An analysis of energetic cost for an irrigation network in France

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     ✓ Network Performance
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**Presentation of Carpentras Canal**

**Figure 1.** The considered area

a: France Map  
b: Vaucluse Department
Presentation of Carpentras Canal

- Mediterranean climate: hot, dry summers and mild, wet winters
- Source of water: the Durance dam and the Rhone river
- Length of main canal: 69 km
- Installation of the **ASA** of Carpentras canal and implementation of an irrigation gravity system: 1853
- Implementation of a pressurized irrigation network: 1975
- Irrigable area: 12000 hectares
- Number of members: 14000
- Irrigation practices: vineyards, olive trees, fruit trees, etc.
- Number of pumping stations: 34
- Number of storage tanks: 24
- Length of the underground piping: 1000 Km

**ASA**: Association Syndical Authorized
Problem Definition and Objective

Problem Definition

- Increased energy costs of pumping from 2008
- Network performance decrease

Objective

- Decrease of the energy bill (pumping cost)
The subject of the minimization of the cost of pumping has attracted the interest of several authors:

- Definition of number of pumps according the global operating time [1]
- Choice of pumps according the speed (fixed, variable) [2]
- Fault diagnosis (detection and location of water leaks) [3]
- Indicators that evaluate the energy consumption of a water supply system [4]

Methodology: Data Analysis

- **Available Data**
  - Demand
  - Electricity consumption
  - The farm units
  - The network structure

- **Analysis**
  - Demand Evolution
  - Water volume
  - Electricity suppliers’ billing
Available Data

- Demand (Number of members, Terminals watering, Irrigable area, Water volume pumped and billed)
- Energy consumption (detailed electricity consumption, detailed bills, contracts options of electricity suppliers, etc.)
- Units (pumps, piping, storage tanks, etc.)
  - Pumps (power, flow, HMT)
  - Pipe (diameter, length, type of material)
  - Storage tanks (capacity, height, form)
- Network structure: mesh, geographical position of members
Figure 2. Demand evolution in the pressurized irrigation network of Carpentras

Note: Constant evolution with an annual average of 2% for the irrigable area (120 ha) and 3.3% for terminals (329).
Figure 3. Evolution of volume of water consumed (m³) in the total network

Notes:
- Constant evolution with a slight decrease in the last years
- High consumption in 2003 and 2012 (hot and very dry years)
- Low consumption in 2008 (very wet year)
The pumped volume of water is based on the constant flow rate \( Q \) and the operating time of pump \( T \):

\[
V_p = Q \times T
\]

If \( T \) is unknown, it will be estimated by the ratio between the energy consumption \( E \) and the rated power \( P \) of pump [5]:

\[
V_p = Q \times \frac{E}{P}
\]

Analysis: Water Volume

Example for Validation

**Figure 4.** Load curve of « Brotteaux » pumping station during 2014
### Analysis: Water Volume

#### Example for Validation

<table>
<thead>
<tr>
<th>Seasons 2014</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps in operation</td>
<td>1 Pump</td>
<td>2 Pumps (mode alternate)</td>
</tr>
<tr>
<td>Rated power (P in kW)</td>
<td>90</td>
<td>400</td>
</tr>
<tr>
<td>Flow rate (Q in m³)</td>
<td>360</td>
<td>1000</td>
</tr>
<tr>
<td>Energy consumption (E in kWh)</td>
<td>21 220</td>
<td>275 281</td>
</tr>
<tr>
<td>Volume estimated (V in m³)</td>
<td>84 880</td>
<td>688 202</td>
</tr>
</tbody>
</table>

**Table1.** Data from a station equipped with a flow meter «Brotteaux»

**Notes:**

- The pumped volume of water registered by a flow meter is $75.10^4$ m³ in 2014.
- The estimated volume of water is $77.10^4$ m³ in 2014.

**Result:** There is a 3% difference between the volume of water pumped and estimated.
Figure 5. Evolution of the water volume registered an estimated « Grande Bastide »

**Result:** 57% of the water volume is pumped but not billed

**Possible Causes:** leaks, lack or dysfunction of water meters
Notes:
From 2002 to 2008: constant evolution of the bill (the average cost of a kWh with taxes is 0.037 €)
From 2009 to 2014: significant increase in bill (the average cost of a kWh with taxes is 0.067 €)
Figure 7. Evolution of the energy consumed (kWh)

Notes:
- Constant evolution with a slight decrease in the last years
- High consumption during 2003 and 2012 (hot and very dry years)
- Low consumption during the wet year 2008 (same trend as the volume of water)
- The evolution of the bill does not follow the evolution consumption from 2008
Analysis: Energy Bill

Evolution of the cost of kWh in ASA (France)

Figure 8. Evolution of the cost per kWh in ASA

Notes:
- The cost of one kWh increased with a significant way in ASA
- The cost of one kWh in Carpentras is above the average of others ASA

[6] Source CACG (Development Company for Gascogne): data collected from 51 collective irrigation structures in France
Many kinds of contracts: \( t_c \in T_c = \{ \text{Blue, Yellow, Green} \} \)

Many tariff versions: \( v_t \in V_t(t_c) = \{ \text{SU, MU, LU, VLU} \} \)

- SU : Short Utilization
- MU : Medium Utilization
- LU : Long Utilization
- VLU : Very Long Utilization

Many tariff periods: \( i \in I(t_c) = \{ 1, 2, 3, 4, 5 \ldots \} \)

- 1 : Rush Hours
- 2 : Winter Peak Hours
- 3 : Winter Off-Peak Hours
- 4 : Summer Peak Hours
- 5 : Summer Off-Peak Hours
...
Analysis: Energy Bill

Electricity billing in France

- Power subscribed by a tariff period: \( p_1 \in P_i(t_c) = \{p_1, p_2, p_3, p_4, p_5, \ldots\} \)

- Coefficient of reduced power: \( k \in K(t_c, i, v_t) \)

- The total bill is composed by a fixed prime, cost of consumed energy, cost of exceeded power and taxes:

\[
B_t = P_f(t_c, p_s, v_t) + C_E(t_c, E, v_t) + C_d(t_c, p_s, p_c) + \text{Taxes}
\]

In 2014: \( B_t = 23\% + 43\% + 10\% + 24\% \)
Hypothesis

Fixed kinds of contract (Green for example):
\[
t_c = t_c^o
\]

Subscribed power fixed:
\[
p_i = p_i^o = \{p_1, p_2, p_3, p_4, p_5\}
\]

Fixed prime:
\[
P_f = C_{vt} \cdot [p_1 + \sum_{i=2}^1 k_i^{vt} \cdot (p_i - p_{(i-1)})]
\]

Cost of consumed energy:
\[
C_E = \sum_{i=1}^1 E_i \cdot C_i^{vt}
\]

\[
B_t = C_{vt} \cdot [p_1 + \sum_{i=2}^1 k_i^{vt} \cdot (p_i - p_{(i-1)})] + \sum_{i=1}^1 E_i \cdot C_i^{vt} + C_d(t_c^o, p_s^o, p_c) + \text{Taxes}^o
\]
Simulation of the different tariff versions

**Result:** In this station, an optimal choice of the tariff Version (SU) may reduce the total bill about 16% between 2004 and 2014.
Conclusion

- Analysis of energy costs and network performance
- Optimization of contracts: tariff versions and subscribed power
- Expand network performance evaluation on all stations
- Control and monitoring of pumping station [7]
- Installation of hybrid systems for the production of renewable energy [8]

THANK YOU FOR YOUR ATTENTION