RURAL ELECTRICATION PLANNING SOFTWARE (LAPER)

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Synopsys

There is no doubt left about the benefit of electrication and subsequently the need for electricity services. Established utilities often tend to focus on the needs of urban areas, thus leaving rural areas apart. A small number of pilot projects in rural electrication have already been undertaken, but they had a short lifetime, due to a lack of technical and economical robustness or because local requirements had been met partially.

The LAPER software is a tool for sustainable rural electrication of vast regions. It uses all available geographical data, creates villages-types in order to be able to use standardised electrical equipment for electrication, and compares the costs of all possible solutions of electrication (i.e. mini-grids, diesel gensets, solar panels, small hydro- or windgenerators).
In the first step, geographical and socio-economical data are gathered for the GIS database. Typical villages are created by using the Village Type Manager.

The second step consists of specifying investment and operation costs related to the different means of electrication. In order to initialise the calculation code for the electrication masterplan, a network that connects all villages has to be drawn. This network is needed only as a starting point. The Optimum Network calculates the first draft of an optimal electrical design for the “all-network” solution.

In the next step, the costs of electrication by network, generator, photovoltaic, hydroelectric and wind power are compared within each village. If decentralised electrication is cheaper for a given village, verification is made that the increase in the network cost calculated for the other villages (caused by the non-participation of this village in the construction and maintenance of the MV-lines) does not exceed the gain generated by the decentralised electrication of this village. If it is established that, for at least one village, decentralised electrication is more advantageous, a new iteration has to be performed. This is due to the fact that, once one or more villages have been withdrawn from the network, the network cost per connected village increases. The comparison with decentralised modes must be carried out again.

The core of a village and his peripherals are not treated equally : the peripherals are always electrified by solar panels. At the end of this iteration, the costs sorted by year and village as well as the global costs of the electrication are given.

The last part of the program determines the order of electrication of the set of villages. The criteria taken into account can be political, technical and geographical.

The study strategy manager enables the user to simulate different economical situations or to run the program with different costs for electrication equipment.

At the end, a map containing the electrication mode of every village and the mini-grid left is drawn.

LAPER software not only provides costs of the electrication of vast rural regions but also guides the user in planning the electrication, and in choosing the suitable equipment for it, thus assuring sustainable development of rural electrication projects.

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ABSTRACT

Today, 40% of the world population need rural electrication (RE). The World Bank and other donors for RE-projects need a clear assessment of the viability and sustainability of the proposed electricity generation facility.
Electricité de France (EDF) and the French Agency for Environment and Energy Management (ADEME) have developed LAPER, a planning software using a GIS-based method for the electrication of vast regions. This program determines a masterplan using geographical data enhanced by socio-economic inquiries. After choosing the optimal means of electrication (MV-network, PV-panels, gensets, micro-windgenerators or micro-hydrogenerators) for each village, LAPER calculates an investment plan and an electrication schedule for the region, taking into account political, financial and geographical criteria.
The results are stored graphically and by tables in the GIS.

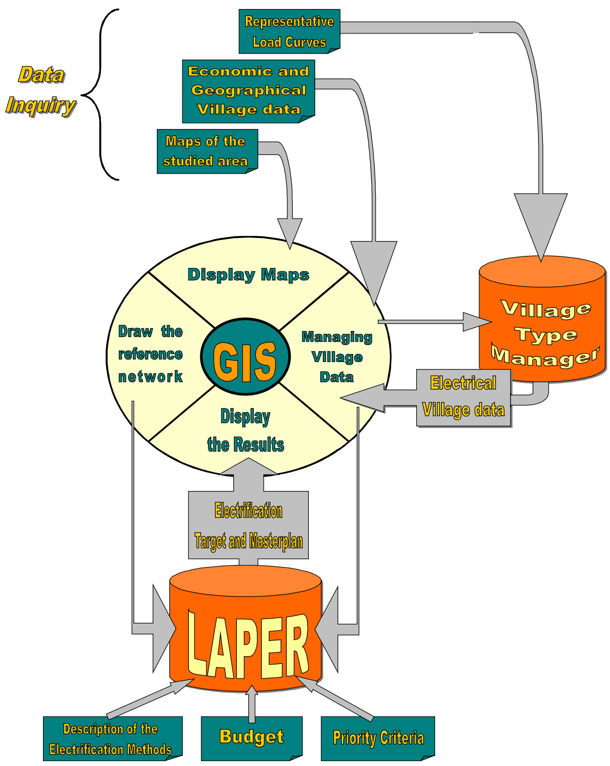
INTRODUCTION

Rural electrication has been increasingly at stake for many years. Today, a huge part of the population world-wide is still deprived of electricity, making it critical for governments of developing countries to ensure that energy supply spread over their territory, even in secluded areas. The recent evolution of planning softwares and the launch of products dedicated to rural development has raised opportunities of cooperation between these governments and western power distribution companies.
LAPER is one of those rural oriented planning softwares. It has been developed at EDF Research and Development, following a five year cooperation between EDF and the French Association for the Development and Management of Energy. Until now, several field studies have already been carried out with this product in the following countries : Madagascar, Morocco, Vietnam, Palestinian Territories, Egypt, Jordan.

Interactivity and flexibility are among the main characteristics of LAPER. We shall now present its features and its way of processing, which can be split into five steps :

1. Data collection : needs and means
2. Initial state design
3. Search for the optimal electrication pattern
4. Electrication schedule
5. Results

All those five steps are processed within two modules which are linked together : the GIS and LAPER module. Village data collection as well as the display of the whole area and characteristics are performed through the use of the GIS. The LAPER module is then used for the electrication data collection, the search for the optimal electrication pattern and schedule, and the calculation of all economic related figures (budgets, costs…).
Th following sketch provides an overview of the LAPER / GIS architecture :



The search of the optimal solution in LAPER consists in a step by step replacement – using alternative sources of energy - of the virtual power grid which as many villages as possible are initially connected to (taking into account all geographical constraints showed in the

GIS display). The first virtual grid is supposed to be designed by the user.

DATA COLLECTION

Needs

The final aim - a reliable electrication pattern - can only be achieved after all useful data have been gathered. Such data cover a wide scope of information and some of them have to be adapted before they become part of the process. Two parameters among them are of paramount importance :

- population classification according to load profiles
- evolution of energy consumption

The very first classification step consists in breaking consumers over three categories : Big Consumers, Collective Equipments and Standard Households. No doubt the consumption characteristics of these categories are fairly different, yet it is possible to reach a more detailed level of classification through specifying various consumption sub-categories for the Standard Households. Then, the user will indicate in the data sheet the proportion of Standard Households belonging to each pre-defined sub-category, for each and every village. Sub-categories features can be specified by the planner in the LAPER module.

Besides, since every village has undergone an in depth analysis prior to the planning study, the data sheet contains a significant amount of information, which can either be basic (situation, wind speed, distance to the nearest river…) or more complex (socio-economic study, consumption habits, main activity in the village…).

Means

Features related to electrication modes can be specified through the use of the LAPER module. The modes allowed are the following :

- **MV network**
- **Solar panels**
- **Hydroelectricity**
- **Fuel engine / wind power**

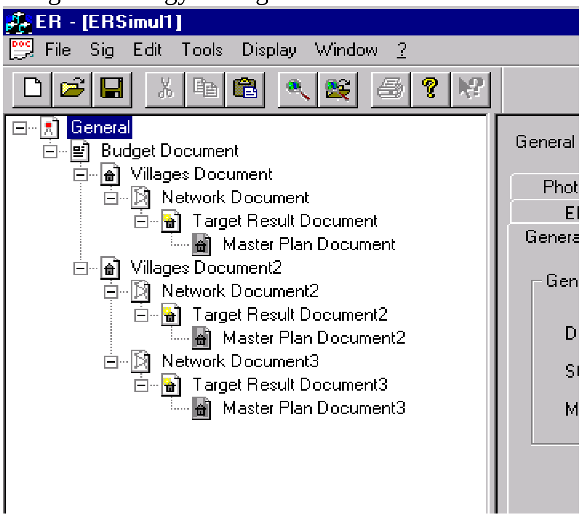
The LAPER module processes the calculation of all related costs, taking into account every parameter specified by the planner (costs per unit and performance levels). A clear difference is seen between investment costs and running expenses. MV and LV losses are part of the expenses calculation, except for hydroelectricity, since there is no fuel cost related to this mode.
Wind power is only considered here as an alternative for fuel generation. Whenever the cost / benefit ratio is proved to be favourable for wind power within a determined period in a village, the optimal solution for this village to be compared with other electrication means will be a combination of fuel and wind power. Else, only fuel generation will be compared to other means.

The total investment cost for every electrication mode (I_{LV}, I_{MV}, I_{hydr}, I_{pv}, I_{fuel}..) consists of the sum of investment costs of all related devices.
Besides, given that the lifetime may be different for every device (solar panels, LV control panels, batteries…) periodical renewing investments must be taken into account for the cost calculation. Since those devices may also become unable to cope with growing energy consumption before their time is over, periodical extension investments must be done and reported in the costs.

The total amount that is to be spend for the electrication project has to be specified by the planner in the LAPER module, as well as the annual available amount. We shall see later on how important the annual breakdown is.

INPUT FOR THE INITIAL STATE

The GIS provides the user with a direct access to the location of the villages and their respective geographical context (levelling of the ground, rivers, roads, etc…).
The planner may then draw what he considers as the most suitable power grid to which the maximum amount of villages can be connected. He may choose between several kinds of lines, since the main line is automatically set as a three phased one, and the secondary lines as single phased ones. The software then carries out an electric check of the designed grid. The power grid cannot grow during the study, since the process consists in trying to substitute dispersed generation facilities to the network. The grid that the planner initially designs is thus the largest possible. The following example is a study zone as seen through the GIS.
Several strategies may be tested within the same project, using the strategy manager as shown below :



SEARCH FOR THE OPTIMUM ELECTRICATION PATTERN

The optimisation algorithm is rather simple. It consists in minimising the global cost of the whole area's electrication. This cost consists of the sum of investments and running expenses. The sum covers the whole duration of the study period, as we consider that electrication is achieved at t = 0.

$F(T) = \sum_{t=0}^{T} \frac{A(t) + C(t)}{(1+i)^t}$, we use the annualised investment A(t) thus taking into account the fact that the life expectancies of devices are different and may exceed the duration of the study. We obtain this annualised investment for each device through multiplying the initial amount (I) by the annual factor corresponding to its life expectancy (D).

The exact formula is the following : $\frac{i \times (1+i)^D}{(1+i)^D - 1}$

As far as the MV network is concerned, each and every village bears the entire expenses incurred for lines to which it is the only one connected. Expenses for shared portions of lines are broken down according to the consumption of each village.

The first step consists of selecting the most economical dispersed mode of electrication for each village. Then, for every village which was initially connected to the network, the network is replaced by the selected dispersed mode (this is to be done whenever the selected dispersed mode is more economical than the network for a given village). The global cost born by every disconnected village will then dwindle, whereas the MV network expenses born by all villages that will remain connected will increase, since they may bear additional shared expenses formerly shared with the newly disconnected village. The global cost for all villages that are already supplied through dispersed generation remains, of course, unchanged. Hence we have to compare, at each step (whenever a given village i is disconnected), two possible costs for the whole community, :

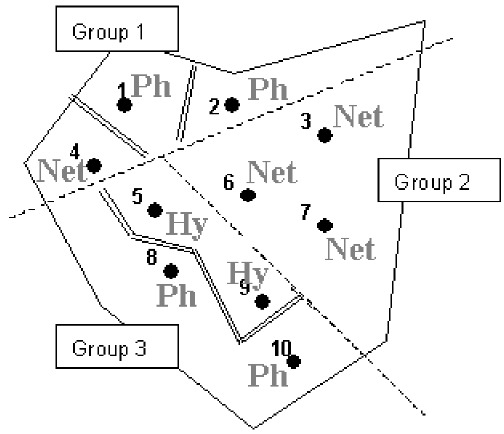
$F_1 = F_{network}^{all..villages.-.village..i} + F_{network}^{village..i}$

et $F_2 = F_{network}^{all..villages.-.village..i} + F_{dispersed..gen}^{village..i}$

A given village must switch to the appropriate dispersed generation whenever F1 is greater than F2. Once there is no reason left to disconnect any village, we consider that we have reached the final stage.
We then have to set an electrication schedule for the whole area.

ELECTRICATION SCHEDULE

During the first step, it was made possible for the planner to gather villages in separate groups (according to their characteristics). LAPER then splits these groups, so as to gather all villages that are supplied through the same generation mode.



Several criteria can then be taken into account so as to plan the electrication schedule. Each criterion's value may vary from given village to another one. The planner may also give a specific weight to each criterion. The criteria are the following :

The planner can set the value of the three following criteria :

- ***Political criterion*** ***($Crit_p$)***
- ***Financial resources criterion*** ***($Crit_s$)***
- ***Development criterion*** ***($Crit_d$)***

The value of the last two criteria is automatically set by LAPER :

- ***Financial criterion*** ***($Crit_f$)***

(distance between the village and the substation)

- ***Inter-region balance criterion*** ***($Crit_e$)***

(favours an homogeneous pattern of electrication : the fewer electrified subgroups a given group has, the higher the level of priority of these subgroups).

The last criterion may evolve each year, since its value depends on the ongoing pattern of electrication.
Noting p_s, p_f, p_e, p_p, p_d, the weights (ranging between 0 and 1) of each criterion, the annual criterion for a given village is :

$$Crit = p_s \cdot Crit_s + p_f \cdot Crit_f + p_e \cdot Crit_e + p_p \cdot Crit_p + p_d \cdot Crit_d$$

The amount of available financial ressources may also be a decisive factor, as far as the schedule is concerned. Each following step can only be reached provided that the resources are available. One or several years may pass without any village being connected to any mode of electrication. At the end of the period, some villages may also remain deprived of electricity.

RESULTS

At the end of the study, it is possible to check the characteristics of each and every village through

LAPER : date of electrication, electrication mode, investments, income, amount of supplied clients.
It is also possible to get the results for the whole area, or for a given year.

All results can be transferred from LAPER to the GIS, where a table will then be available with all characteristics of the final network. Besides, it is possible to visualise the whole area year after year.

Whenever new calculations are processed through LAPER, a new transfer can be achieved, so as to update all tables and maps of the GIS.

The map below is an example of what can be visualised through the GIS (every dot is a village, and the form of the dot indicates the electrication mode).