Lateral electrification, for a new way of rural electrification in Madagascar

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ABSTRACT

By 2030, access to electricity for 70% of households from a modern source of electricity or light is one of the ambitious economic and social goals of the new energy policy in Madagascar. These goals could be achieved by expanding and interconnecting large centralized grids and extending them to the most remote rural centers. However, this "top-down" model of electrification faces many obstacles. It requires massive public and private investment over the next decade and is only possible if political stability and public financial strength are permanently combined. Moreover, this model, based mainly on the use of centralized electrical energy sources (hydraulic, fossil, etc.), seems ill-suited to the energy challenges of the 21st century, characterized by the need to develop decentralized renewable energy sources and their diffusion. This paper, therefore, proposes to define another possible response to this challenge by disseminating an alternative, progressive and decentralized electrification model called "Lateral Electrification".

Keywords: *new energy policy, rural electrification, power grid, centralized and decentralized electrification.*

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1 INTRODUCTION

Several African countries have abundant energy resources, including Madagascar with a hydroelectric energy potential of 7800 MW, sunshine duration of about 5 hours per day throughout the western part of the country, wind potential on the north and south coasts of the country, etc. [2].

To ensure the use of these various resources, many countries in sub-Saharan Africa have partnered with private sector actors to address the low access to electricity in this region [3]. To this end, the Malagasy state has concluded a management contract for the national company and has amended the legal framework several times to liberalize the energy sector and open it to foreign investors, etc. [4, 5]. However, the results obtained do not meet the expectations, such as the low increase, if not stagnation, of the access rate to electricity and the high price of it, and firewood and coal remain the main sources of energy in our country [10, 12].

Possible answers have been found after several analyzes of these contradictions, including large investments in electrical infrastructure with the uncertainty of a long return, especially in rural areas, and political instability where foreign investors become targets of administrative, fiscal, and judicial harassment in case of regime or government change, a perfectible legal framework that is sometimes unpredictable and can challenge the realization of certain projects, etc. [9, 11, 12].

On the other hand, the model of the traditional grid has never been questioned, because of the colossal investments for its development and its incompatibility with the low concentration of the population, especially in the rural areas, which represent more than 70% of the Malagasy population [1, 9].

This paper mainly deals with the synthetic state of the art of the most popular electrification models in the world and the country, supported by an upstream critical analysis, before presenting the lateral electrification model that revolves around the diffusion and progressive interconnection of decentralized and renewable electrical systems, the nano-grids.

2 ELECTRICAL INFRASTRUCTURE OF MADAGASCAR

2.1. Madagascar Electricity Context

Since 1975, the State has entrusted JIRAMA with the operation of all facilities for the generation, transport, and distribution of electrical energy in Madagascar. During the year, the State finds that the presence of a single player is no longer sufficient to ensure the efficiency and full growth of a sector that represents one of the essential factors of development. economic and social development of Madagascar [4].

Therefore, at the end of 1990, a new law (No. 98-032) was drafted to allow new operators to operate in the sector, on the one hand, to relieve the Malagasy State in financing the country's electrical infrastructure, and on the other hand to promote the efficiency and quality of the services offered to users through competition. This leads to the creation of a fund to finance rural electrification development programs (FNE) and the creation of public institutions that support the development of rural electrification (ADER) and the regulation of the electricity sector (ORE) [4, 12].

In its 2007 report, MAP noted a slight increase in electricity coverage after delays in the commissioning of ADER and ORE [7, 8]. In the same year, JIRAMA had restructured to meet the increasing power demand due to strong economic growth. However, on the side of JIRAMA or private operators supervised by ADER, the production of electricity from thermal power plants is increasing. This trend was favored by Law No. 98-032, which does not contain provisions for the use of renewable energy sources [7, 10].

Consequently, in 2011, thermal power plants contributed about 45% of power generation at the level of all concessions of the state company and 74% at the level of private operators in rural areas [10].

To participate in global efforts to combat climate change and increase the electrification rate from 15 to 70% at affordable prices in Madagascar by promoting the various renewable energy sources to reach 85% of electricity generation, the Malagasy state developed a new energy policy in 2015 [6].

This new energy policy was followed by Law No. 2017-020, which corrected the shortcomings of Law No. 98-032 in terms of institutional powers and governance of the sector, thresholds for authorization and concession contracts, cumbersome procedures provided for in the law, lack of provisions for the use of renewable energy sources, etc. [5, 6].

Despite the energy policies pursued by policymakers in Madagascar, 8 out of 10 people still live without electricity today and this number is likely to increase significantly in the coming years, especially in rural areas, due to population growth and low public and private investment in these areas.

2.2. Electrification model in Madagascar

The electrical infrastructure in Madagascar is based on the 20th-century "top-down" electrification model, in which electricity generated by central production units is transported and/or distributed to urban and/or rural centers [1, 9].

2.2.1. Nationals grids

Almost all of Madagascar's district capitals are concessioned by JIRAMA, which means that the entire power grid is built and operated by this company. On the other hand, other operators can build and operate production facilities by selling electricity to JIRAMA, which thus becomes the central buyer [2, 4, 5].

Thus, the JIRAMA grid may or may not be interconnected, and the price per kWh varies in each perimeter depending on the commodity resources of the power plants (hydraulic, fossil, etc.).

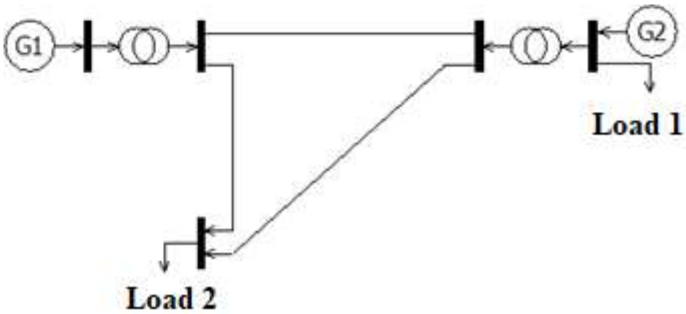

Fig 1: Interconnected grids fed by two different sources.

Hydroelectric power plants are often geographically separated from centers of consumption. Power generated there passes through the transmission system to reduce voltage drop and line losses before being transmitted and distributed. The other power generation plants directly use the distribution and dispatch grids to transmit power.

2.2.2. Local power grids

In the areas outside the scope of JIRAMA, private operators under the supervision of ADER are working to generate electricity through generators or by converting locally available energy, i.e., energy from hydropower, solar energy, wind energy, energy from biomass, etc. [4, 5].

The isolated power plants are usually operated by a single operator and fed by a single or hybrid energy source. They use the distribution grid directly (without going through the transmission and distribution grid).

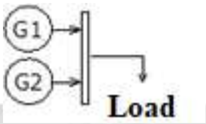

Fig 2: Hybrid system to supply a village

2.2.3. Individual systems

Faced with the impotence of national and local grids, many households resort to personal or fee-based island systems. Paid stand-alone systems, which cover a wide range of prices and services, are sometimes portable devices consisting of a small PV system and a few hours of storage capacity, such as lanterns and solar kits. Solar kits can power several LED lamps, charge some phones, and connect a TV or a radio [9].

On the other hand, personal autonomous systems are permanently installed systems (home solar, generator, etc.) that typically power lighting circuits, power outlets for connecting phone chargers, televisions, radios, fans, refrigerators, etc.

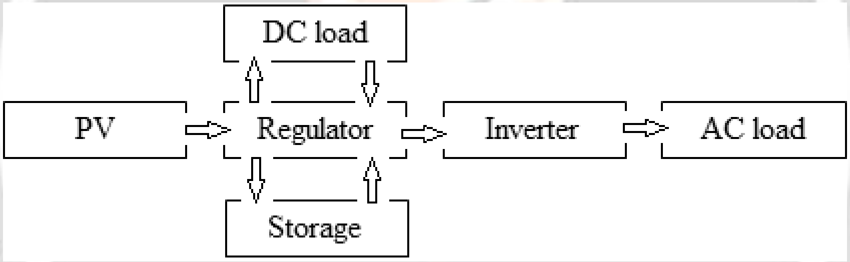

Fig 3: PV system to power DC and AC loads

2.3. Limits of the electrification model in Madagascar

The construction or expansion of centralized grids is a high investment, especially for hydropower, for which our country has the enormous potential [1, 9, 10]. Apart from the technical and socio-economic studies and fundraising, the implementation time is quite long due to the often complex administrative procedures for obtaining permits or operating concessions, organizing tenders for the execution and supervision of the works, and finally the actual execution of the works and commissioning [9].

Such delays between the planning and execution of electrification work in a rapidly changing environment are the cause of many sizing problems. Given the large investments involved, any oversizing of the supply involves significant economic costs (which is the case for almost all isolated centers), and any undersizing inevitably leads to load shedding (as in the case of the JIRAMA company) [9].

Moreover, in the rural environment where the majority of the Malagasy population lives, it is difficult to distribute electricity to isolated centers due to the scattered population with low consumption. Therefore, operating costs are quite high and have a long payback period in a high-risk environment.

Individual systems on the market lack flexibility and do not cover the entire electricity needs of consumers. As a result, most users of such systems use them to supplement rather than replace conventional electricity. The capacities of the individual systems are fixed and cannot be technically increased. They must be replaced with higher capacities as household energy demand increases. In addition, the technologies of the power grid in Madagascar do not allow interconnection with autonomous systems. Therefore, these individual systems provide only a temporary solution to users' growing energy needs, and the associated costs are not affordable for all Madagascans [9].

3 LATERALE ELECTRIFICATION

The limitations of the three approaches above require a fourth way to balance the short-term needs of each individual and the long-term interests of all: (i) Satisfying the short-term needs of customers means providing them with fast, adequate, easy, flexible, and affordable access to electricity; (ii) Serving the long-term interests of citizens means participating in the building of an ecological, decentralized, collaborative, smart, and sustainable 21st-century electricity infrastructure.

The combination of these two imperatives seems possible today, but requires the combination of conceptual, technical, and organizational innovations, which would be: (i) a new electrification model that combines the qualities of the centralized electrification model and the generalized self-production model; (ii) hybrid technical solutions located between individual systems and grids; and (iii) innovative organizational solutions at the border between commercial and public service logics.

3.1. Nano-grids

Nano-Grids are autonomous building blocks for the generation, storage, and distribution of electricity that initially provide an electrical service limited to the essential domestic needs of the off-grid population (lighting, phone charging, multimedia, etc.).

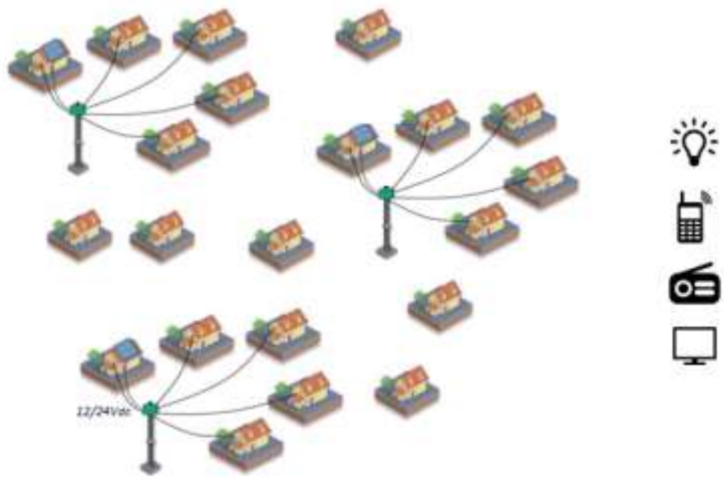

Fig 4: Smart nano-grids

These systems, which are organized around a single power pole and can be installed in less than a day, can be set up within days of a group of users signing up.

3.2. Micro-grids

The interconnection of several nano-grids [13] between them constitutes the first stage of aggregation, the aim of which is to increase the scope and availability of the service for all users thanks to the proliferation of consumption and the pooling of production and storage within a larger trading platform.

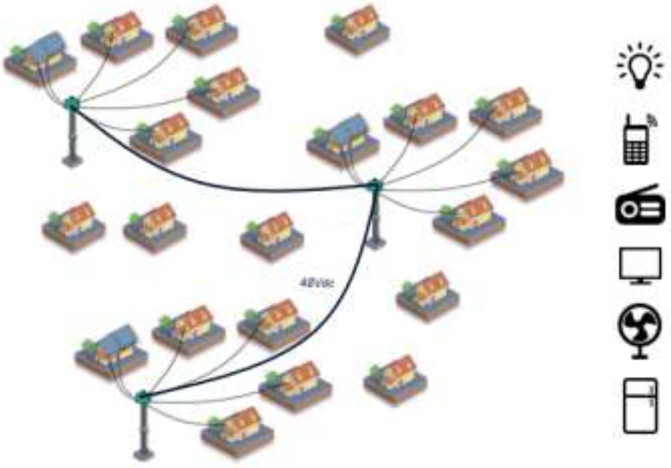

Fig 5: Smart micro-grid

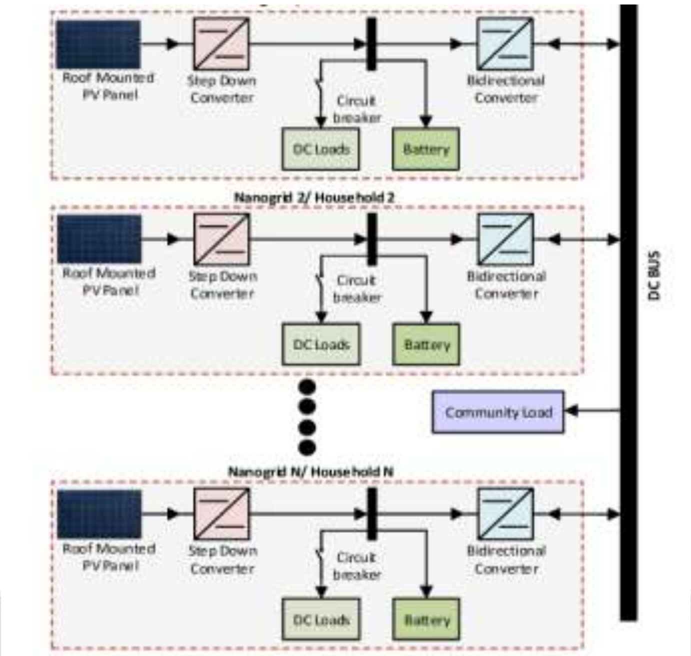

Fig 6: Cluster of multiple nano-grids interconnected

Energy exchange between nano-grids occurs via two-quadrant transducers (reversible in current). This exchange is a function of the state of charge of the individual batteries of the nano-grids, the voltage of the 48V bus DC, etc.

3.3. Mini-grid

The second stage of aggregation consists in connecting several micro-grids [13] or to an isolated center, with the same goal of increasing the scale and availability of the service to all users and allowing the connection of productive uses, using the same mechanisms as in the previous stage (proliferation and pooling).

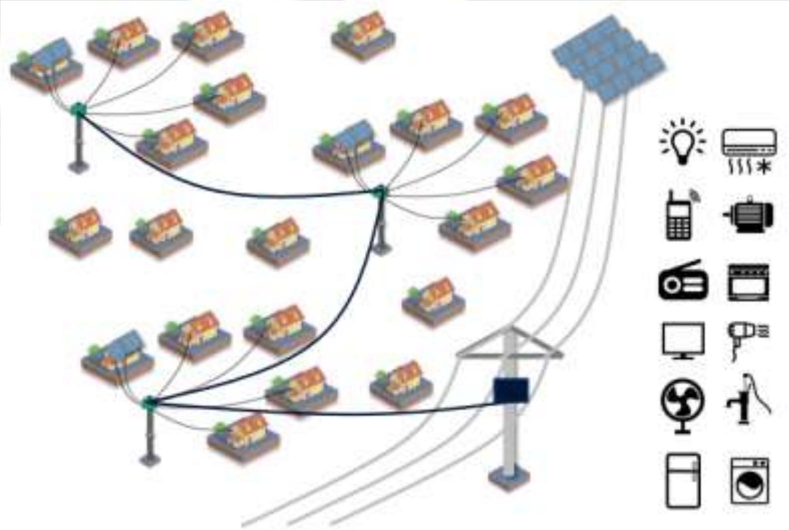

Fig 7: Smart mini-grid

3.4. Grid

The final aggregation step is to interconnect several mini-grids or connect them to the main grid (e.g., the JIRAMA company's grid), resulting in all types of users having access to an overall power supply. . However, the "grids" built in this way differ from traditional electricity grids in the extremely decentralized integration of production, storage and intelligent management of the balance between supply and demand at different levels (households, villages, region, etc.).

This electrification model is called "Lateral Electrification", where the electricity flows neither down nor up. Thus, the unit of production is neither centralized nor decentralized, but transverse and decentralized, and can be interconnected, allowing a gradual transition from decentralization to centralization.

4 CONCLUSION

Electricity grids based on centralized generation have been the only form of access to electricity until recently and continue to be preferred by all countries in the world because of their economic and environmental efficiency. However, they require a long implementation time, which is incompatible with the urgency of the need, and optimization of the balance between supply and demand at different time horizons to ensure technical and economic feasibility.

On the other hand, large massive investments are involved to develop these electrical infrastructures “from the top down”. Driven by the public sector, these are inconceivable in unstable states due to the weakness of their budgetary resources, the limited planning capacity of their administrations, and the absence of continuity of the state between the leaders, etc. Driven by the private sector, such capital invested come with

Inevitably from corruption and political interference on the part of multinationals anxious to secure their investments over the long term, whatever the cost, but also from major economic, social, and environmental inefficiencies linked to the weak control and regulation capacities of their activities by local governments.

Individual systems have spread dramatically over the past decade and are expected to continue to proliferate over the next few years due to their adaptability to customer usage and ease of use. But individual systems are only short-term solutions given their lack of flexibility, lack of modularity, non-interconnectivity, high long-term costs, short lifespan, etc.

In this context, the weakness of the current development of electric infrastructures in Madagascar and Africa paradoxically represents a tremendous opportunity to rapidly develop electrical infrastructures based on technological opportunities (photovoltaic solar electricity production and electricity storage, power electronics, embedded computing, mobile payment solutions, etc.) partly ignoring and learning from the mistakes of the models of the previous century.

Lateral electrification differs from current electrification approaches (individual systems and conventional networks) in its progressive nature both from the point of view.

Both in terms of the size and complexity of the electric infrastructure developed and the extent of the electrical service that it can deliver to users. To adapt flexibly to the evolution over time of the electrical needs of the territories, lateral electrification is a process of progressive construction of decentralized electrical infrastructures. This process begins (i) with the dissemination of nano-grids that meet the short-term needs of users (ii) followed by their interconnections to form a micro-grid where which allows economic monitoring of the natural increase in the density of electrical demand and serves new uses (iii) then the interconnection between several micro-grids or micro-grids with an isolated center forms a mini-grid making it possible to connect productive uses, and (iv) its final step is to connect to the JIRAMA grid and allow all types of users to access a total electrical service.

Lateral electrification is an agile process of building a “bottom-up” decentralized, decarbonized, and intelligent electricity infrastructure through the combination of a progressive technological, a collaborative organizational, and a comprehensive marketing approach.

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