It Takes a Village

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THE WORLD BANK, ONE OF THE MOST IMPORTANT supporters of rural electrification projects, estimates that approximately 1.2 billion people do not have regular access to electricity. In Latin America as a whole, according to the International Energy Agency, the electrification rate has reached 92.3% but that still leaves 33.8 million people without access to electricity (see Figure 1). They live mostly in rural and isolated areas that are often neglected by electrification projects due to the high associated costs and technical difficulties.

Many of these projects are, in fact, often tied to a single energy source (e.g., diesel, hydro, or solar) and supply only a single dwelling or a small village. Such supply solutions depend heavily on weather conditions, transportation constraints, and resource availability, with a consequent lack of reliability and security. The World Bank also identifies these projects as turnkey systems, with little or no community involvement, that often suffer from technical problems soon after installation due to a lack of local capabilities and proper maintenance procedures.

The World Bank argues that technical problems reduce the benefits of off-grid investments, citing evidence from places such as Vientiane Province in Laos where, after only a few years of operation, more than 80% of solar home systems (SHSs) were not working properly. Another documented case comes from Thailand, where 59 micro hydroelectricity systems were implemented but only 25 remain in operation due to poor maintenance procedures. Similar results have also been seen in Chile, where statistics held by the national system in charge of investment in electrification projects in remote areas show that the diesel generation equipment used by these projects has an average life span of three years before it must be replaced.

Community participation has been recognized as a powerful tool for the maintenance and operation of systems that serve the community itself. The U.S. Agency for International Development (USAID) program "Making Cities Work" also promotes the idea that community participation builds support, provides a sense of ownership, increases sustainability, and reduces maintenance costs. In this context, there is

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Social SCADA and Approaches to Community Engagement in Isolated Microgrids

significant experience with programs involving water and sewage systems. But it is not easy to establish interaction between power systems and the community and, since even low voltages of electricity can be harmful or fatal to humans, appropriate precautions must be put in place.

The particular characteristics of rural—as distinct from urban—communities include higher levels of sociability among their members, a trait that facilitates community involvement in energy procurement and promotes long-term sustainability. Some intervention methodologies seek to promote learning among stakeholders and their embrace of sustainability. They utilize a process of coconstruction, adaptability (the ability of the community to cope with external changes and to incorporate those changes internally), and reflexivity (the ability of the developers to identify, incorporate, and redefine unexpected aspects of the project that arise during the assessment process) that moves a system from a particular regime (i.e., diesel-based power supply) to a more sustainable use of resources. Other documented cases have made use of the *community renewable energy* concept, under which communities finance and develop their own small-scale renewable energy projects and assume responsibility for the maintenance and operation of their own microgrids.

Microgrids were defined by the International Council on Large Electric Systems (CIGRÉ) in 2010 as electrical distribution systems using distributed energy resources such as distributed generators, storage devices, or loads that can be controlled and coordinated, either while connected to the main power network or operated in island mode. The development of cost-effective microgrids that offer secure, efficient, and sustainable electrification solutions at the local level has therefore been proposed. This type of solution is suitable for the application of renewable energy, especially in places with an agricultural base or where hydro, wind, and solar energies are available. In particular, an isolated microgrid must, like a bulk power network, be able to integrate and coordinate several energy sources with appropriate load-frequency strategies and the active participation of the local community.

Due to the electricity access needs indicated above, most microgrid developments in Latin America seek to provide power supply in isolated rural locations. Figure 2 shows various microgrid projects identified in the region and their stages of development.

In the case of Chile, a survey carried out in 2013 identified 79 isolated locations for the development of microgrid projects as a solution for providing rural electricity access. This survey filtered the entire universe of isolated communities by applying the following criteria: 1) the number of homes to electrify; 2) the community's Human Development Index score; 3) migration patterns; and 4) the prior existence of an electrification project. Figure 3 shows the results by geographic area.

In the light of the main issue addressed here, that of community engagement, several challenges for the development

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of microgrids were identified; they relate to technical as well as social matters. These challenges are shown in Figure 4 and summarized below. As shown in the figure, isolated microgrids offer opportunities for further development in both social and technical areas. Hereby, two community engagement tools are presented: a methodological framework for community engagement in isolated microgrid projects and the social SCADA system. The results of their application in the Huatacondo microgrid are also shown and discussed.

Community Engagement Approaches for Isolated Microgrids

A Microgrid Development Methodology

Given that in Latin America, as elsewhere, isolated microgrid projects tend not to be attractive to private companies because of the lack of adequate policies and regulatory frameworks, one proposal is that local actors should be responsible for ensuring the project's sustainability. In this approach, support from various actors from the institutional and private sectors acting in concert is also pursued. A central element of this methodology is to consider both the technological and socioenvironmental aspects of the development process and to include the community itself as an active participant in planning and decision making. The proposed methodology is summarized in Figure 5 and described step by step below.

Stage 0: Building a Suitable Team

Setting up a microgrid in a community is a task that requires a competent interdisciplinary team. A project in a community setting certainly needs a technical solution, but it must also adapt itself to local realities, coexist with local practices, and enhance local capabilities. Previous experiences in developing countries have shown the importance of educating and training community members, making it necessary to involve people from many different professional fields (engineers, social workers, sociologists, geographers, and so on) in the effort. Cooperative international networks are also envisioned for this purpose.

Stage 1: Technical and Social Feasibility

The objective of this stage is to evaluate the technological, social, and environmental aspects of the project's components. In technical terms, the use of a microgrid as a tool for renewable energy development implies a campaign to measure factors such as wind speed, solar radiation, and water flow and a survey of the use of fossil fuels and biomass in the community's economic activities (e.g., for transportation). It is also necessary to estimate electricity consumption using historical data, direct measurement, or population surveys. With this information and considering the available

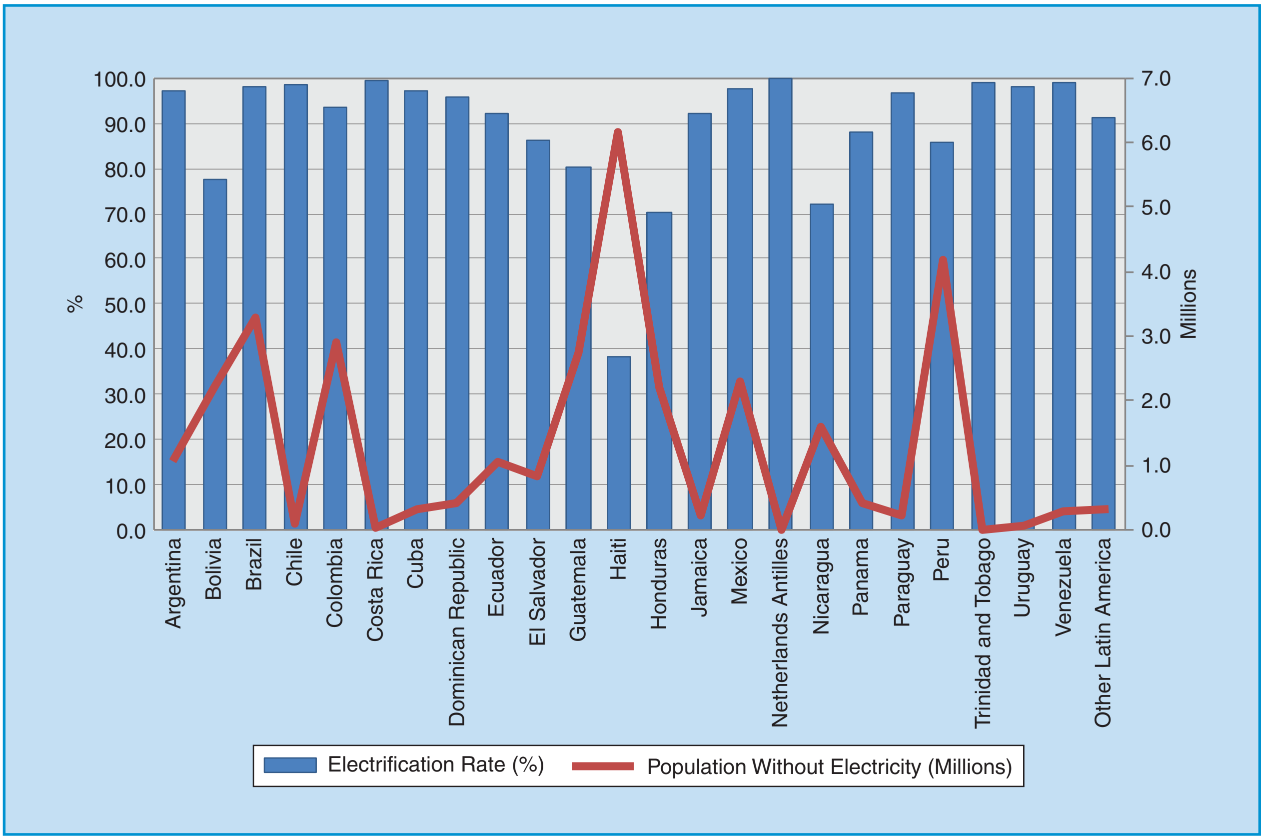

figure 1. Electrification rates and population without electricity in Latin America (source: IEA).

technologies, the design process focuses on evaluation of the technical costs and benefits of the microgrid.

At this point, the investment cost of setting up a microgrid must be known and should be checked against budgetary capabilities to obtain a clear vision of the additional funding or subsidies that may be required.

In social terms, the main focus should be on identifying relevant stakeholders, building trust among community members, and identifying the views and narratives of community members as the basis for participatory planning. In this phase, it is important to determine how the community is organized and whether local people can carry out administrative tasks or need external training to do so. Constant interaction across the team in sharing the results of each task is essential for evaluating the project's viability.

Stage 2: Participatory Planning

This is the stage in which the project takes on concrete form and relevant decisions about the characteristics of its implementation are taken. Plans are made and decisions taken with the active participation of the community, taking into account the opinions of all relevant stakeholders. It is essential to share visions, promote dialogue, and create consensus. Workshops and meetings should seek to promote meaningful participation rather than paternalism. In other words, they should strive not only to inform and respond to concerns but also to consider the community's point of view in the design of the project.

Stage 3: First Impression

In the days immediately following the start of operation of the project, when the community is able to see its real impact, it is essential to register all the impressions of stakeholders and the community and watch their interaction with the energy system before adapting it to facilitate technological adoption. It is at this stage that changes in energy behavior patterns start to be reflected in concrete actions and the community starts to learn through practice how to operate the energy system and organize and manage it. Capacity building and support are essential in this stage.

Stage 4: Trial Phase

For a project to be successful, it is essential to create a long-term strategy that ensures operability and sustainability over time. It is particularly important that projects be developed under a financial structure that ensures economic sustainability. In isolated microgrids, basic maintenance and operation may be carried out by the community. It is therefore important to make them aware of possible failures and provide basic maintenance training.

Sustainability indicators are developed, including both substantive (economic, social, and environmental) and procedural

figure 2. Microgrid developments in Latin America.

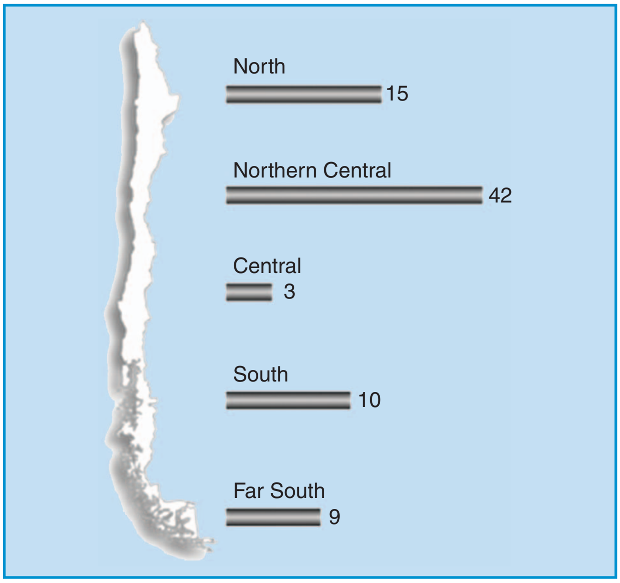

figure 3. The number of feasible isolated microgrid opportunities for the Chilean case.

(participation) aspects to monitor the microgrid's performance. These indicators are based on general issues (i.e., community organization and decision-making processes) as well as community priorities and reflect changes in technical, social, economic, and environmental issues that are relevant to the community and the project.

The maintenance costs in microgrids are low compared with the investment cost but need to be covered by some entity. This entity should ideally be the community but could also be local government or some other institution. In most cases, the system's financial structure is based on defining tariffs that may be able to cover maintenance and operation costs. The tariff design process should take into account the socioeconomic background of the community—in other words, whether it has sufficient economic capacity. Special guidance and training should be provided to help the community look for alternative funding sources (e.g., microcredits, government programs, or cooperation agencies).

A Social SCADA System

The traditional supervisory control and data acquisition (SCADA) system is based on gathering, processing, and analyzing real-time data from the field. It requires highly trained personnel for its operation and control through a human-machine interface (HMI). By contrast, a "social SCADA" system uses a simplified HMI to facilitate the exchange of information between the microgrid system and the community. Under this system, the operators need only basic training to interact with the electricity system. Figure 6 depicts the social SCADA concept as the sum of the social component (i.e., the community) and traditional SCADA applications.

The Social Component

The social component is built from an initial description of the community in terms of social interactions and the use of land that identifies the relevant local stakeholders and the willingness of the local population to participate in the project. The social component facilitates community participation in the decision-making process for the development of the energy system.

To implement a social SCADA system, the community needs to evolve from a conventional SCADA system to a system characterized by being small in scale, locally appropriate, environmentally and socially sustainable, and focused on benefits to the community. Social SCADA contributes to achieve a more resilient community, which means an increased capacity of adaptation to changes over time using local resources.

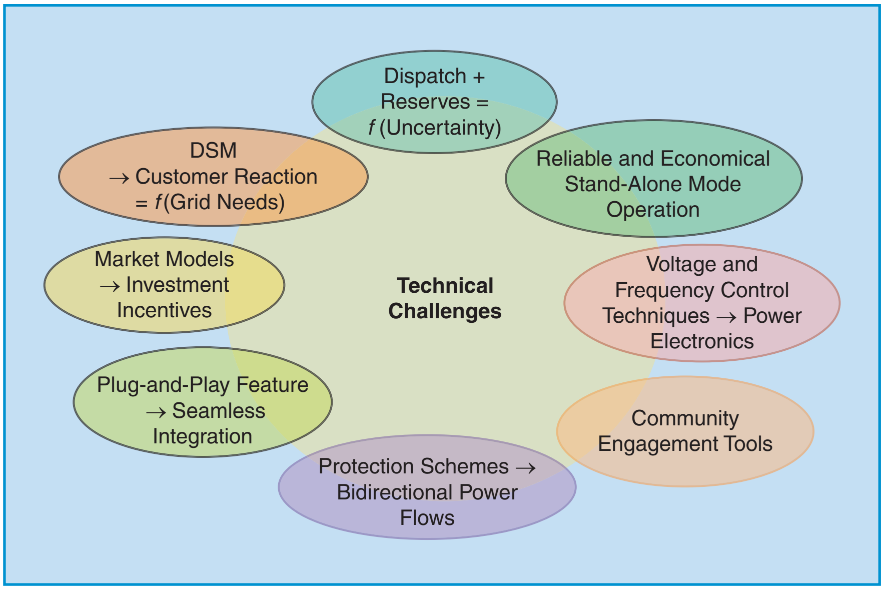

figure 4. Microgrid challenges.

The Microgrid Component

Another necessary step for implementation of a social SCADA system is the characterization of the microgrid. The main aspects to consider are:

- ✔ primary resources for electricity generation (i.e., solar radiation, wind, water, biomass, and/or fossil fuels)
- ✔ generation unit technologies
- ✔ power and communication networks
- ✔ electricity consumption
- ✔ operation, monitoring, and control systems (local and remote).

These components define the microgrid configuration and determine how it can be managed by the community.

SCADA Systems and Microgrid Architecture

A SCADA system is actually a software application that allows monitoring, operation, and control of a system with dispersed components when centralized data acquisition and control are important. It also includes the required analytical capabilities in a calculation engine and a set of custom-made interfaces for interacting with operators and the field equipment.

The Social SCADA Proposal

The social SCADA concept integrates the community with the energy domain, starting with identification of the former's energy needs and recognizing that the system depends on the community for its maintenance and operation. In other words, it is a traditional SCADA system completed with a nonspecialist component that helps support decision making by the local community.

The social SCADA system offers a set of tools and interfaces that support interaction with the community in managing and operating the microgrid. These tools and interfaces cover the following aspects:

- ✔ real-time operation of the microgrid
- ✔ maintenance of the generation units
- ✔ resource management and optimal dispatch of the generation units
- ✔ support to the community in the decision-making process regarding the development of the system, e.g., in the planning of the new generation units.

To perform these tasks, the social SCADA architecture includes three modules that differentiate it from traditional SCADA with respect to its interaction with the community:

1) A supervision module that monitors and supervises the microgrid's performance. The information is then communicated to the community, enabling it to participate in the operation of the system by also displaying information regarding system status. This information includes alarms and alerts when preventive maintenance is scheduled or when corrective actions in the generation units are required.
2) A decision-support module that provides support to the community's inhabitants regarding development of the system.
3) An optimal-dispatch module that adjusts the set points of the generation units by calculating them and sending them to the local controllers with the aim of improving the use of natural resources.

Communications Architecture of a Microgrid

Figure 7 shows the proposed communications architecture of the microgrid as a part of the local system. It includes either single or multiple distributed generation (DG) units. Each DG unit has its own local controller to handle the relevant electrical variables. Each local controller receives a set point when its generation unit is running and the required instructions when the power plant has to start operation. Figure 7 also shows the load, which has a control to ensure efficient energy management, and the communications equipment for sending signals to customers to promote energy savings and efficient use of the resources.

The system also has a historical server to store data such as control variables, alarms, and events. The energy management system (EMS) is hosted in the application server and provides set points for the generation units, signals for consumers based on demand response, and the HMI for displaying the operation of the microgrid.

The overall costs of a social SCADA system integrated in a microgrid include the software licenses, a basic server (a conventional PC), the HMI (for example, an interactive whiteboard), and additional visualization devices.

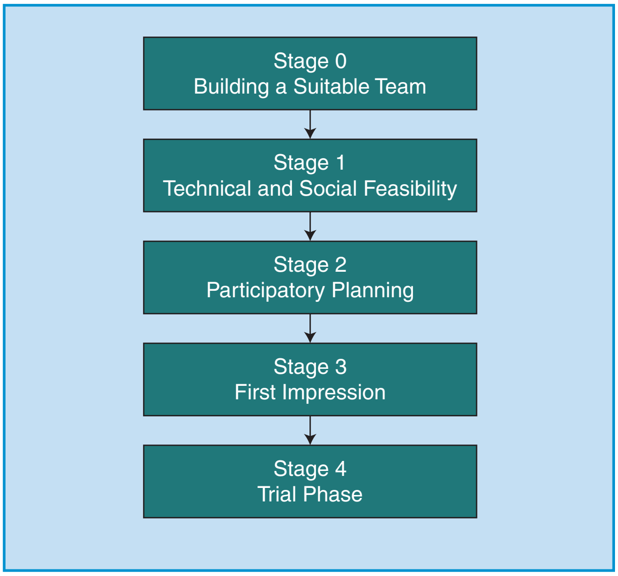

figure 5. The methodology for the development of microgrids.

Huatacondo Case

This section presents the microgrid of the Huatacondo community as a case study for social SCADA systems. Huatacondo is a small, isolated village in the Atacama Desert in northern Chile that is home to about 30 families. The Atacama Desert region presents unique conditions that inform the design of this project. According to several studies, northern Chile is one of very few regions in the world with annual global irradiance values exceeding 2,500 kWh/m^2

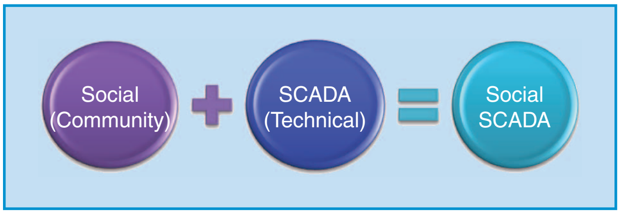

figure 6. The components of social SCADA.

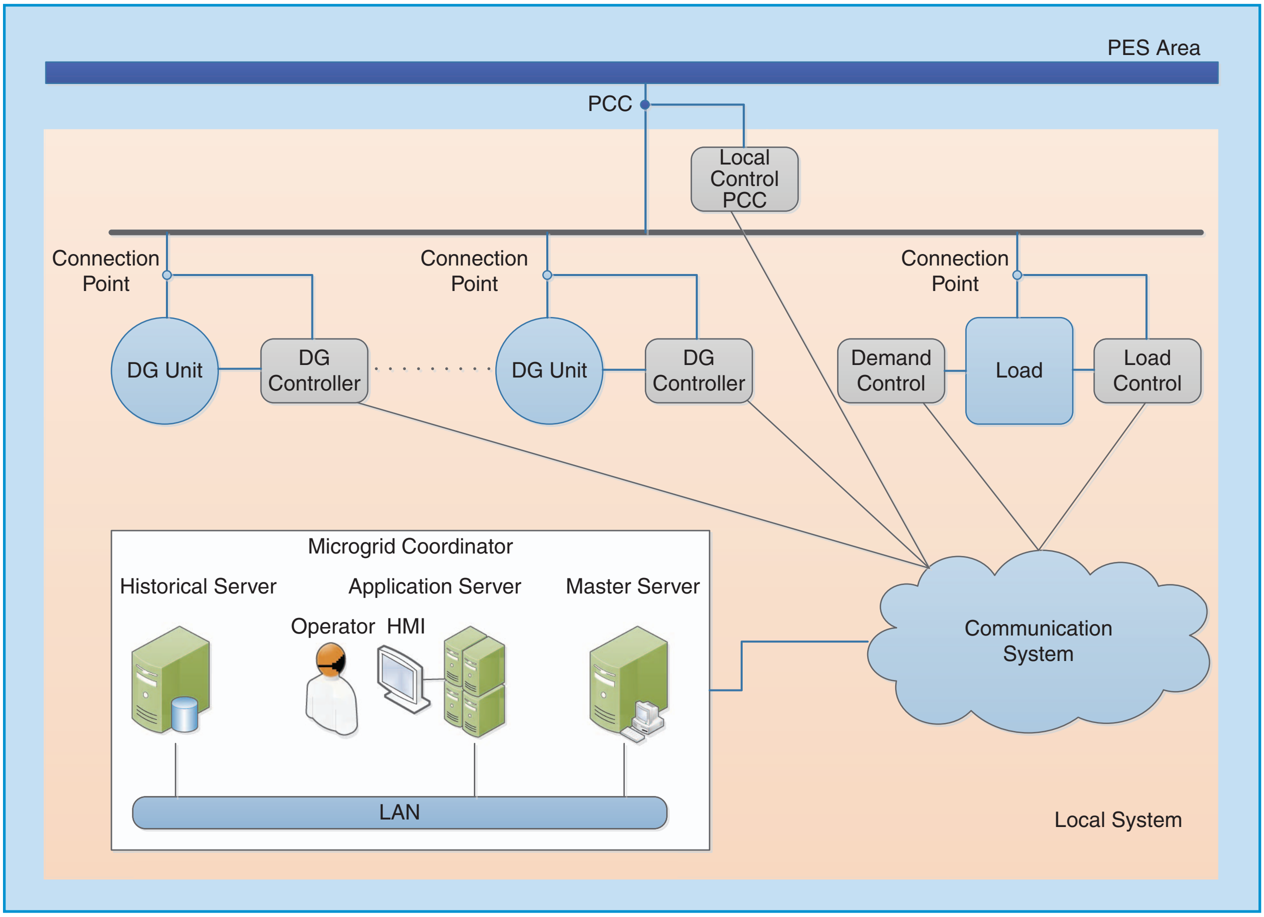

figure 7. Communications architecture of a microgrid.

(Tucson, Arizona, exhibits a value of 2,080). Its skies are also exceptionally clear, with an annual average clearness index that is close to the world's maximum. Recent reductions in solar technology prices have made solar projects increasingly economical.

Microgrid Description

Huatacondo has an electricity network that is isolated from the interconnected system and originally supplied electricity for only ten hours a day, using a diesel generator. The project consists of a microgrid that takes advantage of the area's particularly abundant renewable resources to provide 24-hour electricity. Since the village has also experienced problems with its water supply system, the project design included a component to manage that resource. Furthermore, to compensate for generation fluctuations due to the use of renewable energy sources, a demand-side component was included in the system. Figure 8 provides an outline of the system, including photovoltaic panels, a wind turbine, a diesel generator, a battery bank, a water supply system, and a demand-side management mechanism.

The EMS of the proposed microgrid has the following objectives:

- ✔ to minimize use of diesel
- ✔ to calculate set points for active and reactive power generation from the generation sources, including the battery bank
- ✔ to determine the operation of the electric water pump to keep the level of water in the water tank within predefined limits
- ✔ to send signals to consumers to promote behavioral changes.

Development of the Huatacondo Microgrid

Stage 0

The project was developed at the electrical engineering department of the Universidad de Chile, where the original designers had no expertise or experience in social development. A natural resources engineering student, a geography student, and a master's student in sustainability, guided by experienced professors, were then included in the "social area" of the project's design in a bid to develop engagement with the community and the environment. Due to the multiplicity of disciplines, one of the biggest challenges the team faced was to create a mechanism for sharing different approaches and points of view as well as a mechanism for decision making in the context of multiple objectives and for dealing with trade-offs.

Stage 1

The team's first visits to Huatacondo provided a general impression of the available resources and the local social organization. The local community, local and municipal governments, and two mining companies with operations in the area were identified as relevant stakeholders. These actors had direct influence on the existing energy system. This system was maintained by the community through an electricity committee. Diesel fuel was provided by the municipality, and the mining companies and villagers did not contribute to the cost of the energy system, paying only a fixed tariff to cover maintenance costs.

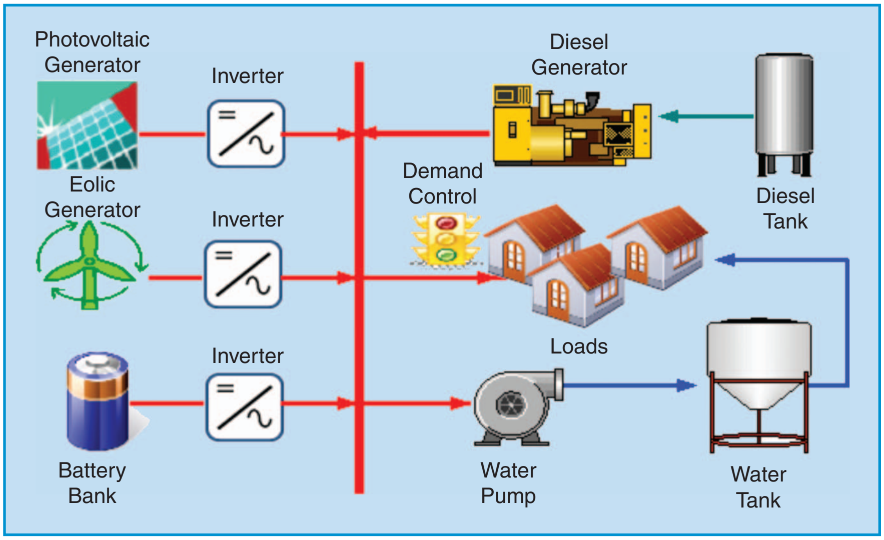

figure 8. A diagram of the Huatacondo microgrid.

Huatacondo is a well-organized community with a high level of social capital, and it is very capable of developing its own projects and initiatives. The team found that relations with other stakeholders are good, with no major conflicts to endanger the project, although relations with private organizations are perceived as not being transparent.

At this stage, the basic features of the energy system were determined. On the basis of data obtained from surveys and a measuring campaign, it was concluded that the village's main natural energy resource was the sun, with just one month of cloudy sky in a normal year and a very high average daily level of irradiation (6.99 kWh/m^2). Wind and biomass were also found to be good potential resources.

Stage 2

Relevant institutions within the community were identified so as to use the existing social structure for planning and decision making and give different interests power over the project's development. The local institutions directly connected with the project are the electricity committee, the neighborhood council, and the drinking water committee. Meetings with these bodies were held to create an understanding of the logistics of the operation of the electricity and drinking water systems, to size devices, to estimate maintenance processes, and to understand past problems. One of the barriers found at this stage was the difficult relations existing between the drinking water committee and the members of other local institutions. It was necessary to hold several meetings within the community and with the local government to understand the conflict and reach an agreement on how to resolve it.

Three planning meetings were held with all the community's inhabitants to define the location of generation units and other relevant aspects of the project. Villagers contributed considerably to understanding the viability of resources by sharing their local ecological knowledge (e.g., of high-wind-speed locations) and their experience gained through work in their village, while the project designers contributed experience regarding the optimal location of units, taking into consideration the distance to the grid, local geography (the location of mountains that could decrease solar power), and the factors that would affect selection of the connection points of the generation units. At this stage, it was possible to draw up a detailed action plan for the project that clearly defined the scope of intervention and the allocation of responsibilities. This was only feasible due to community engagement and participatory planning.

Also at this stage, the system operator (responsible for maintenance) was appointed, and the new responsibilities of the neighborhood council were assigned. The system operator started to interact more closely with the technical experts and was included in technical discussions in every phase of the implementation, enabling him to address doubts and express opinions. The persons who were to be responsible for maintenance were trained in the principal aspects of every unit (wind generator, battery bank, and so on), and the head of the village incorporated reviews of maintenance and key weaknesses of the system into his planning tasks.

Stage 3

The early days of the microgrid system's operation provided important information about its suitability and operability in the community context. Most important, villagers were able to experience 24-hour electricity and evaluate the project's possible impacts and benefits. Impact assessment was carried out with two separate groups. On the one hand, villagers positively evaluated the system's implementation and initial operation and were also positive about its future development. On the other hand, the migrant population was more skeptical about the project's benefits for the community and its impact on

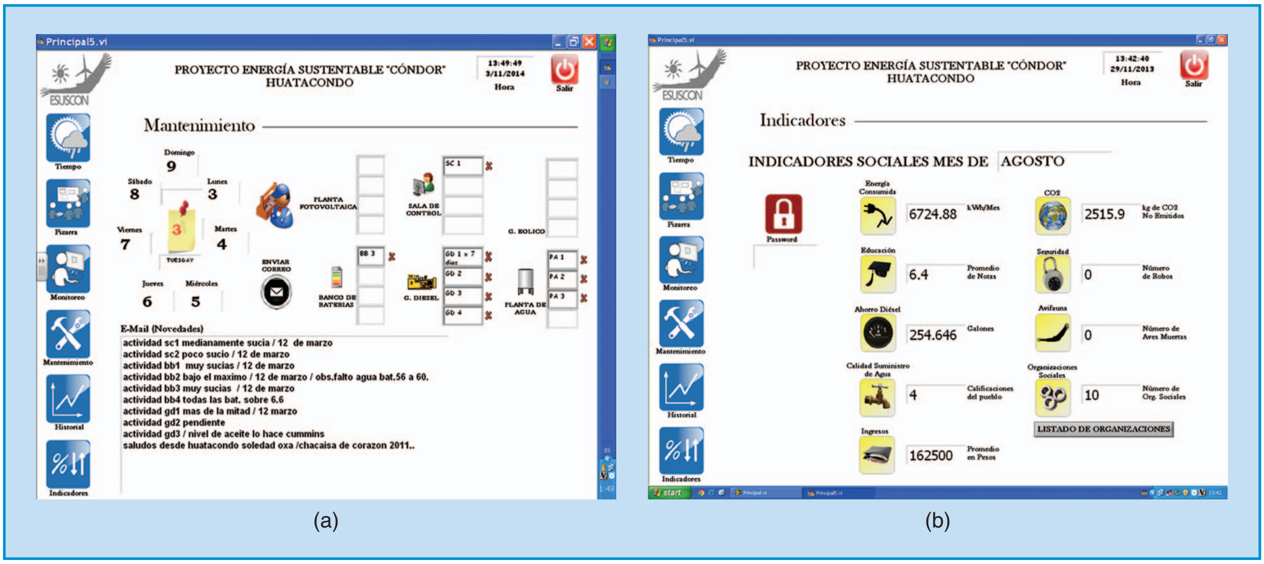

figure 9. The HMIs for (a) maintenance management and (b) sustainability indicators. The HMIs are presented in Spanish, as they were designed for the Huatacondo community's use.

their livelihoods, expressing concern about the loss of cultural identity that electricity implies and about whether the project would reinforce a paternalisitc relation of the villagers with mining companies, jeopardizing the community's capacity for adaptation and its autonomy.

It was important at this stage to reinforce behavioral changes regarding electricity consumption. When the new system was explained, villagers indeed dramatically reduced their average aggregate power demand from 30 kW to 12 kW in a normal day.

Stage 4

Many projects that are operational when installed subsequently fail, leading to user dissatisfaction and abandonment of the project. For this system's basic maintenance and operation, the community e-mails maintenance reports with annotations, observations, and questions. Such feedback is essential to creating and reinforcing awareness of the energy system.

The Social SCADA System at Huatacondo

Once the social characteristics of the Huatacondo community had been identified and a description of the power system completed, the relevant information required by its inhabitants to enable a Socia; SCADA was defined. This process guarantees the community's engagement and acceptance of the project.

A computational tool was developed for supervision of the maintenance and generation system, allowing the inhabitants to be aware of the actual status of the energy system and providing useful information for decision-making processes. The following functionalities were determined to be relevant for the community:

- ✔ a monitoring system for generation units, including the energy supplied by each unit
- ✔ sustainability indicators
- ✔ maintenance management
- ✔ the ability to measure energy consumption per household
- ✔ demand response
- ✔ an alarm system.

In the following section, a more detailed description of two of the most important of these functionalities is presented.

The maintenance management interface is capable of communicating the predictive maintenance schedule and its corresponding weekly tasks to the community. Figure 9(a) shows the maintenance management HMI and scheduled tasks for a specific week. The sustainability indicators are a set of indicators that were created as a way of monitoring the community's development over time; they provide information such as reductions in greenhouse-gas emissions, fuel savings, average family income, and educational attainment. Figure 9(b) shows this interface. In this case, the overall cost for the social SCADA system was about US$3,000.

Community Perceptions

A survey of perceptions of the impact of the Huatacondo project at the community level that covered 95% of households was conducted in August 2011, almost a year after the commissioning stage was completed. Its results, shown next, indicate high acceptance of the microgrid within the community.

Impacts on the Community

Regarding impacts on the community, 73% of the respondents stated that the project had a positive effect on their daily lives since they could now perform more recreational and economic activities that require electricity, and 20% thought that the microgrid had neither positive nor negative effects. Meanwhile, 7% believed that 24-hour electricity could have negative effects on the community.

Impacts on the Local Physical Environment and Landscape

- ✔ 57.5% of respondents thought the microgrid had no effect on the local fauna, while 42.5% expressed concern about possible collisions between the condor birds that regularly fly in the area and the wind turbine.
- ✔ 92.5% stated that the project did not affect the local vegetation since the equipment was installed far away from areas containing farms, crops, and native plants.
- ✔ 82.5% reported a positive effect on the landscape because the project brought modernity and technological innovation, while 12.5% stated that the project did not affect the local landscape and 5% considered it to have negative effects on the landscape.

Impacts on Productive Activities

Most people said that it was now possible to undertake new economic activities or enhance existing ones. In particular, 27% believed the project to be beneficial for the development of tourism and associated services; 23% said that it would benefit agriculture through irrigation technology; 18% suggested that it would benefit construction activities due to the longer period in which electrical tools could be used; and finally, 2% felt there could be a negative impact on agricultural development because farmers might neglect their farms and crops to pursue other activities that were now possible.

During the period of microgrid operation using the social SCADA system, the operators have reported the following results:

- ✔ one equipment failure in the period 2010–2014
- ✔ a high level of community commitment to maintenance activities and demand-response programs
- ✔ a high level of interest on the part of the people in charge of maintenance and operation activities, as reflected in low rotation in the maintenance team
- ✔ no accidents involving people or animals.

In addition, the social SCADA system offers the same benefits as traditional SCADA systems, including:

- ✔ improved diesel consumption, with a reduction of 50% as compared to the previous system
- ✔ improved reliability levels
- ✔ higher power quality.

Conclusions and Future Developments

This article discusses different ways of achieving community engagement with a microgrid system to promote the long-term sustainability of power supply systems for isolated locations. These concepts and applications foster community participation in the system's development and operation.

A microgrid development methodology is first presented, with the aim of promoting local community participation in a project. This methodology considers not only the project's implementation but also its long-term sustainability, which may be ensured through the use of a "social SCADA" system that gathers and stores data about both the microgrid's operation and the community, including sustainability indicators.

These proposals were tested together with the community in a small, isolated village called Huatacondo in the Atacama Desert of northern Chile. The impact of the social SCADA system on the community was positive; the majority of Huatacondo's inhabitants approved of the project after one year of operation.

Future developments may create additional modules that would support the community's decision-making processes by, for example, envisaging the technical future of the microgrid or the future social state of the community. In addition, resilience development and monitoring in microgrids are identified as key challenges for future developments.

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For Further Reading

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