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Thermal Regulation in Interconnection of Thermal Plant Steam Circuits: Case of Three Thermal Power Plants of Burkina Faso Northern Ouaga Production Service (Sptn)

Madjoyogo Herve Sirima[1], Bétaboalé Naon[2], Frédéric Bationo[1]

[1]Mechanization Department, Institute of Research in Applied and Technological Sciences, National Center for Scientific and Technological Research, Ouagadougou, Burkina Faso

[2]Study and Research Group in Mechanics, Energetics and Industrial Technics, University Institute of Technology, Nazi BONI University, Bobo – Dioulasso, Burkina Faso

Email address:
madjoyogo2@yahoo.fr (M. H. Sirima), betaboale@yahoo.fr (B. Naon), hervemadjoyogo@gmail.com (F. Bationo)

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Abstract: This work is carried out as part of the thermal regulation of our interconnection system. The boilers and steam circuits of the National Electricity power plants have a potential for recoverable steam. The practical aspect of this study is the thermal regulation of the interconnection system in order to avoid against pressures that can lead to catastrophic risks. This thermal regulation not only has adverse consequences, but also optimizes steam demand and the use of Distillate Diesel Oil (DDO). In this work we have described the thermal control device by a programming in GRAFCET and LADER. This is made possible by identifying different pressures and temperatures. In the light of this study, it is clearly established that the thermal regulation remains not only protective system but also optimization of DDO and Heavy Fuel Oil consumption.

Keywords: Thermal Regulation, Programming, Grafcet, Lader, Pressure, Temperature

1. Introduction

The interconnection network of the vapor circuits requires protections [5]. The essential role of these is to prevent system installations from the harmful effects of abnormal conditions occurring in the system. These include elevations of pressure and temperature of different boilers. The objective of this work is the development of a regulation system [3, 6, 9] allowing a good follow-up of the interconnection of the remote steam circuits, the use of steam at full load to the overheating of HFO and the study of the influence of certain parameters on the kinetics of superheating and the quality of this product.

2. Materials and Methods

a) Choice of interconnection devices

Protection is provided by two functions:

1) Detection by sensors;
2) Cut-off following any detection by circuit breakers or thermal relays.

i. Detection of defects

La Protection will be by protection relay. The role of the protection relays is to detect any abnormal phenomena that may occur on a steam circuit. The objective is the elimination of defects to limit thermal stress [10, 4, 11, 7] which is among other very high pressures and temperatures exceeding the operating standards and mechanical stresses (flow turbulent, bent flow, etc....) [5] to which these defects subject the equipment. This elimination is obtained by isolating the smallest possible part of the network where a defect appeared.

ii. Connection of relays

The beginning of the protection chain consists of the sensors of the electrical quantities. The protection relays are located between the measuring reducers which provide them with the quantities to be monitored.

Protection against abnormal pressures and temperatures:

A constant time thermal relay is placed on the outlet of each steam manifold of the different boilers for overload protection. This relay allows, in case of need of steam by a group ready to be started, with a suitable setting of the delay to obtain an opening of the steam manifold outlet of another operating genset without impairing the other installations from the power station.

b) Pipes with very low thermal conductivity coefficient

We have heat transfer by conduction with a hollow cylinder.

The thermal conductivity will be deduced taking into account the distances separating the three thermal power stations. Given the large distances separating the three thermal power stations, it would be important to have a very low coefficient of conductivity [14, 8, 13] to avoid the formation of a considerable volume of condensates during the transfer. *"Confers λ calculation."* To do this, we will take the smallest power and the greatest distances. This is the power of the DEUTZ group and the distance between the DEUTZ plant and the BWSC & MAN plant [15].

Doubles of the approximate distances separating the three Centrals are among others:

DEUTZ ⟷ WARTSILA ⟹ 180 m

DEUTZ ⟷ BWSC&MAN ⟹ 500 m

WARTSILA ⟷ BWSC&MAN ⟹ 260 m

$$\emptyset = 2\pi l\lambda \frac{\Delta T}{Log\left(\frac{R2}{R1}\right)} \Longrightarrow \lambda = \emptyset \frac{Log\left(\frac{R2}{R1}\right)}{2\pi l\Delta T}$$

$$\lambda = 490000 \times \frac{Log\left(\frac{10}{7,5}\right)}{2\pi \times 500 \times 494,15}$$

λ =0,0394 W/m.K

$\emptyset$: Power in Watt (W)

λ: Coefficient of thermal conductivity in W/m.K

l: Distance between two of the three thermal power stations in m

ΔT: Steam temperature in Kelvin (K)

R1: Inner radius of steam duct in mm

R2: Outside radius of the steam duct in mm

We therefore need a pipe of thermal conductivity λ = 0.0394 W/m.K or a pipe whose thermal conductivity is close to this value.

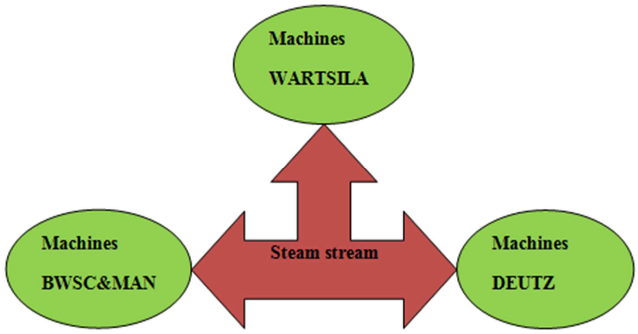
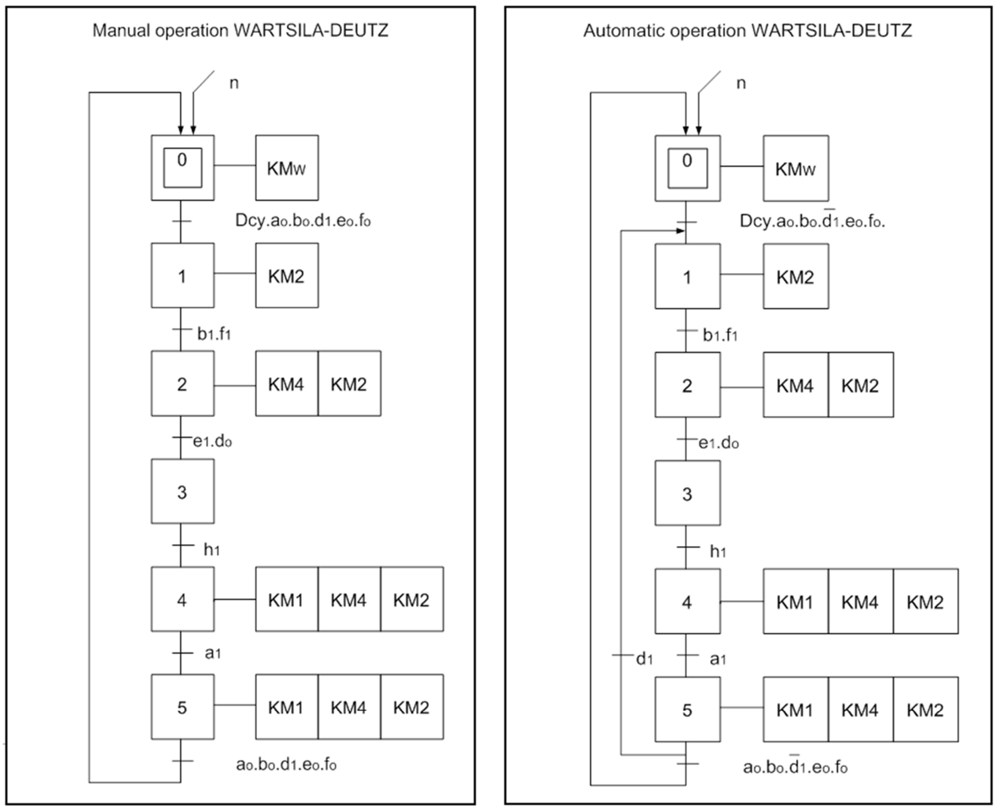


Figure 1. *Simplified interconnection of steam transfer streams.*

3. Results and Discussion

a) The GRAFCET of proposed system (Manual Start and Auto Start

The programming in GRAFCET [12] is carried out taking into account the generating set which was started in first position. That is to say if it is the DEUTZ Generator or the WARTSILA Generator or the BWSC & MAN Generator.



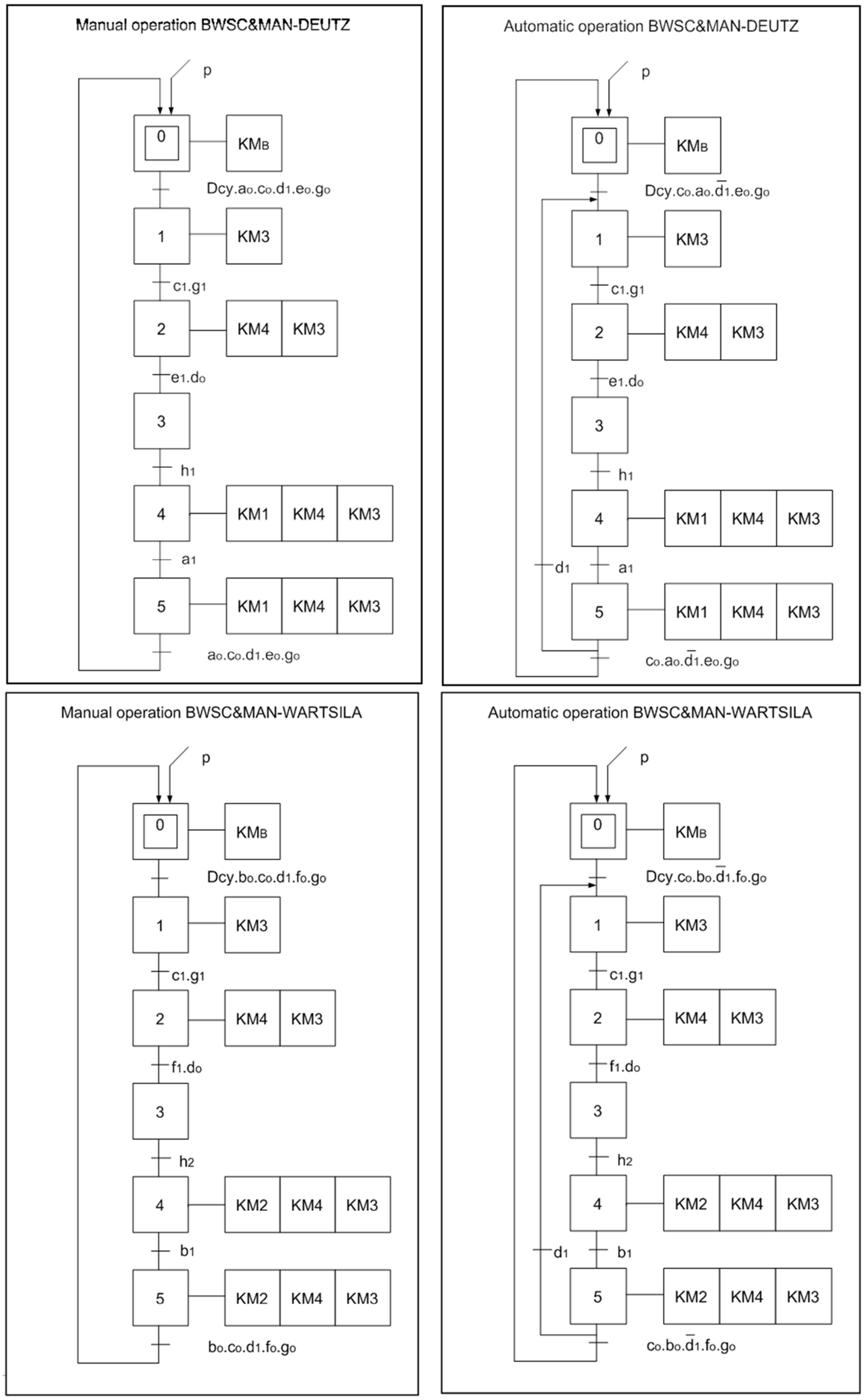


Figure 2. *Grafcet of interconnection system of steam transfer streams.*

Table 1. *Actions and commands.*

Actions	commands
Pregraissage DEUTZ	KM_D
Pregraissage WARTSILA	KM_W
Pregraissage BWSC&MAN	KM_B

Actions	**commands**
Start of generator DEUTZ	KM1
Start of generator WARTSILA	KM2
Start of generator BWSC&MAN	KM3
Closing the interconnecting conduits	KM4

Table 2. *Information and sensors.*

Informations	**Sensors**
Initialization DEUTZ	m
Initialization WARTSILA	n
Initialization BWSC&MAN	p
Generator DEUTZ working	a_1
Generator DEUTZ stopped	a_0
Generator WARTSILA working	b_1
Generator WARTSILA stopped	b_0
Generator BWSC&MAN working	c_1
Generator BWSC&MAN stopped	c_0
Closed conduits	d_1
Open ducts	d_0
Steam Presence Recommended Level DEUTZ	e_1
No steam DEUTZ	e_0
Steam Presence Recommended Level WARTSILA	f_1
No steam WARTSILA	f_0
Steam Presence Recommended Level BWSC&MAN	g_1
No steam BWSC&MAN	g_0
HFO DEUTZ overheated	h_1
HFO WARTSILA overheated	h_2
HFO BWSC&MAN overheated	h_3

3.1. The Equations of Steps and Actions in Manual and Automatic Operation of the Grafcets [1, 2]

Table 3. *Activation and deactivation equations of different stages.*

Manual operationDEUTZ-WARTSILA(DW) and DEUTZ-BWSC&MAN(DB)	
Stages equations	Actions equations
$E_0 = (m + E_5*d_1 + E_0)*\overline{E_1}$	$KM_D = E_0$
$E_1 = (E_0*dcy*a_0*b_0*c_0*d_1*e_0*f_0*g_0 + E_1)*\overline{E_2}$	$KM1 = E_1+E_2+E_3+E_4+E_5$
$E_2 = (E_1*a_1*e_1+ E_2)*\overline{E_3}$	$KM2 = E_{4DW}+E_5$
$E_3 = (E_2*f_1*d_0 + E_3)*\overline{E_{4DW}}$; $E_3 = (E_2*g_1*d_0 + E_3)*\overline{E_{4DB}}$	$KM3 = E_{4DB}+E_5$
$E_{4DW}=(E_3*h_2+E_{4DW})*\overline{E_5}$; $E4_{DB}=(E_3*h_3+E_{4DB})*\overline{E_5}$	$KM4 =E_2+E_3+E_{4DW}+E_5$
$E_5 = (E_{4DW}*b_1+E_5)*\overline{E_0}$; $E_5 = (E_{4DB}*c_1+E_5)*\overline{E_0}$	$KM4 = E_2+E_3+E_{4DB}+E_5$
Automatic operation DEUTZ-WARTSILA(DW) and DEUTZ-BWSC&MAN(DB)	
Stages equations	Actions equations
$E_0 = (m + E_5*\overline{d_1}*a_0*b_0*c_0*e_0*f_0*g_0 + E_0)*\overline{E_1}$	$KM_D = E_0$
$E_1 = (E_0*dcy*a_0*b_0*c_0*\overline{d_1}*e_0*f_0*g_0 +E_5*d_1+E_1)*\overline{E_2}$	$KM1 = E_1+E_2+E_3+E_4+E_5$
$E_2 = (E_1*a_1*e_1+ E_2)*\overline{E_3}$	$KM2 = E_{4DW}+E_5$
$E_3 = (E_2*f_1*d_0 + E_3)*\overline{E_{4DW}}$; $E_3 = (E_2*g_1*d_0 + E_3)*\overline{E_{4DB}}$	$KM3 = E_{4DB}+E_5$
$E_{4DW}=(E_3*h_2+E_{4DW})*\overline{E_5}$; $E4_{DB}=(E_3*h_3+E_{4DB})*\overline{E_5}$	$KM4 =E_2+E_3+E_{4DW}+E_5$
$E_5 = (E_{4DW}*b_1+E_5)*\overline{E_0}$; $E_5 = (E_{4DB}*c_1+E_5)*\overline{E_0}$	$KM4 = E_2+E_3+E_{4DB}+E_5$
Manual operation WARTSILA-DEUTZ(WD) and WARTSILA-BWSC&MAN(WB)	
Stages equations	Actions equations
$E_0 = (n + E_5*d_1 + E_0)*\overline{E_1}$	$KM_W = E_0$
$E_1 = (E_0*dcy*a_0*b_0*c_0*d_1*e_0*f_0*g_0 + E_1)*\overline{E_2}$	$KM2 = E_1+E_2+E_3+E_4+E_5$
$E_2 = (E_1*b_1*f_1+ E_2)*\overline{E_3}$	$KM1 = E_{4WD}+E_5$
$E_3 = (E_2*e_1*d_0 + E_3)*\overline{E_{4DW}}$; $E_3 = (E_2*g_1*d_0 + E_3)*\overline{E_{4DB}}$	$KM3 = E_{4WB}+E_5$
$E_{4WD}=(E_3*h_1+E_{4WD})*\overline{E_5}$; $E_{4WB}=(E_3*h_3+E_{4WB})*\overline{E_5}$	$KM4 =E_2+E_3+E_{4WD}+E_5$
$E_5 = (E_{4WD}*a_1+E_5)*\overline{E_0}$; $E_5 = (E_{4WB}*c_1+E_5)*\overline{E_0}$	$KM4 = E_2+E_3+E_{4WB}+E_5$
Automatic operation WARTSILA-DEUTZ(WD) and WARTSILA-BWSC&MAN(WB)	
Stages equations	Actions equations
$E_0 = (n + E_5*\overline{d_1}*a_0*b_0*c_0*e_0*f_0*g_0 + E_0)*\overline{E_1}$	$KM_W = E_0$
$E_1 = (E_0*dcy*a_0*b_0*c_0*\overline{d_1}*e_0*f_0*g_0 +E_5*d_1+E_1)*\overline{E_2}$	$KM2 = E_1+E_2+E_3+E_4+E_5$
$E_2 = (E_1*b_1*f_1+ E_2)*\overline{E_3}$	$KM1 = E_{4WD}+E_5$
$E_3 = (E_2*e_1*d_0 + E_3)*\overline{E_{4WD}}$; $E_3 = (E_2*g_1*d_0 + E_3)*\overline{E_{4WB}}$	$KM3 = E_{4WB}+E_5$
$E_{4WD}=(E_3*h_1+E_{4WD})*\overline{E_5}$; $E4_{WB}=(E_3*h_3+E_{4WB})*\overline{E_5}$	$KM4 =E_2+E_3+E_{4WD}+E_5$
$E_5 = (E_{4WD}*a_1+E_5)*\overline{E_0}$; $E_5 = (E_{4WB}*c_1+E_5)*\overline{E_0}$	$KM4 = E_2+E_3+E_{4WB}+E_5$

3.2. Addressing

Table 4. *Identification of different elements of addressing.*

ADDRESSING					
Stages		**The entrances**		**The exits**	
DEUTZ		m	$\%I_{1.0}$	KM_D	$\%Q_{2.0}$
E_0	$\%M_0$	n	$\%I_{1.1}$	KM_W	$\%Q_{2.1}$
E_1	$\%M_1$	p	$\%I_{1.2}$	KM_B	$\%Q_{2.2}$
E_2	$\%M_2$	dcy	$\%I_{1.3}$	KM_1	$\%Q_{2.3}$
E_3	$\%M_3$	a_1	$\%I_{1.4}$	KM_2	$\%Q_{2.4}$
E_4	$\%M_4$	a_0	$\%I_{1.5}$	KM_3	$\%Q_{2.5}$
E_5	$\%M_5$	b_1	$\%I_{1.6}$	KM_4	$\%Q_{2.6}$
WARTSILA		b_0	$\%I_{1.7}$		
E_0	$\%M_6$	c_1	$\%I_{1.8}$		
E_1	$\%M_7$	c_0	$\%I_{1.9}$		
E_2	$\%M_8$	d_1	$\%I_{1.10}$		
E_3	$\%M_9$	d_0	$\%I_{1.11}$		
E_4	$\%M_{10}$	e_1	$\%I_{1.12}$		
E_5	$\%M_{11}$	e_0	$\%I_{1.13}$		
BWSC&MAN		f_1	$\%I_{1.14}$		
E_0	$\%M_{12}$	f_0	$\%I_{1.15}$		
E_1	$\%M_{13}$	g_1	$\%I_{1.16}$		
E_2	$\%M_{14}$	g_0	$\%I_{1.17}$		
E_3	$\%M_{15}$	h_1	$\%TM_1Q$		
E_4	$\%M_{16}$	h_2	$\%TM_2Q$		
E_5	$\%M_{17}$	h_3	$\%TM_3Q$		

4. Conclusion

The experimental study presented in this work is a contribution to improving the availability of full-load steam in order to optimize the overheating of HFO [15]. It saves considerable time on the duration of overheating and the permutation of the DDO to the HFO in order to save in terms of fortune.

Our interconnection system allows a considerable economic gain despite some shortcomings that we hope to improve very soon.

And afterwards, we first grasped the principle of operation of different boilers and steam circuits [15], and then we proposed a new model, of which, we were obliged to study the possibility of implementation.

Thus, we proceeded to the programming in GRAFCET and LADER, to the establishment of the equations of the steps and the actions in manual and automatic operation of the GRAFCETS.

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