ISSN 2229-5518

Techniques of Increasing Micro Grid Reliability

M. F. A. Omar, Dr. M. A. A. MEHANNA, Dr. Salah.K. EL-Sayed
Department of Electrical Engineering, Faculty of Engineering, Al-Azhar University, Cairo, Egypt.
MFOMAR80@gmail.com

Abstract— One of the methods used today to increase power grids reliability is dividing the main (unified) grid to Micro Grid. This paper offers a study what is the technique that can be used to increase micro grid reliability. The reliability indices will be either customer base indices or energy sales base indices. The techniques will vary according to variable factors. Factors based on micro grid size, and the others based on the number of persons use this grid. The improvement impact for the different techniques will make the main map, which technique will be better for each micro grid. Techniques target the outage time & techniques target the outage loads.

Index Terms— Micro grid, System average interruption duration index, Customer average interruption duration index, Energy not supplied, Average energy not supplied, Renewable energy source, Photo voltaic, Mean time to transfere switch, Mean time to repair.

1 Introduction

Now a day's utilities make an evolutionary change in the electricity infrastructure, and micro grids (MG) may hold that key to modernization and the realization of the Smart Grid. So the main factors affect the decision of this revolution in changing the mind from unified & centralized grid to micro grid is, how much there will be reliability improvement. What is the Micro Grid (M.G) &what is its size? A small scale system and located near the consumer is called the Micro-Grid (MG) system. The interconnection of small generation to low voltage distribution systems can be termed as the Micro Grid. Micro Grids can be operated with and without a connection to the main power network. [2]

Micro grid scale is variable scale according to zone where it could be self-dependent in the generated power [2,4]. In other word if it is disconnected (operate in the islanded mode) it will be self-dependent grid [2]. Micro grid scale could be limited also by the scale of distribution generation (DG) in range of (50K.V. A to 20 M.V.A). Reliability indices which will be focused in this paper could be divided into two categories. Customer Based Indices, and energy based indices [1]. Both of the two categories could be used to assess the past performance of the grid. As mentioned before the scale of the micro grid in this paper is limited within the common range of the available DG capacities in Egypt. There will be different modules of (MG) each module is identified according to the availability of operation in islanded mode forming micro grid. Techniques used also target the reliability indices improvement, which done by two ways minimize the outage time or minimize the outage loads.

2. Reliability Indices Definition and Formula

Customer Based Indices which are:

SAIDI: System Average Interruption Duration Index, indicates the total duration of interruption an average customer is subjected for a predefined time interval.

CAIDI Customer Average Interruption Duration Index, indicates the average time required to restore the service.

The other two indices are energy sales base indices which are:

ENS Energy not supplied by the system

AENS Average energy not supplied, AENS or Average system curtailment index, **ASCI [1,4].**

The reliability indices which will be measured by each technique will be calculated using the following input:

$\lambda s = \sum_i \lambda i \quad (failure\ rate)$ it is the number of failure of the net work item per year……. (1)

$Us = \sum_i \lambda i \times ri$ (Average Annual Outage Time) where ri is the estimated time to repaire. (2)

rs= (Average Outage Time/Repair time)..(3)

Ni number of customers, Li load value in KW ... (4)

According to those previous data the indices will be calculated as follow:

SAIDI= Sum of customers interruption duration / total no.of customers) $\sum(Ui \times Ni)/\sum(Ni)$(Hours/customer year)

CAIDI=Sum of customer interruption durations/total no. of customer interrupted $\sum(Ui \times Ni)\ /\sum(Ni \times \lambda i)$ (hours/customer interruption)

ENS=L(LOAD(KW)*U (Outage duration) (KWh/yr)

$= \sum(Ui \times Li)$

AENS (Average energy not supplied) calculated by dividing the ENS over the total number of customers $= \sum(Ui \times Li) / \sum(Ni)$ (KWH/CUSTOMERS/YR)

There are four techniques in this paper to improve reliability indices in micro grid. Those techniques are (Design technique, Operation technique) [1,5].

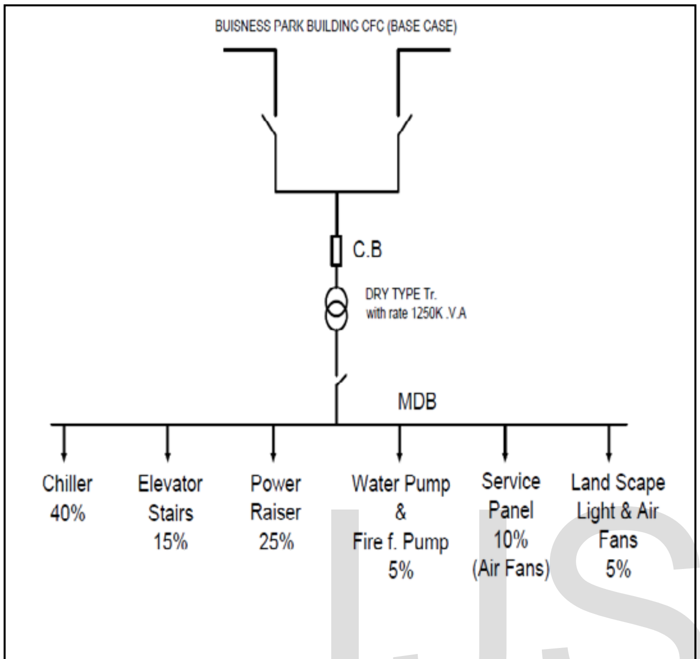

Fig.1 S.L.D BASE CASE DESIGN TECHNIQUE

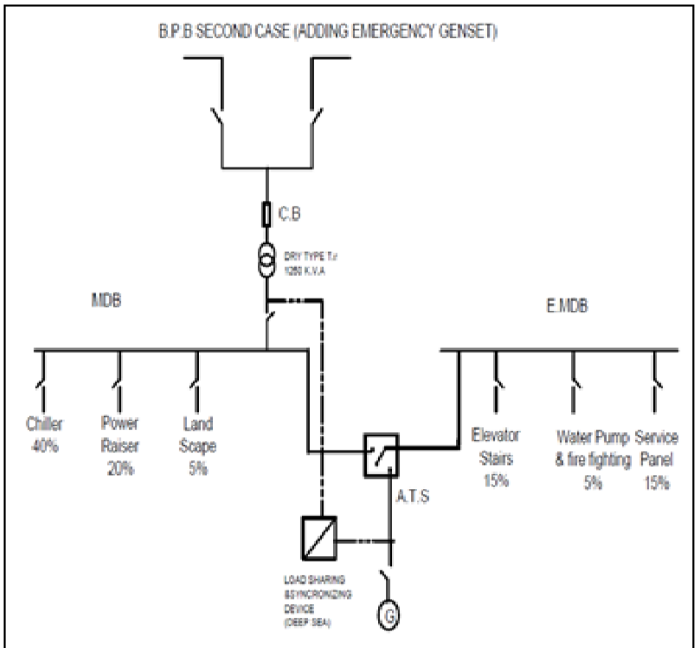

Fig.2 S.L.D CASE 2 ADDING EMRGENCY GENERATION

1-DESIGN TECHNIQUE (MINIMIZE OUTAGE LOAD)

This technique will be applied over two modules of micro grid scale. This technique studies the impact of using emergency generation, and RES Renewable Energy Source (PHOTO VOLTAIC ARRAY) on reliability indices.

1.1 Module 1 commercial load small scale MG 650 K.V.A, 400 person

1.1.1 Base Case

Module description

It is commercial load in new Cairo Egypt as shown in fig.1 where the building occupied by number of people nearly 400 persons the total load of the building is within 650K.V.A.

ITEM TYPE	Failure/year(ƛ)	MTTR(hr.)	MTTS(hr.)
R.M.U L.B.S	0.05	1	0.116
M.V.C.B	0.03	3	
Tr.	0.015	12	
L.V.M.C.B	0.03	1	
Bus way raiser	0.01	2	
Main L.V cable	0.02	3	

Table 1 – Component failure rate

According to data in table 1 and equations 1,2&3 indices could be calculated using the following data.

Data used in component failure rate based on two sources. Operation record where component number of failure over one year with respect to the predicted number of failure mentioned in the manufacturer specification. The manufacturer specification which usually relate the failure by (operating hours or number of switching)

Table2-Base Case Design technique indices calculation

ITEM	F/y λi	MTTR ři	Us	Li(kw)	Ni	Ni *λi	Us*Ni	Li *Ui
L.B.S	0.05	0.166	0.0083	750	400	20	3.32	6.225
M.V.C.B	0.03	3	0.09	750	400	12	36	67.5
Tr.	0.015	12	0.18	750	400	6	72	135
L.V C.B	0.03	1	0.03	750	400	12	12	22.5
BUS RAISER	0.01	2	0.02	750	400	4	8	15
L.V CABLE	0.02	3	0.06	750	400	8	24	45
						62	155.32	291.225
	SAIDI	0.39						
	CAIDI	2.51						
	ENS	291.23						
	AENS	0.73						

1.1.2 **Second Case Adding Emergency Generator of 40% Loading.**

The only addition over table 1 the following data

Generator failure rate:0.05

MTTR (mean time to repair 1.2 hour)

Table 3Case 2 Design Technique indices calculation

ITEM	F/y λi	MTTR ři	Us	Li(kw)	Ni	Ni *λi	Us*Ni	Li *Ui
L.B.S	0.05	0.166	0.0083	432	400	20	3.32	3.5856
M.V.C.B	0.03	1.8	0.054	432	400	12	21.6	23.328
Tr.	0.015	7.2	0.108	432	400	6	43.2	46.656
L.V C.B	0.03	0.6	0.018	750	400	12	7.2	13.5
BUS RAISER	0.01	2	0.02	750	400	4	8	15
L.V CABLE	0.02	3	0.06	750	400	8	24	45
D.G	0.05	1.2	0.06	288	400	20	24	17.28
						82	131.32	164.3496
	SAIDI	0.33						
	CAIDI	1.60						
	ENS	164.35						
	AENS	0.41						

1.1.3Case 3- Design technique adding RES unit with emergency generation.

Adding RES (renewable energy source) with load share of 20% of total load. Since it is day light source there will be average value of share as it is non battery PV (photo voltaic) units it could be considered as 10% total load sharing.

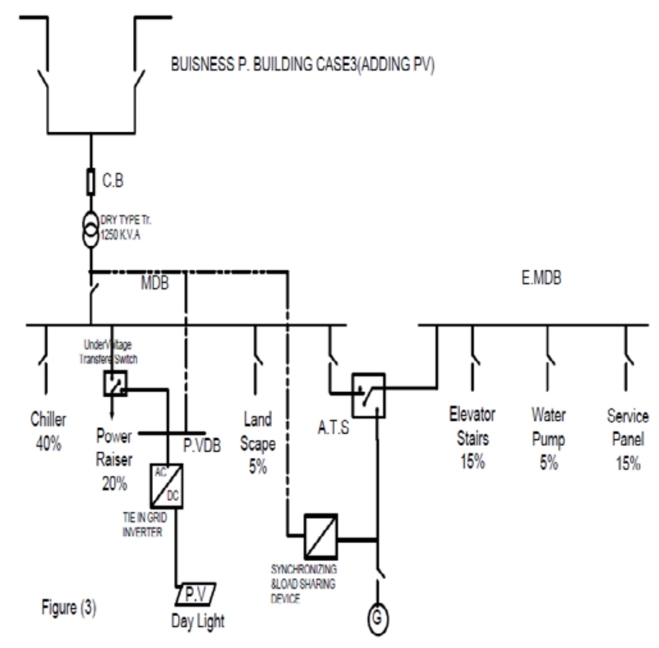

Fig. 3: S.L.D Case 3 Design technique adding RES to emergency generator

	F/y λi	MTTR r i	Us	Li(kw)	Ni	Ni *λi	Us*Ni	Li *Ui
L.B.S	0.05	0.166	0.0083	375	400	20	3.32	3.1125
M.V.C.B	0.03	1.8	0.054	375	400	12	21.6	20.25
Tr.	0.015	7.2	0.108	375	400	6	43.2	40.5
L.V C.B	0.03	0.6	0.018	750	400	12	7.2	13.5
BUS RAISER	0.01	2	0.02	750	400	4	8	15
L.V CABLE	0.02	3	0.06	750	400	8	24	45
D.G	0.05	1.2	0.06	288	400	20	24	17.28
PV SYSTEM	0.01	1	0.01	75	400	4	4	0.75
						86	135.32	155.3925
	SAIDI	0.34						
	CAIDI	1.57						
	ENS	155.39						
	AENS	0.39						

Table 5 comparison between 3 cases of Design technique indices calculation.

Reliability indices comparison for previous three cases			
Indices	case 1 (without Genset & RES)	Case 2 E.Genset & without RES	Case 3 with Genset&RES
SAIDI	0.39	0.33	0.34

CAIDI	2.51	1.60	1.57
ENS	291.23	164.35	155.39
AENS	0.73	0.41	0.39

Table 6 Improvement percentage in case 2&case 3 Design technique

Reliability indices	improvement after add GEN.40% load share	improvement after add RES 10% load share
SAIDI	15.4%	-3.0%
CAIDI	36.3%	1.9%
ENS	43.6%	5.5%
AENS	43.8%	5.1%

1.2Module 2 Design Technique Residential Load With Total Load 5.750 M.V. A & 940 Person.

In this module the indices calculation will be based on the following assumption:
The period of MTTS (mean time to transfer switching) between grid isolation and Gen. Startup is nealy 5min. 0.083 hr.
The MTTR (mean time to repair) if it is permanent fault in the main grid will be 2 hr.
The repair time (rs) could be calculated using this formula.
(rs)= (0.083 hr.*GEN%OF LOAD COVERAGE) +(2hr.*%of un covered loads) …. (5)
Assume that Gen. (f/yr=5%) and percentage of Generator reliability95%.
Us (outage time) = [rs*95%] + [MTTR*5%]
N is the no. of customers.

Table7- Transformer Load & Percentage of Generator Coverage Module 2 Design Technique

TR. ROOM	Tr. Capacity (K.V.A)	LOADING FACTOR	LOAD AFTER DIVERSITY(K.V.A)	GEN.capacity (K.V.A)	GENSET %OF LOAD COVERAGE	% OF UN COVERED LOADS
Tr. 1	1500	70%	1050	600	57.14%	42.86%
Tr. 2	2000	65%	1300	800	61.54%	38.46%
Tr. 3	1000	70%	700	400	57.14%	42.86%
Tr. 4	1500	50%	750	600	80.00%	20.00%
Tr. 5	1500	65%	975	600	61.54%	38.46%
Tr. 6	1500	65%	975	600	61.54%	38.46%
sum			5750			

1.2.1Module 2- case 1 (base case without add RES)

Fig. 4 S.L.D show the residential load (Tr. Room configuration) with 40% load share of total load.

S.L.D of group of loads over M.V level as shown in figure 5

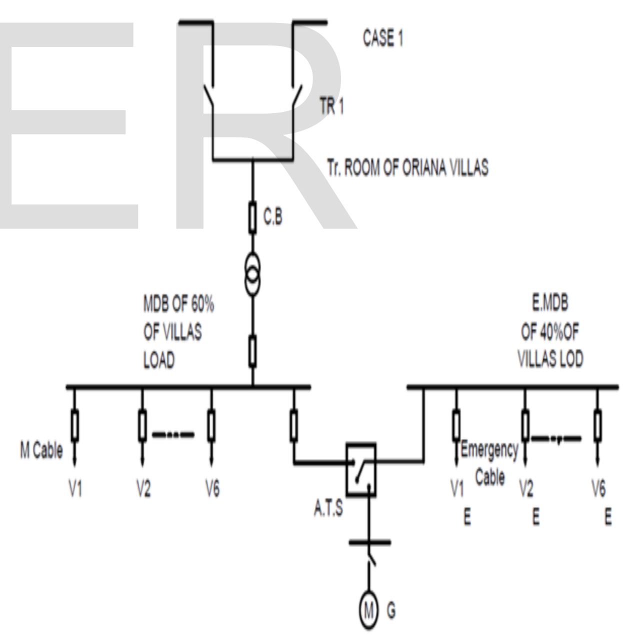

Fig. 4 S.L.D Base Case Module 2 Design Technique

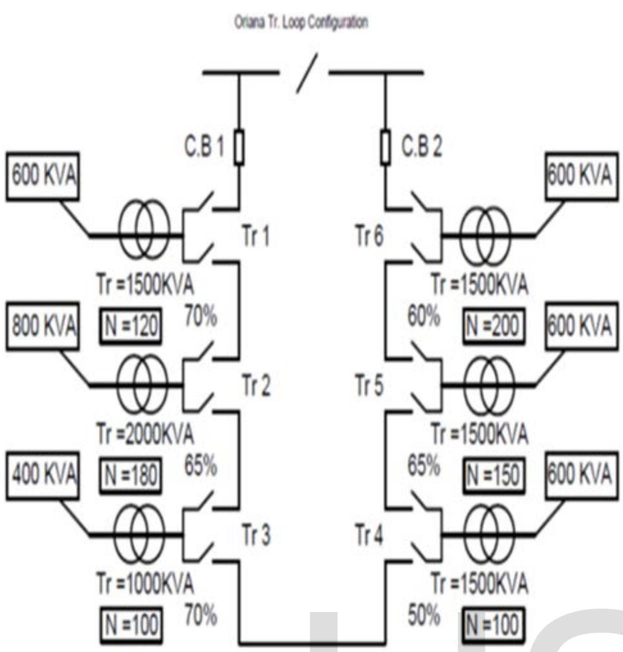

Fig.5 S.L.D show the residential Tr. Room MV level configuration.

Table 8-Module 2 Design Technique base case indices calculation

Tr.ROOM	GENSET %OF LOAD COVERAGE	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
Tr.1	57.14%	0.90457143	0.959343	1312.5	120	6	115.1211	1259.138
Tr.2	61.54%	0.82030769	0.879292	1625	180	9	158.2726	1428.85
Tr.3	57.14%	0.90457143	0.959343	875	100	5	95.93429	839.425
Tr.4	80.00%	0.4664	0.54308	937.5	100	5	54.308	509.1375
Tr.5	61.54%	0.82030769	0.879292	1218.75	120	6	105.5151	1071.638
Tr.6	61.54%	0.82030769	0.879292	1218.75	200	10	175.8585	1071.638
SUM				7187.5	940	41	705.0096	6179.825
	SAIDI	0.75						
	CAIDI	17.20						
	ENS	6179.83						
	AENS	6.57						

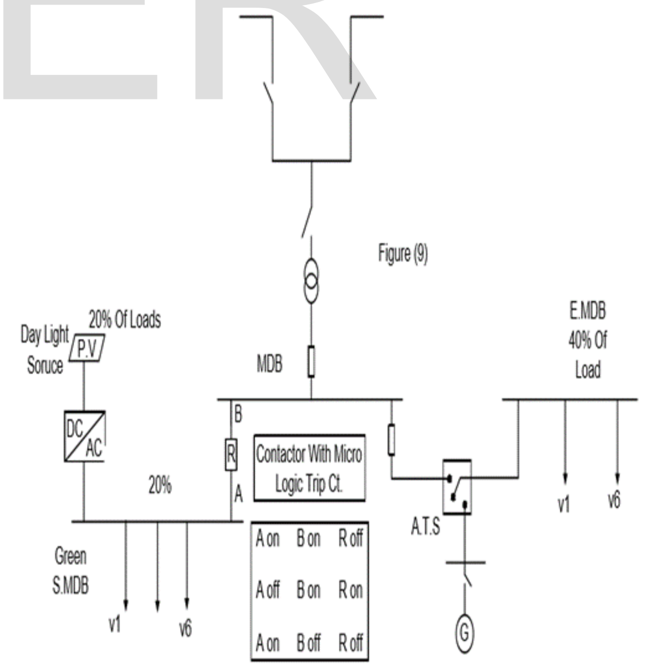

Fig. 6 S.L.D show Transformer room configuration after adding RES with share 20 % day light 10% over the day

ISSN 2229-5518

. Case 2 Module 2 Design Technique Adding RES with Load Sharing 10 % of Total Load.

As shown in Fig. 6 after add RES to transformer room to share the loads by 10% as shown in fig.6.

Table 9 Case 2 Module2 Reliability Indices Calculation

Tr.ROOM	GENSET %OF LOAD COVERAGE	% OF UN COVERED LOADS	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
Tr.1	71.43%	32.86%	0.716429	0.780607	1312.5	120	6	93.67286	1024.547
Tr.2	76.92%	28.46%	0.633077	0.701423	1625	180	9	126.2562	1139.813
Tr.3	71.43%	32.86%	0.716429	0.780607	875	100	5	78.06071	683.0313
Tr.4	100.00%	10.00%	0.283	0.36885	937.5	100	5	36.885	345.7969
Tr.5	76.92%	28.46%	0.633077	0.701423	1218.75	120	6	84.17077	854.8594
Tr.6	76.92%	28.46%	0.633077	0.701423	1218.75	200	10	140.2846	854.8594
SUM						940	41	559.3301	4902.906
	SAIDI		0.60						
	CAIDI		13.64						
	ENS		4902.91						
	AENS		5.22						

Table10 Reliability indices improvement before and after adding RES.

comparing reliability indices for the two experiment modules			
Reliability Indices	Oriana module 1 without RES	Oriana module 2 with RES	Improvement percent.
SAIDI	0.75	0.60	20.67%
CAIDI	17.20	13.64	20.70%
ENS	6466.25	4902.91	24.18%
AENS	6.57	5.22	24.18%

Second Technique (Operation Technique)

(**Minimize Outage Time**)

Module Description

In this case there will be a sample on the M.V level of CFC grid, and in case of emergency where the two shown loop are isolated from the rest of loops forming Micro Grid. Here are some facts about this micro grid:

1-It is shown that there are three types of load in this micro grid:

First: Residential loads, second: Business building, third: facilities load.

2-There will be total number of customers will be 8700 customers.

3-This micro grid will be only provided with protection devices C.B at the start and the end of the loops.

This module will face two faults in the same time as follow:

First the M.V cable of the loop had permenant fault of insulation failure

Second the Circuit Breaker (C.B) of loop2 is out of duty due to chamber insulation failure.

This scenario from the registeration data is considered one of the worst scenario the customer face in outage time.

Case 1-base case (M.G without Tie in cable) 8700 persons 6.208 M.V. A

Tr.ROOM	GENSET %OF LOAD COVERAGE	% OF UN COVERED LOADS	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.V.A)	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
B.P1	57.14%	42.86%	0.261714	0.34862857	1050	1312.5	600	30	209.1771	457.575
B.P2	80.00%	20.00%	0.1664	0.25808	750	937.5	400	20	103.232	241.95
B.P3	66.67%	33.33%	0.222	0.3109	900	1125	500	25	155.45	349.7625
B.P4	50.00%	50.00%	0.2915	0.376925	1200	1500	800	40	301.54	565.3875
HONDA	61.54%	38.46%	0.243385	0.33121538	650	812.5	200	10	66.24308	269.1125
TOYOTA	61.54%	38.46%	0.243385	0.33121538	650	812.5	200	10	66.24308	269.1125
WATER STATION	0.5	0.5	0.2915	0.376925	504	630	3000	150	1130.775	237.4628
SEWAGE STATION	0.5	0.5	0.2915	0.376925	504	630	3000	150	1130.775	237.4628
sum					6208	7760	8700	435	3163.435	2627.826
	SAIDI		0.363613							
	CAIDI		7.272265							
	ENS		2627.826							
	AENS		0.302049							

Table 11 Case 1 Operation Technique Reliability indices calculation

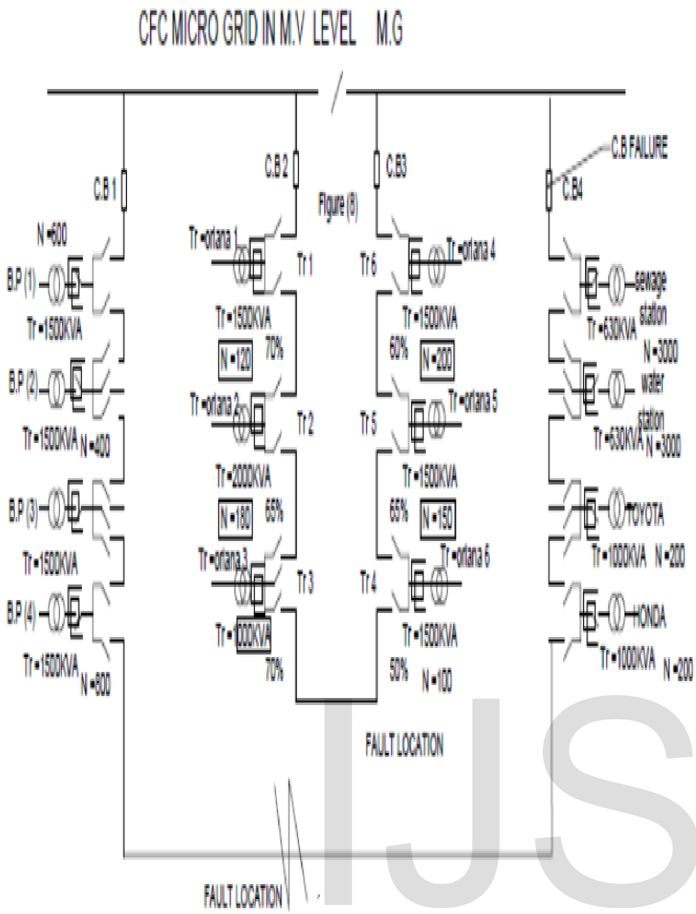

Fig.7 S.L.D of Case 1 Operation Technique Without Add Tiein Cable

General Facts about the case study
In this case the MTTR=2 hour (for loads from sewage to Honda) because of the following:
The feeding system is radial feeding as C.B4 at the other side of the loop is failed due to insulation break down.
The time needed to identify the fault location will be 30 min regardless it's physical location (this is due to the manual strategy for fault location identification.
We chose the path of the tie in cable to be satisfy the following (the shortest distance for the economic impact, the mid load point for the two loops as possible)
It is the most effective case where the tie in cable minimize the outage time clearly.

Tie in cable could represent emergency cable for loads.
There must be adjustment for protection devices after adding the tie in cable taking in consideration the injection current value.
This technique could also be called (current injection technique) where current injected from loop to other increasing the reliability indices of both loops.
This technique could be used over the M.V&L.V level (MG).

Case 2-base case (M.G Adding Tie in cable)

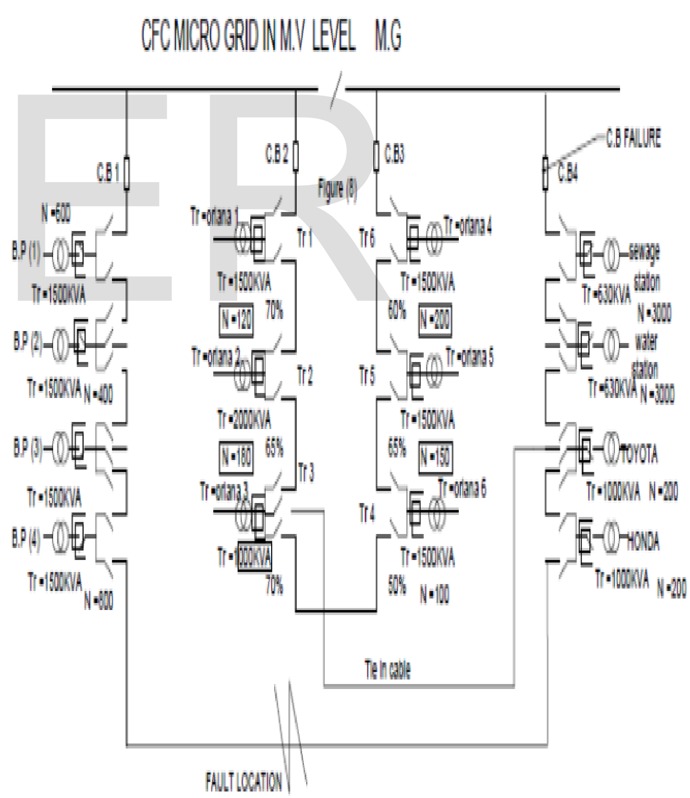

Fig.8 S.L.D of Case 2 Operation Technique Add Tiein Cable

Tr.ROOM	GENSET %OF LOAD COVERAGE	% OF UN COVERED LOADS	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.V.A)	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
B.P1	57.14%	42.86%	0.154571	0.15934286	1050	1312.5	600	30	95.60571	209.1375
B.P2	80.00%	20.00%	0.1164	0.12308	750	937.5	400	20	49.232	115.3875
B.P3	66.67%	33.33%	0.138667	0.14423333	900	1125	500	25	72.11667	162.2625
B.P4	50.00%	50.00%	0.1665	0.170675	1200	1500	800	40	136.54	256.0125
HONDA	61.54%	38.46%	0.147231	0.15236923	650	812.5	200	10	30.47385	123.8
TOYOTA	61.54%	38.46%	0.147231	0.15236923	650	812.5	200	10	30.47385	123.8
WATER STATION	0.5	0.5	0.1665	0.170675	504	630	3000	150	512.025	107.5253
SEWAGE STATION	0.5	0.5	0.1665	0.170675	504	630	3000	150	512.025	107.5253
							8700	435	1438.492	1205.451
	SAIDI		0.165344							
	CAIDI		3.306878							
	ENS		1205.451							
	AENS		0.138558							

Table 12 Case 2 Operation Technique Reliability indices calculation

Reliability indices	SAIDI hr./ customer yr	SAIDI hr./customer yr	SAIDI hr./customer yr	SAIDI hr./customer yr
M.G without tie in cable between M.V loops	0.90	17.60	4416.20	0.51
M.G with tie in cable between M.V loops	0.30	5.02	1503.50	0.17
improvement percentage	66.67%	71.48%	65.95%	66.67%

Table 13 Reliability indices improvement with and without tiein cable

CONCLUSION

Design Technique (load sharing technique) minimize the load outage

This achieved by adding emergency generation with ratio near to 40%of total loads, and adding RES (renewable energy source) PV (photo voltaic arrays) with load share average 10 % of total loads. And we conclude that adding RES had LOW IMPACT on reliability indices for small scale micro grid (less than 2M.V. A). The failure rate of the micro grid component also could be taken in consideration in indices calculation for small scale micro grid, but in large scale micro grid the component failure rate could be neglected.

(operation technique) or (current injection technique) minimize outage time

This achieved by installing tie in cable. This technique found other feeding source to the disconnected loads.

The following conclusion about the micro grid could be taken in consideration as follow:

1- Micro grid is limited grid could be self-dependent at any time when disconnected from the main grid this is called (islanded mode).
2- It is not condition to be in islanded mode, but we could make the improvement in connected mode (connected to the main grid).
3- It is preferred than the unified system because it is more controllable than the unified grid.

4- It has variable scale not limited with certain size the only limitation that it could be self-dependent in case of islanding mode.
5- The researcher estimate that the average scale depend on common distribution generation scale is 20 M.V.A.
6- Any improvement in reliability will directly affect the customer as it is more adjacent and direct affect the customer need.

REFERANCES

[1] Tempa Dorji, master of science in electric power engineer, Norwegian University of Science and Technology, Reliability Assessment of Distribution Systems, May 2009

[2] Abinash Singh, Balwinder Singh Surjan, MICROGRID : A REVIEW, International Journal of Research in Engineering and Technology, Volume 03 Issue: 02 / Feb- 2014, Available @ http://www.ijret.org
.

[3] Rade M. Ciric, Nikola Lj.Rajakovic, On the Reliability of Low Voltage Network with Small Scale Distributed Generators, World Academy of Science, Engineering and Technology Vol:3 2009-06-22

[4] Mitchell Lee, Daniel Soto , Vijay Modi , Cost Versus Reliability sizing strategy for isolated photovoltaic micro-grids in the developing world, Renewable Energy Journal, 69(2014) 16-24

[5] K.Venkateswarlu, J.Krishna Kishore, “Modeling and Simulation of Micro Grid System Based on Renewable Power Generation Units by using MultilevelConverter”, International Journal of Engineering Research & Technology, Vol. 1, Issue . 6, August 2012.