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OPTIMIZATION OF THE STRUCTURES OF THE ELECTRIC FEEDER SYSTEMS OF THE OIL PUMPING PLANTS IN ALGERIA

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ABSTRACT
In Algeria, now, the oil pumping plants are fed with electric power by independent local sources. This type of feeding has many advantages (little climatic influence, independent operation). However it requires a qualified maintenance staff, a rather high frequency of maintenance and repair and additional fuel costs. Taking into account the increasing development of the national electric supply network (Sonelgaz), a real possibility of transfer of the local sources towards centralized sources appears.These latter cannot only be more economic but more reliable than the independent local sources as well. In order to carry out this transfer, it is necessary to work out an optimal strategy to rebuild these networks taking in account the economic parameters and the reliability indices.

1. INTRODUCTION
The reliability problem has always been one of the major concerns of electricians and manufactures for the design of electric feeder systems (E.F.S) of the industrial facilities. This problem is fundamentally importante in the E.F.S of the oil pumping plants (O.P.P) in Algeria where oil industry has always played a determinent role in its economic balance.
Now, the O.P.P. are fed with electric power by independent local sources. This type of feeding has many advantages (little climatic influence, independent operation). However, it requires a qualified maintenance staff, a rather high frequency of maintenance and repair and additional fuel costs.
Taking into account the increasing development of the national electric supply network (Sonelgaz), a real possibility of transfer of the local sources towards centralized sources appears. These latter cannot only be more economic but more reliable than the independent local sources as well. In order to carry out this transfer, it is necessary to work out an optimal strategy to rebuild these networks taking account the economic parameters and the reliability indices.
The oil pumping plants belong to the second category[1]. In order to ensure a high level of reliability of their E.F.S, two power supply sources are envisaged, one principal, the other of reserve.

2. SUGGESTED ALTERNATIVE FOR THE E.F.S OF O.P.P
The oil pumping plants belong to the second category[1]. In order to ensure a high level of reliability of their E.F.S, two power supply sources are envisaged, one principal, the other of reserve .The pricipal standard diagrams of the EFS are as follows (Figure 1):

3. MATHEMATICAL FORMULATION
It is known that the reliability of the E.F.S of the industrial installations is linked to the exploitation of the capital costs of these networks, the increase in reliability involves a reduction in the costs of unavaibility of the E.F.S costs more[2], this is why the criterion of the optimal structures of the the E.F.S. of O.P.P. could be formulated as follows[3]:

$$C_T = C_{T1} + CT_{unav} \longrightarrow min \qquad (1)$$

$$C_{T1} = C_{cap} + C_{exp} \ ; \ C_{exp} = C_{fe} + C_{losses} \qquad (2)$$

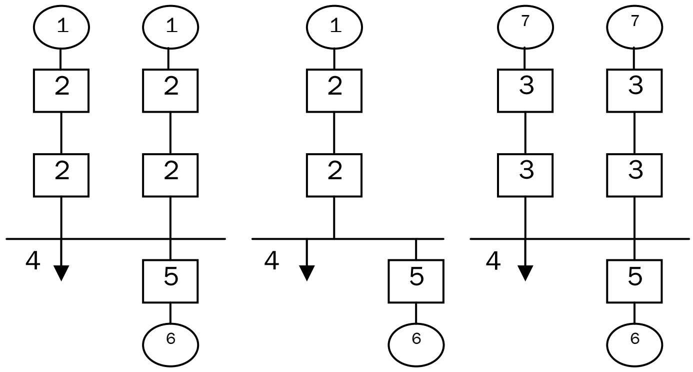

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Figure 1. Standard diagram of the EFS structures: 1.external source of the national network; 2. circuit breaker of line; 3.circuit breaker; 4.electric load;5.coupling circuit breaker of the source of reserve; 6.reserve source (electric diesel group);7.local source (turbo generator).

C_T : yearly total cost; C_{cap} : capital cost including the costs of the network and the stations;
C_{exp} : cost of exploitation; C_{fe} : cost of the electric invoice of power or fuel, this cost is formulated as follows [3]:

$$C_{fe} = C'_T \,.\, h'_T \,.B' \,.\, P' + C''_T \,.\, h''_T \,.\, B'' P'' \qquad (3)$$

C'_T ,C''_T :cost of fuel of the local and centralized sources (\$/T); h'_T, h''_T:annual time of use of the installations (h/years); B', B'' :annual average fuel consumption per kWh (T/kWh);P', P": annual average power (kW).
C_{losses} : losses of electric power in the lines, this cost is obtained as follows:

$$C_{losses} = \sum_{i \in M_{exist}} \frac{Co\ .Ti\ .Ri}{U_i^2 \cos\ \alpha_i^2} P_i^2 + \sum_{j \in Mnov} \frac{Co\ .Tj\ .Rj}{U_j^2 \cos\ \alpha_j^2} P_j^2 \qquad (4)$$

Co: cost per unit of kWh of the losses of power electric (\$/kWh); T:time of losses of power electric (h); R : active resistance of lines (Ω);U : voltage level of the electric network (kV);P:active power transmitted (kW); Mexist, M_{nov} : existing and lately build electric installations;Cos α : power factor.
CT_{unav} :cost of unavailability of the E.F.S in case of failure (\$).
The cost of unavailability of the E.FS of the O.P.P is formulated as follows :

$$C_{unav}=W_o.T_r \,.\, \delta_o \qquad \delta_o = g(C_g - C_p - C_t) \qquad (5)$$

W_o : frequency of stop of the oil pumps ;T_r : time of repair of the E.F.S in case of failure;
g : reduction in the volume of oil transported at the time of stop of the O.P.P.;C_g , C_p , C_t : cost of oil to export, cost of its production, cost of its transport respectively.
The frequency of stop of the oil pumps W_o and the time of repair T_r of the E.F.S in case of failure can be obtained on the basis of the semi- Markovian's processes [4]
Under operation, the E.F.S of the O.P.P. can have several states, on the basis of the semi-Markovian's processes, the evolution of the E.F.S operation can be described by the states and the probability of transition P_{ij} according Fig.3.

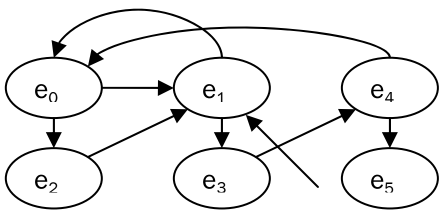

Figure 2. Semi-Markovian's processes and transitions graph.

E_o : PS under operation, RS in reserve; e_1: PS in repair, RS under operation; e_2:PS in failure, $t_{encl} > t_{adm}$;
e_3 : PS in repair, RS in failure; e_4 : PS under operation , RS in repair; e_5:PS in failure, RS in repair.
PS: principal source; RS, reserve source ; t_{encl} : time of interlocking of the reserve source; t_{adm} : acceptable time limits of interlocking of the reserve source .
The random values of the MTBF (middle time between failure) ξ_0 , ξ_1 as well the repair time η_0 , η_1

of the principal source and the reserve source respectively follow an exponential law [5] , $P_i(t)$, $G_i(t)$ with the parameters λ_i , μ_i (I = 0, 1).

The calculation probability P_{ij} of transitions between states could be calculated as follow :

$$P_{01}=1-q \qquad P_{02} = q \tag{6}$$

q : probability of failure of the circuit breaker of interlocking the reserve source.

$$q=P(t_{encl}>t_{adm})=1-F_{encl}(t_{adm}), \text{For } t_{encl}=\text{const and } D(t)=P(t_{adm}<t)=\frac{t-t_{adm\min}}{t_{adm\max}-t_{adm\min}} \tag{7}$$

$$q=\int_0^\infty [1-F_{encl}(t)]dD(t)=\frac{t_{encl}-t_{adm\min}}{t_{adm\max}-t_{adm\min}} \tag{8}$$

$F_{encl}(t)$: distribution law of the random value t_{encl}; D(t) : distribution law of the random value t_{adm}.

$$P_{10}=P\{\eta_0<\xi_1\}=\int_0^\infty G_0(t)dP_1(t)=\frac{\mu_0}{\lambda_1+\mu_0} \qquad P_{13}=P\{\eta_0>\xi_1\}=\int_0^\infty [1-G_0(t)]dP_1(t)=\frac{\lambda_1}{\lambda_1+\mu_0} \tag{9}$$

$$P_{40}=P\{\xi_0>\eta_1\}=\int_0^\infty [1-P_0(t)]dG_1(t)=\frac{\mu_1}{\lambda_0+\mu_1} \qquad P_{45}=P\{\xi_0<\eta_1\}=\int_0^\infty P_0(t)dG_1(t)=\frac{\lambda_0}{\lambda_0+\mu_1} \tag{10}$$

$P_{21}=P_{34}=P_{51}=1$

Knowing the existance distribution law $T_{ij}(t)$ in the state e_i at the time of the transition to the state e_j we determine the existence distribution law $F_i(t)$ and the existence mean time T_{ei} at the state e_i as follows

$$F_i(t)=\sum_{j=0}^{n} P_{ij}T_{ij}(t) \qquad T_{ei}=\int_0^\infty t\,dF_i(t) \tag{11}$$

$$T_{01}(t)=P\{\xi_0<t/t_{encl}<t_{adm}\}=1-e^{-\lambda_0 t} \qquad T_{02}(t)=1-e^{-\lambda_0 t}$$

$$T_{21}(t)=P\{t_{encl}-t_{adm}<t\}=\frac{t}{t_{adm\max}-t_{adm\min}} \qquad T_{10}(t)=P\{\eta_0<t/\eta_0<\xi_1]=1-e^{-(\mu_0+\lambda_1)}$$

$$T_{13}(t)=P\{\xi_1<t/\xi_1<\eta_0\}=1-e^{-(\mu_0+\lambda_1)} \qquad T_{34}(t)=P\{(\eta_0-\xi_1)<t/\eta_0>\xi_1\}=1-e^{-\mu_0 t}$$

$$T_{40}(t)=P\{\eta_1<t/\eta_1<\xi_0\}=1-e^{-(\mu_1+\lambda_0)t} \qquad T_{45}(t)=P\{\xi_0<t/\eta_1>\xi_0\}=1-e^{-(\mu_1+\lambda_0)t}$$

$$T_{51}(t)=P\{\eta_1<t\}=1-e^{-\mu_1 t} \tag{12}$$

We determine that:

$$T_{e0}=\frac{1}{\lambda_0}\ ;\ T_{e1}=\frac{1}{\mu_0+\lambda_1}\ ;\ T_{e2}=t_{encl}-\frac{t_{adm\max}+t_{adm\min}}{2}\ \ T_{e3}=\frac{1}{\mu_0}\ ;\ T_{e4}=\frac{1}{\mu_1+\lambda_0}\ ;\ T_{e5}=\frac{1}{\mu_1} \tag{13}$$

The stationary probabilities P_i of occupation at the state e_i can be given by solving the following system:

$$P_i=\sum_{j\in e} P_{ji}.P_j\ ;\ \sum_{i=0}^{5} P_i=1 \tag{14}$$

$$P_0=\frac{\mu_0(\lambda_0+\mu_1)+\mu_1\lambda_1}{(\lambda_0+\mu_1)[2(2\lambda_1+\mu_0)+q\mu_0]+q\mu_1\lambda_1}=\frac{\mu_0(\lambda_0+\mu_1)+\mu_1\lambda_1}{K}\ ; \qquad P_1=\frac{\mu_0(\lambda_0+\mu_1)+\mu_1\lambda_1}{K}$$

$$P_2=\frac{q[\mu_0(\lambda_0+\mu_1)+\mu_1\lambda_1]}{K}\ ; \qquad P_3=P_4=\frac{\lambda_1(\lambda_0+\mu_1)}{K}\ ; \qquad P_5=\frac{\lambda_0\lambda_1}{K}$$

The mean time between failures (MTBF) of the EFS can be obtained as follows :

$$MTBF=\frac{\sum_{e_n\in e_+} P_{e_n}.T_{e_n}}{\sum_{i\in e_+,\,j\in e_-} P_i.P_{ij}}=\frac{(\lambda_0+\mu_1)+(\lambda_1+\mu_0)(1+\mu_1/\lambda_0)}{q[\mu_0(\lambda_0+\mu_1)+\mu_1\lambda_1]+\lambda_1(2\lambda_0+\mu_1)} \tag{15}$$

P_{en} : stationary probability at state e_n; T_{en} : average time of occupation at state e_n; e^+ : states of good functioning of system; e^- : failure's states of system.

So the frequency of stop of the oil pumps W_0, Refer to "(19)," can be calculated as follows :

$$W_0=\frac{1}{MTBF} \tag{16}$$

The time of repair T_r of the E.F.S in case of failure is calculated as follows :

$$T_r = \frac{\sum_{e_n \in e_-} P_{e_n} . T_{e_n}}{\sum_{i \in e_+, j \in e_-} P_i . P_{ij}} = \frac{q[\mu_0(\lambda_0 + \mu_1) + \mu_1 \lambda_1] T_{e2} + \lambda_1(\lambda_0 + \mu_1)/\mu_0 + \lambda_0 \lambda_1 / \mu_0}{q[\mu_0(\lambda_0 + \mu_1) + \mu_1 \lambda_1] + \lambda_1(2\lambda_0 + \mu_1)} \quad (17)$$

The complete representation of the graph is definited algebraically using the matrix A_{ij} which is formulated as follows:

$$A_{ij} = \begin{cases} -1 \text{ if } (a_i, a_j) \text{ nodes bound by existing line} \\ 0 \\ 1 \text{ if if } (a_i, a_j) \text{ nodes bound by new line} \end{cases} \quad (18)$$

On the basis of matrix A_{ij} defining completely the structure of the diagrams of power supply of the O.P.P., it easy to determine the length of the feeder L_{ij} :

$$L_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (19)$$

During the presence in the E.F.S. of a j^{-rd} O.P.P. an autonomous source i^{-rd}, the length of the line is equal zero same if the j^{-rd} and i^{-rd} nodes are bound i.e. A_{ij} =1, L_{ij} =0.

The calculation of costs C_{T1} will thus be carried out as follows:

If A_{ij} = 1 and L_{ij} # 0, so the calculation costs C_{T1} is for the external source of the network, if A_{ij} = 1 and L_{ij} = 0 then the calculation of the C_{T1} is determined for the autonomous sources, in this case the losses of electric power are null, if A_{ij} = -1 and L_{ij} # 0 the calculation of the costs C_{T1} is made for the a existing lines, this cost includes only the losses of electric power.

When considering that the cost of the unavaibility depends on the structure alternative of the E.F.S of the O.P.P.,(Figure.1), it is necessary to determine the type of the structure alternative chosen, that can be possible from matrix A_{ij} and the N(i) operator, which fixes the number and the type of the source

If A(ij) = 1 and L(ij) #1 for the two s/system N(i) = 2, the cost of unavailability is calculated for the structure's alternative (Fig. 1a.).

If A(ij) = 1 and L(ij)=1 (1 s/system) and A(i,j) =1 and L(ij) = 0 (2 s/system) N(i) = 1, the cost of unavailability is calculated for the structure's alternative (Fig. 1b.)..

If A(ij) =1 and L(ij) = 0 for the two s/system N(i) = 0, the cost of unavailability is calculated for the structure's alternative (Fig. 1c.).

During calculation, it is necessary to take into account the following technical constraints:

1. the number of sources is limited to two.
2. The sources where the O.P.P. are dependent must have a sufficient power.
3. The length of lines should not exceed the length critized L_{cr} for a selected level of voltage.

4. CONCLUSION

The method presented makes it possible to determine the optimal structure's alternative of the E.F.S. of the O.P.P. taken in a single system (technological process and electric feeder system). This method doesn't take into account economic parameters but the indices of reliability as well.

In this context, a data-processing program was elaborate to offer best alternative of the electric feeder systems of the oil pumping plants. This program was been approved by the national company of oil and gas (Sonatrach) in Algeria. This work was supported by the ministry for the higher education and scientific research, contract code n° J3501/02/01/03.

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