Smart Islanding in Smart Grids

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***Abstract*—In recent years, the concept of the micro grid has been developed thanks to various benefits of distributed generators , the major advantages is the improvement in the reliability by supplying load during power, the instability of electric infrastructure due to damage caused by disasters, technical problems or electrical failures may be left some region without electricity for a short or long time, In such instances, Micro Grids needs to be smart and can be able to handle itself autonomously [1]. Therefore, the energy management can play an important role to achieve the self-governing operation of the Smart Micro Grid. The distributed generators can't ensure energy for the area with the same frequency like power plants. But, the problem is to evaluate the outage (categories, time to be reconnected), how identify entities to include in the selection, manage their demand response with the existed resources (stored or local produced...) and the possibility to include other entities to the selection in the emergency case. This paper reviews some of the major challenges of islanding, and we propose a classification of demand by priority, the classification depends also on the typology of the area (industrial zone, city, medical zone…), and if contains some regional resources. In this paper we study a static area isolation that contains some static entities like hospital, factory, green houses, renewable energy, hotel, plug-in vehicles, and storage farm. The objective is to propose a solution as a Dynamic Energy Management (DEM) to perform distributed control on the islanded area and to response to citizen demand (health , work , energy for crucial industrial/hospital machines) during the islanding time , we add a new level of control in the standard smart grid architecture to allow real time exchanging status and data from a different selected entities who demand energy to a regional data center, The regional data center will be a self-decisive system and his role is to manage and control the regional grid to ensure a successful island operation. We analyses decisions marked by Dynamic Energy Management system accorded case and by local parameters. A simulation result show the change of voltage to the DEM.**

Keywords-islanding; management energy; smart grid; emergency; disaster; micro grid; renewable energy

I. INTRODUCTION

The yearly population growth and demand growth required an evolution in existing electric grid to response and resolve the new challenges which presents a problem for international governments. The reason why a lot of protocol are signed like Kyoto protocol that consist to reduce emissions of pollutants and greenhouse gases from power stations into the atmosphere and increasing the amount of electricity coming from renewable resources and the fact of improving energy efficiency will reduce the amount of energy that is wasted, and therefore, lower energy demand [2], Strategic analysis of the Kyoto Protocol.

Politic, security and environmental consideration are a major factor in the increased application of renewable resources, the problems are:

- The increasing of the CO_2-emissions
- The increasing of energy demand
- Instability of countries who produce energy due to war
- volatility of oil and gas
- Problem of change in planet temperature,
- transmission and distribution line losses
- Problem of reliability of power supply by supplying load during power outage by operating in an island mode,
- Limit of Consumer Service
- Real-time energy management system to manage the peak
- Etc….

Distributed generation (DG) registered an exponential growth and had become a global interest to develop a Smart Grid concept with the potential to improve local reliability, reduce costs, and increase penetration rates for distributed renewable generation.

Energy suppliers using power plants based on conventional fuels (coal, gas, etc.) are also investing in the renewable sector such as wind turbines and photovoltaic systems and we see a significant penetration of DG in many distribution systems worldwide.

The strength of MG is when we integrate a large numbers of Distributed Energy Resources (DERs) based generation units, in figure 1 we define a different resources and entities who presented the resources of smart grid.

We define in figure 2 the categories of energy resources (ER) distributed and non-distributed energy resources (NDER), The Distributed energy resources (DER) are smaller power sources that can be aggregated to provide power necessary to meet regular demand. As the electricity grid continues to modernize, DER such as storage and advanced renewable technologies can help facilitate the transition to a smarter grid. The Non Distributed energy

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resources (NDER) present the existing power plants generator.

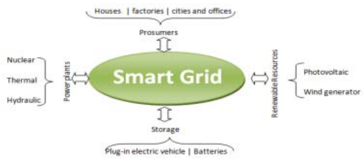

Figure 1. Energy resources.

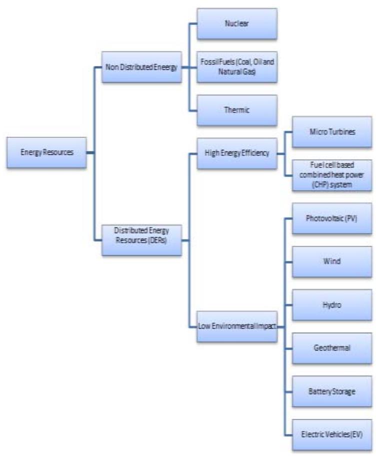

Figure 2. Distributed and non-distributed energy resources.

However, there are many issues introduced by DG and the most critical one is islanding [3]. Islanding is a situation in which a distribution system becomes electrically isolated from the remainder of the power system and yet continues to be energized by the DG connected to it. Currently, it is seen as a major problem and all DG units need to shut down when a distribution system is islanded [4].

Another challenge regarding the island operation is how to find the appropriate reaction in island mode, have a procedure to manage energy stored in the region isolated, how the system operator can ensure that the islanded system is still stable when suffering a loss of the external grid, balance energy between appliances by priority, and how response for long time possible.

This paper presents a variety of islanding detection methods. Section two discusses about islanding methodology, Section third party present Dynamic energy management system (DEMS).

The paper concludes with the discussion on the different possible decisions within parameters and status of energy resources and also depends on context and environment of the non-detected zone (NDZ).

II. STATE OF ISLANDING DETECTION METHODS

Unlike conventional power systems, where generation power plants are located far away from population centers (load) and only connected via transmission lines, Today, many distributed generators are located in areas geographically distributed according to the conditions (sun and wind) to meet the local demands or act as backup generators for emergencies in islanding mode.

Electric infrastructure is vulnerable to damage during disasters and the downstream micro grid may be left without electricity for a long time and by consequence some region can be also without the necessary of living like hospital treatment, the idea that we present in this paper is to have a classification by emergency of demand and have an algorithm who implement the logic of our classification.

Islanding detection methods are generally divided into local and remote methods as shown in Fig. 3 [5]–[18].Communication based methods are based on measurement of some parameters or variables on the micro grid side, including passive methods, active methods and hybrid method.

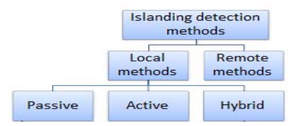

Figure 3. Islanding detection methods classification.

Fast islanding detection algorithms must be set up. For intentional islanding, the fast and effective islanding detection method also helps in fast controller actions [19].

A. Passive Methods

Passive methods monitor parameters and measure local variables including voltage, for example, some methods cited in review of islanding detection methods for micro grid:

- Voltage and current harmonics detection.
- Over/under voltage and over/under frequency.
- Rate of change of frequency.
- Rate of change of frequency over power.
- Rate of change of power output.
- Phase jump detection.
- Voltage Unbalance.

B. Active Methods

Active methods inject small disturbances into the micro grid and monitor their impact on local variables, for example, some methods cited in review of islanding detection methods for micro grid:

- Active frequency drift.
- Frequency jump.
- Active frequency drifts with positive feedback.
- Frequency shift.
- Voltage shift.
- Sliding mode frequency shift.
- Variation of active and reactive power.
- Negative-sequence current injection.
- Impedance Measurement.
- Detection of Impedance at Specific Frequency.

C. Hybrid Methods

Hybrid methods employ both the active and passive detection techniques. The active technique is implemented only when the islanding is suspected by the passive technique. Some of the hybrid techniques are discussed as follows:

- Technique based on positive feedback (PF) and voltage imbalance (VU).
- Technique based on voltage and reactive power shift.

D. Remote Methods

Remote methods detect islanding through communication with the main grid and monitoring of the circuit breaker status:

- Power Line Carrier Communication.
- Signal Produced by Disconnect.
- Supervisory Control and Data Acquisition.

E. Comparison of Islanding Methods

We state many islanding detection methods, which can be classified into remote and local methods. Local techniques are further divided into passive, active and hybrid methods. Each technique has its own advantage and disadvantages. Summarization of islanding detection methods different categories for advantages and disadvantages are shown in Table 1 cited in [15], [20].

TABLE I. TSLANDING METHODS

IDM	Advantages	Disadvantages
Remote Method	• Highly reliable • No impact on power quality and system transient response. • Error detection can be eliminated	• Expensive to implement
Passive Method	• no impact on power quality, • Detection speed is fast.	• Difficult to detect islandingwhen the load and generation in the islanded system closelymatch • If the setting is too aggressivethen it could result in nuisance • tripping(applied in single DG systems) • error detection rate is higher than AM
Active Method	• Can detect islanding even in a • perfect match between generation and demand in the islanded system • reduce the sizeof NDZ • Decrease error detection ratio	• inevitable to deteriorate power quality • Introduce perturbation in thesystem • Detection time is slow as aresult of extra time needed to see the system response forperturbation • Perturbation often degrades the power quantity • degrade the system stability
Hybrid Method	• Have small NDZ. • Perturbation is introduced onlywhen islanding is suspected. • Complex systems. • With the combination of methods, it can improve multiple performance indices simultaneously by their compensation.	• Islanding detection time isprolonged

III. METHODOLOGY

A. Data Detection Methods

Fast islanding detection in our case is especially important and required, we suppose that the communication between a regional power plant (RPP), regional electrical substation (RES) and the regional data center (RDC) is assured by wired line communications , The RDC represent the new level in the architecture of micro Grid who present in our paper, the role of the RDC is control , measures a real time data from all entities of micro Grid ,perform and ensure a successful island operation.

The RDC is in permanent listening of the two received information from the main grid and from the substation and it compare the two values. A difference between data means that there is a problem and we should communicate information to power plants to avoid producing energy and implement the policy of emergency in this region.

$$E\ (\text{Power Plant}) - \Delta E = E\ (\text{Substation})$$

ΔE is the energy estimate loosed by power transmission.

The energy produced by the power plant less the energy lost due to the Joule effect or radiation from the sun present the energy received to the substation.

In figure 4, we present a outage detection caused by disaster or by a technical default with data detection method in a region that contain a power plant, substation , data center, renewable resources and some prosumers (consumers that produce energy). The blue line presents the exchange of data (measures, status …) with RDC. The green line presents the energy transmission. Prosumers are the costumers than consume and can also produce energy, in some case its came independents of the grid and can be powered by its resources like Plug-in electrical vehicle , battery, wind or solar resources and in some case they charge the storage farm , bidirectional transmission between storage farm and prosumers .Solar and Wind can energize prosumers and charge batteries of the region , all decisions are made by the RDC within the parameters received from all bus in each entities connected to the micro grid.

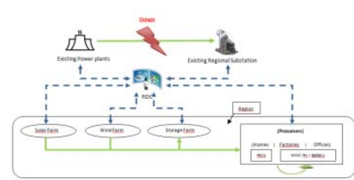

Figure 4. Islanding detection.

The Penetration of DG in SG require a new evolution of the existing power control and new functions of the distributed management systems .A new level of controlling between centralized control and area is added to collect information from different sources of energy in the region like batteries, Plug-in vehicle (PEV), Solar generation, wind generation … And also to transmit information to power plan data center to make decision of reducing production or sending energy to another region , the objective is to manage the demand response of regions , the new level exit between the area and the centralized center as shown in Figure 5.

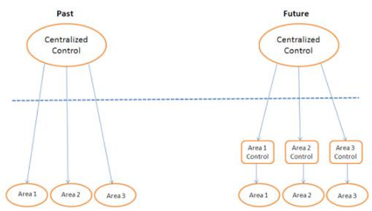

Figure 5. Evolution of power system control level.

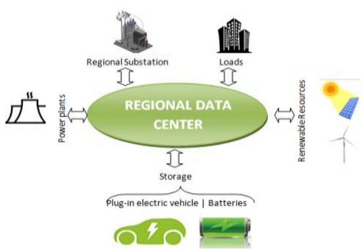

Figure 6. Power system scheme.

B. *Case Study of Outage*

SMG shown in fig.6 is the system used to present the DEMS scheme. The region is powered by a Mini Hydro Generator (MHG), Solar Power Plant (SPP) and Wind Power Plant (WPP). The MHG represent the main grid and the principal source of energy, SPP and WPP are intermittent energy, in the other hand the SMG are an others sources to store energy like Pumped Hydro Storage (PHS), Batteries and energy coming from prosumers, The PHS is use to pump water from the lower reservoir to the upper reservoir and is a solution appears to be able to face both the high electricity production cost and the continuously increasing power demand [21]. To have a successful islanding we should integrate a different kind of energy storage and we should install Real Time Data Collection Units (RTDCU) to measure the voltage of each bus connected to SMG, all information are collected by the DEMS.

This paper employs Dynamic Energy Management Scheme to control and perform distributed control on the islanded region. DEM Scheme controls the charge discharge transactions of the energy storage modules to oppose the frequency excursions in a real time environment [22].

IV. Dynamic Power Management System

This paper proposes a Dynamic Energy Management Scheme [22] to evaluate distributed control on the islanded SMG. DEM Scheme controls the charge discharge transactions of the energy storage modules to oppose the frequency excursions in a real time environment and control switch on/off of the loads of house energy and control speed drive used to pump of water.

The top scheme shows the resources who energized our DEMS and decisions that can take place according to the parameters collected The DEMS in the normal case is powered as already mentioned by main grid, SPP and WPP, The main grid is not stable and it supposed disconnected in the islanding approach , we have in this case two resources (SPP,WPP) as stable energy (we suppose that the environment context is stable and in the best condition to have a stable energy), on the other side of DEMS we have a pumped hydraulic storage with speed drive parameter, charge /discharge of batteries, and an switcher to on/off the loads of house's energy , The smart house supposed powered by the SMG and also by battery energized by PV/Turbine and PEV that represent a mobile energy in our SMG.

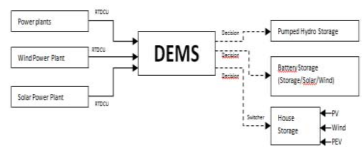

Figure 7. DEMS scheme.

The isolation of the area triggered an emergency gait and subsequently taking decisions on depends on parameters collected by the RDCUs. In the next section we present a DEMS approach and analyses the different decision within the values of parameters collected.

A. *DEM Approach*

The DEMS receive a parameters from a different bus and the objective is to perform the response of all demand and control consumption of energy in islanding zone until reestablishment of the principal energy, the distribution of the storage energy will be done within a classification of each appliance and his level of emergency, for example all medical appliances are classificated in the high level and all comfort appliances like

Air-conditioner or washer machine are defined in lower level, the classification is depends on the context, the prosumers (producer and consumer in the same time) and the environment variables are a important factors of the classification.

The DEM is capable of making decisions based on the real status of parameters in the SMG. This scheme demands the micro grid to be 'smart' and fast to make decisions at regular intervals. DEMS signals the respective decisions to the charge/discharge controller (CDC), VSD and house switcher which are responsible to carry out the decisions in the battery, PHS and houses storage energy respectively as listed in table 2.

In Fig.8 we present the role of the DEMS in taking decision based on the parameters of the resources existing in non detectible zone (NDZ) and its real time statuses that allow taking decision in regular intervals and based on the similar situations.

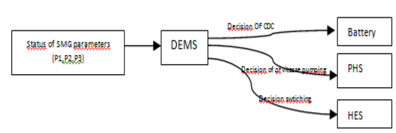

Figure 8. DEMS decisions.

The different parameters in the islanding operations are

- P1: Status of exchange with the main grid.
- P2: Status of load demand on NDZ.
- P3: Status of PHS.
- P4: Status of battery.
- P5: status of level of charge in the battery.
- P6: status of switcher loads.

TABLE II. OPERATIONS MODES

Mode	P1	P2	P3	P4	Observation
1	0	0	0	0	Energy produced locally (EPL) is used to satisfy local demand (LD). home controller is switched to OFF (home is powered by local battery)
2	0	0	0	1	EPL> LD and batteries level charge is deep of discharge limit
3	0	0	1	0	EPL > LD and Batteries fully charged
4	0	0	1	1	EPL> LD and batteries level charge is not fully charged
5	0	1	0	-1	EPL is not enought to response the local demand , we use the energye storaed in batteries farm. home controller is switched to ON (consume from (SMG)
6	0	1	0	0	EPL = LD
7	0	1	0	1	EPL > LD and batteries level charge is deep of discharge limit
8	0	1	1	0	EPL > LD and Batteries fully charged
9	0	1	1	1	EPL > LD and batteries level charge is not fully and need charging

TABLE III. OPERATIONS MODES

cases	Decision description
1	Maintain situation
2	Charge the battery
3	Discharge the battery
4	Adjust the speed of Pumping
5	Perform switch load lanagement
6	Charge batteries and perform load management
7	Discharge batteries and adjust speed of pumping

P1 represent the energy exchange with the principal main grid that can take values {-1, 0, 1}, in the islanding state P1=0 (no energy exchange), P1=1 in the case of importing energy from grid and -1 if we export energy to grid. P2 represent the status of consuming of energy {1, 0}, P3 present if the state of PMS is pumping or not {1, 0}, P4 represent the status of action on batteries {-1(Discharging), 0(no action), 1(Charging)}, P5 represent the level of charge in batteries {1 (full), 0 (Charging), -1 (deep discharge limit) }, P6 represent the status of switcher loads {ON, OFF}, if the switch ON the loads, the costumer's site is energized by the SMG, if not is powered by its own resources (Solar , wind , PEV). The objective is that the costumer's enjoy almost all the time by implementation of a demand response program (DRP) in each costumer's location.

In islanding state (P1=0), an 9 possible operations modes are identified by combined the four parameters (P1, P2, P3 and P4) as shown in Table 2

In the next party we analyses and discuss a different decision can be making on depends on the different operating mode listed in Table 3.

Decision 1 suggests maintaining the same situation.
Decision 2 suggests charging of battery.
Decision 3 suggests discharging of battery.
Decision 4 indicates the adjustment of speed of PHS.
Decision 5 suggests performing LM.

Decision 6 suggests charging batteries when energy is consumed by costumers and level of batteries is deep of discharge limit.

Decision 7 is required when the PH is pumping and batteries are discharging.

V. ANALYSES DEMS DECISIONS

We suppose that the frequency is stable to 50 Hz for the SPP and WPP, A combination of inputs values give a lot of a possibility, we take a logical possibility in our implementation of DEMS , some DEM decisions are listed in Table 4

TABLE IV. DEM DECISIONS

case	P1	P2	P3	P4	P5	P6	Decisions
1	0	0	0	0	0	OFF	1
2	0	0	0	1	0 or -1	OFF	2
3	0	1	0	-1	1 or 0	ON	3
4	0	1	1	-1	1	ON	4
5	0	0	1	0	1	OFF	5
6	0	1	0	-1	-1	ON	6
7	0	1	1	0	1	ON	7

Case 1: The Decision is to maintain the same state of SMG because the EPL is met by the LG.

Case 2: DEMS suggests to charge the battery because we don't have loads and level of batteries is deep on the limit (EPL>LD)

Case 3: Similar to case 2, DEMS suggests discharging the battery, we have a local consuming and the level of batteries is full and switch is ON.

Case 4: This decision to adjust the speed of PHS is taken because we have local loads, level of batteries is full , and we response demand by ELP and discharging the batteries , the result is to adjust the speed of PHS.

Case 5: The presence of EPL is pronounced by the presence of PHS. All the loads are disconnected from the SMG.

Case 6: This decision to response load with a lower level of energy stored in batteries and in the case of discharging. The objective is to return the switch to OFF (Home will be powered by its local resources).

Case 7: Level of battery is full and no action and we have a demand with a PHS pumping, the ideal decision is to adjust the PHS and discharge batteries.

All DEM decisions are based on possible occurrences of SMG and the objective is to stay connected and response to locals demand. The load profiles figured in Fig9, 10 and 11 present the data used in this simulation , Fig 1 is the Hydro Generation Schedule, Fig. 10 and 11are the domestic and industrial load profiles respectively. A simulation results simulated in GridLab-D show the change of voltage in some intervals of time due to a DEM decision.

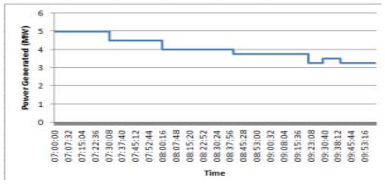

Figure 9. Hydro generation schedule.

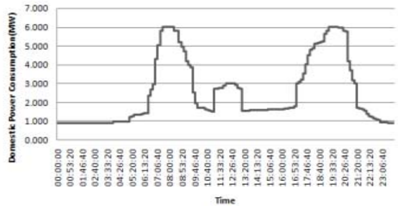

Figure 10. Domestic load profile.

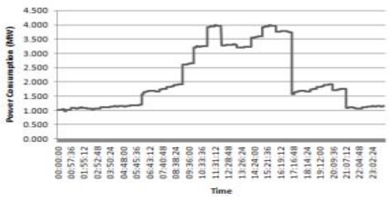

Figure 11. Industrial load profile.

Figure 12. Simulation results.

VI. CONCLUSION

In this paper, we propose a new smart islanding mode to control and perform the distributed energy in an islanded zone due to an outage and its possible to be one of solution to resolve the problem of transmission of energy to a far area that cost a expensive maintenance of power line transmission and the destination is to small population.

The DEMS objective is to resolve outage problem in a regular intervals and to response the maximum of demand until resolving the islanding problem and be reconnected to main grid by taking the right decisions that depends on the context.

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