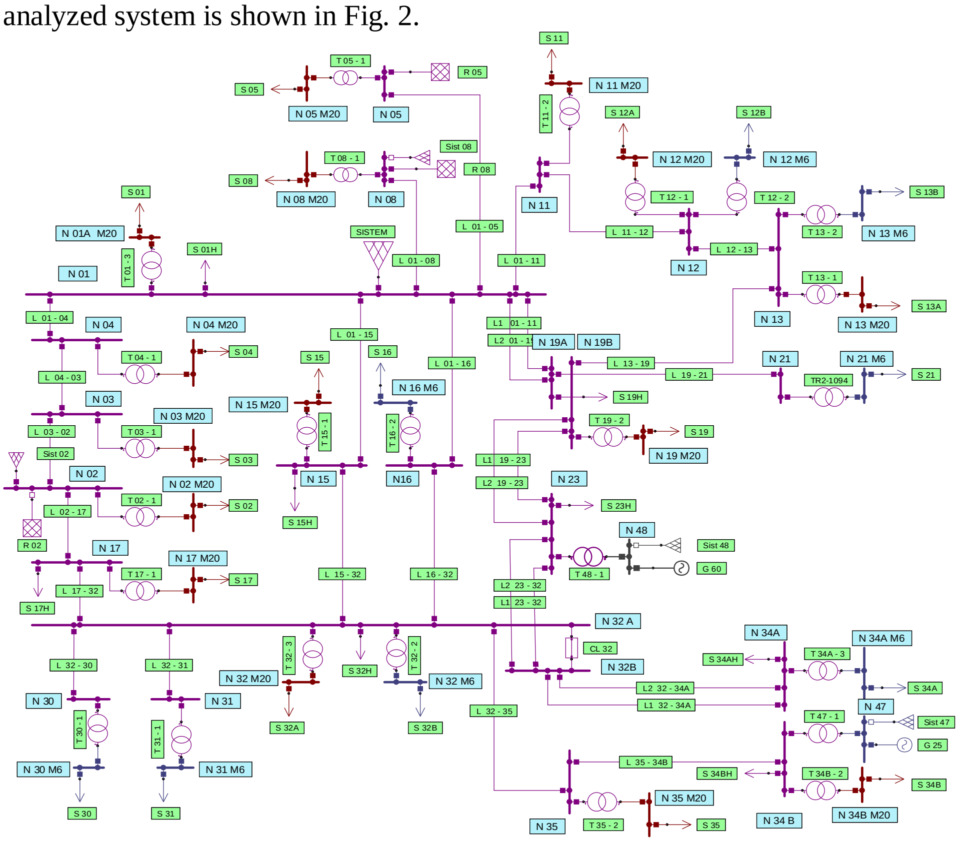

Fig. 2 – Single line diagrams of analyzed distribution network (110 kV).

The 110 kV considered network is supplied with electricity from two local TPPs (G60 and G25) and from national power system, and contains 39 single or double circuit overhead lines, and a total of 22 step-down stations equipped with one or two power transformers. Theoretical simulations from the proposed scenarios deem out of service (partial or permanent) the two TPPs, one by one or simultaneously.

For the steady-state analyzes of proposed 110 kV network NEPLAN (Newton - Raphson method) software was used. In addition to active and reactive daily load curves the input data necessary for power flows computation refers to topological and material characteristics of all components, *i.e.* power lines and power transformers.

For this purpose, the considered scenarios are the following:

a) Scenario 1 – the real operation case when the network is supplied with electricity from the transmission network (national power system) and the two TPPs.

b) Scenario 2 – when the network is supplied with electricity from the transmission network and TPP 2, the TPP 1 being out of service.

c) Scenario 3 – when the network is supplied with electricity from the transmission network and TPP 1, the TPP 2 being out of service.

d) Scenario 4 – when the network is supplied with electricity only from the transmission network, the two TPPs being out of service.

Using the SCADA systems, the daily active and reactive load curves for each bus (medium voltage busbars of power transformer) were recorded (Neagu *et al.*, 2014). Analysis of daily load curves of cold winter state revealed that the most loaded working day was Wednesday, January 22, 2014.

The operating steady state of the network in the aforementioned four scenarios were performed for the 10^{oo} o'clock, corresponding to peak load from daily load curves in winter state.

Thus for all simulated scenarios the following results were obtained:

1º For each 110 kV overhead line: the active and reactive power flow; the active and reactive power losses, the line loading.

2º For each power transformer: the active and reactive power flow; the active and reactive power losses, the transformer loading, high and medium voltage in absolute and percentage values.

However, for an easy interpretation of the results for the three theoretical simulation scenarios (2, 3 and 4) and real simulation scenario (1) the main results are summarized in Table 2; the notation represent: TPP – thermal power plant; P/Q – active/reactive power; $\Delta P/\Delta Q$ – active/reactive power losses; Imp – imported; Gen – generated; Cons – consummated; L – lines, T – power transformer.

Table 2

Results for Scenario 1 (Real Case) and Scenarios 2-4 (Theoretical Cases)

No. of scenario	P_{Imp} MW	Q_{Imp} MVar	P_{Gen} MW	Q_{Gen} MVar	P_{Cons} MW	Q_{Cons} MVar	ΔP MW	ΔQ MVar	ΔP_L MW	ΔQ_L MVar	ΔP_T MW	ΔQ_T MVar
1	57.301	19.919	184.801	59.479	182.803	54.788	1.954	6.353	0.592	–15.653	1.362	22.007
2	72,814	26,732	184,299	58,292	182,324	54,67	1,975	5,269	0,682	–15,388	1,293	20,657
3	112,168	39,355	183,668	53,915	181,476	54,458	2,167	1,074	1,113	–14,134	1,054	15,208
4	127,868	46,799	183,368	53,359	180,99	54,34	2,432	0,655	1,464	–13,093	0,968	13,748

For the analysed network, there is a series of active and reactive power flow changes regarding the overhead lines in the three theoretical simulation scenarios (2, 3 and 4) as opposed to real case (scenario 1). Thus, in Table 3 are reviewed only overhead lines which indicated significant changes of power flow at peak load, for all proposed scenarios. For these overhead lines the current flow and loading factors compared to the admissible current from thermal point of view are specified.

Table 3
Current Flow Variation and Loading Factor on 110 kV Overhead Lines

No. crt.	110 kV line name	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
		I A	Loading %	*I* A	Loading %	*I* A	Loading %	*I* A	Loading %
1	L 01-06	22	4.43	50	10.35	113	23.35	143	29.57
2	L 01-04	39	8.0	32	6.69	22	4.52	18	3.41
3	L 04-03	46	9.48	41	8.45	30	6.26	26	5.35
4	L 03-02	79	16.06	74	15.16	62	12.77	57	11.65
5	L2 19-23	57	11.77	38	7.75	18	3.61	37	7.73
6	L1 23-32	72	14.77	92	18.95	3.0	0.68	23	4.81
7	L2 23-32	72	14.77	92	18.95	3.0	0.68	23	4.81
8	L 17-32	73	17.42	79	18.87	92	21.94	99	23.46
9	L 01-08	16	3.32	16	3.32	20	4.11	20	4.11
10	L 11-12	59	14.06	99	23.46	209	49.84	250	59.52
11	L 01-11	105	25.03	144	34.40	255	60.74	296	70.40
12	L 35-34B	39	8.12	46	9.39	41	8.44	45	9.30
13	L 32-35	14	2.99	72	14.86	16	3.32	71	14.71
14	L 12-13	35	7.16	8.0	1.55	117	24.11	157	32.46
15	L 13-19	88	18.20	49	10.03	63	13.01	103	21.33
16	L 16-32	8.0	1.65	23	4.79	85	17.58	115	23.79
17	L 15-32	12	2.48	10	1.97	20	4.13	28	5.81
18	L 01-15	16	3.22	24	4.94	42	8.59	48	9.84
19	L1 19-23	58	12.06	39	8.05	18	3.75	39	8.02
20	L 02-17	145	34.45	151	35.93	164	39.06	170	40.3

Clearly, the change of active and reactive power flow on overhead lines produce inevitable the active power losses variations. The variation of these active power losses in overhead lines, power transformers and to the entire system are shown in Table 4 and graphically in Fig. 3.

Table 4
Active Power Losses (MW) for Analysed Network, in the Four Proposed Scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
110 overhead lines	0.592	0.682	1.113	1.464
Power transformers	1.362	1.293	1.054	0.968
TOTAL	1.954	1.975	2.167	2.432

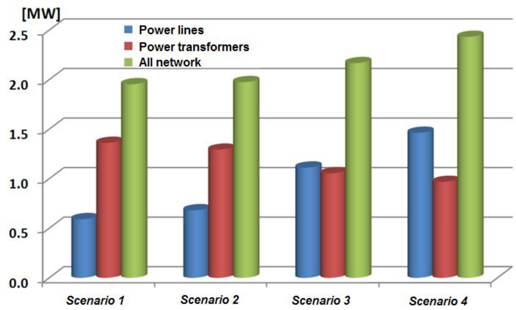

Fig. 3 – Active power losses for analysed network,
in the four proposed scenarios.

In Fig. 4 are presented the voltage variations in absolute and percentage values only for three buses (13, 19B and 31) in the four proposed scenarios.

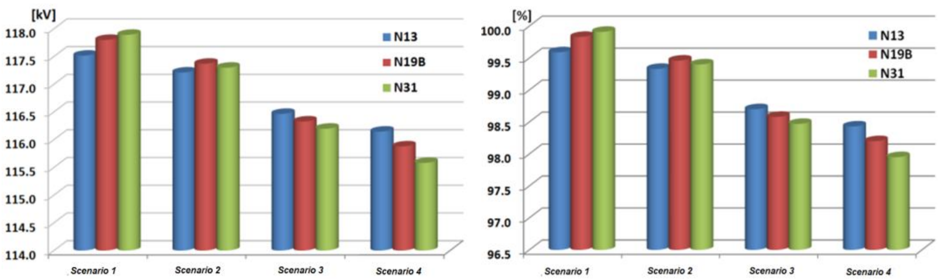

Fig. 4 – Voltage variation only for three network buses.

The analyzed distribution system is supplied with electricity through FAI power station, equipped with two autotransformers (220/110 kV) with apparent power of 200 MVA. In normal steady state, only one of autotransformers is in operation, the second being cold reserve. By analyzing the results of the four proposed scenarios, in Table 5 the active and reactive power imported from the transmission network is indicated. In all three theoretical simulated scenarios, the imported powers are higher than in real case (scenario 1).

Table 5

The Active and Reactive Power Imported from Transmission Lines through FAI Station

Scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4
P, [MW]	57,301	72,814	112,168	127,868
Q, [MVAr]	19,919	26,732	39,355	46,799

Apparent power taken from transmission network does not exceed the rated power of the autotransformers from the FAI station, but the load increase in autotransformer, the active power losses also will increase in the winding, namely: 38.83% (scenario 2); 73.95% (scenario 3); 80.15% (scenario 4).

5. Conclusions

In Romania, the TPPs from majority cities are old, being frequently out of service, with effects both in high voltage distribution network and transmission network.

After analyzing the results, the following conclusions were drawn:

a) the active/reactive power flows and loading factors are changed on each 110 kV overhead lines. In all analyzed scenarios, the overhead lines loading do not exceed the admissible current;

b) the voltage variation in all distribution network buses, both at high and medium voltage, at peak load are within allowable limits according to current Romanian regulations;

c) the partial or total withdrawal from service of TPPs has led to increased power losses in the 110 kV overhead lines.

The active power losses in transmission network are different in the last three proposed scenarios (2, 3 and 4), compared to the real case (1).

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INFLUENȚA RETRAGERII UNOR CENTRALE ELECTRICE DE TERMOFICARE ASUPRA REGIMURILOR DE FUNCȚIONARE ALE REȚELELOR DE 110 kV

(Rezumat)

Politica energetică trebuie să țină seama de conservarea energiilor neregenerabile şi de protecția mediului înconjurător. Lucrarea prezintă o abordare analitică pentru determinarea influenței retragerii temporare sau permanente din funcționare, în vederea retehnologizării, a unor centrale electrice de termoficare locale asupra nivelului de tensiune şi a pierderilor de putere/energie în rețelele publice de distribuție a energiei electrice de 110 kV. În partea finală a lucrării este prezentat un studiu de caz pentru o rețea reală de distribuție.