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Reviews on Microgrid Configuration and Dedicated Hybrid System Optimization Software tools

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Abstract: Connecting the electric grid to rural and remote areas is very uneconomicalto carry out. Moreover, the utility network is not designed to fulfill the growingneeds of the population and may be destabilized by newconsumers.Therefore, it is more economical to electrify those areas with a micro-grid bymeans of existingrenewable energy sources available locally. The micro-gridconfiguration represents the energy distribution architecture from theproducing sites to consumers and eventually the interconnection betweenseveral sites and several consumers. The design and study of such a gridconfiguration is realized using simulation tools and has to be considered fromthe system level with economical matters in addition to the technical aspects.As for the nd optimize hybrid systems.In this paper, an analysis of the current status of electrification in Laos ispresented. Then, a literature review of the existing micro-grid configuration ispresented and a case study of a typical rural, remoteand isolated village inLaos is simulated, using some of the selected software tools.

Keywords: energy excess, hybrid systems, micro-grid, multi-objective optimization ,renewable energy

1. Introduction

Autonomous off-grid rural electrification based onthe on-site production of renewable energyhas been proven to be capable of delivering a degree of quality and reliable electricity forpowering rural villages, i.e. lighting, cooking, communication etc. In [1]. it is reported that offgridrenewable energy technologies satisfy energy demand directly and avoid the need forlong and expensive distribution infrastructures.

Combinations of different but complementary energy generation systems based onrenewable or mixed energy (renewable energy with a backup bio-fuel/diesel generator) areknown as a renewable energy hybrid system. The grid formed by this system is known as micro-grid due to its size compared to the main grid. According to energy conversiontechnologies,differentmicrogridconfigurations have been studied, developed andimplemented worldwide to meet the energy demandsof off-grid modern societies.When designing a hybrid system for the production of electrical energy, various aspectshave to be considered, such as cost and environmental impact (CO_2 emission). Availabilityand reliability will be, however, among the key issues. Therefore, the design of the microgridis a multi-objective problem. It is reported in [2]. that multi-objective design methods havebeen appliedsuccessfullyinseveralfieldsofengineeringwithseveralmathematicatechniques. The study results will then be used as part of the decision-making process forinvesting.In this paper, firstly, the status and development of electrification as well as the availablrenewable energy sources in Laos are presented in the second section. In the

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third section,the review of research on different micro-grid configurations is summarized, concluding withthe current implementation in Laos. In the fourth section, a short review of existing simulationtools is presented. Then, a case study, with respect to economic optimization for a selectedNorthern Lao village, is performed using two different simulation software tools. Theoptimization results are then compared, regarding the unmet load and the unused energyexcess Furthermore, the need to optimize excess energy as a part of the optimization criteriaand the demand of more flexible software tools, with respect to the sizing and optimizing ofmicro-grid components, are raised and discussed. Finally, the unavoidable needs of microgridsfor the development of rural electrification in Laos are highlighted.

2. Micro-Grid

There are several different definitions of micro-grid as many as there are researchprojects about it [3] .In summary, however, a micro-grid can be seen as a semiindependentgrouping of generating sources and controllable end-use loads. Thesupply sources may consist of conventional generator sets, micro turbines, fuel cells,photovoltaic (PV), small scale renewable generators, heat recovery from thermal
generation, and storage devices In fact, it is a small scale power supply grid thatis designed to provide energy for a small community. The small community may be ahouse, an isolated rural community, a mixed suburban environment, a commercialarea, an industrial site or a municipal region. The key concept that differentiates amicro-grid from a conventional power utility grid is that the power generators are small often referred to as micro or distributed generators, of a similar size to the loads withinthe micro-grid, they are usually geographically distributed, and they are located inclose proximity to the energy users. The generators and loads are controlled to meet the consumer's energy demand while achieving a local energy and power balance [3].Figure 1 represents a micro-grid architecture consisting of a group of radial feeders,which may be part of a distribution system. There is a single point of connection to theutility, called the point of common coupling PCC. Feeders A, B and C have sensitiveloads, which require local generation. The non-critical load feeders do not have anylocal generation. Feeders A-C can be isolated from the grid using the static switch inless than a cycle.

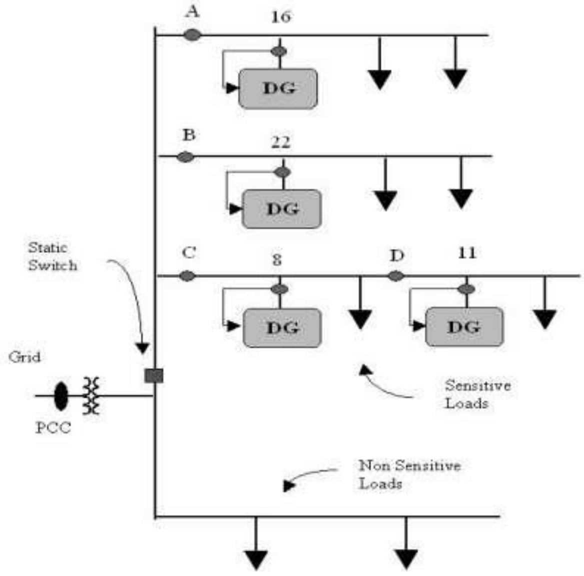

Figure 1: Micro-grid architecture

2.1. Micro-Grid Configurations

Differentmicro-gridconfigurationshavebeenpresented in several research works [4]. They are generally, however, grouped into 3 types: DC coupled, AC coupledand AC and DC coupled configurations.In a DC coupled configuration, all energy sources are linked together on the DC sidebefore being connected to the AC side (loads and/or grid) via inverters Nowadays, DC coupled configurations are used mostly for smaller hybrid systems upto a certain size (a few kW), depending on various external parameters [5]. Solarhome systems are a simple form of a standalone DC coupled micro-grid configuration,where only PV generators are used to provide energy to consumers, such as housesor small first aid stations at the scale of a village. Up to now, several hundred thousandSHS, in the power range of about 200 W, have been installed mainly in remote ruraland isolated areas of Asia, Africa and South America. They are supported by anadditional small inverter, so the consumer can use the DC system to supply anstandardized AC load

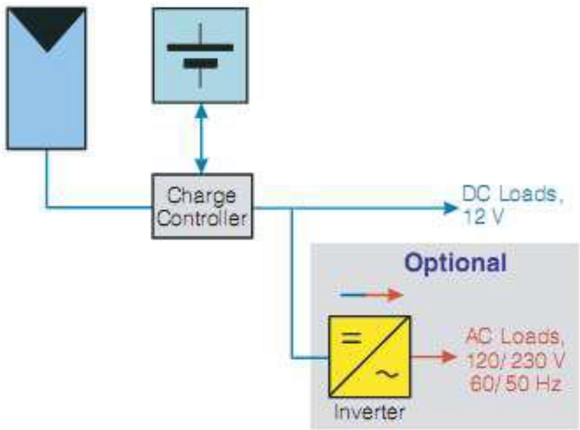

Figure 2: Solar home system

However, if higher power or energy is demanded and cannot be met in a cost-effectivemanner by the SHS, several generators must be inserted into the system. Additionalgenerators are typically wind, hydro, conventional or bio-diesel generators. In such asystem, represented here by Figure 3, all the AC energy sources, such as windgenerators and gensets, are converted to DC and coupled to the battery. The powerrange for a DC coupled configuration is extremely broad and can be used costeffectivelyfor various off-grid applications[5].

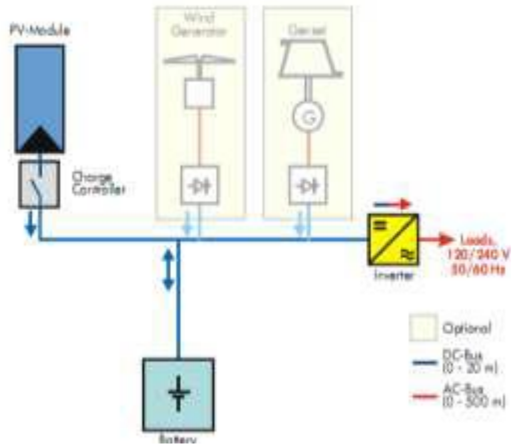

Figure 3: DC coupledconfiguration

In general, when systems increase in size, they are implemented as AC coupled hybridsystems. Using the concept of "modular system technology.DC coupling iscompletely avoided and batteries, as well as PV modules, are equipped with extrapower electronics. More flexible systems with modularly structuredcomponents are achieved by coupling all consumers and generators on the AC side,as presented in Figure 4.

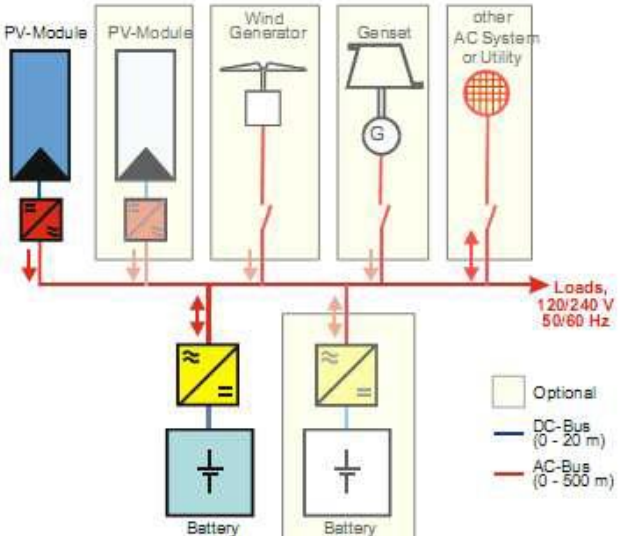

Figure 4:A modular AC coupled configuration

Depending on the application type and available energyresources,differentconventionaland renewable energy generators could be added to the system to form ahybrid energy system. Furthermore, this configuration can easily be expanded byintegrating further components or generators in order to cover the rising energydemand. Such systems are used to supplyallelectrical consumers, especially ruralvillages or communities in developing and threshold countries where electricity, waterpumping and water disinfection are basic needs Various applications are alsoimplemented in Europe e.g. on the isolated island of Kythnos, Greece

Nowadays, the AC coupled technology is commonly used in the power range aboveseveral kWs and can be realized in both single and three phase structures.

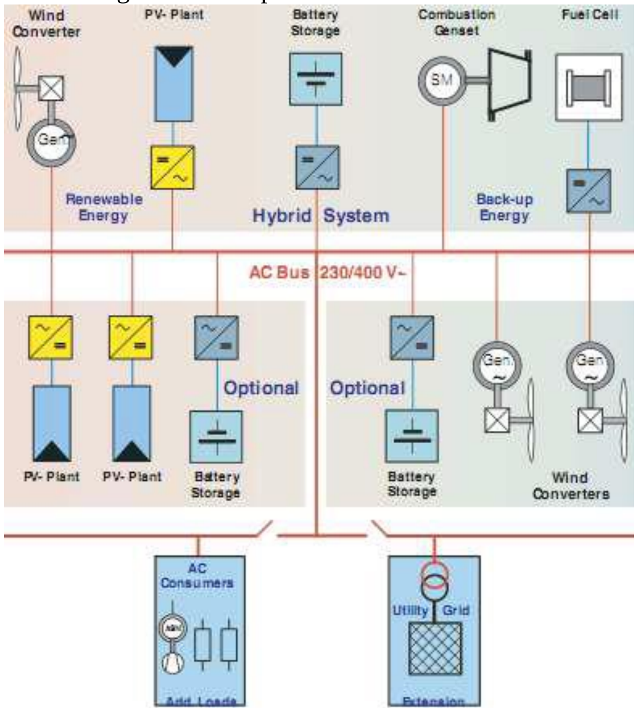

Figure 5: An expanded modularAC coupledconfiguration

As mentioned earlier, DC coupling is the natural solution in small systems, but in largesystems, AC coupling is advantageous. In the wide range in between, it is alsopossible to combine AC and DC coupled in one system, namely, an AC and DCcoupled configuration. This technology has emerged due to the need to supply(medium power) AC loads by DCpower sources and to charge the batteryonthe DC-side also via combustiongenerators, such as diesel gensets, as illustrated in Figure 6. Such a configuration isused to supply remote or rural consumers who have larger energy demands than theSHS (e.g. small villages, farms etc.). The common power range is between 1 and 5 kWand the DC-voltage range is between 12 and 48 V [5].

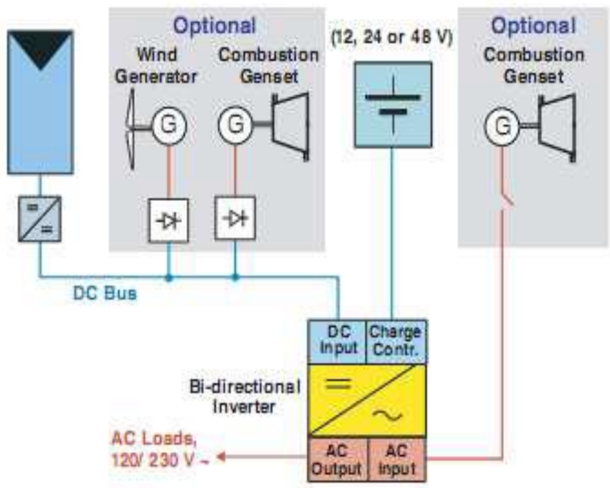

Figure 6: AC and DC coupledconfiguration

The AC and DC coupled configuration is developed and implemented in the form of ahybrid PV-genset DC/AC bus configuration, mainly in North America [6]. Theresearch in [38] reveals that when compared to the AC and DC bus configuration, itcan satisfy AC loads directly (compared to DC system) and has a smaller gensetruntime and hence reduced annual energy consumption than the AC system.In Laos, up to now, the DC coupled configuration in the form of a solar home system, aPV battery charging station (BCS) as shown in Figure 7, a PV water pumping systemand an AC coupled micro-grid, have been implementedfortheoff-gridvillages and/orcommunities [6]. The latter is, however, a very rare case and accounted onlyfor only a fraction of the former. The reason for the few is due to small availablebudgets supportingtechnologydevelopmentandimplementation in the country.

Figure 7: A battery chargingstation in a NorthernLao village

Whatever the application, the selection of the micro-grid configuration and the designof all the components are handled by the use of simulation tools. In fact, the complexityof the hybrid system requires a system-level approach, appropriate models and anefficient optimization algorithm.

3. MicroGrid Presentation to the Utility Grid

MicroGrids must connect to the utility grid without compromising grid reliability or protectionschemes or causing other problems, consistent with the minimal standards for all connecteddevices. However, MicroGrids can offer more value to the grid than simply “doing no harm.”MicroGrids can benefit the grid by reducing congestion and other threats to system adequacy ifthey are deployed as active, interruptible, or controlled loads that can be partially shed asnecessary in response to changing grid conditions. It could also be designed to behave and animpedance load, modulated load or a dispatched load to list a few. In addition, MicroGrids couldprovide premium power and ancillary services, such as local voltage support[6].

3.1. Load as a Resource

A MicroGrid can be thought of as a controlled cell of the power system within which heat and power are generated for local customers, and generation and load are passively controlled. TheMicroGrid load could be shed or dispatched from the utility power system in response to systemneeds, and the MicroGrid also could contract to provide predictable, firm levels of energy andancillary services to the main grid. The MicroGrid could reduce its load on the utility grid eitherby raising the share it generates to meet its own loads or by reducing its load. If the value of theMicroGrid presenting itself as a dispatchable load were taken into account when MicroGridequipment was installed, essential load-shedding capabilities could be built into the system.CERTS MicroGrid White Paper DRAFT Do not cite or quote Traditional load shedding has been in the form of interruptible contracts or tariffs.2 Typically, acustomer agrees to be curtailed up to an agreed number of times and durations. The customer’sreward is either a reduced energy rate that lowers the customer’s overall energy bill or a capacityand/or energy payment on the actual load being placed at risk of interruption. Usually,customers are notified by phone, fax, or mobile text messaging, when their service must beinterrupted, and verification that the customer load was shed as requested takes place ex postbased on meter data. A customer can choose not to comply with the direction to shed loadalthough penalties are often levied and may be severe for non-compliance. A MicroGrid couldeasily participate in this type of load-shedding program. In some load-curtailment programs,loads are interrupted immediately and without warning. In New Zealand, for example, large numbers of loads have agreed to the installation of under-frequency relays that enable extremelyrapid curtailment. A MicroGrid can participate in a similar program if it had the capability trespond by rapidly increasing its self-generation or reducing its load.Joint, local control of generation and load is at the heart of the MicroGrid concept, which gives aparticular meaning to demand-side management. Rather than controlling load for the purpose ofadjusting its profile to benefit the wider power system, the MicroGrid controls generation andload together to meet the objectives of MicroGrid customers as economically as possible. Thekey issue for utility grid reliability is how to offer incentives to MicroGrids to invest and behavein a fashion that enhances grid reliability: e.g., real time pricing or contracts/rate discount optionsfor load curtailment. Load shedding that takes place more rapidly thantheelectricity commoditymarket can respond to system conditions e.g. load curtailment is a particularly important service that the MicroGrid could offer[6].

4. Control Methods for MicroGrids

Power electronics provide the control and flexibility for the MicroGrid to meet its customers’ aswell as the utilities’ needs. MicroGrid controls must insure that: new microsources can be addedto the system without modification of existing equipment, the MicroGrid can connect to orisolate itself from the utility grid in a rapid and seamless fashion, reactive and active power canbe independently controlled, voltage sag and system imbalances can be corrected, and theMicroGrid can meet the utility’s load dynamics requirements.Microsource Controller techniques described below rely on the inverter interfaces found in fuelcells, photovoltaics, microturbines, and storage technologies. A key element of the controldesign is that communication among microsources is unnecessary for basic MicroGrid control.Each inverter must be able to respond effectively to load changes without requiring data fromother sources or locations[6].

5. Protective Relaying and MicroGrids

The protective relay design for MicroGrids must be different from what has historically beenused for utility distribution systems because MicroGrids add a significant number of electricalsources to a customer's system, which has historically contained only loads. Some of thedifferences resulting from this change are obvious; for example, once sources are added, energycan flow in either direction through protection system sensing devices. There are no twodirectionalflows on most radial systems. A more subtle difference between MicroGrids andtraditional utility distribution grids is that MicroGrids will experience a significant change inshort circuit capability when they switch from grid-connected to island operation. This changein short circuit capability will have a profound impact on the vast majority of protection schemesused in today's systems, which are based on short-circuit current sensing. The protection issues that must be resolved for MicroGrids will be discussed in two scenarios:

1. The first scenario is "normal" operation, in which the MicroGrid is connected to the utilitygrid when a grid event occurs. The protection system must determine the response of theindividual DER that make up the MicroGrid as well as the response of the device that willdisconnect the MicroGrid from the utility grid and switch it to islanded operation. Thisdevice is labeled "Main MicroGrid separation device" in is a versionof that is modified to highlight protection issues.
2. The second scenario involves an event on the MicroGrid while the MicroGrid is in island Operation moe.

6. Conclusion

Small DER may best meet customers' needs and add benefit to the utility grid if these resourcesare organized into MicroGrids operated as single, controllable systems that can connect to theutility grid or operate independently; this is a new approach for integrating DER into the utilitydistribution system.The benefits of a MicroGrid include. To its customers, cost-efficient provision of reliable, high-quality power that meets therequirements of sensitive loads and takes advantage of the opportunities to use waste heat.The small size of individual sources allow placement flexibility to optimize the needs ofelectrical and/or heat loads.To the utility grid, a MicroGrid operates as a single, controllable system such as adispatchable load that can reduce grid congestion and offset the need for new generating
Capacity[6].

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