USING RENEWABLE ENERGIES FOR RURAL DECENTALISED ELECTRIFICATION IN DEVELOPING COUNTRIES

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ABSTRACT.

EDF is currently studying a diagnostic method aiming at defining the electrification policy of a large area of a country. That method will be especially fitted for countries which electrical system is still restricted to urban areas. Among the researches performed, a specific R&D effort is done to enhance the performance of photovoltaïc and wind energy systems and to define their role in the whole process. The undergoing work aims first at defining technical and economic criteria that could help authorities to decide between the building or the extension of a network and autonomous systems using renewable energies and second at designing low cost distribution network technology for highly populated areas and a range of standardised autonomous electricity production systems for villages remote from networks or scattered dwellings.

In 1996 and 1997, under EdF's pluri-annual R and D programme, aiming to develop a range of optimised systems using renewable energies for Rural Decentralised Electrification, a set of specifications called « specifications for the use of renewable energies in rural decentralised electrification » has been drawn up, in partnership with ADEME and the French photovoltaic industry. This work has been carried out by working groups involving all the main French players in the field of renewable energies.

Key words : 1 - Rural electrification, 2 - Renewable energies, 3, Developing countries

INTRODUCTION

In 1993, EDF the French utility and ADEME, the French governmental agency for Energy, signed an agreement on several topics. Two among them were :

- 1 - to improve Demand Side Management in France,
- 2 - to promote the use of Renewable Energies for supplying electricity to isolated sites in mainland France and also in French overseas departments.

Furthermore, EDF is increasing its international activities and, at the same time, half of humanity is yet awaiting electricity, economical development and improvement of it's quality of life.

So a project called « Energy for all » aiming at building Rural Decentralised Electrification programmes is underway at EDF, in parallel with an R &D programme.

Though the issues were numerous, it quickly appeared in 1995, when the project was prepared, that there was a lack of specifications both for the French programme and for the international activities of EDF.

There are few isolated sites in the developed countries due to the high level of development of transmission and distribution networks. The situation is very different in the developing countries, where half of humanity, i.e. almost two and a half billion people, are waiting for access to electricity. The electrification of these countries cannot be undertaken in the same way as in the developed countries, due to the massive investments which would be required. This electrification can, however, be achieved, within a reasonable period of several decades, by using new solutions. EDF offers a strategy and a method which are described in this document.

EDF has developed a planning method which makes it possible to take into account a country's overall electrification requirements, and to select which zones are to be electrified by means of a network and which by means of decentralised systems.

A specific R&D effort has been devoted to the task of refining this method. As regards rural regions, EDF is developing a solution involving decentralised systems using solar, wind, mini-hydraulic or conventional (diesel) energies. Moreover, a network service has been developed using more basic standards. By using a more basic mechanical system and also a more simplified electrical system (single-phase between phases network or dual phase), this solution means that the required energy can be supplied to scattered populations at a lower cost.

A TOOL TO ASSIST DECISION-MAKING

To develop an electrification policy for any given country, it is firstly necessary to take a long-term view (20 to 30 years ahead) of the electrification target which it is desired to achieve and then to put in place the means for achieving this target (the master plan).

In order not to arrive at an arbitrary separation of the two methods of electrification (decentralised and centralised), it is essential to adopt a global approach to such planning. As regards the decentralised component, this necessitates a village-by-village approach and the taking into account of various criteria - sociological, environmental and geophysical - in addition to purely economic aspects. This approach allows the requirements of a given village to be estimated year by year and allows them to evolve in accordance with the level of affluence and with economic development prospects. The housing conditions of each village are also important for determining the best electrification solution to be adopted and estimating the amount of the investments required.

In some cases, the installation of decentralised systems may constitute a pre-electrification stage pending the arrival of the network Figure 1). In this case, it must be possible to incorporate the system into the network once it arrives. It is therefore likely that an electrification solution made up of a local micro-network, associated with production sources based on renewable or conventional energies will be an attractive solution. When the network arrives, the sources can be transferred to a more remote village and the micro-network supplied with power via a transformer.

Such an electrification target can be presented today using geographical information systems (GIS). Each village is thus identified on a map of the country and colour coding can be used to indicate the method of electricity supply adopted.

The master plan, for its part, must enable the optimum date to be determined for carrying out the necessary works. The villages are classified by the decision-maker according to multi-criteria analysis methods (economic and political criteria etc.) for the purpose of planning the electrification works year by year or on the basis of five-year plans.

This entire process provides, period by period, a list of the villages to be electrified, the electrification method used (network, decentralised multi-user systems, decentralised single-user systems), the amount of investments required for each period and the number of structures to be built. These annual or five-year plans can be displayed by the GIS.

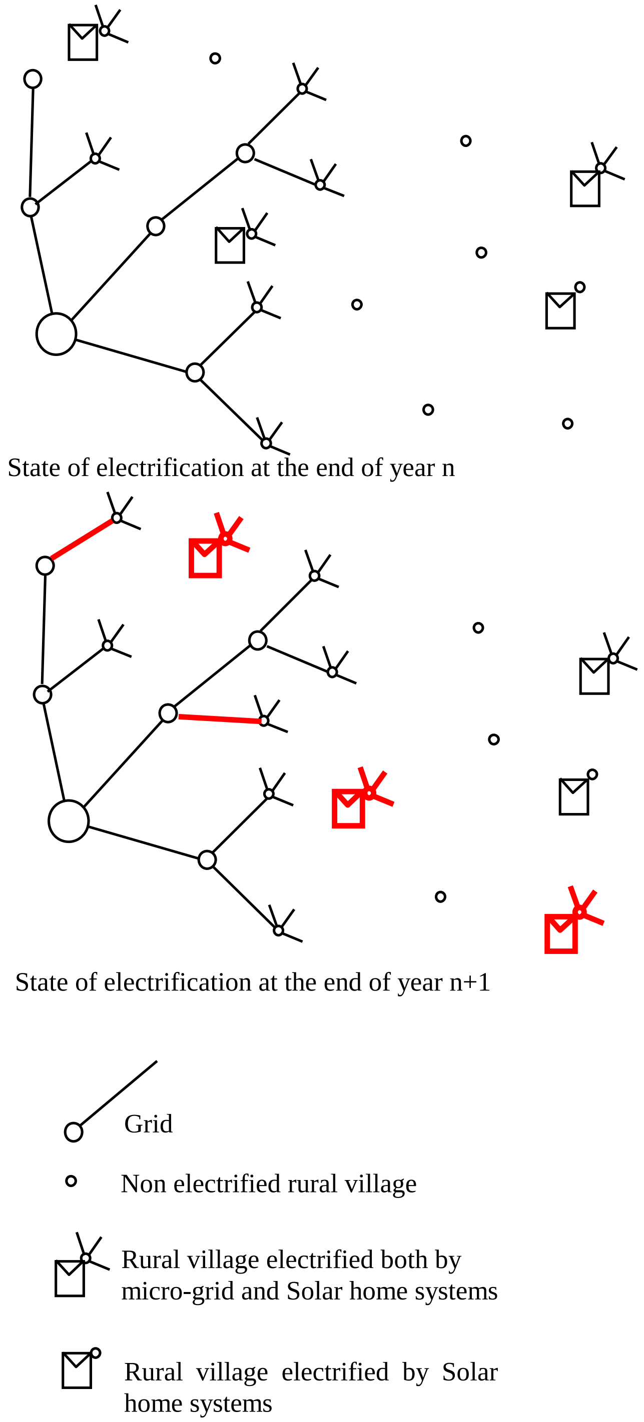

Fig 1 : Pre electrification by renewable energies, following the master plan

R&D TO ASSIST THE ELECTRIFICATION OF DEVELOPING COUNTRIES

A specific research and development effort is being applied by EDF to this subject. A project has been defined covering a three-year period with two main objectives: quality control for decentralised systems based on renewable energy and defining a range of systems able to meet the requirements of the largest number of users.

As far as quality control is concerned, EDF's R&D Division has implemented feedback procedures to measure the socio-economic impact associated with the use of this type of installation and to analyse any problems which may have arisen in previous years.

As regards the definition of a range of systems, EDF is firstly undertaking analysis to identify user requirements, both in the developed countries and the developing countries. This analysis will produce a typology of users and a range of products will be offered so that predefined systems are available which correspond to the most common profiles of use.

These measures are accompanied by the preparation of technical specifications and testing specifications intended to guarantee a predefined quality level for the equipment and systems to be installed in future years.

So that it can offer a full range of technical options, EDF has also developed a single-phase between phases (or dual-phase) network at a more basic standard for the electrification of rural areas.

Network services

The triple-phase networks used in our European countries are powerful but much too luxurious and thus too expensive for the electrification of developing countries. These countries are increasingly envisaging the use of single-phase networks. EDF has developed a single-phase between phases (dual-phase) network concept comparable to the North American-type networks.

A comparison of these two concepts reveals that, for an equivalent or even lower cost, the French network protection system is simpler and thus easier to operate and maintain, thus increasing its reliability.

In the French system, transient single-phase faults, which are by far the most common faults, usually affect a large number of customers but are removed in a few fractions of a second by a very brief power cut, or even rendered imperceptible to the customer by means of a shunt circuit breaker. The disruption of networks by low-voltage periods is thus minimised.

Drops in voltage and losses are two to three times lower in the French system.

The safety of equipment and persons is also significantly better, due to the greater sensitivity of the protective devices and the lower fault currents. Disruption of the neighbouring networks, e.g. telecommunications, is also lessened by the reduction in stray currents.

This French dual-phase system is easier to build on for the purpose of adapting to network evolution, connecting up new customers and satisfying new requirements.

From an economic point of view, the investment costs are more or less equivalent for both systems, but the operating costs (losses, maintenance, repairs) are lower for the French system.

Decentralised services, defining a range of systems

Via this range of systems, the objective which has been set is to offer users the energy they can afford: no more and no less. If operations are not profitable from an economic and financial point of view, the long-term viability of the installations will not be guaranteed.

The range is geared to multi-user systems (Multiple-Home Systems or MHS) and single-user systems (Solar Home Systems or SHS).

The first of these is intended for densely populated rural areas. These systems comprise a micro-production station, a micro-distribution network and user installations at the premises of consumers.

This concept is particularly attractive as regards the pre-electrification stage. In fact, once a network arrives, the production installations can be moved on to more isolated villages and the micro-network connected to the general network via a transformer.

Where the network is not scheduled to arrive in the village within the period covered by the study, the question then arises of choosing between a centralised multi-user system at village level and single-user systems. This question can be resolved by means of a comparative study of the net present value cost figures for both electrification solutions, but it must also take into account the sociological and cultural aspects. Depending on local mentalities, it may be necessary to opt for a micro-power station and micro-network (communal) system or single-user systems of the Solar Home System type (individual).

Other considerations may influence the decision, such as the time period for which power is to be supplied. The simplest systems use small diesel engines and a micro-network is then essential to distribute the energy amongst users. The diesel normally operates for limited periods during the day, e.g. from 7 p.m. to 10 p.m. The power requirement for productive use, for instance in a village, may also be a criterion for choosing a micro-network solution.

The use of hybrid micro-power stations allows an enhanced continuity of the power supply to be envisaged. Energy is produced by a photovoltaic field or a small wind-powered machine, and stored in batteries during the day. The energy may be available within the network for much of the day, or even throughout the day. The diesel generator set is only used as a top-up supply, when the amount of electricity provided by renewable energies is insufficient.

However, these systems are more costly in investment terms than those consisting solely of small diesel generators. Yet their net present value costs calculated over fairly long periods may give them an advantage, as they have a long lifespan, of approximately 20 years, whereasthat of small diesel generators is fairly short (several thousand hours at most, i.e. two to three years of use). When the net present value cost is calculated over a long period and with low discount rates, e.g. over a period of 25 to 30 years with a discount rate of below 10%, it tends to favour renewable energies. If the calculation is made over a shorter period (several years), with high discount rates (15 or 20%), the diesel solution becomes inescapable.

Given the low current electricity requirements of these populations, coupled with their limited means to pay for it, the power capacities to be installed are modest. The energy requirements per user range from several dozen to several hundred Wh per day. These requirements should be compared with our Western requirements, which are of the order of several kWh to several dozen kWh per day, which represents at least a factor of between 10 and 100 in the requirement ratio.

However, so that these semi-centralised systems, based on the use of renewable energies, can guarantee a reliable and stable electricity supply over much of the day, it is necessary to place limits on each user, both as regards the available power, which is also the case with customers connected to the network, and also the quantity of energy they may consume on a daily basis. This assumes that the user will manage his daily energy "allocation". Yet this also applies to the use of oil lamps, which have a limited capacity, or batteries, which only allow a radio to operate for a limited number of hours.

Where the population is very scattered, the single-user system solution is the automatic choice. Given the low amounts of energy normally involved, these systems can be small in size and their cost is then relatively low, especially if these systems can be produced in large numbers. Here too, the user must manage the available quantity of energy. In countries receiving a large amount of sunshine, such as those in Africa, a photovoltaic system containing a 50 Wc module and a battery can provide lighting on a daily basis for one family, plus a few hours power for radio and television.

Of course, given the small amount of energy produced each day, it is absolutely essential to use appliances which consume very little electrical energy, such as low-energy lamps, for instance. If this were not the case, it would be necessary to invest much more heavily in the production source (photovoltaic panels and batteries) to obtain a service which would be no better.

The purpose of the research under way at EDF's R&D Division is to determine a range of systems which are as standardised as possible, so as to reduce their cost, improve their reliability and meet the identified requirements of the greatest number.

This assumes an in-depth study of the requirements of potential users located in rural areas in the developing countries.

GUARANTEEING THE QUALITY OF THE DECENTRALISED SYSTEMS INSTALLED

Under the R & D programme of EDF, work was undertaken in order to write a range of genuine specifications able to improve the quality and reliability of photovoltaic systems.

The first version of the specifications was published in June 1997 and presented in the EDF's R & D facilities in Clamart in October 1997. But to be widely useful and to reach its original goal, the document must be discussed with foreign partners, improved, completed and proposed to the CENELEC and IEC working groups.

Working method

The work was carried out by working groups using the functional requirement study method (figure 2). Each group had to reflect about the functions that each component and system must achieve. The groups had also to assess the level of performance to be reached for each function. The result is a functional specification or a technical specification, depending on the subject of the work.

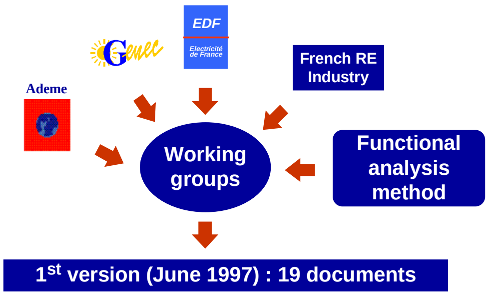

Fig 2 : The working method

The work has been carried out in almost 20 months and has involved more than 30 French experts, coming from ADEME, industrial companies and EDF, in the field of photovoltaic electricity generation, rural electrification, small-scaled wind machines, micro-networks, power electronics, and so on.

The writing and the publication of the documents has been carried out by the R & D Division of EDF.

Structure of the specifications for Decentralised Rural Electrification (DRE)

The currently available version is composed of 19 documents. The purpose of the specifications for DRE is to help the introduction of renewable energies into rural electrification programmes.

The structure of the DRE specification is designed to help a project supervisor to go from needs to product or to the right electrification system.

The three more important steps to be followed by a project supervisor are shown by figure 3 : first to choose the right system for the right place and the right user, second, to design the most cost effective system according to the place, and third, to prepare the operation, maintenance and renewal of the installations.

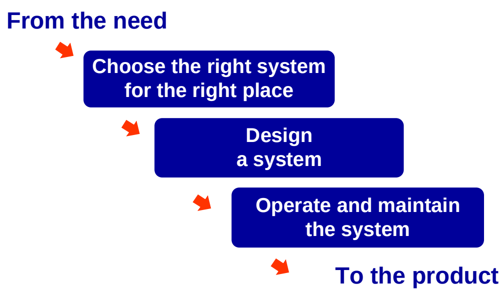

Fig 3 : The purpose of the DRE specifications

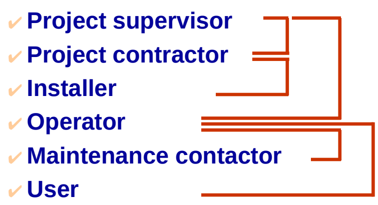

Fig 4 : The main actors involved in the realisation of a project

The experience of numerous projects in the past shows clearly that every project omitting one of these three key points is a failure, and that after a few months or, in the best cases, after a few years, all the installations or systems are out of order.

Furthermore; most experiences of management by users associations have proved to be failures too. For a sustainable electrification, the electrical systems must be operated by efficient professional companies as it is the case in our own countries.

The documents are classified, in the current version, into four parts and in the future into five parts.

The version of June 1997 is composed of the following documents :

Part A - From energy need to an adapted electrification system

- A1 : From the need to be satisfied to a range of electrification systems
- A2 : The results expected from system sizing
- A3 : Contractual relationships between the parties involved
- A : Quality assurance of the design of the realisation

This part A of the specifications is dedicated to the quality of the project. It is clear that the quality of products is a necessary condition for a successful electrification but it is not the only one. The best industrial products have to be installed and operated in the best way to be fully efficient. Especially, a socio-economic study must be carried out be the project contractor to be sure to match the needs of the user and to install affordable systems.

The figure 4 shows the main actors involved in the realisation of a project, and their relationship framework.

The project contractor is responsible toward the project supervisor for the quality of the installations, and for the quality of installed products.

The project supervisor entrusts the installation to an operator who is responsible toward the user for the quality of the delivered service.

The part B deals with the system design. When the groups began to work, they quickly realised that it was compulsory to build a classification of the systems. This classification is proposed by the B1 part and the following documents propose guidelines for design, energy management, data acquisition, safety. All these guidelines are adapted according to the kind of systems.

B - Guidelines for design and operation of systems

- B1- Structure of electrification systems
- B2 - Rules for design of electrification systems (part 1 and part 2) *
- B3 - Rules for energy management
- B4 - Rules for data acquisition
- B5 - Rules for protection of people and property from the risks of electricity
- B6 - Rules for operation, maintenance, and renewal

The figure 5 gives the summary of the architecture which is composed of eight types of systems. Diesel only systems are taken into account because they are widespread in rural electrification and that they are in competition with the systems using renewable energies and sometimes complementary to them as it is the case in T5 type which is an hybrid one.

The classification is focused on three main kind of systems : battery-less systems, Individual Electrification systems (IES), and community Electrification systems (CES)

Battery-less REN	**T1**	**REN**
IES ***(Single-user)*** **Individual Electrification Systems**	**T2** **T3**	**REN + storage** **Hybrid + storage**
CES **(Multi-user)** **Community Electrification Systems**	**T4** **T5** **T6** **T7** **T8**	**REN + storage** **Hybrid + storage** **Coupling REN / Diesel** **Diesel + storage** **Diesel**

Fig 5 : The eight types of systems

The part C proposes specifications for the main components of the system.

C - Technical specifications of components

- C1 - Generator and photovoltaic array (part 1 and part 2)
- C2 - Wind turbines
- C3 - Diesel generators
- C4 - Batteries
- C5 - Inverters
- C6 - Energy managers
- C7 - Environmental and climatic testing

The part D comprises currently only the D3 document which is a functional specification for a CES power station and of a CES micro-grid. The D1 document will be available in the next version in the beginning of 1999.

D - Assistance in specifying systems

- D1 - Method for characterising the needs *
- D2 - Assistance in choosing a system *
- D3 - Example of a functional description of a collective electrification system
  - part 1 : micro-power station,
  - part 2 micro-grid

E - Product specifications *

The part E is currently empty. Some draft specifications already exist at EDF for portable lamps, IES, interface board for micro-grid. Similar documents are also available in different countries and we think that it is better to reach an international agreement on the texts before to integrate them in the DRE specifications.

What use for the DRE specifications

The version of June 1997 of the DRE specifications is not a final version. It has to be improved by feed-back from field experiment, which will be done by EDF on several pilot sites in 1997 and 1998.

Several pilot sites are underway, located in France, West Africa and Indonesia, involving the electrification of several tens of thousands of people. The electrification systems used for these pilot sites are both micro-power stations with micro-grids (CES) and solar home systems (IES).

These electrification programmes are a very good field experiments and are supplying a lot of information able to improve the current specifications.

But these specifications have also to be discussed internationally and to be improved by a feedback, as complete as possible, coming from the experience of international actors involved in the field of renewable energies and rural electrification. They could become a common basis of specifications helping to build huge electrification programmes in the developing countries. They could be useful for all initiatives aiming at the improvement of the quality of rural electrification using renewable energies.

To ensure that these systems are really mature electrification systems in competition with classical ones, it is necessary to standardise them in the same way as classical electrification systems.

CONCLUSION

EDF’s approach for rural electrification proposes to build a master plan and to choose the right electrification system for the right place. To compete with the network solution, the solution of autonomous systems using renewable energies must be as professional and industrial as the conventional solutions. The electrification solutions for the rural population of developing countries must match their requirements and also their buying power but mustn’t be handicraft solutions. So, it is necessary to undersize strongly the systems compared to the one used in developed countries, but to ensure a very good quality.

The first step for writing general specifications for the use of renewable energies in rural electrification programmes is now achieved. But the next step is to be done by an international work to build a common basis for specifying photovoltaic systems.

The DRE specifications, proposed by the French renewable energies actors, could be a building brick for international standardisation, and may be a stepping stone to international certification.

The French authors of the DRE specification are ready to co-operate in any international initiative aiming at the improvement of the quality of photovoltaic systems.

We think that to ensure the quality of the electrical service provided to the user, it is compulsory to ensure the three main following key points all together : the quality of manufactured products, the quality of carrying out of projects, and the quality of operation, maintenance and renewal.